A Novel Mode and Frequency Reconfigurable Origami Quadrifilar Helical Antenna

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***Abstract*—This paper presents a design of origami mode and frequency reconfigurable quadrifilar helical antenna that can reconfigure itself to operate at different modes (i.e., normal or axial mode) and different frequencies. This antenna is also collapsible and therefore, it is very suitable for satellite and space applications.**

Keywords- origami; quadrifilar helical antenna; normal mode;axial mode

I. INTRODUCTION

Helical antennas have been used in various space telemetry applications, such as, satellites, space probes, GPS and ballistic missiles, because that of their circular polarization [1]. Recent research on helical antennas has examined their miniaturization, gain enhancement and bandwidth increase [2]-[4].

Origami has been recently applied to various areas, such as, biochemistry, architecture, robotics, [5], astronomy, and electromagnetics, [6]-[11], due to its unique geometries as well as capabilities of collapsibility and reconfigurabilty.

This paper presents a novel mode and frequency reconfigurable origami quadrifilar helical antenna that can operate in: (a) normal mode in UHF and L bands with a total height of 371 mm, (b) axial mode with circular polarization in L band and S band at two other reconfigurable heights of 200 mm and 48 mm. This origami antenna can collapse for convenience of transportation or stowing and it can be used in various spaceborne and airborne applications.

II. ORIGAMI ANTENNA DESIGN

The folding pattern of the origami cylinder base for the proposed quadrifilar helical antenna (QHA) is shown in Fig. 1. The solid lines are hills and dashed lines are valleys. The origami cylinder is formed by folding the creases in Fig. 1 and connecting the left side of the pattern to its right side from the top to the bottom, as shown in Fig. 2.

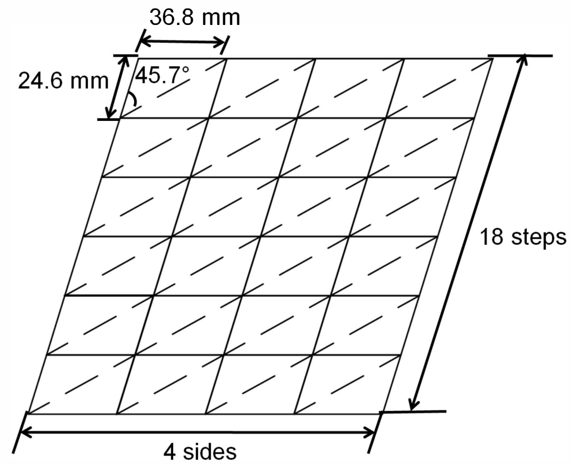
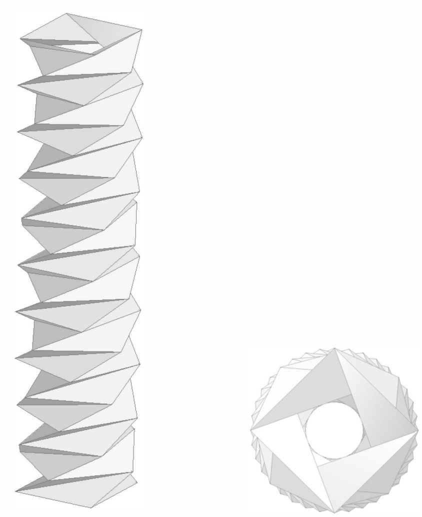


Figure 1. Folding pattern of origami cylinder base for the proposed QHA.



(a) (b)

Figure 2. Folded cylinder base of the QHA: (a) perspective view; (b) top view.

The proposed mode and frequency reconfigurable origami QHA in Fig. 3 was designed and simulated in ANSYS HFSS to operate in the L and S bands by optimizing its geometric parameters. The optimized design is shown in Fig. 1. The side length of the square ground is

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134 mm. The four conductive arms are placed symmetrically around the origami cylinder base along the vertical hill lines. The arms are fed with lumped ports in quadrature phases.

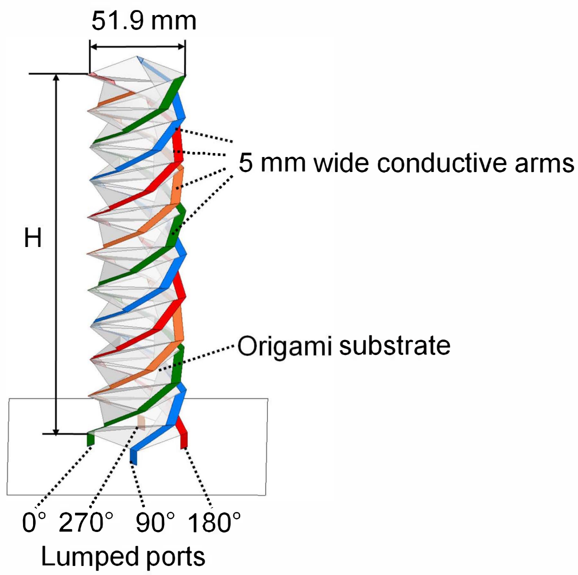

Figure 3. Model of mode and frequency reconfigurable origami QHA.

III. SIMULATED RESULTS

Typically, the normal mode for a helical antenna occurs when λ_o>>C, where C is the circumference of the helix; while the axial mode occurs in the range of $3\lambda_o/4<C<4\lambda_o/3$ [1].

For this origami antenna structure, the total antenna height, *H,* can change by applying a force on top of the origami cylinder. Therefore, this antenna can reconfigure to operate at different modes or frequencies. The simulated S_{11} at different antenna heights, *H,* are shown in Fig. 4.

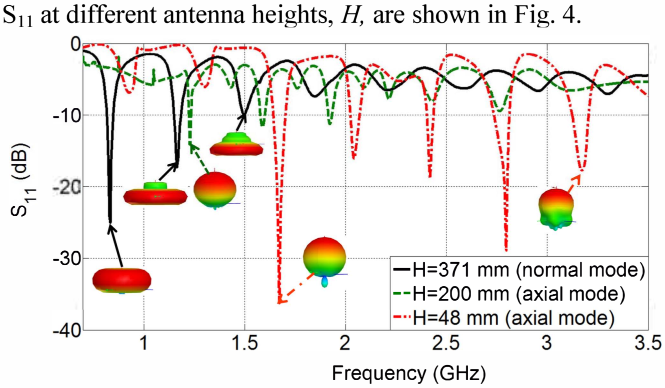

Figure 4. Simulated S_{11} of the mode and frequency reconfigurable QHA

The simulated realized gains and operating modes at the operating frequencies of the three states are listed in Table I and Table II. It can be seen that when this antenna is fully deployed, i.e., *H*=371 mm, it can operate in normal mode at 0.83 GHz, 1.17 GHz, or 1.5 GHz. Also, when *H*=200 mm, this antenna works in axial mode at 1.23 GHz with a realized gain of 5.2 dB, and when *H*=48 mm, it can operate in axial mode at 1.67 GHz and 3.18 GHz with realized gains of approximately 8 dB. This antenna is circularly polarized when it operates at the axial mode frequencies discussed here, and the simulated axial ratios are shown in Table III. The radiation patterns at the operating frequencies of the 3 states are shown in Fig. 5-7.

TABLE I. PERFORMANCE AT THE STATE OF NORMAL MODE

Antenna Height (mm)	371		
Operating Frequency (GHz)	0.83	1.17	1.5
Max. Realized gain (dB)	4.3	5.1	4.6

TABLE II. PERFORMANCE AT THE STATES OF AXIAL MODE

Operating Frequency (GHz) / **Antenna Height (mm)**	1.23	1.67	3.18
200	5.2	0.6	1.1
48	-9.1	7.8	8.9

TABLE III. AXIAL RATIO AT THE STATES OF AXIAL MODE IN THE AXIAL DIRECTION (THETA=0°)

Antenna Height (mm)	200	48	
Operating Frequency (GHz)	1.23	1.67	3.18
Simulated Axial Ratio (dB)	0.5	0.05	0.1

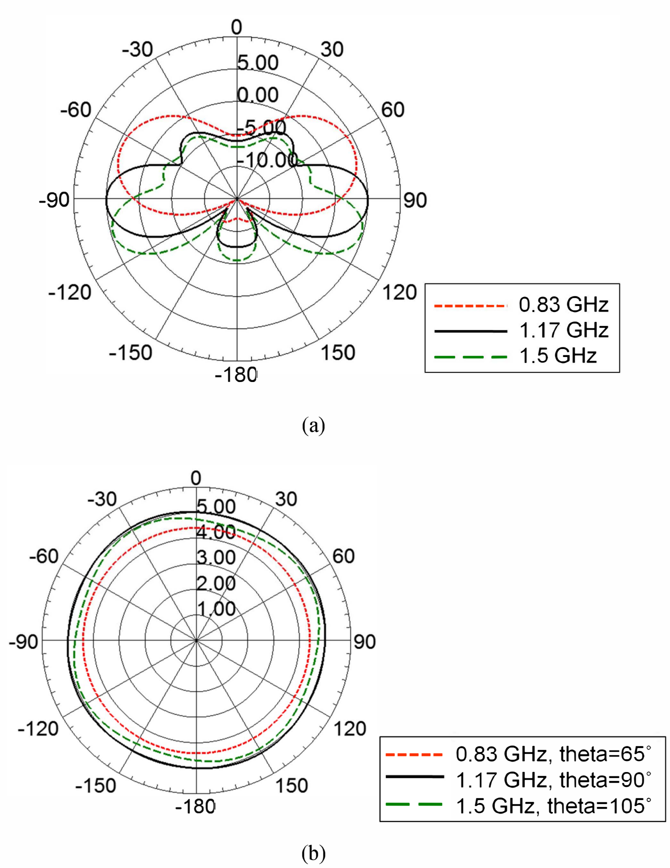

Figure 5. 2-D patterns at operating frequencies in normal mode at H=371 mm: (a) elevation plane; (b) azimuth plane.

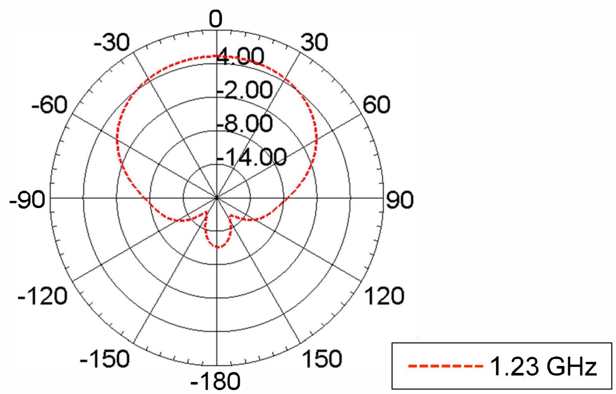

Figure 6. Elevation plane at H=200 mm.

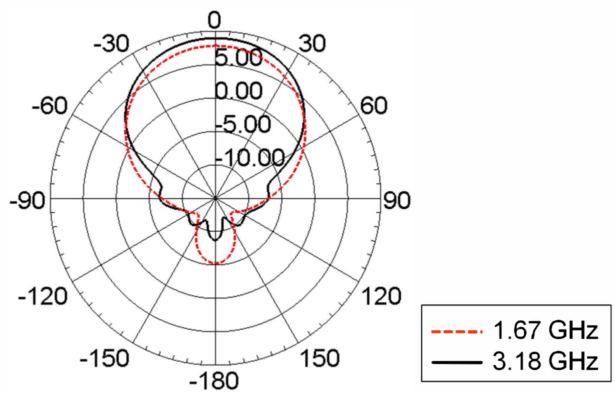

Figure 7. Elevation plane at H=48 mm.

IV. Conclusion

This paper presented an origami design of a mode and frequency reconfigurable quadrifilar helical antenna for spaceborne and airborne applications. This antenna can operate in the normal mode in UHF band and L bands Also, it can operate in axial mode with in circular polarization in L band and S band.

Acknowledgment

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