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A bandwidth-enhanced metamaterial absorber based on dual-band sub-cells

Ding-E Wen[a], Qi Zhang[a], Xuemei Huang[a], Fan Ding[b], Xiaojun Huang[c,*]

[a] Science and Technology on Electromagnetic Compatibility Laboratory, Wuhan 430064, China
[b] Ship Research and Design Center, Wuhan 430064, China
[c] College of Physics and Electrical Engineering, Kashgar University, Kashgar 844000, China

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ABSTRACT

In this paper, a coplanar bandwidth-enhanced metamaterial absorber is presented based on the combination of three dual-band sub-cells. The simulated results show that the absorber is polarization insensitive and adaptive for wide angles of oblique incidence. The simulated FWHM absorption bandwidth is 1.09 GHz (6.04–7.13 GHz), with the relative FWHM absorption bandwidth of 16.6%. A sample is fabricated. The experimental results verified that FWHM absorption bandwidth is 1 GHz (6–7 GHz), with the relative FWHM absorption bandwidth of 15.4%, and the absorption peak of 77.5% is obtained.

1. Introduction

With the development of the metamaterial, many papers related to metamaterial absorber have emerged in recent years. Metamaterial absorber has huge potential for use in RCS reduction and EMC problems [1]. Many authors have presented research on single-band, dual-band, triple-band and quadruple-band metamaterial absorber [2–4]. Also, many efforts have been presented to realize broadband metamaterial absorber [5–20]. First, Liu et al. [5] realized a coplanar broadband metamaterial absorber by arranging seven metallic circular patches with different radii. Later, Wang et al. [7] proposed a coplanar broadband THz metamaterial absorber by arranging four metallic circular patches with different radii. Multilayer structure is also a common way to realized broadband metamaterial absorber [12–17], though the multi-layer structure is expensive to fabricate and inconvenient to install in practice application. Except for the method that multiple resonators generate multiple absorption peak values, there are some unique methods to form broadband spectra [18–20]. Yuan and Cheng [19] realized a broadband metamaterial absorber based on lumped elements. Recently, Wang et al. [20] proposed a wideband metamaterial absorber based on resistance film. Watts et al. [1] give a significant review on metamaterial absorber.

In this paper, the objective is to propose a coplanar broadband metamaterial absorber. A kind of dual-band sub-cell is used and combined to realize the broadband absorber.

2. Design, simulation and experiment

The unit cell of the absorber is composed of three dual-band sub-cells. Each sub-cell consists of an annular patch nested with a folded square patch illustrated in Fig. 1(a) shows the dual-band sub-cell 1. The outer and inner radius of the annular

* Corresponding author. Fax: +86 13387574565.
E-mail address: hxj0212@126.com (X. Huang).

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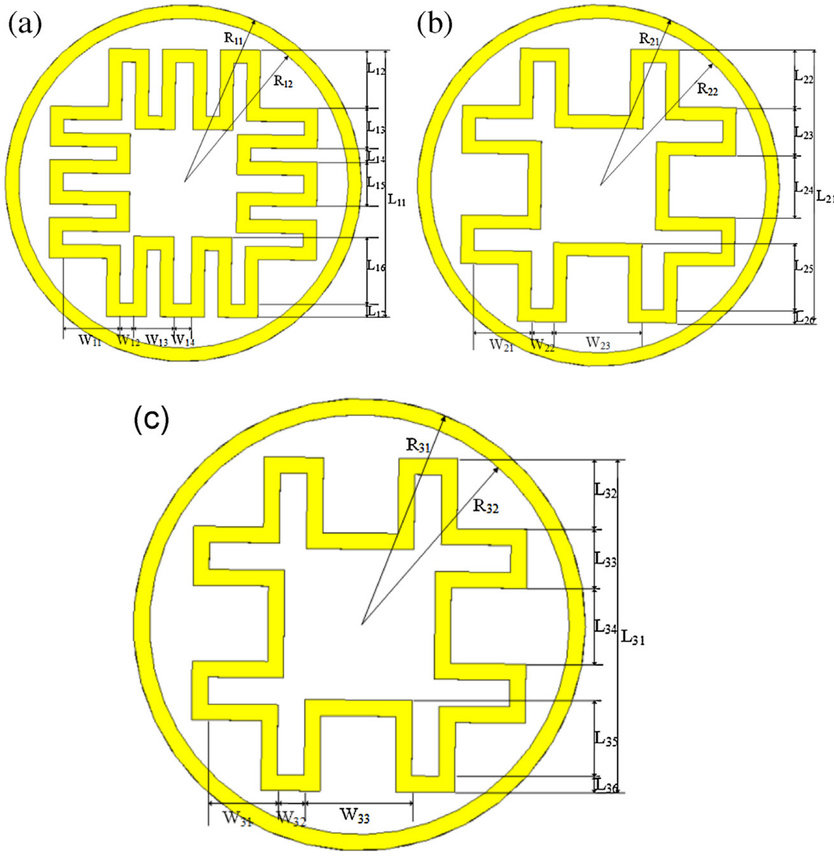

Fig. 1. The schematic diagram of the sub-cells: (a) sub-cell 1, (b) sub-cell 2, and (c) sub-cell 3.

patch is R_{11} = 4 mm and R_{12} = 3.7 mm, respectively. The geometric parameters of the folded square patch are also illustrated in Fig. 1(a), that is, L_{11} = 6 mm, L_{12} = 1.3 mm, L_{13} = 0.9 mm, L_{14} = 0.3 mm, L_{15} = 1 mm, L_{16} = 1.5 mm, L_{17} = 0.3 mm, W_{11} = 1.3 mm, W_{12} = 0.3 mm, W_{13} = 0.9 mm, and W_{14} = 0.4 mm.

The configuration of the dual-band sub-cell 2 is shown in Fig. 1(b). The outer and inner radius of the annular patch is R_{21} = 4.1 mm and R_{22} = 3.8 mm, respectively. And the geometric parameters of the folded square patch are, L_{21} = 6.2 mm, L_{22} = 1.3 mm, L_{23} = 1.1 mm, L_{24} = 1.4 mm, L_{25} = 1.5 mm, L_{26} = 0.3 mm, W_{21} = 1.3 mm, W_{22} = 0.5 mm, and W_{23} = 2 mm.

The structure of the dual-band sub-cell 3 shown in Fig. 1(c) is the same with the sub-cell 2 but with different geometric parameters. The outer and inner radius of the annular patch is R_{31} = 4.2 mm and R_{32} = 3.9 mm, respectively. And the geometric parameters of the folded square patch are, L_{31} = 6.2 mm, L_{32} = 1.3 mm, L_{33} = 1.1 mm, L_{34} = 1.4 mm, L_{35} = 1.4 mm, L_{36} = 0.3 mm, W_{31} = 1.3 mm, W_{32} = 0.5 mm, and W_{33} = 2 mm.

Then, the three sub-cells are arranged to form the unit cell of the broadband metamaterial absorber. The arrangement of the sub-cell 1, the sub-cell 2 and the sub-cell 3 is illustrated in Fig. 2(a)–(c), respectively.

Fig. 3 is the sketch graph of the unit cell of the absorber, which is the combination of the three sub-cells. The patches are all on the top layer. The bottom layer is a continuous metallic film to realize zero transmission. The dielectric layer between the metallic layers is 2 mm thick FR-4 substrate, whose relative permittivity is 4.3 and loss tangent is 0.025. The thickness of the metallic layer is 0.03 mm, which is made of copper. The periodicity of the unit cell is L = 28 mm.

The CST Microwave Studio software package is used to process the numerical simulation. The periodic boundary condition is used in simulation, so only needs to simulate one unit cell to obtain the EM characteristics of the whole array. The S parameters are directly achieved from the simulation, then the absorptivity of the absorber is calculated using the formula $A(\omega) = 1 - R(\omega) = 1 - |S_{11}(\omega)|^2$. To assure the accuracy of the result, the tetrahedral mesh is used. For the experimental process, the absorber was fabricated using a conventional printed circuit board process with the same structural parameters as the simulation model. A partial photography of the fabricated MMA is shown in Fig. 4, which consists of 15 × 15 elements. The reflection spectra S_{11} was measured in a microwave anechoic chamber using an Agilent E8362B network analyzer connected to two identical double-ridged horn antennas and calibrated by replacing the sample with a copper board of the same size as perfect reflector. To avoid the near-field effects, the height of the system and the distance between the antennas and the sample were 1.5 m and 60 cm, respectively. The source and the receiver horns were each inclined at an angle of with respect to normal to the sample surface.