

Characterization of Two Types of Conformal Antennas for Cubesats

Jesús A. Arellano, Mangalam Chandak, Maryam Jamali, Reyhan Baktur
 Utah State University
 EL 150, 4120 Old Main Hill, Logan UT; 435-797-2955
 Reyhan.baktur@usu.edu

Robert Burt
 Space Dynamics Laboratory
 1695 North Research Park Way, North Logan UT; 435-713-3337
 Robert.Burt@sdl.usu.edu

ABSTRACT

Antennas conformal to a Cubesat surface have many advantages compared to deployed antennas. This study presents two types of conformal antennas that do not compete for the expensive surface real estate with solar cell. The first type of antenna is optically transparent antennas integrated directly on top of commercial solar cells. The second solution is slot antennas that can be placed around solar cells. For the transparent antenna, by optimizing the antenna geometry, we are able to achieve about 95% transparency. We have measured the performance of solar cells with the antenna integrated on them. It is found that the overall effect of the antenna on the entire solar panel is less than 3% and therefore promising the future implementation of such antennas in small satellite missions. For the slot antenna design, compared to the previous fully integrated prototype, we present an alternative excitation method to achieve circular polarization. In addition, this study provides a solution for UHF antennas, which is very challenging with traditional methods due to the size limitation of Cubesats. It is shown that one can feasibly design a UHF antenna with slot geometry by considering all four walls of a Cubesat.

I. INTRODUCTION

Antennas conformal to the small satellite surface have many advantages compared to the deployed wire antennas. There is less failure in antenna performance since there is not risk of not being able to deploy, and the entire payload is cheaper. The challenge, however, is to ensure that the antennas do not take extra surface area, which is needed for solar cells. This challenge is particularly prominent for Cubesats because of the extremely limited surface real estate. In order for the antenna not to compete for the Cubesat surface, there can be two types of antenna design. The first type is highly transparent antenna so that the antenna can be directly placed on top of solar cells [1], and the second type is slot antennas that can be placed around solar cells [2]. We have shown progress in both designs in the past. In this paper, we report the latest results in the two designs that include solar cell tests, a more effective feeding method, and feasibility study in achieve UHF antennas with slot geometry that are suitable for Cubesats.

II. TRANSPARENT MESHED PATCH ANTENNAS

It has been shown from the previous studies [1] that meshed patch antennas allow one to achieve a cost

friendly, effective, and highly transparent antenna. The studies were performed in simulation level and the antennas were prototyped with lower transparency due to the limited fabrication facility.

With the advance in inkjet printing method and the quality of conductive ink, we are now capable of printing meshed antennas on thin transparencies and then integrate them with solar cells. The transparency of the antennas is about 95% and such a transparency is achieved by controlling the line-width and the number of lines.

Figure 1 shows a laboratory assembly of a 95% transparent meshed antenna integrated on top of two active solar cells. It should be noted that, in practice, the thick non-transparent feed-line shown on in the picture can be either hidden between solar cells or at the edges of the Cubesat. The antenna was printed using a regular inkjet printer (C 88+ Epson) and conductive ink (JS-B25P) developed by Novacentrix Corporation [3]. The advantages of using this printer are the use of piezo technology which ensures precise control of ink and ink ejection and compatibility with a wide range of inks. The antennas were printed on a transparency with a special coating that allows the ink to adhere better compared to regular plastics. The ink does not need a

very high temperature to be cured as oppose to previous commercial inks. We only baked the antenna in a 100 Celsius oven for a few hours to achieve functioning antennas.

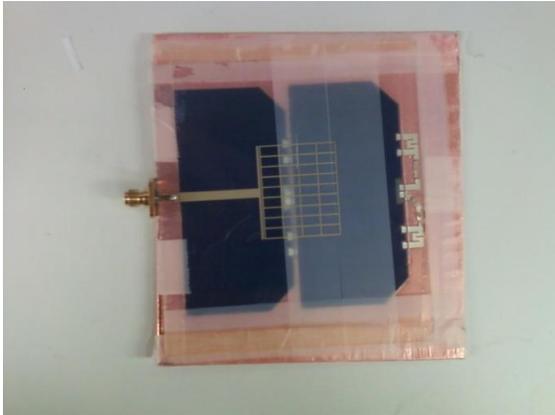


Figure 1: Meshed Patch Antenna HFSS Model

The antenna in Figure 1 was measured with an Agilent 8510C network analyzer for return loss, and the radiation pattern were measured using NSI's spherical nearfield scanner in a fully shielded anechoic chamber at USU. The measured return loss (S11 parameter) and radiation pattern are shown in Figure 2 and 3.

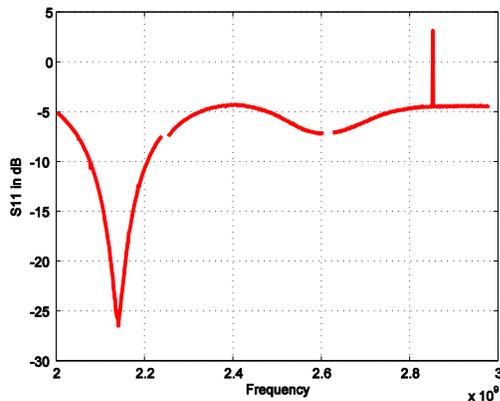


Figure 2: S11 Measurement

It is seen from Figure 2 and 3 that the resonant frequency, shape of the radiation pattern, and the cross polarization level are all acceptable. Although there is clear loss (Figure 2), but we believe that was due to the assembly and soldering, and can be improved with a more precise prototyping.

The gain of the antenna is low (less than 0 dB) at present. But we believe with better fabrication, higher conductivity of the ink, it is feasible to have an antenna with at least 2 dB gain, which might be improvable when raising the frequency, or size of the solar panel.

The panel in Figure 1 is for one wall of a 1U Cubesat, when all four walls are considered, or a 2 to 3U Cubesat is considered, it is expected that the gain can be higher.

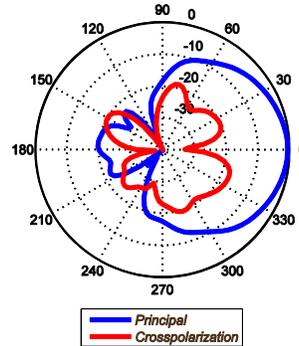


Figure 3: Radiation Pattern (Vertical Cut)

The solar cell performance under a 95% transparent antenna was measured at the Space Dynamics Lab. It is found that, when a 95% mesh (not including the feed-line) is placed on top of a functional two-cell solar panel, the effect of the mesh on the solar panel performance is less than 3%. Such an effect is comparable to the shadow of a wire antenna cast on solar panel. Therefore, it is feasible to integrate a highly transparent meshed antenna on top of solar cells for future Cubesat flight mission.

III. CIRCULAR POLARIZED CROSS SLOT ANTENNA

This study shows an alternative design of cross-slot antenna. The previous study used an additional length of the microstrip feed-line to achieve the phase difference needed for a circular polarization (CP) [2]. The new design has one single straight feed-line, and the CP is achieved using the cross-slot geometry and the distance between the two slots to the feed-line.

The layout of the antenna is shown in Figure 4, where two layers of substrates are present as in previous design. The microstrip line sandwiched between the antenna (cross-slot) and the ground is used to excite the two slots and then the four side-walls were shielded with conductor to reduce the unwanted radiation loss. The design frequency is 2.62 GHz, and the substrate is chosen to be Roger 4003 with a relative permittivity of 3.55 and the dielectric loss tangent of 0.0027. The antenna is studied using Ansoft's HFSS software. The geometry (length, width, and position) of the cross slot, position and length of the feed-line were adjusted to achieve both good S11 and axial ratio (a measurement for CP). The size of the ground (or the substrate) is 100

mm by 100 mm, which is exactly the size of a 1U Cubesat panel.

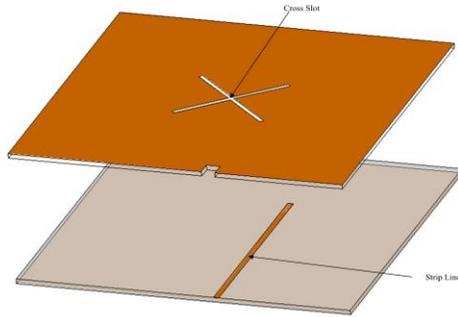


Figure 4: Assembly of the Proposed CP Cross-Slot Antenna

Our study showed a less than -20 dB return loss for the design frequency and less than 3 dB axial ratio in the operational band (shown in Figure 5). The simulation result also showed good efficiency (> 70%) of the proposed design, promising a potential application of the design in near future Cubesat missions.

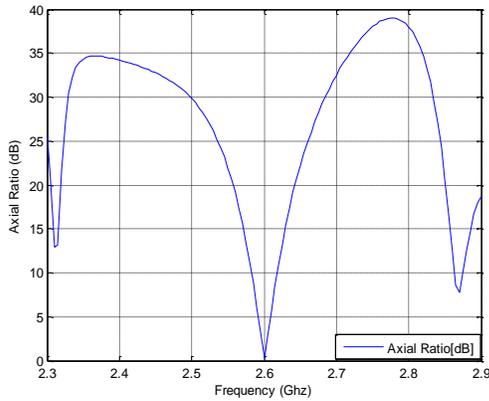


Figure 5: Axial Ratio of the Cross Slot Antenna

IV. CIRCULAR POLARIZED UHF ANTENNA

Ultra high frequency (UHF) is a very important band in satellite communication, but the challenge in designing conformal antenna with this band is much higher than S or higher bands. Our objective is to achieve a feasible design for 350 MHz. While it is already challenging to fit a conformal antenna to this frequency, the challenge doubles when one plans to achieve a circular polarization. The reason is simple. At 350 MHz, the free space wavelength is more than 850 mm, and often time two linear antennas are needed to achieve a CP.

So, there is not enough room on a Cubesat to accommodate such an antenna. Although some methods exist in antenna miniaturization [4]-[6], there is still a compromise between the antenna's gain and the size, which makes it un-realistic for Cubesat application. Our proposed design is to utilize the all four walls of a Cubesat and to use a very low-loss substrate (quartz fuse).

We first placed a square loop antenna on a 3U Cubesat as shown in Figure 6. The loop is actually composed from slots as in the previous session. We then added two parasitic square loops. By adding the loop, not only the resonant frequency is reduced to lower, but also the gain was improved. Table 1 shows the design experiment. In order to reduce the frequency to 350 MHz, we modified the radiating loop (the one at the bottom) to a meander shape. It is also seen that with the proposed antenna geometry, parasitic elements, and proper feeding method, it is reasonable to achieve good axial ratio. The axial ratio from the design in Figure 6 is 2.6 dB at 350 MHz, which is acceptable in practice.

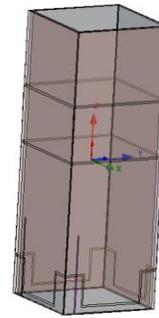


Figure 6: Conformal UHF Antenna

The radiation patterns of the three antennas in the design experiments are shown in Figure 7. It is seen that the final meander design yields an omni-directional pattern that is similar to those of dipole antennas, suggesting the feasibility of replacing the dipole UHF antennas.

Table 1: Design Experiment

Structure	Frequency (MHz)	Gain (dB)	Efficiency (%)	Axial Ratio(dB)
Square loop Slot	404.3	3.54	95	0.05
Add parasitic slots	380	5.15	83	1.05
Meandered ring	349	4.37	86	2.6

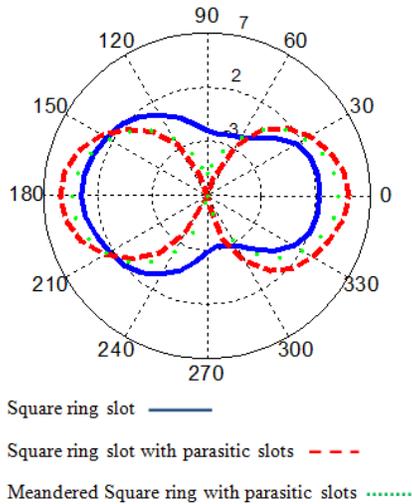


Figure 7: Radiation Patterns for Three Different Antennas

V. CONCLUSION

Two types of antennas that are conformal to Cubesat surface and can be integrated with solar cells are presented. Both design show good performance and feasibility in providing an alternative to current deployed dipole antennas. The designs are for S band and can be modified to higher bands easily. We have also shown a feasibility study in achieving conformal UHF circularly polarized antenna.

VI. REFERENCES

1. T.W. Turpin, "Meshed Patch Antennas Integrated on Solar Cell - A Feasibility Study and Optimization" M.S. Thesis, ECE Dept., USU, Logan, UT, 2009.
2. M. N. Mahmoud, "Integrated Solar Panel Antennas for Small Satellites," M.S. Thesis, ECE Dept., USU, Logan, UT, 2010.
3. Novacentrix Corp. "Metalon Conductive Inks for Printed Electronics," www.novacentrix.com.
4. M A. Al-Joumayly, N. Behdad, "A Highly-Efficient, Unidirectional Miniaturized Slot Antenna" in IEEE, 2008.
5. K. Sarabandi, R. Azadegan, "Design of an efficient miniaturized UHF planar antenna", in IEEE Transaction on antennas and propagation, Vol. 51, NO. 6, June 2003.
6. W. Hong, N. Behdad, K. Sarabandi, "Size reduction of cavity-backed slot antennas", in IEEE Transaction on antennas and propagation, Vol. 54, NO. 5, May 2006.