Absorber Based on a Frequency Selective Surface Built on FR4 Substrate

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***Abstract*—A frequency selective surface consisting of a periodic copper pattern, built on a grounded FR4 substrate is introduced. The structure operates as an absorber for waves at 2.46 GHz, up to an incidence angle of 60º. Variation of the geometrical parameters allows for the modification of the working frequency, as also demonstrated by the parametric studies reported in the paper. Properties of the structure have been assessed by full-wave simulation.**

I. Introduction

Frequency selective surfaces (FSSs) are 2D periodic dielectric or metallic-dielectric structures that are used to control propagation of incident electromagnetic waves [1]. Absorbers are FFSs that absorb electromagnetic waves at certain frequencies or frequency bands, while transmitting or reflecting the waves at other frequencies.

Absorbers have military applications for rendering invisible targets at the absorbing frequencies and civil applications, e.g., by incorporating the FSS in room walls for screening against signals at absorbing frequencies but leaving other signals (such as GSM) unaltered [2]. Thin absorbers operate by matching the surface impedance to the free-space impedance. Multi-layer absorbers additionally take advantage on multiple reflections between layers and provide multiple absorption bands in general [3,4]. Flexible surfaces and switchable solutions have also been reported [4,5].

In this paper, an FSS that works as an absorber at frequencies below 10 GHz is proposed. Electromagnetic waves having a frequency close to 2.45 GHz are absorbed by the FSS. This frequency belongs to ISM, Bluetooth, Wi-Fi WLAN and LTE bands. In addition, by modifying the substrate thickness, the absorbers functionality is moved to around 7.2 GHz (covering C Band and Fixed Wireless Systems).

II. Proposed Structure

A. Initial structure

The unit cell of the FSS is presented in Fig. 1. It is square shaped, with an edge of 15 mm ($=d_x=d_y$) and it is built on FR4 substrate (ε_r=4.3, tan δ=0.025), having a thickness s_t=2.6 mm. One face of the substrate is covered with a metal (copper) pattern, consisting of four identical "leafs", while the other face is covered with a continuous metallization, and acts as ground plane.

The other dimensions are as follow: trace width w=0.2mm, a=1.5mm, b=1.1 mm, c=2.2 mm. The FSS results by 2D repetition of the unit cell in the d_x and d_y directions. The reflection coefficient of the structure has been assessed by full-wave simulation, using [6].

In Fig. 2 the magnitude of the reflection coefficient S_{11} of a linearly polarized plane wave in normal incidence is reported (E vector parallel to y-axis, indicated as TE polarization). The structure introduces a notch at 2.46 GHz (-28 dB), which means that waves from the Bluetooth, Wi-Fi WLAN and LTE bands are absorbed with the use of this design. In the TM case, the same behavior is noticed (at 2.46 GHz, but with -25 dB).

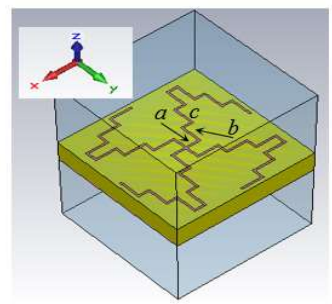

Fig. 1. CAD model and geometrical parameters of the unit cell

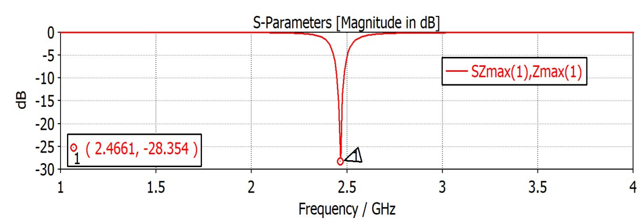

Fig. 2. Reflection coefficient, TE polarization

A. Sensitivity to angle of incidence

To assess the sensitivity with respect to the angle of incidence of the electromagnetic plane wave, a parametric study on the structure in Fig. 1 has been performed. Due to symmetry of the structure with respect to the center of the unit cell, only variation of reflection coefficient with the colatitude angle has been considered.

In Fig. 3 results of parametric variation of the reflection coefficient with the colatitude angle (theta) have been reported for TE case. This parameter has been varied between 0 and 60º in 5 steps. Consistency can be seen in TE mode up to 60º, the reflection coefficient being smaller than -10 dB for these incidence angles. This represents the S_{11} parameter for the case when the electric vector of the incident wave is parallel with the *y*-axis of the coordinate system in Fig. 1. Next, the S_{11} parameter for the case when the electric vector of the incident wave is parallel with the *x*-axis of the coordinate system in Fig. 1 was investigated, which represents the TM polarization. Similar results have been obtained (not reported).

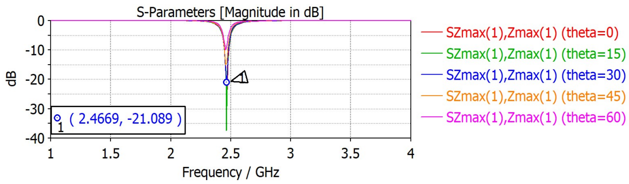

Fig. 3. Parametric study for angle of incidence theta, TE incidence

III. Parametric Studies

A. Substrate thickness

A parametric study was performed for the structure in Fig. 1, as concern the variation of the FR4 substrate thickness. The modification of the substrate thickness changes the length of the wave path within the structure and impacts the frequency response. As reported in Fig. 4, by modifying this parameter by considering values of 1.4, 1.6, 2, 2.6, 3.2 mm for the substrate of the FSS with the unit cell represented in Fig. 1, a second notch is introduced around 7 GHz, while the notch at 2.46 GHz diminishes.

For example, if the substrate thickness is decreased to 1.4 mm and all other dimensions are kept constant, then the FSS acts as an absorber at a frequency of 7.29 GHz (Fig. 5). However, the reflection coefficient is below -10 dB only up to an incidence angle of 45° for TE polarization (Fig. 6), but over 60° for TM case.

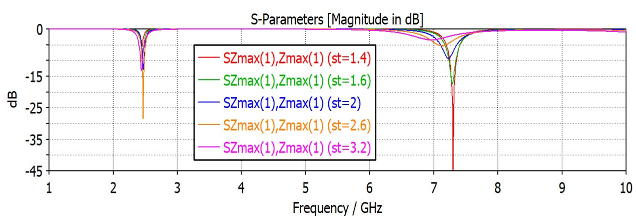

Fig. 4. Parametric sweep for the substrate thickness *st*.

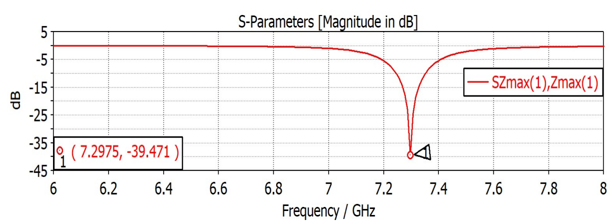

Fig. 5. Reflection coefficient, *st*=1.4mm, TE incidence.

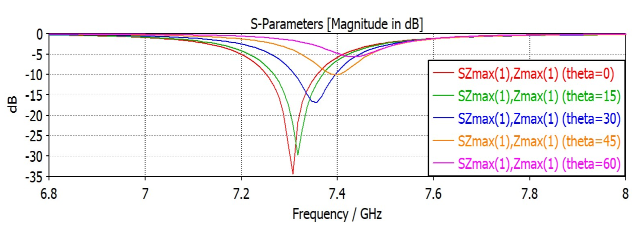

Fig. 6. Parametric study for angle of incidence theta, TE case, *st*=1.4.

B. Variation of other parameters

Variation of the geometrical parameters of the structure allow for the fine-tuning of the absorber. Firstly, we have varied the width *w* of the copper traces that make the pattern of the unit cell. Results plotted in Fig. 7 indicate a modification of the central frequency between 2.44 and 2.50 GHz for a variation of *w* between 0.2 and 1 mm. Secondly, variation of the parameter *a* between 0.5 and 2 mm modified the notch frequency in the range 2.47-2.59 GHz.

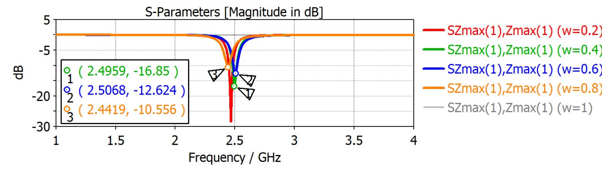

Fig. 7. Parametric variation of the trace width *w* of the initial design.

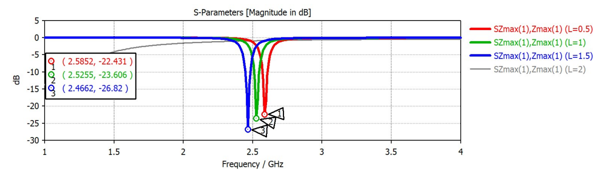

Fig. 8. Parametric variation of the dimension *a* in the initial design.

IV. Conclusions

An absorber relying on an FSS built on an FR4 substrate has been proposed in this paper. One side of the substrate has been covered with a periodic pattern having a square-shaped unit cell, the other side being the ground plane. The patterns consisted of four symmetrical "leaves" that ensured a response insensitive to the variation in the azimuthal direction of the incident waves. Correct operation of the absorber up to an angle of 60° has been demonstrated by simulation. Various parametric studies have been carried over in order to assess the flexibility of the design. Both gross- and fine-tuning of the operation frequency have been demonstrated.

Acknowledgment

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References

[1] B. A. Munk, Frequency Selective Surfaces: Theory and Design, NJ: Wiley, 2000.

[2] R.S. Anwar, L. Mao, H. Ning, “Frequency Selective Surfaces: A Review,” Appl. Sci., vol. 8, pp. 1-47, 2018.

[3] A.K. Singh, M.P. Abengaonkar, S.K. Koul, “Dual- and Triple-Band Polarization Insensitive Ultrathin Conformal Metamaterial Absorbers With Wide Angular Stability,” IEEE Trans. on Electrom. Compat., vol. 61, no. 3, pp. 878-886, June 2019.

[4] X. Xiu, W. Che, W. Yang, “Low-Profile Dual-Polarization Frequency-Selective Rasorbers Based on Simple-Structure Lossy Cross-Frame Elements,” IEEE Antennas Wireless Propag. Lett., vol. 17, no. 6, pp. 1002-1005, June, 2018.

[5] S. Ghosh, K.V. Srivastava, “A Polarization-Independent Broadband Multilayer Switchable Absorber using Active Frequency Selective Surface,” IEEE Antennas Wireless Propag. Lett., vol. 16, pp. 3147-3150, 2017.

[6] CST, Computer Simulation Technology (v2021), www.3ds.com.