A Multiband Terahertz Electromagnetic Absorber

Lalit singh parmar
parmarlalitsingh@gmail.com
M. Tech Scholar, Department of Electrical & Electronics Engineering, BRCM CET, Bahal, (Haryana), India
Mr. Sandeep Kumar
sjhakhar1989@gmail.com
Assistant Professor, Department of Electrical & Electronics Engineering, BRCM CET, Bahal, (Haryana), India
Dr. Vivek Kumar
hodeee@brcm.edu.in
Professor & Head, Department of Electrical & Electronics Engineering, BRCM CET, Bahal, (Haryana), India

ABSTRACT

A structure that can create single absorption band in the terahertz regime is also suggested in order to construct an adjustable high-absorption multiple bands metamaterial absorber that will be useful in many engineering sectors, such as detecting and terahertz imaging. The MIM-based construction has a cross and four circular rings with quarter-sections encircled by square rings in the top layer. The structural configurations can be changed to change the overall number of resonance bands. The objective is to design a single band metamaterial absorber functioning in infrared regime. The novel structure is based on simple circular shape resonator and has not been proposed before. By combining multiple sizes raindrop-shaped resonators on the top layer, a single band absorption in infrared regime can be realized.

Keywords:THz, MTM, Metamaterial, Absorber

INTRODUCTION

Metamaterials are constructed materials with special characteristics, including left-handedness, the reverse Doppler Effect, negative refractive index, and so on. Researchers are very interested in many possible practical applications, such as absorbers, antennas, and timing, due to the special characteristics of artificial composite structures known as "metamaterial." The domains of electromagnetic interference suppression, stealth technology-appropriate absorbers, and medical equipment such as scanners to lessen the absorption of toxic electromagnetic signals by people are where metamaterial has the most promise. These microwave absorbers based on metamaterials are very thin, polarization-insensitive, small, and enable nearly perfect absorption. Due to their excellent electromagnetic absorption, small size, ultra-thin thickness, and low-profile design, metamaterial absorbers have recently been utilized as prospective substitutes for traditional absorbers. Due to these benefits, various microwave metamaterial absorbers are now used in single-band, dual-band, multi-band, and wideband applications across all frequency ranges. Although metamaterial absorbers have several advantages, they have limited bandwidth. New structures are suggested by this research for broad absorption bandwidth. The earlier development of EM absorbers has been mostly focused in the RF regime (3kHz ~ 300GHz), due to the large demand in the applications such as communications and military defence. THz absorbers operate in a higher frequency regime (0.3 ~ 3T Hz) and are actively employed the medical applications such as a non-invasive alternative to X-ray imaging as well as in homeland security applications where THz waves are used to detect concealed weapons underneath garments. With special features including a lower refractive index, negative permittivity, and negative permeability, metamaterial, the rightmost artificial structure, has drawn interest in a variety of applications. It is a periodic structure made up of a collection of unit cells that may modify the incident electromagnetic wave's magnetic and electric properties. The electromagnetic spectrum is well represented by these incident waves. Electrons within a material move around electromagnetic waves when they strike it due to the electromagnetic fields created by the waves. This results in energy exchange between a material's molecules and atoms. They refrain from discussing chemical synthesis methods. By altering the shape of the structure, they are able to create special qualities that go beyond those of natural materials. Therefore, the focus of the researchers must be on creating the best structure possible for the required features.

ABSORBER MATERIALS

The materials consist of carefully-designed patterns that are usually arranged in a periodic manner much smaller than its working wavelength. The properties of the metamaterials can be tailored precisely to control the impinging electromagnetic waves in different ways such as steering, redirecting, focusing, absorbing, and reflecting. Such precise control of EM waves have been demonstrated for EM clocking, perfect absorbers, energy harvesting, and imaging beyond diffraction limit. Negative refractive index metamaterials, also known as left-handed metamaterials, is one of the most well-known examples of metamaterials which take advantage of artificial electric and magnetic resonance (electric permittivity, $\varepsilon < 0$, and magnetic permeability, $\mu < 0$, respectively) to realize a negative refractive index [3, 4]. Such discovery resulted in a new class of applications such as flat lens, invisibility, and beyond-diffraction imaging. Another type of metamaterials are high impedance surfaces, consisting of layers of metal and dielectric thin films whose geometric shapes and dimensions are precisely controlled to exhibit desired properties such as phase shifting and frequency selective responses. [5]. One can obtain complete absorption at the targeted wavelength, in particular, when the effective surface impedance of a high impedance surface matches the free space impedance [6]. These metamaterials, also known as metamaterial perfect absorbers, have been shown effective throughout a large portion of the electromagnetic spectrum, from microwaves to the optical regime. Because they contain a variety of subwavelength constituents, metamaterials can display amazing electromagnetic phenomena. The resonances of the sub-wavelength constituents produce the special characteristics of metamaterials. The dielectric permittivity, magnetic permeability, and conductivity of a material determine its capacity to propagate waves. Veselago[10] conducted the first theoretical investigation into the plane wave propagation in materials with negative and negative in 1968. In contrast to typical materials, he discovered that in the medium of negative and negative, the group velocity propagates in the opposite direction of the Poynting vector. 1999 saw Smith et al .[11] experimentally demonstrated the first material with both negative ε and μ. Later, Pendry[12] explained the existence of a negative refractive index. After these works, plenty of research has been conducted in this field from microwave to optical spectrum regime of electromagnetic waves [13]. Unlike conventional materials that depend on material chemical composition, the electromagnetic properties of metamaterials are strongly determined by the structures themselves. Due to the existence of the ground plane on the bottom layer, with thickness greater than the skin depth, the transmission through the structure can be effectively suppressed, which indicates S21 (ω) = 0. So, the absorption equation can be altered to the following:

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

A single-layer metamaterial absorber (MMA) might have a single layer or many layers. According to Fig. 1.10, the single-layered structure is comprised of a dielectric material with metallic patterns inserted on the top surface and a metallic ground on the bottom surface. As shown in Fig. 1.11, the multi-layer structure is composed of several dielectric substrates sandwiched between two metallic layers. The metallic patterns are created such that certain frequencies cause the structure to vibrate. To stop the transfer of electromagnetic waves, the bottom ground surface is typically formed of totally coated metal. Destructive interference of the incident electromagnetic waves is the MMA's absorption process.

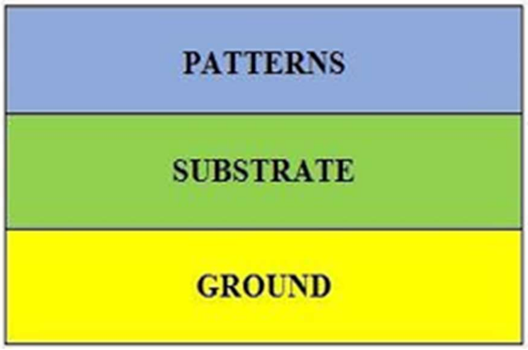

Figure 1. Single Layer Structure

The output current (S21|) and reflecting power (S11|), is provided by Eqn. 1.1, is used to calculate the absorptivity (A) of the absorption method when the simulations are complete. Due to the entire metal ground, the S21 becomes zero, stopping wave transmission. To create the ideal metamaterial absorber, the wave reflection should be reduced. This is accomplished by impedance matching the structure to the open space impedance. Eqn. 1.2 provides the input impedance (Z). An impedance-matched structure should have an imaginary input impedance of zero and a real input impedance of unity.

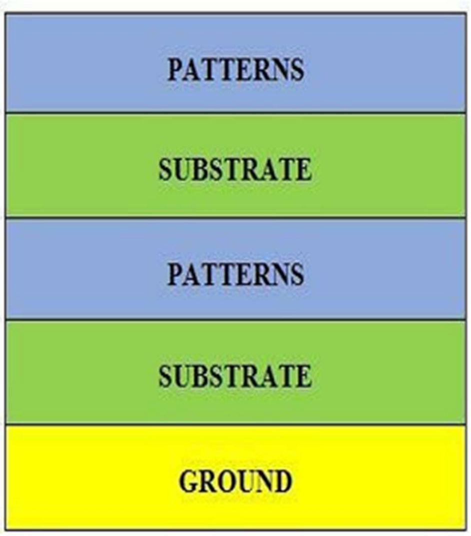

Figure 2. Multi-Layer Structure

Permittivity $\varepsilon(\omega) = \varepsilon 1 + i\varepsilon 2$ and permeability$\mu(\omega) = \mu 1 + i\mu 2$ are examples of effective medium properties that define the metamaterials. These intricate effective parameters, which often relate to attenuation in a medium, are calculated using the effective medium technique.The structure with high attenuation and high absorption is built by the absorber using the loss of these characteristics and the effective medium design. The actual components of the important parameter are related to the electromagnetic wave propagation.The imaginary (loss) components are smaller than the real components. By manipulating the resonances independently in μ and ε, both the incident magnetic and electric fields could be absorbed. The effective permittivity (Ɛeff) and effective permeability (μeff) are calculated using electric susceptibility (χes) and magnetic susceptibility (χms), as shown in Eqn. 1.3, Eqn. 1.4, Eqn. 1.5 and Eqn. 1.6, where k0 is the wavenumber of the free space and d is the distance travelled by the incident electromagnetic wave.

AIM & OBJECTIVE

The objective is to design a single band metamaterial absorber functioning in infrared regime. The novel structure is based on simple circular shape resonator and has not been proposed before. By combining multiple sizes raindrop-shaped resonators on the top layer, a single band absorption in infrared regime can be realized. A structure that can create single absorption band in the terahertz regime is also suggested in order to construct an adjustable high-absorption multiple bands metamaterial absorber that will be useful in many engineering sectors, such as detecting and terahertz imaging. The MIM-based construction has a cross and four circular rings with quarter-sections encircled by square rings in the top layer. The structural configurations can be changed to change the overall number of resonance bands. The problem here is to investigate and design the narrow-band metamaterial absorbers for the infrared frequency spectrum. In this chapter, we studied and analysed the effects of narrow band metamaterial absorbers for Infrared Frequencies. It is suggested to use a fresh, straightforward design for the top layer based on the most typical shape, the circular one. The absorption band may be narrowed based on our theoretical investigation of adjusting the symmetry and homogeneity of the metallic micron circular disc on top.

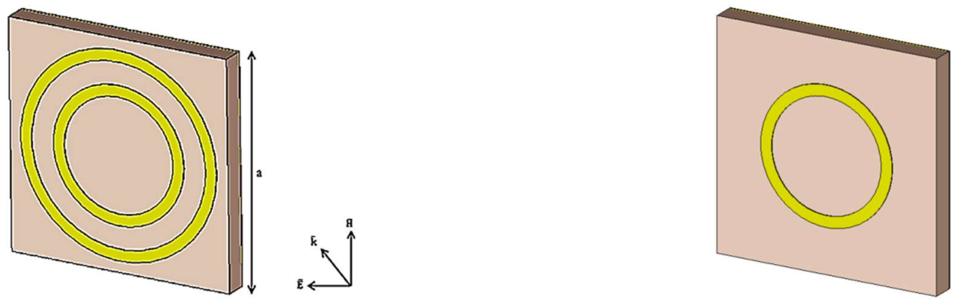

Figure 3. Absorber Structure Design Evolution

IMPLEMENTATION

Absorber Structure Design

Only one-unit cell is depicted in Figure 1, which displays the single-band absorber construction that is suggested. Gold arrays on top, a gold ground plane, and a conductive material between two metal layers make up its three functional layers. The periodic gold arrays on top are 45 nm thick, while the gold ground plane on the bottom is 100 nm thick. They are separated by a 60 nm dielectric spacer called SiO2 that has a constant refractive index of 1.45 and is thought to be lossless [8]. The period length p1 of each cell is set to be 1.5 μm. The related structure parameters. A Lorentz-Drude model was used for the gold material [6]. The incident wave was set to be plane waves parallel to the X-Z plane with TE polarized along the Y direction. Periodical boundary conditions were applied on the vertical sides of the structures. Port boundary condition was used between the interference of the PML layer and air layer. The wavelength-dependent reflection parameter R (λ) was obtained from the S-parameter of the port and the absorption of the structure was calculated by A (λ) = 1 - R (λ). Due to the existence of the bottom ground layer, which is thicker than the skin depth at the desired wavelength range, the total transmission is close to zero. The symmetric absorber is not sensitive to TE and TM polarizations because of the four-fold.

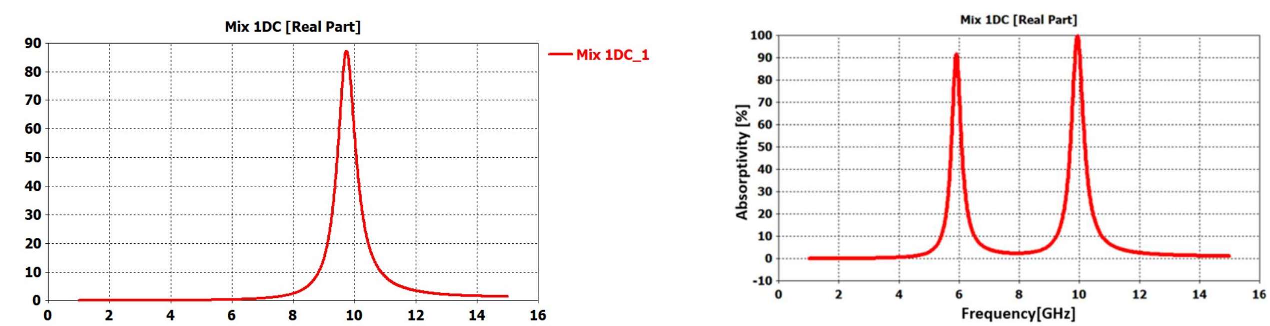

Figure 4. Absorber Response for both the Structures

Result Analysis

The Investigations have also been done on how parameter changes affect the performance of the intended absorber. Simulations in the CST programme have been run while taking into account different parametric modifications to analyse the performance of the suggested absorber. We are modifying one set of parameters during simulation while holding all other values constant at once. Whenever the height of the substrate was further raised from 0.07 to 2 micrometres, a significant reduction in absorptivity was seen. As a result, it has been determined that 0.07 micrometres is the ideal height for producing near unity absorption. 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 3.9. 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.

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