Two-layered Dual-band Perfect Metamaterial Absorber at K band Frequency

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Abstract

This paper presents a study of a novel absorber structure based on two-dielectric-layers, two perfect absorption frequency bands at K band (f_1 = 26.5 GHz and f_2 = 28.6 GHz) go under observance. The study of the dependence of absorption and frequency on a relative distance between the layers of material and the material structure parameters are discussed.
Key word: metamaterial, absorber, reflection, two-layer.

1. Introduction

Perfect metamaterial absorber for different frequency bands or for a wide frequency range is an important topic in the field of new materials. This kind of material possesses special electromagnetic properties that do not appear in conventional materials [1-3], which is why metamaterials may offer potential applications in military and advanced technologies. The ability of this metamaterial in controlling electromagnetic waves or optical properties can help developing many applications such as biosensors, super lens, shielding room or improving the performance of solar cells and antennas [1,4-8] and in particular, the possibility of metamaterial changing the direction of the electromagnetic wave that can lead to the applications of electromagnetic cloaking and invisible objects [9-11]. Along with this development, the absorber metamaterials have been attracting a lot of research groups worldwide by its potential applications in absorbing the electromagnetic wave and in its possibility for the graphene perfect absorbers [9-13].

Some common problems of absorbing material are the complex structure, the dependence of absorption parameters on the structural parameters and the narrow absorption bands. In order to create multi-band absorbing structures or extend the frequency range, currently, lots of methods such as combining the multi-size structure or using multi-cell, combined layer structure are being studied [5,7,10]. This study presents first an investigation into a two-layered structure that provides two clearly independent absorption peaks at K band of 26.5 GHz and 28.6 GHz with the absorbance reaches 99%. The numerical results of the investigation indicated a strong dependence of the structural parameters on the performances of the structure.

2. Simulation and results

The structure composes of two layers as shown in figure 1. The optimized dimensions for a unit cell in the simulation are a = b = 10 mm, c = 2 mm, the cross structure of each layer is made of copper (the electric conductivity of the copper piece is 5.96×10^7 Sm^{-1}) with the thickness of 0.03 mm for the simulation. The dielectric layer is FR4 (ε = 4.3, $\tan\delta$ = 0.025) with the thickness of 0.4 mm. The two layers are of the same dimension and the distance between them is set at h = 0.75 mm. The upper layer has no ground plane while the bottom layer has a copper ground plane that covers entirely the backside of the structure. We use software package CST- Microwave Studio based on finite integration technique for the simulation. By setting the boundary conditions of electrical and magnetic wall fields for the structure, the simulation results obtained reflect the electromagnetic response of an unlimited periodical metamaterial structures.

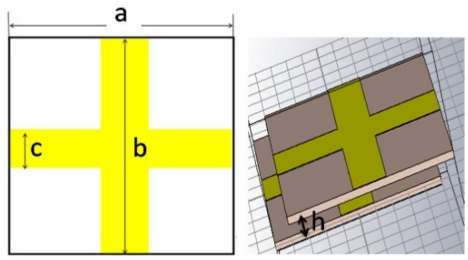


Figure 1: Unit cell of the absorber structure in simulation.

Figure 2 shows the results of the absorption peaks of optimized structure, the absorbance reached over 98% at the peak of the frequency of 26.5 GHz and 99% at the frequency of 28.6 GHz. The energy of absorbing electromagnetic waves in this case transformed into heat energy in the material and two resonance mechanism, when two resonances overlap, the power absorption efficiency reaches the maximum [2,3].

For the metamaterial, the small changes in size or allotropies could lead to major changes in the physical or electromagnetic properties of structures. To better understand the effects of the structural parameters, the following study presents the results of calculations obtained when changing the important parameters in the circuit, such as the distance h, the dimensions of the metal cross structure and the polarization angle of the incident wave. These results are presented in Figure 3, Figure 4 and Figure 5 respectively. Note that in our analysis, "absorption peak" means that at this position, the reflection of the structure reaches the minimum, so it was also the location of a "minimum reflection point" on the figures.

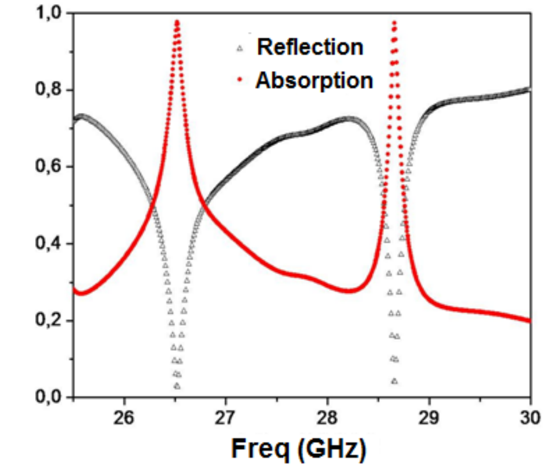


Figure 2: The reflection and absorption of two-layer absorber structure.

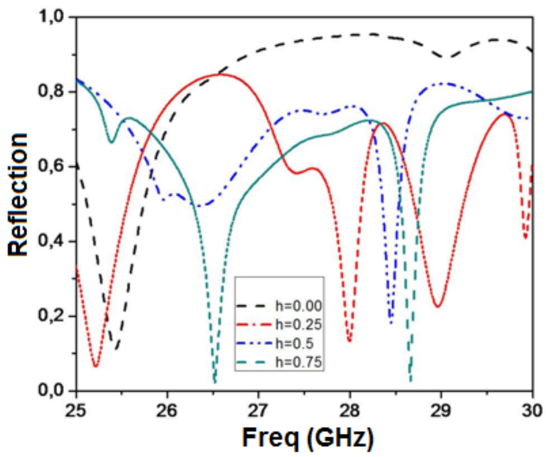
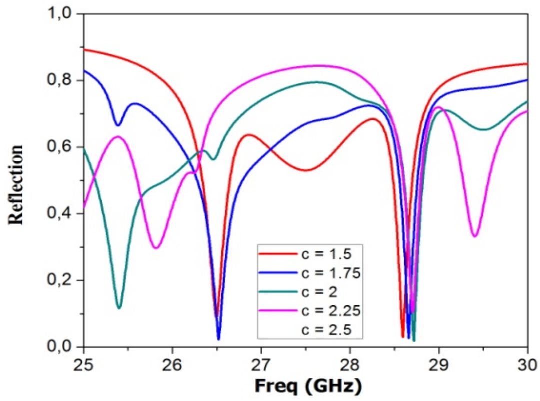


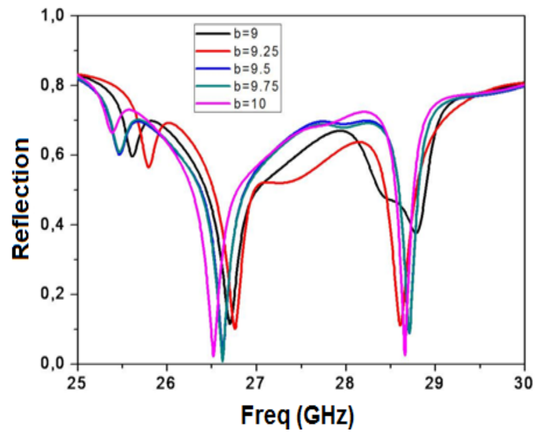
Figure 3: The dependence of absorption frequency on the distance *h*.

Figure 3 shows that the absorption frequencies depend strongly on the distance between the top layer and bottom layer h. When h increases, the new absorption peaks appear and the absorption frequency augments. This can be explained by the interference of electromagnetic waves between two layers of the structure. An increase in the distance may provide a good condition for the wave interference, which causes the resonance of the frequency at the absorption peaks.

For the study of parameter b, when b increases from 9 to 10 mm with the step of 12.25 mm, the first and second peak (from the left of the figure) have shifted toward high frequency, the third peak almost does not depend on the parameter b except when the value of b is 9 mm (Figure 4a). This can be explained that when the value of b is small, the equivalent value of the circuit has a strong effect, causing a remarkable change in resonant frequency. Figure 4b presents the dependence of absorption frequencies on the parameter c. It is observed that effect is more clear in the case when c increased. This can be explained similarly as in the case of parameter b. The change of c dimension causes an increase of the equivalent inductance which affects strongly on the resonance frequency.



(a)



(b)

Figure 4: The dependence of absorption frequency on the (a) parameter *b* and (b) parameter *c*.

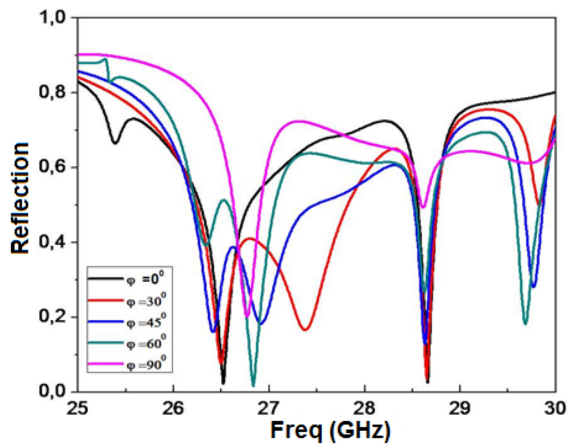


Figure 5: The dependence of absorption frequency on the

polarization angle.

Figure 5 shows the dependence of absorption frequency on the polarization angle φ from 0 to 45o. We see that the absorbance of the structure is not strongly dependent on the angle of incidence caused by the symmetric property of the studied structure. However, a new peak appears around 27 GHz, which could be due to the minimal shift between two layers of the structure in the simulation setup.

3. Experiment

To validate the simulation, an absorption measurement was carried out. The prototype of the two-layer structure was realized using standard photolithography method. Figure 6 shows the prototype of one layer after the fabrication. The optimized two-layer case absorption is measured using two working horn antennas in the absorption frequency range. These antennas are connected to a network analyzer (Anritsu 37369D) and measured in free air.

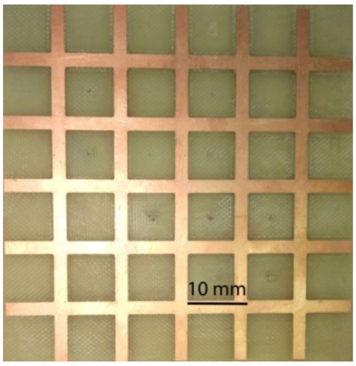


Figure 6: Prototype of one layer fabricated structure.

The comparison of the simulation to the experiment is shown in Figure 7. We see a good correspondence between the results obtained, however, differences in frequency and absorption levels are also observed. This can be explained by the imperfections of the realization, the inaccuracy of permittivity of the material, and the uncertainties ensued in the measurement.

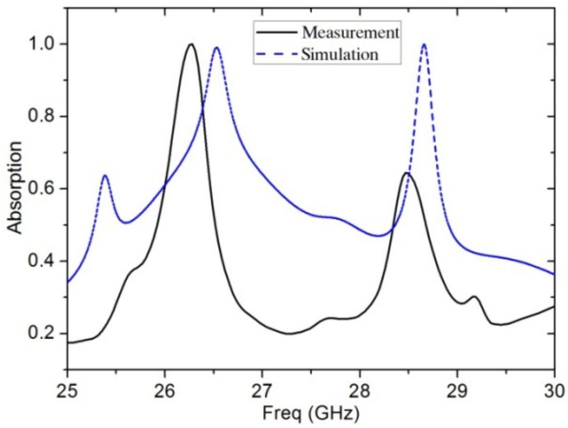


Figure 7: Results of measurement and simulation of the two-layer structure.

4. Conclusion

In this study, we presented the dual-band perfect absorption properties of a metamaterial structure with the optimal dimension of the two-layer structure at K band. The study showed the influence of structural parameters on the absorption properties of the absorber metamaterial structure. This study also showed the new suggestion of the method for altering the frequency characteristics of the absorber metamaterial by intervention the geometry and the configuration of the structure. The experimental results are in good agreement to the simulations.

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