A Reconfigurable/Deployable Helical Antenna for Small Satellites

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Abstract—**In this paper a helical antenna that is deployed on a small satellite platform is presented. The antenna achieves reconfiguration in stages by deploying in and out of the satellite in a rotational matter to achieve frequency tuning. The antenna is circularly polarized with a wide bandwidth and a reasonable gain. The merging of deployable and reconfigurable antennas allows deployment on demand and adds more capabilities and adaptation ability to space communications.**

I. Introduction

Current deployable antennas for space communications deploy once in space and remain deployed without any potential for adaptability. These antennas occupy a large landscape and steering them into different directions requires a lot of maneuvering.

Many different types of deployable antennas have been used successfully on-orbit. Radio frequency reflectors are a common antenna type used in the fields of communications, radio astronomy, and microwave power transmission [1]. Other deployable antenna types include linear and planar structures. One example of a linearly deployed antenna is the 25-meter class, Very Low Frequency, antennas to be used on the Demonstration and Science Experiments (DSX) spacecraft for radiation belt remediation experiments [2].

The ability of space and satellite antennas to cover different applications and radiate on different frequencies of operations as well as different radiation directions is currently solved with the use of multiple antennas. The addition of these deployable bulky antennas consumes landscape as well as weight and cost. The advancement in space technology increases the performance requirements on space antennas. High performance antennas for space-based applications further require that the antennas be light-weight, miniaturized and ideally conformal to the platform. Reduced weight, size, volume, and conformity to the platform reduce the gross lift off weight, thereby saving on operational costs through fuel savings.

In this paper we add reconfiguration capability to a deployable helical antenna. The reconfiguration process achieved is based on mechanical reconfiguration that makes use of actuators. Several mechanically reconfigurable antennas have been presented in literature such as a rotatable patch that tunes its operating frequency for wireless communications [3]. Another patch antenna tunes its operating frequency by changing the height of its ground plane [4].

The potential payoff of physically reconfigurable antennas is their tuning ability without resorting to switching components and their biasing networks. The adaptability of changing characteristics allows the necessary fast response and recovery for many satellite missions. The design also includes software controlled features for physical antenna reconfigurations. It also encompasses operation in conjunction with Software Defined Radio (SDR) to adjust the antenna to any changes due to the satellite environment or changes in its mission

II. Reconfigurable Helical Antenna

In this section we present a helical antenna designed specifically for space applications, it operates at UHF frequencies and tunes it operating frequency by changing its height above the ground plane in a rotational manner. The antenna concept is shown in Fig.1. Packed inside the satellite, the antenna is compact and stowed in a designated cavity. The antenna deploys progressively into a desired position achieving a required operating frequency. Fig.2 shows the antenna deployed on top of a 120 cm x 120 cm ground plane as well as a small cavity where it will be compressed. The dimensions of the ground plane are optimized using HFSS. Fig.3 elaborates the reconfiguration process of this antenna through the various consecutive stages. The antenna movement is also retractable allowing a complete control over the frequency spectrum. The proposed helical antenna is designed to have a total length of 1λ (120 cm) at the lowest desired frequency (250 MHz). This antenna is designed using berrylium copper and its operation covers a frequency range from 240 MHz till 450 MHz.

The design of this antenna can be broken down into four sections as shown in Fig.1. Starting at the lowest frequency (250 MHz shown in red in Fig.1) the antenna has one single turn with a pitch that is equal to its diameter. However, the diameter has a change of 0.5 cm per turn for all four sections. For L_1, L_2, L_3 and L_4 the values are found by letting the circumference:

$$C = (S - 2\times(0.5\,cm))\pi \qquad Eq.1$$

Table 1 shows the different dimensions and physical properties of this antenna

Once this antenna is fully deployed on a satellite, actuators are proposed to lower this antenna at various stages into a cavity inside the satellite. The antenna can also be moved upward as well. A ground plane has proven to be important for the operation of this antenna. The ground plane is optimized to reduce back lobe radiation and add constructively to the antenna operation.

Table1: Dimensions and Physical Characteristics of Helical Antenna

Radiating Element	Turn (N)	Spacing (S)	Circumference $C = D\pi$	Length of Wire ($L_n = N\sqrt{S^2 + C^2}$)
Violet	N_4 =1	S_4 = 2cm	C_4 = 6.28 cm	L_4=6.59 cm
Yellow	N_3 =1	S_3 = 3cm	C_2 = 9.42cm	L_3 = 9.88 cm
Blue	N_2 =1	S_2 = 4cm	C_2 = 12.57 cm	L_2 = 13.18 cm
Red	N_1 =1	S_1 = 5cm	C_1 = 15.7 cm	L_1 = 16.47cm
Total	N = 4	S = 14cm	N/A	L = 46.14cm

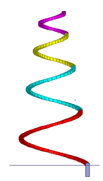

Fig.1 Helical antenna with its four different sections

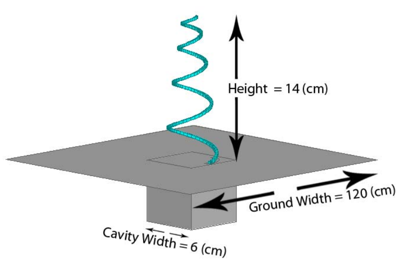

Fig.2 Antenna Deployed with Cavity and dimensions

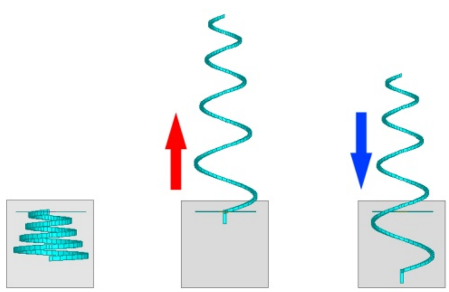

Fig.3 Antenna Stowed, Deployed and Operational modes

III. Operation and Results

Once the antenna is fully deployed, it begins to operate at the lowest frequency around 250 MHz. As the antenna is lowered into the cavity, the frequency of operation increases . A 50 Ω feeding mechanism is designed to keep a direct contact with the radiator as it moves up and down on board of the satellite. The antenna tunes its operation over the entire desired band as shown in Fig.4. The antenna preserves its radiation pattern throughout the operational bandwidth as shown in Fig.5.

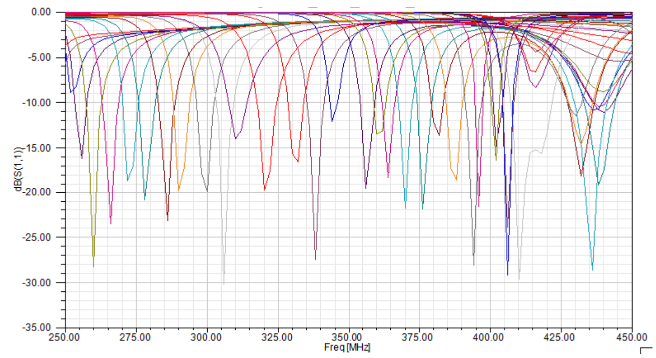

Fig.4 The frequency tuning shown in the antenna's reflection coefficient for various positions

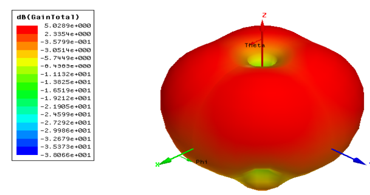

Fig.5 Radiation pattern of the helical antenna throughout its operation

IV. Conclusion

In this paper we discuss adding reconfigurability to a deployable antenna for small satellites. The presented reconfigurable deployable helical antenna deploys in steps to perate within the frequency band of 250-450 MHz. and achieves frequency tuning while preserving its radiation characteristics.

References

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