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Compact Printed Quadrifilar Helix Antennas for Stratospheric Balloons Telemetry

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Introduction

Printed Quadrifilar Helices (PQH) antennas have found application in L-band telemetry for meteorological stratospheric balloons. The PQH antenna, patented by the CNES [1], is relatively simple to manufacture and low cost. Such an antenna has good circular polarization coverage with excellent axial ratio over a wide range of elevation angle. However the reduction in size of modern stratospheric balloon payloads asks for more compact PQH antennas.

Consequently, the challenging problem consists of reducing the axial length of conventional PQH antennas with a minimum impact upon their overall performances. In the literature, meander lines [2, 3] and pre-fractal (space-filling) curves [4] were applied to the arms of helix antennas in order to reduce its length. Compact PQH antennas with meander lines have been reported in [3] but the performances of the proposed antennas in term of the axial ratio (which are of crucial importance in our application) are not compared with those of conventional PQH antennas. In [4] pre-fractal curves have been used to reduce the axial length of monofilar helices antennas but, from a practical point of view, the extension to quadrifilar helices appears to be highly problematic.

In this communication, the four arms of quadrifilar helices antennas are pre-fractal and printed on the cylindrical surface of the antenna. Very few of such pre-fractal PQH antennas are found to achieve the technical requirements for L-band stratospheric balloons telemetry. We present in this paper a solution with a 33% axial length reduction when compared to the original PQH antenna. The obtained axial ratio is lower than 2 dB for elevation angle between -80° and 80° .

Design of pre-fractal Printed Quadrifilar Helices antennas

Based on the Iteration Function System (IFS) algorithm [5], a specific software has been developed to generate the pre-fractal profile of PQH antennas. The total length of such profiles is adjusted in order to obtain the same operating frequency (1.85GHz) for each studied PQH antenna and to achieve the technical requirements in terms of radiation pattern (radial mode) and input impedance (close to 50Ω). The axial ratio is required to be lower than 2 dB over elevation

angle range as large as possible. In order to achieve circular polarization, the four arms of the PQH antennas are excited with the following classical phase law: 0° , 90° , 180° and 270° .

The pre-fractal profiles with interesting characteristics are shown in Figure 1. These profiles are printed on a thin low-permittivity dielectric substrate (Figure 2) and wrapped around a cylindrical support. The Figure 3 shows the resulting PQH antennas. The design and the simulation of these antennas are performed using IE3D software based on the Method of Moments.

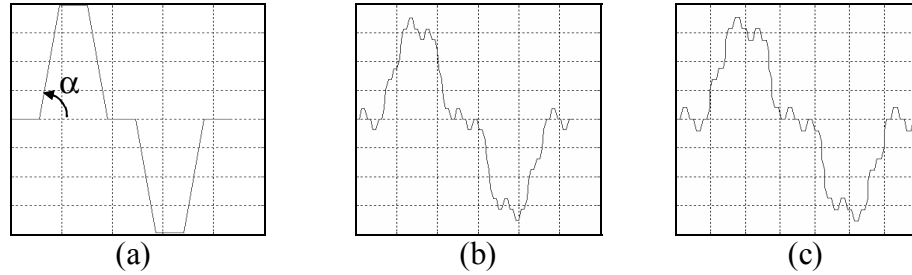


Figure 1. Pre-fractal profiles: (a) at the first-order iteration; (b) at the second-order iteration with $\alpha=30^\circ$ and (c) at the second-order iteration with $\alpha=45^\circ$.

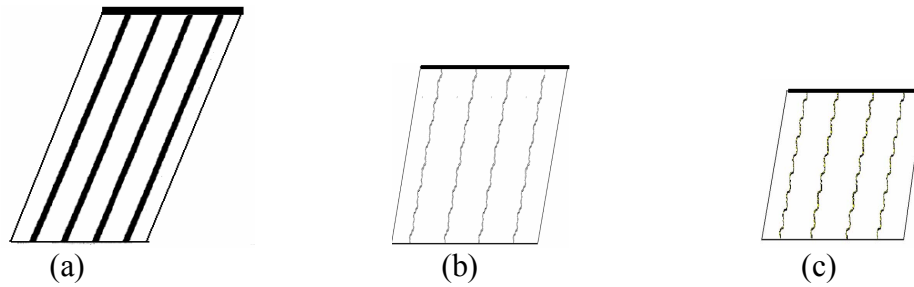


Figure 2. Planar representations of: (a) the conventional PQH antenna; (b) the pre-fractal "PQH-F1" antenna with the profile shown in Fig.1b and (c) the pre-fractal "PQH-F2" antenna with the profile shown in Fig.1c.

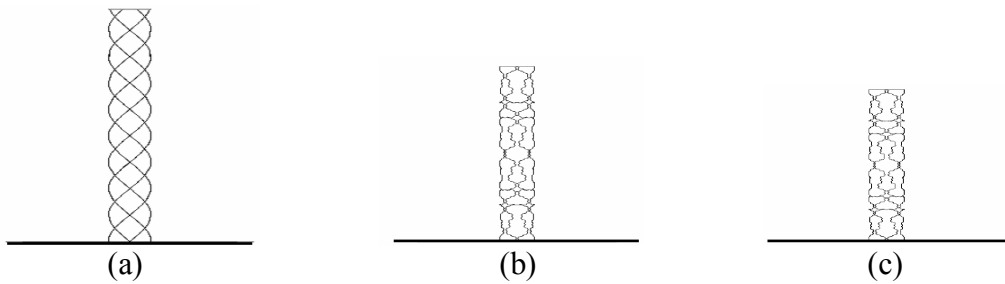


Figure 3. Three Printed Quadrifilar Helix having the same operating frequency: (a) the conventional PQH antenna; (b) the PQH-F1 antenna and (c) the PQH-F2 antenna

The PQH-F1 and PQH-F2 antennas reduce the axial length of the conventional PQH antenna by 33% and 38%, respectively. The Figure 4 displays the simulated LHCP and RHCP directivity patterns of these two compact antennas at the desired operating frequency. In term of the LHCP gain pattern, these two antennas will be slightly out of the requirements in some radiating directions (the desired minimal LHCP gain patterns are displayed in the figure). However, the axial ratio of the PQH-F1 antenna is lower than 2 dB for elevation angle between -70° and 70° . Moreover, with printed line widths of 1mm, the input reflection coefficient is found to be close to -16 dB for the PQH-F1 antenna while this coefficient is close to -22.5 dB in the case of the PQH-F2 antenna with line widths of 0.8mm.

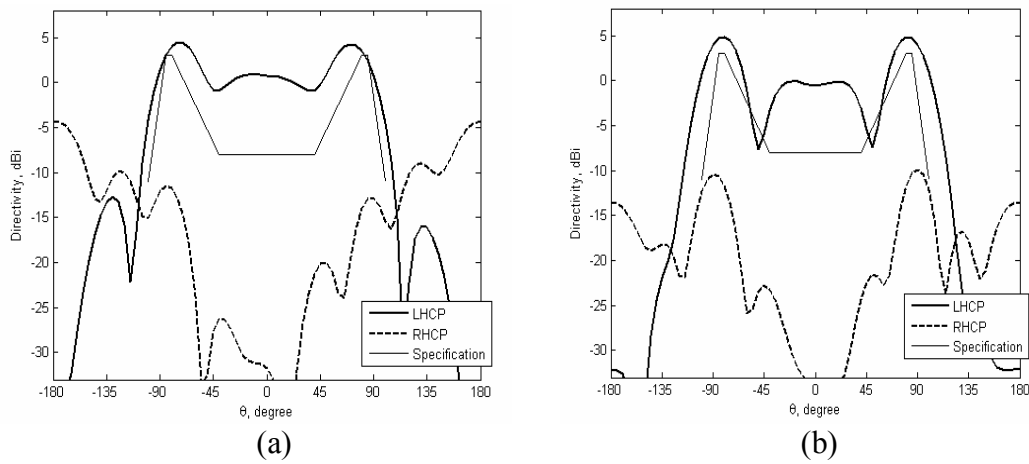


Figure 4. The simulated radiation patterns for :
(a) the PQH-F1 antenna and (b) the PQH-F2 antenna.

Table 1 summarizes the characteristics of the PQH, PQH-F1 and PQH-F2 antennas.

	Conventional PQH	PQH-F1	PQH-F2
Antenna axial height	340 mm	227 mm	211 mm
Total wire length	380 mm	322 mm	341 mm
Operating frequency	1.85 GHz	1.85GHz	1.85 GHz
Size reduction	0 %	33 %	38 %
Input reflection coefficient	-25 dB	-16 dB	-22.5 dB
width of the printed lines	5.5 mm	1 mm	0.8 mm

Table 1. Characteristics of the PQH, the PQH-F1 and PQH-F2 antennas.

Very few pre-fractal PQH antennas are found to achieve the technical requirements for L-band stratospheric balloons telemetry, especially in term of

co-polarized field. In the generation of the pre-fractal profile, as the order of iteration increases in the IFS algorithm, the resulting pre-fractal PQH antenna seems to enhance the axial mode to the detriment of the desired radial mode of radiation. Moreover, according to the electromagnetic simulations, we have observed that classical sinus-type profiles offer analogous performances to pre-fractal PQH-F1 and PQH-F2 antennas in terms of directivity patterns and size reduction.

Conclusion

Two pre-fractal Printed Quadrifilar Helices antennas have been presented. These compact antennas offer good compromises between size and performances. The designs introduced in this paper reveal the feasibility of an axial length reduction between 30 to 40% without significant cross-polarization degradation. Experimental validations will be presented at the conference.

Acknowledgement

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