Polarization Reconfigurable Antenna for Small Satellite Application

Taha Yekan and Reyhan Baktur
Department of Electrical and Computer Engineering, Utah State University
Logan, Utah, USA
taha.shahvirdi@aggiemail.usu.edu and reyhan.baktur@usu.edu

***Abstract*—A polarization reconfigurable antenna design that enables integration with CubeSat solar panels is presented. The antenna reconfigures between two polarizations by switching pin diodes. The design method and results are presented.**

I. INTRODUCTION

Increasing communication needs demand antennas with diversity [1], and accordingly antennas with polarization reconfigurability through switching have been sought after. Although the main application of antennas with polarization diversity has been in wireless local area networks (WLAN), mobile satellite service and microwave tagging, such class of antenna may be valuable in future space missions, in particular, Cube Satellites (CubeSat) . A basic CubeSat is usually called 1U CubeSat (Fig. 1.a), and it is common to fly 1.5U CubeSat such as the DICE spacecraft (Fig. 1.b) for enhanced mission capacity. Although CubeSat often uses only one type of circular polarization (CP), having a polarization reconfigurable antenna will be an enhancement and consistent with CubeSat philosophy where smaller, cheaper and better are the basis principles.

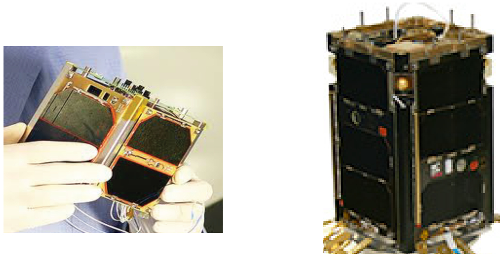

(a) (b)

Fig. 1. CubeSats: (a) 1U, (b) USU's DICE.

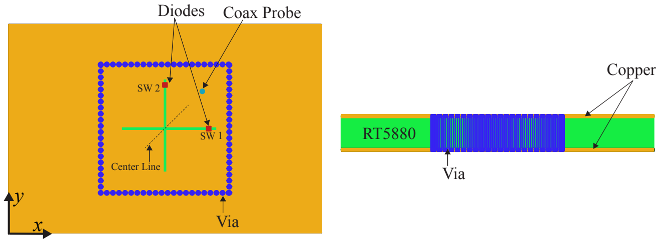
It is straightforward to understand how a CubeSat's mission capacity can be enhanced by having multiple polarizations. As the size of a CubeSat is the biggest limiting factor, being able to integrate a single antenna with polarization diversity with the solar panel will be extremely valuable because one can solve two problems (1. a polarization reconfigurable antenna, and 2. integration of antenna with the solar panel to save surface real estate) at the same time. This paper presents an antenna topology that allows switching between two circular polarizations and can be integrated with the solar panel of a 1U or 1.5U CubeSat. Although there are various reported methods to integrate antennas with solar panels [2], the antenna design of this work is based on cavity backed slot antenna because of its simplicity and minimal impact on the solar cell, including no needs for custom designing solar cells [3].

II. DESIGN

Fig. 2.a shows the top view of the antenna geometry. The cavity backed crossed slot antenna is integrated with the solar panel of a 1.5U CubeSat; and therefore, the panel dimensions are 10 cm × 15 cm. The antenna geometry is based on PCB technology, which is a common base for CubeSat surface mount panel. On a PCB substrate, where top and bottom layers are copper (Fig. 2.b), a cross slot (composed of two orthogonal slots) is etched on the top layer to create a CP. The slot antenna is excited by a coaxial probe that is placed on the center line of the cross, and the top and bottom layers need to be connected, common to a cavity backed slot antenna design [4]. In order to suppress unwanted cavity modes excited by the probe, instead of connecting the two layers through the side walls of solar panel, a square walls of vias, a.k.a. substrate integrated waveguide (SIW) were created around the crossed slot, just to be sufficient for the antenna while suppressing higher modes.

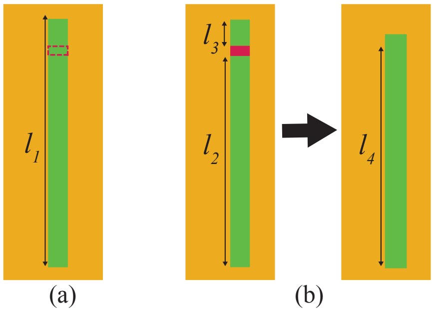
The antenna is designed to function at 2.3 GHz. During the simulation using Ansys' HFSS, in order not to consume up computing time, the vias were first modeled as solid conductor, and then converted to SIW using the previously reported method [5].

A CP is produced by the two slots and a 90 degree phase shift. A left handed CP (LHCP) or a right handed CP (RHCP) can be achieved by adjusting the length difference between the two orthogonal slots. When the slot length on y direction is longer, a LHCP is obtained, and a RHCP is produced when the slot on x is longer than the other slot. A Roger's RT5880 (height 1.5 mm, dielectric constant 2.2 and loss tangent 0.009)



(a) (b)

Fig. 2. Reconfigurable antenna geometry: (a) Top view, (b) Side view.



(a) (b)

Fig. 3. Switch effect on the slot length: (a) Switch is off, (b) Switch is on.

was chosen to be the PCB substrate. To create the length difference for the slots, two diodes (SW1,SW2) were used as shown in Fig. 2.a. The diodes in this project are BAP65LX pin diode manufactured by NXP (www.nxp.com). The on and off stages of the diode change the length of a slot as follows (Fig. 3). When the diode is off, then it has appropriately no impact on the slot. When the slot is on, it acts as a short to bridge the top layer conductor across the slot. Such a short truncates the effective length of the slot from l_1 to l_2 or l_4 (when considering the coupling between l_2 and l_3). In simulation, when the diode is on, it was modeled by series resistance R_s = 0.5 Ω representing the switch loss and package parasitic inductance L_p = 0.6 nH. When the diode is off, it was modeled by series capacitor C_s = 0.5 pF and package parasitic inductance. As a summary, a LHCP is achieved by switching SW1 on and SW2 off, and a RHCP is achieved when SW1 is off and SW2 is on.

III. RESULTS

Fig. 4 is simulated S_{11} for the two polarizations. The impedance matching is achieved by tuning the coax feed along the center line. Fig. 4 shows good impedance matching has been achieved. The difference between the impedance bandwidth of the two polarizations, is due to the fact that the solar panel is rectangle and does not have diagonal symmetry. The axial ratio (AR) is plotted in Fig. 5 and is below 3 dB for both polarizations. The simulated radiation patterns are presented in Fig. 6. Fig. 6.a shows that when SW1 is on, a LHCP has been achieved on the boresight as the RHCP is 20 dB below the LHCP. This is consistent with the achieved AR (Fig. 5). Fig. 6.b shows that switching SW2 on gives rise to a RHCP.

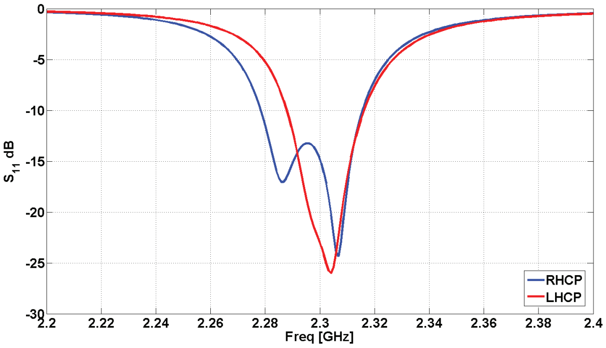


Fig. 4. Simulated S_{11} response.

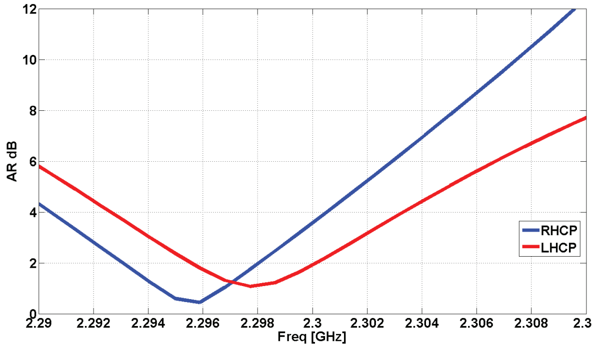


Fig. 5. Simulated AR.

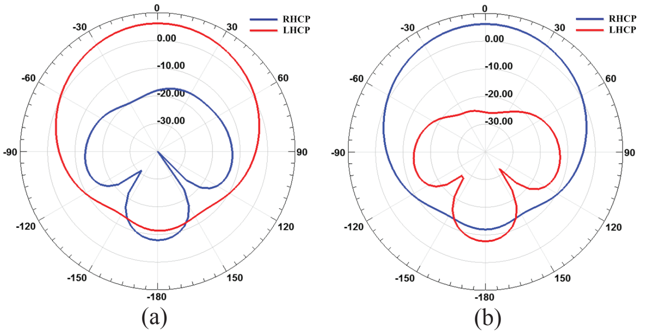


Fig. 6. Simulated radiation pattern: (a) when SW 1 is on, (b) when SW 2 is on.

IV. CONCLUSION

The paper presents a design that enables an integration of a polarization reconfigurable antenna with the solar panel of a 1.5U CubeSat. The antenna geometry is based on a cavity backed slot, and the polarizations are switched between LHCP and RHCP by using pin diodes. The antenna properties (S_{11}, AR and pattern) confirm that the proposed design is capable of reconfiguring two CPs. Although the simulation is presented for a 2.3 GHz antenna, the design can be easily adjusted to other S band or higher frequencies. Also, the antenna design is not limited to 1.5 U, and can be adjusted to suit 1U to multi-U CubeSats.

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