

A Thin Polarization Insensitive Frequency Selective Surface for X-Band RCS Reduction

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Abstract—This study presents a thin, polarization-insensitive frequency selective surface (FSS) designed for radar cross section (RCS) reduction in the X-band. The proposed design uses a Jerusalem cross unit cell to achieve polarization insensitivity and consistent RCS reduction performance. By optimizing the unit cell geometry and substrate thickness, the simulated reflection coefficient (S11) reaches -15 dB across the entire X-band, while maintaining a compact overall thickness of 4.2 mm. Numerical simulation results are provided to demonstrate the effectiveness and applicability of the proposed FSS design.

I. INTRODUCTION

Over the past few decades, electromagnetic absorbers have become a well established technology that has enabled numerous applications in radio frequency shielding, special filtering, and stealth technology [1]–[3]. In the early years, Salisbury screen, Jauman or multilayered structures [4] based absorbers were commonly used as microwave absorbing materials. However, the Salisbury screen based absorbers exhibit very narrow absorption bandwidth and require a spacer of $\lambda/4$ thickness, which often results in bulky and less practical designs. While Jauman or multilayered structures offer improved performance with broader absorption bandwidth, their significant thickness puts challenges, particularly in outdoor and aerospace applications where lightweight and compactness play crucial role.

In more recent years, significant efforts have been put into employment of frequency selective surfaces (FSSs) for the design of electromagnetic absorbers [5], [6]. FSS consists of periodic unit cells which can be considered as inductive or capacitive elements, effectively acting as high-pass or low-pass filters. The FSS-based absorbers are realized using periodic array of the chosen unit cell shapes printed on dielectric substrates backed by metallic ground plane. Due to the ohmic loss on unit cell array and dielectric/magnetic loss in the substrate, selective shielding of electromagnetic wave can be achieved. By optimizing the shape and dimension of the unit cell and substrate, FSS-based absorbers can realize excellent shielding effectiveness, including polarization insensitivity, stable performance over wide incident angles, and broadband absorption. These properties allow them to be considered as an attractive candidate in various stealth applications such as radar cross section (RCS) reduction.

To this end, in this work, a thin, polarization-insensitive FSS based on a Jerusalem cross unit cell with $50 \Omega/m^2$ surface impedance has been designed and optimized for RCS reduction in the X-band. By optimizing the unit cell dimensions and substrate thickness, the simulated S11 parameter reaches -15

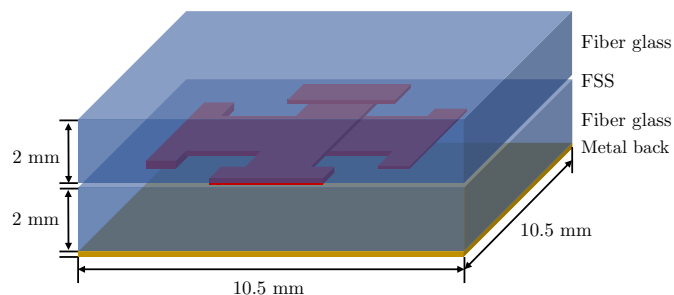


Fig. 1. The schematic illustration of the proposed FSS structure.

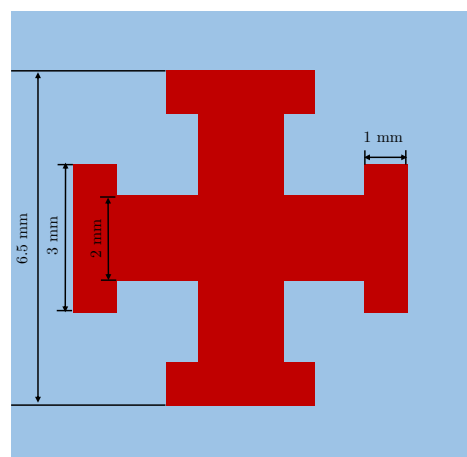


Fig. 2. The dimensions of the FSS unit cell.

dB, while maintaining an overall thickness of just 4.2 mm and ensuring polarization insensitivity.

In this paper, we present the simulation results, which demonstrate the performance and the applicability of the proposed FSS structure. The experimental results and its comparison with simulation results will be presented during the conference.

II. FSS DESIGN

The proposed FSS design is illustrated in Fig. 1 with detailed components. The Jerusalem cross unit cell which consists of a central cross shape with extended arms is used in the proposed FSS structure. This unit cell is 90° symmetric, which is beneficial for achieving polarization insensitivity along with providing identical response for both TE and TM

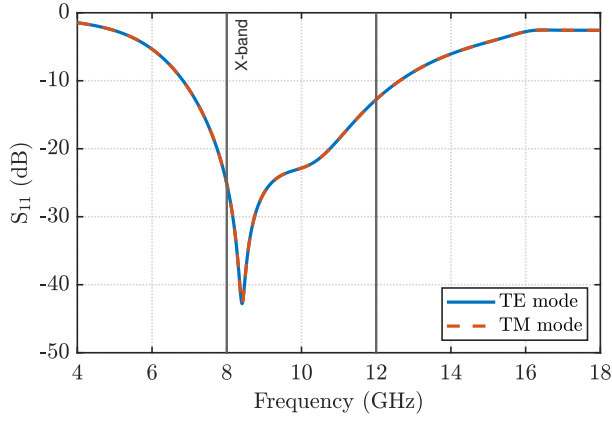


Fig. 3. Simulated S-parameters for TE and TM modes of the proposed FSS.

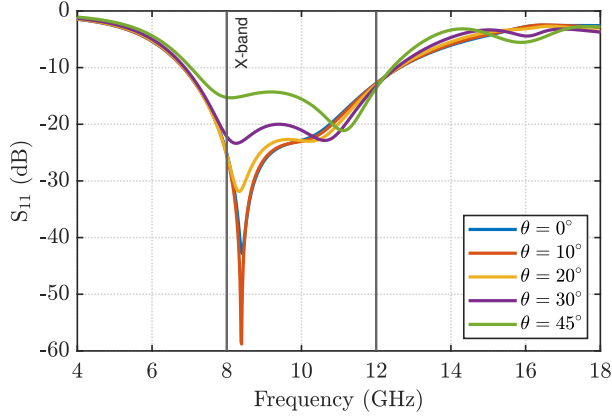


Fig. 4. Simulated S-parameters with varying incident angle.

modes. This design is achieved after rigorous optimization of the unit cell geometry and the electromagnetic properties of material component. The FSS layer, consisting of a resistive sheet with a surface impedance $50 \Omega/m^2$ with a thickness of 0.1 mm, is sandwiched between two 2-mm-thick fiberglass layers and backed by a 0.1 mm metallic ground plane to enhance absorption. The final optimized dimensions of the FSS unit cell structure are illustrated in Fig. 2.

III. RESULTS AND ANALYSIS

A. Reflection Parameters of FSS Structure

To demonstrate the performance of the designed FSS structure, the frequency response for TE and TM modes are plotted in Fig. 3. The simulation has been performed by using the CST studio with a Floquet port excitation and periodic boundary condition. The FR4 layers have the following properties: $\epsilon_r = 4.3$, $\tan\delta = 0.025$ layers.

Fig. 3 plot demonstrates that the simulated reflection coefficient (S_{11} parameter) for both TE and TM modes overlap between 4 GHz and 18 GHz, which can be attributed to the 90° symmetric geometry of the FSS structure. Additionally, the simulated S_{11} remains consistently below -15 dB throughout the X-band frequency range as indicated in the plot, which makes the structure promising for applications in

RCS reduction at X-band. The absorption can be calculated using the expression $A(\omega) = 1 - R(\omega) - T(\omega)$, where $A(\omega)$, $R(\omega)$, and $T(\omega)$ are respectively the absorption, reflection, and transmission at given frequency ω . Based on this calculation, a minimum absorption level of 96.8 % is achieved across the X-band. From above analysis, it can be concluded that the proposed FSS is promising for applications in RCS reduction or EM shielding at X-band.

B. Performance Assessment for Varying Angle of Incidence

In this section, the impact of the incident angle on the frequency response of the proposed FSS is analyzed. The incident angle varies from 0° to 45° . The simulated reflection response of the FSS for the TE mode is plotted in Fig. 4. As shown in Fig. 4, the simulated S_{11} performance exhibits a slight increase with increasing incident angle. However, an average S_{11} value of approximately -15 dB is consistently maintained, even at an incident angle of $\theta = 45^\circ$, across the X-band frequency range. This is due to the unique geometry of the Jerusalem cross, which contributes to the angular stability. This property results in minimal shifts in the resonant frequencies leading to consistent reflection coefficients as illustrated in Fig. 4.

IV. CONCLUSION

In this paper, a thin and polarization-insensitive FSS is designed for RCS reduction across the X-band. The optimized final design achieves polarization insensitivity, angular stability, and keeps consistent reflection coefficient lower than -15 dB across the entire X-band with only a total thickness of 4.2 mm. It should be noted that the manufactured $30 \text{ cm} \times 30 \text{ cm}$ FSS is on the way and the experimentally measured results will be compared with numerical simulation and presented during the conference.

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