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# POLARIZATION INSENSITIVE, NON-METALLIC AND FLEXIBLE METAMATERIAL ABSORBER FOR X-BAND APPLICATIONS: DESIGN, FABRICATION AND CHARACTERIZATION

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**Abstract—***In this paper, an efficient metamaterial absorber composed of expanded graphite based conducting layer and unit cells, separated by a flexible dielectric substrate for X-band conformal applications is presented. Expanded graphite is easy to synthesis and can be used as unit cells and conducting layer. Linear Low Density Polyethylene (LLDPE) is processable, can develop to be used as substrate at X-band microwave frequency and consider for this study. Optimization of unit cell and the proposed absorber is carried out using CST Microwave Studio. The proposed absorber is showing excellent 98% absorption at its resonating frequency 10.6 GHz. Moreover, dependence of the proposed absorber on polarizations is also investigated. The proposed absorber possesses the advantages of being ultrathin, lightweight, flexible and corrosive resistance.*

**Keywords***: Flexible metamaterial absorber, LLDPE substrate, expanded graphite*

## 1. INTRODUCTION

In the last decade, metamaterial, also known as artificial material is one of the mostly invested and hot topics among the scientific community. They have gained special attention because of their unique properties like negative permittivity, negative permeability and negative refractive index and so on [1]. Because of these fascinating properties, the territory of metamaterial has been extended towards the applications like perfect metamaterial absorbers, metamaterial antennas, super lenses, energy harvesting device, sensors etc., where metamaterial absorbers are studied more extensively as electromagnetic interference (EMI) becomes more prominent now a days [2]. For common perspective, metamaterial absorbers are basically two dimensional array of conducting resonator structures fabricated on dielectric substrate, in which the absorber characteristics purely depend only on the resonator structures [3]. As compared to conventional EMI absorbers, metamaterial absorber possesses advantages like thin, light weight and freedom in unit cell designing [4]. Moreover, in metamaterial absorber, by properly tailoring the unit cells, composite material parameters i.e, permittivity and permeability can be deliberated to a desired value and hence, their impedance matching at the air-absorber interface, which is one of the most important points while designing an EMI absorber [5].

The first perfect matematerial absorber (MMA) was presented by Landy et al. at microwave frequency in 2008, based on Veselago and Pendry's theoretical and experimental work [6-9]. His perfect absorber, composed of electric ring resonator and cut wire, was capable of absorb all the incident EM waves at the resonating frequency by tuning the magnetic and electrical resonances independently. After the effective demonstration of Landy, different metamaterial absorbers have been developed and investigated in every frequency spectrum from radio, microwave, mm-wave, THz, MIR, NIR and optical [2]. However, in most of the reported work, metamaterials are fabricated on like, FR4, Silicon wafer substrate etc., using Copper, Gold metallic layers. These kinds of substrates make the absorber rigid and unsuitable for use on non-planar surfaces like redome, body worn applications and health monitoring devices etc. [10]. Moreover, unit cells made up of copper and gold make the absorber corrosive and costly.

In this paper, we propose a new approach of design and simulation details of a metamaterial absorber in X band microwave frequency made up of flexible LLDPE substrate using expanded graphite (EG) based unit cells. LLDPE substrate is flexible and lightweight, having low water absorption and high tensile strength. EG has almost same order of conductivity as copper and is selected for designing the unit cells.

## 2. DESIGN AND SIMULATION

Fig. 1 shows the prospective view of proposed absorber and the unit cell with the different geometric parameters in the inset. The unit cell consists of two conducting layers separated by dielectric LLDPE substrate of dielectric constant 2.2~2.4 at X band. Both, top and bottom layers made up of EG conducting layer having conductivity in the order of ~$10^6$S/m. The top layer is basically periodic resonators laminated over LLDPE substrate, while the bottom layer is continuous conducting layer.

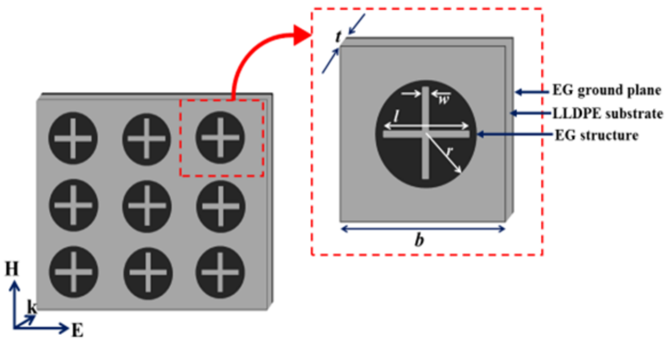



**Fig. 1: Schematic diagram of proposed absorber with the parameters in the inset**

Commercially available CST Microwave studio is employed for simulation and optimization of the proposed absorber. Unit cell boundary conditions are used in frequency domain solver to simulate the proposed absorber structure. Electric, magnetic fields and direction of propagation of the incident EM wave on the absorber are shown in the Fig.1. The optimized parameters of the unit cell are presented in the Table I.

**Table I: Optimized unit cell parameters**

| Unit cell parameters | Values (in mm) |
|---|---|
| Radius of the circle | 3.3 |
| Length of the cross patch | 6.0 |
| Width of the cross patch | 0.5 |
| Substrate thickness | 0.5 |
| Ground plane thickness | 0.1 |
| Lattice constant | 12 |

## 3. SIMULATED RESULTS AND ANALYSIS

The important parameter of an absorber is its absorption, $A(\omega)$, and is defined using the following formula [11],

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

Where, $R(\omega)=|S_{11}|^2$, and $T(\omega)=|S_{12}|^2$ are reflectance and transmittance of absorber respectively. From (1), it is seen that absorption can be maximize, by minimizing the reflectance and transmittance. Reflectance is minimized by matching the impedance at air-absorber interface i.e, matching the absorber impedance equal to free space impedance, while transmittance is minimized by putting conductive layer in the bottom side. Hence by proper matching and optimization, maximum absorption can be achieved. The simulated reflectance and absorbance of the designed absorber is presented in the Fig. 2. It is observed that the proposed absorber is showing 98% absorption at the resonating frequency 10.60 GHz and minimum reflection at the same frequency.

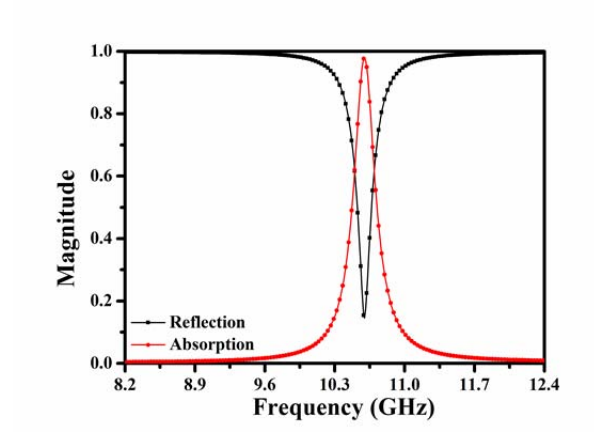
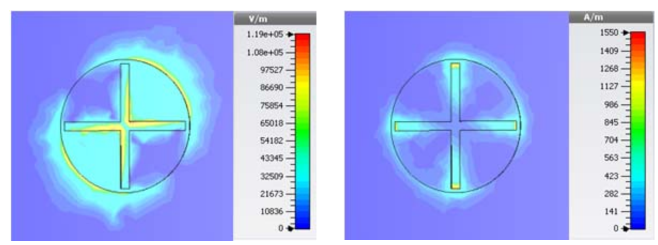



**Fig. 2: Reflection and absorbance of absorber**

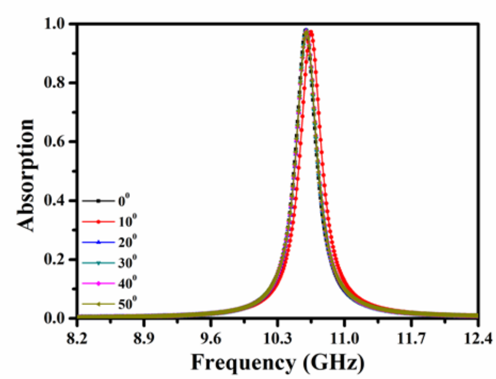
In order to understand the physical mechanism of the proposed metamaterial absorber, electric field and magnetic field are simulated at the resonating frequency 10.60 GHz. It is seen from the Fig. 3 that, electric field concentration is high at the middle corners of the cross structure, while magnetic field is high at the edge of the cross structure. These mean the separate portions of unit cells are independently responsible for electric and magnetic resonance.



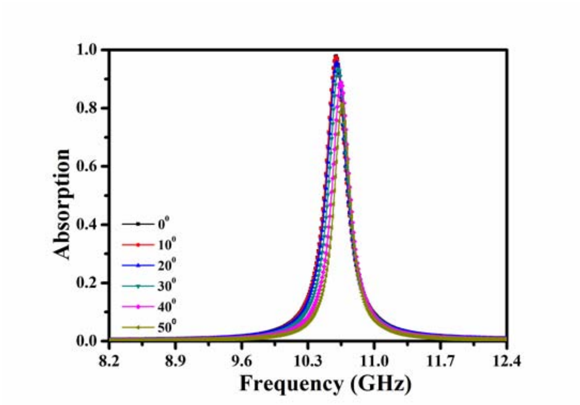

**(a)** **(b)**

**Fig. 3: E and H field concentration at 10.6 GHz**

Moreover, effect of polarization angles on characteristic absorption is also observed. Fig. 4 showing the dependence of absorption on polarization angles from $0^0$ to $50^0$ in a step size of $10^0$.




**(a)**




**(b)**

**Fig. 4: Absorption rates (a) TE incident (b) TM incident**

It is seen from the Fig. 4, for TE polarization wave, the magnitude of absorption are decreases with increasing the incident angles. However, the absorption is still more than 80%. It may be due to the fact that the magnitudes and phase shifts of reflection at the air absorber interface changes gradually with respect to those of normal incidence as the incident angle increases, resulting in the weakened overall absorption. But, for the TM polarized wave, the absorption is independent on incident angles, however a minor shift in resonating frequency. This is because, the unit cell structure is more insensitive to the TM wave [12].

## 4. CONCLUSION

In this paper, a flexible metamaterial absorber for conformal application has been successfully proposed, optimized and simulated. The absorber is showing excellent absorption of 98% at its resonating frequency 10.60 GHz. In order to fully understand the mechanism of absorbing features, we present the electric and magnetic field distributions of the absorber at the resonant frequency. Simulation is also performed to observe the dependency of absorption on TE and TM polarized wave. Considering the absorption and flexibility of the LLDPE substrate, this promising absorber has the potential to be used in different EM wave absorbing applications.

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