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A Quad-Band Metamaterial Absorber For Various Applications

Nilesh Lokhande
M.Tech scholar Dept. of Electronics and Communication Engineering
Truba College of Science & Technology,
Bhopal, India

Rajesh Sharma
Assistant professor Dept. of Electronics and Communication Engineering
Truba Institute of Engineering & Information Technology,
Bhopal, India

Meha Shrivastava
professor Dept. of Electronics and Communication Engineering
Truba Institute of Engineering & Information Technology,
Bhopal, India

Abstract—This paper present a quad-band metamaterial absorber which consist two L-shaped structure arranged in two dimensional periodic array with a metallic ground plane. Under normal incidence this structure manifests four sharp peak absorptions at 3.75, 5.05, 7.35 and 8.96 GHz with pinnacle absorptivity of 94.28, 99.67, 99.98 and 99.90% respectively. This structure with symmetry from two side and provides nearly 100% absorption for all angle of polarization. Moreover, This Structure is polarization senstive for oblique incident angles till 45°. Corresponding to the highest frequency the absorber is ultra-thin and uses commercially available FR-4 as substrate. The designed quad-band absorber can be employ in innumerable feasible execution like thermal emitters, sensors, receivers, shielding, optical reorganization, radar signal absorption, forbid drugs and many communication utilization.

Keywords—metamaterial;quad-band; microwave absorber; polarization-insensitive.

1. INTRODUCTION

Metamaterials are manmade structure which has negative permittivity and negative permeability at one particular frequency [1]. These structures are generally periodic in nature and are arranged in such a way to ful-fil the above requirements. After the invention of metmaterials researchers show a lot of interest in this particular field and start finding the applications in different areas such as Cloacking [2], Antenna [3], Superlens [4], Metamaterial Absorbers (MA) [5]. The Metamaterial absorbers are generally periodic array of Frequency Selective Surface (FSS). The commercial available absorbers are fragile and bulky which are now a days is replaced by (MA).

MA generally consists of three different layers in which the top and bottom layers is made up of copper and the layer between them is made up of FR4 substrate act as a dielectric substrate. Actually a sub wavelength unit, also known as meta-atoms or meta-molecules is manufactured, compress simulated electric and magnetic field component of the incident electromagnetic waves [6]. Magnetic component affects dielectric

substrate while electric component affects top layer of FSS material. This allows the procurement of tailored mediums with random but fruitful material parameters [7]. Ultimately conduction current flows at top and bottom metal layer and displacement current through substrate. By achieving resonance frequencies, permeability and permittivity of the racially balanced structure can become equivalent to each other. As the input impedance of the structure matches to the free space impedance of air, reflection from the absorber drastically decreases [8].

MA finds the applications in the field of: solar cell [9], radar application [10], electromagnetic wave absorption [11], terahertz imaging device[12], wireless communication [13], satellite networks[14], air surveillance radar and many defense applications etc[15].

This paper present a quad-band metamaterial absorber which consist two L-shaped structure arranged in two dimensional periodic array with a metallic ground plane. Under normal incidence this structure manifests four sharp peak absorptions at 3.75, 5.05, 7.35 and 8.96 GHz with pinnacle absorptivity of 94.28, 99.67, 99.98 and 99.90% respectively. This structure with symmetry from two side and provides nearly 100% absorption for all angle of polarization. Moreover, This Structure is polarization senstive for oblique incident angles till 45°. Corresponding to the highest frequency the absorber is ultra-thin and uses commercially available FR-4 as substrate. The designed quad-band absorber can be employ in innumerable feasible execution like thermal emitters, sensors, receivers, shielding, optical reorganization, radar signal absorption, forbid drugs and many communication utilization.

2. Unit Cell Structure layout

The proposed MA unit cell structure is shown in Fig.1. The overall dimension of the proposed MA is 15mm 15mm. MA generally consists of three different layers in which the top and bottom layers is made up of copper having Conductivity $\sigma = 5.8*107$ S/m and thickness of 0.035 mm, where bottom is ground plane and top is the novel design. The layer between them is made up of FR4 substrate act as a dielectric substrate having relative permittivity $\epsilon r = 4.2$ and dielectric loss tangent $\tan(\delta) = 0.02$. The thickness of the substrate is consider as 1.6mm. The structure is consider as polarization insensitive.

From the absorptivity equations (1) it is shown that for absorption two parameters are consider and , where is the reflected power and is the transmitted power. The structure is fully covered with copper from the ground therefore the transmitted power is zero and absorptivity is fully depend on

parameter. It is concluded that lower the value of parameter higher will be absorptivity and vice-versa.

$$\text{Absorptivity} = 1 - |S_{11}(\omega)|^2 - |S_{21}(\omega)|^2 = 1 - |S_{11}(\omega)|^2 \quad \ldots..(1)$$

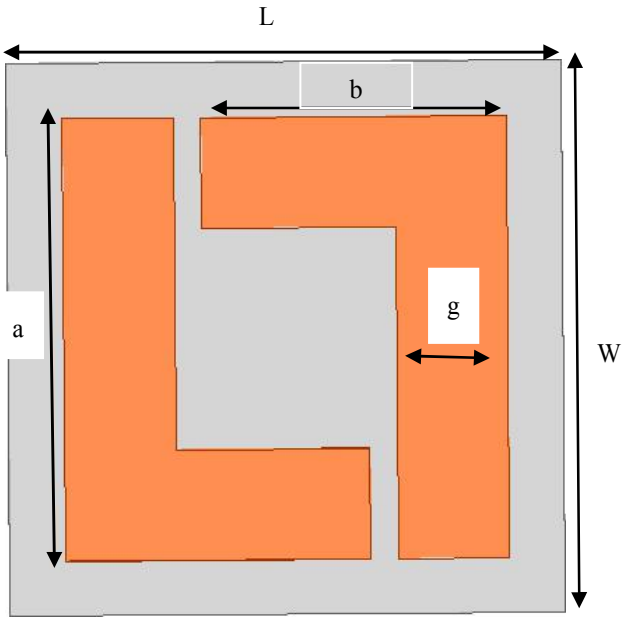

Fig.1.shows Front-part of proposed unit cell geometry .
(Dimension of the unit cell: W=15mm, L=15mm, a=12.7mm, b=4mm,g =2.2mm)

3. SIMULATED RESULT AND ANALYSIS

The proposed unit cell structure is simulated using the commercial available ANSYS HFSS. The structure is provided with periodic boundary condition consists of Master and Slave Boundary. The reflection coefficient plot obtained shown in Fig. 2 have absorption at 3.75 GHz, 5.05 GHz, 7.35GHz and 8.96 GHz and at all the four frequency the peaks obtained is above 90% and summarized as 94.28%, 97.27%, 99.67% and 99.90% respectively.

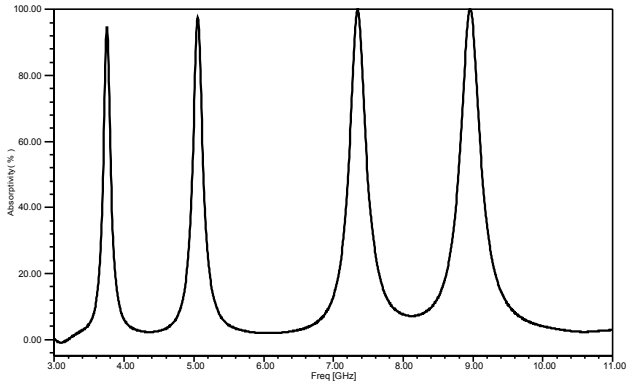

Fig.2. Four-band absorption of proposed structurte.

Normalized input impedance Z(ω) is calculated from equation (2) with the help of effective permittivity and effective permeability and from the plot obtained as shown in Fig. 3 it is observed that propoer impedance matching is done because the real part and the imaginary part is almost equal to unit.

$$Z(\omega) = \sqrt{\frac{\mu(\omega)}{\epsilon(\omega)}} \ldots\ldots\ldots (2)$$

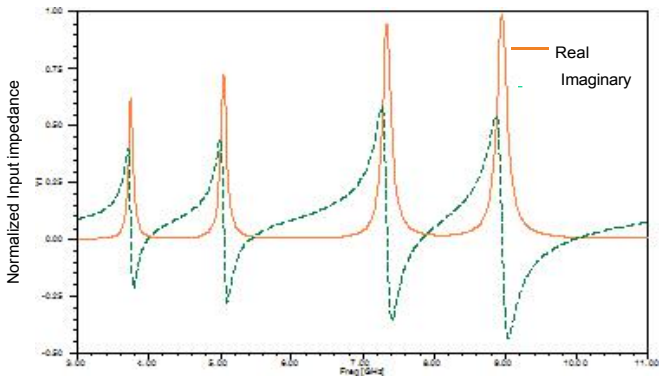

Fig.3. Normalized input impedance Z(w) of proposed structure

The electric-filed, magnetic-field and surface current distributions of the top and bottom surface at all four different absorption frequencies obtained in order to better understand the absorption mechanism of the proposed structure. Electric and magnetic innervations is described by too concentrated electromagnetic fields at the distinct segments of the structure such as middle loop, exterior split loop, interior cross connected loop and also too outer split ring with all the apex absorption frequencies 3.7 GHz, 5.05 GHz, 7.30 GHz and 8.9 GHz respectively.

The proposed structure is a polarization insensitivity because it is not a fourfold symmetry. Response of the structure with the divergence of phi-angle of incidence as shown in Fig. 4.Absorptivity is same even till 60^0 of angle of incidence.

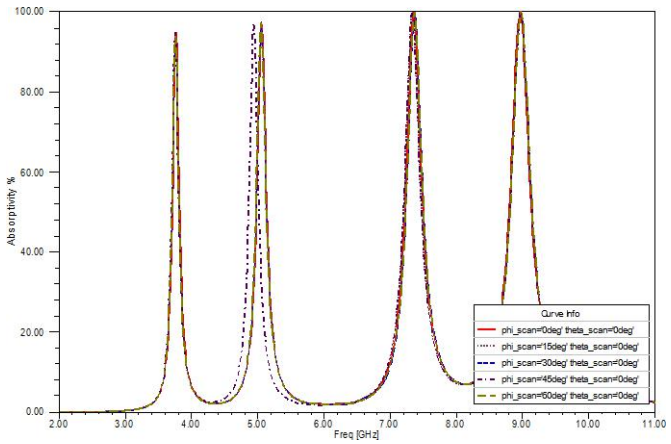

Fig. 4. Response of the proposed structure under different angles of incidence.

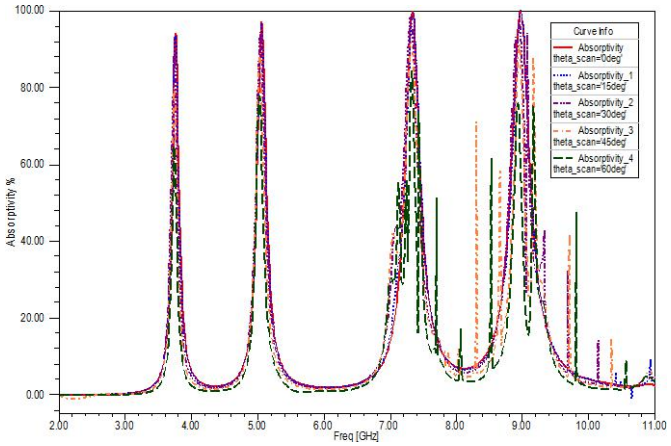

Fig. 5. Response of the proposed structure under different oblique angles of Incidence.

The structure is inspected for various theta-angle of incidence i.e. under oblique incidences as shown in Fig. 8. Till 60^0 angle of incidence (with variation of theta), it has high absorption but further on that the absorptivity decreases moderately.

4. CONCLUSION

An ultra-thin four band square ring metamaterial absorber has been displayed. The field such as electric and magnetic and surface current distribution at different frequencies is illustrated in order to perceive the physical mechanism of absorption. Moreover, introduced design is four-fold symmetric as well as polarization sensitive characteristics for normal incidence. This shows good absorption behavior (nearly unity) up to 45° angle of incidence and can be used for various applications.

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