# A Wideband Circularly Polarized Stacked Antenna with Corner Perturbations for CubeSats

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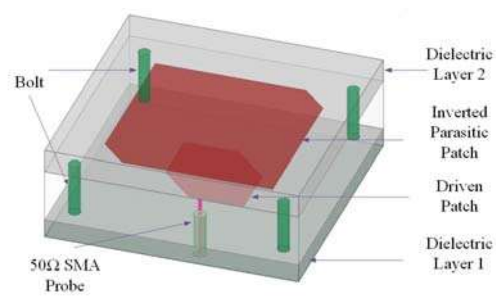
***Abstract*— This paper presents a single-feed circularly polarized wideband printed antenna for small satellites, which can be used with NASA Near-Earth Networks (NEN) for both uplink and downlink communications. This electromagnetically coupled stacked antenna is capable of working with a duplex transceiver and has the advantage of not requiring two different antennas for transmitting and receiving. It shows a significantly wide axial ratio (AR) < 3dB bandwidth of 1.24 GHz from 7.02 GHz to 8.26 GHz (16.23%). An optimized combination of stacked patches provides a 27% $S_{11}$ < -10 dB bandwidth. This wideband covers the NASA NEN's X-band uplink and downlink frequencies. The overall antenna size for a single element is 17 mm × 17 mm × 6.5 mm, which can provide a peak gain of 8 dBi. This antenna can save up to at least 50% area required by the conventional two-antenna solution for uplink and downlink, which is critical for CubeSat applications.**

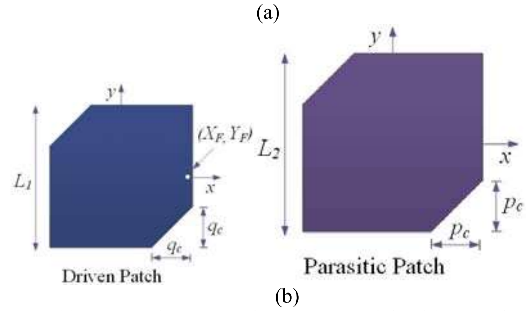
***Keywords—Small Satellite, circular polarization, wideband, axial ratio***

## I. Introduction

Small satellites are predominantly shaping future space research and industry. Most of the giant government and private organizations are moving towards this miniaturized version of spacecraft because of its matured capabilities for enabling numerous space experiments. This also challenges engineers and researchers associated with CubeSat subsystem development to downsize their respective components or systems with the same or improved capability. Hence, reducing the number of components is another quest of the system designers as this results in simultaneous reduced power and space requirements. The communication subsystem of small satellites often consists of radio, a number of antennas, and antenna positioners. Among them, antennas have a direct conflict with the solar panels for accommodation at outside faces of small satellites. The more the space available in the outside wall, the more space is available for installing solar cells to generate more electric power for the spacecraft. That's why small satellite system designers always prefer the option of the least space-occupying antenna combination. Then comes one of the most important and major tasks of frequency licensing. For this, the system designers have to choose two frequency bands allocated for one or multiple ground stations for transmitting and receiving data. The common trend for a communication system is to use two different antennas for uplink and downlink communications. The reason behind this is that it is a challenging task to cover both the allocated uplink and downlink frequencies with one antenna. Moreover, small satellites need circular polarization rather than linear polarization to avoid strict antenna alignment requirement and reduce the polarization loss [1]. It is always desirable to have a singly-fed circularly-polarized antenna to achieve both uplink and downlink communications.




(a)




(b)

**Fig. 1:** (a) Proposed antenna, (b) geometry of the driven and parasitic patch with negative perturbations

Ref. [2] provides a solution of a single antenna with dual-band circular polarization radiation to cover the uplink and downlink frequencies of NASA Deep Space Network, which could be used for the NASA Near Earth Network (NEN). [3] documented all the NASA NEN ground stations' allocated

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frequencies for uplink and downlink satellite communications. However, NASA NEN's X-Band downlink frequency starts from 7500 MHz and can go up to 8500 MHz where the uplink frequencies are 7025 MHz to 7200 MHz. In this paper, a wideband antenna based on stacked patches and corner perturbations is proposed to operate at NASA NEN's uplink and downlink frequencies.

## II. Antenna Geometry

The proposed electromagnetically-coupled patch antenna follows the theory and design procedure documented in [4]. However, based on its application's criteria, 50Ω coaxial probe feeding is chosen over the line feeding with a tuning stub. Overall, the antenna contains three metal layers, two dielectric layers and an air gap of 3.6 mm. The base substrate is Rogers RT/duroid 6010 with 1.27 mm thickness and relative permittivity of 10.2. The impedance matching and the circular polarization bandwidth highly depend on this base substrate. The first metal layer is a ground plane made of 35 µm-thick copper. The driven patch is on the base dielectric layer and excited by a 50Ω SMA probe at a point 2.8 mm away from the center of the driven patch. The second dielectric layer is Rogers RT/duroid 5880 with a thickness of 1.575 mm and relative permittivity of 2.2 on which the third metal layer is etched. The air gap is between the base dielectric and the inverted parasitic patch, as shown in Fig. 1 (a). This parasitic patch is electromagnetically-coupled to the driven patch without any direct electrical contact. Fig. 1(b) and Table I describes the geometry of the patches used in the design. The ground plane size is 17 mm × 17 mm, which determines the overall antenna size. Circular polarization from both patches are achieved by applying corner perturbations to the driven and parasitic patches.

TABLE I. The Design Parameters of the Proposed Antenna

| Driven Patch size (mm) | Driven Corner Perturbation (mm) | Parasitic Patch (mm) | Parasitic Corner Perturbation (mm) | Probe Position ($X_F$, $Y_F$) (mm) |
|---|---|---|---|---|
| $L_1$= 6 | $q_c$ = 2.3 | $L_2$= 11.8 | $p_c$= 1.7 | (2.8, 0) |

## III. Results

The optimization process has targeted achieving both wide impedance and axial ratio bandwidths covering both uplink and downlink frequencies. In order to achieve these, the patch dimensions and perturbations are optimized carefully to adjoin the resonances generated by driven and parasitic patches. Finite element method (FEM)-based simulation tool: Ansys HFSS 2020 is used to optimize the antenna. A wide bandwidth for $S_{11}$ < - 10 dB is obtained from 6497 MHz to 8517 MHz (2020 MHz or 26.9%), as shown in Fig. 2. The simulated axial ratio < 3 dB bandwidth is 7020 MHz to 8260 MHZ (1240 MHz, 16.23%). Based on the polarization rotation direction, there are two types of circularly polarized antennas: Right-Hand Circularly Polarized (RHCP) antennas, and Left-Hand Circularly Polarized (LHCP) antennas [5]. This antenna is a RHCP antenna with a simulated peak gain of 8 dBi. Fig. 3 shows the axial ratio and RHCP gain versus frequency plots of the proposed antenna. Here, the driven patch operates at the first axial ratio minimum region while the parasitic patch provides the operation at the

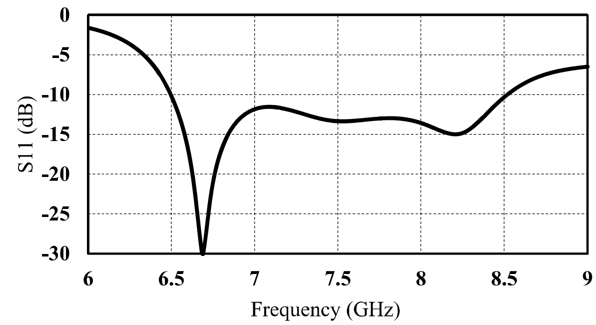


**Fig. 2:** Simulated $S_{11}$ versus frequency plot

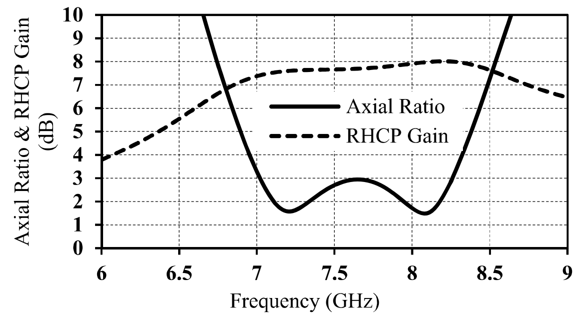


**Fig. 3:** Axial ratio and RHCP gain versus frequency plots

second axial ratio minimum region, and together they provide the targeted wideband circular polarization operation. The antenna has wide AR beamwidths in both planes. At the first minimum AR frequency (7212 MHz), the beamwidth is $97^0$ ($-37^0$ to $+60^0$) in the φ= $0^0$ plane and $134^0$ ($-61^0$ to $+73^0$) in the φ= $90^0$ plane. These values are $108^0$ and $93^0$ respectively in those plane for the second minimum AR frequency (8076 MHz). The 3 dB RHCP gain beamwidths are around $75^0$ to $85^0$ in both planes for the first and second AR minima respectively.

## IV. Conclusion

This paper presents a circularly polarized antenna that has a wide 3dB axial ratio bandwidth of 16.23%, which covers the uplink and downlink frequencies of NASA NEN. This high gain antenna with a very small size of 17 mm × 17 mm is a compact solution for CubeSats compared to that with two separate antennas for uplink and downlink communications. This will allow extra space in small satellites to install additional solar cells to obtain more power.

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