A Low Cross Polarized Reflection Wideband Microwave Absorber

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Abstract

A polarization-insensitive absorber operating in a microwave frequency regime having a large absorption bandwidth is presented in this work. On top of the substrate, a Frequency Selective Surface (FSS) pattern is printed which constitutes two resistive sheet-based resonators that produce ohmic loss, which significantly increases the absorption bandwidth. The absorber is angularly stable up to a maximum of 60 degrees, both for TE and TM polarizations, however, the TM case is more stable. The cross-polarized reflection coefficient level clearly shows that the proposed model functions as an absorber from (9.68 GHz - 20.72 GHz) rather than a polarization converter.

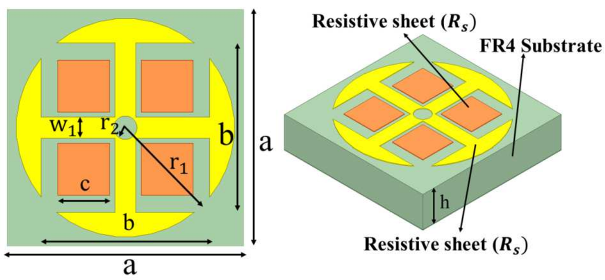
1. Introduction

Artificially-engineered structures known as FSS (Frequency selective surface) are capable of passing and stopping incoming electromagnetic waves [1]. Filters [2], absorbers [3-7], and polarization converters [8-13] are among the many devices that can benefit from their use. Electromagnetic wave absorbers or Radar absorbing structures [14-15] are among the most common uses of FSS. Radar cross-section or Radar signature can be reduced by using electromagnetic wave absorbers. However, traditional absorbers such as Salisbury screen [16], Jaumann [17], and ferrite absorbers [18] have practical limitations. The air absorber interface is where the metamaterial-based absorber or FSS transfers the absorber impedance to free space impedance. Compared to traditional absorbers metamaterial absorbers have a low profile. A metamaterial-based absorber was initially created by Landy et al. [19]. When developing an absorber, it is vital to consider the polarization aspect. The lack of polarization conversion and cross-reflection plots in most of the absorbers in [20-22] made it difficult to identify whether the structures were absorbers or polarization converters.

An absorber that is polarization-insensitive and has a low degree of cross-polarized reflection is proposed in this study. The top layer of the substrate is composed of metallic resonators based on resistive sheets, with a substrate thickness of 2 mm. Various metrics, including surface current profile, and normalized impedance, are plotted to verify the proposed design.

2. Layout of the Unit Cell

The absorber unit cell that has been presented here has a single-layer configuration. At the air absorber interface, a FSS pattern with sheet resistance in the top layer converts the design impedance to free space impedance. Between the upper and lower surfaces, as depicted in Fig. 1 (b), there is a FR4 dielectric substrate with a loss tangent of 0.025 and relative permittivity of 4.4. Copper is used to completely laminate the bottommost layer. The geometry describing the unit cell dimensions is represented in Fig. 1 (a).



(a) (b)

Figure 1: Unit cell geometry: $a = 9.1$ mm, $b = 6.5$ mm, $c = 2$ mm, $r_1 = 4.2$ mm, $r_2 = 0.45$ mm , $w_1 = 0.45$ mm $R_s = 100$ ohm/sq, $h = 2$ mm. (a) Front View (b) Side view.

The Absorptivity can be determined by [23]

$$A = 1 - |S_{11}|^2 - |S_{21}|^2 \quad (1).$$

where $|S_{11}|^2 = |R_{xy}|^2 + |R_{yy}|^2$ and $|S_{21}|^2 = |T_{xy}|^2 + |T_{yy}|^2$. Co- and cross-polarized components, respectively, are denoted by the subscript yy and xy for a TE polarized wave. Since the structure is fully laminated on the back side, electromagnetic waves cannot pass through it, which leads to $|S_{21}|^2$ becoming zero. Therefore equation (1) reduced to

$$A = 1 - |R_{xy}|^2 + |R_{yy}|^2 \quad (2)$$

The EM wave impedance at the air absorber contact is given by

$$Z_{in} = Z_{FSS}||Z_{dielectric}$$

where, Z_{FSS} denotes the impedance provided by the FSS pattern etched on the top of the substrate, and $Z_{dielectric}$ represents the impedance provided by the dielectric substrate.

The reflection coefficient at the air absorber contact may be computed as follows:

$$\Gamma_{in} = \frac{Z_{in} - Z_o}{Z_{in} + Z_o}$$

The input impedance is a real quantity at the resonance frequency. In order to have a high absorption reflection level, Γ_{in} has to be at its lowest possible value. This is only possible if the input impedance Z_{in} equals the free space impedance Z_o (377 ohm).

3. Simulated Results

A finite-element-based simulation tool known as HFSS (High-Frequency Structure Simulator) is utilized to carry out the Full Wave simulation of the proposed design. To realize the periodicity in the *x* and *y*-axis, periodic boundary conditions are utilized. The simulated co (R_{yy}) and cross-polarized reflection coefficient (R_{xy}) is described in Fig. 2, where the cross-polarization level is quite low, indicating that the proposed structure behaves as an absorber.

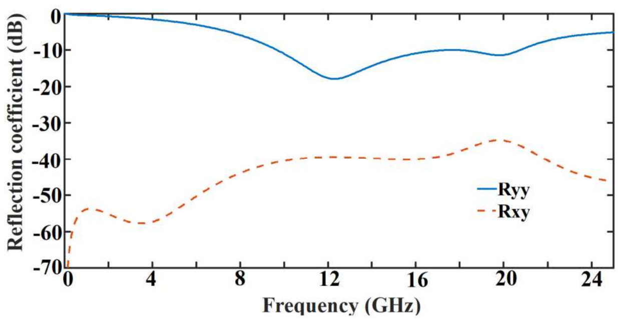


Figure 2. Simulated co and cross-polarized reflection coefficient (dB).

Fig. 3 shows the structure absorptivity response. The absorption bandwidth is 11.1 GHz (9.68 GHz - 20.72 GHz), with 90% as the reference level.

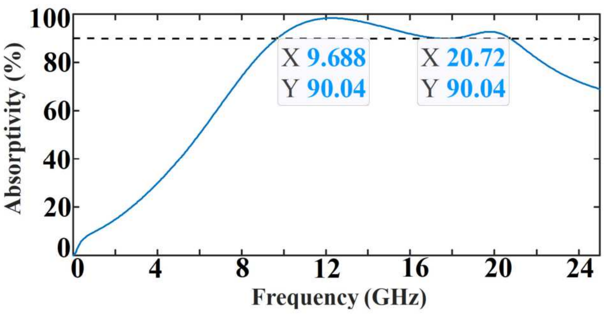
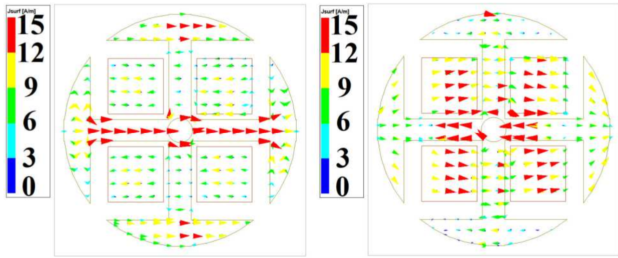


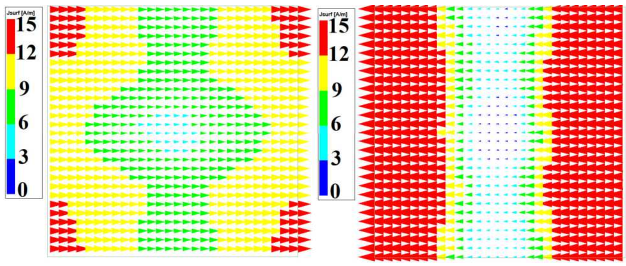
Figure 3. Simulated absorptivity as a fuction of frequency.

Figs. 4 and 5 illustrate the surface current density at the absorptivity peaks on the absorber front and rear surfaces, respectively. The figures show that the surface currents are antiparallel, i.e., 180 degrees out of phase with each other, resulting in magnetic resonance.



(a) (b)

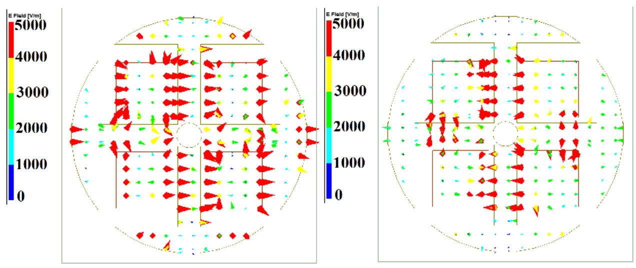
Figure 4. Distribution of surface current at the upper region of the substrate at (a) 12.31 GHz and (b) 19.76 GHz.



(a) (b)

Figure 5. Distribution of surface current at the lower region of the substrate at (a) 12.31 GHz and (b) 19.76 GHz.

Fig. 6 depicts the electric field profile at the upper region of the substrate. The plots demonstrate that at both resonance peaks, the highest amount of electric field couples with the structure contributing to electric resonance. The design achieves a high absorption level by using both electric and magnetic resonance properties.



(a) (b)

Figure 6. Electric field profile at the upper region of the substrate.

Fig. 7 presents the normalized impedance plot. Within the absorption frequency range, the real portion and imaginary component of normalized impedance are equivalent to unity and zero, respectively, implying perfect impedance matching with free space impedance.

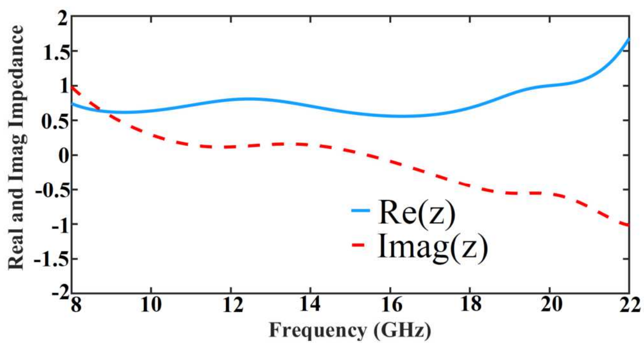


Figure 7. Simulated normalized impedance plot.

Absorption is plotted under the normal incidence of an incident electromagnetic wave for various polarization angles to determine if the devised structure is polarization-insensitive., as described in Fig. 8. The absorber is unaffected by polarization because of the unit cell fourfold symmetry.

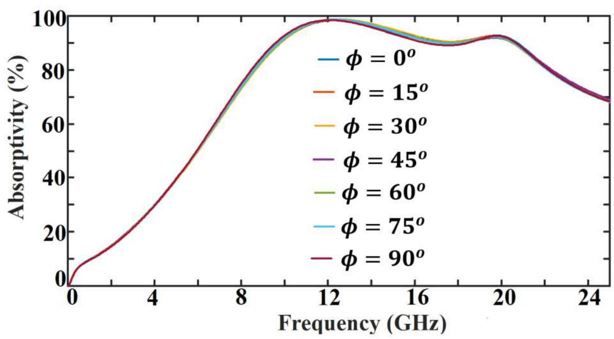


Figure 8. Simulated absorbance under variation in polarization angle.

Fig. 9 and Fig. 10 illustrate the performance of the absorber with varying incidence angles when subjected to TE and TM polarization, respectively. The structure maintains its absorptivity above 60 percent till 60 degrees under the TE polarization case, whereas under TM polarization, absorptivity above 80 percent is achieved till 60 degrees. So, the proposed structure has good angular stability but more in TM polarization.

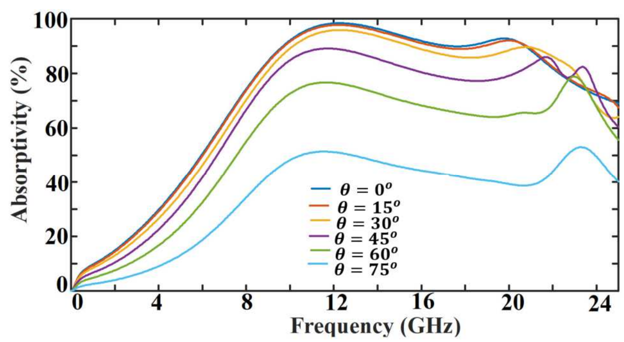


Figure 9. Simulated absorptivity with variation in oblique incidence angle under TE polarization.

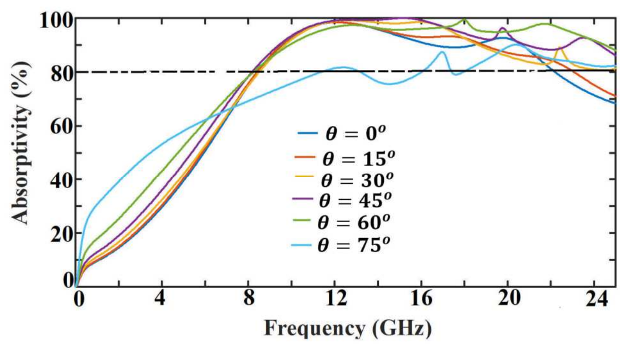


Figure 10. Absorptivity in terms of variation in oblique incidence angle under TM polarization.

4. Conclusion

This work presents a wideband, polarization-insensitive, and angularly stable microwave absorber spanning part of the X-band, a whole section of the Ku band, and part of the K band. In addition, several metrics, such as surface current profile and normalized impedance plot, are provided to validate the proposed design. For both TE and TM polarization, the absorber offers high angular stability up to 60 degrees. As a result, the proposed absorber has applications in stealth technology, electromagnetic interference/compatibility, and other fields.

7. References

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