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SIMPLE DESIGN OF CO-POLARIZATION BROADBAND METAMATERIAL ABSORBER FOR C-BAND APPICATIONS

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ABSTRACT

A simple design of a novel co-polarization wideband metamaterial absorber (MA) for C-band applications is proposed and numerical investigated. The unit cell of the proposed MA is designed by combining the haft-moon shaped resonator (HMSR) and interior circle resonator (ICR) structures, based on FR4 substrate. The absorption performances of the proposed absorber are numerical investigated. The proposed absorber achieves the co-polarization absorptivity higher than 90% covering the entire C-band from 3.95 GHz to 8.02 GHz under normal incidence for transverse electric (TE) and transverse magnetic (TM) polarizations. Moreover, the average absorption can be maintained above 80% even for incident angles up to 60o under both TE and TM polarizations. The physical mechanism of the proposed MA is investigated by using the electric and surface current distributions, which is also supported by the retrieved constitutive electromagnetic parameters. The design in this work is a compact structure (unit cell dimension of ~λ/6.5 and thickness of ~λ/11.8 at the center frequency), broadband, and wide incident angle insensitivity, which can be applications in the C-band defense and stealth systems.
Keywords: Metamaterials, Single layer, Ultrathin absorber, Perfect absorption.

INTRODUCTION

Metamaterial absorber (MA) has attracted considerable interest in both fundamental research and device applications, since Landy et al. reported a thin perfect microwave MA based on electric and magnetic resonances in 2008 [1-3]. However, the realizing MA structures having a simple design, thin thickness, easy fabrication process and broadband absorption features for practical applications in microwave range such as radar cross section reduction (RSC), stealth technology and EM interference (EMI) reduction remains truly challenging. Furthermore, the design of broadband microwave MAs have been mostly focused on the frequency band above C-band, but very few design of MA for lower frequency absorption band, such as C-band, has been reported [2,4].

In this paper, we propose a simple design of a novel co-polarization wideband metamaterial absorber (MA) for C-band applications. The unit cell of the proposed MA is designed by combining the haft-moon shaped resonator (HMSR) and interior circle resonator (ICR) structures, based on FR4 substrate.

EXPERIMENTAL

Fig. 1 shows the unit cell of the proposed broadband MA. The broadband MA is formed by the periodic arrangement of the unit cells in the lateral directions and the vertical thickness consists of two metallic films separated by a dielectric layer. The metallic layers are made of copper with an electric conductivity of and thickness (t) of 0.035 mm. The dielectric layer is made of FR4 with a relative dielectric constant of 4.3, a loss - tangent of 0.025, and thickness (h) of 4.2 mm. The front layer is constituted by the combination of haft-moon shaped resonator (HMSR) and interior circle resonator (ICR) structure. The geometrical dimensions of the unit cell are R_1=6.3 mm, R_2=3.35 mm, r=3.65 mm, and a=15.4 mm. The center of the circles with radii R_1 and R_2 are $O_1(0,0)$ and $O_2(1.775,-1.175)$, respectively. For back layer of the structure, copper is used in order to block all transmission.

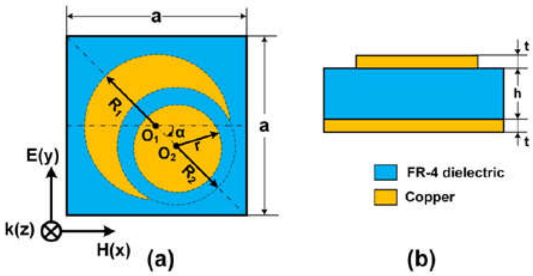

Figure 1. A unit cell geometry of the proposed MA: (a) top-view and (b) side-view.

In order to investigate the absorption performance of the proposed MA, the numerical simulation is performed by using frequency domain solver in a Computer Simulation Technology (CST) Microwave Studio. In the boundary condition set up, z-direction and x-y plane are for the direction of propagation and the E-H fields, x and y axes are fixed to the unit cell and z axis is open, the plane waves are normally incident to the structure along the z direction.

The absorption is defined by $A(\omega) = 1 - T(\omega) - R(\omega)$, where $T(\omega)$ and $R(\omega)$ are transmission and reflection, respectively. The $A(\omega)$ and $T(\omega)$ are determined from the frequency-dependent S-parameters $S_{11}(\omega)$ and $S_{21}(\omega)$, where $T(\omega) = |S_{21}(\omega)|^2$ and $R(\omega) = |S_{11}(\omega)|^2$. The reflection is calculated as $R(\omega) = |r_{yy}(\omega)|^2+|r_{xy}(\omega)|^2$, where $r_{yy}(\omega) = |E_{yr}|^2/|E_{yi}|^2$ and $r_{xy}(\omega) = |E_{xr}|^2/|E_{yi}|^2$ are reflection coefficients for co-polarization and cross-polarization for y (or TE) polarized wave, respectively. In the conventional absorber model, the back layer acts as physical barrier to block the transmittance. Since $T(\omega)$ is eliminated by the ground plane, thus, the absorption is simplified to $A(\omega) = 1 – R(\omega)$.

RESULTS AND DISCUSSION

The absorption performances of the proposed absorber are numerical investigated. The proposed absorber achieves the co-polarization absorptivity higher than 90% covering the entire C-band from 3.95 GHz to 8.02 GHz under normal incidence as seen in Fig.2. Moreover, the average absorption can be maintained above 80% even for incident angles up to 60^o under both TE and TM polarizations.

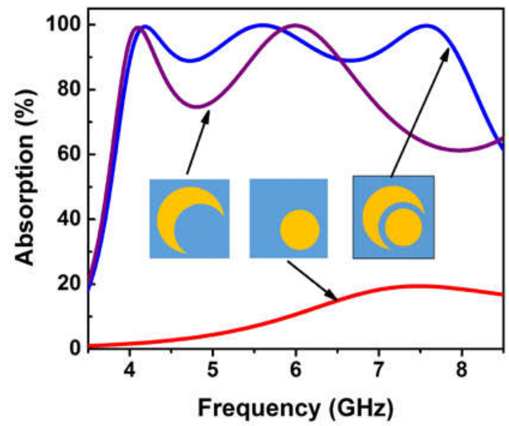

Figure 2. Absorption spectra of two components of the combined proposed MA structure.

To investigate the mechanism absorption of the proposed MA, the distributions of electric field and surface current at three resonance frequencies of 4.19 GHz, 5.63 GHz, and 7.58 GHz are performed as shown in Fig. 3.

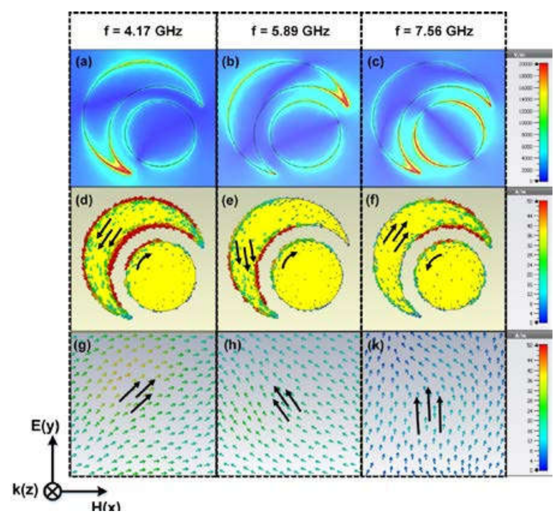

Figure 3. Distributions of (a),(b),(c) electric field, and surface current on (d),(e),(f) the front layer and (g),(h),(k) back layer of a unit cell under TE polarization with various resonant frequencies of 4.19 GHz, 5.63 GHz, and 7.58 GHz, respectively.

It can be seen from Figs. 3(a-c), the electric field with a specified frequency is concentrated at a certain part of MA. At lower frequencies of 4.19 GHz and 5.63 GHz, electric field tends to accumulate at inner top and bottom part of the HMSR, respectively. Meanwhile, at higher frequency of 7.58 GHz, the electric field is concentrated not only the outer of ICR mainly, but also in inner the top and bottom part of the

HMSR. The top and bottom surface current distributions are illustrated in Figs. 3(d-k). At the three resonance frequencies, the surface currents are mainly contributed by HMSR, while a significant amount of current flows through the ICR at higher frequency of 7.58 GHz. At the frequency of 7.58 GHz, the surface currents on the ICR and the HMSR are anti-parallel to that on the bottom layer. This means the peak at the higher frequency is not only mainly contributed by the magnetic resonance of the ICR, but also rather weak anti-parallel currents between the ICR and HMSR. However, at the lower resonance frequencies of 4.19 GHz and 5.63 GHz, the surface currents are strong coupled along the edges of HMRS. Thus, the strong induced electric field is created and it reverses to the incident electric field, which confirms the excited electric field is stronger than the incident electric field. It is clear that the electric resonance is excited at 4.19 GHz and 5.63 GHz. At the same time, the surface current distribution on the HMSR is anti-parallel with the current distribution in the ground layer, thus the circulating current is created and formed the induced magnetic field. The induced magnetic field is reverse with incident magnetic field, indicating that the strong magnetic resonance is also contributed in these resonant frequencies. Therefore, both the magnetic and the electric resonances are excited simultaneously at the lower frequencies of 4.19 GHz and 5.63 GHz.

CONCLUSION

A simple design of a novel co-polarization wideband MA based on asymmetric structure is proposed and investigated using numerical method. The unit cell of the proposed structure consists of metallic shape created by the combination of HMSR and ICR structure and ground plane separated by a dielectric layer. The effect of the structural parameters on the co-polarization absorption is thoroughly investigated. The proposed MA shows a co-polarization absorptivity of higher than 90% in wide bandwidth from 3.95 GHz to 8.02 GHz, which covers the entire C-band. The total average absorption can be retained above 75% for the wide incident angle up to 60o under both TE and TM polarizations. The electric and surface current distributions at three distinct absorption peaks are analyzed to explain the absorption mechanism. Also, the physical mechanism, which is confirmed by the retrieved constitutive electromagnetic, is mainly contributed by the magnetic resonance. In addition, the proposed MA presents an excellent practical feasibility in term of compact structure (unit cell dimension of ~λ/6.5 and thickness of ~λ/11.8 at the center frequency) and wide incident angle insensitivity. The proposed MA in this work may find applications in the C-band defense and stealth systems that require only co-polarization.

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