DESIGN AND RF TESTING OF REFLECTARRAY FOR CUBESAT AT X-BAND

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***Abstract*—A reflectarray has been designed and measured. The reflectarray is intended for use as downlink antenna on the 2-by-3 unit surface of 6U and 12U CubeSats in the X band from 8.025 GHz to 8.4 GHz. A main design requirement has been to minimize the internal volume in the CubeSat required to stove the antenna.**

The antenna design is based on a polarising reflectarray surface and is designed to work in the frequency band from 8.025 GHz to 8.4 GHz. The antenna has been manufactured and measured. concept.

I. INTRODUCTION

CubeSats are a family of small satellites made up of cubic units [U] – each unit being 10 cm by 10 cm by 10 cm. The current standard for CubeSats [1] covers satellites up to a size of 12U corresponding to a size of 20 cm by 20 cm by 30 cm. The standardised sizes of the CubeSat implies that it is relatively cheap to launch the satellites using a provider of standardised launch services. This, in combination with a large number of providers of CubeSat subsystems (attitude control, propulsion, TTC, etc.) means that the CubeSat form factor is popular for both university satellite missions [2], for technology demonstration missions [3], and for a number of commercial constellations [4].

When designing antennas for CubeSats, a key design requirement is to reduce the volume needed for the stowed antenna during the launch of the satellite. Another key requirement is that the antenna shall be manufactured using commercial off the shelf components to the largest extent possible.

For many CubeSat missions, the amount of data to be retrieved from the satellite is limited and antennas operating in UHF or S-band are suitable. These can be either monopole antennas [5] or simple printed patches and wire structures [6], [7], [8]. The antennas have the advantage of being mechanically stable during the launch of the satellite, simple and cheap to manufacture, and takes up only a small volume on the CubeSat. However, the gain of these antennas are typically not greater than up to around 8 - 9 dB [6].

For Earth-observation missions, the amount of data required to be downloaded means that a higher antenna gain as well as a larger bandwidth are required to close the link budget. To achieve the higher gain it is necessary to have electrically larger antennas and the bandwidth requirement means that it is necessary to increase the operating frequency [9].

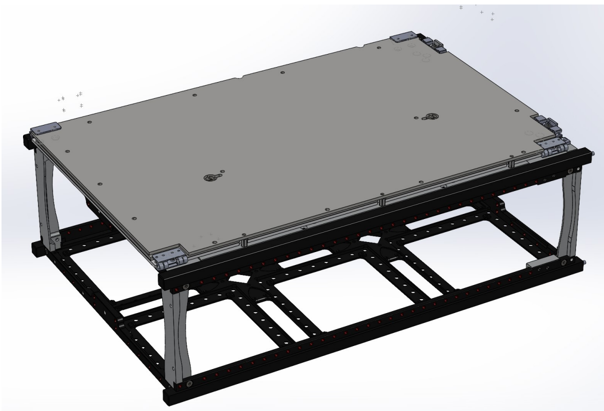

Fig. 1: CAD model of the stowed antenna mounted on a 2 by 3 unit satellite.

As part of an ESA project, TICRA has designed an antenna for use on CubeSats. The antenna is intended for data-downlink in the Earth-observation data spectrum in the X band from 8.025 GHz to 8.4 GHz.

The antenna is required to be circularly polarised (RHCP) to make the data link insensitive to the rotational orientation of the satellite and it has been a specific requirement that the antenna shall take up the smallest possible volume inside the CubeSat.

II. ANTENNAS DESIGN

To meet the design requirements, a reflectarray antenna has been designed.

The reflectarray is particularly well-suited for use on CubeSats since it can be designed using flat panels that can be deployed from the satellite body. In the chosen design, a three-panel reflectarray with each panel being 20 cm by 30 cm. During the launch of the satellite, the panels can be stowed on the CubeSat as shown in Fig. 1 and the total thickness in this configuration is less than 8 mm. This means that the reflectarray can be stowed between the CubeSat and the interior of the launch pod during the launch and therefore does not need to take up volume inside the satellite.

To further reduce the volume required by the antenna, the feed has been designed as a cavity with a depth of 2.6 mm and two apertures that illuminates a reflecting

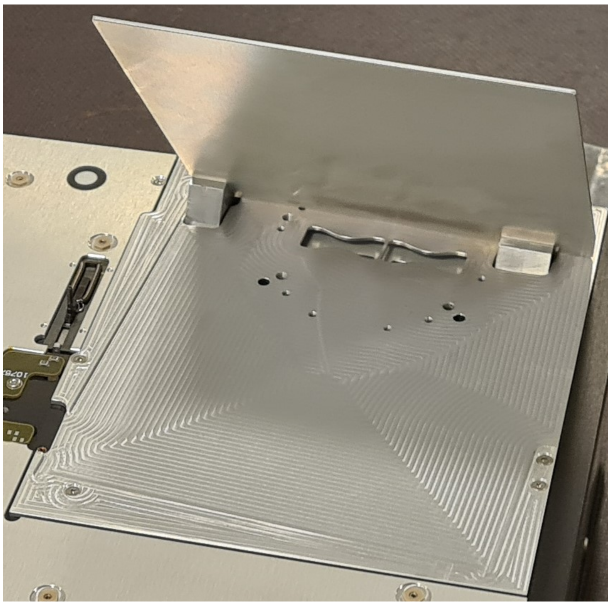

Fig. 2: Photo of the feed. The feed is designed in CHAMP 3D and manufactured in aluminium.

plate, which in turn illuminates the reflectarray. A close-up of the feed is shown in Fig. 2. The feed was designed using CHAMP 3D in TICRA Tools [10], is linearly polarised, and has return loss better than 15 dB across the frequency band. Since the feed is only 3.6 mm in total thickness (2.6 mm cavity depth plus 1 mm aluminium wall), the unit below the feed can still be fully used to mount payload units.

Because the feed generates a linearly polarised field (polarised orthogonally to the surface of the CubeSat), it is necessary to design the reflectarray in such a way that it converts the linearly incident field to an RHCP reflected field.

The elements on the reflectarray are simple crossed dipoles as the one shown in Fig. 3. The cell has a size of 10.67 mm by 10.62 mm. The lengths of the two dipoles (l_x and l_y) of the cross are used as design parameters and so is the widths of the dipoles (w_x and w_y). The substrate in the cell is Rogers RO4003, is 0.813 mm thick, and is backed by a ground plane. The reflectarray was designed and optimised in QUPES in TICRA Tools [10]. The reflectarray was optimised for maximum gain and the final design, shown in Fig. 4, has 1703 elements across the three panels. The gain of the antenna was calculated to be 29.2 dBi at 8.025 GHz and 29.4 dBi at 8.40 GHz. To avoid blockage from the feed plate, the beam from the reflectarray has been tilted in a 20 degree angle away from CubeSat body.

III. Measurements

The antenna has been manufactured and measured at the antenna test facilities at the European Space

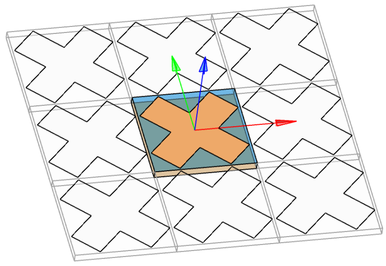

Fig. 3: Unit cell with cross used in the reflectarray. From QUPES in TICRA Tools.

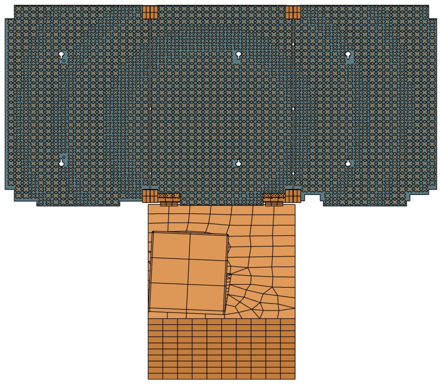

Fig. 4: Full reflectarray after optimisation. Screenshot from TICRA Tools.

Research and Technology Centre (ESTEC) in Noordwijk in the Netherlands. A photo of the deployed antenna mounted in the measurement room is shown in Fig. 5. The CubeSat was tilted 20 degrees during the measurement and the results obtained in the coordinate system aligned with the beam direction of the main beam from the reflectarray.

During the measurement, the antenna was mounted on a 6U CubeSat and a waveguide-to-coaxial adapter was used to connect the antenna to waveguide interface of the antenna to the SMA-connector of the measurement system.

The gain of the antenna was measured to be 29.4 dBi and 29.2 dBi at 8.025 GHz and 8.4 GHz, respectively, which is as expected: The loss of the waveguide-to-coaxial adapter is around 0.14 dB and the uncertainty of the facility is ± 0.3 dB 3σ.

In Fig. 6 to 9 the simulated and measured patterns for 8.025 GHz and 8.4 GHz are shown, respectively. The cut $\phi = 90°$ is the plane in which the reflectarray is 60 cm wide and this is clearly seen in the more narrow beam. From these figures, it is seen that a very good agreement between simulations and measurements was obtained,

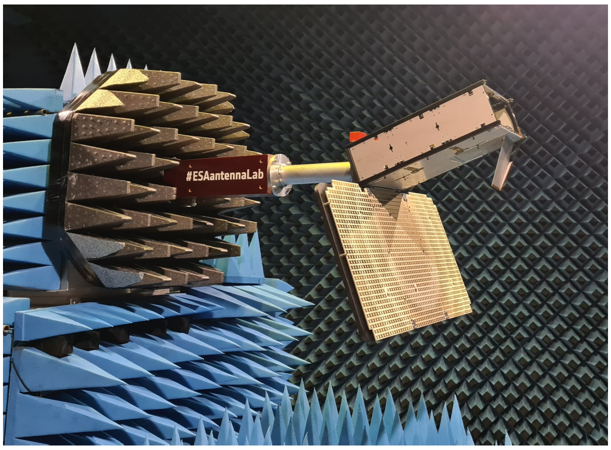

Fig. 5: Deployed antenna mounted in antenna measurement facility.

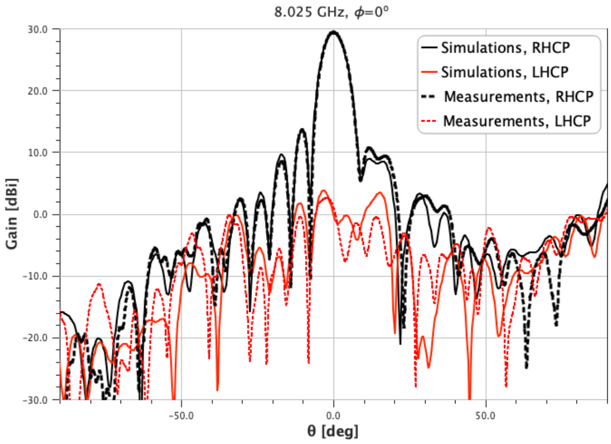

Fig. 6: Comparison of simulated and measured gain at 8.025 GHz in the cut $\phi = 0°$. RHCP in solid lines, LHCP in dashed. This cut is the plane containing the CubeSat body.

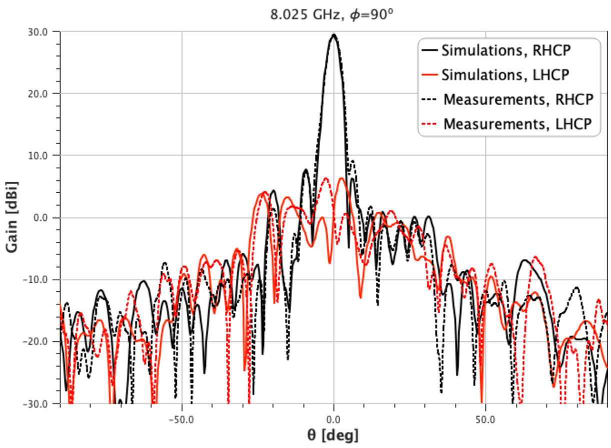

Fig. 7: Comparison of simulated and measured gain at 8.025 GHz in the cut $\phi = 90°$. RHCP in solid lines, LHCP in dashed.

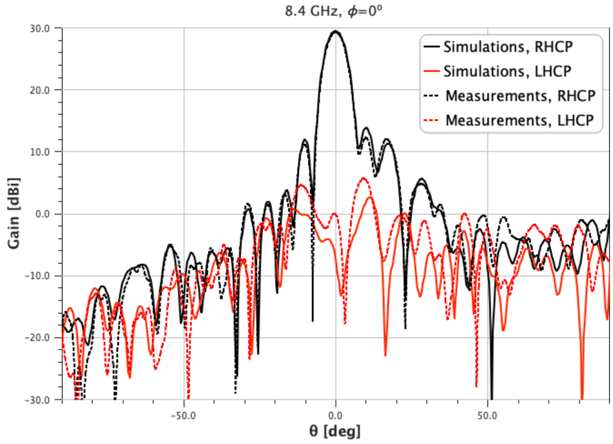

Fig. 8: Comparison of simulated and measured gain at 8.4 GHz in the cut $\phi = 0°$. RHCP in solid lines, LHCP in dashed. This cut is the plane containing the CubeSat body.

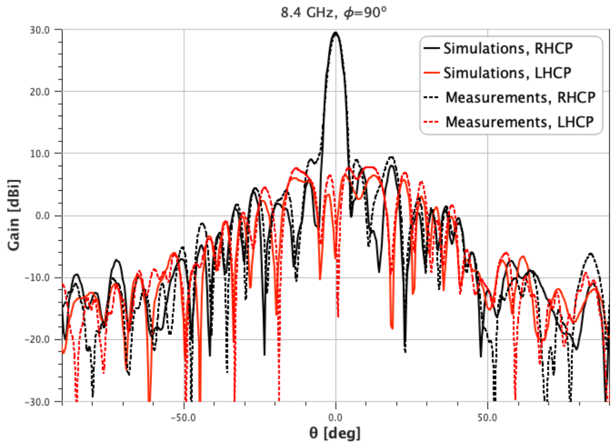

Fig. 9: Comparison of simulated and measured gain at 8.4 GHz in the cut $\phi = 90°$. RHCP in solid lines, LHCP in dashed.

thus confirming the reflectarray operates as designed.

The antenna shall in the next steps undergo further environmental and RF testing in order to reach full flight qualification.

IV. Conclusion

A reflectarray antenna for CubeSat applications has been designed, manufactured and measured. The antenna has been designed to operate in the frequency band from 8.025 GHz to 8.4 GHz and take up as little volume in the CubeSat as possible.

The resulting design consists of a cavity feed that protrudes less than 4 mm into the CubeSat. This implies that there is still room for a full unit of payload below the feed. The feed is linearly polarised and to achieve the required RHCP for the downlink, the reflectarray has been designed to generate circular polarization.

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