Tx/Rx Reflectarray for Multiple Spot Beam Applications in Ka-band

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***Abstract*—The design of a polarization selective reflectarray for dual-band dual-circular polarization for multiple beam applications in Ka-band is presented. The reflectarray separates the reflected RHCP and LHCP beams by one beamwidth. and this is achieved in both Tx (19 GHz) and Rx (29 GHz). With this concept, a multiple beam coverage employing the 4-color frequency/polarization re-use scheme can be covered using two reflectarrays while maintaining the single-feed-per-beam operation.**

***Index Terms*—satellite applications, reflectarrays, HTS, multi-beam**

I. INTRODUCTION

Multiple beam reflector antennas are becoming more and more popular for telecommunication applications due to their capability of delivering high capacity for high-throughput satellites (HTS). Currently, the state-of-the-art is to employ four dual-band (Tx/Rx) single-feed-per-beam (SFB) reflectors to cover a contiguous spot beam coverage using the 4-color re-use scheme, one reflector for each of the colors [1]. Recently, significant efforts have been made to reduce the number of main apertures onboard these HTS and ESA has promoted solutions [2] to achieve this while maintaining SFB operations. However, these concepts rely on the use of dual-reflector systems which increase the complexity of the antenna system.

In [3], we proposed an innovative reflectarray concept to reduce the number of apertures, while considering a single offset antenna system and maintaining SFB operation. The idea is to use a parabolic polarization selective reflectarray that can radiate two of the beam types in the 4-color re-use scheme. The two beam types shall discriminate in polarization, meaning that for one polarization, the reflectarray needs to scan the beams in one direction, and in the orthogonal polarization, the reflectarray needs to scan the beams in the opposite direction. In this way, a single reflectarray can generate two of the four colors in the 4-color re-use scheme and another reflectarray can generate the remaining colors resulting in a total of two apertures to cover the full multiple beam coverage.

In [3], the concept was demonstrated for the Tx-band (20 GHz) only, whereas in a real Ka-band mission, the reflectarray must operate in both Tx (20 GHz) and Rx (30 GHz). In this paper, we present the design of a Ka-band polarization selective reflectarray operating in both Tx and Rx bands.

II. REFLECTARRAY DESIGN

The design of a dual-band reflectarray with separated beams for the two orthogonal CP is not an easy task, and fulfilling the stringent RF requirements of a real flight mission demands designs with high complexity. To use the concept from [3], the reflectarray has to be doubly curved and the manufacturing process is not a straightforward task. As far as the authors are aware of, no one has yet manufactured a doubly curved reflectarray. Consequently, to ease the manufacturing process and to avoid uncertainties, only single layer designs using substrate materials where the RF characteristics are well controlled are considered.

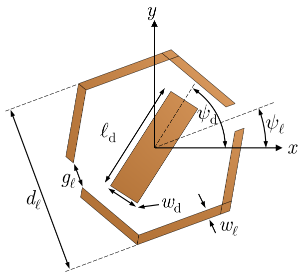


Fig. 1. Split hexagonal-loop dipole element.

The reflectarray is designed to radiate the two beam types in the 4-color re-use scheme that are discriminated in polarization and operate in one of the sub-bands. For RHCP, the beams are scanned in half a beamwidth (0.9°) in one direction, whereas for LHCP the beams are scanned half a beamwidth in the opposite direction. In this way, it is possible to have contiguous beams that are usually covered by two reflectors using only a single reflectarray.

As shown in [3], the variable rotation technique (VRT) can be used for controlling the phase of the elements for circular polarization. Many types of single-layer dual-band elements using the VRT have been studied in the literature. In our case, we use the split hexagonal-loop dipole element shown in Fig. 1 printed on a single layer Duroid substrate with a dielectric constant of 3.66, loss tangent of 0.0037, and a thickness of 1.524 mm. Essentially, the idea of this element is that the outer loop controls the phase in the Tx band and the inner dipole controls the phase in the Rx band. In this way, the reflection phase can be adjusted independently in the two frequency bands by ψ_l and ψ_d. And for for each combination of these angles, the other parameters are optimized to ensure low cross polarization. In practice, there is a significant coupling between the outer loop and the dipole, resulting in a more complicated relation between the phase of the reflected field and the rotation angles.

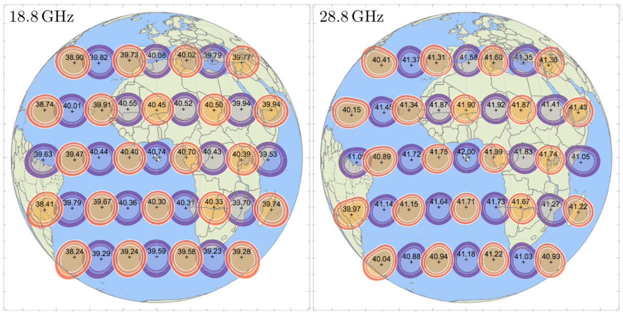


Fig. 2. Beams generated by the reflectarray when illuminated by the feedarray. The two colors represent the RHCP and LHCP. The peak position of the beams are indicated by a cross (+) with associated peak value, and different contours show -2, -3, and -4.3 dB below peak.

The reflectarray is illuminated by a feedarray consisting of 22 feeds in a hexagonal grid. For each of the feed, we consider the pattern of an existing horn designed for a flight mission in Ka-band. It has a diameter of 66 mm and operates at Tx: 18.8-19.3 GHz and Rx: 28.7-28.9 GHz. The reflectarray is then optimized, following the direct optimization approach described in [4], for all feeds simultaneously to fulfill the beam specifications (gain, C/I, cross-polarization) in both Tx and Rx.

In Fig. 2, the Tx and Rx beams at 18.8 GHz and 28.7 GHz are shown. Using the 22 feeds, it is possible to generate 41 beams over the Earth. The Tx beams scan well with little beam distortion whereas the distortions are more visible for the Rx beams. Compared to the nominal reflector radiation pattern, the beam shapes are quite similar, indicating that the degradation in peak value and the beam distortion for the scanned beams are mainly due to scan aberrations.

The cross-polarization for the reflectarray is slightly higher compared to the nominal reflector, where the worst case cross-polar is around 15.0 dBi and 10 dBi for the reflectarray and reflector, respectively. C/I performance is on the other hand better using the reflectarray where the worst case aggregated C/I is around 14 dB compared to 9 dB for the reflector. The patterns for the other Tx/Rx frequencies resemble those at the center frequencies and are therefore not shown.

The manufactured reflectarray breadboard, the first of its kind, is shown in Fig. 3 and preliminary measurement results are shown in Fig. 4, where the simulated and measured patterns of the center beams are displayed. An excellent agreement between simulations and measurements is observed.

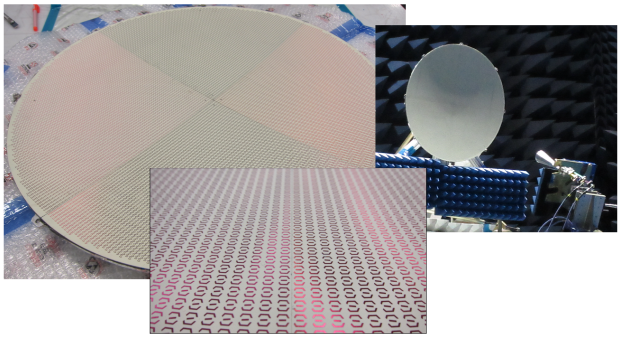
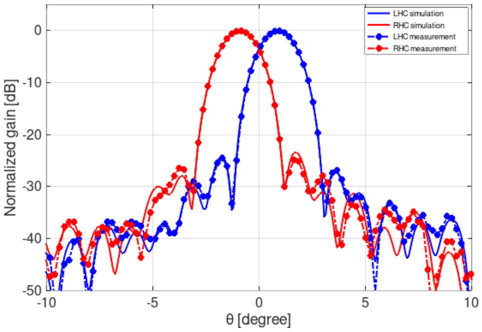
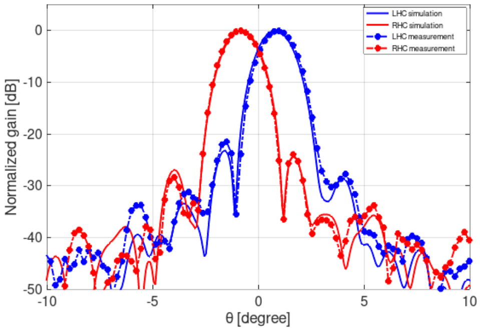


Fig. 3. Curved Tx/Rx reflectarray breadboard.



(a) 18.8 GHz



(b) 28.8 GHz

Fig. 4. Comparison between simulations and measurements.

The results presented here demonstrate that a curved polarization selective reflectarray can indeed radiate two of the beam types in the 4-color re-use scheme in both Tx and Rx. Using another reflectarray that generates the remaining beams in the other sub-bands, global coverage can be achieved using only two reflectarrays while maintaining SFB operations.

ACKNOWLEDGMENT

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