High-Performance Curved Reflectarrays for Telecommunication Applications

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***Abstract* – The use of curved reflectarrays for telecommunication applications is presented in this paper. For contoured beam applications, the curvature of the reflectarray surface can be used to enhance the bandwidth significantly, yielding reflectarray designs that are equivalent in performance compared to traditional shaped reflector antennas. For multiple spot beam applications, the curvature of the reflectarray surface can be used to enable the possibility of radiating more than one beam types in the 4-color frequency/polarization re-use scheme using a single feed. As a result, the number of main apertures needed to cover a multiple spot beam coverage can be reduced from four to two.**

***Index Terms* — Reflectarrays, Satellite applications, Telecommunication**

1. Introduction

Printed reflectarrays provide a way to realize low-cost high-gain antennas and has in the past decade been of great interest for space applications [1]. Printed reflectarrays are usually flat and their flat nature has made them interesting for space applications for several reasons. However, the flatness is also one of the reasons that reflectarrays have narrow bandwidth compared to reflectors. Consequently, printed reflectarrays, despite having many advantages, have not yet gained widespread acceptance for space applications.

In this paper, we consider curved reflectarrays and show how they can be used for telecommunication applications to provide attractive solutions as compared to conventional reflector antennas.

2. Direct Optimization Technique

For the design of the curved reflectarrays we use the direct optimization technique (DOT) presented in [2] where all array elements are optimized simultaneously to fulfill certain far-field specifications. The DOT has several advantages compared to the conventional phase-only approach, and as a result better designs can be realized. The analysis method used in the DOT is based on a spectral domain method of moments assuming local periodicity (LP-SDMoM), and the optimization algorithm is a gradient-based minimax algorithm.

3. Contoured Beam Applications

For contoured beam applications the shaped reflector is currently the preferred choice. The shaped reflector is a mature technology, but the cost associated to its manufacturing is high and the delivery time is long, mainly due to the mold which depends on the specific mission requirements. Printed reflectarrays do not have these disadvantages and contoured beam reflectarrays have also been reported in various works, e.g., [3]. However, due to the bandwidth limitations imposed by planar reflectarrays, none of the reflectarrays presented in the literature can compete with the shaped reflector in terms of performance.

The concept of a curved reflectarray was first suggested in [4] and has several advantages. A curved reflectarray reduces the spatial phase delay, hence improving the bandwidth. Furthermore, a doubly curved surface is inherently stiffer and can thus be made more lightweight than its planar counterpart. Finally, an existing parabolic mold can be reused for multiple missions, significantly reducing cost and delivery time.

Using the DOT, a curved contoured beam reflectarray has been designed to radiate a contoured beam on a European coverage for dual linear polarization in both Tx (11.45-12.75 GHz) and Rx (13.74-14.25 GHz) frequency bands. The optimized reflectarray fulfills all the coverage specifications and the performance is equivalent to that of a shaped reflector optimized for the same coverage specifications.

The radiation patterns calculated using the higher-order multi-level fast multipole method (HO-MLFMM) in GRASP and the LP-SDMoM are shown in Fig.1. An excellent agreement is observed between the two solutions, thus validating the performance of the design.

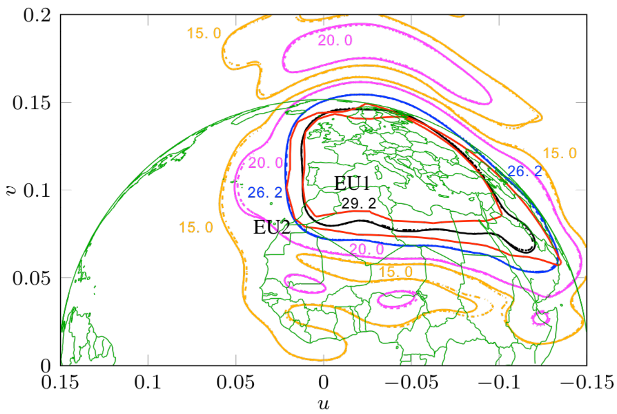

Fig. 1. Co-polar radiation pattern calculated using HO-MLFMM (solid) and LP-SDMoM (dashed) of optimized curved contoured beam reflectarray at 14.25 GHz.

This shows that curved reflectarrays are viable candidates for replacing shaped reflectors for telecommunications applications.

4. Multiple Spot Beam Applications

In the last decade, there has been an increased interest in broadband satellites utilizing multiple beam antennas (MBA) for High Throughput Satellites (HTS). MBA have the ability to provide higher capacity compared to contoured beam antennas due the possibility of frequency (F_1, F_2) and polarization (P_1, P_2) reuse such as the 4-color reuse scheme shown in Fig. 2.

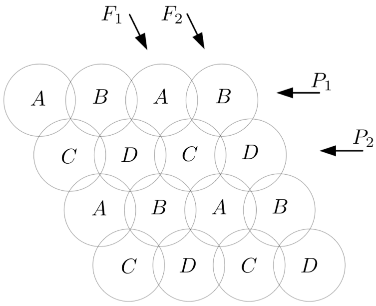

Fig. 2. Beam layout of the 4-color reuse scheme.

The current state-of-the-art to cover the 4-color reuse scheme is to use four dual-band (Tx/Rx) single-feed-per-beam (SFB) reflector antennas [5], one reflector for each of the beams. Accommodating four reflectors on a satellite requires significant space and ways to reduce the number of main apertures are of great interest. The use of multiple-feed-per-beam reflectors [6] can be considered to reduce the number of main apertures, but at the cost of performance degradation. Using a curved reflectarray, it is possible to reduce the number of main apertures while maintaining a performance that is comparable to that of the four-reflector solution.

Consider the offset reflectarray shown in Fig. 3. The idea is to adjust the elements to scan the reflected beam half a beamwidth for one polarization (*A*-beams) and another half towards the opposite direction for the orthogonal polarization (*B*-beams). This can be achieved using, e.g., the variable rotation technique (VRT) [7].

Using this concept, the 4-color reuse scheme can be covered using two reflectarrays while maintaining a performance that is comparable to the four-reflector solution. The concept can theoretically be applied for planar reflectarrays. However, due to their poor scanning properties, planar reflectarrays are not a viable solution for HTS applications.

Using the DOT, we designed a curved reflectarray that could generate the *A* (RHCP) and *B* (LHCP) beams. Using 9 dual circularly polarized horns, the reflectarray generates 18 beams as shown in Fig.4. The blue and black beams correspond to the *A* and *B* beams, respectively. In the figure, the -2 and -3 dB contours and the peak of each beam are shown. Using a reflectarray designed to radiate the *B* and *D* beam, the full reuse scheme can be covered.

The concept is promising and indicates that curved reflectarrays can be used on board a satellite to reduce the number of apertures needed for HTS applications.

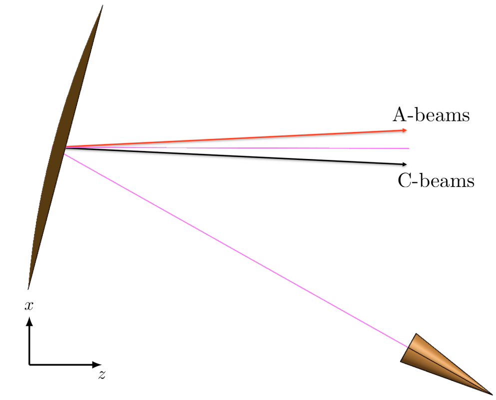

Fig. 3. Curved reflectarray configuration to radiate two types of beams in the 4-color reuse scheme using only a single feed.

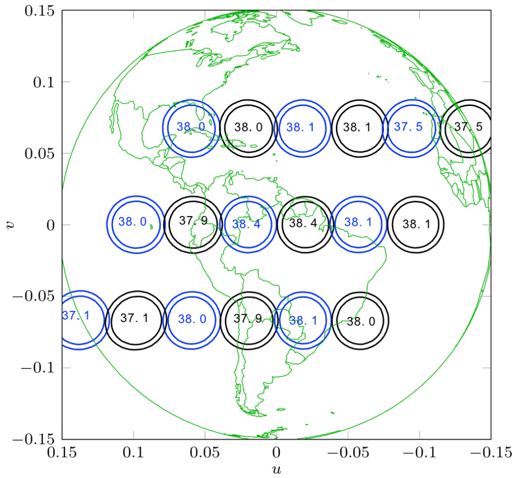

Fig. 4. The radiation pattern of the optimized curved multiple spot beam reflectarray.

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