



Rapid Virtual Prototyping for Cubesat Scale Deployable Reflector Antennas

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Abstract

An open source approach to rapid virtual prototyping of parabolic reflector antennas is proposed. The impact of focal distance, illuminator offset from focal spot, and platform scattering are examined for an antenna to be mounted to an 8U CubeSat chassis with a constant arc length for the parabolic reflector. A total of 30 parametric variations were simulated and antenna patterns predicted in 16 minutes. The selected parabolic reflector was prototyped and measured on platform, with a correlation of 0.59 between the predicted and measured antenna patterns, with maximum total directivity of 20.6dBi and 17.6dBi respectively.

1 Introduction

CubeSat antennas present a challenge to the implementation of reliable high gain antennas due to significant space and weight requirements. Deployable antenna structures have been proposed to overcome this limitation by increasing the effective aperture, and the associated directivity of the antenna [1]. This allows for the employment of higher order modulation schemes for communications links, improving data rates which are dependant upon high signal to noise ratios (SNR) to maintain the desired bit error rates [2]. However the deployment mechanisms can be complex and represent a single point failure for communications systems [3]. Because of these challenges, CubeSat often employ a relatively simple dipole or yagi antenna to provide initial low data-rate communications [4]. However this approach occupies more of the extremely limited mass and space provided by the form factors. In addition to communications, antennas as payload for the satellite also represent challenges for deployment, as synthetic aperture radar can provide an attractive sensor package, but require a very high directivity antenna in order to achieve useful performance without significant amplification. However the larger the aperture, the more complicated the deployment mechanism becomes [5]. There are some approaches for CubeSat scale satellites, however the reductions in mass also introduce higher potential for vibration and flexure in operation [6].

This paper proposed an open source approach for rapid virtual prototyping of antenna patterns in a way which supports the integration of multiphysics modelling. This will allow not only a more rapid assessment of the suitability of different designs based upon rational constraints such as

location on platform, maximum mass, reflector size when stowed and deployed and others.

The challenge of predicting the effects of design parameters in a realistic environment represent an ongoing area of research. When an antenna array is considered, the rectilinear projection of the planned aperture can allow for a robust assessment of the maximum potential directivity on boresight, and as the main beam of the array is scanned [7]. This can be extended using raycasting techniques and computational modelling to make assessments of the effects of platform and array curvature on the maximum performance of the antenna array [8]. However, this does not allow for consideration of the effects of beamwidth or sidelobe levels for less abstract antennas. What is required is an accessible model which can model the effects of structure, materials on the overall pattern with consideration of overall radiated power, polarization vectors and platform effects.

2 Virtual Prototyping

LyceanEM was used to model the effects of the parabolic reflector and CubeSat chassis structure on the overall antenna pattern [9]. Initial efforts using LyceanEM were hampered by the lack of a general purpose meshing framework for arbitrary shapes, resulting in reduced prediction accuracy [10]. In order to address this deficiency while allowing for direct implementation of computer aided design (CAD) LyceanEM was rebuilt using gmsh and Meshio [11, 12]. These software libraries allow for the underlying mesh to be based on a parametric CAD model which can be shared between multiple solvers. This will allow future research to investigate the potential for multiphysics based virtual prototyping to investigate the vibration and thermal implications of different design parameters not only on the physical structure, but on the overall system performance.

An 8U host chassis was selected for this research, and a fixed arc length was selected as the primary constraint for the virtual prototyping, setting the total length at 30cm. This was chosen as a constraint as the maximum length which could be implemented on the CubeSat chassis with appropriate retention and deployment mechanisms. This allows the investigation of the effects of parameters such as focal ratio and illumination pattern on the resultant pattern of the deployed antenna. The host prototyping chassis is

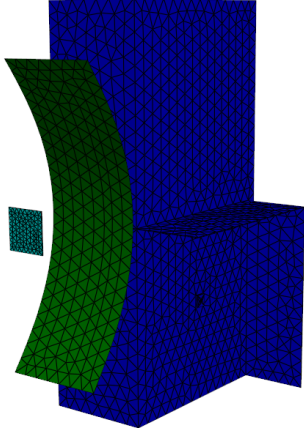


Figure 1. Visualisation of the selected configuration of parabolic reflector (green), patch antenna (aqua), and CubeSat Chassis (blue)

shown in Figure 1, using PyVista to visualise the mesh generated by gmsh [13].

All 30 variations were simulated and stored in 16 minutes, including generation and meshing of the solids using the OpenCASCADE toolkit within gmsh using a target mesh size of no larger than 0.5λ . The use of this framework with LyceanEM allows for the resultant electric field vectors from a given illuminating antenna to be considered, as shown in Figure 2. LyceanEM uses an extended application of the Rayleigh-Sommerfeld Diffraction Integral to allow for consideration of polarimetric scattering in both the near and farfield with suitable acceleration [14].

3 Deployable Parabolic Reflector Antenna

The parabolic reflector was manufactured, and the full 8U CubeSat mock up is shown in Figure 3 (dimensions $400 \times 200 \times 100$ mm), with a wire monopole and reflectors on the ventral face, and a parabolic antenna and illuminating patch antenna, as shown in the virtual model in Figure 1. A focal ratio of 0.31 was selected for construction, providing a balance between maximum directivity and minimizing the beamwidth and sidelobe levels of the main beam. The effects of focal length with a fixed parabola arc length on maximum directivity are shown in Figure 4, with the selected e-plane slices of the total directivity patterns predicted as shown in Figure 5. These pattern slices represent the predicted patterns for the illuminating patch placed at the focal point.

The predicted total directivity pattern for the selected parameters is shown in Figure 6, and the equivalent pattern for the measured prototype in Figure 7.

The correlation between the co-polar measured and modelled patterns was 0.59, representing good agreement on main beam position and main features, while not providing a good prediction on the measured field away from the

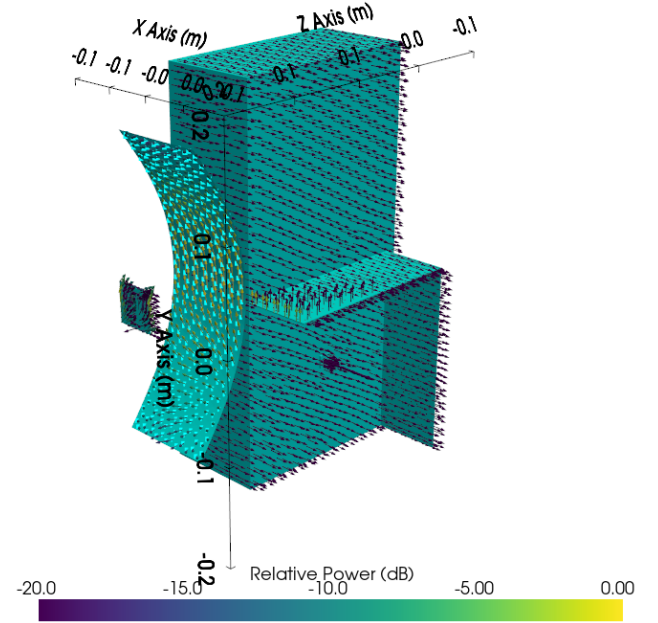


Figure 2. Illuminated field vectors with arrow glyphs indicating the electric field vector direction and magnitude

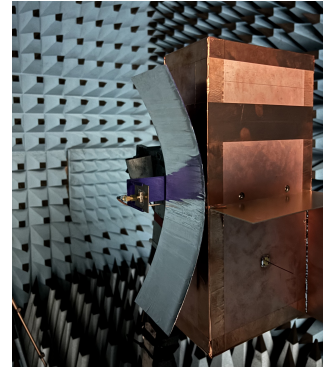


Figure 3. CubeSat Chassis with selected parabolic reflector and illuminating patch

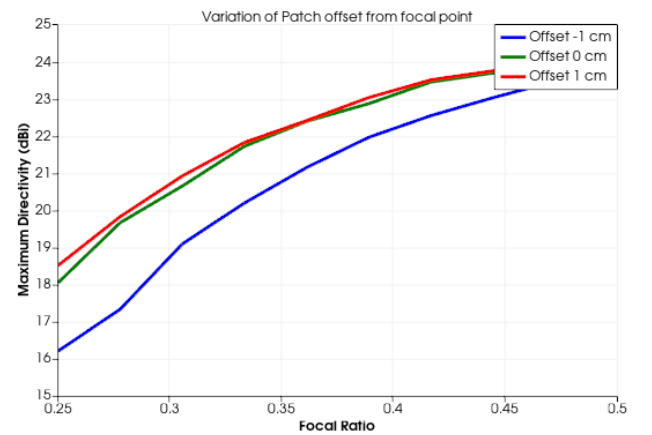


Figure 4. Variation in Maximum Directivity for the Parabolic reflector antenna with illuminating patch, with variation in focal ratio (F/D), and offset of the illuminating patch from the focal point of the parabola

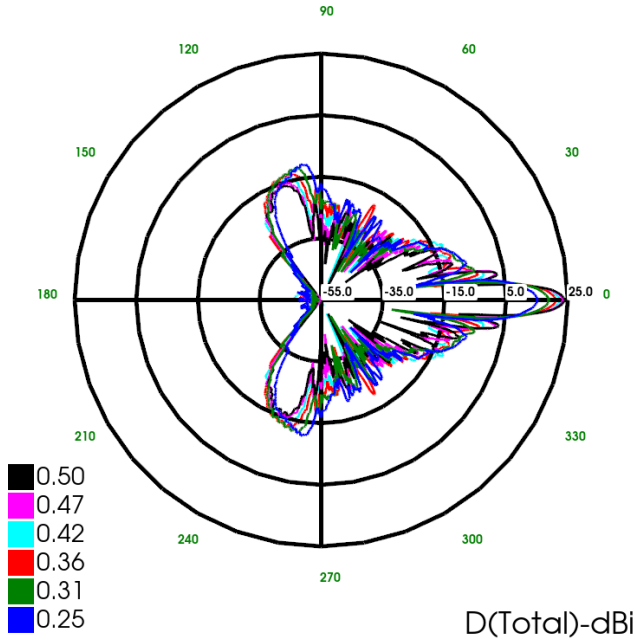


Figure 5. E-plane comparison of the total directivity pattern for different values of focal ratio

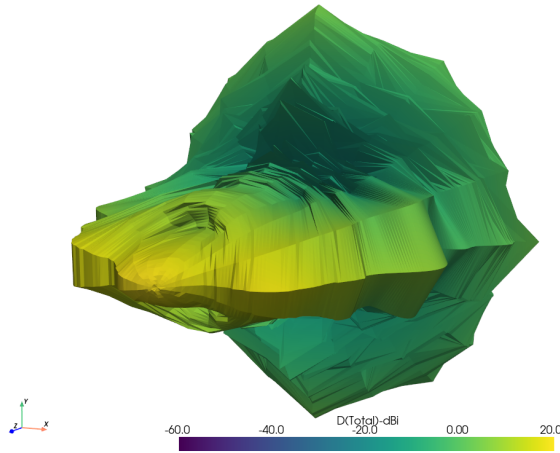


Figure 6

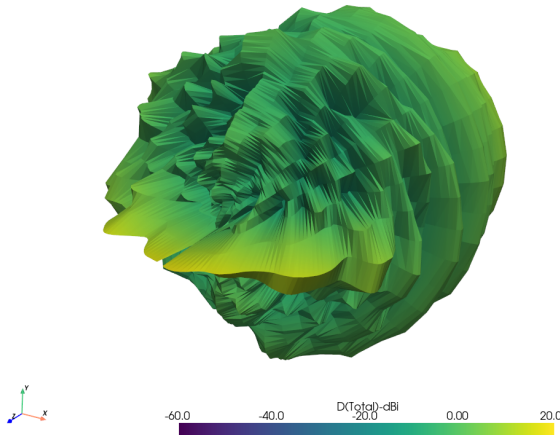


Figure 7

boresight of the antenna. The measured maximum total directivity for the antenna was 17.6dBi, compared to a prediction of 20.6dBi for the model with the selected parameters.

4 Conclusion

The approach allow for the consideration of a significant search space together with the host platform in a very short timeframe. While the correlation between the predictions and the final measured pattern was poor at 0.59, there are some factors which would likely improve future models. The feed mechanism for the illuminating patch antenna was not included in the virtual prototyping, and this would introduce coupling to the patch and the reflector. In addition, the effects of creeping wave propagation over the surface of the structures is currently not considered within the model, and extended scattering is discarded in favour of rapid modelling, as the focus is on rapid virtual prototyping. In future research, parametric definition of the illuminating antenna and support structures will be included, and consideration should be given to different approaches on the inclusion of creeping wave and fringing fields within the model.

5 References

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