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Novel Terahertz Dual-Polarized Frequency Selective Surface with High Frequency Selectivity

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***Abstract* – This work presents a novel terahertz frequency selective surface design, which is constructed by split loop resonators coupled by apertures. This three-layer structure has a narrow bandpass response with two transmission zeros beside the passband, thereby achieving high frequency selectivity and suppressing the sidebands. Due to the symmetric structure, the proposed surface exhibits dual-polarized characteristics.**

***Index Terms* — Frequency selective surface (FSS), terahertz (THz) device, dual-polarized characteristics, transmission zero.**

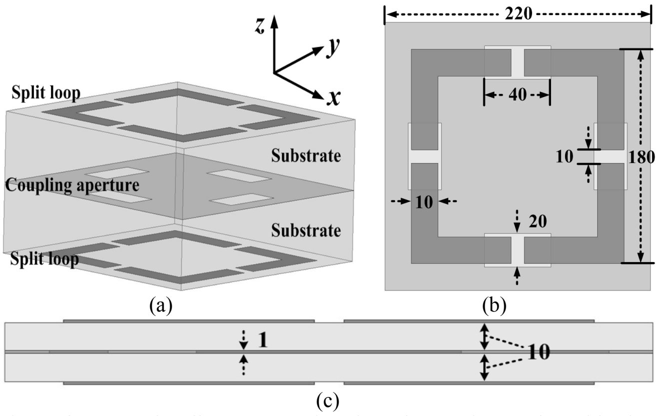
I. INTRODUCTION

Recently, research on terahertz (THz) devices has been rapidly expanded due to a wide range of applications. Frequency selective surfaces (FSS) are widely used as filters, polarizers, radomes and sensors [1]. A variety of THz FSS structures have already been investigated for earth observation remote sensing instruments [2]. In [3], a single-face, membrane-supported, miniaturized-element FSS has been proposed for image rejection of a *J*-band up-convertor mixer. However, the frequency selectivity of the reported THz FSSs is not so good that they may not be suitable for applications requiring high selectivity. Furthermore, the FSSs presented in [2] and [3] only operate under a single polarization, which further limits their applications

In this work, a dual-polarized FSS structure based on aperture coupled resonators is proposed for THz applications. It has high frequency selectivity resulting from the produced transmission zeros. In addition, the FSS is easy to design and fabricate due to the simple and planar structure.

II. FSS STRUCTURE AND ANALYSIS

The objective of this work is to design a high frequency-selectivity FSS for THz applications. In [4], a coupling FSS structure based on the aperture coupled microstrip patch has been designed. However, there is not any transmission zero around the passband. In this work, based on the coupling resonator theory, an FSS with multiple coupling paths is designed. This structure produces two transmission zeros at finite frequencies, thus achieving high frequency selectivity and suppressing the sidebands.



(a) (b) (c)

Fig. 1 The FSS unit cell: (a) perspective view, (b) top view, and (c) side view (All the dimensions given are in micrometer).

A. FSS structure

The THz FSS is designed using split loop resonators coupled by apertures. It consists of three metal layers separated by two substrates. In this work, BCB polymer is applied as the substrate to support the structure because of its low loss and high mechanical strength. Based on the measurement method described in [5], dielectric constant and loss tangent of the used BCB polymer are set as 2.48 and 0.01 at 700 GHz in the following simulations. Fig. 1(a)-1(c) show the configuration of the proposed FSS unit cell, and also dimensions are labeled in micrometer. In the FSS unit cell, the loop rings on the top and bottom layers are splitted into four identical parts as four half-wavelength resonators. Four coupling apertures etched on the middle ground are vertically located below the junctions of adjacent resonators. The FSS is realized by periodically arranging the unit cells.

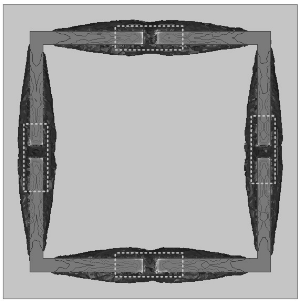


Fig. 2 E-field distribution of the FSS unit cell at the operating frequency.

B. Analysis of the FSS

As shown in Fig. 1, the resonators on the top and bottom layers can be coupled by the coupling apertures on the middle layer, therefore obtaining a narrow bandpass response. There are two transmission poles in the passband, where one of transmission poles is due to the individual resonators, and the other appears as a combined effect of the resonators plus the effect of the coupling apertures. The operating frequency of the FSS is mainly determined by the dimensions of the split loops and the periodicities of the unit cell, while the shape of the frequency response is mainly controlled by the dimensions of the coupling apertures and the thickness of the used substrate. Actually, there are electric and magnetic couplings between the resonators on the top and bottom layers, thus additional transmission zeros would be produced at real finite frequencies [6].

Fig. 2 shows the electric field (E-field) distribution of the FSS unit cell at the operating frequency, in which the grey color corresponds to zero electric field and black corresponds to the strongest electric field. As observed, the electric field is mainly concentrated around the junctions of the adjacent resonators. This fact demonstrates that the coupling between the resonators is mainly electric coupling. Therefore, there are two transmission zeros nearby the passband. The transmission zero at the lower sideband is caused by the mixed electric and magnetic coupling paths, while the transmission zero at the upper sideband is caused by the harmonic effects [6]. Adjusting appropriately the location of the coupling apertures can affect the strength of the electric and magnetic couplings and then change the frequencies of the transmission zeros.

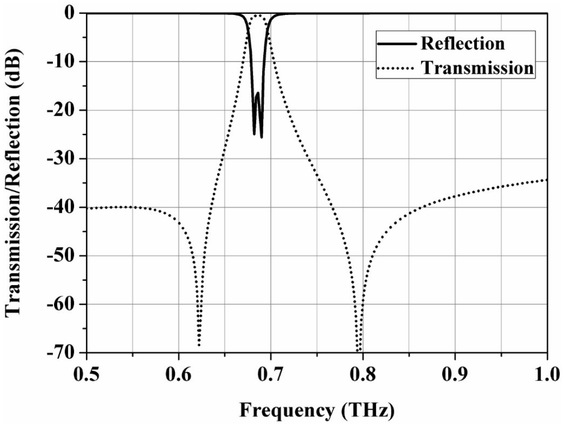


Fig. 3 Frequency responses of the proposed FSS.

III. SIMULATION RESULTS

The proposed FSS is modeled using the commercial software HFSS. Fig. 3 shows the simulated frequency responses of the proposed FSS at normal incidence. As described above, the FSS produces two transmission poles in the passband. It has insertion and return losses of 0.5 dB and 16 dB at the operating frequency of 680 GHz, respectively. In addition, this symmetric response structure has a fractional 3-dB bandwidth of 3.1% (21 GHz). The two transmission zeros are located respectively at 622 GHz and 795 GHz all with an attenuation level of over 70 dB, which are helpful to achieve superior frequency selectivity and suppress the lower and upper sidebands. The experimental FSS structure will be fabricated based on the micromachining technique [2] and tested using the THz time-domain spectroscopy (TDS) system [5].

As shown in Fig. 1, the designed FSS is symmetric for horizontal and vertical polarizations, thus exhibiting dual-polarized characteristics. In case of normal incidence, the symmetric FSS structure for transverse-electric (TE) and transverse-magnetic (TM) polarizations has same frequency responses. For various incident angles, the bandwidth changes slightly in different ways for different polarization states. The experimental verification will be performed in the future work.

IV. CONCLUSION

A novel FSS with a simple coupling structure has been investigated for THz applications in this work. Because of multiple coupling paths and harmonic effects, two transmission zeros have been produced and located respectively at the lower and upper sides of the narrow passband. The proposed dual-polarized FSS has high frequency selectivity.

ACKNOWLEDGMENT

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