Indonesian Journal of Electrical Engineering and Computer Science
Vol. 6, No. 1, April 2017, pp. 180 ~ 184
DOI: 10.11591/ijeecs.v6.i1.pp180-184

X-Band Operations Metamaterial Absorber with Extended Circular Ring Topology for Size Reduction

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Abstract

A metamaterial electromagnetic wave absorber consisting of a big circular ring patch with four smaller suppression circular rings is presented in this report. The metamaterial electromagnetic wave absorber introduces the concept of size reduction by suppressing the resonance frequency. An FR4 substrate was used and the incidental wave angles were varied from 0^0 *to* 60^0*. Simulations results shows peak absorption of 100% was achieved at 10.7 GHz by the absorber for both TE and TM polarization incident waves. Minimum absorption for both TE and TM mode of 90.6% was achieved under TE mode. The metamaterial absorber was being tested with and Ultra-wide band antenna and the results were reported.*

Keywords*: Metamaterial, Absorbers, Ultra-wide band, SSR*

1. Introduction

Electromagnetic waves (EMW) absorbers are structures that neither reflect nor transmit (EMW) but instead they minimize reflection by maximizing energy loss within the structure's substrate. The theories and concept behind exotic properties of metamaterials (MTM) have long been established [1]. As proposed, MTM being unique structures which where purposely engineered exhibit properties not existing in nature have in recent years drawn numerous attention. Scholars and researchers in the fields of EM (electromagnetic) are at their max trying to exploit all the benefits MTM can offer.

The engineering of these elements which involves the manipulating or tempering with the structural configuration of these substances yields unusual properties, which could be desirable for certain applications such as low profile ground plane, cloaking, EM filters, sensing, focus antenna beam, reflectors, phase shifting [2] etc. Furthermore, MTM is divided into subareas which includes artificial magnetic conductor, AMC, electromagnetic bandgap (EBG), frequency selective surface (FSS), left-handed metamaterial (LH-MTM)

2. Proposed Design

The proposed MTM absorber structure was designed using FR4 substrate with a dielectric constant of 4.6 with loss tangent of 0.019. One side of the structure consists of one big circle (ring A) and four smaller ones (rings B-E), whereas the other side consist of full ground plane as shown in Figure 1.

Secondly, a simple ultra-wideband microstrip patch antenna for x-band operations shown in Figure 2 was designed to test the performance of the proposed MTM absorber. Similarly, the antenna was built on an FR4 substrate of same characteristics as that of the MTM absorber. Absorbance, A(ω) was calculated using A(ω)=1-R(ω)-T(ω) where reflectance, R(ω) is |S11| ^ 2 and transmittance, T(ω) is |S21| ^ 2 [4]. Microwave Studio of Computer Simulation Technology CST® 2015 was used for simulation.

Received November 2, 2016; Revised January 25, 2017; Accepted February 15, 2017

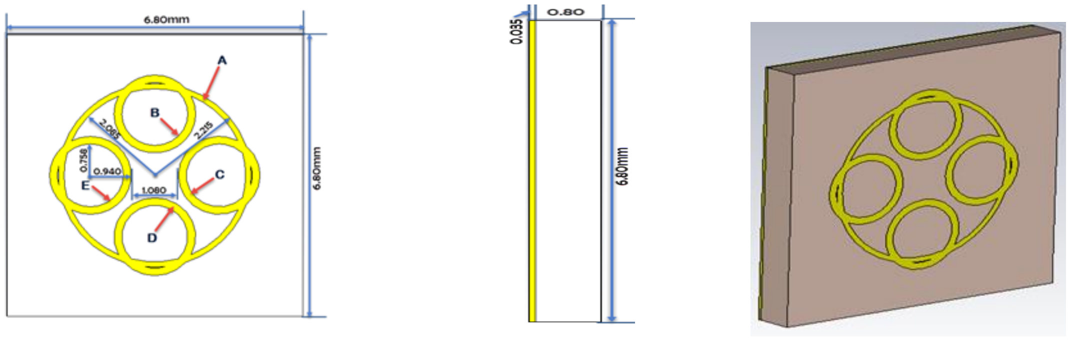

Figure 1. (a) MTM absorber (b) Side view (c) Perspective view

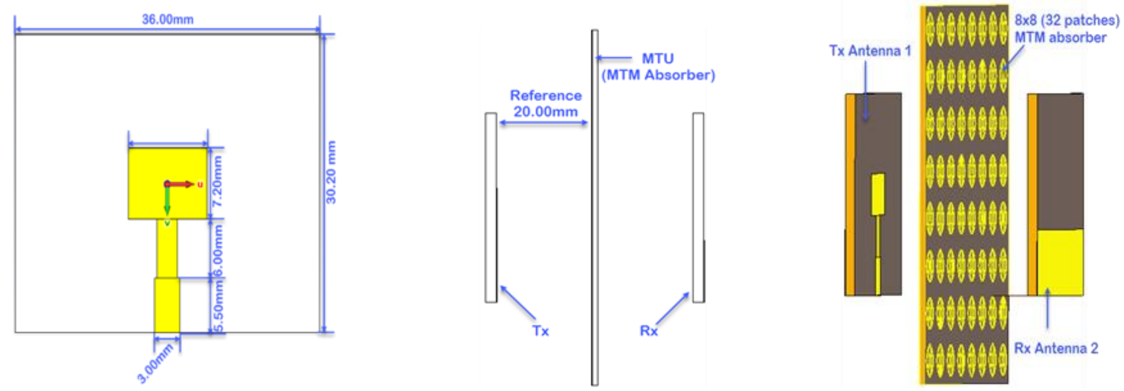

Figure 2. (a) Ultra-wide band antenna (b) Setup arrangements (c) Setup perspective view

3. Simulation Results and Analysis

3.1. Parametric Study on Both Antenna and Absorber

First before testing the performance of the proposed designed MTM absorber, some brief independent parametric studies were conducted on both MTM absorber and the antenna. This was done in order to be able to distinguish the effectiveness of the MTM absorber. Meanwhile an ultra-wide band antenna was chosen in order to determine or find out what happens at the out of the MTM resonance frequency.

With respect to the MTM absorber, the simulation for the parametric studies did not put into consideration, the return loss it only focused on the resonance frequency. In order to display the effect of rings (B-E) on the resonance frequency of the absorber, the absorber was first simulated without rings (B-E) and it resonated at 12.46 GHz. Next, by adding rings (B & D) the resonance frequency was suppressed from 12.46GHz to 9.55GHz which is lower than desired frequency. Rings (B & D) were removed and rings (C & E) were added which pushed the resonance frequency even further to 13.98 GHz. Finally putting all the rings (B, C, D & E) together the absorber was to resonate at the targeted frequency (10.74GHz). Figure 3a, shows the simulation results of with no rings, with rings (B & C) and with rings (B-E) respectively.

On the other side, the two antennas (Tx & Rx) where simulated without the MTM absorber in order to determine the optimum distance for the resonance frequency of 10.74 GHz. Having origin point (0) in between the two antennas, they were simulated for 19.0mm, 20.0mm, 21.0mm, 22.5mm, 24.0mm and 26.0mm. the results as shown in Figure 3b indicated the best optimum distance is 21.0 mm and thus it was used as reference point for other simulations.

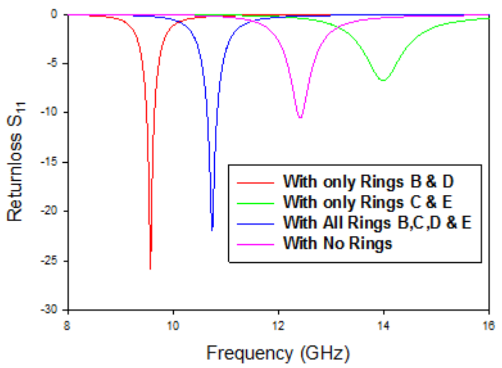

Figure 3a. Effect of rings (B-E) on resonance frequency

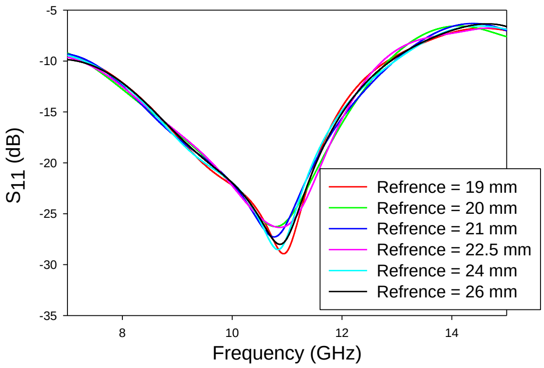

Figure 3b. Effect of reference point distance on 10.7 GHz resonance frequency

3.2. TE Mode Performance of The MTM Absorber

The simulation of the proposed MTM absorber was carried out at resonance frequency of 10.74 GHz using different polarization angles (0^0, 15^0, 32^0, 45^0 and 60^0). Almost 100% absorption were achieved for angles 0^o, and 32^o, whereas 98.62%, 94.67% and 90.64% being the least were achieved at angles 45^o, 15^o & 60^o respectively. There is a minor but negligible shift in resonance frequency as the incidence angle is increased. In addition to the shift, there is reduction in absorbance performance which still maintain above 90% at 60^0.

3.3. TM Mode Performance of The MTM Absorber

In a similar fashion, the TM mode for the proposed MTM absorber was simulated. The same resonance frequency (10.74 GHz) and variation angles were maintained (0^0, 15^0, 32^0, 45^0 and 60^0). For the TM mode, almost a 100% absorption was achieved for all simulated angles (0^0, 15^0, 32^0 & 45^0) except for incidence angle 60^0 in which 96.72% absorption was achieved. Figure 4 shows both the TM and TE mode performance results while Table 1 shows the comparison between the two modes at resonance frequency.

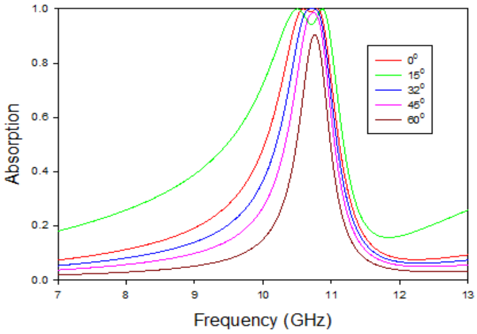

Figure 4a. TE mode performance of the MTM Absorber.

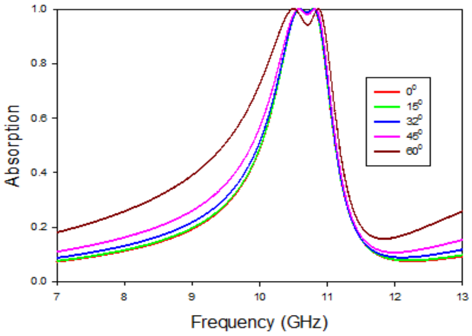

Figure 4b. TM mode performance of the MTM Absorber

Table 1. TE vs TM modes comparison at 10.74GHz performance of the MTM absorber

Angles (Degrees)	TE Mode Absorption (%)	TM Mode Absorption (%)
0	99. 60	99.88
15	94.67	99.75
32	99.98	99.51
45	98.62	98.93
60	90.64	96.72

3.4. Simulation of The MTM Absorber with The Ultra-Wide Band Antennas.

As mentioned earlier, the antenna was simulated as shown in the setup Figure (2b & 2c). in this setup the 21.0mm was taken as optimum distance because it resonates excellently at that distance. The simulation was done while the angles were varied except for the last angle (60^0) the distance was increased to 30mm due to the absorber touching the antenna. The results of the simulation show all throughout the angles there is difference at the exact resonance frequency thus indication there is absorbance.

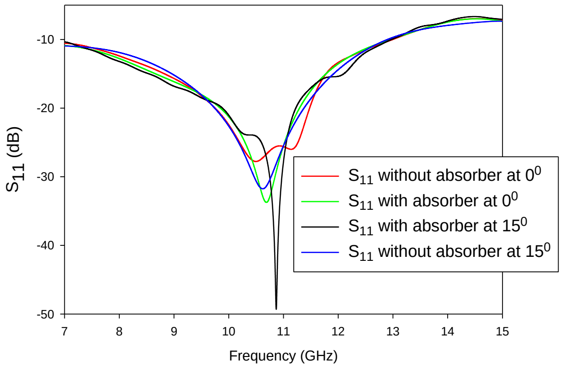

Figure 5a. S_{11} for incident angle 0^0 and 15^0

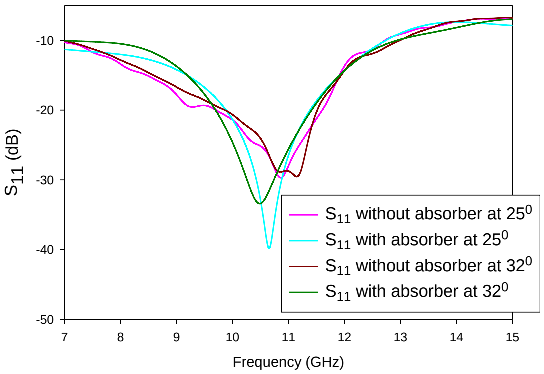

Figure 5b. S_{11} for incident angle 25^0 and 32^0

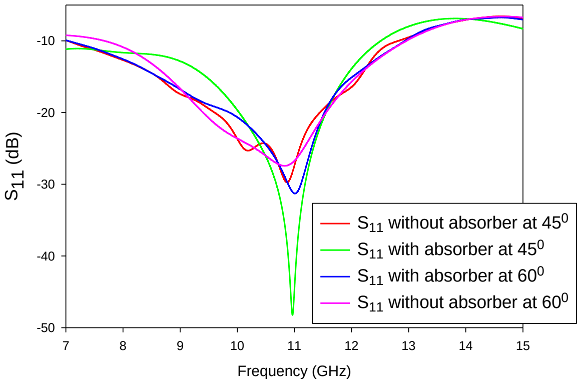

Figure 5c. S_{11} for incident angle 45^0 and 60^0

In this case, A(ω)=1-R(ω)-T(ω) where reflectance, R(ω) is |S11|2 and transmittance, T(ω) is |S21|2 [4] failed to work in calculating the total absorbance. Below are the simulation results of the reflectance coefficient of the antenna with and without the MTM absorber. It should also be noted that the shift in resonance frequency still exist just like in the case of when the MTM absorber is simulated with plane wave guide. The simulation results are shown in figure 5a, 5b and 5c.

4. Conclusion

In this report, an electromagnetic wave metamaterial absorber was presented. The performance of the metamaterial absorber at resonance frequency for both TE and TM modes were observed. It performed excellently with more than 90% absorption for angles between 0^0 to 60^0 for both TE and TM. It was noted that the performance drops as the incident angle increases.

Furthermore, effect of the smaller rings (B-E) on the entire structure was also observed and it proved to suppress or surpass the resonance frequency while still maintaining small size major ring. On the other part, the MTM absorber was tested with an Ultra-wide band antenna to see the performance where it also proved it effects the performance of the antenna.

Acknowledgements

authors thank the Ministry of Higher Education (MOHE) for supporting the research work, Research Management Centre (RMC), Universiti Teknologi Malaysia (UTM), Faculty of Electrical Engineering for the support of the research under grant no. 12H09, 4L811**.**

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