# A Transparent Dual-Band Cubesat Antenna Based on Stacked Patches

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## I. Introduction

Since cubesats are small in size, an efficient use of their scarce area becomes critical. External surface of the cubesats is shared by solar panels, measuring equipment and antennas. By using deployable parts the area can be extended, but they introduce the risk of mechanical failure.

The goal of this project is to design an antenna that is transparent to visible light, so it can be placed on top of solar panels, while allowing sunlight to reach the solar cells.

## II. Proposed system

To simplify the implementation of the antenna, the proposed system has been designed as a two-dimensional array module of patch antennas. An example of a prospective rectangular grid is shown in figure 1. Each element is associated with a dual-band branch-line coupler for obtaining two exits with a $90°$ phase shift. These two exits will be the inputs of two linear and orthogonally polarized antennas, so the user can choose either right or left circularly polarised antennas.

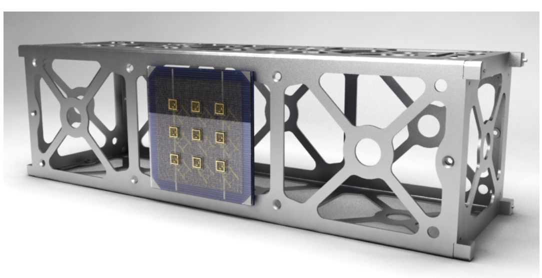

Fig. 1. Example of a 3x3 rectangular array module mounted on a cubesat solar panel.

The two dimensional design allows flexibility in the array configuration. Using both a glass substrate and transparent metallic patches, the module becomes transparent. Since these modules can be placed on top of the cubesat solar panels, the valuable surface area of the satellite can be used efficiently. With a larger area, the antenna will be able to produce higher directivity and more diversity in the radiation patterns.

To demonstrate the potential of our idea, a single antenna and an array have been simulated in a full wave simulator, *CST Microwave Studio*.

## III. Antenna properties

Patch antennas are suitable for this application since they have a flat geometry and can produce highly pure polarization [1]. Additionally, they can be integrated in arrays. These can be employed to produce directive beams when the solar panels of the satellite are not facing the desired direction of Earth. By changing the phase of the antenna elements of the array, the main lobe direction can be adjusted.

To make the antenna system more versatile, it is designed for dual band. The chosen operating bands are X ($8\,\mathrm{GHz}$) and Ku ($11.2\,\mathrm{GHz}$). Choosing high frequencies effectively shrinks the size of each patch, giving the possibility of creating an array on a surface no larger than the solar panel ($8\,\mathrm{cm} \times 8\,\mathrm{cm}$).

## IV. Antenna design

The proposed system consists of four, etched layers of copper with glass as substrate glued between them, see figure 3. Glue is used to avoid custom ordered glass thickness.

To achieve the goal of transparency, the copper layers (excluding feed lines) will be etched as square grids. By making the layers a fine grid, the operating bands (X- and Ku- bands) will act as if the layer is solid [2]. However, higher frequencies that are utilised in solar panels pass through the holes. Therefore, the collected energy will be minimally affected.

In our preliminary design, the grid holes are $0.6\,\mathrm{mm}$ wide with $0.05\,\mathrm{mm}$ wide copper lines. This gives approximately $85\,\%$ transparency, as illustrated in figure 2.

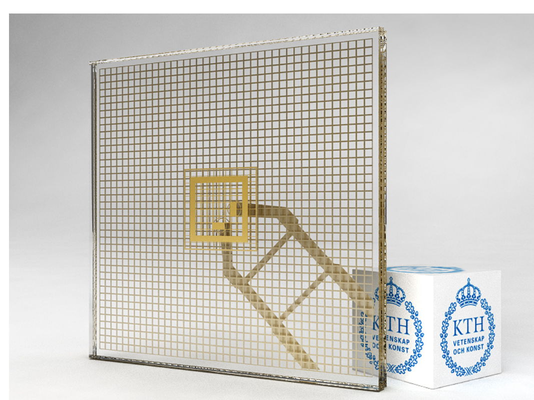


Fig. 2. 3D-rendering of concept antenna with a single element and a $1\,\mathrm{cm} \times 1\,\mathrm{cm} \times 1\,\mathrm{cm}$ reference cube. The holes are $0.6\,\mathrm{mm}$ wide with $0.05\,\mathrm{mm}$ wide copper lines. This gives approximatively $85\,\%$ transparency.

The scheme of our patch antenna is shown in figure 3. The configuration is a stacked patch in order to produce two bands of operation [1]. The top layer is the patch for the Ku-band. This element will be fed via two probes from a feeding network on the bottom layer. Under the Ku-band patch is the X-band patch. This element is not connected to the probes, but is rather fed via resonance from the upper patch.

In our initial studies, both patches were to be aperture fed. Not using probes would simplify the construction. However, in that case, the far-field of one of the operational frequencies will be in the abnormal region, having a null in the broadside direction [3].

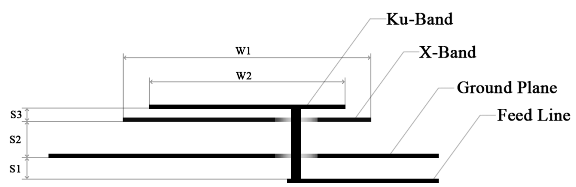


Fig. 3. Side view of the stacked patch antenna. The parameters are $W1 = 8.0\,\mathrm{mm}$, $W2 = 6.3\,\mathrm{mm}$, $S1 = 0.7\,\mathrm{mm}$, $S2 = 1.1\,\mathrm{mm}$, $S3 = 0.4\,\mathrm{mm}$. Total thickness around $2.3\,\mathrm{mm}$

The ground plane is in the third layer. The antenna elements will be fed through probes connected through microstrip lines below the ground plane. The feed lines will not be etched into a copper grid but will instead be kept solid as the transmission of light is barely affected. However, gridding these lines will produce a relevant degradation of the performance of the antenna system.

The branch-line coupler will be implemented on the same layer as the feed lines, see section VI.

## V. Results

The parameters of the current design is showed in figure 3. This design uses an upper patch measuring $6.3\,\mathrm{mm}$ and a lower measuring $8.0\,\mathrm{mm}$. The total thickness fulfils the specification of the contest.

These sizes are dimensioned for a dielectric constant $\varepsilon_r = 3.75$, which is the value given by the manufacturer (will be measured). The simulated results of the antenna are illustrated in figures 4 and 5.

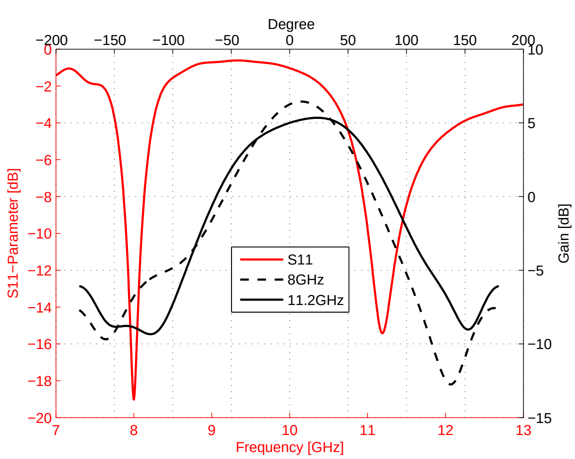


Fig. 4. $S_{1,1}$ and gain of the single antenna. The $-10\,\mathrm{dB}$ return loss bandwidth is $2.39\,\%$ at $8\,\mathrm{GHz}$ and $3.22\,\%$ at $11.2\,\mathrm{GHz}$.

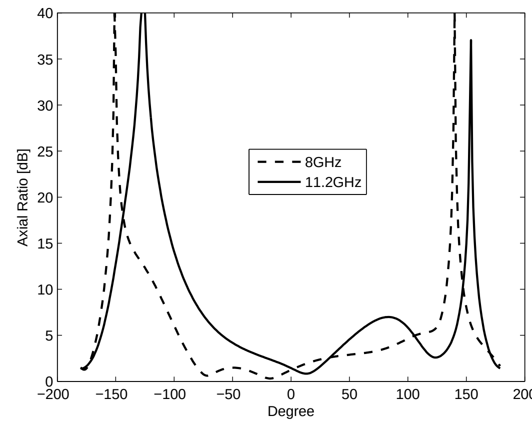


Fig. 5. Axial ratio of the single antenna in dB. This is below $3\,\mathrm{dB}$ in both beams described in section V.

Our antenna has a maximum gain of $6.45\,\mathrm{dB}$ and $5.34\,\mathrm{dB}$ for $8\,\mathrm{GHz}$ and $11.2\,\mathrm{GHz}$ respectively. The $3\,\mathrm{dB}$ beamwidth is $82.2°$ and $117.8°$. From an orbital altitude of $500\,\mathrm{km}$ the antenna will illuminate a disk with a diameter of approximately $870\,\mathrm{km}$ and $1650\,\mathrm{km}$. Due to the symmetrical design of patch antennas, the axial ratio is below $3\,\mathrm{dB}$ in the whole illuminated area. The $-10\,\mathrm{dB}$ return loss bandwidth is $2.39\,\%$ at $8\,\mathrm{GHz}$ and $3.22\,\%$ at $11.2\,\mathrm{GHz}$.

When the single antenna is placed into a 3 by 3 array, the illuminated area shrinks to $280\,\mathrm{km}$ and $210\,\mathrm{km}$ in diameter as the beamwidth goes down to $31.2°$ and $23.6°$.

## VI. Working plan

The coupler is still under development, but is being designed following the guidelines in Wong and Cheng's work [4]. Antenna dimensions may need reworking as the materials have limitations. If aperture coupling can be solved, it will be implemented in the final version. Estimation of cost is given in the following table.

## VII. Bill of Materials

| Item | Budget |
|---|---|
| Quartz glass, 0.5 mm thick, 100 pcs | 200 $ |
| Copper foil | 20 $ |
| Bond-ply adhesive tape | 15 $ |
| Etching supplies | 20 $ |
| Antenna connectors | 20 $ |
| Glass drill | 15 $ |
| Total: | 290 $ |

## References


[1] S. Maci and G. B. Gentili, "Dual-frequency patch antennas," *IEEE Antennas and Propagation Magazine*, vol. 39, no. 6, pp. 13–20, 1997.

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[4] F.-L. Wong and K.-K. M. CHENG, "A novel planar branch-line coupler design for dual-band applications," in *IEEE MTT-S International Microwave Symposium*, 2004.