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THz Photo-Polymeric Lens Antennas for Potential 6G Beamsteering Frontend

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Abstract **– This paper presents a 3D-printed THz hemispherical lens antenna integrated with the open-ended rectangular waveguide at WR-10 band for antenna characteristics enhancement, e.g., gain and half-power beamwidth (HPBW). The digital light processing (DLP) technique, which is one of the famous 3D printing techniques, is chosen for fabricating the hemispherical lens antenna. The proposed design can be integrating the 3D-printed lens antenna without any extra assistant tools during assembly lens antenna with an open-ended WR-10 waveguide. In the simulation, the lens radiuses are investigated by varying from 2 mm to 5 mm in step with 1 mm. The optimum dimensions of the 3D-printed hemispherical lens antennas are obtained by using the 3D electromagnetic simulation tools. Based on the simulation results, at 90 GHz, the lens radiuses of 2 mm, 3 mm, 4 mm, 5 mm, and 6 mm, provide the maximum realized gain of 11.7 dBi, 13.1 dBi, 14.8 dBi, 15.8 dBi, and 16.3 dBi, respectively. The proposed technique gives many advantages, including ease of design, inexpensive material, low-cost fabrication process, rapid prototyping, etc. Moreover, the narrow HPBW and high gain of the proposed lens antenna can be applied to the 6G beamsteering frontend system.**

Keywords **— 3D-printing technology, dielectric lens, additive manufacturing, gain enhancement.**

I. INTRODUCTION

6G is the next generation of telecommunication technology that will significantly increase productivity and drive new opportunities in human life. Now, 6G is under developing processes [1] by integrating with many technologies such as artificial intelligence (AI), augmented reality (AR), extended reality (XR), the internet of things (IoT), automation, and robotics. 6G requires extensive performance improvements [2] for achieving data rates of up to 1,000 Gbps. The operating bands of 6G are the utilize frequencies up to 3 THz. The antenna is the one part of the Tx and Rx systems, which are required to develop and improve the performance, i.e., antenna gain and narrow HPBW. Many pieces of research [1]-[2] focused on improvements in the antenna's performance for supporting the 6G technology and utilizing it with other applications.

3D printing technology offers several advantages, such as rapid prototyping, low material and manufacturing costs,

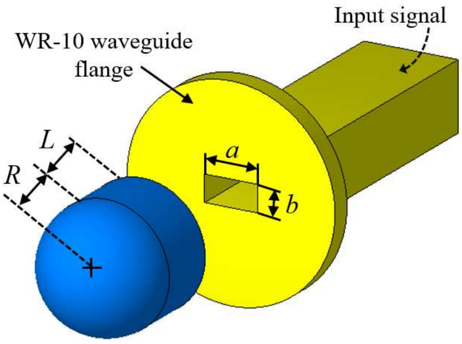

Figure 1. The geometry of the hemisperical dielectric lens antenna fed by open-ended WR-10 waveguide.

and lightweight. Various 3D printing techniques, e.g., fused deposition modeling (FDM), polymer jetting (PolyJet), digital light processing (DLP), and stereolithography apparatus (SLA), are mostly used for design and fabricating in microwave, millimeter-wave, and up to THz components [3]-[5]. The FDM is the lowest printing resolution, which is limited by the filament and nozzle sizes. The DLP and SLA techniques use a light source for curing resin-based photopolymers. The DLP and SLA provide a higher resolution by controlling the beam spot of the light source in a 3D patterned process. The PJ technique performs the 3D patterned structure like an inkjet printing technique. In this paper, the DLP technique was chosen for design and fabricating the 3D-printed hemispherical lens antennas because the resolution of this technique is suitable for operating at the WR-10 bands [5].

This paper reports a portable low-cost hemispherical dielectric lens antenna for reducing HPBW and enhancing the realized gain. The proposed antenna operates from 75 GHz to 110 GHz, covering the whole of the WR-10 band. The 3D-printed hemispherical lens antenna is designed for integrating with conventional open-ended WR-10 waveguide without any adhesion layers between two components. Six conditions, e.g., without lens, lens radiuses of 2 mm, 3 mm, 4 mm, 5 mm, and 6 mm, are investigated in the CST Studio [6] to observe the realized gain and HPBW of the antenna.

II. LENS ANTENNA DESIGN

Figure 1 shows the perspective view of the geometry of the 3D-printed dielectric lens antenna fed by the open-ended WR-10 waveguide. The design consists of two components: 1) the 3D-printed hemispherical dielectric lens antenna; and 2) the conventional WR-10 rectangular waveguide. The proposed lens antenna is composed of two necessary parameters, e.g., extension length of the lens antenna, L, and lens radius, R. The extension length of the lens antenna is reported in [3] by the ratio between the extension length and lens radius (L/R) of 1. The resin-based photopolymer 3DR3582C is selected to use for printing a dielectric lens antenna due to the standard photocurable polymer in the DLP technique. The relative permittivity, ε_r, and loss factor, tan δ, which are reported in [3], are 2.85 and 0.03, respectively. The cross-sectional dimensions of the standard WR-10 rectangular waveguide are a = 2.54 mm and b = 1.27 mm. To observe the performance of the designed antenna, the 3D electromagnetic simulation tool, CST Studio [6], is selected to monitor their characteristics.

III. SIMULATION RESULTS

The correlation between the lens radius, R, and antenna characteristics is studied by generating six conditions in the simulation. Figure 2 shows the simulated gain at the zero-degree antenna of six conditions from 75 GHz to 110 GHz. Before assembly the lens antenna, the open-ended WR-10 waveguide has an average gain over the frequency bans of 7.6 dBi. After assembly the lens antenna, the lens radius is varied from 2 mm to 6 mm with step of 1 mm. the average realized gains of R = 2 mm, R = 3 mm, R = 4 mm, R = 5 mm and R = 6 mm, are 11.2 dBi, 13.3 dBi, 14.8 dBi, 15.7 dBi and 16.3 dBi, respectively. Figure 3 depicts the simulated 2D radiation pattern at 90 GHz with six conditions. The calculated HPBW of six conditions, e.g., without lens, R = 2 mm, R = 3 mm, R = 4 mm, R = 5 mm, and R = 6 mm, are approximately 68.6 degrees, 34.9 degrees, 28.8 degrees, 21.6 degrees, 17.1 degrees, and 14.8 degrees, respectively. Based on the simulated results, the results show that the size of the lens radius can control the gain and HPBW of the dielectric hemispherical lens antenna.

IV. CONCLUSIONS

A 3D-printed lens antenna fed by the open-ended waveguide without any adhesion levels for antenna characteristics enhancement has been presented. The proposed lens antenna was fabricated by using the DLP 3D printing technique. It offers several key advantages such as ease of design, low-cost and low fabrication process.

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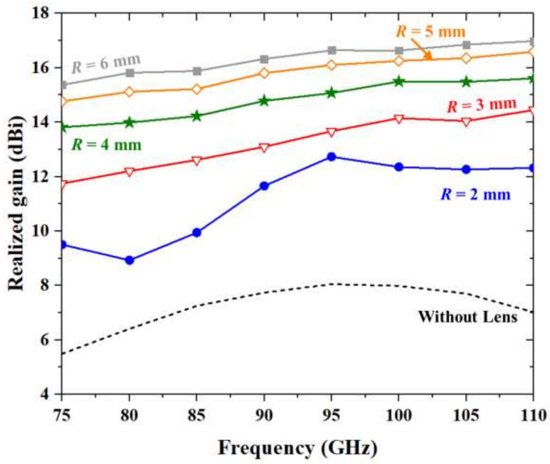

Figure 2. The simulated realized gain at 0 degree over the WR-10 freqeuncy bands with six conditions, e.g., without lens, R = 2 mm, R = 3 mm, R = 4 mm, R = 5 mm and R = 6 mm.

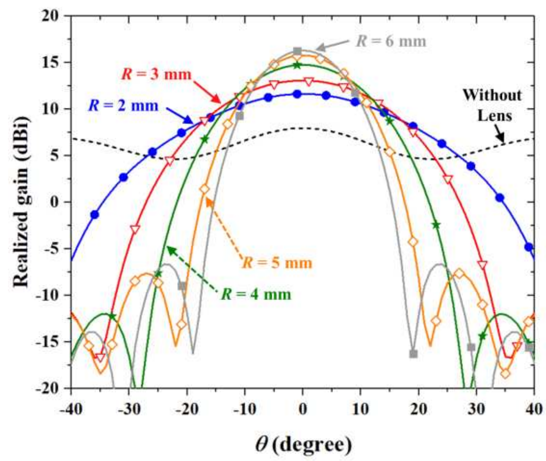

Figure 3. The simulated 2D-radiation pattern at centre freqeuncy of 90 GHz with six conditions, e.g., without lens R = 2 mm, R = 3 mm, R = 4 mm, R = 5 mm and R = 6 mm.

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