A Deployable Vivaldi-fed Conical Horn Antenna for CubeSats

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***Abstract*—The advent of CubeSats has revolutionized the space research industry. The small physical size and constraints owing to outer space applications present significant challenges for antenna engineers to come up with innovative solutions. This paper presents a novel wide band antenna high gain antenna which is capable of deploying from a CubeSat platform.**

I. Introduction

The increased popularity of CubeSats as a low cost alternative vehicle for space research has presented numerous exciting opportunities for antenna engineers. Technology advancement has allowed CubeSats to exist along with sophisticated circuitry that enable the processing of several advanced applications for space communication [1]. Researchers are now required to propose advanced antenna solutions that can be folded compactly inside a small size spacecraft and deploy reliably once on orbit.

The preferred antenna choice for a CubeSat platform has been monopoles/dipoles or an array of wire antennas. Such antennas can be arranged in a manner to achieve circular polarization and a high gain [2]. Their popularity is driven by the simplicity of their design and deployment mechanisms. Another CubeSat antenna option can be the Log Periodic Crossed Dipole array which exhibits a wider bandwidth, a narrower beamwidth and presents more deployment complexity in comparison to a dipole. The Conical Log Spiral antenna is also a good alternative due to its wideband operation, circular polarization, and high gain.

CubeSat antenna applications have evolved in the last decade from telemetry, tracking and attitude control to high speed links for data transfer to cater for much more sophisticated applications such as space weather monitors and space telescopes[1]. A high speed link is defined by a higher bit rate which in turn is directly proportional to the bandwidth and gain of the antenna. In other words, in order to achieve a high speed downlink the antenna needs to present a wide bandwidth and drive a higher gain. The primary focus of this paper is to develop a high gain wideband antenna solution that can be deployed from a CubeSat platform.

II. Antenna Concept and Design

In this summary we present a new wideband Vivaldi-fed Conical Horn antenna over a frequency range from 2GHz till 13GHz proposed to be deployed from a 6-U CubeSat platform. The main component of the proposed antenna structure is the Vivaldi shaped fins which is known in literature [3] to exhibit a wide bandwidth due to the current distribution along its exponentially flared edges. Two Vivaldi structures orthogonal to each other have been integrated into the design.

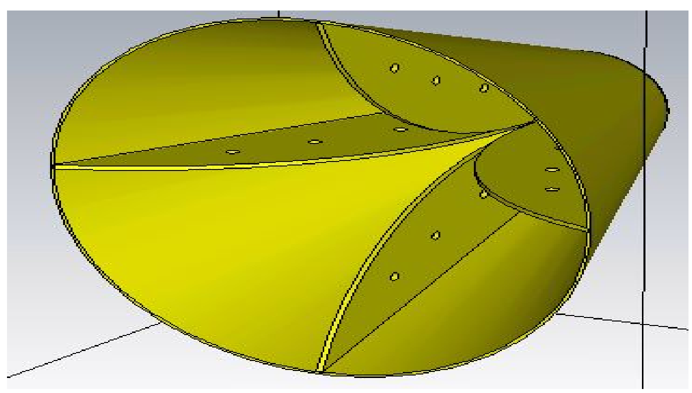

Fig. 1. Cross-Vivaldi fins inside the Conical Horn

The curvature and shape of each fin is optimized while taking into consideration the effect of coupling with the other elements, the spacing between the elements is optimized to reduce interference and achieve a wideband impedance bandwidth from 2GHz to 13 GHz.

The overlap of Vivaldi structures is designed carefully so as to nullify any error in the phase center of the antenna and to provide a circular polarization and a certain beamwidth when fed appropriately. The cross Vivaldi structure in itself exhibits wideband circularly polarized characteristics and a gain between 8.5dBi-10.5dBi over the entire spectrum.

In order to drive a higher gain the cross-Vivaldi structure is carefully incorporated inside a Conical Horn shroud. The horn shroud directly impacts the gain figures while the Vivaldi structure acts as the feeding of the horn. The curvature of the Vivaldi and its feed point is optimized. The cone is initially designed for the lowest frequency and optimized to achieve a $VSWR < 2$ over the entire operating frequency band.

The material composition of the antenna structure is of prime importance when it comes to designing a deployable antenna. The antenna material used is a multilayer structure. The top layer is a phosphor bronze conductive mesh that is composed of 325 wires/inch and a wire diameter of 0.0356 mm. It is layered over a composite that is made up of a plain weave of carbon fiber and epoxy layup, with fibers running in two orthogonal directions. Conductive epoxy is used to stabilize the layering of phosphor bronze on top of the carbon fiber. The conductivity of the layup is measured to be in the orders of $10^7 S/m$.

Fig. 2. Carbon epoxy layup layered with phosphor bronze mesh

The feeding structure of this antenna is relatively simple but the feed point however is pivotal to its operation and it dictates the input impedance of the structure with respect to frequency. The feed mechanism is based on feeding the two Vivaldi fins with equal amplitude and a phase difference of 90° between them. This feed mechanism enables circular polarization. A wideband hybrid phase shifter is required, the outputs of which are directly fed to the optimized feed point below the Vivaldi fins to acquire the desired results.

III. Results

The Concept is designed and simulated on CST microwave studio to verify the functionality of the design.

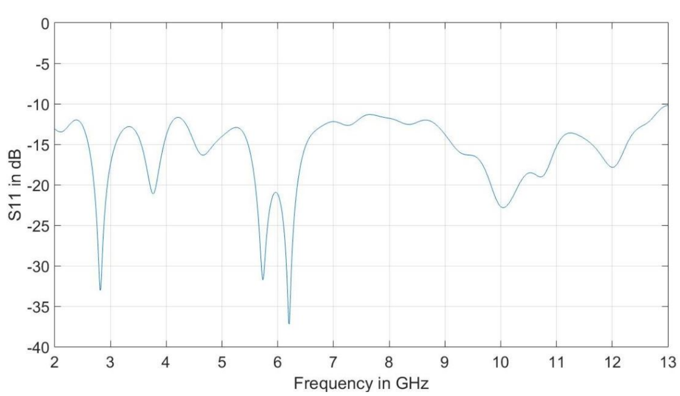

Fig. 3. Reflection coefficient

The reflection coefficient of the simulated antenna is shown for an impedance match at 75 Ohms. The gain of the antenna fluctuates between 10dBi to 17.5dBi, a significant improvement from the cross-Vivaldi structure on it's own.

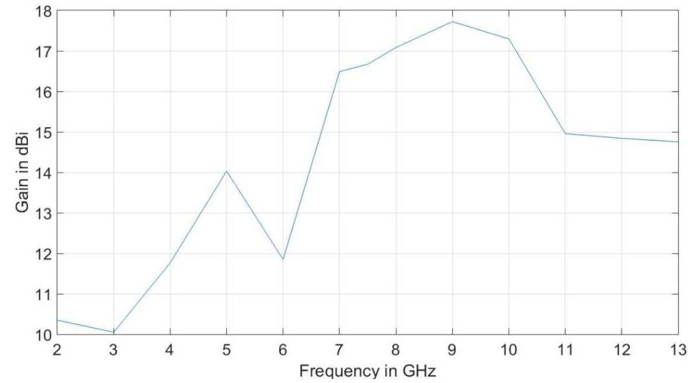

Fig. 4. A plot of gain over the frequency band.

The radiation patterns for lowest, center and highest operating frequencies at 2GHz, 7.5GHz and 13GHz are shown.

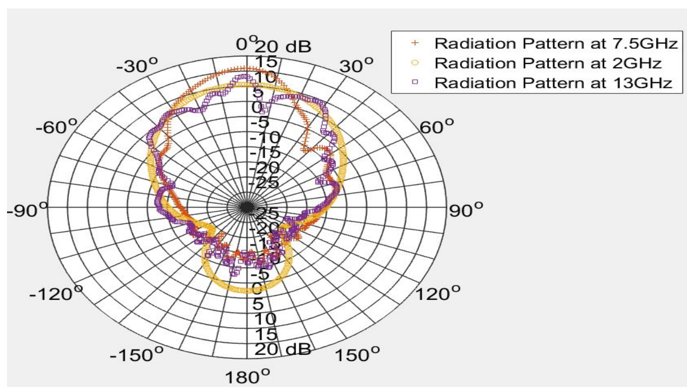

Fig. 5. Radiation patterns for the center, lowest and highest frequencies of the band.

IV. Conclusion

The resulting prototype exhibits a wideband frequency of operation, circular polarization and a considerably high gain over the entire spectrum with a minor back lobe. The novel aspect of this antenna is focused on the fact that it is composed of very light and stiff material that is capable of folding and deploying autonomously while maintaining the reliability of operation of a Quad-ridged Conical antenna structure

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