SMALL MICROSTRIP ANTENNAS FOR CUBESAT

Wellington Guilherme da Silva, Antonio Luiz P. S. Campos

Post-Graduate Programs in Electrical and Computing Engineering (PPgEEC))
Federal University of Rio Grande do Norte - UFRN
Campus Universitário Lagoa Nova - Centro de Tecnologia - Natal - CEP 59.072-970 - RN - Brasil
wellington-silva@uol.com.br, alpscampos@gmail.com

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Abstract

A CubeSat is a type of miniaturized satellite used primarily by universities for space exploration and research, typically in low Earth orbits (e.g. sun synchronous). CubeSat satellites require antennas to realize four fundamental functions: 1) Telemetry, tracking and command (TT&C); 2) downlink for payload data; 3) GPS/GNSS signal reception; and 4) Inter satellite cross links. The area available in an 1U CubeSat for the antenna allocation is 10 cm x 10 cm [1]. CubeSat antennas should be small size, light, low power consumption and low cost. Therefore, these devices are challenging for antenna designers. The size of the antenna is proportional to the wavelength, therefore the size is a problem for low frequencies, especially in the VHF and UHF bands [2]. This work presents antenna miniaturization techniques using microstrip antenna and fractal geometry in order to obtain antennas of adequate size and weight for CubeSat applications.

1. Introduction

The CubeSat standard started as a joint project between Cal Poly State University and Stanford University in 1999. Cal Poly Professor Dr. Jordi Puig-Suari and Stanford Professor Bob Twiggs presented a design protocol that specifies maximum outer dimensions equal to 10 x 10 x 10 cm^3, i.e., a CubeSat has a cubic shape and occupies a volume up to 1 liter [3, 4].

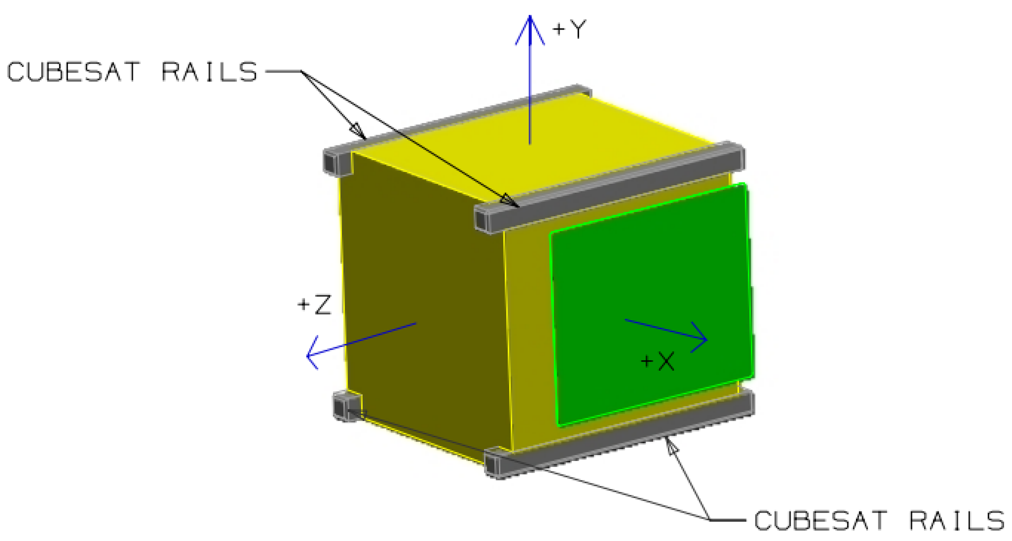

Figure 1: *CubeSat 1U [3]*

The standard 10 x 10 x 10 cm^3 basic CubeSat is often called a "1U" CubeSat, meaning one unit. CubeSats are roughly scalable in 1U increments and larger. The five basic sizes are 0.5U, 1U, 2U, 3U and 6U. While many criticized this standard as being "too small to do anything" universities and industry have shown that a lot of science and data collection is possible with these small satellites. Novel electronics devices, such as cheap cameras, processors and sensors gain space ratings by flying in a CubeSat [4].

Table 1 shows the classification of each satellite, and the corresponding mass and cost. As shown, significant savings in mass, cost, and development time can be achieved by using modern small satellites compared to conventional large satellites [5].

Table 1: *Classification of satellites [5].*

Type	Mass (kg)	Cost (US$)	Time of Development
Large satellite	> 1000	0.1 – 2 B	>5 years
Medium satellite	500 - 1000	50 – 100 M	4 years
Mini-satellite	100 - 500	10 – 50 M	3 years
Micro-satellite	10 - 100	2 – 10 M	1 year
Nano-satellite	1 -10	0.2 – 2 M	1 year
Pico-satellite	< 1	20 – 200 k	<1 year
Femto-satellite	< 0.1	0.1 – 20 k	<1 year

2. Overview of antennas designs for small satellites

The antenna is an essential part of a CubeSat. It performs communications between satellite and the ground station or for inter-satellite crosslink communications. Most antenna implementations target either the TTC or the payload data downlink subsystem. A majority of the CubeSats operates in amateur VHF (144-146 MHz) and UHF (435-438MHz) frequency bands. These frequency band are intended to be used by duly authorized persons for non-commercial purposes and without any pecuniary interest. These bands present typical low data rates between 1200 and 9600 bps. However, these data rates are enough for TT&C applications [6]. However, high-speed downlinks for payload data will need high data rate systems, in these cases S-band (2 - 4 GHz) is the more common solution [1].

There are mainly five types of antennas [7]. They are:

1. Wire Antennas
2. Microstrip Antennas
3. Horn Antennas
4. Array Antennas
5. Reflector Antennas

The most common solution for VHF-UHF antennas in CubeSats applications are the linear wire deployable antennas, specially dipole antennas and its variations. However, deployable mechanic system presents the risk of a deployment failure. This deployment mechanism increases the risk of failure during the mission, and subsequently asks more attention during design, integration and testing of the CubeSat. Furthermore, this system adds extra mass to the CubeSat and it takes up space that could be used by other subsystems [8]. As an alternative to deployable linear wire antennas in order to overcome the failure risk, microstrip antennas are an attractive option.

3. Designing and simulating small antenna for CubeSat

One of the most challenging areas is wireless handset design in which size reduction is limited by the size of two main components: batteries and antennas. This is because antennas (and batteries) do not follow Moore's law for integrated circuits, which predicts that component density on a chip increases by a factor of 2 every 18 months [9]. Miniaturization techniques can be separated in five categories [10].

1. loading the antenna with high-contrast material, high permittivity and/or high permeability.
2. modifying and to optimizing the antenna geometry and shape.
3. using lumped component in order to compensate the reactive impedance.
4. using artificially engineered electromagnetic metamaterials.
5. based on formal optimization method (fuzzy logic, genetic algorithm...).

This work have investigated, designed and simulated three examples of the small antennas in order to get an antenna operating at 435 MHz occupying an area as small as 100 x 100 mm. An initial square microstrip patch antenna was designed and simulated in order to compare the parameters. Two miniaturization techniques are combined to obtain a high degree of miniaturization of a microstrip patch antenna. The first technique is the use of a high permittivity substrate, and the second technique is microstrip patch antennas with Sierpinski geometry.

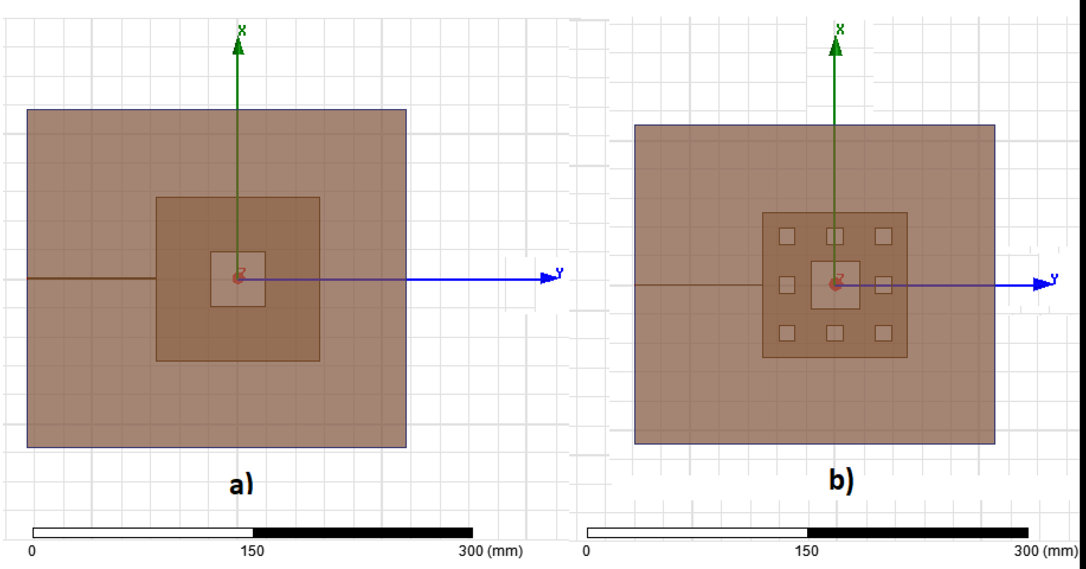

Figure 2: *Sierpinski microstrip patch antenna a) first and b) second iteration.*

The Table 2 summarizes main parameters obtained by designed structures.

Table 2: *Main parameters obtained by designed structures.*

Simulation Cases	FBW (MHz)	Gain (dBi)	Directivity	Width (mm)	Size (%)
Initial	11.0	2.1667	3.8972	156	100
1^{st} Case	4.8	1.8309	3.1430	124	80
2^{nd} Case	6.7	1.6080	3.0304	113	73
3^{rd} Case	6.8	1.6490	3.0637	119	77

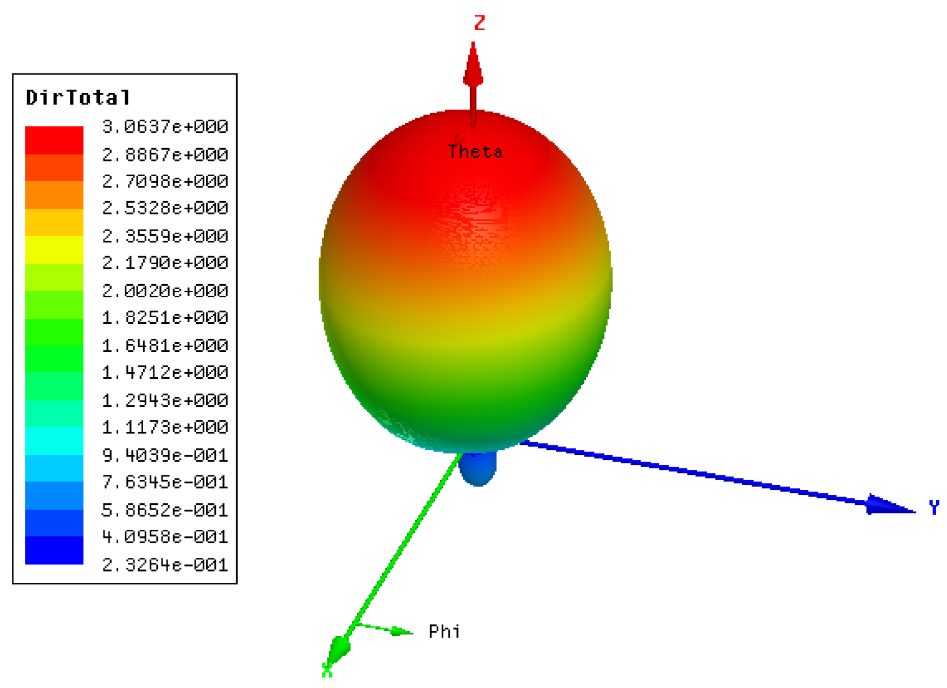

Figure 3: *Sierpinski microstrip patch antenna a) first and b) second iteration.*

4. Conclusions and further work

The combined use of a a high permittivity substrate and a Sierpinski fractal geometry patch resulted in a 27% decrease in the size of an antenna. However, the reduction was not sufficient to obtain an antenna occupying an area of 100 x 100 mm predicted for a CubeSat of 1U. In addition, the simulations presented low efficiency, which was expected due to the reduction of the effective area. This work will be continued looking for a solution that results an antenna with adequate area and efficiency, as well as other desirable parameters such as polarization and radiation pattern.

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