3D-Printed Multi-beam Flat Lens Antenna System

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Multi-beam antennas are becoming the key technologies for fifth generation (5G) and beyond (B5G) wireless communication systems. These antennas can produce multiple simultaneous beams to enable long range communication, support high data transmission rates, and increase spectrum efficiency [1]. Among different multi-beam antennas, lenses have attracted interest because of their high-gain and quasi-optical like performance. Meanwhile, inhomogeneous GRadient INdex (GRIN) lenses can be designed as a flat interface leading to a lower profile design that implies an easier integration in communication systems, while they allow alteration of wave propagation through variation of the distribution of their effective refractive index [2].

The recent advancement in additive manufacturing, as well as the development of metamaterial constructions, has renewed interest in the use of lenses to produce high gain multi-beam antennas with lower cost and high precision manufacturing possibilities. Numerous studies in the literature have detailed 3D-printed multi-beam planar GRIN lens antennas, but many of them suffer from restricted scanning ranges or low efficiencies [3]. Consequently, there is a pressing need for the development of 2-D multi-beam flat GRIN lenses with wide angles and high efficiency.

To address the research gap outlined earlier, a thorough methodology has been formulated for designing a multi-beam flat GRIN lens antenna. The lens profile is found analytically in combination with an arc feed trajectory to produce an approximate linear phase on the lens aperture for the maximum radiation angle of the oblique symmetrical beams based on the results reported in [4]. A schematic of the developed flat GRIN lens system is shown in Fig. 1. This approach improves the scanning performance of the flat lens in the 2D orthogonal plane when compared to equivalent lens designs previously reported. The variation in the refractive index profile of the lens is implemented using a partially filled dielectric periodic cubic unit cell. An array of microstrip patch sub-arrays is used as the feed source. The arrays are arranged in two orthogonal planes to demonstrate the 2D multiple beam performance of the lens antenna system. A prototype lens antenna is fabricated using 3D printing technology operating from 12 to 15 GHz. An array of 13-element patch antennas is used to create beams across ±45° with a scanning loss of less than 2dB, SLL of less than -10dB, and a high aperture efficiency of better than 63% across the operating band.

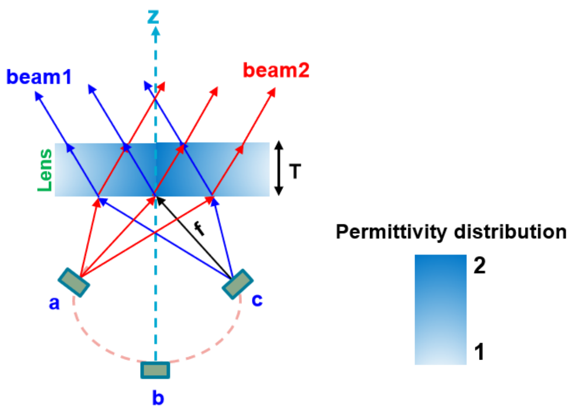

Fig. 1: Multi-beam flat Lens antenna system with radially GRIN lens profile.

[1] Y. J. Guo, M. Ansari, R. W. Ziolkowski, and N. J. G. Fonseca, "Quasi-optical multi-beam antenna technologies for B5G and 6G mm-wave and THz networks: A review," *IEEE Open Journal of Antennas and Propagation*, vol. 2, pp. 807–830, Jun. 2021.

[2] S. Zhang, R. K. Arya, S. Pandey, Y. Vardaxoglou, W. Whittow, and R. Mittra, "3D-printed planar graded index lenses," *IET Microwaves, Antennas & Propagation*, vol. 10, no. 13, pp. 1411–1419, 2016.

[3] Y. Su and Z. N. Chen, "A radial transformation-optics mapping for flat ultra-wide-angle dual-polarized stacked GRIN MTM Luneburg lens antenna," *IEEE Trans. Antennas Propag.*, vol. 67, no. 5, pp. 2961–2970, May 2019.

[4] L.-Z. Song, M. Ansari, P.-Y. Qin, S. Maci, J. Du, and Y. J. Guo, "Two-dimensional wide-angle multibeam flat GRIN lens with a high aperture efficiency," *IEEE Trans. Antennas Propag.*, vol. 71, no. 10, pp. 8018–8029, Oct. 2023.