International Journal of Engineering and Management Research
e-ISSN: 2250-0758 | p-ISSN: 2394-6962
https://ijemr.vandanapublications.com

Peer Reviewed & Refereed Journal
Volume-14, Issue-2 (April 2024)
https://doi.org/ 10.5281/zenodo.10970991

Polarization Insensitive Ultra-Wideband ITO Coated PET Based Metamaterial Microwave Absorber

Krishangopal[1], Deepak Sood[2] and Monish Gupta[3]
[1]University Institute of Engineering & Technology, Kurukshetra University, Kurukshetra, Haryana, INDIA
[2]University Institute of Engineering & Technology, Kurukshetra University, Kurukshetra, Haryana, INDIA
[3]University Institute of Engineering & Technology, Kurukshetra University, Kurukshetra, Haryana, INDIA

[2]Corresponding Author: deepaksood.uiet@gmail.com

Received: 05-02-2024 Revised: 02-3-2024 Accepted: 12-04-2024

ABSTRACT

In this paper, an ultra-wideband compact flexible polarization-insensitive metamaterial microwave absorber is proposed. Transparent PET (polyethylene terephthalate) was used as the dielectric substrate and ITO (indium tin oxide) is used as the conductor for the air and metamaterial structure. The intended absorber provides above 90% absorption in the range of 8.28 GHz to 17.18 GHz under normal incidence. The designed absorber exhibit 80% absorption at oblique angles of incidence. The unit cell size of designed absorber is 0.51λ × 0.51λ w.r.t the center frequency of absorption band. In addition, the designed structure is polarization insensitive absorber as it exhibit the same absorption performance in both TE and TM polarization under the normal incidence of the electromagnetic wave. The study was carried out as a simulation in the HFSS simulator. The results obtained were compared with other reference studies.

Keyword-- Transparent, Ultra-thin, Metmaterial Absorber, Flexible, Wide-band

I. INTRODUCTION

In recent years, importance of metamaterials/metasurfaces increased in device design from microwave to optical regime due their superior properties like negative permittivity and permeability [1]. The metamaterial absorber has attracted common attention due to its promising applications, such as sensors [2], energy harvesting [3–6], thermal emitters [7], modulators [8] and antennas[ ] etc. The sandwich like structure having periodically arrayed metal pattern layer, a dielectric spacer, and a flat metal plate, is one of the traditional design for metamaterial absorbers. There are various absorber applications to use in civil and military radars. In these applications, aim is to reduce the radar cross sectional (RCS) in order to prevent the detection of the target. The first metamaterial absorber designed by Landy inspired the use of metamaterials as absorber [9]. Moreover, various metamaterial absorbers ranging from microwave [9], terahertz [10], infrared and visible bands [11], are proposed and investigated. Different absorbers with single band [12], dual band [13], or multi-band [14] have been designed and studied till date. Further, various metamaterial designs exhibiting broadband absorption are designed so far [15] such as by assembling multi-shaped resonators on the same layer [16-17], by stacking layers [18-19] which makes the device bulky or complex to fabricate. Therefore, the broadband metamaterial absorbers using resistive films have been realized. The indium tin oxide (ITO) based metamaterial absorbers are used as promising alternative with the advantage mechanically flexible, optically transparent, and conductive properties [20-21]. The PET coated ITO based metamaterial absorber simultaneously achieve strong microwave absorption and shielding performance over an ultra-wide microwave region with thinner thicknesses, lighter weights, optically transparent, and wider bandwidths.

In this paper, a design of polarization insensitive flexible ultra-wideband metamaterial absorber based on multilayer ITO resistive patterns films is proposed. A wideband absorption of more than 90% from 8.28 to 17.18 GHz is obtained. The designed absorber is polarization-insensitive with high absorption of above 90% over a wide incidence angle of 30° for both TE and TM polarizations. Optimized parameters corresponding to high-performance absorption are achieved by adjusting ITO coated PET layers and pattern resonances. In comparison to previous reports, our structure exhibit wideband-absorption, polarization-insensitivity in compact size.

II. THEORY AND DESIGN

The schematic of the unit cell of the designed transparent ITO coated PET based metamaterial absorber is shown in Fig. 1. In overall, the design consists of five layers. The top and bottom layers are of ITO with 0.18 μm thickness. The design is patterned on the top ITO resistive layer coated on 0.175mm thick PET substrate layer. The bottom continuous ITO plate is backed by PET. The

Peer Reviewed & Refereed Journal
Volume-14, Issue-2 (April 2024)
https://doi.org/ 10.5281/zenodo.10970991

dielectric constant of PET is εr = 3:2 and the loss tangent is σ = 0.003. The middle part in between the two PET layers consists of an air gap of thickness of 5.83 mm. The bottom continuous ITO layer blocks electromagnetic wave transmission thereby supports better absorption characteristics. The other geometric parameters of the unit cell are as follows: L = 12mm, R1 = 5.5 mm, R2 = 4 mm, W = 0.5 mm, g = 1mm.

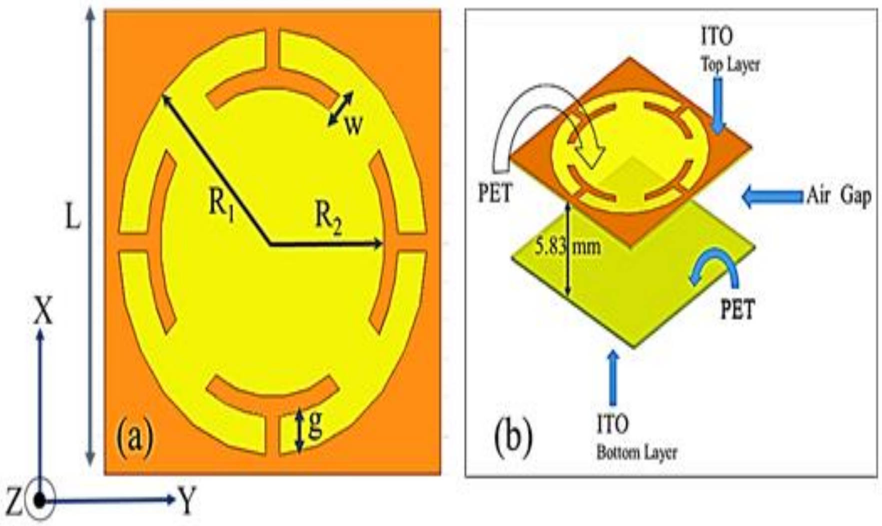

Figure 1: (a) Front view and (b) cross-sectional view of the proposed design

HFSS is used to simulate and optimize the absorption performance of the proposed absorber. The periodic boundary conditions are applied along with the X and Y directions in TE mode. The absorption is evaluated using

$$A = 1 - |S11|^2 - |S21|^2 \qquad (1)$$

In Eq. 1 S11 and S21 represents the reflection coefficient and the transmission coefficient respectively, both of which are obtained through simulation. The simulated absorption, reflection, and transmission responses of the designed absorber are shown in Fig. 2. The transmission coefficient S21 is nearly zero as the bottom ITO layer acts as a perfect reflecting surface. Therefore, the above equation can be reformulated as $A = 1 - |S11|^2$. The proposed absorber exhibit more than 90% absorption from 8.28 GHz to 17.18 GHz under normal incidence. The bandwidth reaches 8.9 GHz, and the corresponding relative bandwidth is 70%.

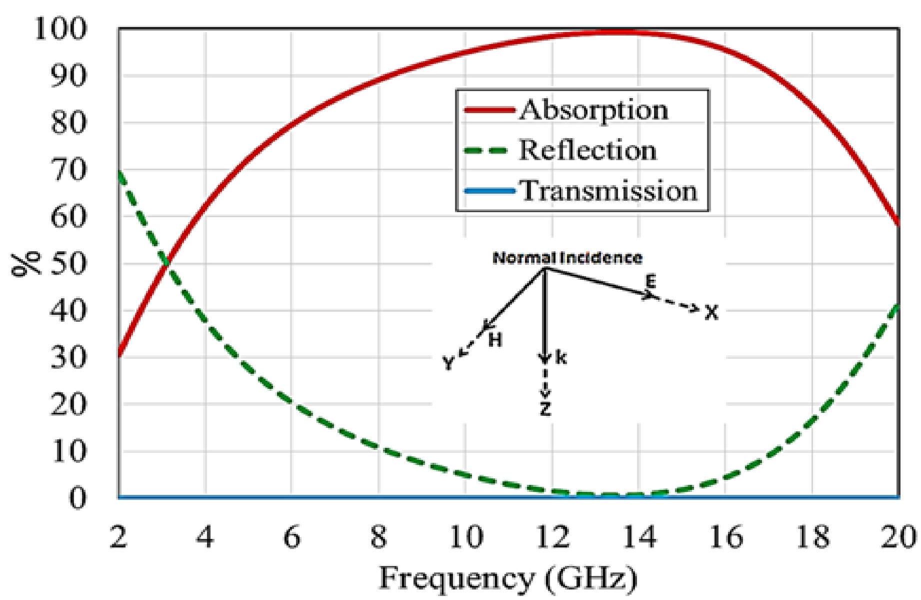

Figure 2: The simulated S_{11}, S_{21} and absorption response for normal incidence of TE-polarization.

III. RESULTS AND DISCUSSION

The design configuration of the structure is fourfold symmetric. For the verification of polarization insensitive behavior, the designed absorber is studied for different angles of polarizations (φ) at regular intervals of 15^0 up to 45^0 as shown in Fig. 3. The absorption response is observed as same for angles and exhibit above 90% absorption from 8.28 to 17.18GHz. For both TE and TM polarizations the absorption performance of the design is studied at different angles of incident wave. For both the polarizations i.e. TE and TM the absorption is same as shown in Fig. 4 and Fig.5. The structure exhibit high absorption over the large frequency range up to 30^0 which proves its angular insensitivity up to 30^0 i.e. the absorber provides wideband absorption for variations in incidence angles of the wave. To explore the physical mechanism of absorption the electric and magnetic field distribution at center frequency i.e. 12.73 GHz is studied. High electric field at the split ends of the structure is noticed and magnetic field is high near the joint parts of the two structures of the design. This shows strong electromagnetic field distribution across the design and thereby results strong absorption.

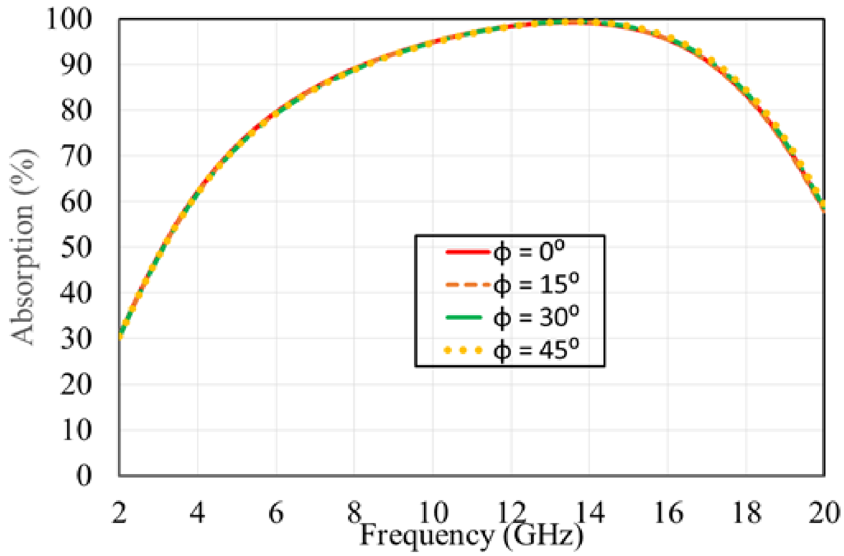

Figure 3: Absorption response of the designed structure at different polarization angles.

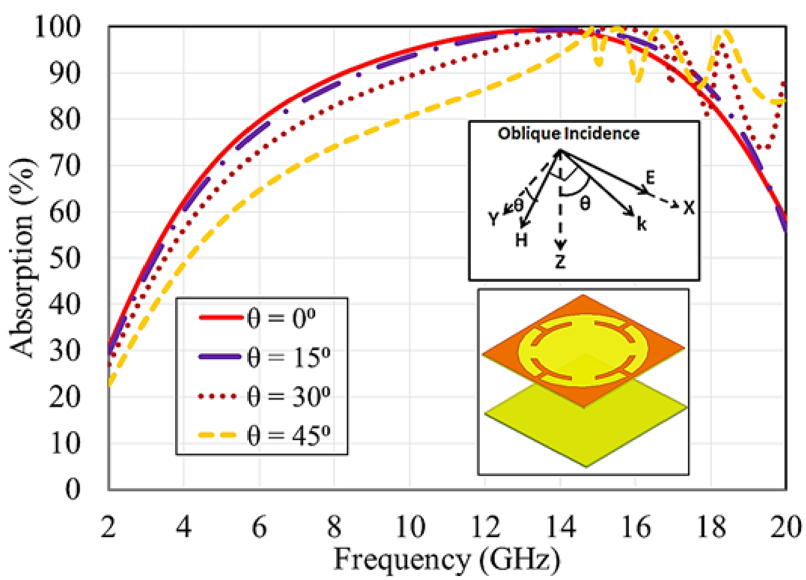

Figure 4: Absorption response for oblique incident angles for TE Polarization.

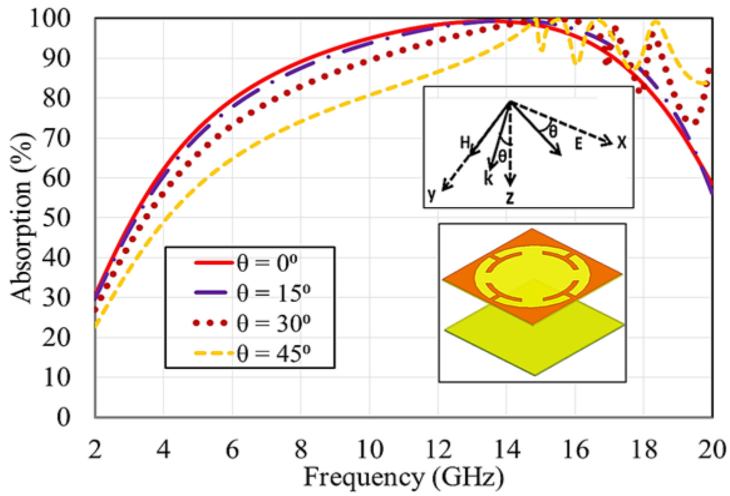

Figure 5: Absorption response at oblique angles of Incidence for TM Polarization.

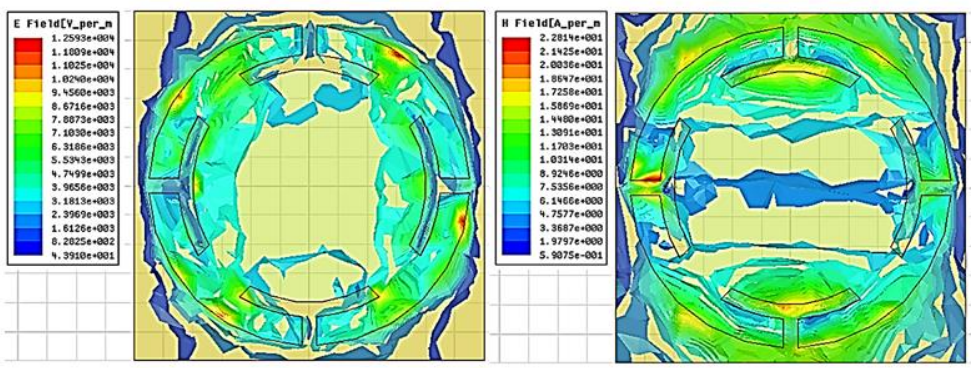

Figure 6: Field distribution of the designed absorber at 12.73GHz.

IV. CONCLUSIONS

In conclusion, an ITO coated PET based ultra-wideband polarization insensitive flexible metamaterial absorber is proposed. The absorber exhibits above 90% absorption range of 8.28 to 17.18 GHz, X and Ku microwave bands. The absorber is polarization-insensitive and exhibits high absorption over a wide incidence angle of 30° in both TE and TM polarization. The physics mechanism of absorption is discussed by analyzing the electric and magnetic field distribution. This study proposes a general way to achieve a wide-band flexible metamaterial absorber which further opens new paradigms in the area of RF engineering.

REFERENCES

[1] Adnan Ali, Anirban Mitra. & Brahim Aïssa. (2022). Metamaterials and metasurfaces: A review from the perspectives of materials, mechanisms and advanced meta devices. *Nanomaterials, 12*, 1-32.

[2] L. La Spada, F. Bilotti. & L. Vegni. (2011). Metamaterial-based sensor design working in infrared frequency range. *Progress in Electromagnetics Research B, 34*, 205–223.

[3] Z. Chen, B. Guo, Y. Yang, & C. Cheng. (2014). Metamaterials-based enhanced energy harvesting: A review. *Physica B: Condensed Matter, 438*, 1-8.

[4] X. Xu, Q. Wu, Y. Pang, Y. Cao, Y. Fang, G.Huang. & C. Cao. (2022). Multifunctional metamaterials for energy harvesting and vibration control. *Advanced Functional Materials, 32*, 1-6.

[5] J. Zhou; P. Zhang; J. Han, L. Li. & Y. Huang. (2022). Metamaterials and metasurfaces for wireless power transfer and energy harvesting. *Proceedings of the IEEE, 110*, 31-55, (DOI: 10.1109/JPROC.2021.3127493).

[6] C. Fowler, S. Silva, G. Thapa. & J. Zhou. (2022). High efficiency ambient rf energy harvesting by a

metamaterial. *Perfect Absorber, 12*(3), 1242-1250.

[7] R. D. Innocenti, H. Lin. & M. N. Cía. (2022). Recent progress in terahertz metamaterial modulators. *Nanophotonics, 11,* 1485–1514.

[8] Y. Li, W. Li,, T. Han, X. Zheng, J. Li, B. Li, S. Fan. & C.W. Qiu. (2014). Transforming heat transfer with thermal metamaterials and devices. *Journal of Optics, 16,* 035102.

[9] N. I. Landy, S. Sajuyigbe, J. J. Mock, D. R. Smith. & W. J. Padilla. (2008). Perfect metamaterial absorber. *Phys. Rev. Lett., 100,* 207402.

[10] L. Huang & H. T. Chen. (2013). A brief review on terahertz metamaterial perfect absorbers. *Terahertz Science and Technology, 6.*

[11] J. Liu, W. Z. Ma, W. Chen, G. X. Yu, Y. S. Chen, X. C. Deng. & C. F. Yang. (2020). Numerical analysis of an ultra-wideband metamaterial absorber with high absorptivity from visible light to near-infrared. *Optics Express, 28,* 23748-23760.

[12] Z. Yin, Y. Lu, S. Gao, J. Yang, W. Lai, Z. Li. & G. Deng. (2019). Optically transparent and single-band metamaterial absorber based on indium-tin-oxide. *RF & Microwave Computer Aided Engineering, 29,* 1-5.

[13] J. Song, L. Wang, M. Li. & J. Dong. (2018). A dual-band metamaterial absorber with adjacent absorption peaks. *Journal of Physics D: Applied Physics, 51,* 385105.

[14] X. Z. Cheng, G. R.-Mei, D. C. Feng, Z. Y.Ting & Y. J. Quan. (2014). Multiband metamaterial absorber at terahertz frequencies. *Chinese Physics Letters, 31,* 054205.

[15] B. X. Wang, C. Xu, G. Duan, W. Xu & F. Pi. (2023). Review of broadband metamaterial absorbers: From principles, design strategies, and tunable. *Properties to Functional Applications, 33,* 2213818.

[16] W. Ma, Y. Wen & X. Yu, (2013). Broadband metamaterial absorber at mid-infrared using multiplexed cross resonators. *Optics Express, 21,* 30724-30730.

[17] L. Ouyang, D. Rosenmann, D. A. Czaplewski, J. Gao & X. Yang. (2020). Broadband infrared circular dichroism in chiral metasurface absorbers. *Nanotechnology, 31,* 295203.

[18] X. He, S. T. Yan, Q. X. Ma, Q. F. Zhang, P. Jia, F.M. Wu. & J.X. Jiang. (2015). Broadband and polarization-insensitive terahertz absorber based on multilayer metamaterials. *Optics Communications, 340,* 44-49.

[19] M.R. Soheilifar. & R.A. Sadeghzadeh. (2015). Design, fabrication and characterization of stacked layers planar broadband metamaterial absorber at microwave frequency. *AEU - International Journal of Electronics and Communications 69,*126-132.

[20] K. Chaudhary, G. Singh, J. Ramkumar, S. Anantha Ramakrishna, K. V. Srivastava. & P. C. Ramamurthy. (2020). Optically transparent protective coating for ito-coated pet-based microwave metamaterial absorbers. In: *IEEE Transactions on Components, Packaging and Manufacturing Technology, 10*(3), 378-388. DOI: 10.1109/TCPMT.2020.2972911.

[21] G. Singh, B. Sharma, A. Bhardwaj, K. V. Srivastava, J. Ramkumar & S. A. Ramakrishna, (2021). Wrapping of curved surfaces with conformal broadband metamaterial microwave absorber," In: *IEEE Antennas and Wireless Propagation Letters, 20*(10), 1938-1942. DOI: 10.1109/LAWP.2021.3100917.