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# Optimisation by Unit-Cell Rotation of Linear-to-Circular Polarising Reflectors for Practical Primary Feeds

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***Abstract*—This paper presents a procedure to optimise by unit-cell rotation a linear-to-circular polariser for near-field incidence. The method is illustrated using an example of an offset flat reflector illuminated by a standard gain horn. Breadboards for the uniform unit-cell array and optimised array have been manufactured and measured, showing good agreement with simulations. Improvements up to 8 dB in the measured cross-polarisation levels of the far-field horizontal plane are obtained for the optimised surface.**

***Index Terms*—reflector antennas, linear-to-circular polarisers, circular polarisation selective surfaces, frequency selective surfaces.**

## I. INTRODUCTION

The simplification of the space segment in satellite communications (satcoms) has become a key aspect to increase the number of missions or instruments to be accommodated on board the same satellite [1], [2]. Linear-to-circular reflection polarisers have been proposed as a promising technology for this simplification. The design of these reflection polarisers typically focusses on broadside plane wave incidence [1]-[5]. However, in practical antenna architectures such as those used for satcom reflectors, the range of incidence angles makes the plane wave assumption not appropriate. The modelling of the feed by an ideal far-field source (such as a Gaussian beam [6]) is also not appropriate if the reflector is not placed in the Fraunhofer region of the feed [7], as it is common in subreflectors.

In recent years, near-field modelling of the feed has been included in the design of reflectarrays [8], [9]. Also for reflectarrays, design techniques based on brute-force element by element optimisation have been developed [10], [11]. However, these optimization methods are computationally costly and may not provide the best results due to the large number of unknowns.

This contribution presents first simulated and measured results from an effort to efficiently design linear-to-circular reflection polarisers with a minimized cross-polarisation (cross-pol) component, while considering the near-field of the feed. The optimisation process consists on a unit-cell rotation, and is based on the following observations: 1) for off-principal planes, the unit-cell needs to be rotated to follow the field's polarisation [12]; 2) optimum local minimisation of the axial ratio upon reflection does not necessarily suggest optimum cross-pol in the far-field. As it will be shown, this optimisation reduces the cross-pol mainly in the horizontal plane of the far-field.

## II. REFLECTOR ANTENNA ARCHITECTURE AND UNIT-CELL GEOMETRY

The configuration chosen for the present paper is an offset flat reflector due to the ease in the manufacturing. The reflector, with diameter $d=27\ cm$, is shown in Fig. 1. The distance between feed and reflector is $f=25\ cm$ to ensure near-field incidence. The offset angle is $\theta_f=35°$ to ensure cross-pol levels that can be easily measured at Heriot-Watt University facilities. The reflector is fed by a standard Flann's gain horn, model 19240 [13], and polarised at $45°$.

The polarising surface laid on top of the reflector is based on the dipole unit-cell presented in [4], optimised for a Taconic TLY-5 substrate and the offset angle $\theta_f=35°$. The unit-cells are oriented along the x-axis. This surface performs a LP-CP conversion, where the co-polarised (co-pol) component corresponds to the left-handed circularly polarised (LHCP) component, and the cross-pol component corresponds to the right-handed circularly-polarised (RHCP) component. To obtain the far-field of the polarising surface, a combination of an in-house tool based on Physical Optics (PO) [14] and CST Microwave Studio [15] for the analysis of the unit-cell is used.

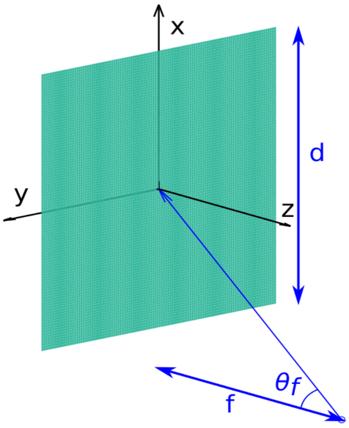

Fig. 1. Antenna configuration with reflector diameter *d=270 cm*, distance between feed and reflector *f=25 cm*, and offset angle $\theta_f=35°$.

## III. OPTIMISATION PROCEDURE

The optimisation procedure to reduce the far-field cross-pol exploits the observations made in section I. The unit-cell rotation is defined by a quadratic formula which input parameters are the incidence local angles ($\theta$, $\phi$). Then an optimisation routine is used to find the unknown coefficients of the formula. The optimisation is applied to several frequencies at the same time. Since it is based on a unit-cell rotation, it will locally improve the AR as the local incidence angle $\phi$ moves away from the centre vertical line of the reflector. For this reason, it is expected that the optimisation will mainly affect the horizontal plane of the far-field, leaving the vertical plane almost unaltered [16].

Due to the placement of the reflector in the Fresnel region of the feed, the horn cannot be considered a point source. A method to obtain the field at the reflector surface and the incidence angles for each unit-cell is applied, leading to slightly different incidence angles for each frequency. The optimisation is therefore applied taking this into account.

## IV. MANUFACTURING AND MEASUREMENTS

The Taconic TLY-5 substrates have been etched on one side with the uniform unit-cells and rotated unit-cells masks, leaving the other side grounded. Then they have been mounted on a supporting structure along with the horn antenna. A photograph of the measured configuration is shown in Fig. 2. The near-field reflected by the surface is measured in a 2D plane by a NSI near-field system. The whole configuration has been rotated so that the broadside directions of the antenna under test and the NSI probe are aligned. The NSI software performs a near-field-to-far-field transformation to obtain the far-field.

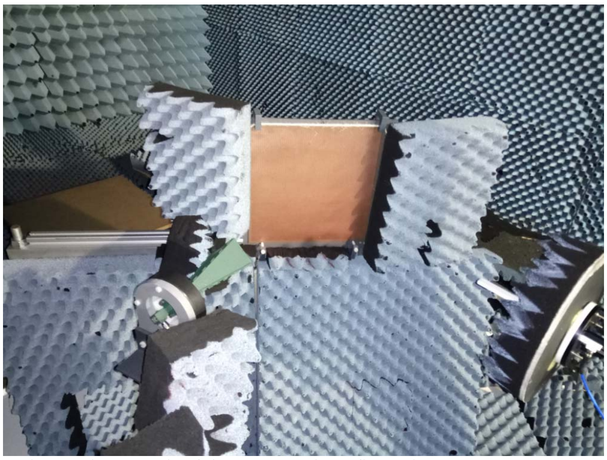

Fig. 2. Photograph of the measured configuration.

Fig. 3 and 4 show the vertical and horizontal planes respectively of the far-field at 17.7 GHz, while Fig. 5 and 6 show the two planes at 18.95 GHz. All the blue lines refer to the uniform unit-cell array, while the red lines refer to the optimised array. Thinner lines refer to simulations, and thicker lines to measurements. Solid lines refer to the co-pol components, and dashed lines to cross-pol components. Simulations and measurements are in good agreement both in the co-pol and cross-pol components. The differences are thought to be due mainly to misalignments between the reflector and the NSI probe. Some other small misalignments are possible to arise between horn and reflector due to errors in the mounting. Extra errors in the manufacturing of the polarising surfaces could also be present.

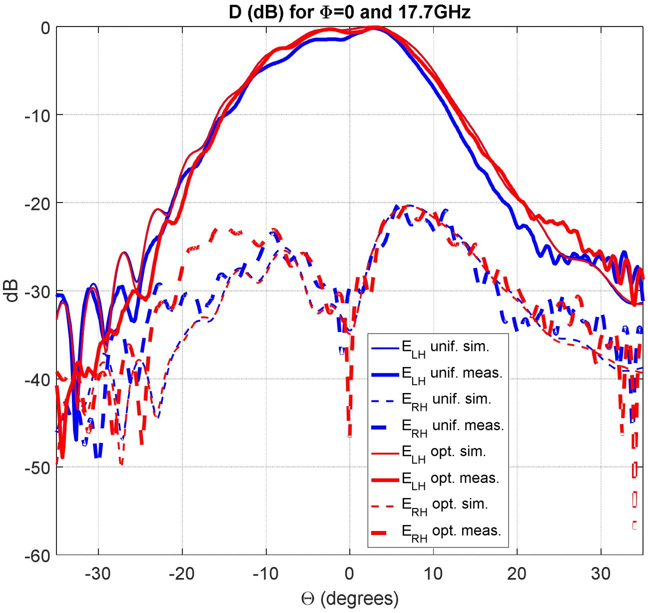

Fig. 3. Vertical plane (*Φ = 0*°) of the normalised directivity (dB) at 17.7 GHz for the two polarising surfaces: array with uniform unit-cells and array with optimised unit-cells by unit-cell rotation.

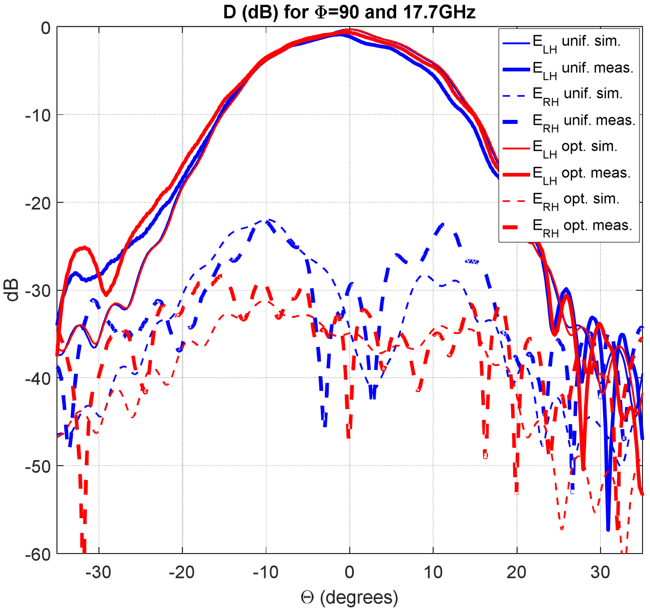

Fig. 4. Horizontal plane (*Φ* = *90°*) of the normalised directivity (dB) at 17.7 GHz for the two polarising surfaces: array with uniform unit-cells and array with optimised unit-cells by unit-cell rotation.

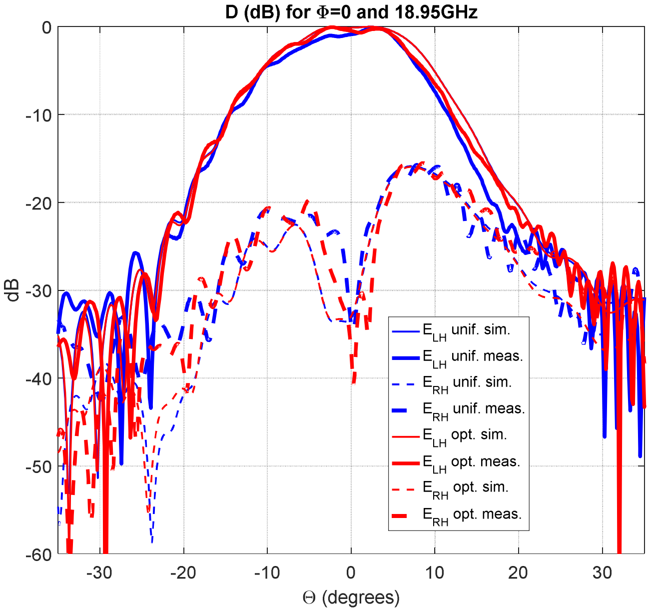

Fig. 5. Vertical plane (*Φ* = *0°*) of the normalised directivity (dB) at 18.95 GHz for the two polarising surfaces: array with uniform unit-cells and array with optimised unit-cells by unit-cell rotation.

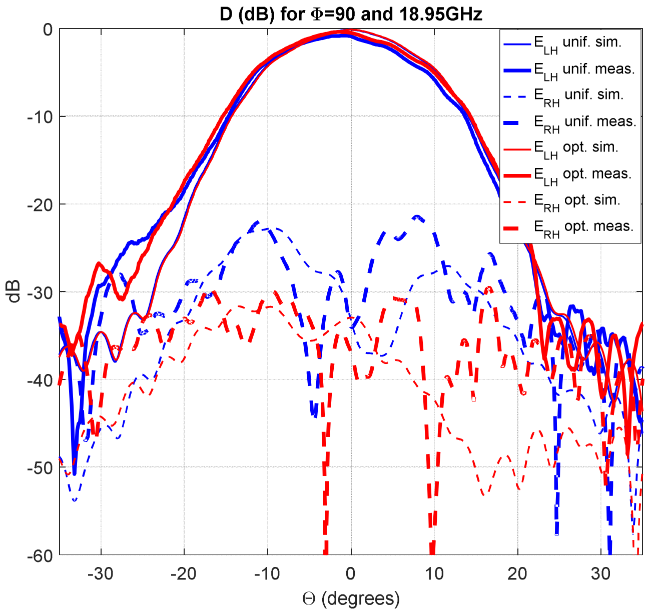

Fig. 6. Horizontal plane (*Φ* = *90°*) of the normalised directivity (dB) at 18.95 GHz for the two polarising surfaces: array with uniform unit-cells and array with optimised unit-cells by unit-cell rotation.

As it was mentioned in section III, the optimisation by unit-cell rotation affects mainly to the horizontal plane, as Fig. 4 and 6 show, while leaving almost unaltered the vertical plane, as Fig. 3 and 5 show. Improvements in the measurements between 6 and 8 dB are obtained for the horizontal planes.

## V. CONCLUSION

An optimisation procedure based on unit-cell rotation has been applied to an offset flat polarising surface placed in the Fresnel region of a Flann's standard gain horn. A quadratic formula has been selected for the optimisation, where several frequencies has been optimised at the same time. Good agreement between simulations and measurements and improvements in the measurements of 6-8 dB in the cross-pol prove the validity of the present procedure.

## ACKNOWLEDGMENT

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