Ultrathin Perfect Metamaterial Absorber Based on Triquetra Shape

Khalid Saeed Lateef Al-badri\textsuperscript{1,2}

\textsuperscript{1}Physics Dept., University of Samarra, Iraq.
\textsuperscript{2}Computer Centre, University of Samarra, Iraq.

saeedkhalid@gmail.com

Abstract. Electromagnetic Metamaterial perfect absorber EM-MMPA is representative an artificial electromagnetic material, which has many application prospects in huge fields like energy harvesting from electromagnetic wave. This work focused on the design and simulation ultrathin structure based on polarization unsensitive. However, based on the three-layer structure of copper reflector, dielectric layer and copper triquetra resonator. Through the results, it is found that, at 10.026 GHz with the fundamental mode of resonance can achieve a polarization unsensitive perfect absorption. Furthermore, all the materials involved in this work are easily available, and the size of the unit cell is also within the range of easy implementation, and it has a good prospect of many numbers of practical application.

1. Introduction

Metamaterial is an artificial electromagnetic material that obtains novel electromagnetic properties by arranging three-dimensionally ordered sub-wavelength "superatoms" in order to obtain novel electromagnetic properties [1-17]. The concept of electromagnetic stealth and perfect lens based on metamaterials was first proposed 2006 by John Pendry et. al in the UK. David Smith and others at Duke University took the lead in realizing electromagnetic stealth based on metamaterials in the microwave band [2] This century has seen a many research on electromagnetic metamaterials. Since, electromagnetic metamaterials working in the microwave [4-8, 18, 20-25], THz [19], infrared [2], near-infrared, and visible bands have been widely proposed and studied [9]. With the deepening of research, it was found that the realization of the novel electromagnetic properties of metamaterials is very dependent on the efficient preparation of structures. Yu and Capasso of Harvard University proposed the concept of electromagnetic supersurfaces in 2011. At present, people can realize a series of planar devices such as flat lenses, beam deflectors, polarization converters, holographic devices, sensor, energy harvesting etc. based on metasurfaces, which shows that people's ability to manipulate the electromagnetic field's freedom is greatly improved. Among many planar devices, electromagnetic wave absorbing materials have huge application prospects in many fields, including the use of efficient energy harvesting, and thus have received widespread attention from researchers. Researchers have also shown that many metamaterials working in different wave bands are perfect absorber [5-9]. However, most of the research attention has been devoted to the flexible tuning of the working band and the continuous absorption of dual-band [10], triple-band [11] and even broadband [12], and for applications such as sensor, it is required that the metamaterial perfect absorber has as narrow bandwidth as possible in the specified working band, that is, the narrowband metamaterial perfect absorber in the specified band, and research in this area is still relatively small. This work starts from...
the requirements of sensor compatibility, the possibility of large-scale application, and the narrowband absorption in a specified band. Theoretical design and numerical simulation study the metamaterial absorber based on the triquetra structure. The systematic study of structural parameters of basic structural units reveals the influence of various structural parameters on the performance of metamaterial perfect absorber MMPA, and it is found that the use of high-order symmetry of structures can obtain the polarization unsensitive of MMPA. On the basis of optimizing each structural parameter, the design of a narrow-band, high-performance metamaterial perfect absorber working at microwave band was finally obtained.

2. Structural design

The schematic diagram of the metamaterial perfect absorber proposed in this paper is shown in Figure 1 (a). The absorber is composed of a three-layer structure a FR4 substrate in the middle upward are a copper as back mirror layer, and a triquetra resonator (triquetra is a triangular shape formed by three half of circles) on top of substrate. The electromagnetic wave EMW is perpendicularly incident from the port1 side to the surface of the triquetra resonator PMMA. Since the triquetra resonator is a symmetric structure, the absorber material does not have polarization insensitive and can be applied to energy harvesting and radar cross section. Figure 1(a) shows a schematic diagram of one-unit cell. Here, since we used the copper at the back of substrate. In this way, the electromagnetic wave will not be able to pass through it. The structure selected in this work is a triquetra with a r=4 mm and w=1.1 mm printed on top of FR4 substrate with h=0.4 mm thickness, dielectric constant 4.3 and tangent loss 0.025.

![Figure 1: (a) Schematic diagram of the PMMA of polarization-insensitive, (b) unit cell.](image)

3. Results analysis and discussion

Using the commercial finite element numerical analysis software CST microwave studio to simulate the triquetra structural unit as shown in Figure 1(b). The simulation process is described as follows: The boundary condition is set as periodic boundary in x and y direction, and the +z and -z direction are set as open add space ports. The absorption spectrum of the triquetra metamaterial perfect absorber
can be seen in Figure 2. The perfect absorption can achieve around the resonance frequency 10.026 GHz and absorption efficiency 98.37%. The surface current distribution as shown in Figure 3 (a) and (b), at upper and lower layer respectively. It can be seen that the resonance mode at 10.026 GHz resonance frequency is a fundamental mode in which the charge distribution in a copper resonator satisfies the characteristics of an electric dipole.

![Absorption Spectrum](image)

**Figure 2. EMW absorption spectrum**

![Current Distribution](image)

**Figure 3. The surface current distribution: (a) upper layer and (b), lower layer, at resonance frequency 10.026 GHz.**

Additionally, can obtain a perfect absorption wave response detailed of polarization studies were carried out on the two parameters phi and theta. Because the symmetric of the triquetra resonator around z axis has a great influence on the polarization wave. It can be seen from Figure 4 that as the gradual increase from 0° to 90°, the response of the metamaterial perfect absorber does not change. Figure 5 shows the behaviour of the magnetic polarization mode of the triquetra absorber as a function of theta. It can be seen that when the theta θ gradually increases from 0° to 60°, the absorption level of the absorber changes in a more complicated manner, but generally is above 90%. In addition, as the theta further increases, the absorption level rapidly decreases. Finally, on the basis of the aforementioned polarization parameter study, comprehensively considering the influence of each of
the two parameters, phi φ and theta θ on the behaviour of the absorber, triquetra is a reasonable high-
performance, perfect absorber, and ultrathin structure.

![Graph 1](image1)

**Figure 4. Influence of the φ in EMA.**

![Graph 2](image2)

**Figure 5. Influence of the θ in EMA.**

4. **Conclusion**

This work is based on single structure of triquetra resonator on top of FR4 substrate and copper 
mirror (i.e. sandwich structure). This promising for large-scale application such as: radar cross section, 
energy harvesting and wave detection. The numerical simulation study a perfect thinstructure 
absorption of metamaterials. By comparing the response of magnetic and electric polarization, it is 
found that the triquetra structure can obtain a perfect absorption response with a polarization 
unsensitive.

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