A Wideband Wide-angle Polarization-insensitive Metamaterial Absorber

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Abstract— In this paper, a wideband metamaterial absorber with wide-angle polarization insensitive characteristic is presented. The metamaterial absorber consists of a periodic arrangement of Jerusalem resonators lumped four resistors. Simulations demonstrate that the absorption rate is above 90% in 8–14.5 GHz, and by changing the direction angle of polarization, we achieve that this structure is polarization insensitive.

1. INTRODUCTION

Matematerials (MM) are novel artificial materials with sepecial properties that arise from their structure rather than their constituent materials. In recent years, much more researches on metamaterial absorber (MMA) are reported. Since the concept of a perfect MMA was proposed by Landy et al. in 2008 [1], there has been considerable attention in creating thinner and lighter MMA. Since then, many MMAs have been proposed and demonstrated with narrow-band, dual-band and multi-band absorption. More recently, several efforts have been made to improve its electromagnetic characteristics, such as polarization-insensitive [2, 3], wide incident angle [4] and wideband absorption [5].

In this paper, an efficient design is presented to achieve a wideband and polarization insensitive MMA in the gigahertz frequency region. This MMA consists of a periodic arrangement of Jerusalem resonators lumped four resistors, dielectric layer and a metallic background plane, and the whole thickness is only 2.8 mm. The simulation results indicate that lumped resistors are the chief contributor of the MMA's wideband absorption, and this structure is polarization insensitive.

2. DESIGN AND SIMULATE THE ABSORBER

2.1. Structures Design

The structure of MMA unit is illustrated in Fig. 1(a). The top layer consists of Jerusalem resonators lumped four series-parallel connection resistors set in a periodic pattern and bottom layer is a metal plane. The periodic array configuration of this unit cell is illustrated in Fig. 1(b) and is designed on a lossy dielectric board FR4 that has a dielectric constant of 4.4, tangential loss of 0.02 and thickness of 3 mm. All metals in the absorber are made of copper with a conductivity of 5.8×10^7 S/m.

2.2. Full-wave Simulation and Analysis

In more directive perspective, the absorption is defined as $A = 1 - S - T = 1 - |S_{21}|^2 - |S_{11}|^2$. To maximize the absorption rate, we can minimize the reflection and transmission simultaneously at the same frequency range. Due to the metal background of the absorber, the transmission $|S_{21}|$ is equal to zero. Full-Wave simulation is taken by using HFSS. By the master-slave boundary conditions, the simulation of the periodic array configuration of the absorber unit cell can be achieved. Through optimizing the parameters in Fig. 1(a), the simulation result is shown in Fig. 2, in which we observe a wideband absorption at about 7.8–15.5 GHz with the absorption rate of over 90%. The surface circuit at resonant frequency is shown in Fig. 3. We can see that most of the current flows through the resistors, which predicts that by tuning the value of the resistor we can match to a best absorption frequency range and rate.

2.3. Resistor Value Simulation

From the surface circuit we know that the value of the resistor is the chief contributor of the absorption. A research on wideband electromagnetic absorber loaded high impedance surfaces has been proposed by Prof. Costa [6]. It is achieved by considering the impedance of surface. In our work resistors bring the high impedance to be employed to increase the MMA's bandwidth, also can bring high loss to improve absorptivity. In Fig. 4 the absorption rates are plotted for $R = 80$, 90, 100, 110 Ω. When $R = 100\,\Omega$ the 90% absorption rate bandwidth ranges from 7.8 to 15.5 GHz.

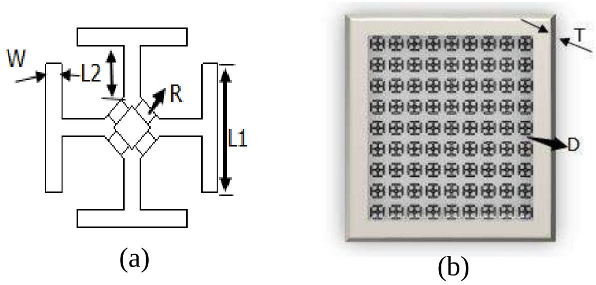

Figure 1: Stucture of MMA, (a) unit cell, (b) periodic pattern cell ($L_1 = 2.8\,\text{mm}$, $L_2 = 1.2\,\text{mm}$, $W = 0.8\,\text{mm}$, $D = 7.9\,\text{mm}$, $T = 3\,\text{mm}$).

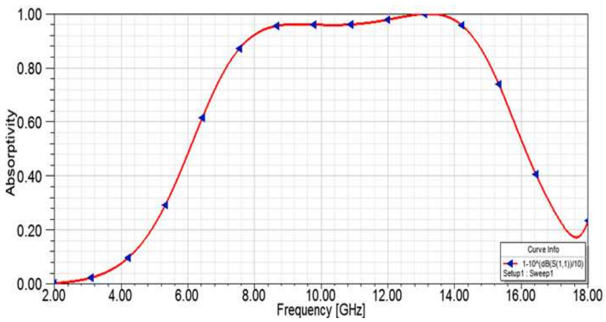

Figure 2: Simulated absorption for normal incident.

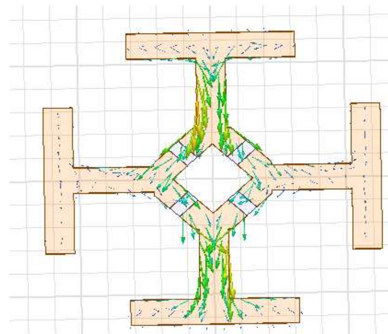

Figure 3: The surface circuit at resonant frequency.

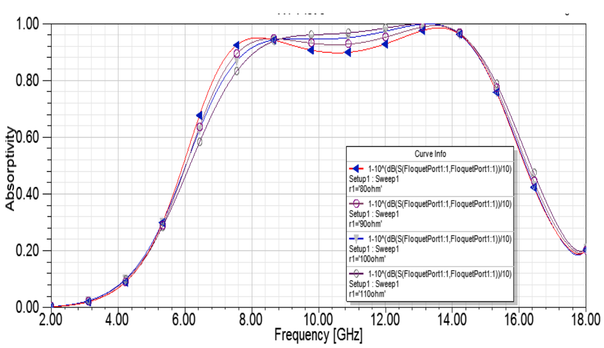

Figure 4: Simulated absorptivity for different resistors R.

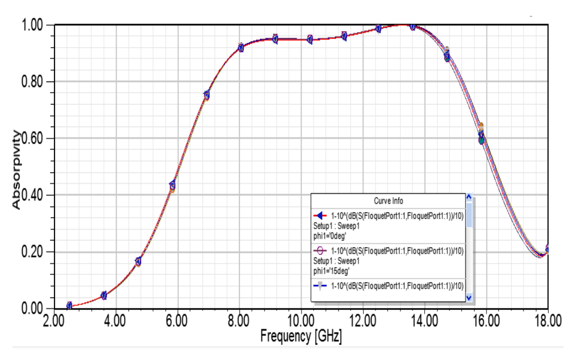

Figure 5: Simulated absorptivity for different incidence polarization angles.

2.4. Polarization Angle Simulation

Another performance we considered is MMA's polarization insensitive. Fig. 5. shows that wideband MMA remain high and stable absorptivity with wide polarization angles. We give the simulations by changing the polarization angle from 0° to 90° by 15° each step, and the results show that the absorption rates of the different polarization angles are almost at the same frequency range, which mean that the wideband MMA is polarization insensitive.

3. CONCLUSIONS

In this paper, we have presented a novel polarization-insensitive and wideband metamaterials absorber, which is composed periodic array configuration of Jerusalem resonators lumped four series-parallel connection resistors cell. The simulation results show from 7.8 to 15.5 GHz absorption rate is above 90%. The wideband absorptivity was achieved because of the series-parallel connection resistors of bringing high impedance surface to achieve wideband impedance matching. Polarization insensitivity capability results from the periodic array configuration of Jerusalem resonators.

ACKNOWLEDGMENT

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REFERENCES

1. Landy, N. I., S. Sajuyigbe, J. J. Mock, D. R. Smith, and W. J. Padilla, "Perfect metamaterial absorber," *Phys. Rev. Lett.*, Vol. 100, 207402, 2008.
2. Luukkonen, O., F. Costa, C. R. Simovski, A. Monorchio, and S. A. Tretyakov, "A thin electromagnetic absorber for wide incidence angles and both polarizations," *IEEE Trans. Antennas Propag.*, Vol. 57, No. 10, 3119–3125, 2009.
3. Bayraktar, Z., M. Gregory, D. Kern, and D. H. Werner, "Matched impedance thin composite magneto-dielectric metasurfaces," Presented at *Antennas and Propagation Society International Symposium*, Charleston, SC, Jun. 1–5, 2009.
4. Hu, C., Z. Zhao, X. Chen, and X. Luo, "Realizing near-perfect absorption at visible frequencies," *Opt. Express*, Vol. 17, 11039–11044, 2009.
5. Ye, Y. Q., Y. Jin, and S. He, "Omnidirectional, polarization–insensitive and broadband thin absorber in the terahertz regime," *Opt. Soc. Am. B*, Vol. 27, 498–504, 2010.
6. Costa, F., A. Monorchio, and G. Manara, "Analysis and design of ultra-thin electromagnetic absorbers comprising resistively loaded high impedance surfaces," *EEE Trans. Antennas Propag.*, Vol. 58, No. 5, 1551–1558, 2010.