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Simulation based Comparative Review on a Metasurface based Perfect Absorber

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Abstract. *In this paper, the different research papers are studied and comparatively analyzed to carry out the simulation based survey of various proposals for improvement to design Metarsurface based Perfect Absorber for GHz and THz frequency band for RF Energy Harvesting applications. Using a structure that can effectively absorb the most radiation is one of the biggest obstacles in reducing the impact of EM wave radiation. A perfect absorber may be created using variety of structures and materials with various specifications. Various structures are designed and simulated by different authors in variety of simulation softwares using useful parameters. Three distinct structures have been created, two of which were created using CST Microwave Studio and the third using HFFS for comparative study. A perfect absorber can be constructed for GHz and THz for dual band and multiband since the operating frequency range and band are not limited.*

Keywords: Metasurface, Perfect Absorber, EM waves, RF Energy Harvesting.

1. Introduction

In today's era of digital and smart world, wireless communication has taken place in the smart technologies and applications. The Antenna is one of the main components of Wireless Communication which transfers data and information to any place in the world. The signals transmitted through the antenna are in the Radio Frequency (RF) range that contains frequency from Hz to THz. Therefore, it is very much required to safe guard surrounding from these high frequency signals.

It is one of the major challenges to reduce the effect of the radiation of the EM waves using a structure that can effectively absorb maximum radiation. Ideally, radiation should be completely absorbed with no reflection of the EM waves. Over a span of several years, varerty of structures have been investigated and designed to achieve this criteria of a perfect absorber. Fig. 1 represents reflection, transmission and absorption characteristic in a material.

The main working principle of perfect absorber depends on overall absorption that can be defined as:

$$A = 1 - R - T = 1 - |S_{11}|^2 - |S_{21}|^2 \quad (1)$$

Where $|S_{11}|$ and $|S_{21}|$ are the reflection coefficient and transmission coefficient respectively. For perfect absorber, these two parameters should be minimized [1].

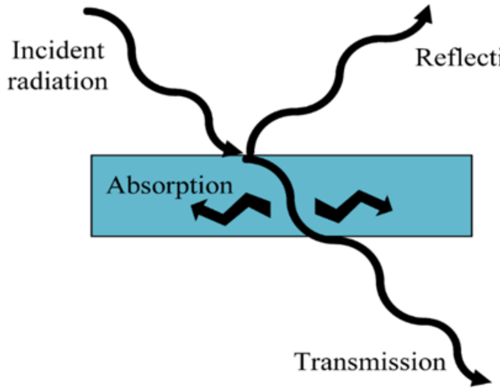

Fig. 1: Representation of reflection, transmission and absorption in a material.

A metasurface or metamaterial is the one of the material with its properties like negative reflective index, negative permeability, and negative refraction. A metasurface is the artificial material composed of metals and dielectrics [2]. There are different application of metamaterials like super lens, cloaking, electromagnetic filters, high frequency polarization converters and absorbers [2]. Therefore, a perfect absorber can be designed using this kind of artificial material.

Through the Literature review, it is found that the materials and methods for implementation depend on the specific application and the simulation software. Using different structures and variations in parame-ters of the metasurface absorber, the requirement of Perfect Absorber can be achieved [3–10].

Also, it is observed that the flame retardant (FR) 4 is used as basic substrate material because of the ease of availability and the Copper is used as a metal. To carry out simulation, HFSS and CST Microwave Stu-dio softwares are used which are very famous and mostly used by different authors [11–20].

There are three different structures designed, out of which two structures are designed in CST Microwave Studio and the third structure is designed in HFFS for comparative analysis.

2. Design and simulation

The Geometry of First structure and designed structure are shown in Fig. 2a and Fig. 2b, respectively. The structure is designed and simulated in HFSS. To design the structure, FR 4 is used as substrate material and the ink material is used for top layer [21–28]. The copper material is used for ground layer. There is a space between the ground layer and the substrate layer. The dimensions of this structure are listed below:

- Length of Substrate and Ground layer (a) =16 mm
- Length of top layer (b) = 9 mm
- Width of the top layer (w1) = 2.2mm
- Thickness of the top layer (tink) = 0.05 mm
- Thickness of Space between the substrate and Ground (tair) = 4 mm
- Thickness of the Substrate (t1) = 0.3 mm
- Thickness of the Ground (tc) = 0.017 mm

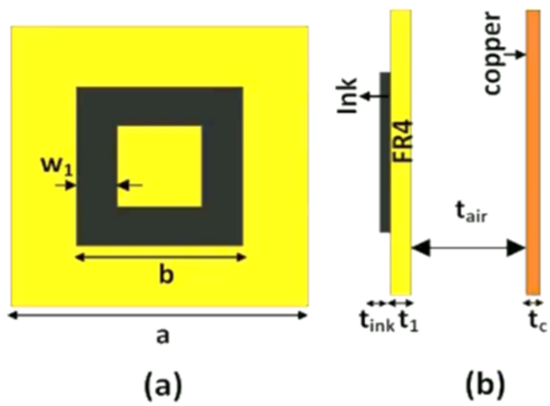

Fig. 2a: Geometry of First Structure.

The top view and side view of designed second structure is shown in Fig. 2c and Fig. 2d. To design this structure, FR4 and Copper material is used for substrate and ground layer. The structure is designed and simulated in CST Microwave Studio software. The dimensions of this structure are listed below:

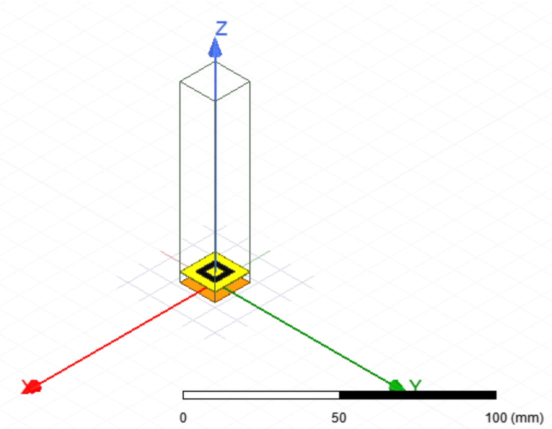

Fig. 2b: Designed Structure.

- Width of the substrate (a) = 10 mm
- Width of the w = 0.2 mm
- Radius of outer circle (r_1) = 4.625 mm
- Radius of middle circle (r_2) = 3.075 mm
- Radius of inner circle (r_3) = 2.15 mm
- Thickness (t) = 1 mm
- Thickness of the Ground (t_c) = 0.017 mm

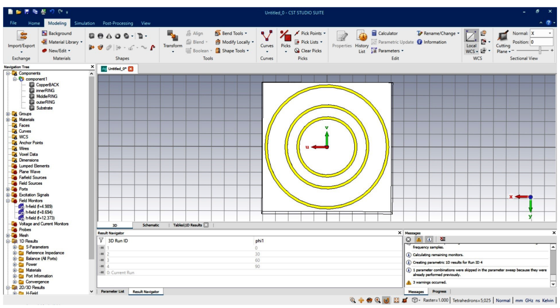

Fig. 2c: Top View of Second Structure.

The top view and side view of designed third structure is shown in Fig. 2e and Fig. 2f. For the top layer and bottom layer, the copper material is used. FR4 is used the substrate material. The structure is designed and simulated in CST Microwave Studio software. The dimensions of this structure are listed below:

- Substrate Material: FR 4 & Top and Bottom Layer: Copper.

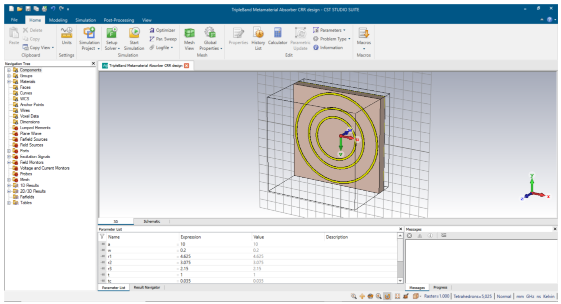

Fig. 2d: Side View of Second Structure.

- Substrate Size p = 8.24 mm
- Substrate Height h = 2.4 mm
- Radius of circle r = 3.5 mm
- Thickness t = 0.013 mm
- Length of 1^{st} Rectangle L = 5 mm
- Width of 1^{st} Rectangle = 3 mm
- Width of 2^{nd} Rectangle d = 3 mm

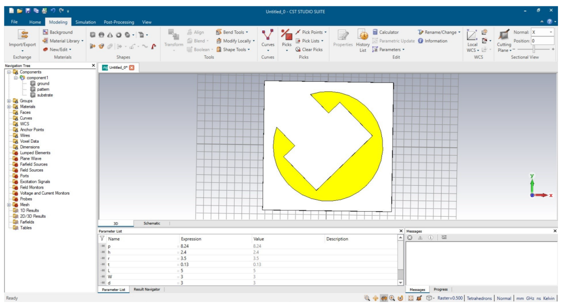

Fig. 2e: Top View of Third Structure.

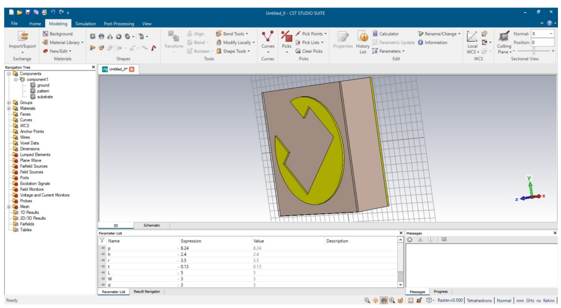

Fig. 2f: Side View of Third Structure.

3. Result and discussion

The absorption v/s frequency plot of the First structure is shown in Fig. 3a. In this result, above the 8 GHz, the absorption is observed for the broadband and after this frequency the absorption is nearer to 90%.

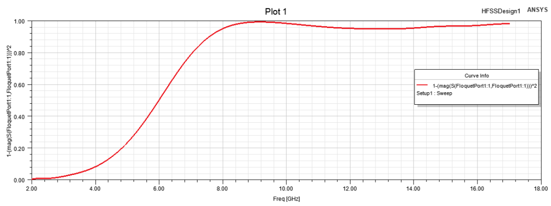

Fig. 3a: The result of first Structure (Absorption A).

The absorption v/s frequency plot of the second structure is shown in Fig. 3b. As per the result, at three frequencies 4.9 GHz, 8.7 GHz and 12.43 GHz, the absorption A is nearly to the unity.

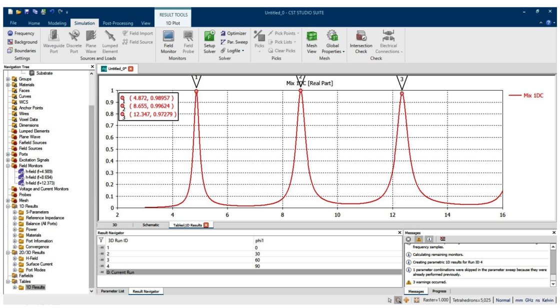

Fig. 3b: The result of second Structure (Absorption A).

The absorption v/s frequency plot of the Third structure is shown in Fig. 3c. As per the result shown in Fig. 3c, the absorption A is nearly to the unity at 5.14 GHz and 90% at 19.47 GHz.

Others parameters like angle of incident, TE TM field, the electric field and surface distribution at different absorption peaks can be simulated for the designed all three structures. The comparative analysis of these structures with respect to absorption is shown in Table 1.

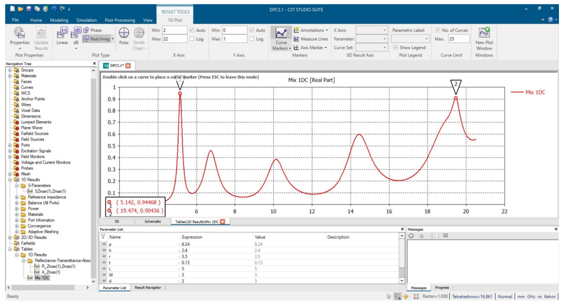

Fig. 3c: The result of Third Structure (Absorption A).

Tab. 1: The comparative analysis of the three design for absorption.

Design	Unit Cell Size (mm2)	Resonant Frequency GHz	Absorption (A) %
1	16x16	8	100
2	10x10	4.9 8.7 12.43	100
3	8.24x8.24	5.14 19.47	100 90

4. Conclusions

As we are using so many devices for wireless communication, the need arises to reduce the RF signal environment around us. Therefore, there is a requirement to implement such metasurface based perfect absorber considering the absorptivity and reflectivity characteristics. There are also so many structures and materials with different parameters can be used to design a perfect absorber. In addition, we can also consider the figure of merit, operation bandwidth and different incidence angles to simulate a perfect absorber. The operating frequency range and band for a perfect absorber is not fixed so it is also possible to design such a perfect absorber for GHz & THz for dual band and multiband.

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