A Novel Low Profile Polarization Insensitive Electromagnetic Shield for X-Band Applications

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2021 Computing, Communications and IoT Applications (ComComAp) | 978-1-6654-2798-2/21/$31.00 ©2021 IEEE | DOI: 10.1109/COMCOMAP53641.2021.9653100

***Abstract*—In this paper, a novel polarization-insensitive frequency-selective surface-based electromagnetic shield is presented for EMI shielding applications. The FSS unit cell consists of a modified Jerusalem crossed loop designed over a low-loss substrate. It achieves an effective shielding at 10 GHz frequency in the X-band. Moreover, it manifests a fractional bandwidth of 24%. In addition, the FSS offers angularly stable response up to 60 degrees for both TE and TM polarizations due to its symmetrical structure. The overall unit cell dimensions are 5.25 x 5.25 mm^2. Thus, the proposed design is a promising candidate for narrowband SATCOM applications.**

Keywords— Frequency Selective Surface, Polarization Insensitive, Electromagnetic Interference (EMI), Spatial Filter, stopband, Electromagnetic compatibility.

I. INTRODUCTION

Frequency selective surfaces (FSSs) are the periodic arrangements of metallic elements in two or three dimensions that show a band-stop or bandpass filtering response when illuminated with electromagnetic waves. FSSs, due to their widespread applications, find their employability in antenna radome design, RCS reduction, analog absorbers, artificial magnetic conductors (AMCs), EBG structures, performance enhancement of antennas, antenna reflectors, High Impedance Surfaces, electromagnetic interference mitigation, satellite communication services, and many others [1-6].

Many FSS configurations are recently reported for various applications. In [6], a single layer polarization-insensitive FSS is studied for EM shielding in the C-band. A corner modified square-ring FSS in [7] shows a polarization-insensitive ultra-wideband response with an attenuation of 47.8 dB. A crossed dumbbell-shaped in [8] and annual ring and flower-shaped FSS in [9], are reported to suppress Wi-Fi and WLAN signals. Another single layer FSS with dual stopband functionality in [10] is proposed for X-band shielding. In addition, in [11], a U-shaped FSS provides shielding in the X and Ku bands. In [12], a dual-band modified square loop FSS is presented for GSM shielding applications. A meander-line FSS geometry in [13] offers RF-shielding for building.

In this paper, a novel miniaturized FSS based EM shield is presented. The FSS consists of a modified Jerusalem cross loop which offers 45 dB attenuation at the desired frequency. In addition, it shows good angular stability up to 60^o for both TE and TM mode polarization. Rest of the paper is organized as sections II and III describe unit cell design-process, results, and discussions. Finally, section IV concludes the paper.

II. UINT CELL DESIGN CONFIGURATION

The unit cell of the proposed FSS is shown in Figure 1. The FSS is designed on a low loss Rogers 5880 slab having thickness *t= 0.787 mm*, *Ɛr=2.2* and *tanδ=0.0009*. Thus, the unit cell has compact dimensions of 5.25×5.25 mm^2.

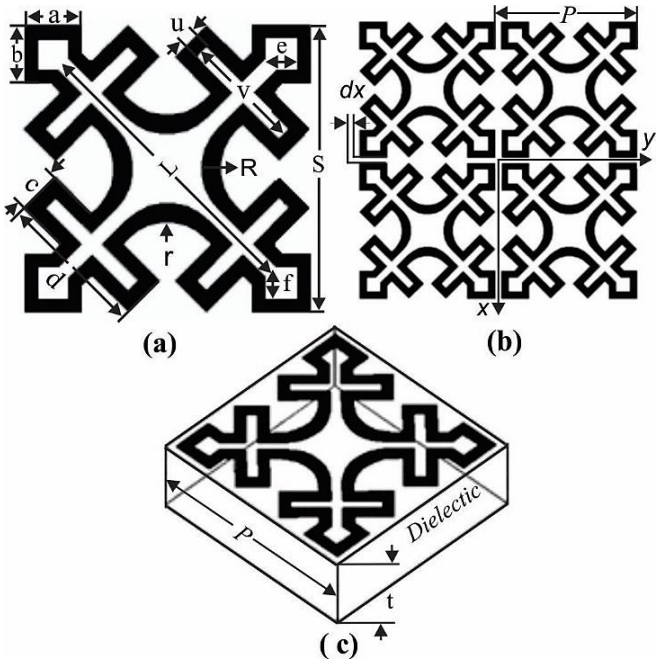

Figure 1: Proposed FSS Unit Cell top view, 2x2 array, and 3D view

The geometry of the proposed FSS is principally evolved through a four-step procedure, as shown in Fig. 2. The FSS consists of a crossed dipole of length 'L' placed diagonally on one side of the laminate, as shown in Fig. 2a. A rectangular strip is etched from the middle to make a crossed dipole loop to achieve miniaturization in structure. In addition, a square loop is incorporated at each leg of the crossed dipole loop to get desired response and to miniaturize the unit cell further, as illustrated in Fig. 2b. Moreover, Fig. 2c shows that a rectangular loop is joined with the geometry to increase its electrical length and achieve maximum attenuation at the frequency of interest. The resulting structure resembles a Jerusalem crossed loop shape. Furthermore, the edges at the center of the structure are chamfered at radii of 'r' and 'R'. These radii are optimized to achieve stopband in the X-band centered at 10 GHz frequency. Table I shows optimized values of design parameters, and all units are in mm.

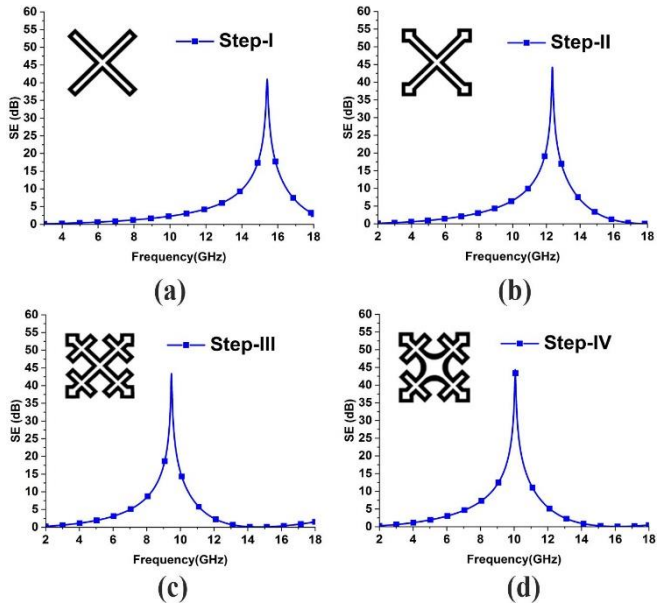

Figure 2: Design process of proposed FSS structure

III. Results and Discussions

A. Electromagnetic Shielding Analysis

The proposed structure is designed and simulated in Ansys HFSS. The performance of the FSS is analyzed in terms of shielding effectiveness which can be expressed as in eq (1). The FSS achieves an effective shielding of at least 45 dB centered at 10 GHz frequency. The FSS has been further examined for various incidence angles as well as polarization states. Figure 3 shows the SE of the FSS unit cell as a function of frequency. It is observed that the unit cell shows an identical response for both the parallel and perpendicular polarization states of the incident wave at normal incidence owing to its four-fold symmetric geometry.

$$SE(dB) = -20 \times log_{10} \left|\frac{E_t}{E_i}\right| - - - -(1)$$

B. Angular Stability

The angular response of the FSS for TE and TM wave modes is illustrated in Figs. 4 and 5, correspondingly. The results show that the FSS offers good angular stability towards angle variations. It is observed that the FSS shows an almost identical response for both TE and TM polarizations when the oblique incident angle is varied from 0 to 60°. However, a grating lobe occurs at higher frequencies when the oblique angle is 30° and 60°. This second resonance is shifted upward as the incident angle increases and notch selectivity is improved. Moreover, the FSS offers a fractional bandwidth of 24% at normal incidence, which slightly increases within the acceptable limits as the incident angle varies. Table II shows fractional bandwidth variations as a function of oblique angle variations. Thus, the FSS manifests narrow bandwidth, which makes it suitable for narrowband operations. In addition, attenuation and selectivity are also improved as the angle is increased. Additionally, a 2×2 array response for TE and TM wave modes at normal incidence is illustrated in Fig. 6. It may be observed that the array has a similar response as the single unit cell. Correspondingly, the performance is alike over oblique angle variations as well.

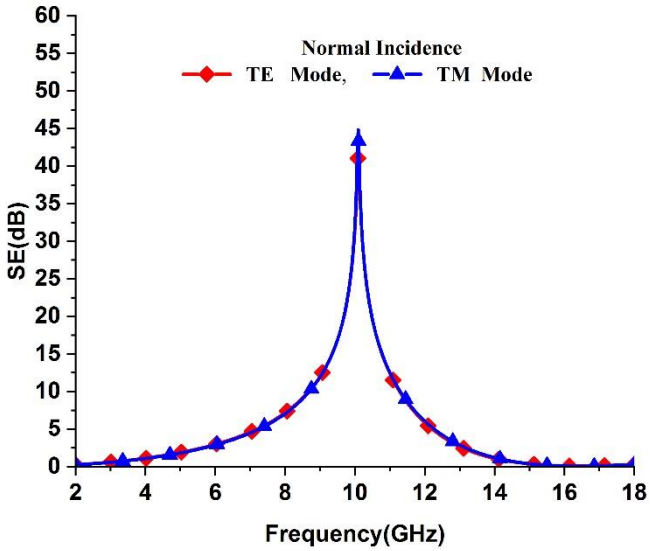

Figure 3: SE at normal incidence for TE and TM polarizations

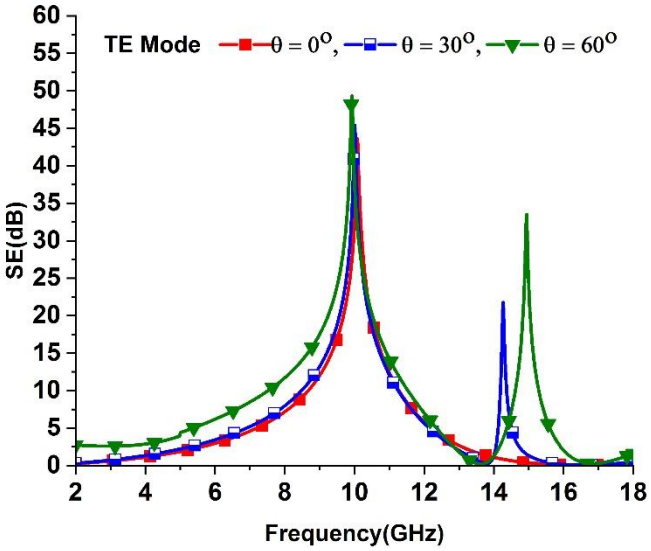

Figure 4: SE as a function of oblique incident angle for TE wave mode

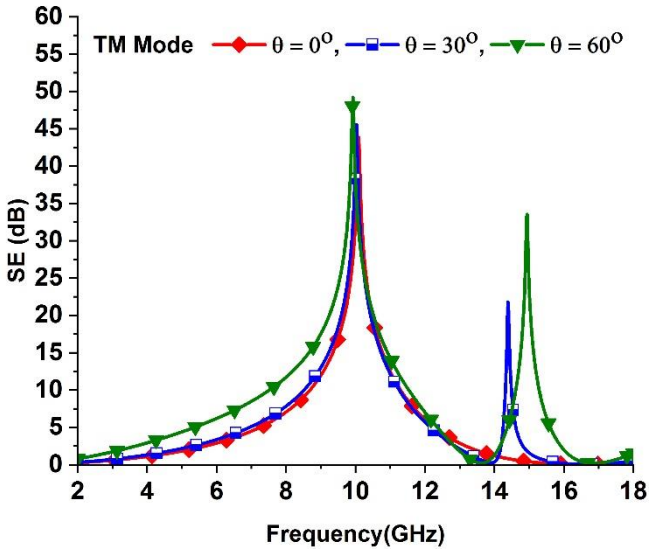

Figure 5: SE as a function of oblique incident angle for TM polarization mode

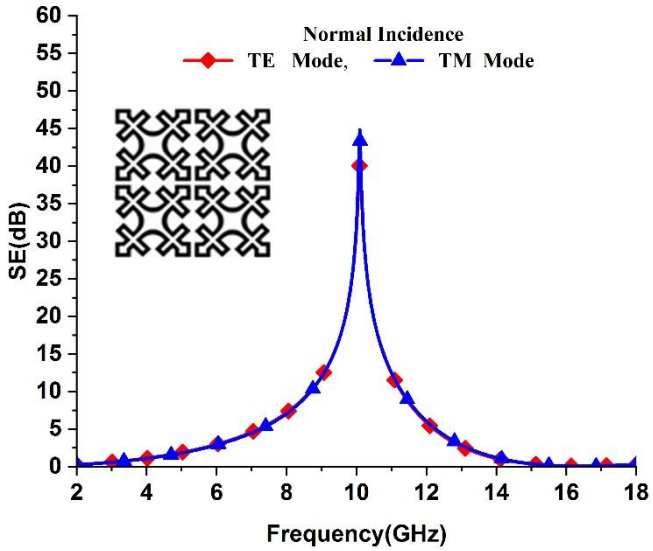

Figure 6: A 2×2 array response at normal incidence

TABLE I. OPTIMIZED DIMENSIONS OF FSS UNIT CELL AND ARRAY

Parameter	Value	Parameter	Value	Parameter	Value
r	1	d	2.5	S	5
R	0.9	e=f	0.5	P	5.25
a=b	1	u	0.25	Dx = Dy	0.35
c	0.75	v	2	t	0.787

TABLE II. FRACTIONAL BANDWIDTH AS A FUNCTION OF INCIDENCE ANGLE

Angle (θ)	Attenuation dB	TE-mode (%)	TE-mode (%)
0°	45.8/46.3	24.17	26.06
30°	46.5/46.7	28.05	27.70
60°	50.1/52.0	42.05	42.04

C. Parametric Analysis

The SE of FSS is analyzed in terms of the relative permittivity of the laminate. Figure 7 shows SE as a function of dielectric permittivity. It is observed that the SE curves slightly shifts towards lower frequency as the permittivity increases.

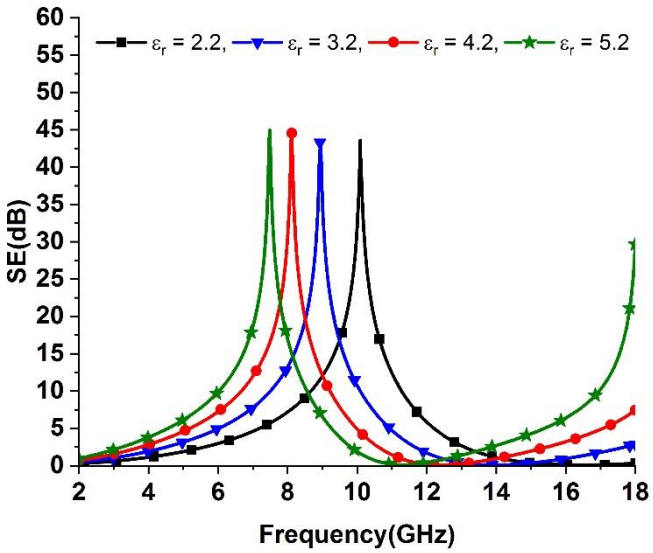

Figure 7: SE of FSS as a function of dielectric constant

IV. CONCLUSION

A novel low-profile FSS shield is presented in this paper. The FSS is designed to suppress communication in the X-band. It provides an attenuation of at least 45 dB centered at 10 GHz frequency. In addition, it offers good angular stability over oblique angle variations. Furthermore, identical, highly selective, angular, and polarization-insensitive responses for TE and TM wave modes are observed, making it a unique EM shield for SATCOM applications in the X-band.

ACKNOWLEDGMENT

This work is supported in part by the National Natural Science Foundation of China (NSFC) under Grants No. 62071306 and 62171289, and in part by Shenzhen Science and Technology Program under Grants JCYJ20200109113601723 and JSGG20210420091805014.

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