Metamaterial Absorber using Complementary Circular Sector Resonator

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Abstract **- In this paper, a polarization-insensitive metamaterial absorber is proposed. The unit cell of the metamaterial is designed with a novel complementary circular sector resonator is introduced for the polarization - insensitivity of the MM absorber. A vertically and horizontally symmetric structure of unit cell enables polarization-insensitivity. The performances of the proposed absorber are demonstrated with full-wave simulation and measurements. The measured absorptivity at 10.32 GHz is close to 99% for all polarization angles under normal incidence. The simulated and measured absorptivity of the normal incidence of the proposed absorber are demonstrated in Fig. 2. The Fig. 2 shows that the absorptivity of the normal incidence of the proposed absorber is kept 99% at 10.32 GHz while the simulated is 96% at 10.36 GHz.**

Index Terms **— Metamaterial (MM), Absorber, Radar cross section (RCS).**

1. Introduction

Electromagnetic (EM) metamaterials (MMs) are artificial materials engineered to have unique properties that have not been found in nature. The MM absorbers have some advantages compared with conventional absorbers such as ferrite, wedged-tapered absorber and Salisbury screen absorber. The MM absorber can achieve high absorptivity in spite of a thin substrate. In addition, functional absorbers can be realized with tunable devices or materials. Due to these advantages of the MM absorber, they have been researched for various applications of the spectrum from microwave to optical signals. Because a MM absorber is based on a periodic array of resonators, it operates at a specific frequency and has a narrow bandwidth. In general, absorptivity of a MM absorber is also dependent on incident polarization and angle. Polarization-insensitive MM absorbers can be achieved by designing a horizontally and vertically symmetric unit cell [1] [2]. In addition, several polarization- and angle-insensitive MM absorbers have been presented [3] [4].

In this paper, a novel complementary circular sector resonator is introduced for polarization -insensitivity of the MM absorber. A vertically and horizontally symmetric structure of unit cell enables polarization-insensitivity. Its geometry is determined through parametric study of the absorptivity at different inner angles of the complementary circular sector. When the inner angle of the circular sector is 85°, the simulated absorptivity of the proposed MM absorber is higher than 96% while the measured is higher 99% when the incident polarization is varied from 0 degree to 90 degree.

2. Absorber Design

The geometry of the proposed fabricated absorber prototype is shown in Fig. 1. A complementary circular sector is realized on the top pattern and the bottom layer is fully covered with a copper sheet.

The absorptivity of the CCS unit cell is varied for different incident angles. It is demonstrated from a full-wave simulation that the proposed complementary circular sector enables absorptivity insensitive to incident angles. When the EM wave incident to the absorber, there are the reflected wave and the transmitted wave.

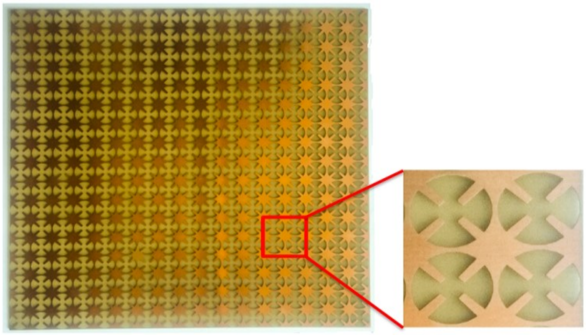

Fig. 1. Fabricated absorber prototype

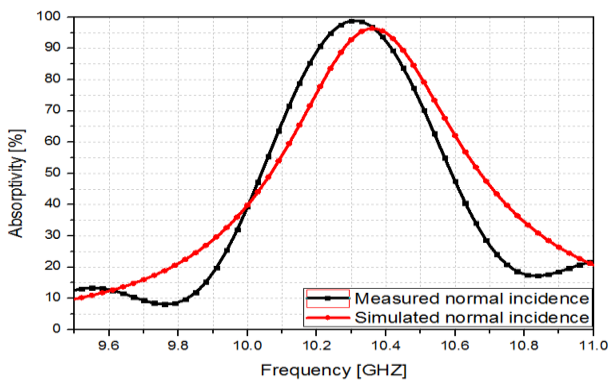

Fig. 2. The Simulated and measured absorptivity of the proposed absorber for normal incidence.

When the EM wave incident to the absorber, there are the reflected wave and the transmitted wave the absorptivity of the absorber can be calculated from reflection and transmission coefficients.

$$A(\omega) = 1 - R(\omega) - T(\omega) \quad (1)$$

In order to achieve high absorptivity, the reflection and transmission coefficients should be minimized. To minimize the reflected wave, the impedance between air and the MM absorber must be matched each other.

The MM displays frequency dependent permittivity and permeability from effective medium approximation. So, the intrinsic impedance of the MM $Z(\omega)$ can be defined by the effective permittivity (ϵ) and permeability (μ) of the medium in equation (2) [5].

$$Z(\omega) = \sqrt{\frac{\mu_0 \mu_r(\omega)}{\varepsilon_0 \varepsilon_r(\omega)}} \quad (2)$$

The MMs can manipulate effective permittivity (ϵ_r) and permeability (μ_r) in mentioned earlier. If the effective permittivity and permeability are equal, the intrinsic impedance $Z(\omega)$ can be matched with the intrinsic impedance of free space Z_0 of 377 Ω. Thus, there is no reflected wave in following equation:

$$\Gamma(\omega) = \frac{Z(\omega) - Z_0}{Z(\omega) + Z_0} \quad (3)$$

$$\Gamma_{\perp}(\omega) = \frac{Z(\omega)cos\theta_i - Z_0 cos\theta_t}{Z(\omega)cos\theta_i + Z_0 cos\theta_t} \quad (4)$$

$$\Gamma_{\parallel}(\omega) = \frac{Z(\omega)cos\theta_t - Z_0 cos\theta_i}{Z(\omega)cos\theta_t + Z_0 cos\theta_i} \quad (5)$$

, where the equation (3), (4) and (5) are reflection coefficient of normal incidence, perpendicular and parallel polarization of oblique incidence, respectively. Furthermore, the MM has a high absorptivity owing to its large imaginary parts of the refractive index n that means the loss factor. The transmitted wave can be dissipated by large loss factor in substrate. As a result, the MM absorber can achieve to minimize reflected and transmitted wave. Therefore, MM-based absorbers can have good absorptivity despite their low profile.

In this paper, there is no transmitted wave, because of fully covered conductor in bottom layer. Therefore, Eq. (1) can be simplified as

$$A(\omega) = 1 - R(\omega) \quad (6)$$

3. Simulated and Measured Results

To prove the performance of the proposed absorber, the absorptivity was measured for polarization-insensitivity. The reflection coefficients were measured using monostatic measurement setup. For the measurement, the vector network analyser (VNA), a horn antenna and board surrounded wedged-tapered absorber. After an antenna was placed in front of the prototype absorber, the reflection coefficients were measured according to rotating the prototype absorber from 0˚ to 90˚. The measured is higher 99% when the incident polarization is varied from 0 degree to 90 degree.

In this paper the simulated and measured absorptivity of the normal incidence of the proposed absorber are demonstrated in Fig. 2. The Fig. 2 shows that the absorptivity of the normal incidence of the proposed absorber is kept 99% at 10.32 GHz while the simulated is 96% at 10.36 GHz.

4. Conclusion

We have designed the angle- and polarization-insensitive MM absorber using the novel complementary circular sector. For experimental demonstration, the MM absorber with 16 × 16 unit cells built on the FR4 substrate using print circuit board (PCB) process as Fig. 1. The absorptivity of the fabricated sample is measured at different polarization and incident angle. The measured absorptivity at 10.32 GHz is close to 99% for all polarization angles under normal incidence. The Fig. 2 shows that the absorptivity of the normal incidence of the proposed absorber is kept 99% at 10.32 GHz while the simulated is 96% at 10.36 GHz.

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