Evaluation of a compressed hyperhemispherical lens as a focal plane feed for Ka satellite applications

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With the satellite communication market growing rapidly and ever-increasing demand for bandwidth, Ka-band is being recognized as the next generation of satellite technology. Those satellites use a multi-beam reflector based antenna to improve the overall system capacity in terms of achieved data rate. Those antennas adopt one feed per beam architecture with each adjacent beams being generated by a horn in a cluster that illuminates the reflector. The cluster of horns tends to be large, bulky and restrictive to generate very close adjacent beams.

The authors have shown in previous works that a hyper hemispherical lens with an array of feeds integrated at the bottom of the lens and producing virtual foci may allow higher number of beams using a single multibeam aperture. However the main problem with the hyperhemispherical lens is the volume and weight. Given the simplicity of the hyperhemispherical lens solution and its feeding it is pertinent to evaluate a compressed version of the lens obtained with optical transformations for the described application in terms of volume, phase center and beam scanning characteristic for use with a single reflector.

Transformation optics provides a systematic method for reshaping lenses without changing their optical properties. This flexibility on the lens geometry requires an equivalent flexibility on the material constitutive parameters. In general, heterogeneous anisotropic (meta)materials with both electric and magnetic responses are required to implement the transformed lenses. In this work, we focus on a coordinate transformation that compresses a region of space, resulting in an overall decrease in the thickness of a lens. The compression of 2D conventional lenses, such as the Luneburg lens, was already addressed in the recent literature. As far as we know, this transformation has not yet been used in three dimensional problems. Herein, we apply this transformation to a 3D hyper-hemispherical lens with relative permittivity $\varepsilon = 2.53$. The lens profile is reduced to half of its size. Small aperture antennas operating at 30 GHz feed the lens at one central and two different off-axis positions.

For correct illumination of the reflector, the phase centers associated with each beam, in the E- and H-planes, must be similar. We should stress that the lens compression changes the position of the phase center in a different manner for each plane so this must be solved with feed co-design. Full characterization of the phase center, radiation pattern, gain and scan characteristics will be presented at the conference.