Design and Analysis of Dual-Loop VHF Circularly Polarized Antenna for Low Earth Orbit Satellites Ground Stations

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ABSTRACT

The State University of Rio Grande do Sul is one of the partners to develop a National Satellite Network Stations for remote sensor data gathering and communication in Universities and Schools. The research has focused on a Low Earth Orbit (LEO) CubeSat system, with support from the Brazilian federal government's and Brazilian Space Research Program. Our objective is to describe the implementation of a compact, low-cost antenna solution for the National Satellite Network, operating in the 145-146 MHz band. This paper proposed a single feeding port, low profile VHF omnidirectional circularly polarized (CP) antenna. The simplicity of the design coupled with broad impedance bandwidth and axial ratio make it suitable for satellite communication terminals.

KEYWORDS

VHF antenna, Wire antenna, Circular polarization, Axial ratio, Radiation pattern.

1 INTRODUCTION

Circularly Polarized (CP) antennas offer a distinct advantage over the Linearly Polarized (LP) antennas for satellite applications. The main advantage of CP versus linear polarization is that CP eliminates polarization mismatch losses caused by Faraday's rotation and varies the squint angle of polarization vectors between stations on the Earth. Conventional approach in designing CP planar loop/dipole antennas uses four or two separate antenna elements fed by their own feeding networks usually containing phase shifters or 90-degree hybrids, which contributes to the system design complexity [1].

It is well known that a one-wavelength perimeter square loop antenna radiates linearly polarized waves [2]. The reason for the linear polarization production is due to the in-phase current distribution along its two radiating sides. A square loop antenna can also radiate a CP wave if a gap is introduced on the loop [3, 4, 5, 6]. The CP radiation is due to the travelling-wave current distribution that becomes excited along the loop. The sense of circular polarization can be switched from left-hand or right-hand, by altering the gap positions [7]. In this article, a simple CP dual-loop planar antenna is proposed. Theoretically this antenna can generate nearly ideally circular polarization at broadside (perpendicular to the loop plane). The structure of the proposed antenna is simple and can be fabricated using thin aluminum tube/wire (light-weight), which leads to the advantages such as low cost and low profile. The design processes of the proposed antenna are explicitly shown, and parametric studies through simulation based on a method of moment (MoM) were carried out. Typical experimental measurement was also conducted and compared to the simulated ones.

2 ANTENNA DESCRIPTION AND DESIGN

Figure 1 shows the geometry of the proposed CP dual-loop. The antenna is designed to resonate in the 146 MHz (λ_0=2.05m), the

Cubesat's VHF downlink band. In Figure 1, the radiating elements are metallic wire elements (aluminum) having a rectangular shape (10mm X 2mm). Length of the gaps section (g_1 and g_2) is optimized in Numerical Electromagnetics Code, NEC-2 [8] for the best axial ratio (AR). The optimized value for g_1 and g_2 is $\approx 0.01\ \lambda_0$. The square side length L1 and L2 is $\approx 0.25\ \lambda_{0,}$ or 510mm. The length of the fp (gap of feed point) is about 10mm. The antenna requires a transformer circuit to realize a balanced feed. A simple unbalanced to balanced 4:1 impedance transformer made of coaxial cable was used.

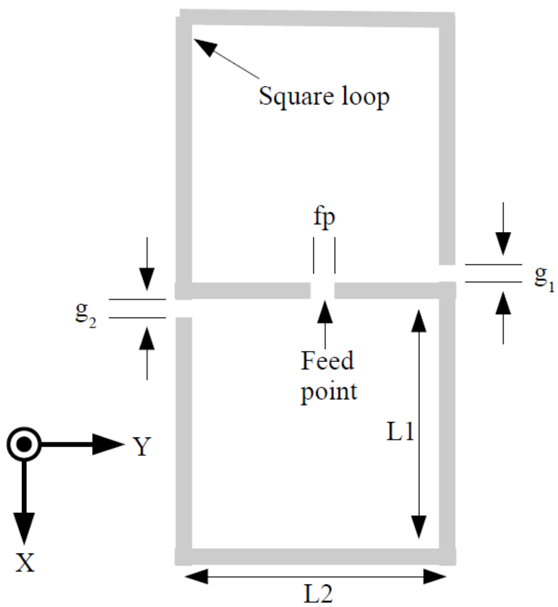

Figure 1. Geometry of the proposed dual-loop CP antenna.

3 RESULTS AND DISCUSSIONS

The goal of this study is to develop a planar dual-loop antenna with good CP radiation and good impedance match at the frequency of 146 MHz. In order to easily evaluate the circumference (length of L1 and L2) of the dual square-loop related to the desirable operational frequency, several simulations have been done by NEC-2 simulator. The influence of various parameters on the antenna performances such as input impedance, height above a flat typical ground, electric field amplitudes/phases, and axial ratio (AR) have been investigated. Figure 2 shows the simulated and measured input impedances of the proposed dual-loop CP antenna. The Figure 3 shows the reactance simulated and measured. Good agreement was achieved between the simulated and measured results.

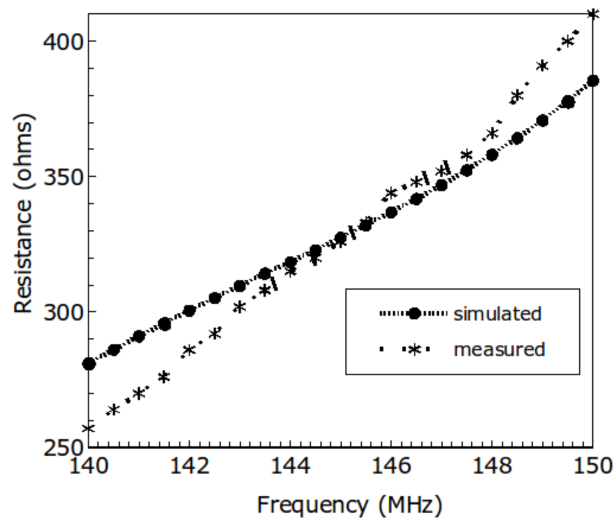

Figure 2. Measured and simulated input impedance.

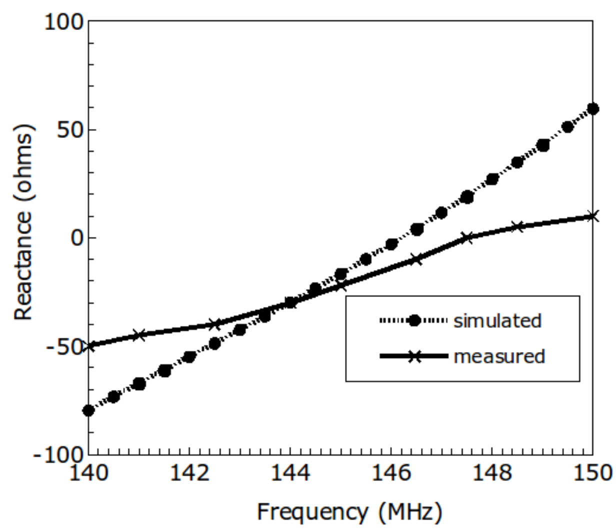

Figure 3. Measured and simulated input reactance.

The measured return loss response of the antenna versus frequency is shown in Figure 4.

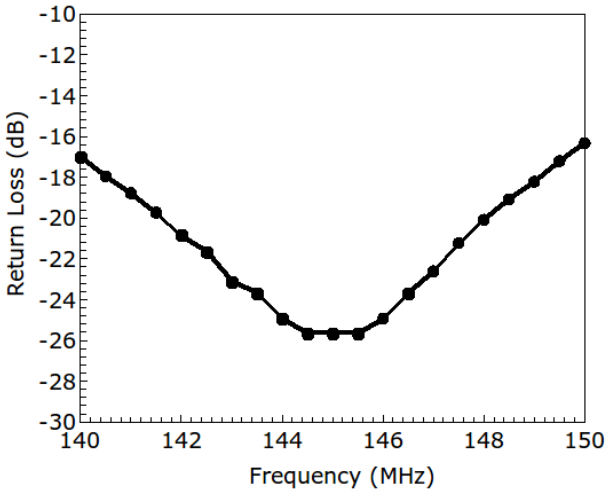

Figure 4. Measured return loss against frequency for the proposed antenna.

The antenna height was 5 meters above flat and unobstructed ground during the measured of return loss in Figure 4.

The measured impedance bandwidth for a return loss more than -10 dB was approximately 20 MHz (135–155 MHz). From the above results, it has proven that the bandwidth of this antenna is more than adequate for use in the Cubesats VHF segment (145-146 MHz).

The Figure 5 shows the simulated axial ratio with respect to the elevation in the *xz* plane.

The discrepancy in the symmetry of the axial ratio for elevation more than 15° in xz plane in the right part of Figure 5 is explained by the presence of the gaps on the loop corners and the effect of the edges on the current distribution.

The elevation-angle ranges, when AR values are less than 3dB, are -50 to 65 degrees at 146 MHz.

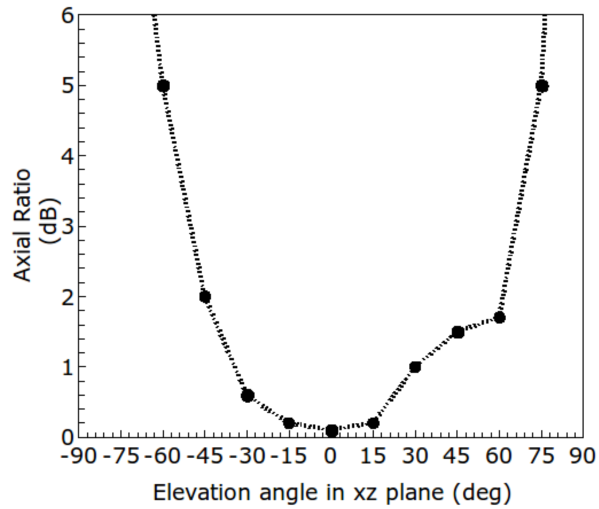

Figure 5. Simulated axial ratio with respect to the elevation in the *xz* plane.

Figure 6 presents the simulated antenna gain for the proposed dual-loop antenna, and steady gain variation of no more than 0.2 dB was observed between 140 and 150 MHz. At 146 MHz, gain of 7.3 dBic was attained by the proposed CP loop antenna.

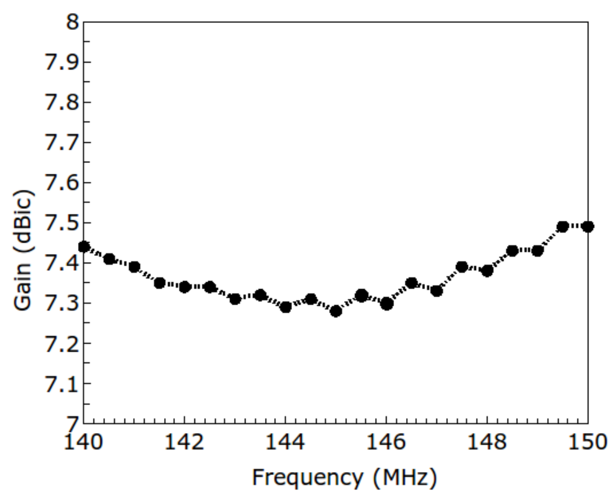

Figure 6. Simulated antenna gain for the antenna studied in Figure 1.

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4 CONCLUSIONS

A simple planar omnidirectional CP square dual-loop antenna for VHF LEO satellite application has been successfully studied and implemented. The impedance bandwidth were 20 MHz (135–155 MHz). The gain at 146 MHz was 7.3 dBic, and steady gain variation of no more than 0.2 dB was observed between 140 and 150 MHz. The proposed antenna has good broadside CP radiation patterns at least covering the range of 115 degrees in elevation. Based on the above, we conclude that the proposed antenna has excellent performance and is highly recommended for LEO satellites ground stations.

ACKNOWLEDGMENT

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