

Innovations in Printed Lens and Transmitarray Antennas: A Survey of Emerging Designs and Fabrication Methods

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The growing demand for high-performance antennas continues to push the limits of manufacturing capabilities, driving the development of innovative techniques. These advancements serve as a catalyst for researchers and engineers to embrace unconventional design strategies. The progression of printed lens and transmitarray antenna technologies exemplifies the synergy between antenna design and evolving manufacturing methods. This invited review paper highlights significant breakthroughs in manufacturing techniques for lens and transmitarray antennas, exploring their transformative influence on design methodologies. Over the years, lens and transmitarray antenna manufacturing has undergone a remarkable developments and in this talk they are grouped as follow: *Before 1980s: Milling and Inject-Molding of Lens Antennas; 1980s: PCB Process Enabling Flat-Panel Transmitarrays and Flat-Layered Meta-Lenses, 2010s: 3D Printing Enabling Novel Dielectric Lens Antennas and Transmitarrays; 2020s and Future: Multi-Material Additive Manufacturing Leading New Eras.* Ample representative examples will be provided to demonstrate the evolution of this very important technology.

Lenses and transmitarrays are both transmissive electromagnetic (EM) devices designed to transform the input wavefront from a feed source into a desired wavefront at the output aperture. Lenses have become essential components in antenna engineering applications for controlling electromagnetic waves across a wide frequency range, from RF to terahertz and optical bands. By utilizing their geometric and dielectric properties, lenses efficiently collimate diverging radiation from point sources or focus plane waves onto designated focal points. This capability has been instrumental in the development of various high-gain and multi beam antennas, transforming low-gain, divergent radiation into highly directive beams. The evolution of lens and lens-inspired antenna technologies has been intricately tied to advancements in manufacturing techniques, which have enabled increasingly sophisticated designs and expanded their application potential. Despite their shared features, the underlying principles enabling this wavefront manipulation distinguish the two.

Lens antennas rely on the refraction of EM waves to shape the wavefront. This is achieved through precise geometric design and the careful selection of dielectric materials, which collectively control the propagation path of the wave. Governed by the principles of geometrical optics (GO), lens antennas typically offer wide bandwidth. However, their thickness scales with aperture size, often reaching several wavelengths. In contrast, transmitarray antennas are constructed from an array of sub-wavelength unit cells. These unit cells are engineered to induce specific phase shifts, allowing accurate synthesis of the transmitarray's aperture phase. While the resonant elements required for high transmission and phase variation generally result in narrower bandwidth compared to lenses, transmitarrays are significantly thinner. Their thickness is determined solely by the unit cell design, which is typically a fraction of a wavelength, regardless of aperture size. Representative examples will be provided to effectively demonstrate the practical applications of the concepts and manufacturing techniques discussed in this talk as shown in the images below. (images from Rahmat-Samii et al, IEEE AP-S Magazine, June 2024).

