

# Wide-Angle Scanning Dielectric Lens Array for Future Millimeter-Wave Communications

Valentina Cicchetti <sup>(1)</sup>, Osamu Kagaya <sup>(2)</sup>, and Yang Hao <sup>(1)</sup>

(1) Queen Mary University of London, London E1 4NS, United Kingdom  
(v.cicchetti@qmul.ac.uk)

(2) AGC Inc., 1-1, Suehiro-cho, Tsurumi-ku Yokohama 230-0045 Japan

A compact planar phased array equipped with an innovative low-cost dielectric lens, which significantly improves performance in terms of gain, beam direction, and sidelobe levels, has been designed and realized. The proposed system, suitable for future millimeter-wave communications, operates from 27.5 to 29.5 GHz, offers high gain, and is capable of beam scanning up to  $\pm 60^\circ$ .

In the literature, transformation optics theories have been applied to the Luneburg spherical lens to design flat dielectric lenses that enable wide-angle beam steering performance for switched arrays with planar feeding. These designs demonstrate substantial gain and good beam directionality up to  $\pm 40^\circ$  (C. Mateo-Segura, A. Dyke, H. Dyke, S. Haq, and Y. Hao, "Flat Luneburg Lens via Transformation Optics for Directive Antenna Applications," *IEEE Transactions on Antennas and Propagation*, vol. 62, no. 4, pp. 1945-1953, April 2014). In this paper, several configurations of flat Luneburg lenses have been carefully studied to improve the radiative performance of the designed phased array. Comprehensive analysis determined that these dielectric lenses significantly improve the gain of the radiative system, with a negative impact on beam steering. In parallel, previous studies have also explored the use of dielectric domes to improve beam steering of phased arrays without affecting performance. These domes, composed of conical or hemispherical shapes, can guide the beams emitted by the feed and maintain or enhance beam steering capabilities (E. Gandini et al., "A Dielectric Dome Antenna with Reduced Profile and Wide Scanning Capability," *IEEE Transactions on Antennas and Propagation*, vol. 69, no. 2, pp. 747-759, February 2021). To summarize, flat Luneburg lenses can enhance the gain of the designed phased array at the expense of beam steering quality, while domes improve beam steering without enhancing performance in terms of gain. Through the analysis of these two dielectric structures, a novel design, shown in Fig. 1, has been identified with the potential to improve the performance of the designed and realized system. The combination of a flat Luneburg lens and a dome, acting as a phased matching layer, appears to be an innovative lens design suitable for enhancing the performance of the compact phased array. The CST Studio Suite software was used to perform the design of the new radiating structure, employing a locally conformal full-wave finite integration technique (FIT). Initially, the phased array was designed by thoroughly analyzing its radiative performance. Subsequently, for the design of the innovative dielectric lens, virtual sources in the near field for each beam steering of interest were used in the simulations, replacing the real phased array source to significantly reduce simulation time. This approach enabled the optimization of the dielectric lens through swarm particle optimization (Z. Qu, S.-W. Qu, Z. Zhang, S. Yang, and C. H. Chan, "Wide-Angle Scanning Lens Fed by Small-Scale Antenna Array for 5G in Millimeter-Wave Band," *IEEE Transactions on Antennas and Propagation*, vol. 68, no. 5, pp. 3635-3643, May 2020) within a reasonable timeframe, taking into account all relevant dimensional parameters as well as the electrical properties of the flat Luneburg lens and the dome. Finally, several 3D printing techniques were explored for the fabrication of the innovative dielectric lens, alongside the analysis and investigation of low-loss materials at Queen Mary University of London.

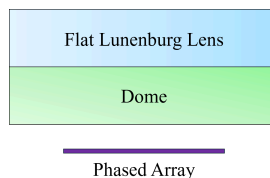


Fig. 1 New Concept of Dielectric Lens.