Effects of the LEO Satellite Structure on the Performance of Quadrifilar Helical Antennas

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Abstract. *This paper presents the effects of a small satellite structure on the characteristics of Quadrifilar Helical Antennas (QHAs). The antenna is first analyzed in free space in order to achieve the desired radiation pattern using Method of Moment (MoM). Two antennas are then simulated in the presence of the satellite structure for two different distances from the satellite surface. It is shown that performance of the antenna is remarkably affected by the satellite structure. Having obtained the radiation pattern of the antenna in the vicinity of the satellite structure, one can use the antenna with the more desirable feature to be implemented.*

Keywords

Quadrifilar helical antenna, Satellite antenna

1. Introduction

Quadrifilar helical antenna (QHA) has been widely used in satellite communication systems due to having good circular polarization, various shapes of radiation pattern, wide beam width, fairy good front to back ratio, small size, and low weight [1-3]. The first application of the QHA in satellite was in 1968 [4]. Nowadays QHA is used as a transmitter antenna in modern small satellites to provide high-speed downlink of the payload data. Especially, the conical radiation pattern of QHA is desirable for low earth orbit (LEO) missions [5-6].

The effects of the ground plane on QHA's performance are so important and some papers have been investigated. In [7], the performance analysis of a vertical and horizontal quadrifilar helical antenna above the average and poor ground plane has been studied. In [8], the effect of the ground plane on QHA phase center and the radiation characteristics of ground position system (GPS) application have been discussed.

In this study, the radiation characteristics of a half-turn QHA have been analyzed both before and after installing on the satellite structure. The satellite type is small with cube geometric shape structure, having size of $5\lambda\times5\lambda\times4.17\lambda$ and a mass below 100 kg. λ is the free space wave length at the operating frequency of 2.5 GHz. Using MoM-based commercial FEKO software; the surface of the cube has been assumed perfect electric conductor (PEC) instead of a good conductor such as aluminum.

This paper has been organized in five sections. In the next section, configuration and design of the antenna has been discussed before mounting the antenna on the satellite. Performance of the proposed antenna in the presence of the satellite body has been investigated in section 3. Experimental results of the antenna implementation on the satellite body have been demonstrated in section 4. Finally, the conclusion is given.

2. Antenna Configuration and Simulation

A conventional QHA consists of four wire helices equally spaced circumferentially on a cylinder and fed with equal amplitude signals with relative phases of 0º, 90º, 180º, and 270º. There are several methods to feed QHAs [9]. In this paper, a 90º hybrid coupler has been used to obtain 90º required phase shift. In order to feed two symmetric helices in each bifilar with asymmetric coaxial cable, it is necessary to use a balun. Here, the feed system has been realized by use of an infinite balun. One bifilar of the QHA with the infinite balun for feeding has been shown in Fig. 1.

The antenna has been analyzed with MoM to have the maximum gain in the elevation 60º and Nadir null less than 10dB in the radiation pattern at 2.5 GHz. Two antennas (*i.e.*, Ant1 & Ant2) have been designed with the geometrical parameters illustrated in Tab. 1.

The simulated relative radiation power and the axial ratio of two antennas have been depicted in Fig. 2. The Nadir null of the antenna is 3 and 6 dB, respectively. The axial ratio is better than 3 dB for both of the antennas in all the elevation angles in the front hemisphere. It seems that Ant2 is more appropriate for LEO satellite application because of well tuned Nadir Null.

3. Effects of the Satellite Body on the Antenna Characteristics

Fig. 3 shows the antenna location to mount on the satellite. Having best symmetrical radiation pattern, the antenna has been fixed in the center of the satellite top plane with the height of h from the satellite surface.

Antennas have been simulated by FEKO software with $h = 0.25\lambda$, 0.5λ, and the results have been depicted in Figures 4 and 5. As shown in the simulation results, Nadir null has been reduced in both of the antennas. In addition, the symmetry of the patterns is fairly good in case of $h = 0.25\lambda$, but the value of the axial ratio especially in Ant2 is improper in case of $h = 0.25\lambda$. Although increasing the antenna distance from $h = 0.25\lambda$ to $h = 0.5\lambda$ results in improving the axial ratio, the symmetry of the radiation patterns has been lost. Nadir null exceeds 10 dB for Ant2 in case of $h = 0.5\lambda$ as well. Consequently, Ant1 has been selected in order to implement.

4. Experimental Results

Fig. 6 shows measurement results of Ant1. It is observed the radiation pattern of the antenna with $h = 0.25\lambda$ is conical shape with the maximum gain nearly at the elevation 60º and Nadir null of 7 dB. In case of $h = 0.5\lambda$ the multiple lobe radiation pattern has been measured as expected from the simulation results.

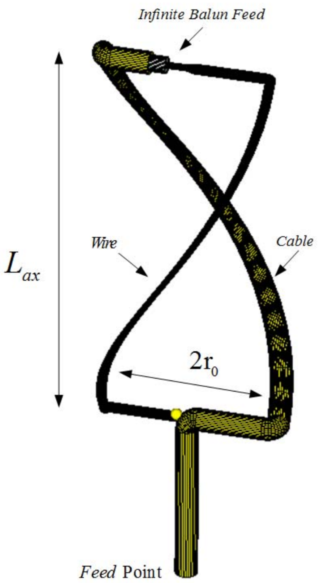

Fig. 1. The structure of the space bifilar.

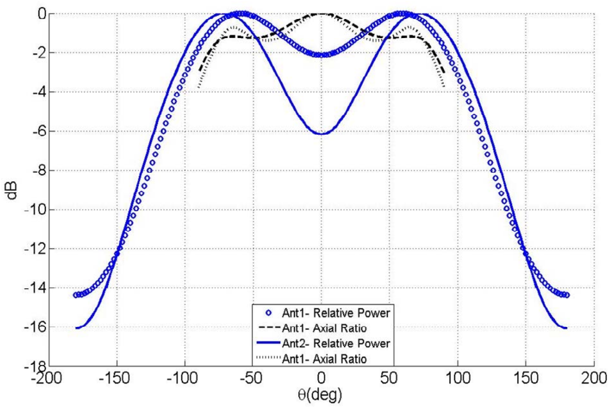

Fig. 2. The simulated relative power and the axial ratio of the elevation radiation pattern.

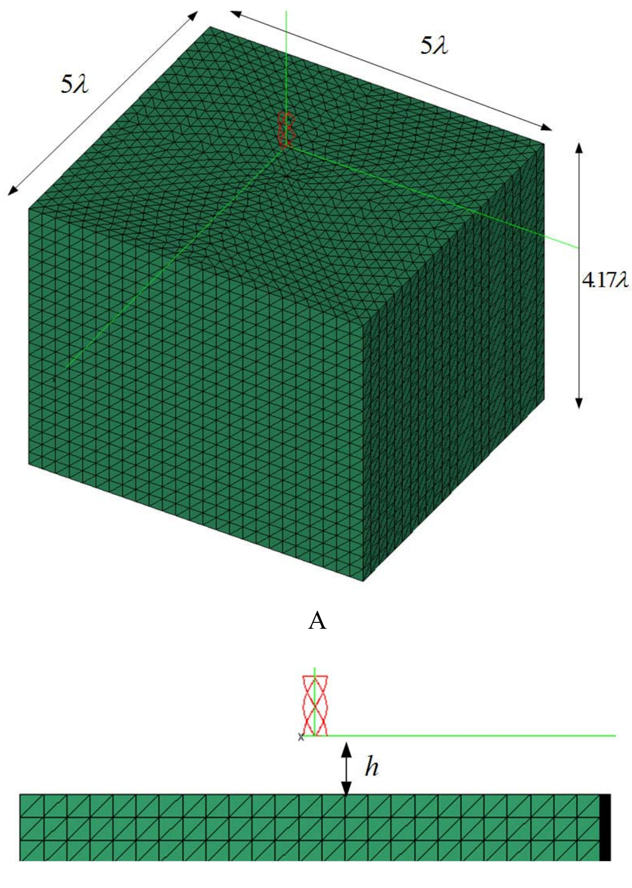

Fig. 3. View of the QHA mounted on the satellite cube. A: 3-D View, B: Front View.

	L_{ax}	r_0	R_1	R_C
Ant1	0.5	0.1	0.008	0.012
Ant2	0.575	0.095	0.008	0.012

Tab. 1. The parameters of the QHAs in terms of λ.

R_1 : Wire radius

R_C: Outer cable radius

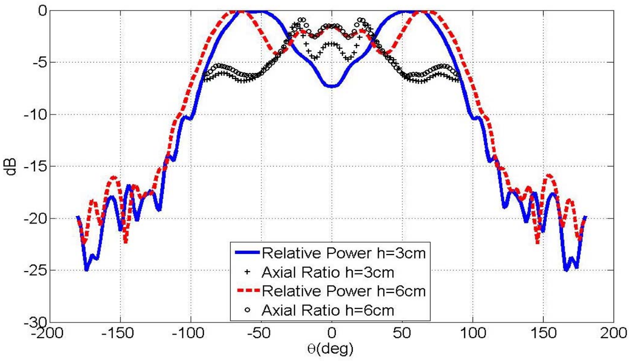

Fig. 4. The simulated relative power and the axial ratio of Ant1 in the vicinity of the satellite body.

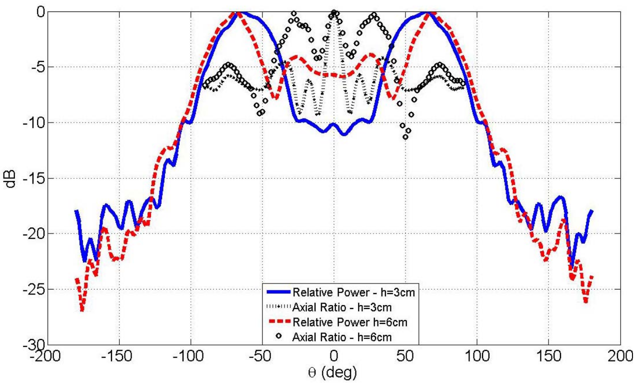

Fig. 5. The simulated relative power and the axial ratio of Ant2 in the vicinity of the satellite body.

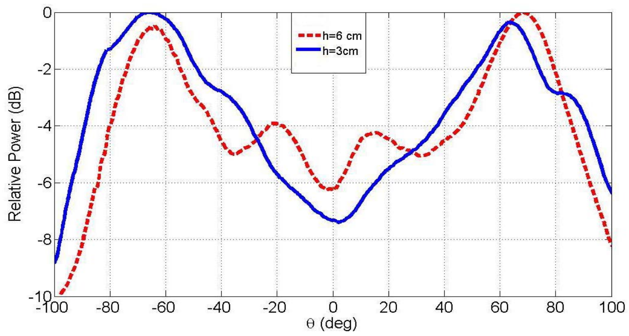

Fig. 6. Measurement of the relative power of Ant1 in the vicinity of the satellite body.

5. Conclusion

The effects of the metallic body of the small satellite on the characteristics of the QHA have been presented. Two half-turn quadrifilar helical antennas have been analyzed in the neighborhood of the satellite structure with the different distances from the satellite top surface. It is shown that the axial ratio, pattern symmetry, shape of the radiation pattern and Nadir null value have been affected by the satellite structure. Better performance is achieved numerically and experimentally for Ant1 in case of $h = 0.25\lambda$. The metallic satellite body deteriorates the desired characteristics of the QHA because of increasing h.

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