Terahertz Reflectarray and Transmitarray

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Abstract **– Reflectarrays and transmitarrays are extremely important in the applications of terahertz (THz) technologies, as they feature merits like high gain and low cost. In this work, a reflectarray and a transmitarray are designed at 300GHz. A 32 × 50 offset-fed wideband reflectarray antenna, based on single-layer elements with a large and linear phase response, shows a fixed beam direction without frequency dispersion over a large frequency band of 0.225 ~ 0.325THz and a gain of 30.76 ~ 33.98dBi. The designed three-layer transmitarray element can provide 360º phase coverage with transmission coefficient over -0.9dB. Simulations show that the three-layer transmitarrays, fed by a 15-dBi horn with a focal to diameter ratio (*F/D*) of 0.88, achieves peak aperture efficiency of 68% with a 1-dB gain bandwidth of 23%. The transmitarrays fed by an open-ended waveguide with *F/D* = 0.3 are fabricated and measured for verification purpose.**

Index Terms **— Antenna arrays, lens antennas, reflectarrays, terahertz, transmitarrays.**

1. Introduction

Generally, terahertz (THz) frequency is a specific spectrum band from 0.1 to 10THz, i.e., a gap between microwave and optical bands. Due to many advantages of THz frequency, e.g., high resolution and large available frequency bandwidth [1], more and more attention is attracted by THz technology. THz antennas, as one of the critical components in THz systems, confronts many problems in designs, fabrications and measurements which will results in low antenna efficiency, significant discrepancies of measured results against simulations and so on.

Since reflectarray and transmitarray antennas have the advantages of low loss, high antenna efficiency, high gain and easy fabrication compared to constraint fed THz arrays, they are suitable candidates in THz systems. Recently, several studies on THz reflectarray antennas working have been reported. P. Nayeri *et al.* designed a three-dimensional (3D) dielectric reflectarray operating at 0.1THz using 3D printed technology [2]. Meanwhile, a novel idea to use graphene instead of metal, due to the high electron mobility of graphene, was proposed by E. Carrasco *et al.* [3]. To reduce the dielectric loss of conventional thick curved lens antennas, transmitarrays with flat structures are investigated in many papers. In this work, new reflectarray and transmitarray are investigated to extend the phase shift range of their elements and to enlarge their operating bandwidths.

2. THz Reflectarray

A single-layer element operating in 0.225~0.325THz is proposed whose geometry is shown in Fig. 1, similar to the one in our previous work [4]. The unit cell sizes can be found in the caption of Fig. 1. A grounded BCB material with a dielectric constant of ~2.45 in the operating frequency band is employed to support an aluminum element configuration. The ground plane is made of a 1um-thick aluminum layer. The element, with three resonances corresponding to an I-shaped dipole and two rectangular loops, are optimized for a larger phase range with good linearity [4], and mutual coupling between the structures will also help to enhance the linearity of the phase curve.

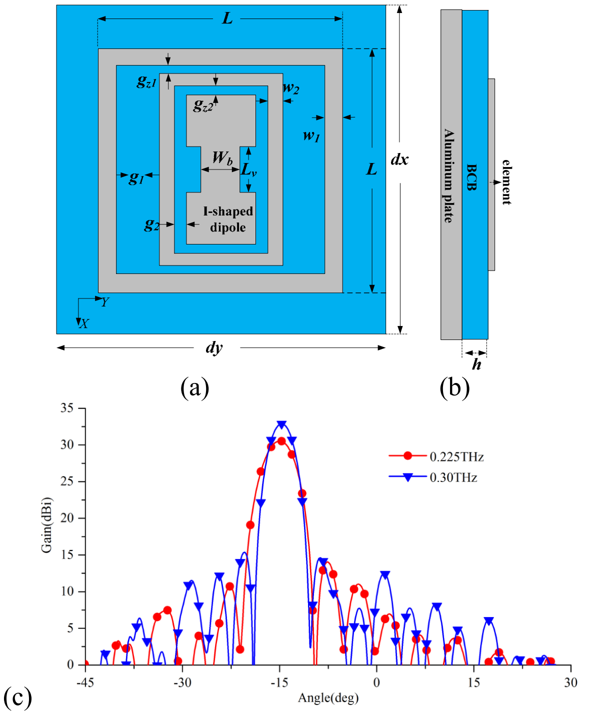


Fig. 1. (a) Top view of the element, and (b) Side view of the element. (c) Simulated array radiation patterns. $dx = dy = 0.5$, $w_1 = w_2 = 0.0182$, $g_1 = 0.035$, $g_2 = 0.02$, $g_{z1} = g_{z2} = 0.009$, $W_b = 0.6$, $L_v = 0.3$ $h = 0.12$(unit: mm)

In this work, a 32 × 50 offset-fed wideband THz reflectarray working in 0.225 ~ 0.325THz is designed. The simulated radiation patterns at 0.225 and 0.3THz for a given feed horn position, shown in Fig. 1 (c). It can be seen that the main beam has little deviation in such a large bandwidth. Note that the beam orientation is in the same direction at other frequencies from 0.225 to 0.325THz, and the peak gain is over 30dBi, which validates the broadband property.

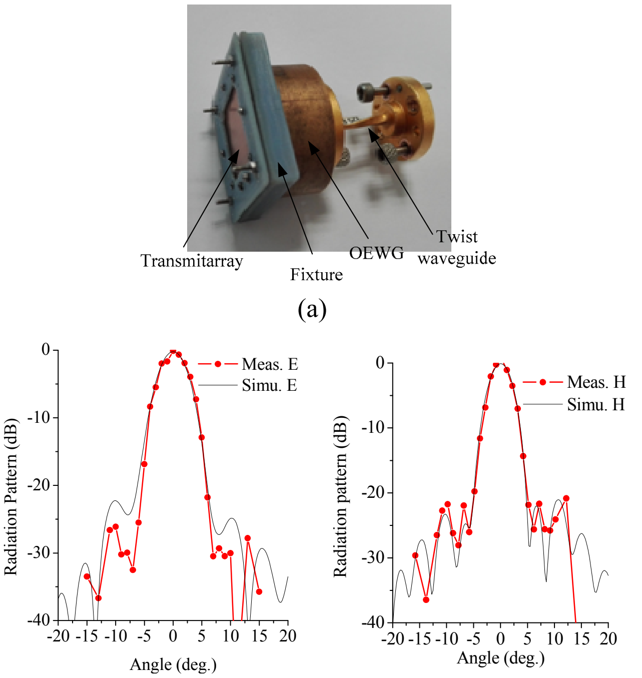
3. THz Transmitarray

The three-layer transmitarray has 33×33 elements with dimensions of 16.5mm × 16.5mm, and a focal length of 5mm. The photograph of the assembled transmitarray is shown in Fig. 2 (a). Here, a fixture is fabricated by a three-dimensional printer with a height of 5mm to support the transmitarray, and a twist waveguide is connected with the feeding OEWG in order to rotate the polarization direction for ease of measurement. Actually, simulations show that the three-layer transmitarrays fed by a 15-dBi horn with a focal to diameter ratio (F/D) of 0.88, can achieve peak aperture efficiency of 68% with a 1-dB gain bandwidth of 23%. However, the required horn is currently unavailable in the lab, and therefore the OEWG has to be adopted.

Finally, the measured gain is 1~2 dB lower than the simulation in the operating frequency band of 230 ~ 270 GHz with a peak gain of 28.7dBi at 250GHz and a peak aperture efficiency of 31.2%. The measured radiation patterns agree reasonably with simulation and the side-lobe levels are better than -20dB both in E and H planes at 250GHz as presented in Figs. 2 (b) and (c). Note that compared to a two-layer transmitarray designed at the same frequency, the bandwidth can be obviously improved by around 50% without reduction in antenna efficiency. Moreover, the array was fabricated based on the printed circuit board techniques, and the airgap between the substrates has influence on antenna gain but not as significantly as that on the constraint fed antenna arrays.

4. Conclusion

To achieve high-gain THz antennas, the reflectarray and transmitarray are exploited at 300GHz, due to their spatial feeding mechanism. In this work, a wideband reflectarray is numerically designed based on the element reported in our previous work, which can be fabricated by micromachining technology in the State Key Lab, and a transmitarray based on multiple layer structure is experimentally investigated.



(b) (c)

Fig. 2. Simulated and measured results of the transmitarray, (a) photo of the prototype, radiation patterns of (b) E-plane, and (c) H-plane at 250GHz.

Acknowledgment

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