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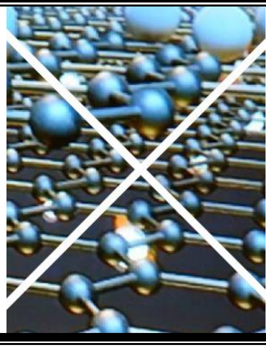

WIDE BAND METAMATERIAL ABSORBER WITH LUMPED ELEMENT

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Abstract

Many researchers take attention to the significance of harvesting energy from electromagnetic radiation to use in sensor networks. The purpose of this study is to design and analysis of a metamaterial absorber that has the ability to absorb energy in the microwave frequency band with perfect absorption. The results show that the proposed design is a good candidate for supply power from electromagnetic waves to sensor networks.

Keywords: Microwave, Metamaterials, Wide band absorber, Perfect absorption.

1. Introduction

Energy requirement increases day by day with the technological developments that we have in the 21.century. This situation emphasize by governments, institutions, and researchers in every platform [1]. Energy is very important for industrial and financial development of every governments. Many studies take attention to significance of harvesting energy from electromagnetic waves to use many applications [2-3].

Metamaterials are a new concept of multidisciplinary research area which is associated to artificial material for determine physical properties that not available independently in nature [4]. Due to this remarkable properties of metamaterials, they have used in many applications [5-6]. Generally, properties and composition of metamaterials depend on the periodic arrangement of structure and unit wavelength of subsystems [8]. Recently, metamaterials have ability to absorb electromagnetic radiation with high level of efficiency studied first time by Landy et al [7].

Dincer et al. designed metamaterial absorber that show tunable dual band. It includes a ring resonator with gap loaded varactor diode that operates in the microwave frequency band [10]. Gunduz et al. presented a multi-band metamaterial

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absorber based on concentric ring resonators can be used in many microwave applications [11]. Dincer et al designed a new perfect metamaterial absorber based on square resonator with gap and investigated in GHz regime. New design achieved above 90% absorption level at resonance frequency [12]. Karaaslan et al. presented a multiband absorber based on multilayer square split ring structure to be used in the frequency of satellite communication region. The proposed metamaterial absorber reached above 90% absorption level [13]. Al badri et al. designed an absorber based on metamaterial and lumped resistance with aim of harvesting energy from electromagnetic waves to supply power to sensor networks. The structure has ability to reach above 90% absorption level by using one spiral ring and 400 ohm lumped resistance [9].

In this work, Reference 9 was investigated and analyzed to get same results with original paper. After getting same result with Reference 9, thickness of dielectric substrate (increase from 2.5 mm to 2.8 mm) and “d” parameter (decrease from 1 mm to 0.72 mm) values have been changed to get better results than original paper. Geometrical dimension configuration of proposed design provides 90 % above absorption with wide band in between 13.3 GHz and 16.8 GHz. Also proposed design provides perfect absorption in between 13.6 GHz and 16.5 GHz.

2. Design

The proposed unit cell structure and dimensions are shown in Figure 1. The proposed design based on spiral ring with two turns that operate as a wide band absorber in the microwave frequency region. The proposed design consists of three layers. A square spiral metallic ring is the top layer of structure. Under the top layer Flame Retardant (FR-4) is located as a dielectric layer of proposed design which has ϵ_r=5 dielectric constant and tanδ=0.04 loss tangent value [9]. Also, dimension parameters are also set out in tabular form in Table 1.

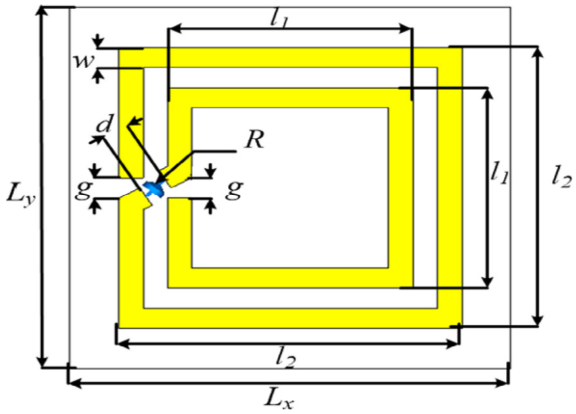

Figure 1. Top view of the proposed design with geometric dimensions [9].

The ground layer is copper with 35 μm thickness which behave as a mirror to prevent all transmission waves and increase absorption level of proposed design. Therefore, scattering parameter s_{21} is zero [9, 14]. In order to get perfect wide band absorption the proposed structure was simulated with full wave electromagnetic software which is called CST (Computer Simulation Technology) established on Finite Integration Technique (FIT), with frequency domain solver.

Table 1. Geometric parameters and values of proposed design.

Parameter	Value (mm)
l1	5
l2	7
Lx	11
Ly	11
d	0.72
g	0.5
w	0.5
Thickness of dielectric	2.8

The proposed design operated at frequency ranging from 11 GHz to 20 GHz. During the simulation, periodic boundary condition is applied along the x and y directions. The propagation constant is in negative direction on the z-axis. Additionally, electric field (E) and magnetic field (H) are applied in the positive direction on the y-axis and positive direction on the x-axis, respectively [9].

3. Results and Discussion

According to general formula of the absorption shown in equation 1, $s_{11}(\omega)$ and $s_{12}(\omega)$ are the scattering parameters which are functions of power flow from reflected and transmitted radiations, respectively [15].

$$A(\omega) = 1 - |s_{11}(\omega)|^2 - |s_{12}(\omega)|^2 \qquad (1)$$

Due to copper ground layer behaves as mirror to prevent all transmission waves, $s_{12}(\omega)$ is zero. Electromagnetic software simulation program calculate absorption according to formula in equation 2.

$$A(\omega) = 1 - |s_{11}(\omega)|^2 \qquad (2)$$

The result of simulation related to reflection coefficient s_{11}^2 that used for calculate the absorption is shown in Figure 2. Figure 4 show that all plots of parameters of equation 1 in together.

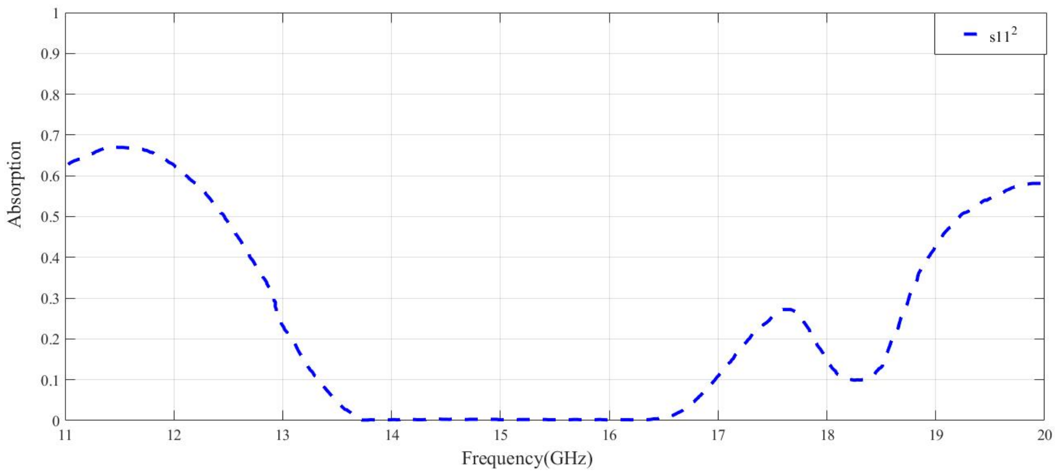

Figure 2. Reflection plot of proposed design.

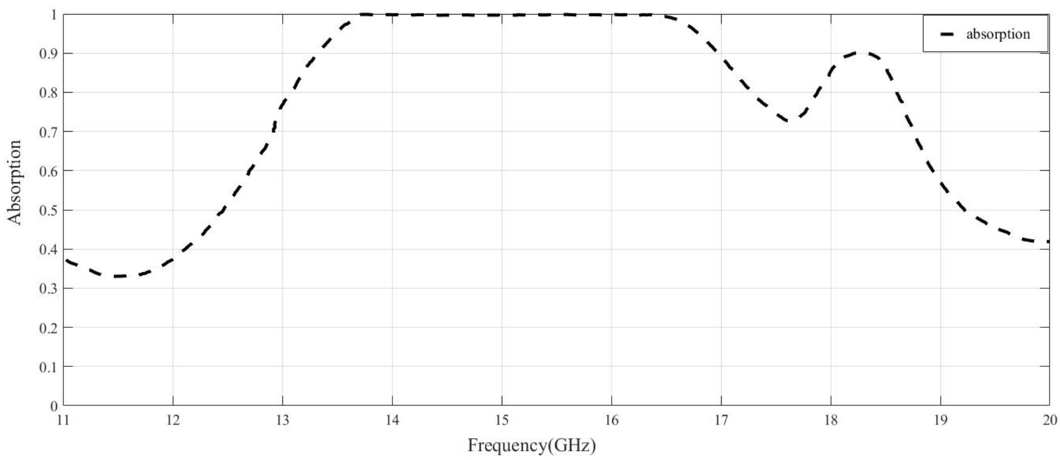

Figure 3. Absorption plot of proposed design.

Absorption plot of proposed design that obtained after simulation in signified frequency region are shown in Figure 3. The combinations of resonant frequencies generate a wide band absorption. High absorption occurs with result of spectral matching of FR-4 with the metamaterial resonance. Due to proper arrangement of geometrical dimension configuration of proposed design achieved above 90% absorption for wide band in between 13.3 GHz and 16.8 GHz. Also proposed design provides perfect absorption level in between 13.6 GHz and 16.5 GHz.

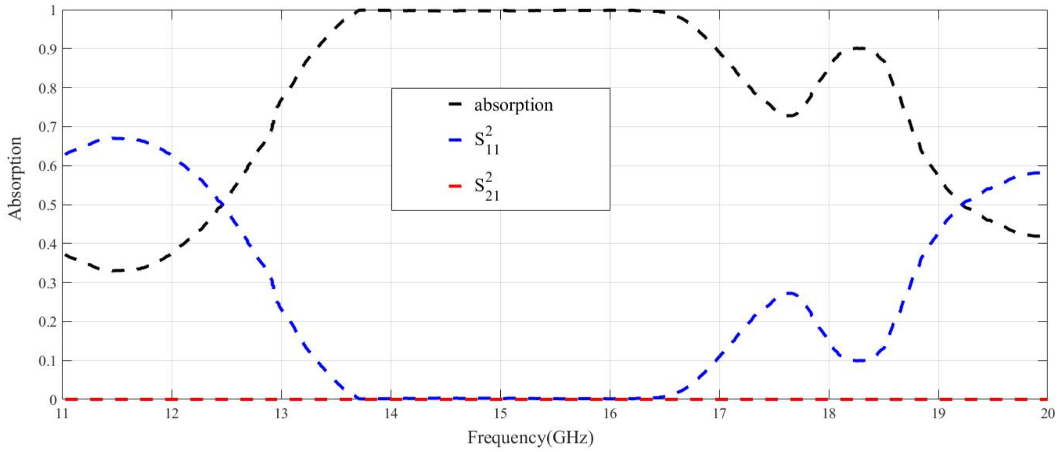

Figure 4. Absorption, reflection and transmission plots of proposed design.

4. Comparison with Previous Studies

In the introduction part of this study, reference study was mentioned. This section will show some comparisons between this study and previous study. As mentioned before, some parameters ("thickness of dielectric" and "d") of the reference study have been changed to get better results. Some important parameters for this type of studies shown in Table 2.

First of all, re-simulated simulation of reference article with the same parameters to make sure that program is working correctly. The same results obtained are shown with the reference article as shown in Figure 5, Figure 6, and Figure 7.

Comparison for the most important coefficient of absorption, S11^2, for previous study and this study shown in Figure 5. It can observe from the Figure 5, changing of parameters provide better results with wider bandwidth. After obtain s11^2 of both previous study and this study, absorption plots of both study was obtained. Comparison of absorption plots for previous study and this study shown in Figure 6. It can be understand from the Figure 6, the changing of parameters increased the perfect absorption bandwidth of the proposed structure, especially between 13.6 GHz and 16.5 GHz which shows a better result than previous study.

Table 2. Comparison parameters with previous study [9].

Parameter	Previous study	This study
Dielectric substrate	FR-4	FR-4
Ground plate	Copper	Copper
Thickness of dielectric	2.5 mm	2.8 mm
Value of R	400 ohm	400 ohm
Value of d	1 mm	0.72 mm

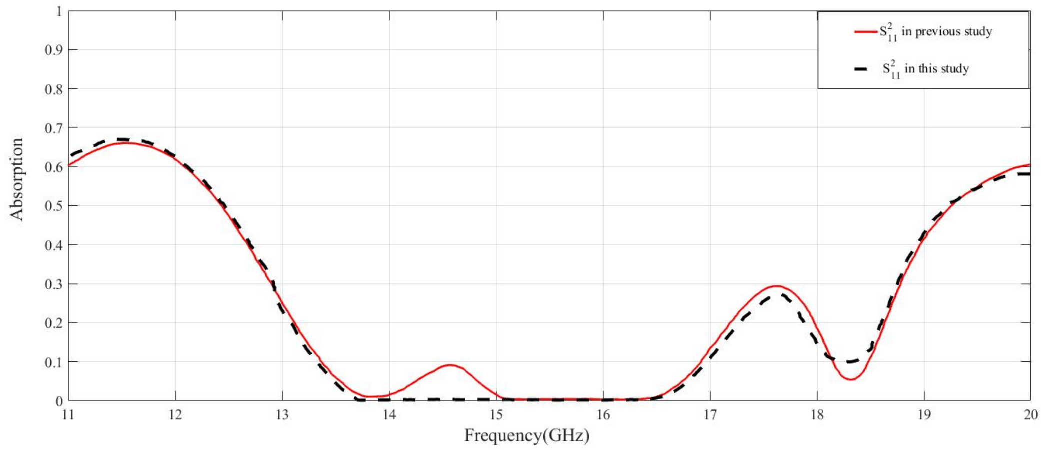

Figure 5. Reflection plots comparison of previous study and this study.

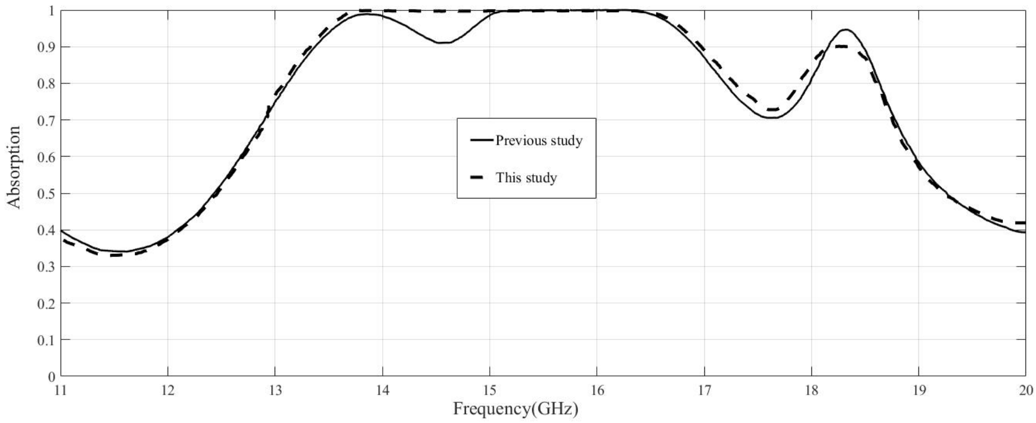

Figure 6. Absorption plots comparison of previous study and this study.

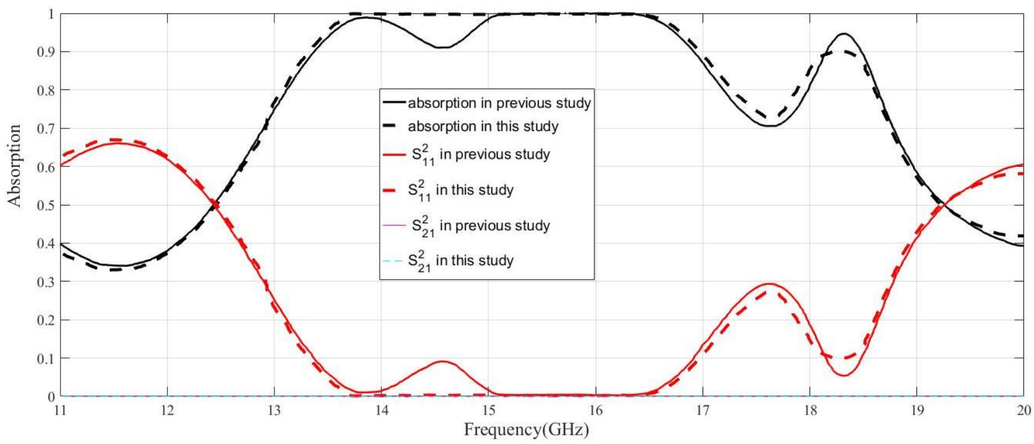

Figure 7. All absorption coefficient plots comparison for both previous study and this study.

5. Conclusion

A broadband metamaterial absorber structure with unity absorption in specified frequency ranges is simulated in this study. Also, due to perfect geometrical arrangement of structure, better results are achieved especially in between 13.6 GHz and 16.5 GHz frequency region. Comparison of simulation results for this study and previous study provide to realize difference between them. Contribution of the this study to the literature is energy harvesting based on a metamaterial with lumped resistance is a good candidate for the maximum absorption in the specified frequency region for supply power to sensor networks with wide absorption band and perfect absorption level via structure which is designed proper geometrical parameters.

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