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# Performance Analysis of Electromagnetic Absorbers

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ABSTRACT :

A new absorber has been developed to efficiently absorb narrow-band terahertz radiation specifically at 110 THz. This absorber demonstrates insensitivity to incident waves of both TE and TM polarizations. Analysis of the electric field distribution reveals that dipolar and hexapolar resonances are responsible for the absorber's distinctive characteristics. Furthermore, the study investigates how the absorption frequencies can be adjusted by varying structural parameters such as cross length and dielectric thickness. Altering these structural elements allows for control over both the absorption frequencies and the overall number of resonance bands present in the absorber design.

**Keywords:** Absorber, Metamaterial, Terahertz

## Introduction :

Perfect absorbers utilizing electromagnetic principles have been a subject of extensive research across various applications. These absorbers minimize reflected and transmitted power, converting incident light predominantly into heat, which can potentially be harnessed for energy in alternative domains. Unlike other metamaterial-based devices that aim to minimize losses, metamaterial absorbers capitalize on such losses, often stemming from finite resistivity in metals or dielectric materials within the system. Metamaterial absorbers, when appropriately designed, exhibit versatility across the electromagnetic spectrum, spanning radio frequency (RF), microwave, terahertz (THz), infrared (IR), and visible light ranges. Diverse types of metamaterial absorbers have been developed to achieve high absorption rates across these wide frequency bands. The origin of dominant loss mechanisms varies depending on the frequency range. For example, absorbers operating at lower frequencies like microwave frequencies exploit dielectric losses associated with structures like split ring resonators and dielectric layers to achieve significant absorption rates, such as 88% absorption at 11.5 GHz. Conversely, absorbers operating at higher frequencies, such as THz, IR, and visible light, are more influenced by Ohmic losses from metallic layers. Microwave absorbers find practical application in RF wireless communication, while absorbers operating at higher frequencies are valuable for imaging and sensing applications. The dimensions of metamaterial structures crucially depend on the operational wavelength, influencing the choice of fabrication techniques. For lower frequency regimes, standard optical lithography on printed circuit boards or wafer-level substrates is feasible due to the smaller critical dimensions achievable with these techniques. However, conventional photolithography becomes impractical for fabricating absorbers in higher frequency ranges like IR or visible light. Advancements in nanofabrication technologies such as electron beam lithography and nano-imprinting have enabled the fabrication of sub-micron scale metamaterial absorbers suitable for IR and visible light applications.

### *1.1. Key Objectives*

Key properties such as angular response and polarization sensitivity are critical considerations in the design of metamaterial absorbers, tailored to specific applications. For instance, metamaterial reflectors leveraging counter plasmons typically exhibit polarization-dependent absorption and feature narrow acceptance angles, making them advantageous for sensing applications where precise directional sensitivity is required. Conversely, achieving high absorption efficiency can be prioritized by employing designs that offer a broad acceptance angle and are insensitive to polarization. This characteristic is particularly beneficial in scenarios like non-invasive standoff chemical and biochemical sensing, where the chemical compounds are distributed randomly over a wide area, leading to stochastic incident angles and varying polarizations of the molecular structures. In such applications, maximizing the total absorption relies heavily on optimizing both the absorber's acceptance angle and its polarization insensitivity. Therefore, the design and selection of metamaterial absorbers should carefully balance these properties depending on the specific operational requirements, ensuring effective performance in diverse real-world sensing and detection tasks.

## DESIGN CONSIDERATIONS :

This study addresses the formulation of a research problem derived from an extensive literature review. Identifying existing gaps in current research, this work aims to contribute by proposing and analyzing a solution based on insights gathered from previous literature. Specifically, the research focuses on the development of narrow-band metamaterial absorbers tailored for the infrared frequency spectrum. The investigation revolves around studying the effects and optimizing the performance of narrow-band metamaterial absorbers specifically designed for infrared frequencies. In order to calculate the absorption properties of the absorbers, the following equation is used:

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

A novel approach proposed in this research involves designing a top layer using a straightforward and commonly used shape, such as a circular configuration.

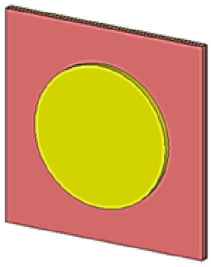


**Figure-1: Absorber Unit Cell Structure**

The theoretical analysis suggests that adjusting the symmetry and homogeneity of metallic micron-sized circular discs on the top layer can effectively narrow the absorption band. Furthermore, employing a Metal-Insulator-Metal (MIM) configuration, the absorber is projected to exhibit a sharp absorption peak with a slightly widened absorption bandwidth compared to other geometries. By transforming the shape from "r" to circular, the absorber achieves enhanced absorption characteristics. Additionally, employing a periodic arrangement of unit cells comprising circular discs of varying sizes further broadens the absorption spectra. This innovative design strategy results in achieving a substantial bandwidth of more than 50% absorbance, spanning from 2.80 μm to 3.90 μm. In summary, this research contributes to the field by proposing and analyzing a novel approach to design narrow-band metamaterial absorbers optimized for infrared frequencies. The findings underscore the effectiveness of employing circular geometries and periodic arrangements of unit cells to achieve enhanced absorption characteristics across a broader spectral range.

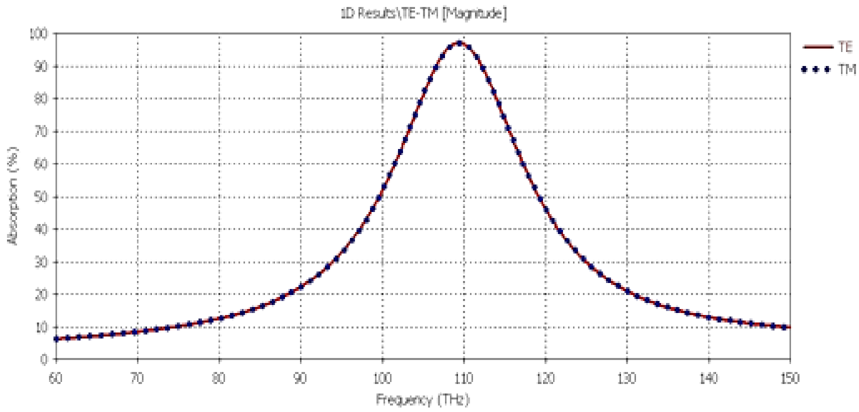
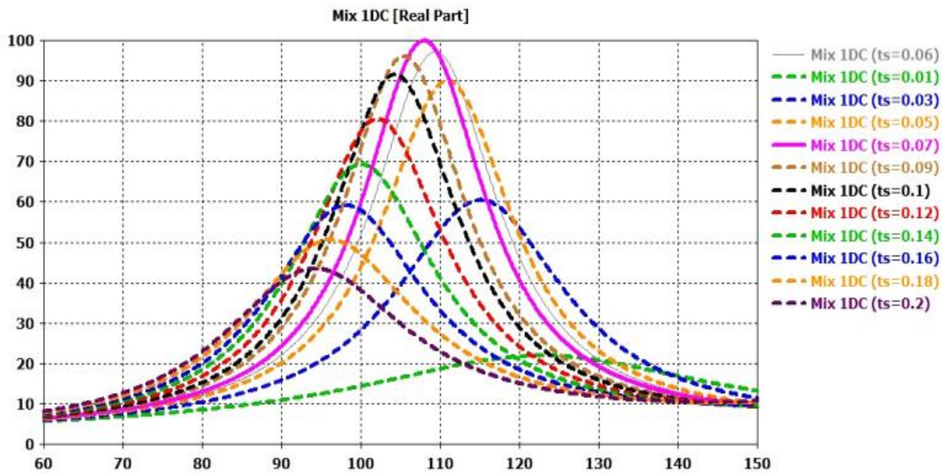



**Figure 2. Absorption spectra for TE-TM polarization.**

## Results & Discussion :

Research efforts have also explored the impact of parameter variations on the performance of the absorber design. Using simulations conducted in the CST program, different parametric adjustments were systematically applied to analyze the absorber's performance. During these simulations, specific parameters were varied individually while keeping all other variables constant. The fluctuation in substrate thickness in terms of absorptivity can be seen in figure-3. When the height of the substrate was raised from 0.01 to 0.07 micrometres, a considerable rise in the absorptivity can be seen in the response plot.

**Figure-3: Plot for Substrate Height Variations**



The effectiveness of the suggested structure has been evaluated in terms of absorption while changing the radius of the graphite disc (r). The radius of the graphite disc has a considerable impact on the absorbtivity of the proposed absorber. The absorption increases as the radius increases from 0.1 to 0.6 micro metres, as seen in figure-4. The absorptivity is substantially lower for smaller radii. This is because the size of the circular resonator is much smaller at lower radii compared to the unit cell; as a result, there is an impedance mismatch and the absorption is nearly negligible since most of the electromagnetic waves are reflected from the top surface of the device. As the radius increases, the absorption bandwidth likewise increases. Due to its higher than 90 degree absorptivity at the resonant frequencies, the final structure's ideal radius is decided to be r = 0.6 m. Additionally, processing it for sensing demands less bandwidth. Additionally, following modelling, it exhibits reasonably close absorption at the best value.

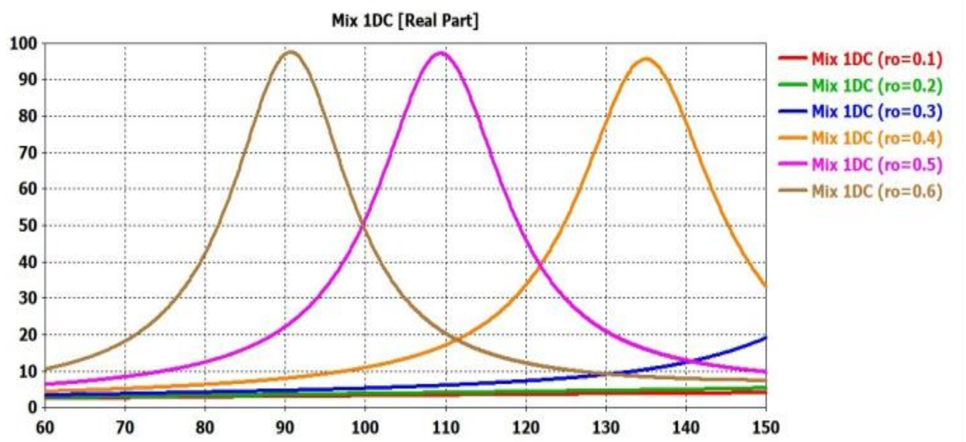



**Figure.4 Plot for the variations in Disk radius**

The suggested absorber's symmetry is what causes it to be insensitive to the polarisation of incoming electromagnetic waves. This may be seen by the charts in figure-5. In this case, the impact of polarisation angle fluctuation in relation to the operational frequency band has been examined. The contour figure demonstrates that the suggested absorber exhibits a consistent absorption response to all values of polarisation angles in the operational frequency band. As a result, the structure behaves polarization-insensitively at all polarisation angle values, making it suitable for use in real-world applications. Moreover, figure-6 indicated that the suggested absorber exhibits a very uniform absorption response (A > 90%) for incidence angles ranging from 0 to 30 degrees. The absorption decreased dramatically with increasing incidence angle and approaches almost 10% at theta equal to 10 degrees. So, in terms of absorption throughout the whole range of lower THz frequencies, the suggested absorber exhibits high angular stability.

**Figure 5: Polarization Plot for different Angles**

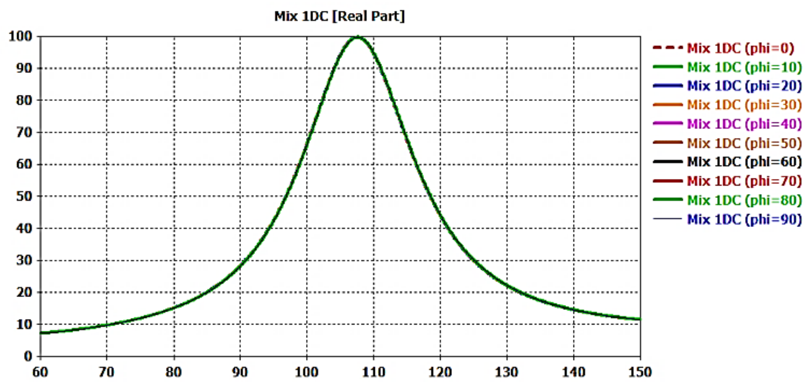
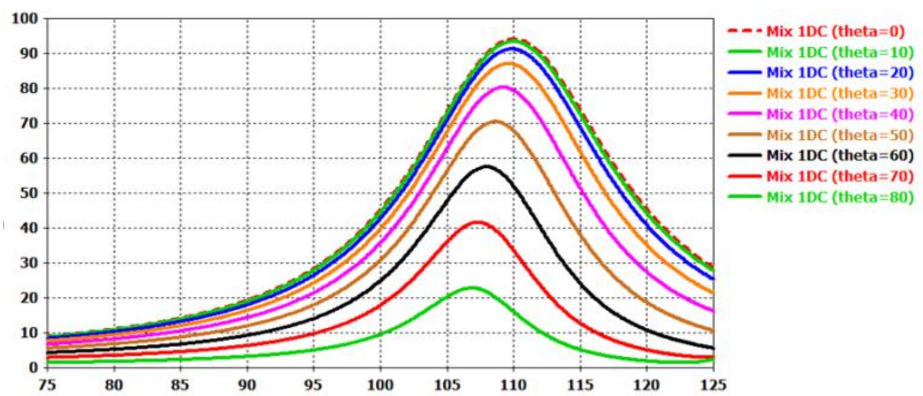



**Figure 6: Incident Angle Plot for the Implemented Absorber**



## Conclusions :

The objective of this research is to develop a single-band metamaterial absorber optimized for operation within the infrared spectrum. The proposed design introduces a novel structure utilizing simple circular resonators, a configuration not previously explored in existing literature. By integrating resonators of varying sizes on the top layer, the absorber is engineered to achieve single-band absorption specifically tuned for the infrared regime. Additionally, the study proposes a structural adaptation capable of generating a single absorption band within the terahertz frequency range. This innovation aims to establish a versatile metamaterial absorber capable of adjusting for high-absorption across multiple bands. Such a device holds significant promise for diverse engineering applications, particularly in sectors requiring precise detection and terahertz imaging capabilities. By advancing these designs, the research seeks to contribute to the development of efficient and adaptable metamaterial absorbers, enhancing their utility in various practical contexts within the fields of infrared and terahertz technologies.

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