Design, Fabrication, and Integration of Meshed Conformal Antennas for Nanosatellite Applications

Larry K. Martin, *Student Member*, *IEEE*, and Wayne A. Shiroma, *Senior Member, IEEE*

***Abstract*—A meshed-topography microstrip patch antenna is designed and fabricated for a nanosatellite. The fabrication involves printing a conductive ink on a polyethylene terephthalate substrate using an Epson Stylus C88+ Inkjet Printer. Simulations were performed with Ansoft High Frequency Structure Simulator software. A 2.2-GHz, uniform-topography patch antenna was first designed, simulated, and fabricated as a prototype for the conductive inkjet printing process. Similar steps were then followed for a meshed-topography version to examine its characteristics. Measured and simulated gain and return loss values are reported.**

Index Terms— patch antennas, photovoltaic cells, nanosatellite.

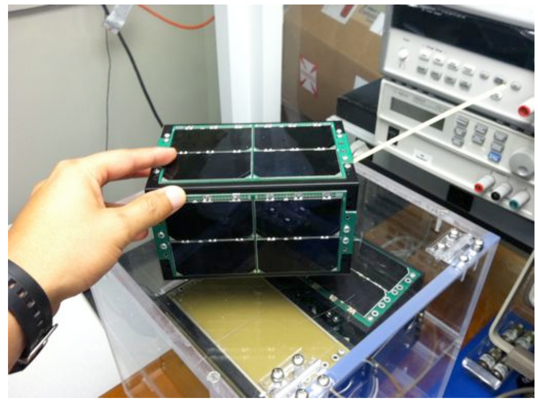

Fig. 1. Example of a nanosatellite with PV cells mounted on the exterior of the structure.

I. Background

NANOSATELLITES have been drawing considerable interest from government, industry, and academia due to their potential to carry out missions similar to their larger counterparts, but at a fraction of the cost. A network of nanosatellites has the potential for more flexibility as they can be reconfigured while in orbit. Although nanosatellites have reduced cost and development time, their downscaled structures also result in less space for photovoltaic cell (PV) placement (Fig. 1), which ultimately translates to less power generation for the satellite. Optimizing the satellite's real estate for PV placement is therefore of great importance.

For nanosatellites whose communication subsystems utilize patch antennas, due to their low cost, ease of installation, low profile, and versatility, an alternative solution to create additional real estate is to alter the surface area of the antenna itself by either modifying the patch's material and/or design, in both cases in favor of transparency. Replacing a traditional patch antenna with a meshed-topography version [1] creates the much-needed real estate for additional PV placement. Fig. 2 compares the two topographies, where additional PVs can be seen under the meshed-topography patch antenna.

Initial studies suggest that meshed-topography antennas are able to radiate almost as well as their uniform-topography counterparts, however the results are still inconclusive [1]

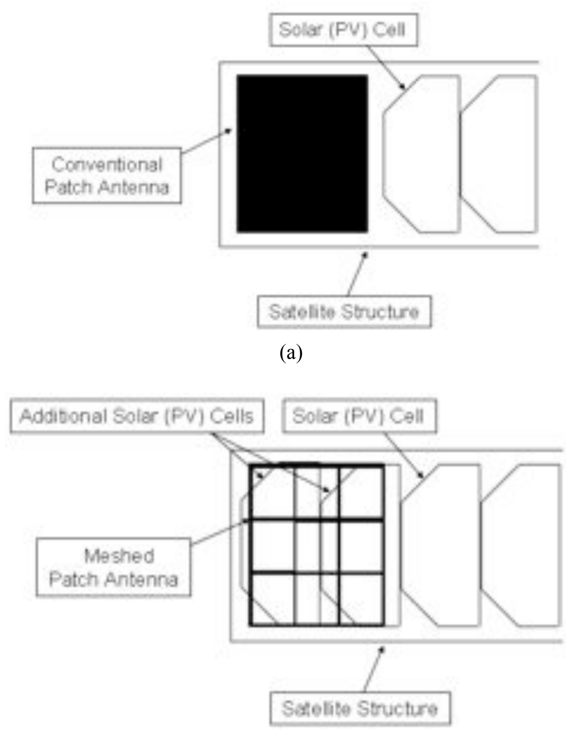

Fig. 2: Nanosatellite with a (a) conventional patch antenna, and (b) meshed patch antenna.

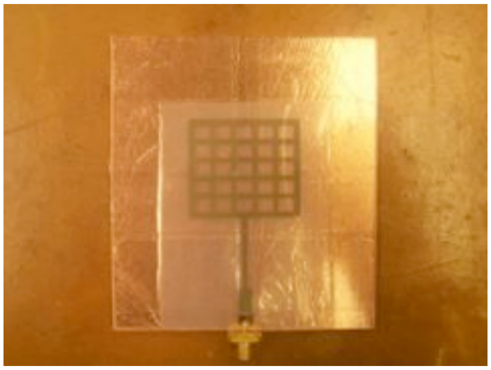

Fig. 3. Meshed-topography patch antenna.

II. Project Work

A 2.2-GHz, meshed-topography patch antenna was designed, fabricated, and tested. The antenna was printed using conductive ink on a polyethylene terephthalate substrate using an Epson Stylus C88+ Inkjet Printer. A 2.2-GHz, uniform-topography patch antenna was also fabricated as a prototype for the conductive inkjet printing process. Measured and simulated gain and return loss values were then plotted and analyzed for comparison. Once the antenna was designed and verified to have optimal gain and return loss results using Ansoft High Frequency Software Simulation software, the antenna was fabricated.

The inkjet printing process involved a pre-printing priming routine, printing of the actual conductive ink patch antenna design, curing of the printout, and a post-printing cleaning routine. The core materials included Novele coated polyethylene terephthalate substrate (PET), JS-B25P Metalon conductive ink, and an Epson Stylus C88+ Inkjet Printer with additional cartridge set. Novacentrix manufactures the JS-B25P conductive ink, but also sells the Novele PET (manufactured by Mitsubishi Imaging) and Epson printer and cartridges.

III. Results

Simulations and experimental return loss measurements were carried out for the antenna shown in Fig. 3, whose transparency was calculated to be 53.7%. The dimensions of each transparent cell were 5.16 mm x 6.164 mm, with a line width of 1.71 mm. The dimensions for the entire antenna were 41.08 mm x 36.05 mm. The feed line remained the same for both designs, to minimize the number of complexities.

Based on measured half-power beamwidths of 97.2° and 61.9° for the *E*- and *H*-plane co-polarization patterns, respectively, the directivity was estimated to be 6.9 dB.

The simulated resonant frequency occurred at 2.19 GHz with a return loss of -10.63 dB, while the experimental measurement showed a resonant frequency of 2.15 GHz and corresponding return loss of -23.76 dB. The difference between the simulated and experimental resonant frequency is 1.8%.

IV. Career Plans

Since graduating with my BS EE in Fall 2011, I have enrolled in graduate school at the University of Hawaii (UH). After earning an MS EE, I will seek employment that challenges my problem-solving skills. Before I graduate, I would also like to complete a summer internship in 2013.

Having the chance to attend the 2012 IEEE MTT-S International Microwave Symposium was an exciting and unique experience. It's not every day that a student is surrounded by hundreds of microwave experts from around the world, and I'm thankful for the opportunity from the MTT-S. In fact, I appreciate being an MTT-S member and the opportunities that come with it so much that I have even played a role in expanding the society's presence in Hawaii as a charter member of the recently formed MTT-S Student Branch Chapter at UH.

References

[1] T. Yasin and R. Baktur, "Optically Transparent Multifunctional Patch Antennas Integrated with Solar Cells for Small Satellites," *25th Annual AIAA/USU Conference on Small Satellites*, Logan, UT, paper SSC11-VIII-5, Aug. 2011.

Larry K. Martin (S'06) was born in 1985 and grew up in Kailua, Oahu, Hawaii. In 2011 he received the B.S. degree in electrical engineering from the University of Hawaii (UH). He is currently pursuing an M.S. degree at UH, focusing on nanosatellites.

Mr. Martin received the 2011-2012 Alton B. Zerby and Carl T. Koerner Outstanding Electrical or Computer Engineering Student Award from IEEE-HKN, as well as the IEEE Larry K. Wilson Regional Student Activities Award for organizing and chairing an IEEE Student Professional Awareness Conference at UH. He is currently serving as the 2012 IEEE Microwave Theory and Techniques Society (MTT-S) Hawaii Chapter Secretary, as well as the student editor for the IEEE *Potentials* Magazine.

Wayne A. Shiroma (S'85–M'87–SM'08) received the B.S. degree from the University of Hawaii at Manoa, the M.Eng. degree from Cornell University, Ithaca, NY, and the Ph.D. degree from the University of Colorado at Boulder, all in electrical engineering.

In 1996, he joined the University of Hawaii at Manoa, where he is currently a Professor of electrical engineering. He has authored or coauthored over 100 publications in the areas of phased arrays, spatial power combining, and nanosatellites. He was also a Member of the Technical Staff with Hughes Space and Communications, El Segundo, CA.

Dr. Shiroma was an elected member of the IEEE Microwave Theory and Techniques Society (IEEE MTT-S) Administrative Committee from 2002-10 and was general chair for the 2007 IEEE MTT-S International Microwave Symposium (IMS). He was the recipient of the 2003 University of Hawaii (UH) Regents Medal for Excellence in Teaching, the ten-campus UH System's most prestigious teaching award. Within the past 11 years, Eta Kappa Nu recognized four of his graduating seniors as the most outstanding electrical engineering students in the U.S.