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A Novel Wideband Metamaterial Absorber for S, C & X Bandwith Good Absorbption

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Abstract

In this paper, we present the design, analysis, and simulation of a wideband metamaterial absorber using Ansoft HFSS. The absorber proposed here consists of two similar structure each composed of C shaped patterns placed diagonally opposite to each other and a metallic back plate separated by FR4- epoxy substrate. The simulated absorptivity graph for this absorber shows two wideband in the range of 3.7 GHz to 5.6 GHz and from 5.92 GHz to 9.26 GHz with a peak at 8.86 GHz and peak absorptivity of 99.98%.
Keywords---Wideband, Metamaterial, Absorber

1 Introduction

Due to unusual properties of metamaterials, such as negative permeability and permittivity, negative refractive index (Veselago, 1968; Smith, 2000; Koschny, 2004), they have already found its use in various applications such as microwave lens imaging, cloaking, stealth technology etc. Metamaterial absorber has attracted much research because of its ultra-thin property, lightweight, and maximum absorption in various microwave frequency bands. It is possible to design such an absorber, which absorbs almost all the electromagnetic energy striking on it. The authors in (Landy, 2008) proposed first metamaterial-based absorber with near unity absorption in microwave frequency range. In (Tuong, 2013), a closed ring resonator (CRR) based absorber has been presented as they are polarization insensitive due to their geometrically symmetric structure. In addition, an absorber was proposed in (Bhattacharyya, 2014), which is bandwidth enhanced ELC resonator based structure for radar applications. ELC based structures are used over SRRs as electromagnetic waves needs to travel much smaller distance. Various multiband absorbers have been proposed in (Costa, 2013; Zhang, 2014; Xu, 2012) when there is a need of an absorber to work at specific frequency. In (Gu, 2010) an absorber was proposed which was embedded with resistors to increase the bandwidth in the GHz regime.

In this paper, a wideband metamaterial absorber is proposed with two wideband ranging from 3.7 GHz to 5.6 GHz and from 5.92 GHz to 9.26 GHz with a peak at 8.86 GHz and 99.98% absorption. The field overlay plots are added for better understanding of the absorption mechanism.

2 Design of Absorber

The absorber discussed here is composed of two similar structures. As it can be seen from figure 1 that each structure is designed in C shaped configuration placed diagonally opposite to each other. The substrate used is FR4-epoxy with relative dielectric constant ε_r = 4.4, dielectric loss tangent δ = 0.02, and a thickness t=0.32cm. The metal used for these structure is copper which has a conductivity σ =5.8x105 S/cm. Metallic ground plate is introduced to achieve zero reflection coefficient. The geometric dimensions of the absorber are- a=0.85cm, b=0.55cm, c=0.4cm, d=0.1cm, e=0.7cm, f=0.65cm, g=0.35cm, h=0.95cm, i=0.7cm, j=1.5cm x=0.054cm, y=0.06cm, and z=0.05cm.

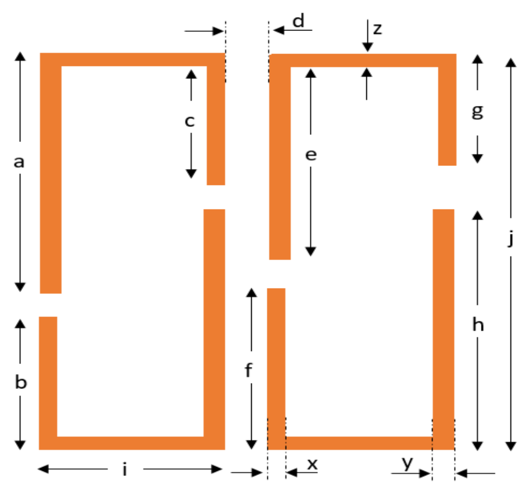

Figure 1: Unit cell geometry

3 Simulation Setup

The software used to compute the absorptivity for this absorber is Ansys HFSS. It is based on finite element method. The appropriate boundary conditions required for simulation are shown in Figure 2. The PEC (perfect electric conductor) boundary conditions are applied to boundary perpendicular to x- axis. The PMC (perfect magnetic conductor) boundary conditions are applied to boundary perpendicular to y- axis. The waveports are given along z- axis. The electromagnetic waves propagates along z- axis.

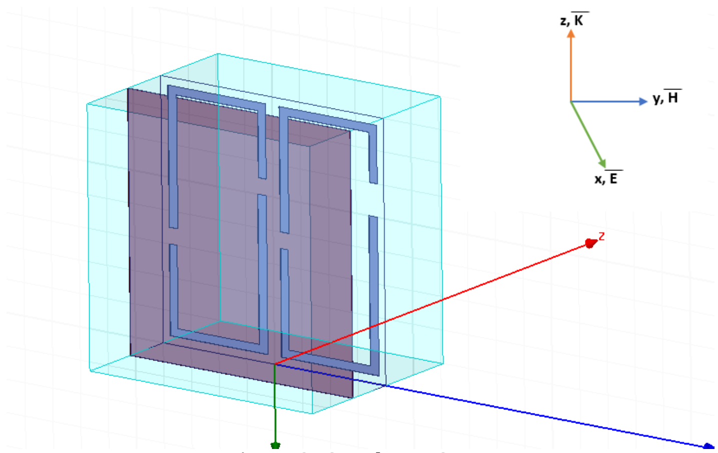

Figure 2: Simulation Setup

4 Absorption Mechanism

The absorptivity of an absorber can be calculated using equation:

$$A(\omega) = 1 - |S_{11}|^2 - |S_{21}|^2 \tag{1}$$

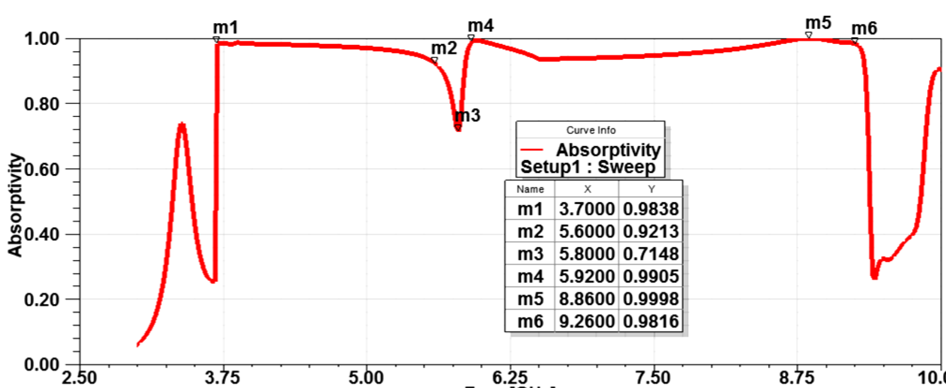

Figure 3: Absorptivity graph

As a ground plane is placed at the back of the substrate, $|S_{21}|^2$ becomes zero. Hence only reflection power causes change in absorptivity. The absorptivity of the proposed absorber can be viewed in Figure 3. It can be seen from Figure 3, that absorptivity greater than 92% is obtained in the band 3.7 GHz to 5.6 GHz, while absorptivity greater than 98% is obtained in band 5.92 GHz to 9.26 GHz. Also peak absorptivity is obtained at 8.86 GHz (99.98%).

The field overlay plots for the peak resonant frequency (8.86 GHz) are shown in figures below. The E field is shown in Figure 4 and H field in Figure 5. The red sections in Figure 4 and Figure 5 represent the places with maximum electric and magnetic energy respectively. The blue sections represent the places with less energy.

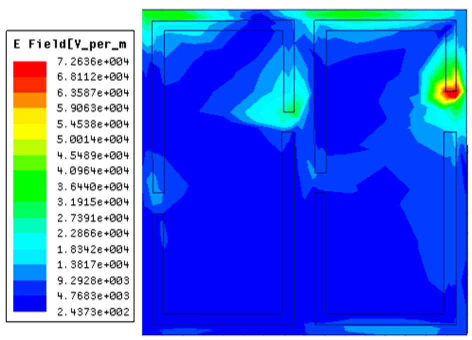

Figure 4: E-field at resonant frequency 8.86 GHz

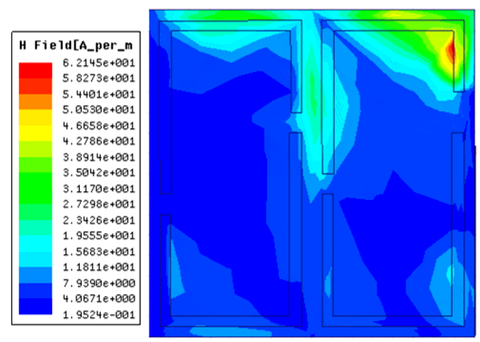

Figure 5: H-field at resonant frequency 8.86 GHz

It can be observed from Figure 4 that maximum electric field energy is concentrated in right most gap of the design. This fact is complemented by the location of the highest magnetic field at the same location shown in Figure 5. This is due to the fact that the gap is exploited in the discontinuity in form of the edge of the structure. Hence, the concentration of the charges are more dense at this gap. The other reason supporting the Figure 4 & Figure 5 is as follows; at this frequency the capacitance offered by that gap has lowest value among the other capacitances forming in the structure

Majority of the surface current is induced at the top right edge of the design which can be seen from Figure 6. These three figures reveal the fact that the major absorption at 8.86GHz is due to the gap present on the top right corner of the structure.

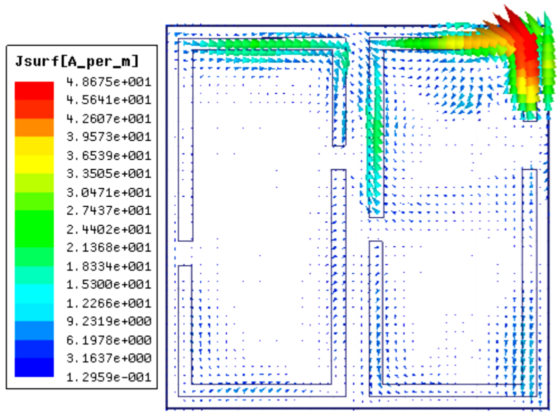

Figure 6: Surface current distribution at resonant frequency 8.86 GHz

Conclusıon

Two wideband 3.7–5.6 GHz (1.9 GHz) and 5.92-9.26 GHz (3.34 GHz) with absorptivity greater than 92% has been obtained from the proposed metamaterial absorber. It consists of two copper ring on FR4-epoxy substrate and a metallic back plate. Absorption mechanism has been studied using electric and magnetic field plots. Current distribution plot is also observed.

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