7-1-2012

# Multifunction solar panel antenna for cube satellites

Olutosen Fawole

Reyhan Baktur
*Utah State University*

# Multifunction Solar Panel Antenna for Cube Satellites

Olutosin Fawole, Reyhan Baktur
Department of Electrical and Computer Engineering
Utah State University
Logan, Utah, USA

***Abstract*— A multiport multifunction antenna that could be integrated with a solar panel is presented. The antenna could achieve right-handed circular polarization, left-handed circular polarization, or linear polarizations by selectively excitation of the antenna ports. This antenna design is an extension and a harmonization of previous works on cavity-backed slot antennas. This design could be further developed into a reconfigurable solar antenna by adding appropriate switching mechanism.**

## I. INTRODUCTION

In recent years, cube satellites (CubeSats) of standard size of 100 mm x 100 mm x 100 mm (the 1U CubeSat) have been revolutionizing space research because of their low-cost, short development time, and ease of deployment [1]. Three 1U CubeSats could be stacked together into a 3U CubeSat for extended science missions. As the size of a CubeSat is very small, there is usually competition for space between satellite solar cells and antennas. One effective method to resolve this issue is to integrate antennas with solar panels without affecting the solar cell performance. From such an integration perspective for satellites, the cavity-backed slot antenna is apposite.

Although slot antennas have been integrated with solar panels [2], but without diversity since an integrated solar panel antenna was designed for each specific mission. However, if a solar panel antenna with multiple functions on a single structure could be designed, then it would be possible to reconfigure such an antenna for different missions. This will result in an enormous time and cost reduction for science missions. This paper addresses such an integrated multifunction solar panel antenna that was designed to achieve right-handed circular polarization (RHCP) at 2.4 GHz, left-handed circular polarization (LHCP) at 2.4 GHz, or linear polarizations (LP) at 2.4 GHz and 1.9 GHz, by exciting different feed points.

## II. DESIGN AND FABRICATION

The proposed antenna is shown in Fig. 1. It consists of Eleven slot apertures on the top layer of a metallic cavity loaded with two layers of dielectric material. The slots are laid out such that when cavity is excited by the probe at the lower point, the differential radiations from each slot will combine in the far field to give LHCP radiation, and RHCP radiation when the cavity is excited by the upper probe [3]. In addition, as forethought, the slots have been laid out such that slots 4 and 5; and slots 4’ and 5’ are close enough to couple mutually to resonate at a secondary frequency in addition to their fundamental frequency when fed with a stripline [4]. The radiation at these resonances will be linearly polarized.

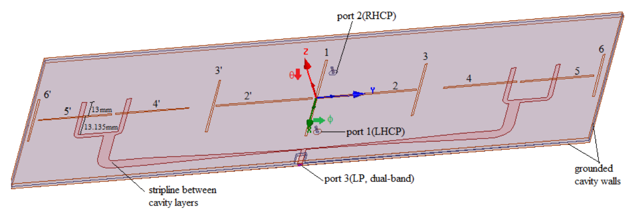


Figure 1. The antenna assembly with annotations. Solar cells could be placed on cavity top in areas not occupied by slots

This antenna was fabricated using two layers of Roger’s Duroid 5880 (relative permittivity 2.2). Each layer has a size of 100 mm x 300 mm (to fit a face of a 3U CubeSat) and thickness of 1.575 mm. Eleven slots, each of width 1 mm, were etched on the top copper surface of the upper substrate using a circuit board milling machine, and the bottom copper surface of the substrate was peeled off. The lengths of the slots and the y displacements of their centers from the y center of the cavity are given in Table I. The slots centers have no x displacement.

TABLE I. SLOT PARAMETERS.

| *Slot* | *Length (mm)* | *Position (mm)* | *slot* | *Length (mm)* | *Position (mm)* |
|---|---|---|---|---|---|
| Slot 6 | 33 | 146.5 | Slot 6’ | 33 | -146.5 |
| Slot 5 | 38 | 125 | Slot 5’ | 38 | -125 |
| Slot 4 | 38 | 85 | Slot 4’ | 38 | -85 |
| Slot 3 | 41 | 53.5 | Slot 3’ | 41 | -53.5 |
| Slot 2 | 50 | 27 | Slot 2’ | 50 | -27 |
| Slot 1 | 60 | 0 | | | |

The stripline was milled on the top surface of the second substrate. The bottom copper surface was left in place to serve as the antenna ground plane. The stripline starts form x position 50 mm and y position 0 mm as a 50-ohm characteristic impedance line of width 2.3 mm. The line extends for a distance of 11 mm, and then branches at a T-junction into two 100-ohm lines of width 0.53 mm. Each 100-ohm branch extends for 10 mm, and then tapers exponentially into a 25-ohm line for wide bandwidth performance [5]. The taper length was 72 mm. The width of the 25-ohm line was 5.8 mm. Each 25-ohm line branches at a T-junction into two 50-ohm lines that feeds two equal-length slots. The feed offset positions for matching these two slots to the feed are 3.15 mm and 15.65

978-1-4673-0462-7/12/$31.00 ©2012 IEEE

mm respectively, and feed offset length is given in Fig. 1. The two substrates were then pressed together, and sticky copper tapes were plastered on the four walls to complete the metallic cavity. To accommodate the probes, two holes were drilled through the assembly at an x position of 23.5 mm and y of 4 mm; and at -23.5 mm and 4 mm. These are the 50-ohm matching points for the rectangular cavity antenna. SMA connectors (ports 1 and 2) were soldered at these points. Also, to accommodate a SMA connector to the stripline (port 3), a 6 mm by 5.3 mm notch was cut out of the top substrate.

## III. RESULTS AND DISCUSSIONS

After fabrication, the return losses and radiation properties of the multiport antenna were measured, and the results were compared to the simulation results. When a port was being characterized, the other ports were terminated with 50-ohm loads. The measured return losses from the circular polarization (CP) ports 1 and 2 are shown in Fig. 2a. Some of the extra resonances seen were found to be due to slots 6 and 6'. Also, the return loss for port 3 in Fig. 2b shows the dual-band operation. The axial ratio (AR) for port 2 is shown in Fig. 3. The radiation pattern from port 2, which is similar to that of port 1 because of symmetry, but with opposite CP, is shown in Fig. 4a. The radiation pattern for the upper and lower frequency of the dual-band port is shown in Fig. 4b and 4c. The AR from these LP ports exceeded 20 dB. Furthermore, the simulated boresight gain for CP was 8.2 dB, and the simulated 3-dB AR bandwidth was 40 MHz. The simulated boresight gain at the upper-band LP was 8.46 dB, while that of the lower-band LP

The observed difference in simulation and measurement results might be due to air in between the substrates because measured values improved when the cavity substrates were pressed together more firmly. The performance of this antenna could be improved with a more refined fabrication method by printed circuit board companies.

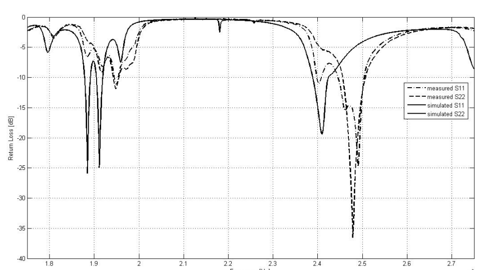


Figure 2a. Return losses (S11, S22) at CP ports.

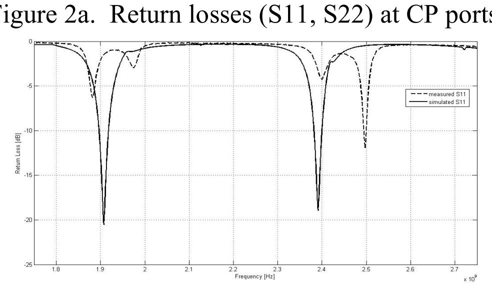


Figure 2b. Return loss (S33) at LP port.

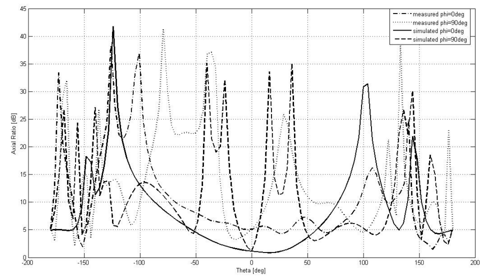


Figure 3. Simulated AR at 2.4 GHz and measured AR at 2.5 GHz for port 2.

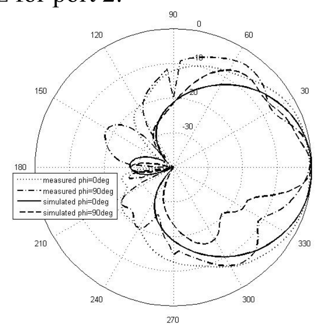


Figure 4a. Simulated and measured radiation pattern for CP port 2.

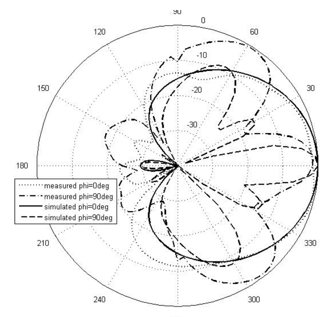


Figure 4b. Simulated and measured radiation pattern for upper band LP.

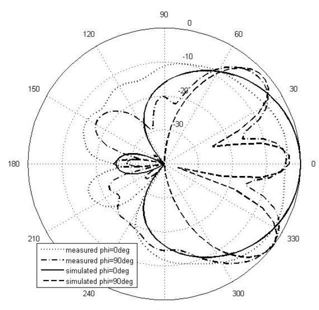


Figure 4c. Simulated and measured radiation pattern for

.

## REFERENCES


[1] S. Gao, U. M. Clark, K. and, and J. Zackrisson, "Antennas for modern small satellites," IEEE Antenna and Propagation Magazine, vol. 51, pp. 40-50, 2009.

[2] S. Vaccaro, J. Mosig, and P. de Maagt, "Two advanced solar antenna solant designs for satellite and terrestrial communications," Antennas and Propagation, IEEE Transactions on, vol. 51, no. 8, pp. 2028-2034, 2003.

[3] D. Sievenpiper, H.-P. Hsu, and R. Riley, "Low-profile cavity-backed crossed-slot antenna with a single-probe feed designed for 2.34-GHz satellite radio applications," Antennas and Propagation, IEEE Transactions on, vol. 52, no. 3, pp. 873-879, 2004.

[4] M. Mahmoud and R. Baktur, "A dual band microstrip-fed slot antenna," Antennas and Propagation, IEEE Transactions on, vol. 59, no. 5, pp. 1720-1724, 2011.

[5] D. M. Pozar, Microwave Engineering. Hoboken, NJ: John Wiley and Sons, 2005.