Advances on High-Performance Curved Reflectarrays for Telecommunication Applications

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***Abstract*—The latest advances on 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 can surpass the performance of a traditional shaped reflector. For multiple spot beam applications, the curved reflectarray can be used to reduce the number of main apertures from four to two, while maintaining single-feed-per-beam operation.**

***Index Terms*—reflectarrays, satellite applications**

I. Introduction

Printed reflectarrays are usually flat and the flat nature has made them an interesting alternative to provide low-cost high-gain antennas for space applications. However, the flatness is one of the reasons that the performance of reflectarrays is inferior compared to reflector solutions. Thus, reflectors are still preferred for most space applications.

Recently, the European Space Agency (ESA) has been involved in promoting the use of curved reflectarrays to provide attractive solutions as compared to conventional reflector antennas for telecommunications applications [1], [2]. In this paper, the latest progress on high-performance curved reflectarrays is presented.

II. Multiple Spot Beam Applications

In the last decade, there has been a significant interest in multiple beam antennas (MBA) for High Throughput Satellites (HTS) in Ka-band. Compared to contoured beam antennas, MBA can provide higher capacity due to the possibility of frequency and polarization reuse. For the traditional 4-color reuse scheme, the current state-of-the-art is to use four dual-band (Tx/Rx) single-feed-per-beam (SFB) reflectors [3]. Four reflectors occupy significant space on a satellite and means to reduce the number of antennas are of great interest.

In [2], a reflectarray concept was proposed where the number of main apertures could be reduced while maintaining SFB operation. The idea is to combine the individual phasing capabilities of the reflectarray and a parabolic surface. If one optimize the array elements to scan the reflected beam for one polarization in one direction and a similar amount in the opposite direction for the orthogonal polarization, then it is possible to cover the 4-color reuse scheme using only two reflectarrays.

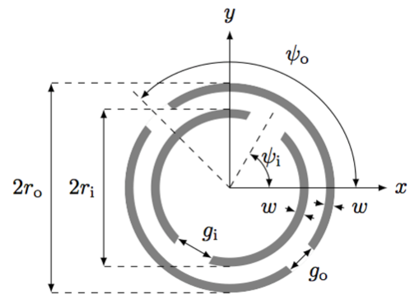

Fig. 1. Concentric split ring element [4].

In Ka-band, the objective is to generate spot beams in dual-circular polarization with orthogonal polarizations in Tx and Rx. In [2], the concept was demonstrated using single-band array elements and the design can not be used to cover a Tx/Rx coverage. In this paper, we demonstrate the concept using dual-band array elements and show how it can be used to cover Tx/Rx (20/30 GHz) operation.

The array element that is considered is the concentric split ring shown in Fig. 1. The outer and inner loops can work as phase shifters for Tx and Rx respectively. This is achieved by adjusting the rotations ψ_o and ψ_i. Due to coupling between the loops, the rotations can not be done independently and an optimization is required. The other parameters (g_i, r_i, r_o, g_o, w) are used to tune the response to obtain low cross-polarization.

Using this element, a reflectarray is designed to operate in dual-circular polarization with orthogonal polarizations in Tx and Rx. The radiation patterns when illuminated by a RHCP (black) feed and a LHCP (red) feed are shown in Fig. 2. It is seen that the reflectarray operates in dual-band with orthogonal polarizations in Tx and Rx.

This shows that 4 beams can be generated using a single reflectarray with a dual-band feed, 2 in Tx and 2 in Rx. Using this operation, the number of main apertures to cover the 4-color reuse scheme can be reduced from 4 to 2. Further development of this concept is currently on-going.

III. Contoured Beam Applications

The shaped reflector is a mature technology and is currently the preferred solution for contoured beam applications. However, due to the mold, the manufacturing cost is high and the

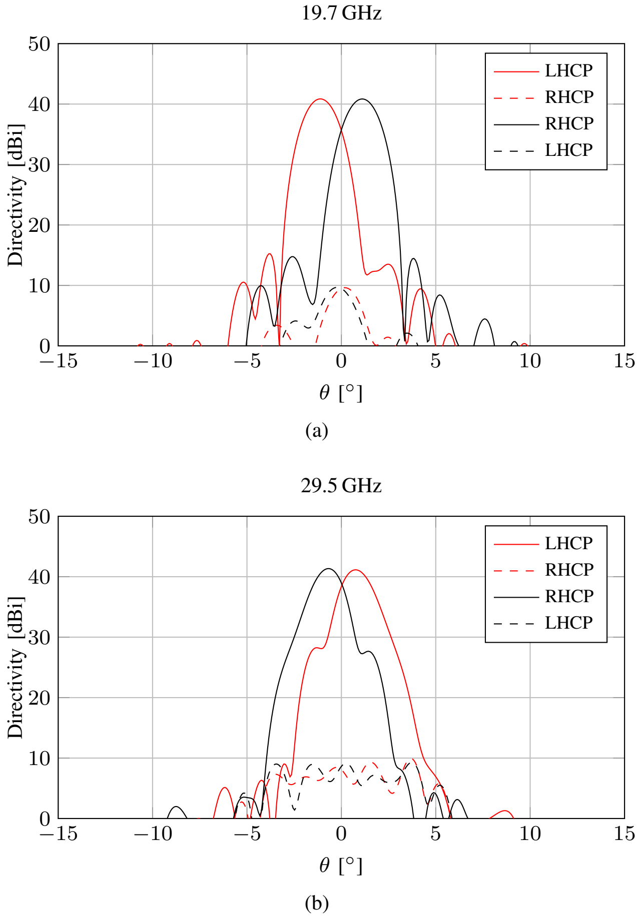

Fig. 2. Radiation pattern of optimized multiple spot beam reflectarray when illuminated by RHCP (black) incident field and LHCP (red) incident field. Co-polar components are shown with solid lines whereas cross-polar are shown with dashed lines.

delivery time is long. Printed reflectarrays circumvent these disadvantages hence significant work on planar contoured beam reflectarrays have been reported in the literature [5]–[7]. However, the performance of these reflectarrays can not reach that of the shaped reflector.

Curved reflectarrays was first introduced in [8] and it was shown in [1] that the performance can be equivalent to that of a shaped reflector. A curved reflectarray is attractive compared to shaped reflectors because a standard parabolic mold can be reused for multiple missions, thereby reducing the cost and delivery time. In this paper, we show that, if properly designed, the performance of a curved reflectarray can surpass that of the shaped reflector.

To serve as reference mission, we consider the coverage from [6]. The mission covers a large CONUS/Canada contoured beam with two high-gain regions over Puerto Rico and Hawaii. The reflectarray shall work in dual-linear polarization in both Tx (11.7-12.1 GHz) and Rx (13.75-14.25 GHz) frequency bands. The design approach is similar to that presented in [7] and the reader is referred hereto for more details. To serve as a reference solution, an equivalently sized shaped reflector optimized for the same coverage specifications has

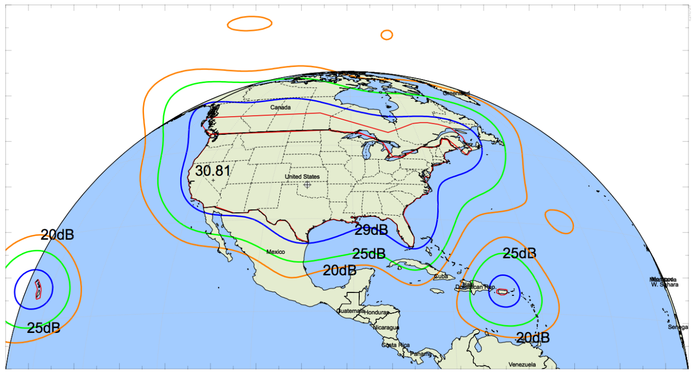

Fig. 3. Co-polar gain of the optimized reflectarray at 11.7 GHz.

been designed.

The co-polar gain pattern of the optimized reflectarray at 11.7 GHz is shown in Fig. 3 and similar patterns are observed throughout the frequencies in both Tx and Rx bands. The optimized curved reflectarray fulfills all coverage specifications with a goal margin of 1.14 dB (1.32 dB if losses are not included) whereas the shaped reflector fulfills the specifications with a margin of 0.95 dB. This is to our knowledge the first time that a reflectarray surpasses the performance of a shaped reflector.

The reason for this performance enhancement is the use of a direct optimization technique on a reflectarray that consists of array elements that can generate multiple resonances. With multiple resonances, it is possible to tune the phase shift and frequency dispersion independently in a wide bandwidth, resulting in improved performance.

Further investigations is on-going with the goal to further enhance the performance of the curved reflectarray.

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