

Traditional Frequency Selective Surface versus Substrate Integrated Waveguide Frequency Selective Surface

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Abstract This paper is devoted to analysis design and fabrication of both traditional and substrate integrated waveguide (SIW) frequency selective surfaces (FSS) of square elements and square lattice. The transmission loss is studied for different angle of incidence; normal, thirty, forty five and sixty degrees. Moreover the common band for different angle of incidence is determined. The FSS is fabricated on Rogers RO4350 (lossy) of relative permittivity 3.33, thickness 1.524mm and loss tangent 0.004. The arrays provide different resonance due to different current modes. It is simulated using CST MWS and measured using the network analyzer. There is a good agreement between the transmission loss of both the simulated and measured results.

Keywords Antenna, Filtenna, Frequency Selective Surface (FSS)

1. Introduction

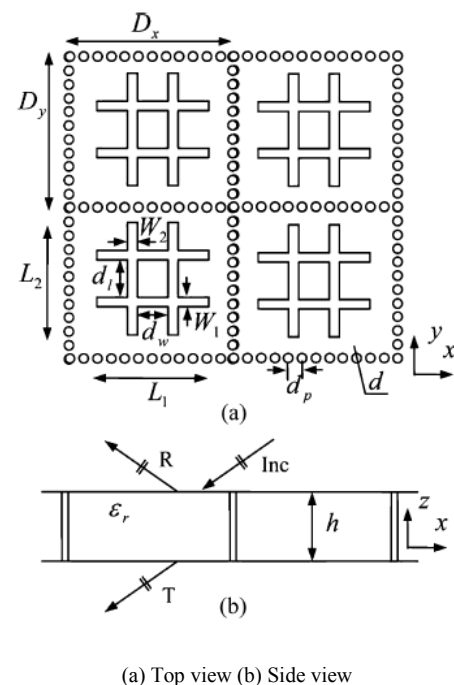
Traditional frequency selective surface has several applications such as polarizers, space filters, subreflectors in dual frequency antennas and as radomes for radar cross section (RCS) controlling [1]. It is easy to fabricate single layer FSS formed by periodic patch arrays or slot arrays of simple elements backed by a supporting dielectric layer, but limited in their performance in terms of tendency to be affected to changes of polarization and sensitivity of incident angles [2-10].

Several techniques have been taken to improve the performance of FSS, such as Dielectric loading FSS and biplanar FSS have been studied by Leubber and Munk [2 and 3]. In addition different periodic elements have been discussed in papers of Shaker [4], Wu Tekao [5 and 6] *et al.* Complementary FSS, close coupled FSS and reconfigurable FSS have been analyzed by Vardaxoglou [7-9]. All above attempts have improved parts of the performance of FSS, but for its low quality factor (Q) of open resonance structure, the performance of these types FSS is not good as expected.

Recent years, SIW technique has been developed to design microwave and millimeter wave components and

subsystems. SIW structure keeps the advantages of conventional metallic waveguides, such as high Q-factor, high selectivity, cutoff frequency characteristic and high power capacity etc. [10-18].

Fig. 1 shows the geometry of the FSS with SIW cavities. Periodic aperture array symmetrically distribute on top and bottom metallic surfaces of the substrate. The SIW cavity is a basic unit cell of the FSS, which can be fabricated by implementing rows of metallic vias on a low-loss substrate with electrodeposited metal coating on both sides [10-18].



(a) Top view (b) Side view

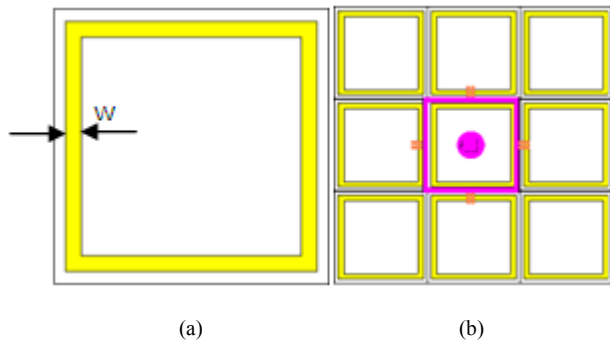
Figure 1. Geometry of a FSS using grid slot SIW cavity

The structure is studied using finite difference frequency domain (FDFD) method [19], where the transmission and reflection coefficients have been calculated.

This article presents a design of a bandpass FSS using SIW technique which is expected to be different from conventional FSS having two main resonant modes; the resonant generated by periodicity and the resonance generated by the SIW cavity.

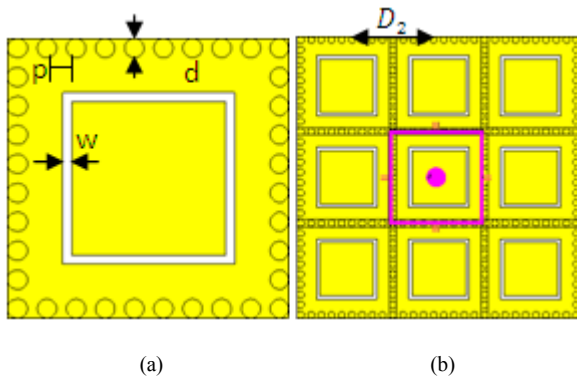
2. Design

Fig. 2 (a) depicts the traditional FSS of square elements and square lattice. The dimensions of the unit cell are $7.515 \times 7.515 \text{ mm}^2$, It is simulated on a dielectric material of thickness 0.075 mm , with $\epsilon_r = 2.33$, and loss tangent 0.0012 . The period D_1 between each square loop is 8.22 mm and the width w for the square's side length is 0.47 mm . On the other hand, Fig. 3 (a) depicts the SIWFSS unit cell design, the spacing p between each via and its diameter d are 1.5 mm and 1 mm respectively. The width and length of the unit cell is $14.5 \times 14.5 \text{ mm}^2$, the period D_2 between each cell is 13.5 mm and the slotted square in the middle of the unit cell is $8.87 \times 8.87 \text{ mm}^2$. It is very important to point out that a very small thickness of a dielectric substrate has been chosen for the sake of comparing the performance of traditional FSS with that of complement SIWFSS.



(a) Square loop FSS unit cell (b) Array of square loop FSS

Figure 2. Traditional FSS square loop



(a) SIWFSS square loop unit cell (b) Array of SIWFSS square loop

Figure 3. SIWFSS square loop

A. Traditional FSS

Fig. 4 depicts the E-plane transmission loss with different angle of incidence 0, 30, 45 and 60 degrees for the traditional FSS structure of the square loop square lattice.

Increasing the angle of incidence gradually from 0 to 60 degrees shows a shift to the right in the resonance frequency. The highlighted area in grey is the common band between all transmission responses which is centered around 10.625

GHz with bandwidth 2.25GHz.

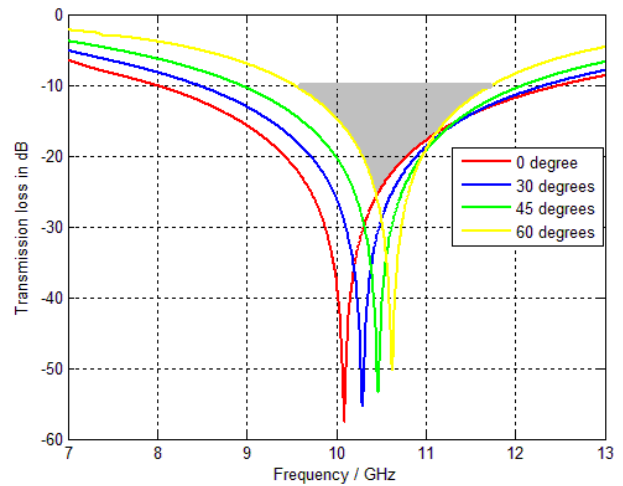


Figure 4. E-plane transmission loss for traditional FSS square elements square lattice

B. SIW FSS

Fig. 5 illustrates the return loss for the SIW FSS. It is important to figure out that the SIW FSS is the complement structure of the traditional FSS. Increasing the angle of incidence gradually from 0 to 60 degrees shows a shift to the left in the resonance frequency. The highlighted area in grey is the common band between all return loss responses which is centered around 9.75 GHz with bandwidth 0.5 GHz.

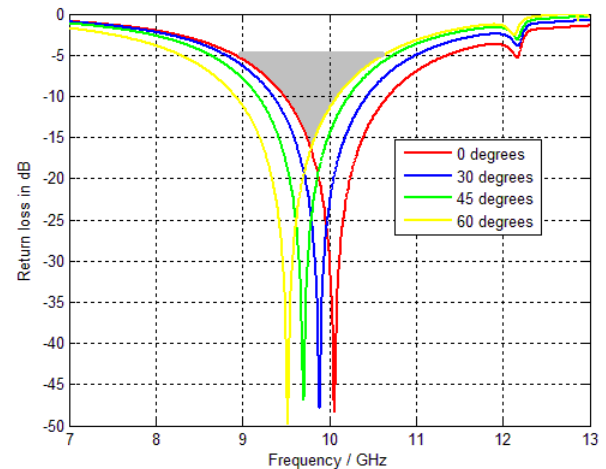


Figure 5. Return loss for the SIW FSS

C. Comparison between Traditional FSS and SIW FSS

From Fig. 4 and Fig. 5 one can conclude the following:

- SIW FSS is more selective than FSS.
- The change in the angle of incidence in the SIW FSS design shifts the resonance to the left gradually as the angle of incidence increase from 0 to 60 degrees, while the resonance in the FSS design shifts to right.
- The common band for the SIWFSS E-plane return loss is centered around 9.75 GHz, with bandwidth

0.5 GHz, while the FSS E-plane transmission loss is centered around 10.625 GHz, with bandwidth 2.25 GHz.

D. Measured Results

For the sake of fabrication and measurements the available material is Rogers RO4350 (lossy) of relative permittivity 3.33, thickness 1.524 mm and loss tangent 0.004. Fig. 6 depicts the fabricated FSS of square loop square lattice. The FSS square elements are $5.62 * 5.62 \text{ mm}^2$ with same side length's width w of 0.47 mm and the period D between each square loop is 6.36 mm .

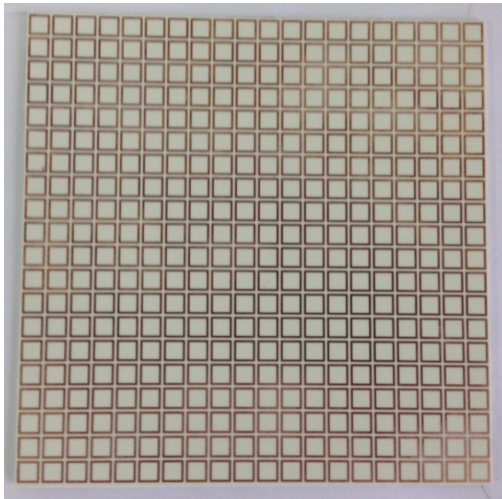


Figure 6. Fabricated FSS square lattice

The measured transmission loss responses are compared to the simulated ones and are depicted in figures 7 to 9 for different angles of incidence from 0 to 60 degrees respectively.

It is clear that both the simulated and measured transmission loss for the FSS square elements square lattice are in good agreement as shown in Fig. 10.

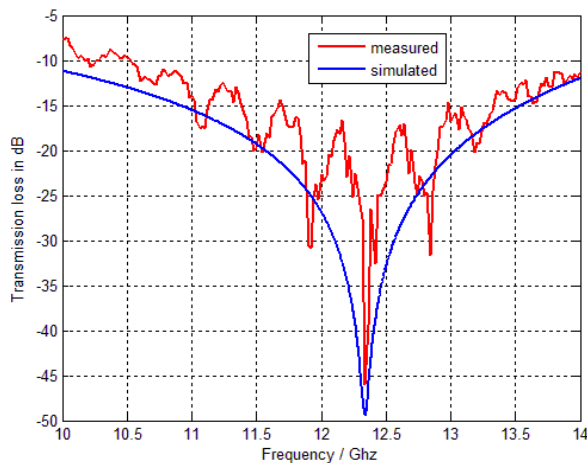


Figure 7. Transmission loss for the simulated and measured FSS square elements square lattice at normal incident waves

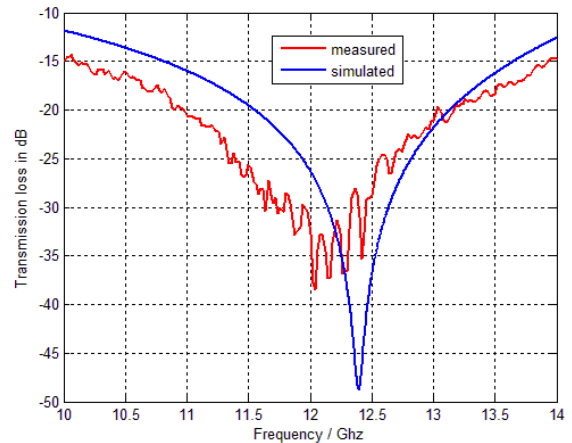


Figure 8. Transmission loss for the simulated and measured FSS square elements square lattice at 30 degrees incident waves

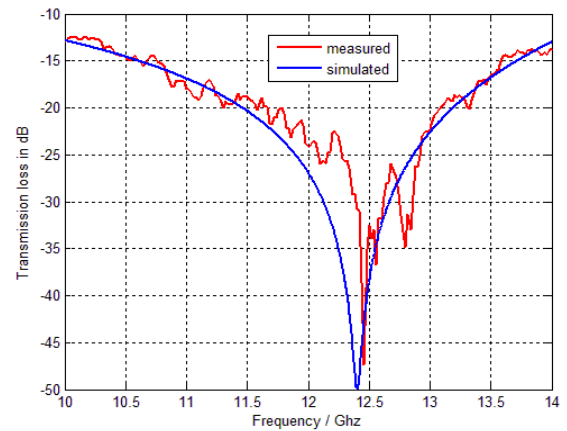


Figure 9. Transmission loss for the simulated and measured FSS square elements square lattice at 45 degrees incident waves

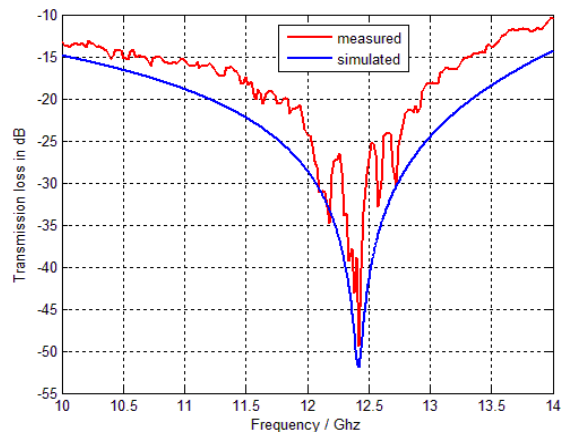


Figure 10. Transmission loss for the simulated and measured FSS square elements square lattice at 60 degrees incident waves

3. Conclusion

A comparison between the performance of the traditional frequency selective surfaces and the substrate integrated waveguide FSS is presented. Both structures are simulated

on Rogers RT5870 (lossy) of relative permittivity 2.33, thickness 0.075 mm and loss tangent 0.0012. The SIW FSS conducts more selectivity than the traditional FSS.

For the sake of fabrication and measurement the article presents square element square lattice traditional FSS fabricated on Rogers RO4350 (lossy) of relative permittivity 3.33, thickness 1.524 mm and loss tangent 0.004. The FSS square element square lattice shows a good agreement between the simulated and measured transmission loss.

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