FSS Based Absorber for EMI Shielding

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ABSTRACT

The paper presents the design of a narrow-band terahertz absorber that exhibits strong absorption at frequencies around 8THz. The absorption frequencies can be adjusted to higher or lower values by manipulating various structural elements, such as the cross length and dielectric thickness.The absorber is polarization insensitive, meaning it can absorb both TE (Transverse Electric) and TM (Transverse Magnetic) polarized incident waves equally effectively. This characteristic makes the absorber versatile and suitable for various applications.The analysis of the electrical field density revealed that the absorber's features are primarily attributed to dipolar and hexapolar resonances. These resonances are the physical phenomena responsible for the strong absorption at the desired frequency. Furthermore, the paper investigates the effects of different structural designs and factors on the absorption frequencies. By altering the structural arrangements, it is possible to modify not only the absorption frequencies but also the total number of resonance bands exhibited by the absorber

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Keywords:THz, MTM, Metamaterial, Absorber

INTRODUCTION

The history of metamaterials is a relatively recent and rapidly evolving field that emerged in the late 20th century. Metamaterials are artificial materials engineered to exhibit properties not found in nature, enabling them to manipulate electromagnetic waves and other physical phenomena in unique ways. The theoretical foundations of metamaterials can be traced back to the work of Soviet physicist Victor Veselago in 1967. Veselago proposed the concept of "left-handed materials" or "negative-index materials" with refractive indices opposite to those of natural materials. He theorized that such materials could exhibit counterintuitive behaviors, including negative refraction and backward propagation of light. The practical realization of metamaterials began in the late 1990s with the invention of the split-ring resonator (SRR) by Sir John Pendry and his team. The SRR consists of a small metallic ring split at one point, which exhibits a resonant response to electromagnetic waves. By arranging these resonators in a periodic lattice, they created a material with negative magnetic permeability, a key component for achieving negative refractive index behaviour. In 2000,

researchers at the University of California, San Diego, and the University of Tokyo demonstrated experimentally that the combination of SRRs and wire structures could create a material with negative refractive index in the microwave frequency range. This groundbreaking work confirmed Veselago's theoretical predictions and marked the first experimental realization of left-handed metamaterials. In 2006, the concept of electromagnetic cloaking using metamaterials gained significant attention with the publication of papers by researchers at Duke University and Imperial College London. These studies proposed and demonstrated the possibility of creating structures that could redirect electromagnetic waves around an object, making it invisible to detection. The concept of cloaking sparked widespread interest and popularized the field of metamaterials. In 2008, researchers at the University of California, Berkeley, developed a novel design for a metamaterial that could achieve negative refractive index behaviour across a broad frequency range, including visible light. They used an array of silver nanowires embedded in a polymer matrix, demonstrating the potential for creating metamaterials with unprecedented optical properties. Transformation optics is a theoretical framework that provides a systematic way to design and analyse metamaterials with desired electromagnetic properties. Proposed by Sir John Pendry, David R. Smith, and others in the mid- 2000s, transformation optics applies mathematical transformations to map the behaviour of electromagnetic waves in a desired manner. This and waveguides. Since these early breakthroughs, the field of metamaterials has witnessed tremendous advancements. Researchers have explored various materials, including metallic structures, dielectric resonators, and graphene, to achieve desired electromagnetic properties. Metamaterials have found applications in areas such as optics, telecommunications, energy harvesting, sensing, and medical imaging. They have enabledthe development of ultrathin lenses, efficient solar cells, perfect absorbers, terahertz devices, and much more. In summary, the history of metamaterials is a story of scientific curiosity, theoretical innovation, and experimental breakthroughs. From theoretical proposals to practical realizations, metamaterialshave revolutionized our understanding and control of electromagnetic waves, opening up a vast array of possibilities for advanced technologies and applications.

Types of EM Absorbers

There are several types of electromagnetic (EM) absorbers, each designed to absorb and dissipate electromagnetic energy in specific frequency ranges and applications. Carbon-based absorbers are widely used due to their excellent electrical conductivity and ability to dissipate electromagnetic energy.

foam absorbers, and Jaumann absorbers were used. A breakthrough in EMI problems and stealth technology was made possible by the development

They are often made of materials such as carbon-loaded rubber, carbon fibre composites, or carbon foam. These absorbers are effective across a broad frequency range and find applications in radar systems, anechoic chambers, and electromagnetic compatibility (EMC) testing.Magnetic absorbers are designed to absorb and dissipate electromagnetic energy in the low-frequency range, typically below 1 GHz. They contain materials with high magnetic permeability, such as ferrite or iron-based compounds. Magnetic absorbers are commonly used in applications such as magnetic field shielding and absorption of low-frequency electromagnetic interference (EMI).Dielectric absorbers are based on materials with high dielectric loss properties. These absorbers are effective in the microwave and millimetre-wave frequency ranges. They are typically composed of foam-like materials or resin composites containing conductive or lossy fillers. Dielectric absorbers are used in applications such as antenna design, anechoic chambers, and electromagnetic wave absorption in electronic devices.Frequency selective surfaces are periodic structures that selectively transmit or absorb specific frequencies or frequency ranges. They consist of conductive elements arranged in a pattern on a dielectric substrate. FSS absorbers find applications in controlling electromagnetic reflections, radar cross-section reduction, and electromagnetic shielding.Metamaterials are artificially engineered materials with unique electromagnetic properties. Metamaterial absorbers are designed to have tailored absorption characteristics at specific frequencies or frequency ranges. They often utilize resonant structures, such as split-ring resonators or metamaterial unit cells, to achieve desired absorption properties. Metamaterial absorbers are employed in various applications, including stealth technology, electromagnetic cloaking, and absorptive coatings.Hybrid absorbers combine different absorption mechanisms to achieve broader absorption bandwidth and enhanced performance. These absorbers may incorporate a combination of magnetic, dielectric, or conductive materials to cover a wide range of frequencies. Hybrid absorbers are often used in demanding applications where a wide absorption bandwidth or high-performance levels are required.It's important to note that the choice of EM absorber depends on the specific application, frequency range, and performance requirements. Each type of absorber has its advantages and limitations, and selecting the most suitable absorber involves considering factors such as absorption efficiency, bandwidth, cost, and environmental conditions.

Design Aspects of EM Absorbers

Military vehicles, such as Navy ships and planes, are equipped with sophisticated electromagnetic systems for communications, radar, navigation, and electronic warfare. These systems work simultaneously in a highly constrained space, which causes serious EMI issues. High power output, sensitive receiver systems, and frequency overlap are the reasons for this. There are severe EMI issues with both telecommunication and satellite communication equipment. Significant EMI issues can be solved with Radar Absorbing Material (RAM). In the past, materials for absorbing radar such as Salisbury screens, iron ball paint absorbers, of electromagnetic absorbers that use metamaterial in a productive and straightforward way.Designing a single-layer absorber involves selecting appropriate materials and optimizing the thickness and properties of the layer to achieve efficient absorption of electromagnetic waves.Identify the desired frequency or frequency range for absorption. This will guide the selection of materials and the design of the absorber.Select a material with suitable electrical properties for absorption at the desired frequency. The material should have a high loss tangent (tan δ) and be capable of dissipating electromagnetic energy effectively. Examples of suitable materials include carbon-loaded rubber, conductive polymers, or metal-dielectric composites.The thickness of the absorber layer plays a crucial role in determining the absorption performance. It should be optimized to achieve maximum absorption at the desired frequency. The optimal thickness can be calculated based on the quarter-wavelength or impedance matching principles, but it often requires simulation and experimentation to fine-tune.The choice of backing and substrate can influence the absorption characteristics. The backing material can be selected to enhance absorption by providing reflection phase cancellation or impedance matching. The substrate material should have minimal interference with the absorption process and provide mechanical support to the absorber layer.The absorber layer can incorporate additional features or structures to improve absorption performance. This can include the use of metamaterial resonators, frequency selective surfaces (FSS), or textured surfaces to enhance absorption and achieve desired bandwidth.Utilize electromagnetic simulation tools to analyse and optimize the absorber design. Simulations can provide insights into the absorption efficiency, reflection properties, and other performance parameters. Additionally, experimental characterization using measurements and testing can validate the design and fine-tune the absorber for optimal performance.Assess the performance of the absorber and compare it to the desired specifications. If necessary, iterate the design process by adjusting material properties, thickness, or additional structures until the desired absorption efficiency and bandwidth are achieved.

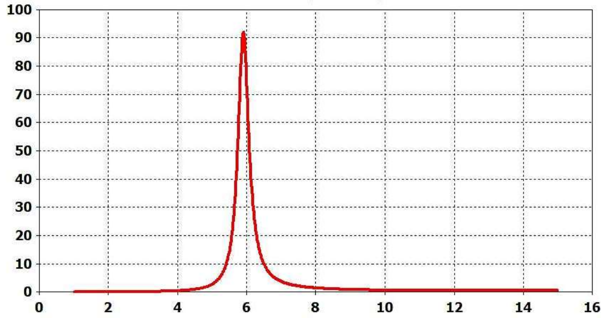

Figure 1: Absorption Spectra for TE and TM Polarization

Resonant Response

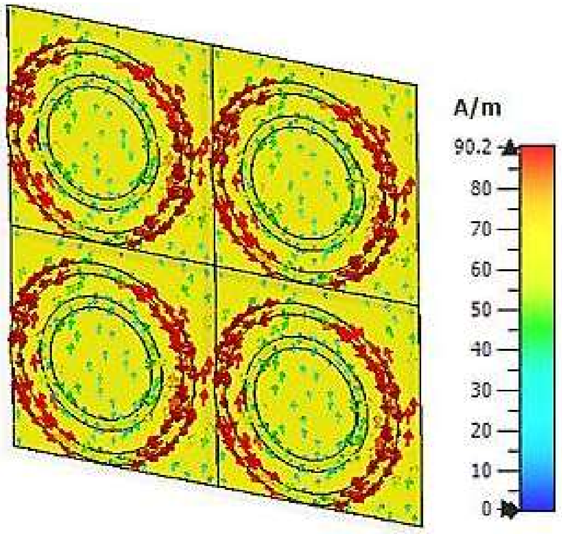

Figure-2: Electric Field Distribution

The electrostatic current (|E| and real |Ez|) spectra for the planned absorber at the previously discovered absorption peak are shown in Figures 3.5 and 3.6 (110 THz). The electric field |E| is notably cantered on the ascending and descending baselines of the circular ring construction for port 1 in mode f=110 THz. So, an overall conclusion can be derived from the electric field analysis that at the resonant frequency most of the electric field with high intensity are located near the circular metal disk only. Therefore, the metal disk can be considered as the resonator in the proposed trilayered structure. The electric field distributions clearly display the excitation of an electric dipole resonance at the resonant wavelength.

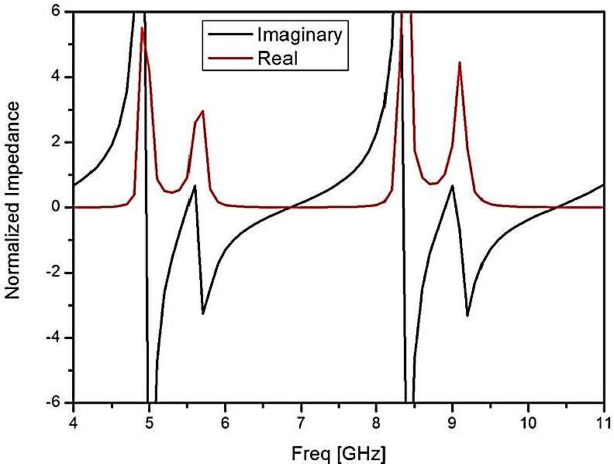

Figure 3: Polarization Plot for different Angles

CONCLUSION

In summary, the paper introduces a narrow-band terahertz absorber that achieves strong absorption at frequencies around 8 THz. The absorber is polarization insensitive and can be fine-tuned by adjusting structural elements. The dipolar and hexapolar resonances are identified as the underlying mechanisms for its absorption characteristics. The study also explores the impact of structural designs and factors on the absorption frequencies and the number of resonance bands.

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].