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Improved Polarization Insensitive Dual Band Electromagnetic Wave Absorber

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Abstract

This paper presents a Dual band electromagnetic wave absorber with improved polarization insensitivity. Here, the proposed absorber consists of two independent resonators ‘P’ and ‘Q’ which are integrated together to provide dual band absorption at 8.05 GHz and 10.95 GHz. The proposed absorber is analyzed using multiple parameters like, surface current density at resonant frequencies, polarization angles, and S-parameters. The measured results indicate that the proposed absorber configuration provides an absorptivity of around 99.9% and 97.3% with wide angular polarization insensitivity bandwidth of 60º (approx) at 8.05 GHz and 10.95 GHz respectively. A good agreement between simulated and measured results validates the performance of proposed absorber.

1. Introduction

In recent years electromagnetic (EM) wave absorbers are widely researched for their wide range of applications. Most EM wave absorbers are the combination of periodic elements which are either left handed materials (metamaterial absorbers-MMA) or frequency selective surfaces (FSS) based absorber [1 - 7]. Most of these absorbers are periodic arrangements of resonant structures which can provide resonance at single, dual or multiple microwave bands. Recently, many multi band absorbers with limited or extended polarization insensitivity have been reported [1 - 6]. Most of the reported absorbers are polarisation insensitive for certain angle of incident. Form literature survey it is observed that it is still a challenge for a single absorber structure to achieve multiple characteristics such as: polarization independence, multi-band, wide-bandwidth etc.

In this paper, an improved polarisation insensitive dual band MMA absorber is presented. Here, two different resonators or unit cells are integrated to form a single unit cell. This unit cell is then combined to form a periodic-grid of 252mm×252mm on FR4 dielectric substrate sheet. The proposed structure is tested in anechoic chamber environment for its absorptivity and polarization angle sensitivity.

2. Absorber Design and Simulated result analysis

2.1 Absorber Design

The proposed absorber structure is inspired by ‘I’ shaped MMA reported in [5]. Here, figure 1 shows the base structure and the set of modifications done to achieve polarization insensitivity for dual band. In the proposed MMA based absorber, the central ‘I’ shape is turned with an angular movement of 45º, such that it forms a central cross configuration as presented in figure 1. The reason of adding cross configuration is to enhance the interaction between MMA structure with normal or angular incident EM wave. The central cross-configuration is connected to a sectioned square. It is observed that after parametric (dimensional) optimization the resonator ‘P’ resonates at 8.05 GHz. To add additional band, a unit cell with a set of four quarter circular curves is further added as shown in figure 1. The unit cell with quarter curve is indexed as resonator ‘Q’. The resonator ‘Q’ is further optimized to provide the resonance at 10.94 GHz.

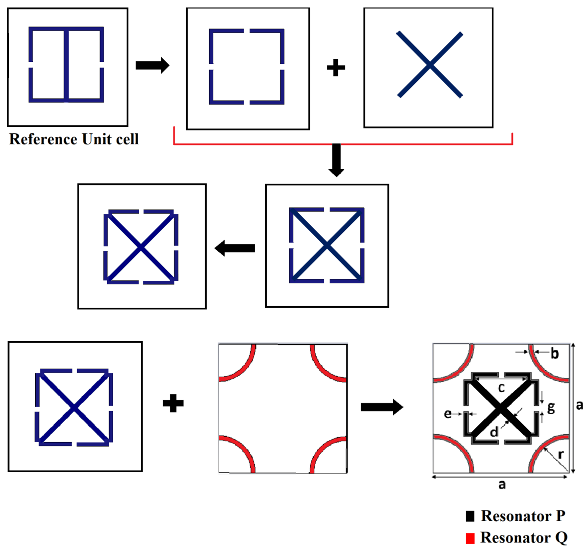


Figure 1. Schematic of proposed Unit cell with dual resonator configuration, (all dimensions are in mm: a = 9, r = 2.4, b = 0.3, c = 4, d = 0.4, e = 0.3, g = 0.4;)

2.2 Simulated Results and Analysis

The proposed MMA absorber is analyzed using periodic structure-based analysis tool of CST microwave studio simulation software. Here, the absorptivity is calculated using S parameter [6]. The extraction of S-parameters and effective impedance are done using periodic boundary condition set-up as presented in figure 2.

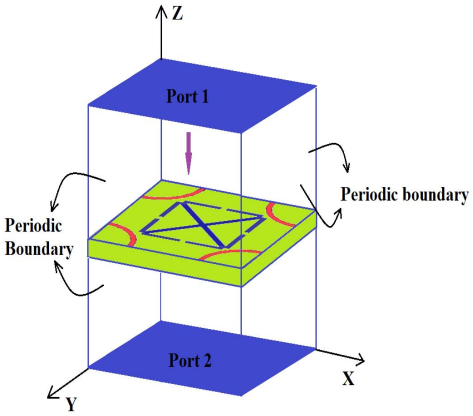


Figure 2. Simulation setup for proposed unit cell, the boundary condition of sides faces are choosen as periodic.

The unit cell of the proposed MMA is realized on FR4 lossy substrate with Ɛr = 4.3, tanδ = 0.025 and thickness = 0.8 mm. The proposed resonator is designed on top surface of the substrate and metallic sheet is placed at the bottom of the substrate. The metallic sheet present at the bottom surface of the substrate prevents any transmission from port 1 to port 2. Initially, the absorptivity is calculated under normal incidence using simulated S-parameters as reported in [5, 6]. Here, S-parameter are extracted and using matlab code, absorptivity vs frequency graph is plotted. It can be seen in figure 3 that the proposed absorber provides the absorptivity of more than 90% at 8.05 GHz and 10.97 GHz.

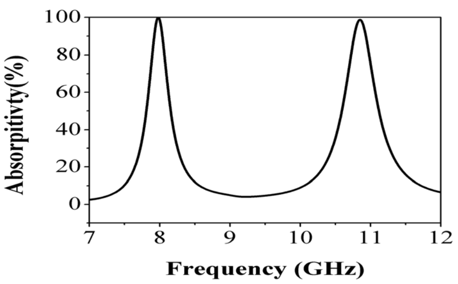


Figure. 3 Calculated Absorptivity for normal incident angle

To ensure the polarization independence, the polarization angle of the incident wave is varied from 0º to 90º and corresponding absorptivity is calculated. Here, the polarization angle is indexed as ϕ. Some of the responses are tabulated in graph presented in figure 4. It can be observed in figure 4 that the absorptivity remains unchanged for different polarization angle.

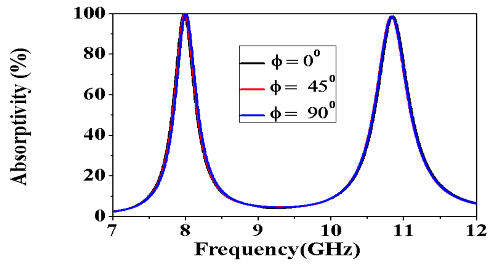


Figure. 4 Calculated Absorptivity for different polarization angle

To analyze the dimensional tolerance on absorptivity, dimensions ‘g’ and ‘r’ are varied and corresponding absorptivity is calculated.

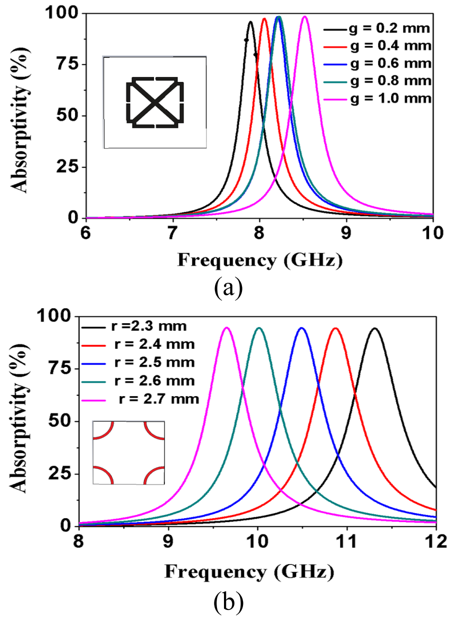
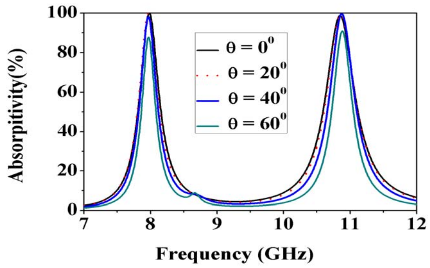


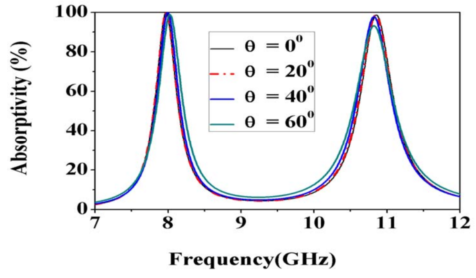
Figure. 5 Calculated Absorptivity for different values of (a) ‘g’ i.e. gap between in the strips, (b) radius of the quarter circles.

In figure 5, the change in absorptivity corresponds to variations in dimensional parameters are presented. Here too normal incidence is considered. It can be seen that as the gap ‘g’ between the strips increases (figure 5(a)) the absorptivity shifts toward upper frequency bands. This is because with increase in ‘g’ the resonator becomes electrically small. Whereas, when the radial length ‘r’ is increased the absorptivity shifts to lower frequency bound, as the electrical length of the resonator in increased.

Apart for normal incidence, obliques incidences for both TE and TM polarizations are also studied and presented in figure 6. For both TE and TM polarizations the percentage and bandwidth of absorptivity remain unchanged at-least till 60º of incidence as shown in figure 6. During simulation it is observed that the percentage of absorptivity reduces for incident angle beyond the 60º, thereby giving a limit to the extent of absorptivity in terms of angular bandwidth



(a)



(b)

Figure. 6 Calculated Absorptivity for different incident angle (θ) (a) TE polarization, (b) TM polarization.

The mechanism of the absorption can be also be understood from surface current distribution. For perfect absorption it is necessary that the surface current in the resonator should backed by an out of phase current specially in metal backed resonator. In the proposed structure it is observed that for both the resonant frequencies i.e. 8.05 GHz and 10.95GHz, the surface current at respective resonator is backed by an out of phase current as shown in figure 7. This leads to an out of phase current cancelation. The normalized input impedance is also calculated to support the absorption characteristics. The calculation of effective impedance is done as reported in [7].

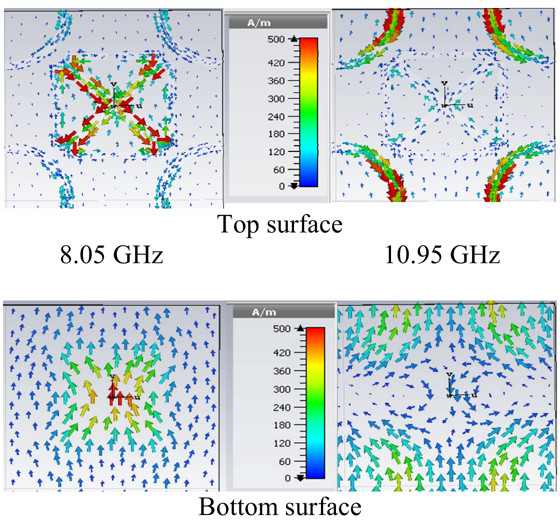


Figure. 7 Surface current distribution at top and bottom surface of the resonator

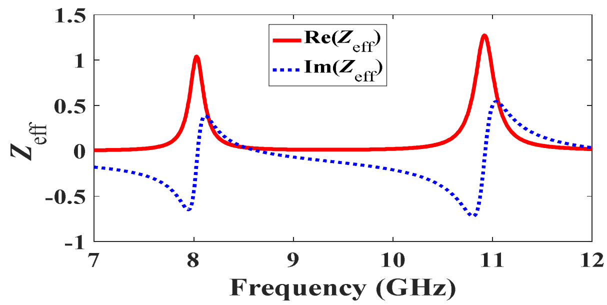
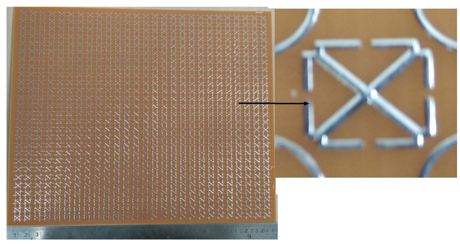


Figure. 8 Calculated values of effective impedance using equation reported in [7].

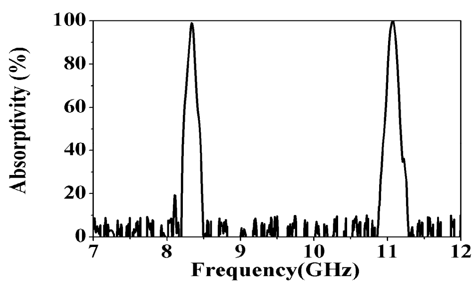
It can be seen in figure 8, that the effective impedance is nearly unity at resonant frequency with zero reactance Since the input impedance $Z_{in} = Z_0 . Z_{eff}$ [7], where Z_0 is free space impedance, it can be observed that the incident wave will only see the free space impedance and with satisfied matching conditions, the reflection of incident wave from the proposed MMA will be negligible.

3. Measured results

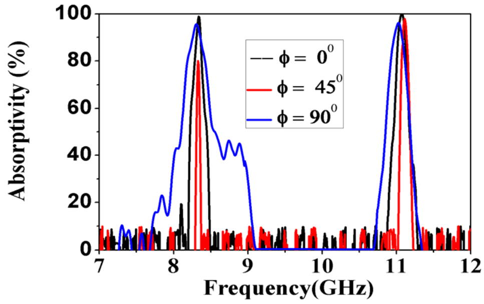
To validate the simulated results, the proposed MMA is fabricated in form of a 27 × 27 unit cells grid printed on 0.8 mm thick FR-4 sheet (figure 9(a)) using printed circuit board (PCB) technology. After fabrication the grid is tested for absorptivity under various conditions. Here, the measurement setup is made using two wide band horn antennas places adjacent to each other and fabricated prototype is placed in front of them (at a distance equivalent to far field for the antennas) to each other in an anechoic chamber environment. A metallic sheet is also used as a reference for perfect reflector.



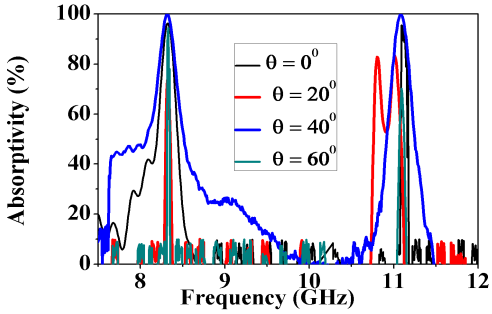
(a)



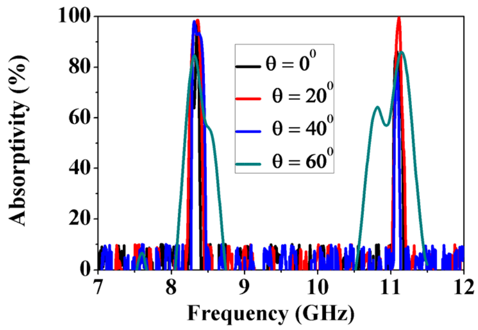
(b)



(c)



(d)



(e)

Figure. 9 a) Fabricated MMA Grid, Measured results: (b) Absorptivity with normal incidence, (c) Absorptivity with normal incidence with different polarization angle (ϕ), (d), (e) Absorptivity for TE and TM polarization with different polarization angle respectively.

As presented in figure 9, the measure results are comparable with the simulated results. It can be seen in figure 9 (b – e) that there are minimal deviations in the measured results compared to simulated one. These deviations can be attribute to measurement setup errors and fabrications errors. During measurement it is observed that the grid/metallic plate fixture stand tend to provide additional angular bend to MMA grid. This gives some additional errors in absorptivity measurements. Form measurement results one can conclude that the proposed MMA absorber configuration provides a distinctive absorption peak at 8.09 GHz and 10.95 GHz which is nearly same as simulated results. Also, the incident angle for any type of polarization is extended up to 60º.

4. Conclusion

In the presented work, an improved polarization insensitive dual band absorber is presented. The measured absorption for 8.09 GHz and 10.97GHz is found to be more than 90%. The incident angle or polarization sensitivity is till 60º which shows that the proposed MMA provides stable absorptivity for both TM and TE polarizations. The absorption concept for the proposed configuration is validated using simulated and measured results. It is observed that the measured results are nearly comparable with the simulated results.

5. Acknowledgements

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6. References

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