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Design, Analysis and Simulation of Metamaterial Electromagnetic Absorber

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ABSTRACT:A Metamaterial Absorber utilizes the effective medium design of metamaterials and the loss components of permittivity and magnetic permeability to create a material that has a high ratio of electromagnetic radiation absorption. Here perfect frequency selective metamaterial Absorber based on resonator with dielectric configuration are numerically presented and investigated for microwave frequency range. FSS MA's have simple configuration which introduces flexibility to adjust their FSS metamaterial properties and to rescale the structure easily for any desired frequency range. Our fabricated design consists of two resonators and a metal wire that couple separately so as to absorb all incident electric and magnetic fields with a single planar layer. Experiments demonstrate that the reflection coefficient $|S_{11}|^2$ and transmission coefficient $|S_{21}|^2$ lowers at 10.43 GHZ. Also absorption comes out to be maximum around 93% at 10.43 GHZ.

KEYWORDS: Metamaterials; FSS (Frequency Selective Surfaces); Eletromagnetic radiation absorption; Transmission coefficient; Reflection coefficient, MA (Metamaterial absorber)

I. INTRODUCTION

Metamaterial absorbers are intended to absorb electromagnetic radiation efficiently. Complex permittivity and permeability are derived from metamaterials using the effective medium approach. As effective media, metamaterials can be characterized with complex $\varepsilon(w) = \varepsilon_1 + i\varepsilon_2$ for effective permittivity and $\mu(w) = \mu_1 + i\,\mu_2$ for effective permeability. Here significance is on the real parts of these parameters. The imaginary components are small in comparison to real parts and are neglected.

Metamaterial based Absorbers is usually composed of three layers:

- The first layer is periodically arranged patterns, whose structure and geometrical parameters should be carefully adjusted to fulfill the impedance matching condition, allowing no reflection of incident electromagnetic wave.
- The second layer is a dielectric layer , which allows a space for the EM waves to be dissipated and sometimes plays a role of resonance cavity to prolong the time taken by the EM waves inside the second layer.
- The third layer is a continuous metallic plate , blocking remnant transmission.

In this paper we present the design, simulation and measurement of metamaterial absorber in the gigahertz frequency range. It is based on impedance matching negative index metamaterials. Theoretically, we can achieve permittivity and permeability which enables the creation of negative index materials.. Therefore, it is possible to absorb both the incident electric and magnetic field. But in practice, it is limited by achievable fabrication Tolerances. Our device experimentally demonstrated a higher Absorptivity of 93% around 10.43GHz.

II. RELATED WORK

Many Researchers have achieved different results at different frequency ranges by working on different parameters and structures. N.I Landy worked on first metamaterial absorber. Designing of Absorber is done by using ERR(Electric Ring Resonator) and cut wire. Structure provides desired electromagnetic response at resonance frequency and by

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matching permittivity and permeability, impedance matching can be attained. He achieved maximum absorption of 88% at 11.5 GHZ. Here N.I Landy discussed the importance of imaginary parts of permittivity and permeability in realizing absorption of EM wave .Authors demonstrated the difference between simulated and measured results. This was due to fabrication errors. By simulations , the authors found dielectric loss greater than ohmic loss. He declared the dielectric loss as the primary loss in the microwave region.

Although the first experimental work on metamaterial absorbers was in the microwave frequency realm, work quickly followed in the THZ regime.

H.Tao Et al proposed a report,“A Metamaterial absorber for the terahertz regime: Design , Fabrication and characterization”. In this paper they work on a metamaterial that act as a strong absorber in terahertz frequencies. This design consisted of a bi- layer unit cell which allows maximization of absorption through independent tuning of electric permittivity and magnetic permeability. Absorption of 70% at 1.3 THZ is demonstrated. Absorption coefficient achieved in this is 2000 per cm. This was the first design that fulfil requirement of devices to work at THZ range. This Absorber was also consisted of ERR and cut wire. The dimensions of absorber design are in micrometer and absorption is achieved by choosing appropriate dimensions.

Also in 2009, H.Tao Et al , “Flexible Wide Angle Terahertz Resonant Absorber Based on Perfectly Impedance Matched Metamaterials” presented a metamaterial absorber which can be used in non – planar applications as it can easily be wrapped around object of small diameter. They used dielectric material as Gallium Arsenide. This absorber operates for wide angle of incidence for TE and TM modes. They used metallic backing for decreasing transmission. He achieved absorbance of 98% at 1.12THZ.This paper includes a very good relation for transmission and absorption.

In 2012, Claire M.Watts Et al proposed a progress report of metamaterial absorber. It includes the different metamaterial designs operable at different frequencies. It revealed that majority of loss is due to dielectric layer rather than ohmic losses. Theoretical consideration of electromagnetic wave theory is discussed here. It includes important results of Fresnel equations and Drude Lorentz model.

Researchers have continuously worked in the field of microwave metamaterial absorbers since this first experimental demonstration was in 2008. A lot of work can be done to improve the current design and can achieve much better results.

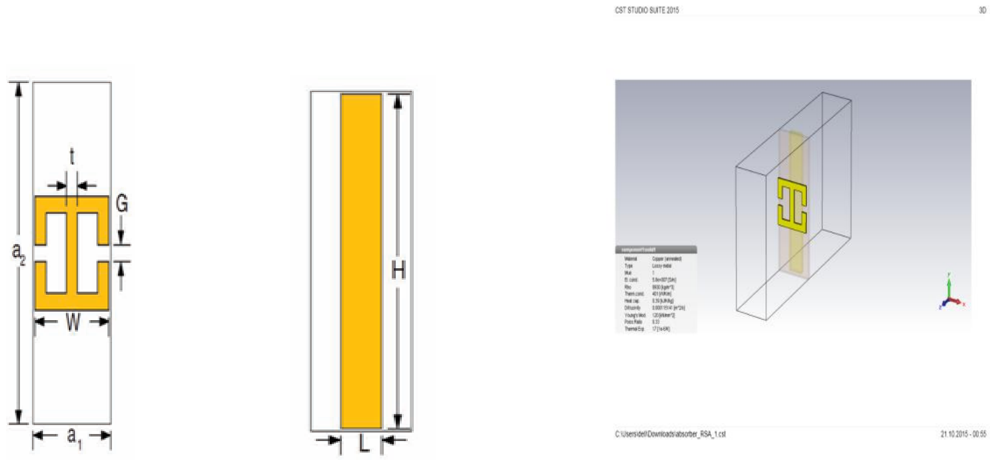
Metamaterial absorber offers various applications as they are efficient and tunable through their designs. They are not only useful for a number of applications but can also be used to study classical electromagnetic wave theory.

III.DESIGN

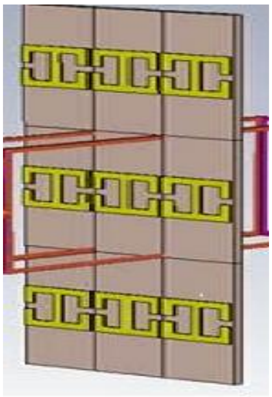
We proposed a metamaterial absorber composed of repeating unit cells arranged in periodic structures using CST microwave studio. This program simulated a single unit cell as shown in fig 1(c) and repeated unit cells in fig 1 (d).Our structure consists of two distinct metallic elements as shown in fig.1(a) and (b).Electric coupling was supplied by electric ring resonator (ERR) as shown in fig 1(a). This element consists of two split ring resonators connected by the inductive ring parallel to split wire. Fig.1(b) shows the cut wire .The magnetic response can easily be derived by changing sizes of cut wire and centre distance between elements. An FR-4 lossy substrate is used as the dielectric spacer. Copper (annealed) is used for ERR. And for cut wire, the material can be gold or silver as they are good conductors at low frequencies such as microwaves with a particular value for conductivity. We performed the computer simulations by Frequency domain Method by setting proper boundary conditions with wave vector being perpendicular to the absorber plane and electric field parallel to x axis and magnetic field parallel to y axis.

Dimensions of ERR: width of substrate (a1)=4.2mm, height of substrate,(a2)= 12mm, width of ERR,(W)= 4mm, gap,(G) = 0.6mm,thickness,(t) = 0.1mm.,thickness of substrate= 0.5mm

Dimensions of cut wire: Height,(H)=11.8mm , width,(L)=1.7mm



1(a) A single ERR 1(b) cut wire 1(c) single unit cell



1(d) Periodic unit cells

Fig 1. Components of Absorber

III.SIMULATION

Simulation process is performed using CST Microwave Studio (CST MWS). CST Microwave studio is a specialist tool for 3D EM simulation of high frequency components. Both time domain solver and frequency domain solver is available. But we performed simulations in frequency domain solver. The frequency domain solver of CST microwave studio is , like the transient solver, a general purpose tool. It delivers electromagnetic near and farfields as well as s-parameters. For application areas like, periodic structures such as FSSs , frequency domain solver is preferred. CST MWS features a special periodic boundary implementation, which automatically creates the boundaries for unit cells. Simulations produced the complex frequency dependent s- parameters S_{11} and S_{21}, where Reflection coefficient, $R(w)=|S_{11}|^2$ and Transmission coefficient, $T(w)=|S_{21}|^2$. Then by using the below equation in Postprocessing, desired value of absorptivity is obtained.

$$A(w)=1-T(w)-R(w)$$

III. RESULTS

Firstly all the s-parameter values were calculated. The combined s-parameters are shown in fig 2. S-parameters play a significant role in designing as they define the input-output relationship between ports. They are easier to measure in CST Microwave studio and work at high frequencies. Here we are interested in reflection and transmission coefficient i.e $|S_{11}|^2$and $|S_{21}|^2$.They are defined as a function of power incident at port1 with no power incident at port 2.

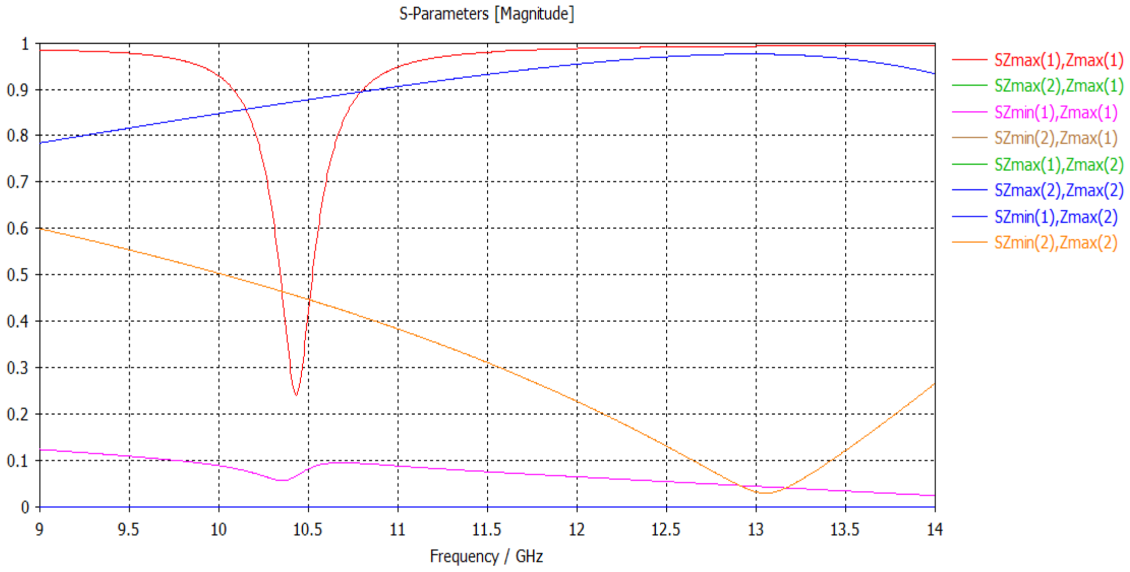


Fig 2. S-Parameters

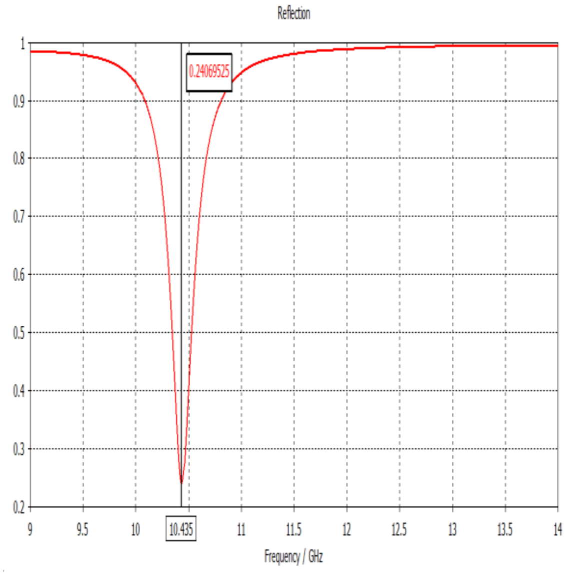


Fig 3(a) Reflection/Frequency

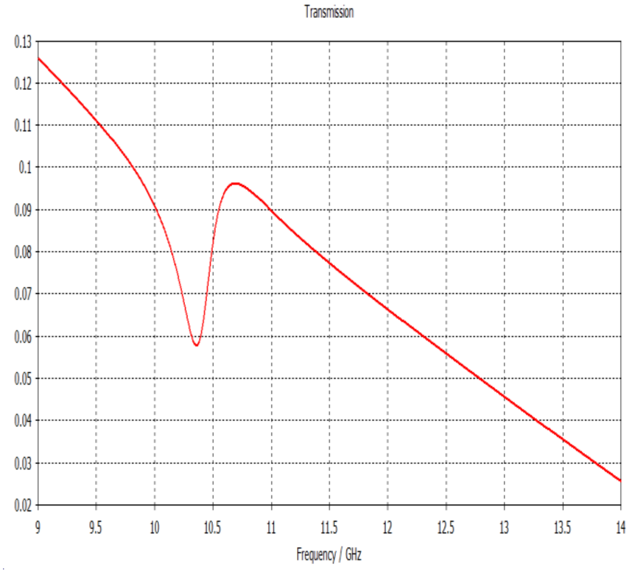


Fig 3(b) Transmission/Frequency

Our results are shown in Fig3. Fig.3(a) displays the reflection coefficient. Reflection coefficient is a parameter that describes how much of an electromagnetic wave is reflected in the transmission medium. It describes how much power is reflected and is also known as Return loss. The graph shows the minimum reflection value at 10.43GHZ whereas the curve is increasing at all the other frequencies. Fig3(b) shows the transmission coefficient. As it can be seen the transmission is falling at this frequency. Fig3(c) shows the Absorptivity. With the minimum reflection and falling transmission , maximum absorption of approximately 93% is achieved at 10.435 GHZ .

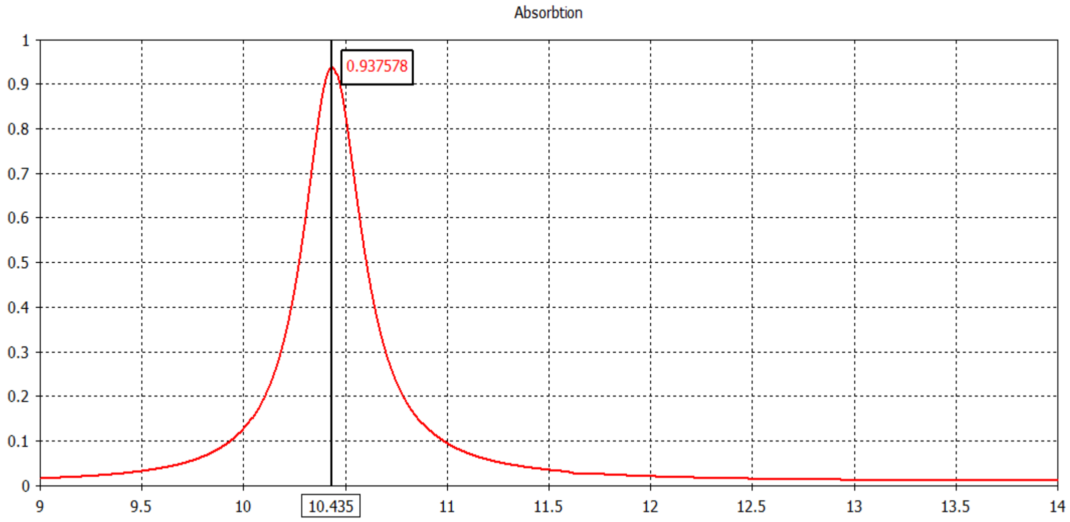


Fig 3(c) Absorption/Frequency

IV. CONCLUSION AND FUTURE WORK

We presented a design and simulation of MM absorber with an absorption peak of 93% at 10.43 GHZ. This design is used instead of conventional split wire design , because of limitations of split wire media .Also this design gives flexibility to adjust its Metamaterial properties and can easily be used for other frequency ranges. There are various applications of this structure from a thermal detector to stealth technology in GHZ frequency range. Recently a research team in Korea has created flexible Metamaterial absorber which is used to suppress electromagnetic radiation from mobile electronics. So, Our Results are not limited to only GHZ, but can be widely used over electromagnetic spectrum. As compared to other conventional Absorbers , which are thick , our results are better and can be widely used for various applications.

Moreover we have used Frequency selective surfaces (FSSs),which have absorbing properties depending on the thickness of dielectric substrate used. It is also found that absorbing properties of FSSs can generate different results if proper parameters are chosen.

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BIOGRAPHY

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