A Low Profile Broadband UHF Canted Turnstile Antenna Phasing Network

Avinash Sharma
Johns Hopkins University Applied Physics Laboratory
Laurel, MD
Avinash.Sharma@jhuapl.edu

Robert K. Stilwell
Johns Hopkins University Applied Physics Laboratory
Laurel, MD
Robert.Stilwell@jhuapl.edu

***Abstract*—A broadband UHF antenna-phasing network providing equal amplitude and quadrature phase shifts to four radiating elements of a canted turnstile antenna was designed and prototyped. The antenna was designed for use on a pair of CubeSats on the ORS Tech 1 and 2 mission, which launched in November 2013. The design consists of a transmission line transformer and a pair of broadside-coupled quadrature hybrids operating over 240 MHz to 390 MHz with a worst case amplitude imbalance within ±0.8 dB and a phase imbalance within ±2.5°. The RF power handling capability is 25 W, continuous wave (CW), and is achieved in a form factor of less than 5 cm X 5 cm X 0.4 cm, ideally suited for low profile applications. The radiating elements, made of flexible tape, are mounted directly on the phasing network circuit board, eliminating the need for coaxial feeds and allowing stow and deploy capability. The prototype was installed in a mockup of the CubeSat, including deployed solar panels and tested at an antenna range facility.**

Keywords—Canted Turnstile Antenna; Broadband UHF Feed; CubeSat;

I. INTRODUCTION

A canted UHF turnstile antenna consisting of four radiating elements is used to provide circular polarization from a CubeSat in low earth orbit (LEO) to a linear polarized ground station. The antenna can be easily tuned to the operating frequency by simply trimming the radiating elements to the corresponding resonant frequency. The phasing network is designed to be broadband to retain the simple tuning of the antenna, instead of a more common narrowband implementation consisting of a pair of coaxial baluns and a 90° coaxial section [1]. To achieve the wider bandwidth, a transmission line transformer balun and a pair of broadside-coupled quadrature hybrids are used. The phasing network fits in a 5 cm X 5 cm X 0.4 cm form factor and can handle an input power of 25 W CW. The amplitude imbalance is less than ±0.8 dB and the phase imbalance is less than ±2.5°, over a 240 MHz to 390 MHz frequency range (~50% fractional bandwidth). The flexible tape radiating elements allow the antennas to be folded towards the body during storage and deploy to the canted angles when required.

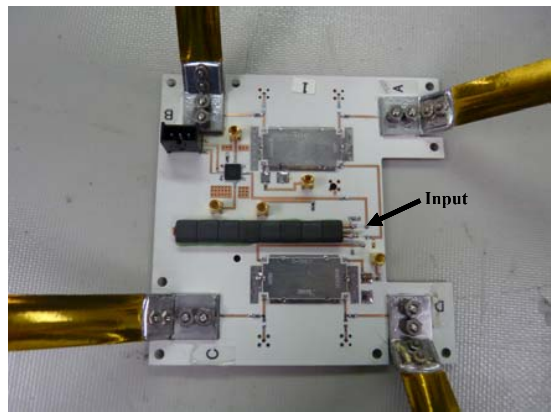

Figure 1 Turnstile Antenna Feed Network Prototype

II. PHASING NETWORK

A. Design

The phasing network, along with the radiating elements is shown in Figure 1. The phasing network consists of a single transmission line transformer balun (TLTB) and a pair of commercial-off-the-shelf (COTS) quadrature hybrids.

The TLTB performs a two-way equal split, with a 0° phase shift to one output (in-phase) and 180° phase shift to the other. The in-phase signal is fed to a quadrature hybrid where it outputs two equal and phase quadrature signals that are routed to the pads labeled A and B in Figure 1. Similarly, the out of phase signal from the TLTB goes to the second quadrature hybrid and its outputs are routed to pads labeled C and D in Figure 1.

The TLTB consists of a 50 Ω micro-coaxial transmission line strung through eight binocular ferrite cores. Eight cores are needed to ensure that the currents at the higher frequencies are attenuated sufficiently, since the permeability of the ferrite cores decreases with frequency. Since the current on the outer conductor of the coax is attenuated, the ferrite cores can handle higher amounts of RF power before saturating, when compared with a conventional flux-based RF transformer balun, in a lower profile (ie: height).

The quadrature hybrids operate from 225 MHz to 400 MHz and rated for 100 W. The tight coupling over the broad

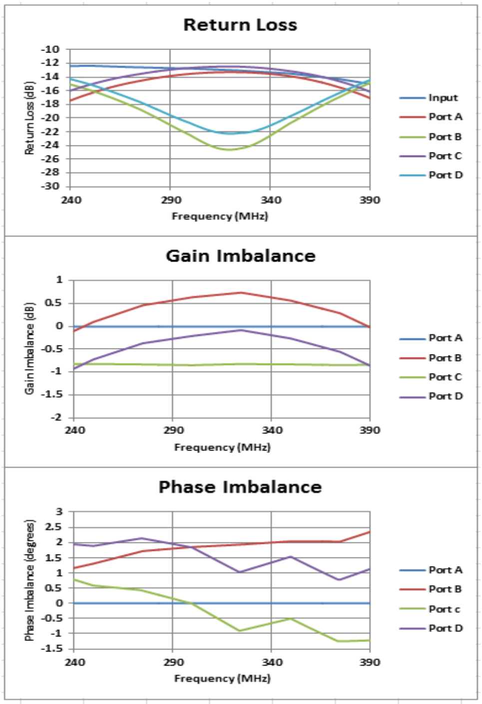

Figure 2 Measured Return Loss, Gain and Phase Imbalance

frequency range is achieved by using a broadside-coupled topology. Note that termination resistors are required on the isolation port of the hybrids and need to be appropriately sized to handle the reflected power at the isolation port in case of an antenna failure. These isolation ports also provide a convenient test point to measure reflected power.

B. Prototype Measurements

The prototype was measured using a Vector Network Analyzer (VNA) and the results are shown in Figure 2. The return loss at the input port is better than 12 dB over the frequency range. A worst case amplitude imbalance of +0.8 dB occurs at 325 MHz and -0.8 dB at a frequency of 240 MHz. The phase imbalance is better than ±2.5° over the frequency range. The calculated insertion loss (dissipative) is 0.45 dB.

III. Turnstile Antenna

The four radiating elements are riveted into the feed network, without the need for coaxial cables/connectors, as shown in Figure 1. The phase progression to the four radiating elements will result in an antenna that radiates a LHCP wave, in the direction of propagation. The elements are trimmed to resonate at a frequency of 325 MHz and installed into a mockup for the CubeSat. This is important since the performance of the antenna is often affected by scattering effects due to its surrounding structures.

Figure 3 shows a picture of the mockup of the CubeSat with the turnstile antenna installed. Note that the solar panels in the final deployed state are used. The antenna is tested in an antenna range facility, located onsite at The Johns Hopkins University Applied Physics Laboratory (JHU/APL). A representative pattern cut is shown in Figure 4. The LHCP boresight gain is +2 dBic and the RHCP boresight gain is -15 dBic, with broad hemispherical coverage. The asymmetry in the CubeSat body degrades the axial ratio performance.

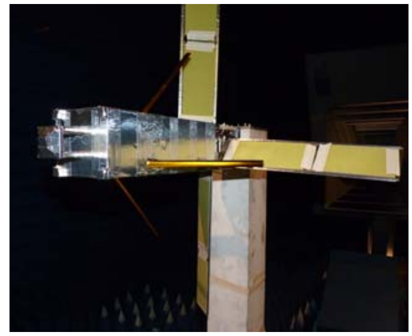

Figure 3 Antenna Mockup in compact antenna range

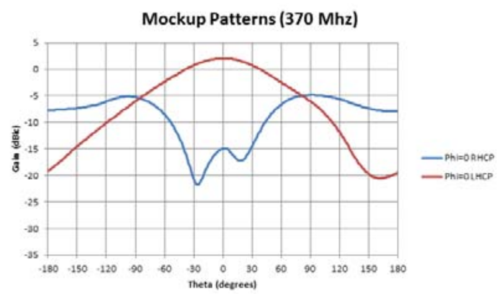

Figure 4 Measured Representative Great Circle Cut

IV. Summary

A broadband feed for a turnstile antenna was designed, prototyped and measured. The amplitude and phase imbalance was less than ±0.8dB and less than ±2.5° over a 240 MHz to 390 MHz frequency range. This allows simple antenna element tuning of narrowband turnstile antennas over this wide frequency band. The performance of a canted turnstile antenna with the feed, operating at 325 MHz, installed on a CubeSat mockup, was measured in a compact antenna range. The boresight LHCP gain of +2 dBic and LHCP gain of -15 dBic was measured. The design was implemented on the ORS Tech 1 and 2 mission, which launched two CubeSats into LEO, and was a successful mission.

Acknowledgment

The authors wish to thank Jeff Will for assembling, tuning and testing the antenna in the antenna range.

References

[1] C.A. Balanis, Antenna Theory: Analysis and Design, New York, 1982
[2] D.M. Pozar, Microwave Engineering, New York, 1998