Design and Simulation of Metamaterial based Resonant Absorber

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Abstract: ***A Resonant absorber using metamaterial structure is designed which is used to minimize the reflection and transmission of light and increasing absorption. This work includes design and simulation results of a metamaterial structure which act as resonant absorber. This design provides absorption of electromagnetic wave at resonant frequency of 10.5 GHz. From transmission line theory resonant absorbers which depends on the material's way to interact with wave at particular frequency. Resonant absorbers are also called as quarter wavelength absorbers. Absorber design is an impedance match problem which can be achieved by attaining condition of resonance. MTM with its strong EM responses is used for designing a resonant absorber. MTM is material with negative value of permeability and permittivity made up of periodic array of electric and magnetic inclusion. Apart from various applications of MTM, it is best suited to be used as absorber. Absorption of 74% is achieved at 10.5 GHz and reflection is reduced to 20% at resonance frequency of 10.5 GHz. The use of silver as material for designing cut wire effected the transmission and transmission is only 6%.***

Keywords*:* Metamaterials, impedance, reflectance, transmission

1. Introduction

An electromagnetic wave incident on an object interacts with that object and results in following phenomenon to take place according to the properties of that particular object.

1) Reflection
2) Transmission
3) Absorption

To attain maximum absorption, minimization of reflection and transmission is required and absorber is used for this purpose. Absorber is a device in which all incident radiation is converted into heat and get absorbed.

1.1 Application of absorber

- To reduce the radar cross-section.
- To reduce EMI.
- To shape antenna pattern.
- Cavity Resonance Reduction.
- Near field absorber.

There exist two types of absorber resonant absorber and broadband absorber. There are various Conventional resonant absorbers that are used but due to certain limitations they are not suitable for above mentioned applications. Hence metamaterial based resonant absorber is more preferable.

Metamaterial is a human synthesized material which has some exotic properties. Metamaterial is fabricated by assembling different objects (metamaterial components example- SRR) so as to replace the atoms and molecules that one would see in a conventional material. Metamaterials consisted of metamaterial elements which are responsible for generating negative permittivity and permeability at operating frequency. Metamaterial is used in various applications like as a cloaking device clocking to make objects invisible, in antenna technology to reduce size, in stealth applications to reduce radar cross-section etc but it is best suited as resonant absorber as there exist ohmic losses in metamaterial which is a limitation in other applications of metamaterial yet this limitation is very useful in resonant absorber made up of metamaterial, since more the losses more will be absorption. Absorber design is an impedance matching problem which can be attained when $\varepsilon = \mu$ and to make both equal, dimensions of metamaterial elements must be precisely chosen to attain condition of resonance at desired frequency.

2. Design

In our design we have designed a unit cell of metamaterial absorber consisted of three layers as shown in figure 1. First layer is of ERR (Electric Ring Resonator), second layer is of dielectric spacer and third layer is a metallic wire. Electric coupling is derived by ERR and magnetic coupling is derived by anti-parallel current in two segments i.e. in wire and central line of ERR.

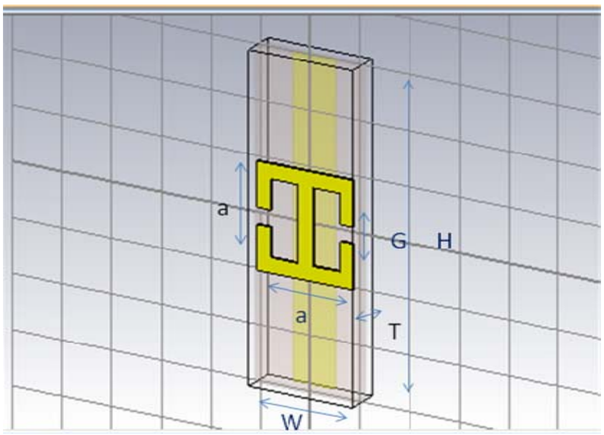

Figure 1: Three layered metamaterial absorber design

Desired magnetic response at desired frequency can be derived by appropriately choosing dimensions of wire, dielectric spacer and electric response is by using appropriate dimensions of ERR.

These scattering parameters are complex parameters. $|S_{11}|^2$ is reflection coefficient and $|S_{21}|^2$ is transmission coefficient. By using A= 1-T-R, absorption is then calculated using post processing in CST microwave which combined two results and generate a new result. As discussed above dimensions of metamaterial elements and dielectric plays a vital role for having desired response at desired frequency. Dimensions of simulated metamaterial absorber:

- Dimensions of dielectric: Material used for dielectric is FR-4, Height (H) = 12mm, width (W) = 4.2, Thickness of dielectric is 0.5mm.
- Dimensions of ERR Material used is Copper, Height of ERR (a) = 4 m, Width (a) = 4 m Thickness = 0.1 mm, Gap (G) = 0.6 mm.
- Dimensions of Wire Material used is Silver Height = 11.8mm, Width = 1.7mm, Thickness = 0.1 mm.

3. Results

Results are obtained for the above designed structure of metamaterial absorber using CST microwave Transient solver. Scattering parameters are derived after simulation. From these scattering parameters magnitude of reflection is derived. According to the selected dimensions and material used for metamaterial elements, minimum reflection takes place at 10.5 GHz and is about 20% as shown in Figure 2 (a). Figure shows a graph between Reflection and frequency. Reflection is between 96% - 100% at all other frequencies except at 10.5 GHz.

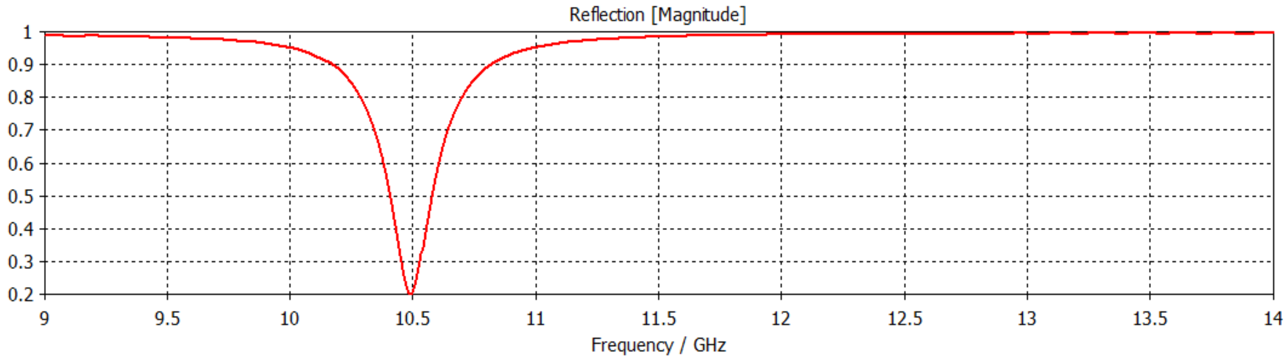

Figure 2: (a) Reflection v/s Frequency

Results are obtained for transmission. Although metamaterial absorber is responsible for minimizing reflection and does not play any role in minimizing transmission, transmission can be minimized by using metallic backing plates but we did not use any metallic backing in this design but still transmission is reduced to a remarkable amount. A peak of nearly maximum transmission is obtained near 10.5 GHz and proves that condition of impedance matching is attained. Transmission is minimized due to use of silver as material. Transmission is nearly 6% at resonant frequency 10.5GHz.

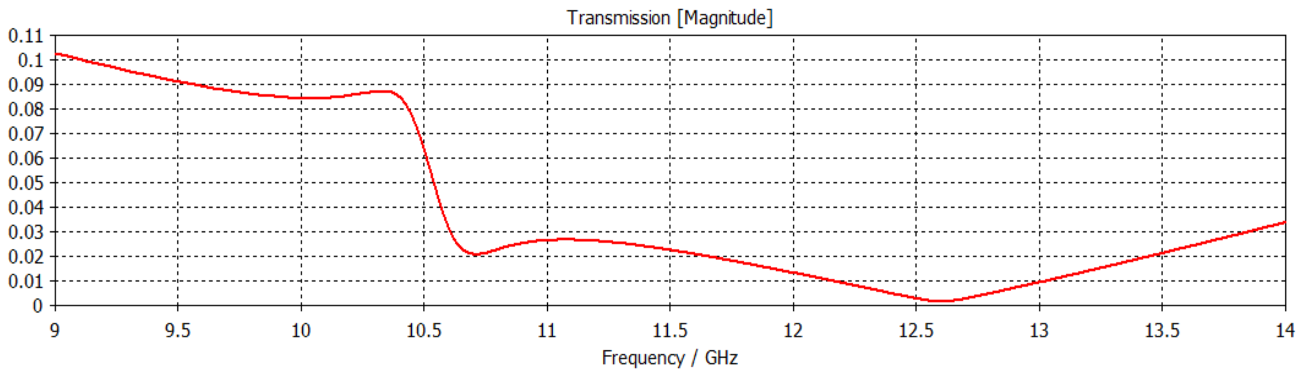

Figure 2: (b) Transmission v/s frequency

Absorption is derived by using formula A= 1-T-R in post processing option of CST microwave. A graph is shown between absorption and frequency. Absorption achieved is 74% at 10.5GHz.

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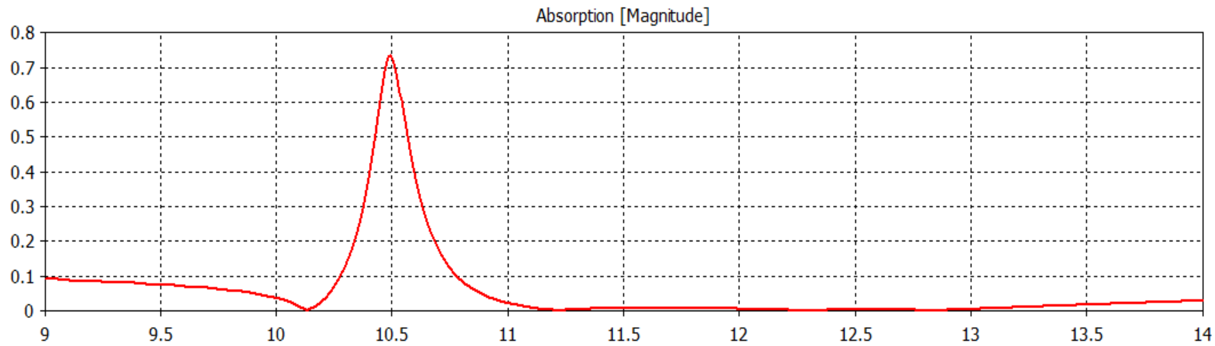

Figure 2: (c) Absorption v/s Frequency

4. Conclusion

It can easily be concluded that it is better to design metamaterial absorber rather than using conventional absorber. Size of absorber is quite small i.e. 0.7 mm. Absorption can be derived at desired frequency range and most importantly just only by varying dimensions of metamaterial absorber, targeted frequency range can be achieved. Metamaterial structures are scalable to operate over most of the elecromagnetic spectrum.

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