Compressed Elliptical Geodesic Luneburg Lens for Ka-band Satellite Communications

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In modern satellite communications, compact, low-cost, and fully-metallic antennas that provides multiband operation, high gain, and steerable beam scanning are demanded (S. A. Matos, et al, High Gain Dual-Band Beam-Steering Transmit Array for Satcom Terminals at Ka-Band, in IEEE Transactions on Antennas and Propagation, vol. 65, no. 7, pp. 3528-3539, July 2017.). Luneburg lens antennas are good candidates since they satisfy the requirements mentioned at the millimetre wave band. While current satellite communication systems are mainly designed for X band, Ka-band is one of the preferred bands for the future satellite communication systems for the new constellations of low orbit satellites (J. R. Costa, et al, Compact Ka-Band Lens Antennas for LEO Satellites, in IEEE Transactions on Antennas and Propagation, vol. 56, no. 5, pp. 1251-1258, May 2008.).

The refractive index distribution of a Luneburg lens provides isotropic focusing performance over all directions (R. K. Luneburg, et al, Mathematical theory of optics. Univ of California Press, 1964.), which makes it ideal for multibeam or beam scanning antennas. Although spherical dielectric Luneburg lens can convert spherical waves to plane waves to any direction, it is difficult and costly to manufacture, and dielectric materials are not suitable under extreme environmental conditions. A two-dimensional rotationally symmetric Luneburg lens can be designed in a metallic parallel plate waveguide by mimicking the refractive index distribution with geodesic curvature. Recently, it has been demonstrated that the height of the geodesic profile can be compressed by mirroring the shape of the curvature (Q. Liao, et al, Compact Multibeam Fully Metallic Geodesic Luneburg Lens Antenna Based on Non-Euclidean Transformation Optics, in IEEE Transactions on Antennas and Propagation, vol. 66, no. 12, pp. 7383-7388, Dec. 2018.).

Here, we propose a new method of reducing the profile of a fully metallic geodesic Luneburg lens using quasi-conformal transformation optics. It has been previously demonstrated that the circular profile of a Luneburg lens can be transformed to a straight line to simplify the feeding network (H. Ma, et al, Three-dimensional broadband and broad-angle transformation-optics lens. Nature communications, 1, 124.). Similarly, the circular geodesic Luneburg lens can be compressed to be an elliptical shape. An elliptical Luneburg lens sacrifices the planar isotropy, affecting the performance at extreme angles. The elliptical geodesic curvature is calculated assuming that the feeding port is place at the end of the short axis of the elliptical shape of the lens and perfect plane waves are generated to the opposite side. With the proper transformation, the scan losses introduced by the elliptical shape are below 1 dB in the operational angular range. A trade off is made between the compressed ratio and scan loss and it must be decided considering the final application.