

Design and Fabrication of a Frequency-Agile Quad-Beam Lens for Terahertz Applications Using Miniaturized-Element Frequency Selective Surfaces

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This paper presents the design and fabrication of a compact, lightweight quad-beam terahertz lens antenna leveraging miniaturized-element frequency selective surfaces (MEFSS) for polarization- and frequency-dependent beam pointing. The lens, with a diameter of 10 cm and a thickness of 1.2 mm, achieves advanced multi-beam functionality across two operating frequencies (222.5 GHz and 227.5 GHz) while maintaining precise control over beam direction and polarization.

The MEFSS lens introduces a novel approach to beam pointing by replacing traditional bulky dielectric lenses with spatially-filtered unit cells, engineered to produce tailored transmission phase responses. Each unit cell operates as a multi-pass band filter, enabling dual-frequency operation for orthogonal polarizations. The design integrates a two-bit (4-state) phase system, yielding 16 unique unit cell configurations that ensure precise dispersion engineering. These cells focus the beams to four distinct directions with a narrow half-power beamwidth ($\sim 0.9^\circ$), suitable for high-speed applications such as automotive radar and terahertz imaging.

Fabrication involved etching fused silica wafers to specific thicknesses using hydrofluoric acid, followed by copper metallization to create the MEFSS patterns. The layers were bonded using a 1 μm conformal parylene-C coating, which acts as a low-loss adhesive. The bonding process, performed with the EVG 510 bonder, emphasized minimal residual stress and alignment accuracy. The resulting lens demonstrates efficient beamforming, with low side-lobe levels (~ 14 dB) and excellent frequency and polarization selectivity.

This innovative lens, shown in Fig. 1, offers significant advancements over traditional methods by combining compactness, high-resolution scanning (up to 20,000 scans per second), and dual-frequency operation. It is poised to enhance applications in terahertz radar systems, next-generation communication networks, and high-resolution imaging.



Figure 1. Fabricated quad-beam lens antenna.