Microstrip Aperture-Coupled Antenna Design for In-Space Power Reception Experiment Using Nano-Sized Satellite

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The concept of space solar power (SSP) satellites has been around since 1968 and is the vision of placing huge satellites (on the order of 1 square kilometer) into geostationary Earth orbit (GEO) to harvest gigawatts of the suns radiant energy and transmit it to Earth where it is collected and converted to usable direct current (dc) power by a rectifying antenna (rectenna) array (larger than the transmitting satellite) and injected into the electrical grid. Yet over 40 years later there is still no operational SSP due to the economics and associated risks, public awareness, political agendas and from lack of demonstrations to these audiences.

Current trends are taking advantage of the evaluation of technology (i.e. faster, smarter, smaller, and cheaper) by utilizing nano-sized satellites for technology demonstrations. In particular (G.P. Barnhard, "Space-to-space power beaming," International Astronautical Congress 2014, Toronto, Canada, Sept. 29, 2014) and (C. Bergsrud, "A space-to-space microwave wireless power transmission experimental mission using small satellites," Acta Astronautica, vol. 103, pp. 193-203, July 2014) are proposing to equipped nano-sized satellites with a rectenna array for in-space power beaming experiments. Power would be transmitted from the International Space Station to a swarm of nano-sized satellites for collection and use. The objective is to set-up a test-bed to further expand SSP awareness and confidence.

This paper conducts a thorough analysis in designing a state-of-the-art microstrip aperture-coupled antenna for the application of microwave power reception on a nano-sized satellite. Microstrip antennas are a good candidate for this application as they offer thin profile, have low mass, and are low cost. Aperture feeding technique has advantages over other microstrip feeding methods by providing better bandwidth, minimizing spurious radiation that could affect the side lobes or polarization of the antenna and avoids vertical elements and soldering.

Some design challenges addressed in this paper include; material selection, printed circuit board (PCB) multilayer antenna design, and thermal evaluation. The material used for antenna design is RT/Duroid 6002 as it has a history of use for space applications, has low dielectric constant, low loss, and is well understood for multilayer design. The topology of this design consist of three conducting layers, from top to bottom; antenna, slotted ground, and feeding network. A linear polarized antenna with aperture coupled feed is presented. The ambient temperature in low Earth orbit (LEO) typically ranges from 150 ^{o}C to -150 ^{o}C which can effect material parameters such as the dielectric constant. A sensitivity analysis of the responses to the antenna design is conducted.