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The design of wideband metamaterial absorber at E band based on defect

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Abstract. A kind of wideband metamaterial absorber at E band is designed in this paper; it is composed of round metal cells with defect, dielectric substrate and metal film. The electromagnetic parameters of unit cell are calculated by using the finite element method. The results show that the wideband metamaterial absorber presents nearly perfect absorption above 90% with absorption ranging from 65.38GHz to 67.86GHz; the reason of wideband absorption is the overlap of different absorption frequency which is caused by electromagnetic resonance; the size parameters and position of defect has important effect on its absorption property. It has many advantages, such as simply, easy to preparation and so on. It has potential application on aerospace measurement and control, remote data communication, LTE wideband mobile communication and other fields.

1. Introduction

The research of microwave absorber is always the front of military struggle. However, the traditional microwave absorber cannot meet the practical requirement with the development of radar detection technology. The metamaterial absorber provides new way to improve the stealth performance of military equipment. The metamaterial absorber essentially is a kind of resonant structure which is composed of resonant metal unit, dielectric substrate and metal film. In 2008, Landy et al firstly proposed the metamaterial absorber based on split ring resonator and short metal wire, it achieved perfect absorption at simple microwave frequency [1]. Since then, the design of metamaterial absorber is expanded from microwave band [2, 3] further to THz band [4, 5], infrared band [6, 7] and light band [8-10]; the absorption frequency is expanded from simple frequency further to dual band [11-13], tri band [14-16], wideband [17] and tunable absorption [18]. The metamaterial absorber is mainly applied on thermal radiation detection [19], thermal radiation imaging [20], and biochemical substance detection [21] and so on.

The microwave at E band with the frequency at the range of 60-90GHz is mainly used on aerospace measurement and control, remote data communication and LTE wideband mobile communication, so the research of metamaterial absorber at E band has great application prospect. A kind of wideband metamaterial absorber at E band based on round metal cells with defect is designed in this paper, its absorption remains above 90% between 65.38GHz t- 67.86GHz, its unit cell has the advantages of simple, easy to prepare and so on.

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2. Model design

The designed unit cell of wideband metamaterial absorber at E band in this paper is shown in figure 1. It is composed of round metal cells with defect, dielectric substrate and metal film; the round metal cells with defect is made of copper with the thickness of 0.05mm, its dimensions are: a=b=4.4mm, r=2mm, w1=0.8mm, w2=0.7mm; the dielectric substrate is FR4 dielectric with the thickness of 0.5mm; the metal film is also made of copper with the thickness of 0.1mm.

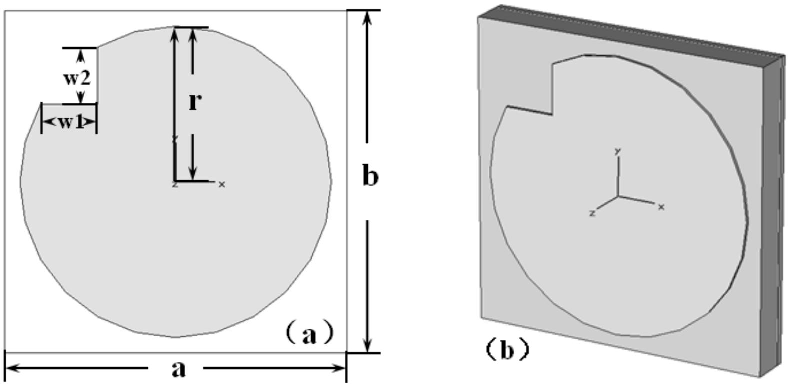

Figure 1. The schematic diagram of unit cell (a) the front view; (b) the perspective view.

The unit cell is designed and simulated by commercial three-dimensional electromagnetic simulation software--Microwave studio CST. In the simulation process, the x and y directions are set as unit cell boundary condition, the z direction is set as open, the all+floquet ports was used to simulate the incoming and outgoing waves. The electromagnetic parameters are calculated by frequency domain electromagnetic solver.

3. Results and discuss

The metal film of unit cell makes the incident wave cannot penetrate, the transmittance is $T(w) = |S_{12}|^2 = 0$. The defect configuration can convert the incident wave partially into the cross-polarization wave, so the absorption should be calculated by $A(w) = 1 - R_{x.x}(y.y) - R_{x.y}(y.x)$ with $R = |S_{11}|^2$.

The calculated absorption is shown in figure 2. We can see from figure 2 that the unit cell presents nearly perfect absorption above 90% with absorption ranging from 65.38GHz to 67.86GHz; its width is 2.48GHz.

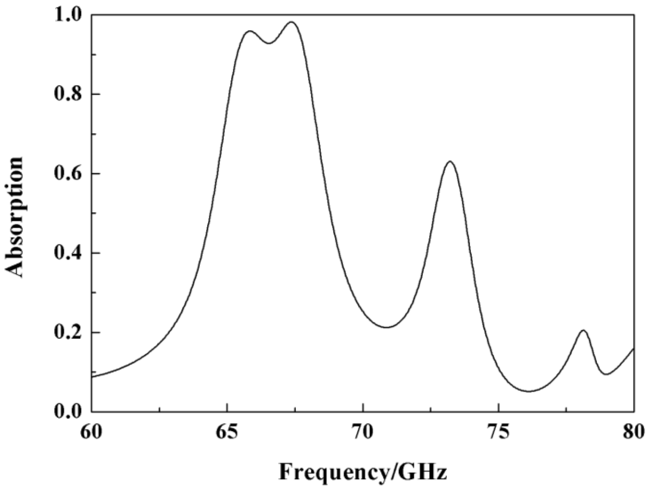

Figure 2. The absorption curve of unit cell.

According to the calculation formula of absorption $A(w) = 1 - R(w) = 1 - \left|\frac{Z(w) - Z_0}{Z(w) + Z_0}\right|^2$, the perfect absorption of incident wave is achieved when the input impedance of metamaterial absorber with free space is equal [22].According to the parameters extracted by simulation, the normalized impedance ($Z(w)/Z_0$) is calculated by scattering parameter method [23], the result is shown in figure 3. We can see from figure 3 that the normalized impedance between 65.38- 67.86GHz is close to one, it indicates that the good impedance match of unit cell with free space is achieved; the perfect absorption can be realized in this case.

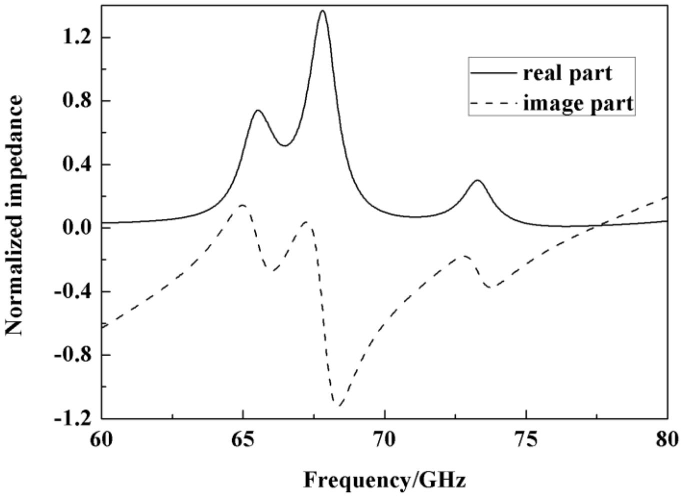

Figure 3. The relative input impedance of unit cell with free space.

In order to explore how the absorption peak is generated, we simulate the surface current of unit cell at 65.823GHz and 67.38GHz, the results are shown in figure 4 and figure 5. It can be seen from figure 4 and figure 5 that the surface current at upper resonant unit is inverse with the surface current at metal film, they form current loop, it indicates that the unit cell couples strongly to the incident magnetic field which lead to an intense magnetic resonance at the absorption peak and the absorption is generated from the loss of dielectric. The overlap of different resonant frequency leads to wideband absorption.

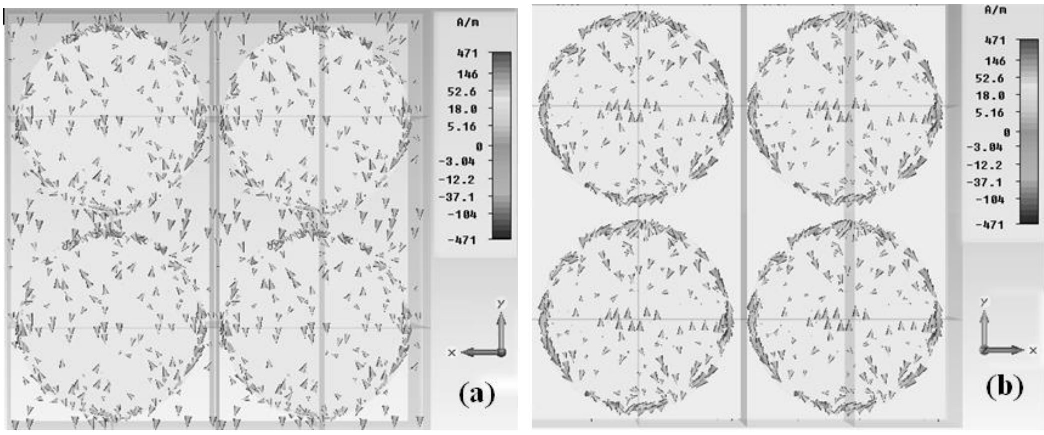

Figure 4. The surface current distribution at 65.823GHz, (a) the upper resonant unit; (b) the metal film.

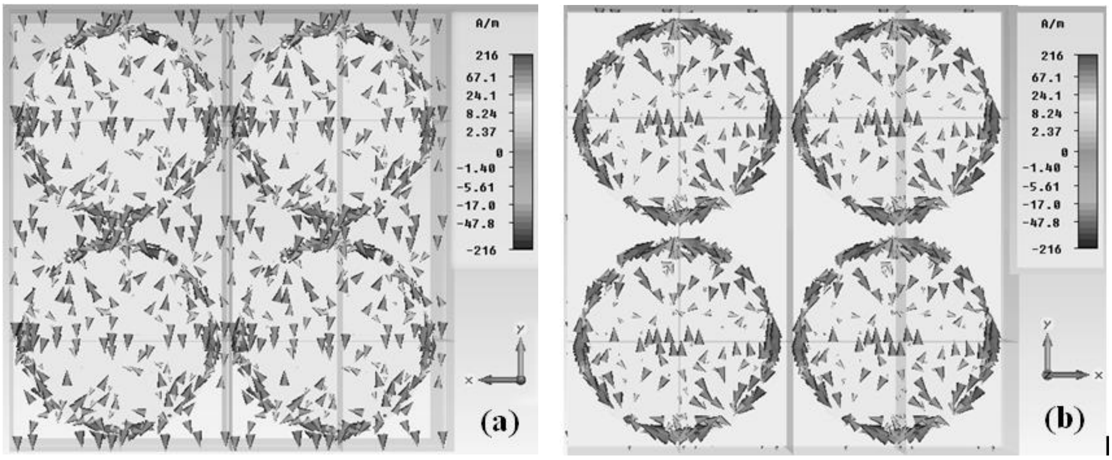

Figure 5. The surface current distribution at 67.38GHz, (a) the upper resonant unit; (b) the metal film.

Here, we discuss the effect of parameters w1 and w2 on the absorption property, respectively. First, in figure 6, we change the parameter w1 from 0.6 mm to 0.8mm with other parameters fixed. There are two group peaks (P1, P2) in the picture. We can see that the relative position of two peaks is sensitive to the parameter w1. When changing the parameter w1 from 0.6 mm to 0.8mm, P1 come close to P2. When the parameter w1 is equal to 0.8mm, the two peaks form a continuous absorption spectrum between 65.38- 67.86GHz with absorptions all above 90%. Figure 7 shows the absorptions with the parameter w2 changing from 0.5mm to 0.7mm.From the picture, the relative position of the absorption peaks is also sensitive to the parameter w2. The result is same with figure 6.

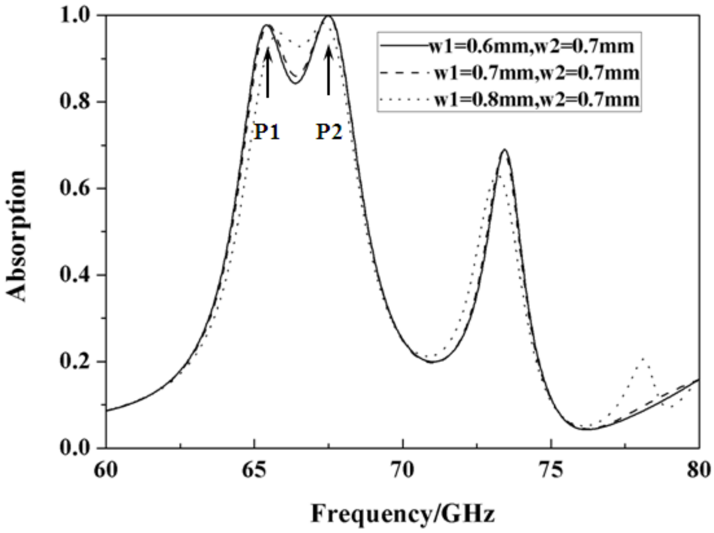

Figure 6. The curve of absorption property with different w1.

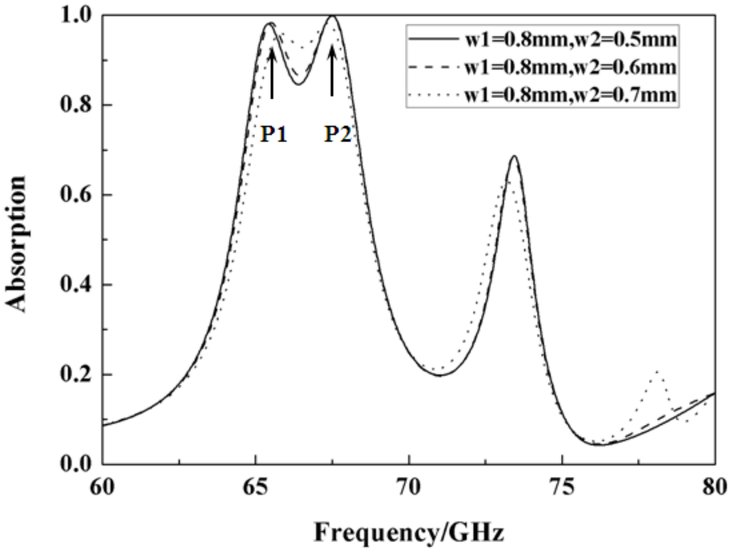

Figure 7. The curve of absorption property with different w2.

Otherwise, we discuss the effect of defect position on its absorption property. In figure 8, we rotate the resonant unit cell along Z axis counterclockwise from 0 degree to 120 degree with other parameters fixed. We can see from figure 8 that the continuous absorption spectrum between 65.38-67.86 GHz with absorptions all above 90% become two absorption peaks (P1, P2) and the P1 absorption peak shift to lower frequency with the increasing of rotating angle.

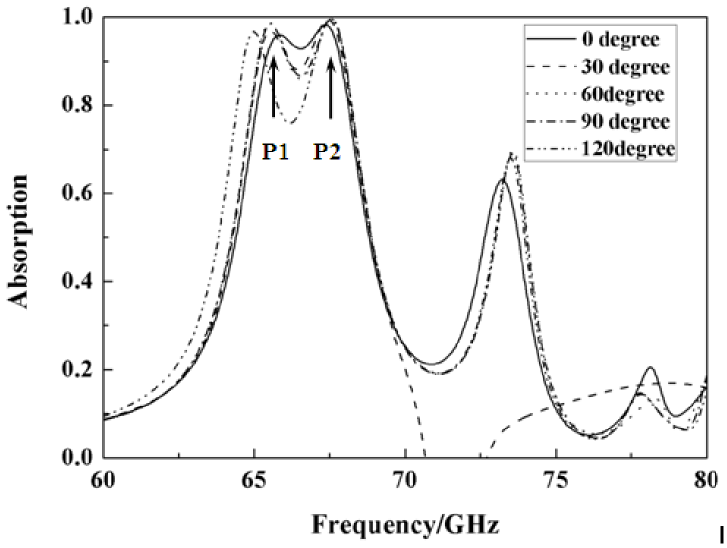

Figure 8. The curve of absorption with different rotation angles.

4. Conclusions

In summary, we propose a wideband metamaterial absorber at E band in this paper which is consisted of round metal cells with defect, dielectric substrate and metal film. The simulation results show that the wideband metamaterial absorber presents nearly perfect absorption above 90% with absorption ranging from 65.38GHz to 67.86GHz. The analysis of the surface current has been performed to better understand the resonant mechanism. Otherwise, we discuss the effect of parameters and position of defect on its absorption property. Therefore, the wideband absorber has potential application in the design and the development of high-performance absorbers for use in aerospace measurement and control, remote data communication, LTE wideband mobile communication and other fields.

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