MULTI-BAND POLARIZATION INSENSITIVE METAMATERIAL ABSORBER FOR EMI/EMC APPLICATION

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Abstract:- *In this paper, a multi band metamaterial absorber at (C, X, Ku, and K Band) is presented in microwave frequency band. The unit cell geometry comprises of two split ring resonators and two square shapes fractal structure in the top surface of a metal-backed dielectric substrate. Simulation result shown that the structure has multi-band absorption response with one band lying C-band, one band lying X-band, two band lying Ku band, and another one band in K-band. The absorber is symmetric in design and shows polarization insensitive behavior under the normal incidence. It also shows high absorption (above 80%) for oblique incidence up to 45o under TE and TM polarization. The proposed structure has been fabricated and absorption is measured in anechoic chamber, which show good result with the simulated response. The designed absorber is appears to the potentially for various EMI/EMC application.*

KeyWords: Metamaterial, microwave absorber, frequency, EM wave, polarization-insensitive.

1. INTRODUCTION

However, with growing technology, a significant research is carried out to achieve multi-band and/or bandwidth-enhanced absorbers with simultaneous polarization-insensitive and wide-angle structure has been proposed characteristics. A split ring resonator (SRR) based metamaterial absorber proposed Due to its unusual electromagnetic properties.

Metamaterial are artificial structurers its engineered arrangement that enhance electromagnetic properties they are not found in natural materials. Researches are making effort eventually become Metter of concern for wide range of microwave frequency band application. Metamaterial absorber superiority over conventional absorber due to their paper thin thickness, incredible absorptivity and easy to manufacture the absorber is constructed of a delicate periodic structures and a metallic background plane, separated by a dielectric substrate.

Generally, these metamaterial absorber structures are composed of three layers. On the top layer, a periodic array of frequency selective surface (FSS) and on the ground a complete metal plane is placed and these two are separated by dielectric substrate. Magnetic field component of incidence electromagnetic waves with resonance frequency leads to excitation of the dielectric substrate whereas electric component of the same leads to excitation of top layer FSS. These excitations ultimately generates a circulating current consist of conduction current (at top and bottom layer metals) and displacement current (via substrate). Hence, at these resonance frequencies, the effective material properties (permeability and permittivity) of the integrated structure can be simultaneously engineered by incident electromagnetic fields such that the effective permeability and effective permittivity of the structure become equal to each other. This entails in reducing the reflection from the absorber structure as the input impedance of the structure nearly equal to the free space impedance of air.

Electromagnetic wave absorbers can be used in devices and many other areas such as: emitters, sensors, terahertz imaging device, spatial light modulators, IR camouflage, wireless communication, radio receivers from interference of radiated fields, EMI shielding, satellite networks, solar cell, Spectroscopic detection, hazardous materials phase imaging and prohibited drugs, air surveillance radar and many defense applications etc. Conventional absorbers being bulky and fragile can be substituted by these metamaterial absorbers due to its inherent advantages such as lighter weight, higher efficiency and ultra-thin thickness. With growing technology, different types of absorber structures have been proposed such as single band, dual band, triple band, bandwidth-enhanced and broadband and multi band etc. some multiband absorbers are proposed by simply scaling a unit cell structure and then combining them to form a new unit cell structure, but they suffer from the constrains of large unit cell size. Hence, there is still an in adequate advancement towards the design and development of multiband MTM absorber which may find its many applications as mentioned earlier.

1.1 CONFIGURATION OF UNIT CELL STRUCTURE

Front view of unit-cell geometry of the proposed design is shown in Fig. 1. It is consists of three layers – uppermost layer, bottom layer and the middle dielectric substrate layer is placed in between them. Bottom layer is complete metal and blocks all transmission of waves through it.For the middle layer commercially available FR-4 dielectric substrate (relative permittivity $\epsilon r = 4.2$ and dielectric loss tangent $\tan(\delta) = 0.02$) with thickness of 1 mm has been considered. The absorber is ultra-thin (with thickness = 1mm ~ λ/40 with respect to the highest frequency) and as dielectric. Copper (Conductivity σ = 5.8x107 S/m) having thickness of 0.035 mm is used for both top and bottom layers. Top layer has two dimensional array of introduced unit cell structure. This includes two square rings – exterior ring, and inner most ring and two square shapes fractal structure. The outer ring and inner has four splits. The inner two square shapes fractal structure to provide extra path to surface current flow.

Fig. 1 shows the front view of the unit cell geometry of the proposed structure with the direction of the field vectors (electric field, magnetic field incident electromagnetic wave).

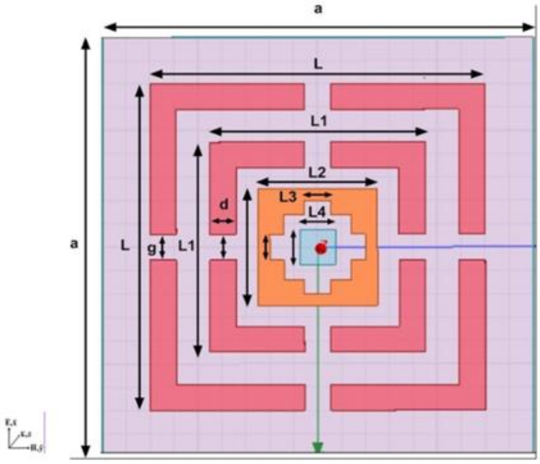


Fig.1 front view of unit cell geometry of proposed structure. (Dimension of the unit cell a = 18mm, L=14mm, L1=9mm, L2=5mm, L3=1.0mm, L4=1.5mm, g=1.1mm, d=1.1mm)

Transmitted power |S21 (ω) |2 will be completely blocked by bottom layer as it is copper laminated which acts as perfect mirror for incident waves. Therefore, reflected power |S11 (ω) |2 can be minimized by only designing of the unit cell structure parameters. Hence, as evident from equation (1), maximum value of absorptivity A (ω) can be achieved by reducing reflected power.

Absorptivity =1 - |S11 (ω) |2 - |S21 (ω) |2

=1 - |S11 (ω) |2 …………………………………… (1)

2. SIMULATED RESULT AND ANALYSIS

Ansys - HFSS with periodic boundary condition(Master and Slave Boundary) is used to simulate the unit cell structure, shows multi band absorption at five distinct minima of return loss |S11(ω)| at 7.05 GHz, 10.25 GHz, 12.12GHz,15.35GHz and18.20 GHz. At shown Fig.2.

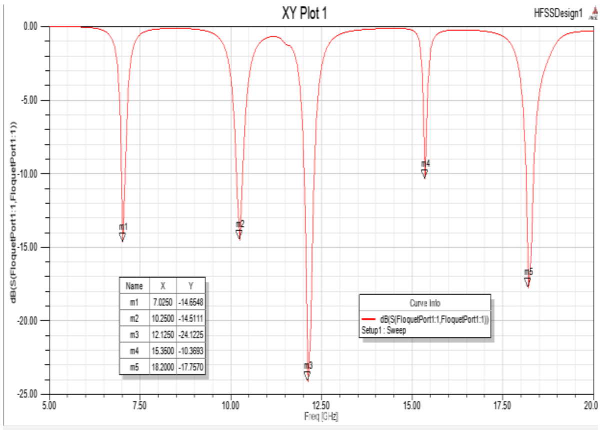


Fig.2 absorption |S11(ω)|

Leading to absorptivity peaks of 96.57%, 96.46%, 99.12%, 90.81%, and 98.32% respectively as shown in Fig. 3.

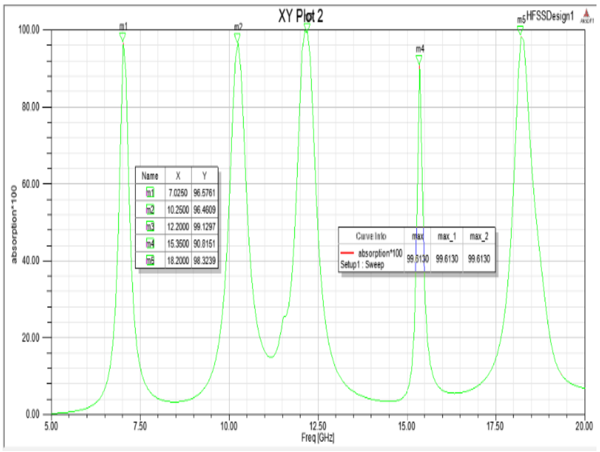


Fig.3. imitated absorption spectra of the five band absorber under normal incidence of wave.

Absorption mechanisms Metamaterial tailors permittivity and permeability and hence, tailor the input impedance by achieving electric and magnetic resonance simultaneously. At certain frequencies the effective impedance Z (ω), which is defined as [5]:

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

Matches to the free space impedance η_ (0) (377 Ohm) and therefore minimizes the reflection.

$$(\omega) = \sqrt{\frac{\mu_0\mu_{eff}}{\epsilon_0\epsilon_{eff}}} = \eta_0\sqrt{\frac{\mu_{eff}}{\epsilon_{eff}}} = \eta_0\sqrt{\frac{\mu' + j\mu}{\epsilon' + j\epsilon}} \ldots\ldots (3)$$

Hence, at absorption frequencies

$$\epsilon' \approx \mu' \text{ and } \epsilon \approx \mu \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Fig. 3 shows that the normalized input impedance Z (w) of the introduced structure matches confined with the free space impedance η0. For all the four absorptivity peaks it can be perceive that the real parts of normalized input impedance Z(w)/377Ω are close to unity, while the imaginary parts of normalized input impedance Z(w)/377Ω are near to zero and hence it reinforces the absorption phenomena.

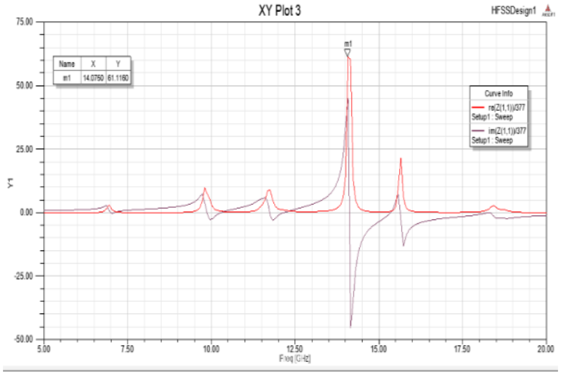
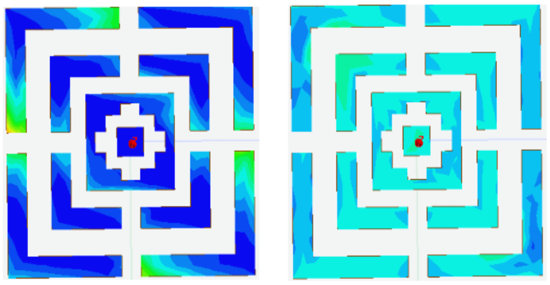
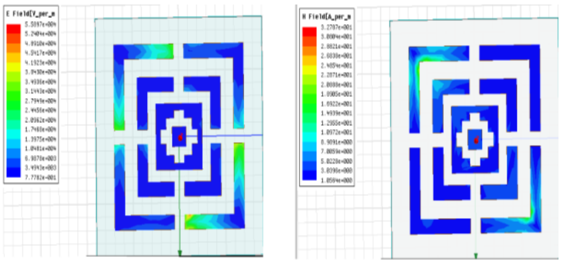


Fig.4. Normalized input impedance Z (w) of the introduced structure.

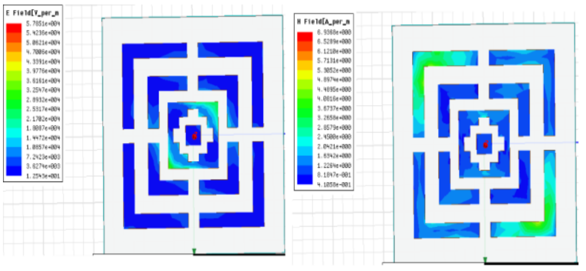
In order to better understand absorption mechanism of proposed structure, the electric field, magnetic field, and surface current distribution of the top and bottom surface have been shown respectively in Fig.5, Fig.6, and Fig.7. At the all five different frequency's.



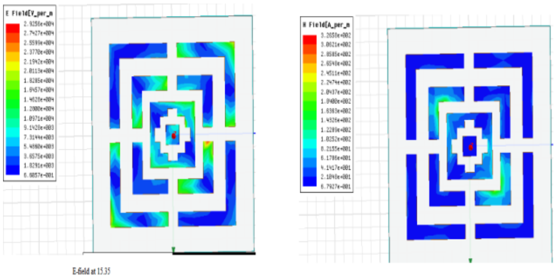
E-field at 7.02GHz H-field at 7.02GHz



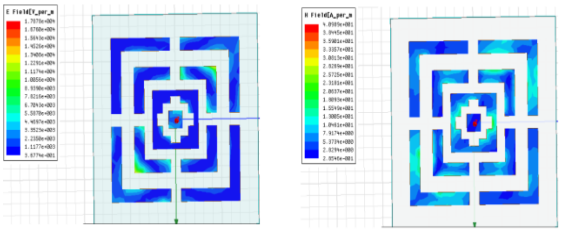
E-field at 10.25GHz H-field at 10.25 GHz



E-field at 12.20 GHz H-field at 12.20 GHz



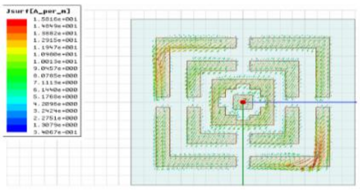
E-field at 15.35 GHz H-field at 15.35 GHz



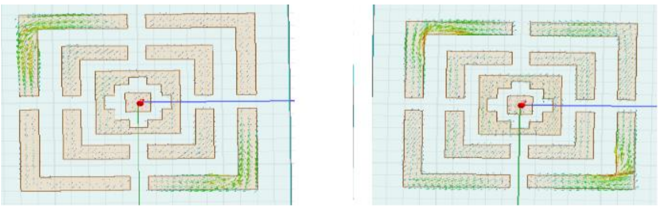
E-field at 18.20 GHz H-field at 18.20 GHz

Fig.5 the electric field, magnetic field distribution

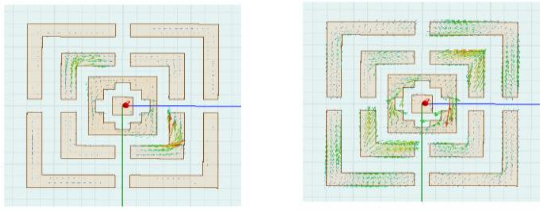
Fig. 5 illustrates the electric and magnetic field distributions with all the absorption peak frequencies. Electric and magnetic excitations is described by highly localized electromagnetic fields at the different portions of the structure such as middle ring, exterior split ring, inner or factual shaped and again outer split ring with all the peak absorption frequencies 7.02 GHz, 10.25 GHz, 12.12 GHz, 15.35 GHz and 18.20GHz respectively.



(a) 7.02GHz

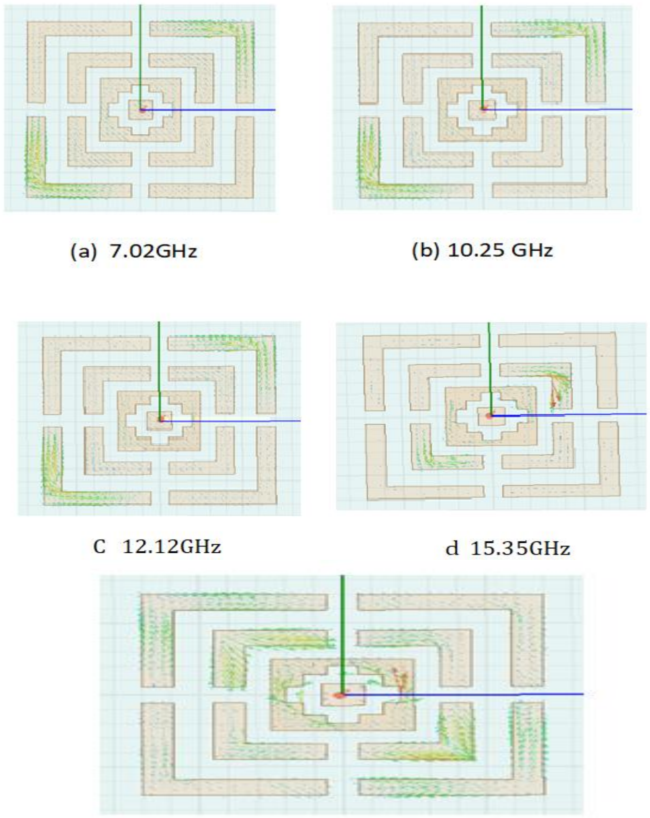


(b) 10.25GHz (c) 12.12 GHz



(d) 15.35 GHz (e) 18.20 GHz

Fig.6 Surface current distributions at top surface at all the five Frequency of absorption.


(a) 7.02GHz

(b) 10.25 GHz

C 12.12GHz

d 15.35GHz

(e) 18.20GHz

Fig. 7.Surface current distributions with top surface at all the five frequency of absorption.

The Fig. 6 and Fig. 7 show the surface current density and are enclose within the middle square ring at 7.02 GHz. However, inner connected square structure shows larger current at 12.12 GHz. The track for the current flow increases because of two square shapes fractal structure in inner geometry, in spite the resultant inductance has been diminished due to parallel combination of rings and fractal structure, consequently in increase of absorption. Unlike single square middle ring which give resonance at single frequency, outermost square ring provide resonances at two variant frequencies. As compared to the other two smaller inner rings, outer ring has bigger length and it is likely to have lowest resonance and thus absorption. But, due to division ring the working inductance gets decreases. This diminished inductance and adds to the absorption frequency. Same can be as seen from the surface current plots.

It is also seen from the Fig. 6 and Fig. 7, the anti-parallel directions of surface currents at the top and bottom layers which formed a circular current loop. Loop current is perpendicular to the direction of incident magnetic field create magnetic field. On the other hand, forming of induced electric field in the direction of incident electric field gives the electric field within the structure (at top and bottom layer copper). Hence more powerful electro-magnetic absorption formed because both electric and magnetic resonances at all peak absorption.

Polarization Insensitivity

The polarization – insensitivity of the absorber has been verified by rotating the fabrication striated around its axis foam 00 to 450. The measured result shows almost identical absorption response for all polarization angle under normal incidence as shown in Fig (8) and Fig (9) shows the measured absorptivity response for different incident angle under the TE and TM polarization, which also shows good agreement with the simulated result.

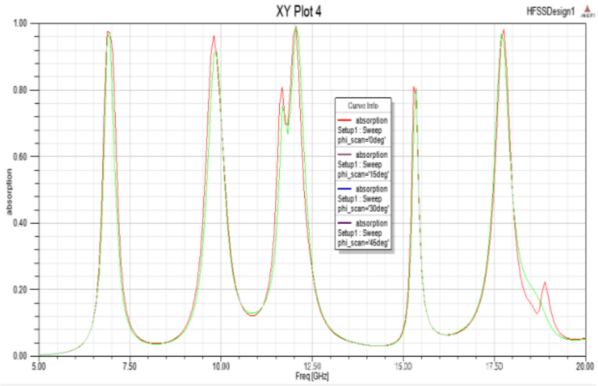


Fig.8 Response of the structure under various angles of incidence (Phi-Angle variation).

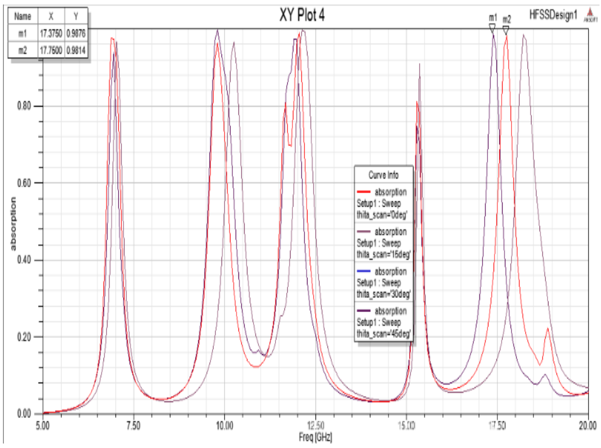


Fig. 9. Response of the structure under various oblique angles of incidence (Theta - Angle variation).

Further, the structure is examined for various theta-angle of incidence i.e. under oblique incidences as shown in Fig.98. Up to 450 angle of incidence (with variation of theta), it has high absorption but beyond that the absorptivity decreases gradually.

3. CONCLUSION

A concentric split ring metamaterial absorber structure has been proposed in this article. The structure shows near-unity absorption for five different microwave bands (C, X, Ku, and K Band aimed for radar applications. The fractal in the inner structure of the structure provides larger absorbance in the higher frequency and better tune ability. The proposed structure is polarization-insensitive under normal incidence and shows high absorption (above 80%) for both TE and TM polarizations. Moreover, the proposed structure has been fabricated and measured in anechoic chamber, which shows good matching with the simulated results under normal as well as oblique incidence condition. The surface current distributions have been illustrated to explain the physical insight of the absorption of the structure. Moreover, the proposed structure The dimensions of the proposed absorber structure can be tuned to apply in various applications like stealth technology, THz imaging and wireless communication, defense application, satellite communication. etc

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