# Design of Multi-Faceted Dual-Polarization Dual-Coverage Contoured Beam Reflectarray

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***Abstract*—The design and optimization of a single-layer multi-faceted dual-polarization contoured beam reflectarray with different coverages in each polarization has been presented. The reflectarray is optimized using a direct optimization technique to produce a contoured beam for a European coverage in H-polarization and a contoured beam for Brazilian coverage in V-polarization in a $10\%$ bandwidth.**

## I. Introduction

Printed contoured beam reflectarrays constitutes an alternative to the shaped reflectors in space applications and have been of great interest for satellite manufactures and space agencies due to their low cost and short manufacturing time [1]–[3]. Although printed reflectarrays possess several attractive features in terms of manufacturing, they have not yet gained widespread acceptance for space applications due to inferior performance compared to shaped reflectors. Consequently, reflectors are still the preferred choice for satellite communications. It is believed that the performance of printed reflectarrays is limited by two factors: one being the inherent narrow bandwidth of printed reflectarrays, and the other being the lack of suitable simulation and synthesis tools.

Regarding the simulation/synthesis tool, most contoured beam reflectarrays presented in the literature are designed using a phase-only optimization technique [1], [2]. Despite being an efficient approach, it possesses the drawback that intermediate steps are required to obtain the design. A direct optimization technique, on the other hand, where all the elements are simultaneously optimized, does not has this issue and may produce more optimal designs [4].

With respect to the limited bandwidth, the bandwidth of printed reflectarrays is determined by the response of the printed elements and the differential spatial phase delay from the feed. One way to reduce the differential spatial phase delay is to use multi-faceted reflectarrays as suggested in [5] and demonstrated in [6]. In this latter work, the multi-faceted reflectarray is designed using a phase-only optimization technique.

The purpose of this paper is to demonstrate a reflectarray designed using the direct optimization technique from [4] and the multi-faceted concept.

## II. Reflectarray Design

For the reflectarray design, a dual-polarization contoured beam reflectarray with different coverages in each polarization is considered. A similar design was presented in [1], but for a planar three-layer configuration and synthesized using a phase-only approach. In our case, the design is a single-layer multi-faceted design.

The configuration of the multi-faceted reflectarray is shown in Fig. 1. It consists of 9 flat panels, each with a dimension of $0.33 \times 0.33\,\mathrm{m}^2$, and imitate the surface of a rectangular parabolic reflector. The reflectarray consists of 9801 rectangular patches and is optimized to produce a contoured beam for a European coverage in H-polarization and a contoured beam for a Brazilian coverage in V-polariation within the frequency range $11.4 - 12.6\,\mathrm{GHz}$ ($10\%$ bandwidth). At the center frequency, the reflectarray is approximately $40 \times 40\,\lambda_0^2$ with $\lambda_0$ being the free-space wavelength. The reflectarray is illuminated using two linearly polarized feeds, a H-polarized feed for the European coverage, and a V-polarized feed for the Brazilian coverage. Both feeds have a taper of $-12\,\mathrm{dB}$ at $26.6^\circ$. The substrate used in the design has a dielectric constant of 3.66 and a thickness of $1.528\,\mathrm{mm}$.

The direct optimization technique is based on a gradient minimax algorithm, thus a good initial optimization point is necessary to ensure rapid convergence and to avoid non-optimum local minima. For the present case, a reflectarray design obtained from a phase-only optimization technique is applied as the starting point.

To obtain the phase distributions required to fulfil the

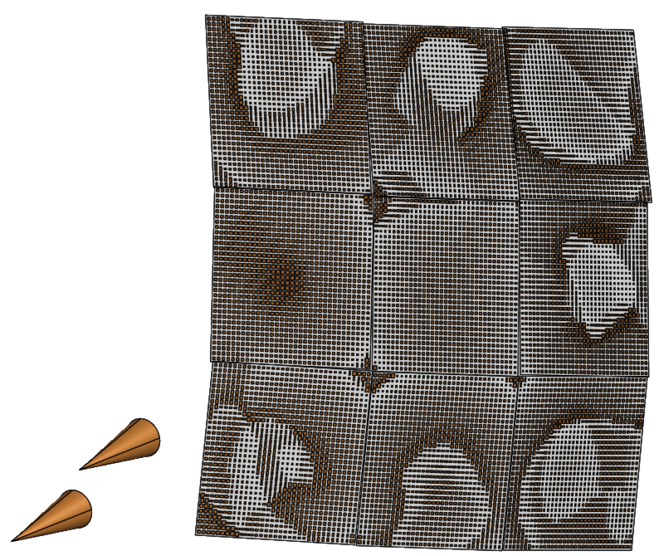
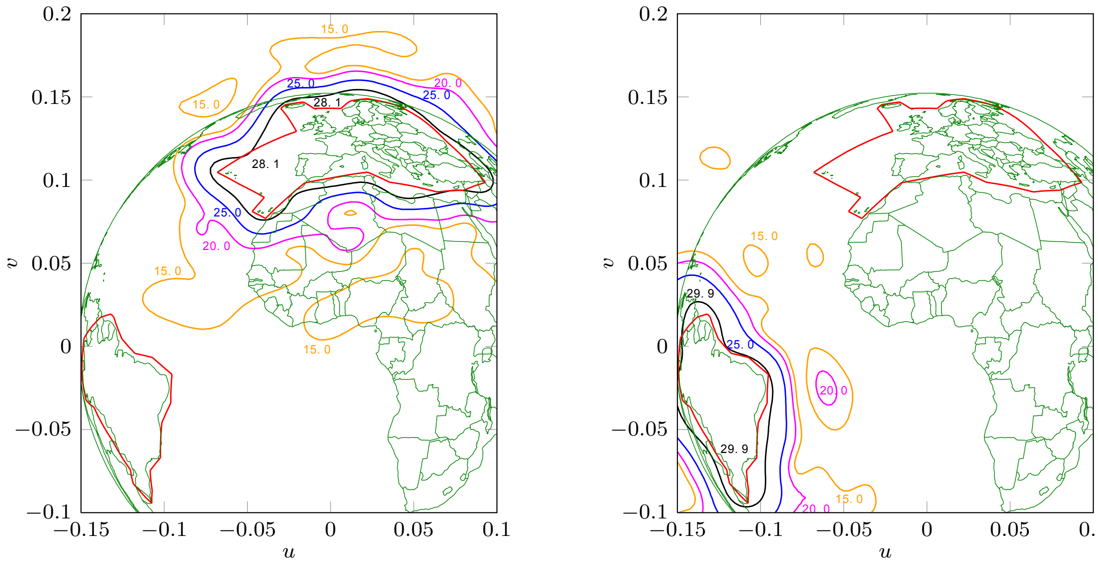


Fig. 1. Configuration of the multi-faceted contoured beam reflectarray.




(a) (b)

Fig. 2. Co-polar radiation of multi-faceted reflectarray for (a) H-polarization and (b) V-polarization at 12 GHz. The coverages are shown as red polygons.

coverage requirements, we use the POS software [7] from TICRA to design two shaped reflectors, one that produces a contoured beam within the European coverage and the other within the Brazilian coverage. From the shaped reflectors, the required phase distributions at the surface of the reflectarray panels are extracted. The dimensions of the rectangular patches are subsequently adjusted to comply with these phase distributions, the $x$-dimensions to match the required phase for H-polarization and the $y$-dimensions for V-polarization, both at 12 GHz. This initial design is then used as the starting point for the optimization of the multi-faceted contoured beam reflectarray in the entire frequency band. The optimized mask layout is shown in Fig. 1.

## III. Numerical Results

The co-polar radiation pattern of the multi-faceted reflectarray at 12 GHz is shown in Fig. 2. It is seen that the reflectarray radiates a contoured beam within the European coverage in H-polarization and a contoured beam within the Brazilian coverage in V-polarization. The performance of the reflectarray as function of the frequency is summarized in Table I. The reflectarray operates within the frequency band of $11.4 - 12.6$ GHz with a minimum directivity of $27.9.0$ dBi within the European coverage in H-polarization and $29.6$ dBi

TABLE I
Performance of Multi-Faceted Reflectarray

| Frequency [GHz] | European Cov. (H-pol.) Minimum directivity [dBi] | Brazilian Cov. (V-pol.) Minimum directivity [dBi] |
|---|---|---|
| 11.0 | 26.6 | 27.6 |
| 11.4 | 27.9 | 29.6 |
| 12.0 | 28.1 | 29.9 |
| 12.6 | 28.0 | 29.8 |
| 13.0 | 25.7 | 27.5 |

within the Brazilian coverage in V-polarization. Outside the frequency band, the minimum directivity drops as expected.

The multi-faceted reflectarray presented here consists of rectangular patches, which are known to have narrow bandwidth. It is expected that the performance can be significantly enhanced if more advanced element types are used. Additional results will be presented at the conference.

## IV. Conclusion

The design and optimization of a single-layer multi-faceted contoured beam reflectarray using a direct optimization technique has been presented. The reflectarray is a dual-polarization reflectarray with different coverages in each polarization. The reflectarray is optimized to produce a contoured beam for a European coverage in H-polarization and a contoured beam for a Brazilian coverage in V-polarization in a $10\%$ frequency bandwidth.

## References

[1] J. A. Encinar, L. S. Datashvili, J. A. Zornoza, M. Arrebola, M. Sierra-Castaner, J. L. Besada-Sanmartin, H. Baier, and H. Legay, "Dual-polarization dual-coverage reflectarray for space applications," *IEEE Trans. Antennas Propag.*, vol. 54, no. 10, pp. 2827–2837, 2006.

[2] J. A. Encinar, M. Arrebola, L. D. L. Fuente, and G. Toso, "A transmit-receive reflectarray antenna for direct broadcast satellite applications," *IEEE Trans. Antennas Propag.*, vol. 59, no. 9, pp. 3255–3264, 2011.

[3] H. Legay, D. Bresciani, E. Girard, R. Chiniard, E. Labiole, O. Vendier, and G. Caille, "Recent developments on reflectarray antennas at Thales Alenia Space," in *Proc. EuCAP*, Berlin, Germany, 2009.

[4] M. Zhou, S. B. Sørensen, O. S. Kim, E. Jørgensen, P. Meincke, and O. Breinbjerg, "Direct optimization of printed reflectarrays for contoured beam satellite antenna applications," *IEEE Trans. Antennas Propag.*, vol. 61, no. 4, pp. 1995–2004, 2013.

[5] A. Roederer, "Reflector antenna comprising a plurality of panels," *US Patent 6411255*, 2001.

[6] H. Legay, D. Bresciani, E. Labiole, R. Chiniard, and R. Gillard, "A multi facets composite panel reflectarray antenna for a space contoured beam antenna in ku band," *Progr. Electromagn. Res. B*, vol. 54, pp. 1–26, 2013.

[7] "POS Software," TICRA, Copenhagen, Denmark.