2024 IEEE International Symposium on Antennas and Propagation and INC/USNC-URSI Radio Science Meeting (AP-S/INC-USNC-URSI) | 979-8-3503-6990-8/24/$31.00 ©2024 IEEE | DOI: 10.1109/AP-S/INC-USNC-URSI52054.2024.10686112

Single Feed Slot-Loaded Dual Band Planar Antenna for CubeSat Applications

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Abstract— **A dual band (S and X) Antenna has been proposed in this article for the communication subsystem of CubeSat, a popular miniature satellite among enthusiasts and researchers. The antenna body has a dimension of 100mm×100mm×24.315mm in total. Using a combination of two planar antenna types, i.e. slot and patch, this compact antenna offers 11.11% of $S_{11} \leq$ -10 dB bandwidth and 1.33% of Axial Ratio (AR) bandwidth in the S-band, as well as 2.32% of $S_{11} \leq$ -10 dB bandwidth and 1.16% of AR Bandwidth in the X-band. While the S-band patch demonstrates a high circular polarization (CP) gain of 9.035dB, the X-band slot antenna provides a moderate 4.65dB CP gain. This antenna is suitable for dual band operations enabling uplink and downlink communications from a single antenna, which will reduce the number of antennas needed in the conventional approach.**

Keywords: CubeSat, dual band, wide bandwidth, Planar antenna

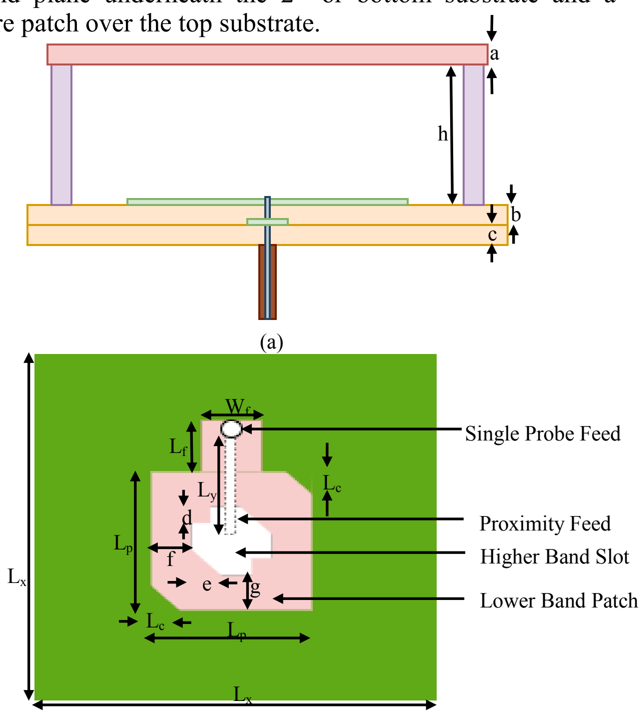
I. Introduction

CubeSat is a cost-effective alternative to traditional satellites which has paved the way for researchers in academia, more precisely students, to take part and excel in small satellite development from the scratch [1]. Since its inception in 1999, CubeSat has evolved a lot in terms of technology used in different aspects of it. One of the integral parts of any CubeSat is the Communication subsystems, which means receiving commands from ground control center and sending science and instrument data to the ground control center. Some of the CubeSats may also need to communicate with each other. To serve such purposes, antenna becomes a mandatory element to transmit the signal to the ground and receive signal from ground through electromagnetic radiation.

Multiple types and configuration of antennas have been used for CubeSat communication system. As CubeSat is small, the usual unit is 'U' which denotes 10cm×10cm×10cm volume [2]. The size may vary in integer multiple of 'U'. The weight of a CubeSat must be within a certain limit depending on its size. To communicate in higher bands at a high data rate, a moderate gain and wide bandwidth antenna is necessary. As satellite is a moving body, antenna misalignment is an issue of concern which can be mitigated by using circularly polarized antennas. Nowadays, CubeSats use low frequency bands to transmit housekeeping data and to receive the commands from ground control. On the other hand, the payload data is usually transmitted through higher frequency bands to ground control. To save space, which is critical in the CubeSat development, a single antenna body has been proposed in this paper where a planer square-shaped patch antenna is designed to radiate in the S band. Inside the patch, a double diamond-shaped slot is introduced for X band radiation. The excitation for the S-band antenna is done by a single probe on a stub attached to the patch. For exciting the slot, another substrate is added between the patch and the ground plane, and. a channel is sandwiched between two substrate layers to create proximity feeding [3]. The Patch is truncated in both corners to generate circular polarization [4]. The double diamond-shaped slot also has perturbations [5] for the same purpose. A superstrate is added on the top to increase the gain at both bands [6].

II. Design Parameters

Fig. 1 shows the geometry of the antenna, where Rogers RT/Duroid 5880 (ε_r = 2.2 and tan δ = 0.009) is used for both the substrates with a thickness of 1.57mm ('b' and 'c'). It has a ground plane underneath the 2nd or bottom substrate and a square patch over the top substrate.



(b)

Figure 1. Geometry of the proposed antenna (a) side view, and (b) top view

The Truncation of corners is Lc= 8.5mm. The superstrate is a Taconic CER-10 Material (ε_r = 10.2 and tan δ = 0.0035) with a height of a=3.175mm. The distance between the top substrate and the superstrate is 18mm ('h'). The dimensions of the substrates and superstrate are 100mm×100mm and 90mm×90mm, respectively. A slot of double diamond shape (DDS) with parameters defined in Fig. 1(b) is introduced inside the patch. The sandwiched feedline (the proximity feed) is placed in between the top and bottom substrate with a length 'Ly' of 27.4mm and a width of 1.33mm. The proposed antenna is modeled and simulated using ANSYS HFSS 2022, and the optimized parameters are presented in Table I.

TABLE I. OPTIMIZED DIMENSIONS OF THE ANTENNA

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
L_x	100	W_f	9.5
L_p	41	a	3.175
L_y	27.4	h	18
L_c	8.5	b, c	1.57
d, e	5.35	f	13.25
L_f	10	g	14.65
Slot Length	14.5	Slot Width	14.5

III. SIMULATION RESULTS

A. S Band Results

The simulated S_{11} and the axial ratio (AR) of the antenna are presented in Fig. 2. The patch antenna shows a wider S_{11} bandwidth (<10dB) ranging from 2.19 to 2.45 GHz, 260MHz in total, and an AR Bandwidth (<3dB) ranging from 2.24 to 2.27GHz (30MHz in total). The peak gain (RHCP) of 9.035dB at the center frequency of 2.26 GHz at φ=0° and θ=0° is obtained also for the structure, which is shown in Fig. 4(a).

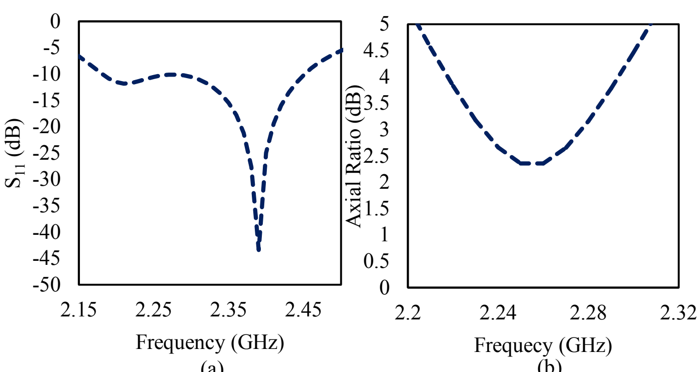


Figure 2. S_{11} vs frequency and Axial Ratio vs frequency plots for S-band

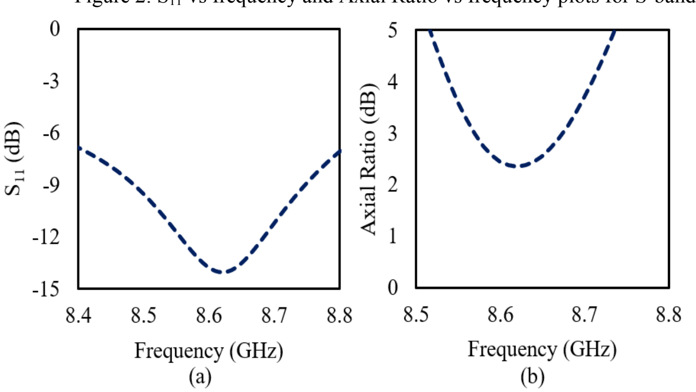


Figure 3. (a) S_{11} vs frequency, and (b) Axial Ratio vs frequency plots for X-band.

B. X Band Results

The S_{11} Bandwidth (<10dB) in the X-band ranges from 8.52 to 8.72 GHz (200 MHz in total) and the AR Bandwidth (<3dB) ranges from 8.57 to 8.67 GHz (100 MHz in total), as can be seen in Fig. 3. Fig.4(b) shows the gain along boresight versus frequency plot in the X-band, where it is evident that the peak gain occurs at 8.66 GHz frequency with a value of 4.65dB.

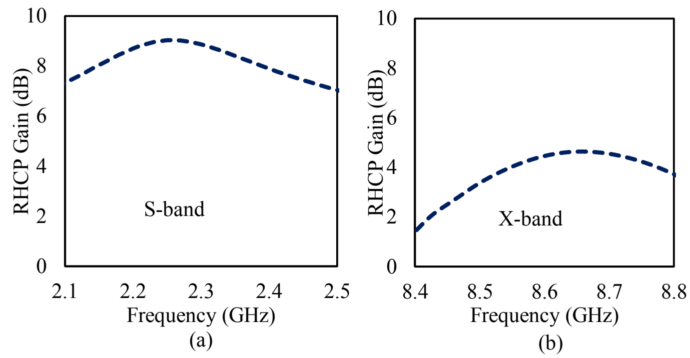


Figure 4. RHCP gain vs frequency plot in the left for S band and in the right for X band for the φ=0° and θ=0° planes

IV. DISCUSSION

In this design, it has been shown that the antenna is capable of radiating in both S and X-bands with moderate gains and wide bandwidth. In circularly polarized antenna, AR bandwidth is very important. It is very difficult to achieve significant AR bandwidth from a single patch/slot antenna. However, the proposed antenna shows 11.11% of $S_{11} \leq$ -10dB bandwidth, 1.33% of AR Bandwidth in the S-band, as well as 2.32% of $S_{11} \leq$ -10dB bandwidth, 1.16% of AR bandwidth in X-band. The antenna does not need any stowing like wire antennas in the space, therefore, it has a reduced risk of failure. Moreover, the high circular gain in S-band and a moderate gain in X-band make the antenna a good contender for dual band CubeSat applications enabling uplink and downlink communications by a single antenna.

ACKNOWLEDGMENT

The authors acknowledge the partial funding provided by the National Science Foundation (Award Number: AGS 1936537) enabling this research project.

REFERENCES

[1] Liu, S., Theoharis, P.I., Raad, R., Tubbal, F., Theoharis, A., Iranmanesh, S., Abulgasem, S., Khan, M.U.A., and Matekovits, L. (2022). "A survey on CubeSat missions and their antenna designs." *Electronics,* 11(13), 2021, pp. 1-2.

[2] Abulgasem, S., Tubbal, F., Raad, R., Theoharis, P. I., Lu, S., & Iranmanesh, S. (2021). "Antenna designs for CubeSats: A review." *IEEE Access,* 9, 45289-45324.

[3] Balanis, Constantine A. "Antenna Theory : Analysis and Design. 3rd ed.", *Hoboken, Nj, Wiley Interscience*, 2005.

[4] S. Gao, Qi Luo, and Fuguo Zhu, Circularly polarized antennas. Hoboken: *Wiley*, 2014, pp 11-12

[5] Chen, Z. N., & Qing, X. (2012, October). "Wideband circularly polarized slot antenna." *In 2012 42nd European Microwave Conference* (pp. 830-833). IEEE.

[6] Younssi, M., Jaoujal, A., Yaccoub, M. D., El Moussaoui, A., & Aknin, N. (2013). Study of a microstrip antenna with and without superstrate for terahertz frequency. *International Journal of Innovation and Applied Studies,* 2(4), 369-371.