Penta-Perfect Metamaterial Absorber for Microwave Applications

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Abstract. This paper presents simulation very simple structure of multi band metamaterial absorber at the microwave frequency band. The unit cell of the proposed structure consists of two copper rings at different radius, loaded onto FR4 substrate with 2.5 mm thick in order to achieve perfect multi absorption bands. The asymmetrical ring structure generally makes it sensitive to electromagnetic (EM) waves polarization. But the Penta-Perfect Metamaterial Absorber PPMMA proposed structure is capable to absorbs electromagnetic wave at wide range of incident EM wave. The CST simulated result of proposed PPMMA structure shows that the five-band realizes perfect metamaterial absorber for normal incident electromagnetic waves of 91.3%, 99.3%, 93.7%, 98.2%, and 97.4% at 12.25 GHz, 12.9 GHz, 16.15 GHz, 16.78 GHz, and 18.44 GHz of absorbance value respectively.

1. Introduction

Negative refractive index materials based on periodic array of conducting elements today become known metamaterials medium. In last 20 years has been investigated and become highly hot topic due to their unusual and exotic properties not found in nature [1,2]. There are many applications in an assortment of engineering fields inherent from specials properties of metamaterial such as object cloaking [3], enhance antenna propagation patrons [3], sensor [4,5], power energy harvesting [6,7], lens imaging [8], solar cells [9] and thermal imaging [10], etc. Metamaterial based on Electromagnetic Absorbers (MEMA) are designed according to the principle of impedance matching with the free space impedance ($\zeta$) at resonant frequency [4,5,11]. A perfect metamaterial absorber can be used to absorb the electromagnetic wave with zero electromagnetic reflection EMR and zero electromagnetic transmission EMT [12,13]. The effective medium structure based MEMA provide almost perfect absorption with ultrathin substrate thickness [14,15] and simple resonator design. Although absorbers based on metamaterial are made much smaller structures to provide almost total absorption of incident EM wave, many studies focused in single band absorber but in recent work presented multi band MMA because they are suffered from narrow absorption bandwidth [1,16,17]. In this work very simple structure are simulated just two rings. This structure can be absorbing electromagnetic wave at 5 bands at 12.25 GHz, 12.9 GHz, 16.15 GHz, 16.78 GHz, and 18.44 GHz with absorption level 91.3%, 99.3%, 93.7%, 98.2%, and 97.4% respectively.

2. Design

In this work very simple three layers’ metamaterial absorber structure. Figure.1 shows proposed designed resonator with its optimized dimensions. The parameters value is listed in to table 1. The top layer and bottom layers of absorber is metallic (copper) with thicknesses 35 $\mu$m and conductivity is 58 $\times$ 10$^6$ S/m. the tow metallic layers separated from each other by FR4 substrate layer with permittivity 4.3, tangential losses is 0.02 and thickness is 2.5 mm.
The unit cell is simulated based on CST microwave studio EM simulator according to frequency solver simulation. The absorption is calculated according to S-parameter results which are carried out CST analyzed and equ.1.

\[ A(\omega) = 1 - |S_{11}|^2 - |S_{21}|^2 \]  

Where \( A(\omega) \) is absorbance, \( S_{11} \) reflectance and \( S_{21} \) transmittance. Because we used entire ground the equ 1. becomes as in equ.2.

\[ A(\omega) = 1 - |S_{11}|^2 \]  

The simulation setup is applied as shown in Figure.2. where \( k^* \) is propagation vector aligned to z-direction, electric field vector E aligned to y-direction and magnetic field vector H aligned to x-direction.

| Parameter     | Value (mm) |
|---------------|------------|
| \( A \)       | 12.25      |
| \( r1 \)      | 3.1        |
| \( r2 \)      | 5.1        |
| \( W \)       | 1          |
| \( G \)       | 1          |
| \( H \)       | 2.5        |

**Table 1.** Dimension value of proposed structure.
3. Results
The proposed metamaterial absorber shows simulated response according to applied electromagnetic which is normally incidence into it. Figure 3 presents five absorption bands at 12.25 GHz, 12.9 GHz, 16.15 GHz, 16.78 GHz, and 18.44 GHz with absorption level 91.3%, 99.3%, 93.7%, 98.2%, and 97.4% respectively.

Figure 3. Absorption characteristic.
For more description the high absorbance a surface current distribution is calculated at the five-resonance frequency as presented in Figure. 4. The resonance type at 12.25 GHz, 16.15 GHz, 16.78 GHz, and 18.44 GHz is electric dipole but the resonance type at 12.9 GHz is electric coupling between two rings.

Figure 4. Surface current distribution (a) at 12.25 GHz, (b) at 12.9 GHz, (c) at 16.15 GHz, (d) at 16.78 GHz, and (e) at 18.44 GHz.

Figure 5. Simulated absorption for a different h thickness.
Similarly, in order to study the parametric effect Figure 5 present the effect of substrate thicknesses in absorption response. The results show perfect absorption at 2.5 mm thicknesses and the absorption shift when h increases or decreases. Figure 6 study the parametric effect of unit cell size in absorption characteristic. The results show the perfect absorption effected by unit cell dimension change.

![Figure 6. Simulated absorption for the different value of a](image)

Figure 6. Simulated absorption for the different value of a

![Figure 7. Simulated absorption for a different TE polarization incident waves.](image)

Figure 7 and Figure 8 show the simulated result of EM absorbance spectrum of the PPMMA structure for TE and TM polarization incident waves respectively. For TE mode the absorption level almost higher than 50% for incident angle less than 60°. Meanwhile the absorbance at three resonant frequencies are shifted. For TM mode the absorption level better than TE mode for incident angle less than 60°.
The proposed absorber can therefore be said to have given good results compared with other multi band perfect metamaterial absorbers reported in the literature, as summarized in Table 2. This structure is a good solution for multi absorption applications.

| References | No. layers | No. resonator/unit cell | Absorption level | No. absorption bands |
|------------|------------|-------------------------|------------------|----------------------|
| [18]       | 3          | 4                       | >90              | 2                    |
| [19]       | 3          | 1                       | >90              | 2                    |
| [20]       | 3          | 1                       | >90              | 3                    |
| [21]       | 3          | 4                       | >90              | 3                    |
| [22]       | 3          | 1                       | >90              | 4                    |
| [23]       | 3          | 4                       | >90              | 4                    |
| [24]       | 4          | 2                       | >90              | 5                    |
| [25]       | 10         | 4                       | >90              | 5                    |

Proposed structure 3 >90 5

4. Conclusion
The present work shows multi band perfect metamaterial absorber. This work shows satisfactory results due to multi microwave absorption band and perfect absorption.

5. References
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