A 3D Printed Terahertz Metamaterial Transmitarray for Beam-Steering Applications

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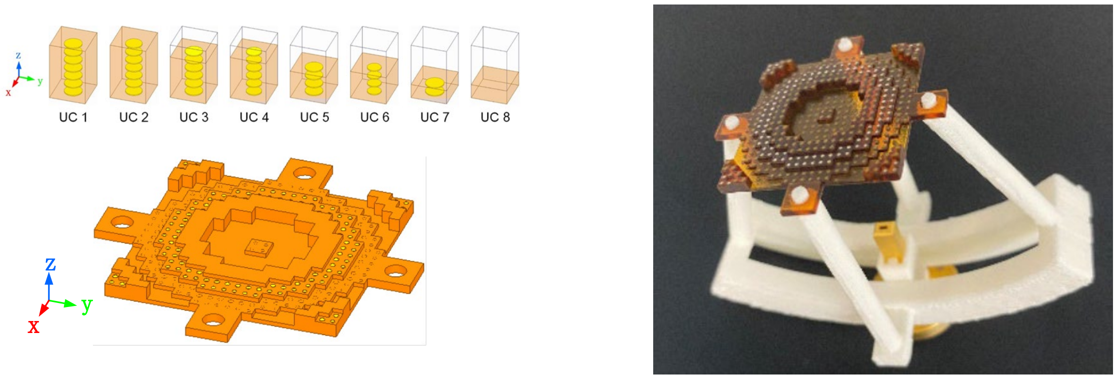
Abstract

Terahertz (THz) technologies above 100 GHz are promising candidates for 6G mobile communication systems [1]. To overcome the atmospheric absorption and realize dynamic systems, researches on THz high gain beamsteering antennas become increasingly important. Compared with phased array antenna, leaky-wave antennas and hemispherical silicon lens antennas, transmitarray antennas (TAAs) have the advantage of low-cost, low-loss and high flexibility.

The THz TAAs are increasingly getting closer to the fabrication limit of the 3D printing and PCB technology, which brings challenge to the design of transmitarray. The common THz TAAs including dielectric [2], Fabry-Perot-like [3], and Frequency selective surface (FSS) [4] are easy to fabrication. Therefore, it is important to design a THz transmitarray unit cell (UC) with a simple structure.



(a) (b)

Fig. 1: 3D printed metamaterial transmitarray: (a) 3-bit metamaterial unit cells (UCs) and the 3D model of transmitarray, (b) Photo of the prototype.

The proposed transmitarray can be seen in Fig. 1 (a), the UCs consists of a part of air and a part of metamterial and the metamaterial includes a dielectric column and several sub-wavelength capacitive metallic patches. By varying the number of the patches layer, diameter of the patches and the proportion of metamaterial to air, eight metamaterial UCs realize 3-bit phase step for 360° full-cycle of transmission phase delay. The phase distribution of the transmitarray can be given by Fermat's principle [2]:

$$\varphi(x,y) = k_0\left(\sqrt{x^2+y^2+F^2} - F\right) + \varphi_0 \qquad (1)$$

where $(\boldsymbol{x},\boldsymbol{y})$ represents the position of the UC, the focal length $\boldsymbol{F}$ is 21 mm, and $\boldsymbol{k_0}$ represents free-space wavenumber at 120 GHz. The novel metalens combines the concept of the dielectric TAAs and FSS based TAAs. Compared with normal dielectric column UC, the proposed UC reduces the thickness of the lens and increases the degrees of freedom. The fabricated prototype can be seen in Fig. 1 (b). By rotating the standard waveguide WR-06 probe along the arc, the TAA can achieve $\pm 30°$ beamsteering and 14.1 dB gain enhancement.

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[3] H. Yang et al., "A THz-OAM Wireless Communication System Based on Transmissive Metasurface," in IEEE Transactions on Antennas and Propagation, vol. 71, no. 5, pp. 4194-4203, May 2023.

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