Investigating a Dual-Band THz Metamaterial Absorber

Shourya
Shouryasingh7001@gmail.com
M. Tech Scholar, Department of Electrical & Electronics Engineering, BRCM CET, Bahal, (Haryana), India
Dr. Vivek Kumar
hodeee@brcm.edu.in
Professor & Head, Department of Electrical & Electronics Engineering, BRCM CET, Bahal, (Haryana), India

ABSTRACT

The work has been carried out in this paper is to investigate the design aspects and the overall response of a dual-band metamaterial absorber operating in the terahertz range of frequencies. The novel simple structure is based on simple circular shape resonator and has not been proposed before. By combining the resonator material on the top layer, a dual-band absorption in the terahertz regime has been realized here and reported in this paper. A structure that can create dual absorption bands in the terahertz regime is also suggested in order to construct an adjustable high-absorption multiple bands metamaterial absorber that will be useful in many engineering sectors, such as detecting and terahertz imaging. The structural configurations can be changed to change the number of resonance bands in the output.

Keywords: THz, MTM, Metamaterial, Absorber

INTRODUCTION

The characteristics of the metamaterials can be carefully controlled to steer, reroute, concentrate, absorb, and reflect the impinging electromagnetic waves in various ways. For EM clocking, flawless absorbers, energy harvesting, and imaging beyond the diffraction limit, such exact control of EM waves has been achieved. One of the most well-known examples of metamaterials that use artificial electric and magnetic resonance (electric permittivity, or 0, and magnetic permeability, or 0, respectively) to realise a negative refractive index is negative refractive index metamaterials, also referred to as left-handed metamaterials [3, 4]. A new class of applications, including flat lenses, invisibility, and beyond-diffraction imaging, were created as a result of this finding. High impedance surfaces are another form of metamaterial. They are made of layers of metal and dielectric thin films, and their geometrical shapes and dimensions are carefully managed to display desirable qualities including phase shifting and frequency selective responses [5]. Particularly when the effective surface impedance of a high impedance surface equals the free space impedance, one can achieve total absorption at the desired wavelength [6]. The effectiveness of these metamaterials, also known as metamaterial perfect absorbers, has been demonstrated throughout a significant section of the electromagnetic spectrum, from microwaves to the optical regime. Metamaterials can exhibit extraordinary electromagnetic phenomena due to the diversity of subwavelength components they possess. The unique properties of metamaterials are produced by the subwavelength components' resonances. A material's ability to propagate waves is determined by its conductivity, magnetic permeability, and dielectric permittivity.

ABSORBER DESIGN

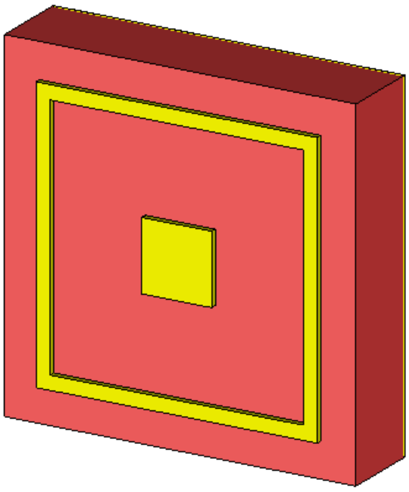

Figure 1. Absorber Multi-layer Structure Design

An effective surface layer and a bottom magnetic ground plane make up the ideal terahertz nanocomposite absorber, which is shown in Figure 1 and is divided into these two components by an exclusion material spacer. The top metallic layer contains two distinct resonant structures, as shown in Fig. 1. The first is a main metallic square resonator, and the second is a secondary metallic SRR frequency of vibration that surrounds the first (a). Due to their high coupling to uniform electric fields and poor coupling to magnetic fields, which leads to two separate frequency dependent electric responses, the two resonators may be thought of as a novel type of electric ring resonator (ERR). On the other hand, a metallic ground plane serves as a conduit for the electromagnetic portion of an EM wave to travel between two resonators, and couple strongly to uniform electric fields and weakly to the magnetic fields, providing two different frequency dependent electric responses $\varepsilon 1(\omega)$ and $\varepsilon 2(\omega)$. However, by combining two resonators with a metallic ground plane, the magnetic component of EM wave couples between two resonators and the ground plane, thus generating two different antiparallel currents resulting in two different frequency dependent magnetic responses $\mu 1(\omega)$ and $\mu 2(\omega)$. The impedance of the absorber can be approximated toward the wave impedance of free space by altering the amplitude and phase region of the electric response and matching magnetic response, resulting in the minimal reflectance at a certain frequency. Furthermore, the metallic bottom layer is thicker than the terahertz wave penetration depth, and the absorber transmission is zero. and provide two distinct frequency dependent electric responses, which couple strongly to homogenous electric fields and weakly to magnetic fields. But when two resonators and a metallic ground plane are combined, the magnetic component of the EM wave couples between the two, producing two distinct antiparallel currents that lead to two distinct frequency-dependent magnetic responses. By adjusting the amplitude and phase region of the electric response and matching magnetic response, the impedance of the absorber may be roughly compared to the wave impedance of free space, producing the least reflectance at a specific frequency. The absorber transmission is zero, and the metallic bottom layer is thicker than the depth of terahertz radiation penetration. As a combination of these two criteria, such metamaterial may enhance productivity and dual-band terahertz absorber. The FDTD method was used to determine the electromagnetic parameters of the absorber with the periodic boundary conditions appropriately specified and the radiation pattern transverse to the absorber plane.

RESULTS & DISCUSSION

By adjusting the electromagnetic resonances individually, we may create a condition where the absorber is equivalent circuit to the free space value in a particular region. The absorber may strongly couple with and absorb the EM wave when they concurrently share a center resonant frequency.

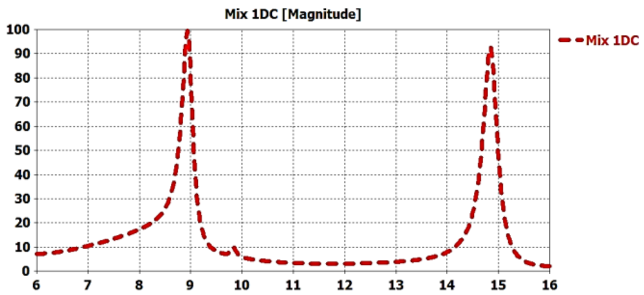

Figure 2. Proposed Absorber's Dual-Band Absorption Response

Electromagnetic metamaterials are artificially structured materials with subwavelength-sized composite arrays of resonant structures which cannot be found in nature. The geometrical configuration of each individual unit cell controls its electromagnetic properties. By carefully designing the structure, metamaterials can display electric and magnetic resonances at specific frequencies, which has attracted incredible attention.

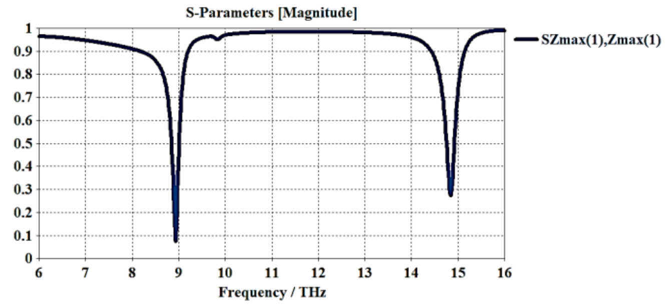

Figure 3. Proposed Absorber's Reflection Curves

The materials that transform the incident EM waves into various types of energy, such as heat or electrical currents, are referred to as EM wave absorbers. They minimise the absorption within the absorber by high inherent loss or appropriate engineering of optical characteristics while suppressing the reflection, transmission, and scattering of the incident waves. Depending So, the absorption equation can be altered to the following:

$$A(\omega) = 1 - R(\omega)$$

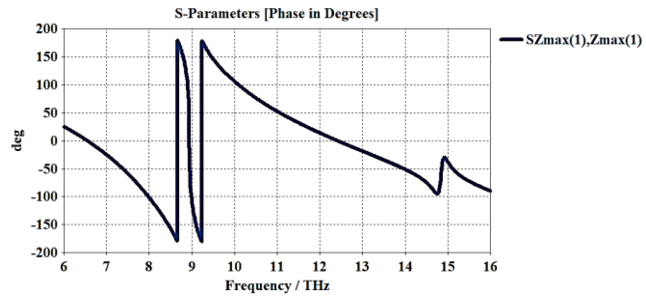

Figure 4.: Proposed Absorber's Phase of Reflection Curves

CONCLUSION

A hypothesised and created thin terahertz absorber with substantial absorption at frequency near 8.94and 14.84 THz is discussed in conclusion. In accordance with design intent, the absorber is insensitive to incident waves with both TE and TM polarisation. It was found that the permanent dipole and hexapolar resonant frequencies are the physical origins of the characteristics presented by this absorber by looking at the electrical field density. Investigations were also done into how the principal structural designs and other elements affected the absorption frequencies.

REFERENCES

[1] W. Dallenbach and W. Kleinsteuber, "Reflection and absorption of decimeter-waves by plane dielectric layers," Hochfreq. u Elektroak, vol. 51, pp. 152–156, 1938.

[2] W. W. Salisbury, "Absorbent body for electromagnetic waves," jun 1952

[3] J. Pendry, A. Holden, W. Stewart, and I. Youngs, "Extremely low frequency plasmons in metallic microstructures," Physical Review Letters, vol. 76, no. 11, pp. 4773–4776, 1996. [Online].

[4] D. R. Smith, "Metamaterials and Negative Refractive Index," Science, vol. 305, no. 5685, pp. 788–792, aug 2004. [Online].

[5] S. B. Glybovski, S. A. Tretyakov, P. A. Belov, Y. S.Kivshar, and C. R. Simovski, "Metasurfaces: From microwaves to visible," Physics Reports, vol. 634, pp. 1–72, 2016. [Online].

[6] N. Engheta, "Thin absorbing screens using metamaterial surfaces," in IEEE Antennas and Propagation Society International Symposium (IEEE Cat. No.02CH37313), vol. 2, no. June. IEEE, 2002, pp. 392–395. [Online]. Available: http://ieeexplore.ieee.org/document/1016106/

[7] A. Alu, A. Salandrino, and N. Engheta, "Parallel, series, and intermediate interconnections ` of optical nanocircuit elements 2 Nanocircuit and physical interpretation," Journal of the Optical Society of America B, vol. 24, no. 12, p. 3014, dec 2007. [Online].

[8] H. Luo, Y. Z. Cheng, and R. Z. Gong, "Numerical study of metamaterial absorber and extending absorbance bandwidth based on multi-square patches," European Physical Journal B, vol. 81, no. 4, pp. 387–392, 2011.

[9] C. Sabah, F. Dincer, M. Karaaslan, E. Unal, O. Akgol, and E. Demirel, "Perfect metamaterial absorber with polarization and incident angle independencies based on ring and cross-wire resonators for shielding and a sensor application," Optics Communications, vol. 322, pp. 137–142, 2014. [Online]. Available: http://dx.doi.org/10.1016/j.optcom.2014.02.036

[10] F. Hu, Y. Qian, Z. Li, J. Niu, K. Nie, X. Xiong, W. Zhang, and Z. Peng, "Design of a tunable terahertz narrowband metamaterial absorber based on an electrostatically

actuated MEMS cantilever and split ring resonator array," Journal of Optics, vol. 15, no. 5, p. 55101, 2013. [Online].