Frequency controlled beam-steering at 0.2THz with diffraction enhancement

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***Abstract*—A frequency-scanning grating-reflector antenna operating in 0.2 Terahertz band is proposed based on the diffraction enhancement mechanism. The antenna was fabricated and the proposed concept was verified based on the quasi-optical measurements.**

I. INTRODUCTION

Benefited from the 'see through' property and the comparatively high resolution available, THz waves have been promising for plenty of applications [1], such as security screening and non-destructive testing. In the frequency band around or above 0.2THz, phased array antennas based on phase shifters are difficult to be designed and fabricated. As a good alternative for fast beam scanning, a 0.2THz band frequency-scanning grating-reflector with planer binary structure was proposed, designed, and measured based on the mechanism of diffraction enhancement.

II. RESULTS

The frequency-scanning grating-reflector antenna system consists of a feed horn, a lens and a grating-reflector, as shown in Fig. 1. A TE polarized Gaussian beam was excited by the feed horn. The lens is used to collimate the beam to achieve a quasi-parallel illumination on the reflector. Based on Floquet's theorem, the radiation angle θ_n and transverse propagation constant β_n of the *n*-th order diffraction mode should satisfy

$$k_0(\sin\theta_n + \sin\theta_0) = \beta_n + k_0 \sin\theta_0 = \frac{2n\pi}{D_x} \tag{1}$$

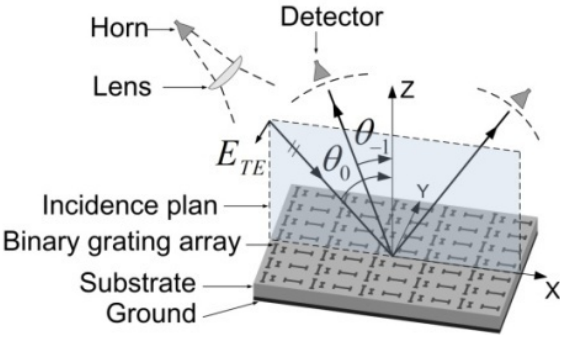

Fig. 1 Presentation of the antenna system.

k_o is the free space wave number. D_x is the period of the x-direction, which can be properly chosen to ensure only the zero order and the n= -1 order (the first higher order) diffracted mode to be the fast wave modes. Based on the concept of diffraction enhancement, a planer binary structure was proposed with each unit cell composed of several elements defined as 'subcells' to improve the coupling between the incident wave and the -1 order diffraction wave. As shown in Fig.2, the phase difference of arbitrary adjacent subcells in the diffraction direction can be evaluated as:

$$\phi_{i,i+1} = k_0 d_i(\sin\theta_{-1} + \sin\theta_0) + (\varphi_{i+1} - \varphi_i) = \frac{-2\pi}{D_x} d_i + (\varphi_{i+1} - \varphi_i) \tag{2}$$

where φ_i and φ_{i+1} are the abrupt phase shifts corresponding to the subcell *i* and *i*+1 respectively, and d_i is the distance of these adjacent subcells. $k_0 d_i(\sin\theta_{-1}+\sin\theta_0)$ is the phase difference corresponding to the path difference. When the distance d_i and the abrupt phase differences satisfy the condition:

$$d_i = D_x\left(\frac{\varphi_{i+1} - \varphi_i}{2\pi} - m\right), \qquad m = 0, \pm1, \pm2... \tag{3}$$

the phase difference $\varphi_{i,i+1}$ in the diffraction direction would be $2m\pi$. The diffracted beams from the neighboring subcells are coherently superposed, and the diffraction enhancement concept is actualized.

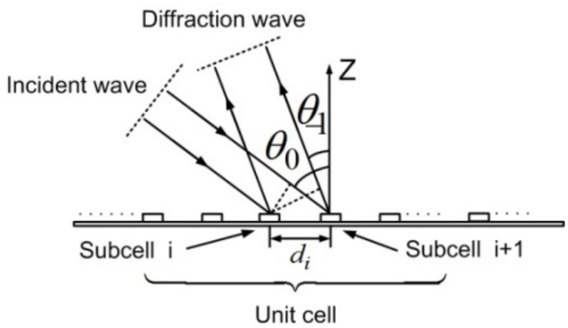

Fig. 2 Description of the planer binary structure

The designed frequency-scanning grating-reflector is shown in Fig. 3. Each unit cell is divided into three subcells with 'I' shape or 'H' shape, as shown in Fig.4.

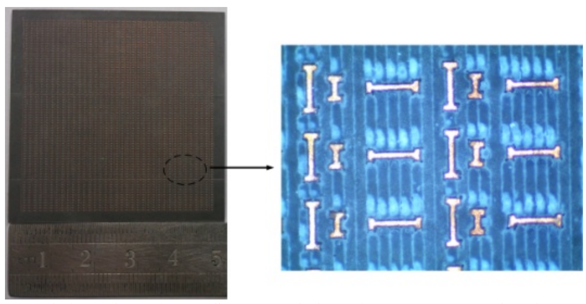

Fig. 3 Fabricated grating reflector and the microstructure under the optical microscope.

The Rogers RT/duroid 5880 with the standard thickness of 0.254mm was chosen as the substrate. The abrupt phase shift of each subcell changes gradually with approximately constant phase differences over the whole band from 180GHz to 220GHz, as shown in Fig. 5, which leading to the effective diffraction enhancement for a large bandwidth. The phase lags for the first and the second subcells are around 70°, which corresponds to the theoretical distance of 0.235mm based on Eq.(3). And the phase gap between the second and the third subcells is around 122°, so the distance is 0.42mm according to Eq.(3) also. Then the distances are slightly adjusted by the optimization process. The design parameters of the unit cell are presented in Table I.

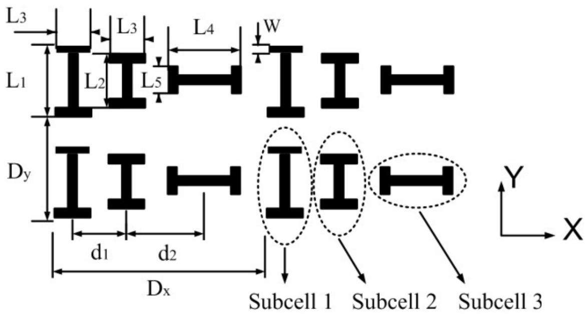

Fig. 4 Geometry of the grating lattice

Table I
Parameters Value of The Unit Cell

Parameters	Dx	Dy	W	L1	L2
value(mm)	1.24	0.6	0.06	0.44	0.24
Parameters	L3	L4	L5	d1	d2
value(mm)	0.14	0.48	0.12	0.22	0.51

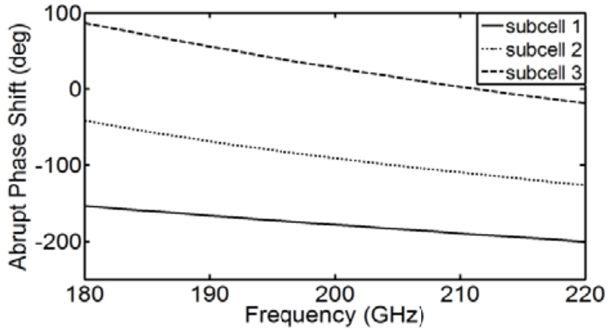

Fig. 5 Abrupt phase shifts of the subcells

The measured diffraction beams scan from -35.47° to -20.02° over 180GHz-220GHz, which is 15.45° over a 20% relative bandwidth, as shown in Fig. 6. And the measured, simulated and theoretical scan angles agree well with each other. Measured normalized radiation patterns in the scanning plane are shown in Fig. 7.

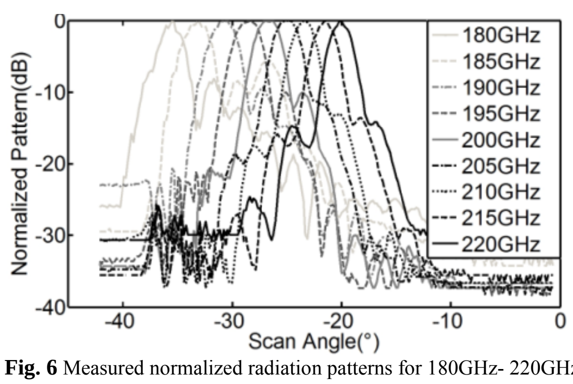

Fig. 6 Measured normalized radiation patterns for 180GHz- 220GHz

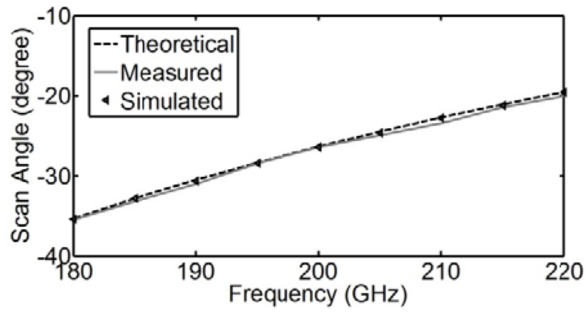

Fig. 7 The comparison of the measured, the simulated and theoretical scan angles.

III. Summary

A frequency-scanning antenna with planer binary structure operating in 0.2THz band is proposed based on the diffraction enhancement. The measured scanning range is 15.45° over the frequency band 180GHz-220GHz. The proposed antenna has potential applications for THz imaging with high speed.

References

[1] K. B. Cooper, R. J. Dengler, Nuria N. Llombart, B. Thomas, G. Chattopadhyay, and P. H. siegel, "THz imaging radar for standoff personnel screening," *IEEE Trans. Terahertz and Technology*, vol. 1, no. 1, pp. 169-182, Sep. 2011.