URSI - RCRS 2022, IIT (Indore), India, 1 - 4 December, 2022

Hexa Band Polarization-Independent Absorber For Terahertz and Lower Infrared Applications

Neti Sharma(1), Vikram Maurya(2), and Sarthak Singhal(3)
(1) Department of ECE, Malaviya National institute of technology, Jaipur, India, 2020pec5509@mnit.ac.in
(2) Department of ECE, Malaviya National institute of technology, Jaipur, India, 2021rec@mnit.ac.in
(3) Department of ECE, Malaviya National institute of technology, Jaipur, India, sarthak.ece@mnit.ac.in

Abstract

In this paper, a hexaband electromagnetic absorber for terahertz and infrared frequency spectrum applications is proposed. The proposed design consists of multiple ring-shaped slots loded metallic resonator, dielectric material and metallic ground plane. The overall volume of the proposed absorber unit cell is 10μm × 10μm × 1.61μm. It has six peaks at 3.17 THz, 7.13 THz, 11.53 THz, 19.58 THz, 21.8 THz and 23.83 THz with absorption peaks (> 90%) of 96%, 93%, 99%, 99.6%, 98.7% and 97.4% respectively. At each absorption peak, the FWHM is 0.32 THz, 0.77 THz, 1.28 THz and 6.61 THz respectively. The proposed absorber is symmetric in nature which makes the structure polarization independent. The proposed absorber dominates previously reported multiband Thz absorbers in terms of number of operating bands, FWHM, absorption peak values and overall volume.
Index Terms—Terahertz absorbers, Closed ring resonator, Electromagnetic absorber.

1. Introduction

An electromagnetic absorber neither reflects nor transmits the incident radiation. Therefore, the power of the impinging wave is mostly absorbed in the absorber materials. Generally, absorbers absorb those frequencies for which the resonating structure resonates. Salisbury screen [1] is the type of traditional absorber, its application is same as the metamaterial absorber but the problem with the salisbury screen is they are bulky and the bandwidth is very narrow. These drawbacks of salisbury screen restrict their use in many applications. To overcome these problems another way is constructing a metamaterial perfect absorber [2] whose thickness is very less and we can change its bandwidth by changing the upper resonator structure. The metamaterial absorber consists of metallic ground plane at the bottom layer, dielectric substrate layer at mid and a metallic resonator at the top layer of the unit cell of the absorber. This type of structure is also called as sandwiched structure.

In recent years multi-band [3]–[5] and wideband [6], [7] absorber have great significance over the single band absorber. With the help of more than one resonant structure having different length in a single unit cell we can make a multi band and wideband absorber. The basic concept [1], [3], [8], [9] of the absorber is to minimize the reflections and transmissions of the incident waves so that the absorptivity comes near about unity. Through impedance matching we can minimize the reflections and by using metallic ground plane at the bottom we can minimize the transmissions. Proper thickness of the ground plane makes transmission zero (T=0) and the perfect impedance matching [1], [2], [6] with free space makes reflections zero (R=0).

$$Z = \sqrt{\frac{\mu\,(\omega)}{\varepsilon\,(\omega)}} = Z_0 \qquad (1)$$

where Z is the impedance of the material, $\mu(\omega)$ is magnetic permeability, $\epsilon(\omega)$ is electric permittivity and Z_0 is the free space impedance. According to the conservation of energy:
A (absorption) + T (transmission) + R (reflection) = 1
so, the absorption (A) is obtained by $A(\omega) = 1 - T(\omega) - R(\omega)$ From CST the amplitudes of the transmission S_{21} and re-flection S_{11} were obtained, and the absorption was calculated using $A(\omega) = 1 - R(\omega) - T(\omega)$.

$$A = 1 - |S_{11}|^2 - |S_{21}|^2 \qquad (2)$$

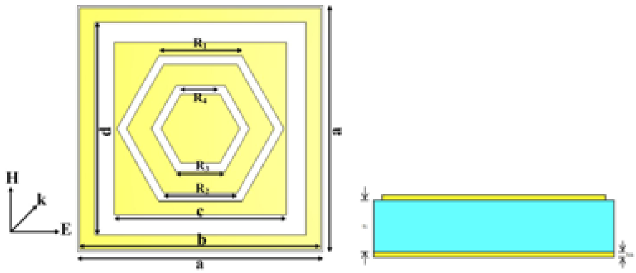
where, S_{21} is zero across the entire frequency range due to the ground plane. So finally, absorption(A) depends on S_{11} that is reflection.

$$A = 1 - |S_{11}|^2 \qquad (3)$$

In this paper, a closed ring resonator (CRR) based structure is proposed using low profile single dielectric layer which shows absorption at multiple distinct frequency bands having sufficient full width at half maximum (FWHM). In this work multiple bands have been observed in the THz region and lower infrared region which makes it useful for broader range of practical applications including increasing stealth technologies, communication, scanners and sensors.

2. Design and Simulation

The proposed absorber structure having metallic ground plane at the bottom and metallic resonator structure at front side separated by dielectric layer at middle. The design con-sists of an outer square ring with two hexagonal rings in centre having different radius on a small square patch. The top view and the side view of the single unit cell of the proposed structure is shown in Fig. (1a) and Fig. (1b) respectively. Electric field, magnetic field, and wave propagation directions are also shown in this figure. From the figure it is clear that the incident wave is falling on the top surface of the structure.



(a) Front parametric view (b) Side view

Figure 1: Proposed absorber structure

The proposed absorber structure is constructed on FR-4 substrate having dielectric constant of 4.3 and dielectric loss tangent of 0.025 and the thickness of the substrate (ts) is 1.54 µm. On the top of the substrate, the CRR structure made of pure copper with conductivity of 5.96×10^7 S/m is fabricated while the back side of the absorber is completely pure copper plated. Unit cell dimension of the proposed absorber is a × a µm. Thickness of the metal (tm) is 0.035 µm at the front as well as the back side. The top metallic pattern of the structure comprises of an outer square ring of dimension b × b µm and inner square metal patch of dimension c × c µm. On this patch two hexagonal rings having outer radius R_1 and R_3 of width 0.4 µm are etched out. The values of the various parameters used in the design are a = 10 µm, b = 9.8 µm, c = 7 µm, d = 8.4 µm, R_1 = 3.4 µm, R_2 = 3 µm, R_3 = 2 µm and R_4 = 1.6 µm. The parameters are optimized iteratively for required results in the preferred frequency band. Fig. (1a) shows various parameters for the design. The electromagnetic absorber is fully simulated and parametrically optimized using a computer simulation software (CST MWS) Studio Suite based on the finite integration technique (FIT) and periodic boundary conditions. The unit cell boundary conditions with floquet-port are used to simulate the absorption spectra. The construction of the proposed absorber structure involved 4 steps shown in fig. 2 and their corresponding absorption spectrums are given in figure 3.

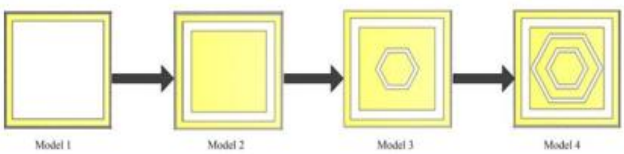


Figure 2: Steps for the structure

3. Results and Discussion

Figure 4 shows the absorption spectra for the proposed absorber. According to the simulation results, there are three resonance peaks in the THz region and three absorption is achieved in the lower infrared region. It has been noticed that the three peaks in THz gap at 3.17 THz, 7.13 THz and 11.53 THz exhibit absorption coefficient greater than 90% and for the infrared region it is noticed that absorption is greater than 90% at 19.58 THz, 21.8 THz and 23.83 THz. We can also consider this multiband absorption as wideband absorption for absorption greater than 80%.

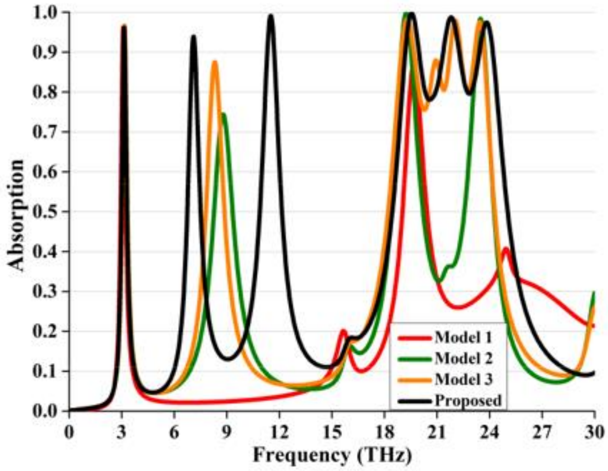


Figure 3: Absorption spectrum for different steps followed

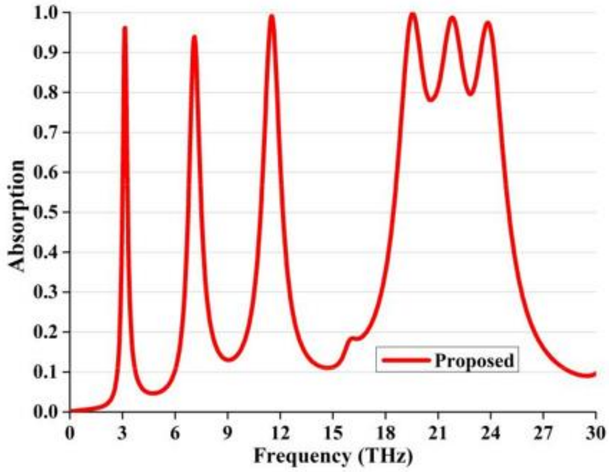


Figure 4: Absorption Spectra for the proposed design

The proposed absorber is symmetric so it can work in both the modes for TE as well as TM mode as shown in fig. 5 and because of the symmetricity the proposed absorber is insensitive to the polarization. Varying the polarization angle (from 0° to 80°) does not affect the absorption spectrum as shown in fig. 6.
Further we investigated the electric field distribution (|Ez|) shown in fig. 7 for the frequencies where the absorption peaks are high.

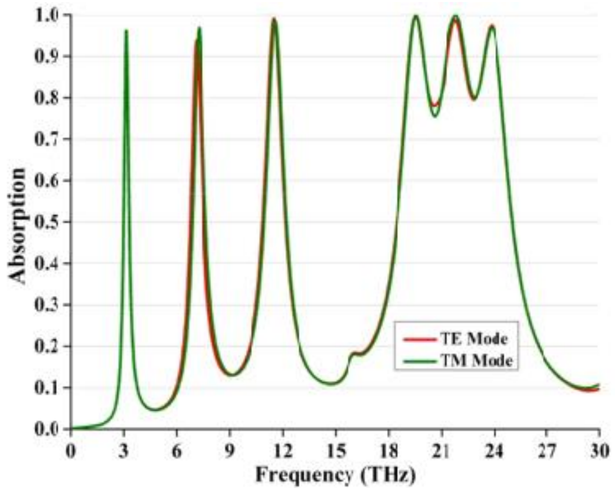


Figure 5: Absorption spectrum for TE and TM mode

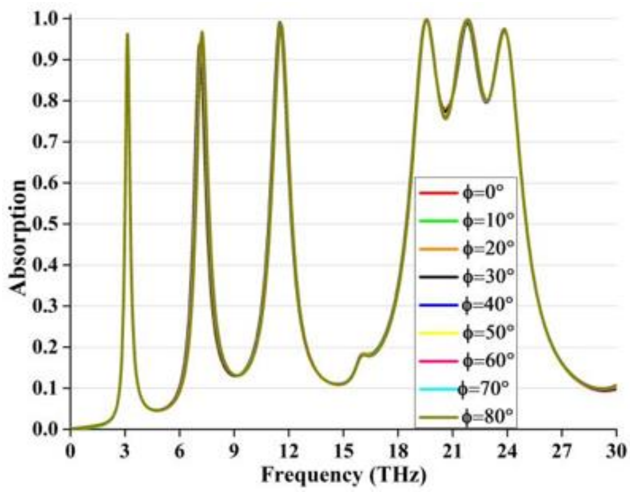


Figure 6: Absorption spectrum for different polarization angle

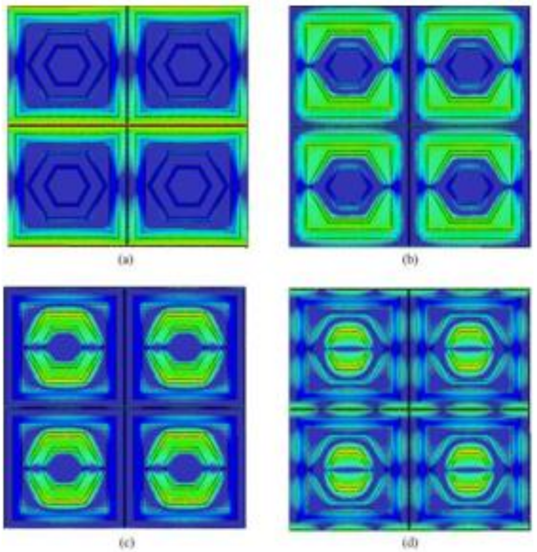


Figure 7: Electric field distribution of 2 × 2 array at (a) 3.17 THz, (b) 7.13 THz, (c) 11.53 THz and (d) 21.5 THz.

Table 1: Comparison between previously reported absorber and proposed absorber.

Ref.\ Year	Material	Config-uration	Unit Cell Dimension (μm)	No. of Bands	Polarization Insensitivity
[3] 2018	Gold	Multi layer	76 × 76	Quad	No
[4] 2015	Gold	Single layer	85 × 85	Quad	Yes
[5] 2020	Graphene	Single layer	4 × 4	Triple	Yes
[11] 2021	Graphene	Single layer	4.48 (Hexagon)	Dual	Yes
This Work	Copper	Single layer	10 × 10	Hexa	Yes

4. Conclusion

In conclusion, a simple hexaband absorber has been proposed and various iterations have been simulated those results in absorptivity in both THz and Infrared region. The results reflect that we have absorption values of 96%, 93%, 99%, 99.6%, 98.7% and 97.4% at the frequencies 3.17 THz, 7.13 THz, 11.53 THz, 19.58 THz, 21.8 THz and 23.83 THz respectively. Good absorption is achieved for both TE and TM mode. The proposed absorber is polarization insensitive. The design has its application in ample of practical uses like sensors, communication devices, imaging and scanners.

5. References

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