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A Novel Single-Layer Quasi-Elliptic Frequency-Selective Surface

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***Abstract*—A novel design of frequency-selective surface (FSS) generating a quasi-elliptic frequency response is proposed in the paper. Each unit cell of FSS comprises a centered rectangular aperture with three closely spaced equal-height posts alternatively installed in the aperture center along its broad walls. Numerical and measured data are presented for X-band FSS providing a narrowband transmission of linearly polarized wave. In particular, the measured bandwidth of 5% centered at 8.16 GHz with transmission zeros separation ratio of 1.3 is achieved for the 45-degree incidence.**

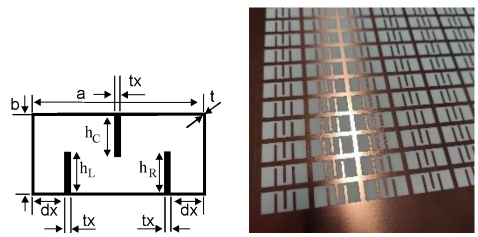
I. Introduction

FSSs with quasi-elliptic responses, providing a high frequency selectivity are in demand as microwave components in different civil and military applications like antenna subreflectors, multi-band base stations, imaging radar for target identifications etc. There have been various realizations of the quasi-elliptic FSSs proposed, yet most of them utilize either multi-layer boards or a complex-shaped non-canonical apertures, e.g. [1-4]. In the paper we propose a new single-layer quasi-elliptic FSS that enables an effective frequency separation of the incident wave into three channels, reflecting at two closely spaced frequencies and transmitting at the middle frequency simultaneously.

II. FSS Design and Discussion

The configuration of the designed FSS is shown in Fig. 1. It is a single-sided printed circuit board (*PCB*). A set of periodically arranged meander-like apertures are cut in the metallic layer of the PCB. Schematic geometry of the aperture cut in the centre of the screen unit cell of $L_x \times L_y$ dimensions is shown in Fig. 1a. A rectangular aperture of the width *a* and the height *b* contains three partial-height rectangular-footprint posts installed alternately in its broad walls. All three closely spaced posts have equal heights ($h_C = h_{L,R}$) and equal widths *tx*. One of them is centred whereas two others are installed at the distance *dx* away from the narrow wall of the aperture. The screen is excited by the linearly polarized wave with the electric field vector oriented along the posts.

To examine the screen proposed, a full-wave simulation of its response was carried out by means of CST MWS software. A typical performance is presented in Fig.2, where the calculated frequency response for PCB designed for X-band for the case of normal incidence is plotted by a solid line. As can be seen from the figure, the response contains two closely located transmission zeros (TZs) TZ_1 and TZ_2 equally spaced with respect to the transmission pole (*TP*).



(a) (b)

Figure 1. (a) - Schematic view of a three-post aperture of FSS elementary cell and (b) – photo of the fabricated prototype.

According to our current study and previous waveguide simulator results [5,6], the resonant behavior of FSS is realized owing to the resonant coupling via the third mode of the aperture. TZs generation is explained here by considering them as classical reflection resonances of quarter wavelength posts. It is seen from Fig. 2 that an FSS with a single center post provides TZ at a frequency that is very close to TZ_1 frequency of a three-post FSS. Whereas a two-post FSS generates TZ at a frequency that is very close to TZ_2 frequency. Within the circuit theory, a post in a rectangular waveguide is modelled by an in-series type circuit and its resonant frequency can be found by using approximated formulae, e.g. [7,8]. The salient feature of the proposed design is an inductive coupling between two in-series type circuits. A circuit model depicted in the inset in Fig. 3 that was applied in [9] for a double-post waveguide design is suitable here as well. Here, the coupling is controlled mainly by changing the only geometrical parameter *dx* defining positions of lateral posts. Fig. 3 shows in terms of frequencies of TZs and TP how the location of lateral posts affects the filtering function. A vertical dotted line marks the case when TZs are symmetrically located with respect to TP. It is seen that behavior of two uncoupled circuits is demonstrated until *dx* is less than *a*/4. As soon as *dx* exceeds *a*/4, the behavior changes to the one of a coupled-resonator circuit as shown in Fig. 3. As a result, all three parametric curves together draw a typical chart for coupled circuits of in-series type.

A prototype containing 14×28 unit cells (shown partially in Fig. 1b) was fabricated to validate the proposed design. Its geometry was optimized for 45° incidence. The prototype is a dielectric layer Rogers 4003C of $t_s = 0.813$ mm thick with dielectric constant ε=3.55 and tan δ = 0.0027 laminated by a copper layer of thickness t=0.035 mm. The unit cell geometry: cell dimensions $L_x \times L_y$ = 20.0 mm × 10.0 mm; aperture dimensions: $a \times b$ =18.0 mm × 10.0 mm; *tx*=1.0 mm, h_C = $h_{L,R}$ = 7.0 mm, dx = 5.0 mm. The measured response of fabricated FSS for several values of incident angles (θ=0°, 15°, 30 and 45°) is plotted in Fig. 4. Besides, the calculated responses for θ=0° and 45° are plotted as well. Note, measured and calculated data are in a good agreement. Being optimized for the incidence under 45°, FSS provides resonant transmission at $f(TP)$= 8.16 GHz with the insertion loss of -1.3 dB and fractional bandwidth measured by -3dB level is 5%. Two TZs are located at $f(TZ_1)$= 6.96 GHz and $f(TZ_2)$= 9.19 GHz. It is seen from the figure that the larger the angle θ, the wider separation between the TZs and the more their frequencies shifting up. Resonant frequency deviation is 1.6% if θ changes by 45°.

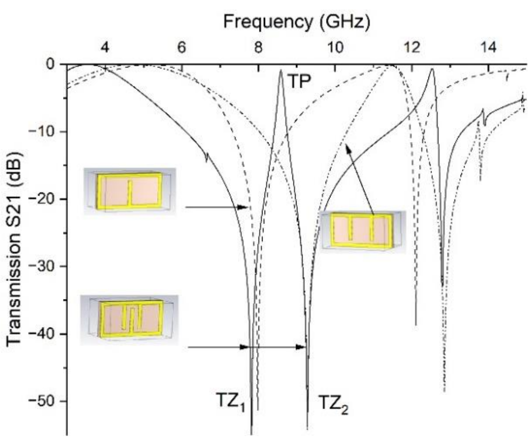


Figure 2. Simulated transmission characteristics for a three-post FSS proposed, one- and two-post FSSs under the normal incidence (solid, dashed and dot-dashed curves, respectively)

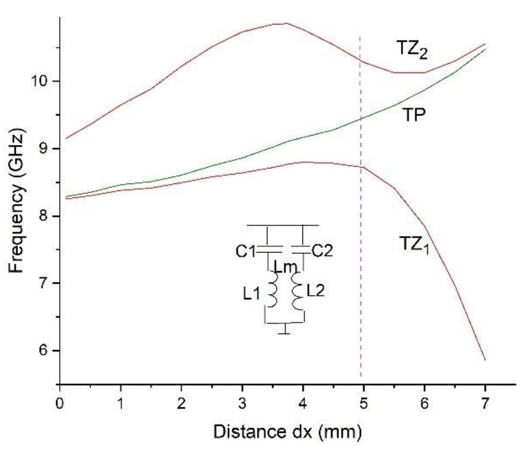


Figure 3. Parametric curves of frequencies of TZs and TP for a three-post FSS with *dx* as a varying parameter.

III. Conclusion

A novel design of single-layer quasi-elliptic FSS was proposed in the paper. Each FSS cell comprises a centered rectangular aperture with three closely spaced equal-height posts alternatively installed along the broad wall of the aperture. The design optimization depends only on the height of the posts and the separation of the lateral posts. The proposed FSS provides an effective frequency separation of the incident wave into three channels, reflecting at two closely spaced frequencies and transmitting at the middle frequency simultaneously.

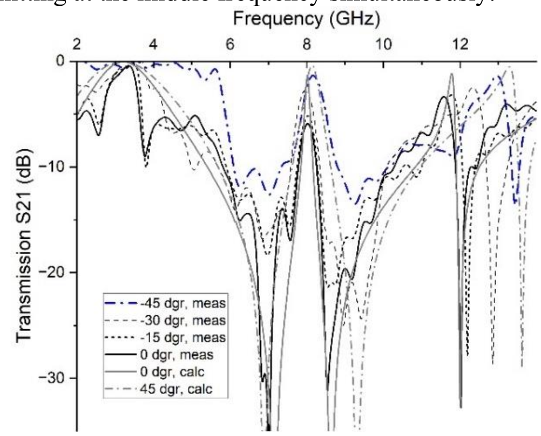


Figure 4. Measured and simulated transmission characteristics of FSS for various values of incident angle θ.

Acknowledgment

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