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# A Dual Band Symmetric E-Shaped Split Ring Metamaterial Absorber For RF Energy Harvesting

**J. John Paul, A. Shoba Rekh**

***Abstract* — In this paper, a new metamaterial absorber which comprises of a symmetrically E shaped split ring resonator patches at the top of the FR4 substrate of height 1.6mm for RF Energy Harvesting is proposed. The proposed design provides two absorption peak one at 5.8GHz with a maximum absorption of about 99% and other at 7.8GHz with a maximum absorption of about 92%. The absorption mechanism is investigated for the proposed metamaterial absorber. Also the polarization behavior of the absorber is also analyzed under various angles of incidence. The absorber has been tuned in such a way to have good broadband response in the UWB range.**

***Keywords: Metamaterial, Microwave Absorber, polarization, UWB***

## I. NTRODUCTION

In the recent days, Energy harvesting is one of promising area of research where researchers pay more interest in implementing low power, self-sustaining devices. These low power devices play a major role in wireless sensor networks (WSN) which are mainly battery operated and their contribution towards IoT makes a huge impact towards remote sensing and monitoring. These self-sustaining devices which are mostly battery operated also come with additional sources to power them through solar, wind, thermal, mechanical and RF Energy. RF Energy harvesting [1] has become one of the promising thrust areas of research. It has also provided resilience to the researchers in limiting the usage of battery and envisage in providing a hazardous free green environment and preparing the future towards green computing. In RF Energy Harvesting, antenna being the first element plays crucial role in harvesting RF energy. But Conventional Patch antennas will have limitations in the absorption rate. The rate of absorption determines the conversion efficiency of RF Energy to DC voltage. In the recent years, researchers arise with different methodologies to improve efficiency. To improve the conversion efficiency at the output side, the RF energy absorbed by the antenna should be also at its maximum. After the investigation on the metamaterial absorber by Landy [2], metamaterial absorbers gained more thrust among researchers due to its advantages over conventional absorbers like ferrite [3], wedged-tapered absorbers [4] and Salisbury screen absorbers [5]. Compared to the conventional absorbers, they show maximum absorption characteristics, realized with an ultra-thin substrate. Additionally the absorption characteristics can also be analyzed with tunable materials [6].

This empowers the metamaterial absorbers to have a clear edge over the conventional absorbers covering a wide range of applications, from microwave frequency range towards the optical frequency range. Several optimized metamaterial absorbers have been proposed for broadband [6-8], multi-band [9] and tunable band [10–13]. Most absorber structures are usually in the millimetre range, which enables easy and quick fabrication through PCB technology, with minimum reflection and maximum power transfer at the ports in the millimetre range.

This paper proposes a symmetrically E shaped split ring resonator on a FR4 dielectric substrate. The proposed absorber provides dual band characteristics with two absorption peaks with a maximum absorption of more than 99% at 5.8 GHz and 92% at 7.8 GHz. To study the absorption characteristics, the proposed structure is also analyzed *via* Electric field and Magnetic field distribution plots. Also to prove its polarisation insensitive behaviour, the absorber is analysed and plotted through various angles of the incident wave.

## II. NIT CELL ABSORBER DESIGN

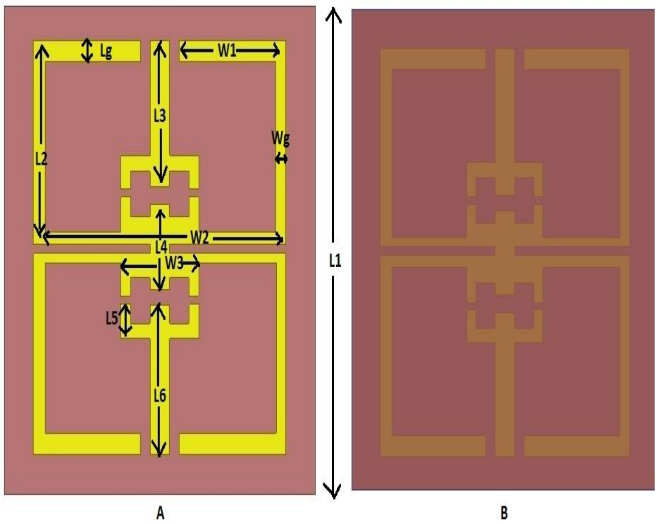


**Fig.1. Proposed Unit cell Absorber (A) Top view, (B) Bottom View**

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The proposed E based unit cell structure is shown in Fig.1 along with its dimensions.

The Top layer (patch) is mounted on the FR4 dielectric substrate (Ɛr = 4.4 and tanδ = 0.025) without ground surface. The diametric and trimetric view of the unit cell absorber is show in the Fig. 2. The numerical studies of the presented absorber structure are simulated in commercial simulation software called HFSS. The unit cell structure dimensions were given in the Table 1.

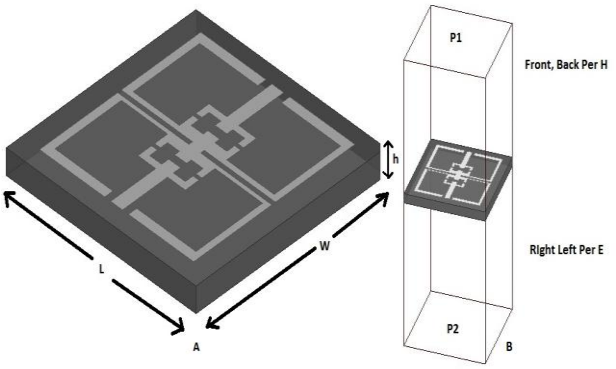


**Fig.2. (A) Diametric, (B) Trimetric view of the proposed E shaped unit cell.**

[A(ω)] refers to the Absorption coefficient of an absorber and the absorption coefficient depends on two parameters, Transmission coefficient [T(ω)] and reflection coefficient [R(ω)]. It is usually calculated using following equations given below:

$$A(\omega) = [1 - R(\omega) - T(\omega)] \quad (1)$$

$$R(\omega) = S_{11}(\omega)^2 \quad (2)$$

$$T(\omega) = S_{12}(\omega)^2 \quad (3)$$

$$A(\omega) = [1 - |S_{11}(\omega)^2| - |S_{12}(\omega)^2|] \quad (4)$$

**Table1. List of dimensions with description**

| Symbol | Value (mm) |
|---|---|
| L1 | 16 |
| L2 | 8 |
| L3 | 4.5 |
| L4 | 2.8 |
| L5 | 2 |
| L6 | 4.9 |
| W1 | 6 |
| W2 | 13 |
| W3 | 4 |
| Lg,Wg | 1 |

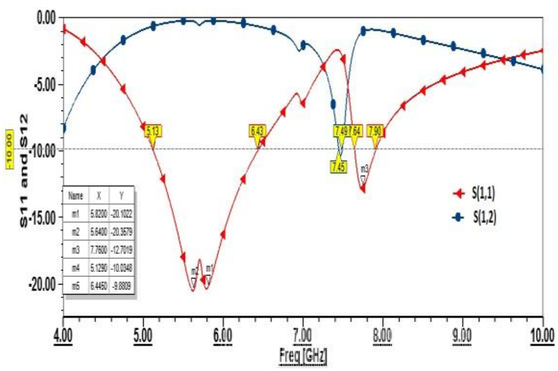


**Fig.3. Simulated S11 and S12 characteristics**

Fig. 3 shows the simulated results of absorption (S12) and reflection (S11) in decibel. The absorber exhibits dual band characteristics with good absorption between 5.13GHz to 6.43 GHz having 5.8GHz as the center frequency at -20dB and another at 7.64GHz to 7.90 GHz having 7.7GHz as the center frequency at -12dB.

## III. PROPOSED UNIT CELL ABSORPTION CHARACTERISTICS

To determine the simulated absorptivity of the proposed absorber, the absorber is placed within the boundary such that the radiating surface is at a distance of λ/4 from the boundary, where wavelength λ is calculated at the antennas resonant frequency. Any two sides of the finite radiation boundary are assigned to be Perfect Electric conductor (PEC) and the other two sides are assigned to be Perfect Magnetic Conductor (PMC). To analyze the absorption characteristics of the proposed absorber, wave port excitation is assigned to the top and bottom of the radiation boundary. Fig. 4 shows the normalized Absorption curves with its maximum and minimum values.

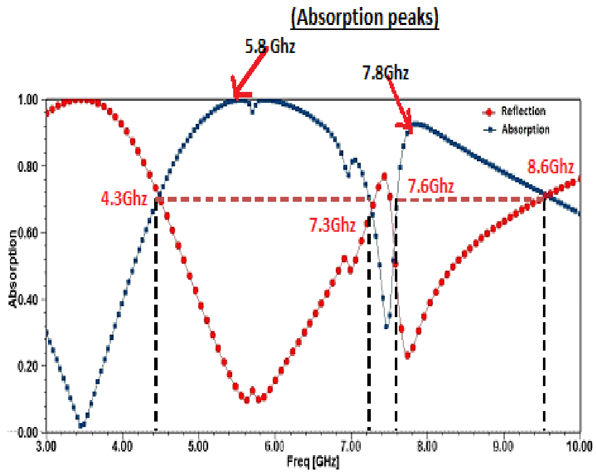


**Fig.4. Normalised Absorption and Reflection curves**

The proposed absorber shows dual band absorption characteristics in the UWB frequency band. The proposed absorber shows good absorption characteristics of above 70% between 4.3 GHz to 7.3 GHz and also between 7.6 GHz to 8.6 GHz. The peak absorption occurs in the dual band one at 5.8GHz with maximum absorption reaches about 99% and other at 7.8GHz with absorption peak shoots to 92%. This suits the absorber to be an appropriate candidate for UWB applications.

## IV. PARAMETRIC STUDY FOR THE UNIT CELL

The absorptive characteristic is studied for the proposed unit cell absorber by varying the different geometric parameters. They are gap (L4) between the rectangles, gap (Lg) between the lengths of the rectangles and gap (Wg) between the widths of the rectangles.

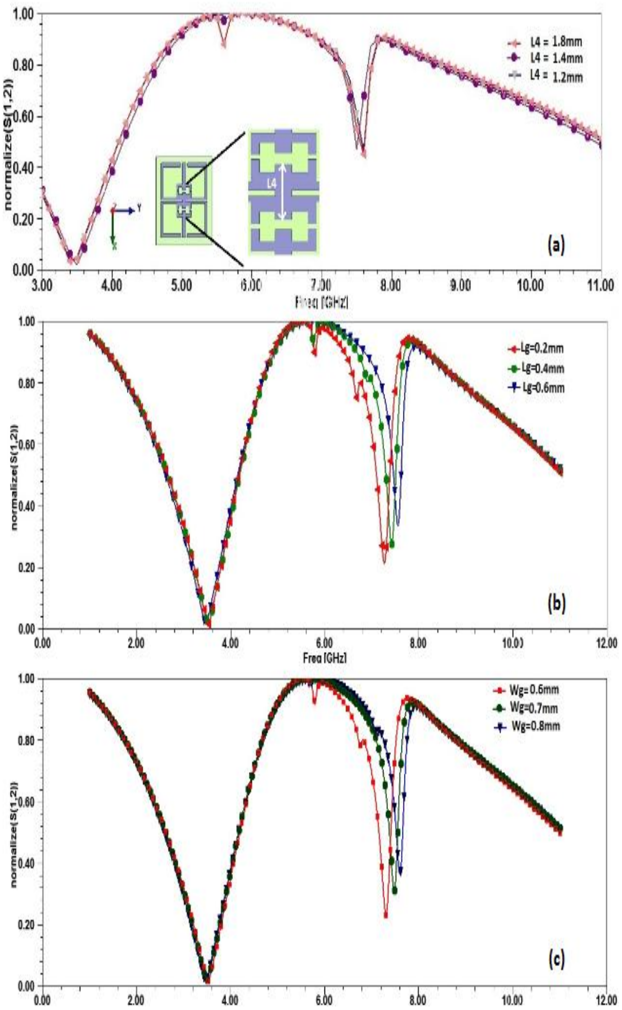


**Fig.5. Absorptivity variations with respect to (A) (L4) Gap variations between the rectangles, (B) (Lg) Gap between the Lengths of the rectangles and (C) (Wg) Gap between the widths of the rectangles**

Fig. 5A shows the absorption characteristics, for the gap variations L4 = 6.8 mm, 7mm and 7.2mm. As we vary the gap, there is not much change in the peak absorption characteristics, but bandwidth starts to increase as the gap starts to decrease. Fig. 5B shows the various absorption characteristics when the gap (Lg) between the lengths of the rectangle is varied. Similar characteristics are observed as that of the L4 variations. As the gap (Lg) varies from 0.2mm, 0.4mm, 0.6mm the bandwidth starts to increase however the peak absorption characteristics remain the same. Fig. 5C shows the absorption characteristics when the gap (Wg) between the widths of the rectangles is varied. The Wg variations are increased from 0.6mm, 0.7mm, 0.8mm. As the gap (Wg) is increased there is not much change in the peak absorption but bandwidth starts to increase. From the parametric study, for the gap variations of the parameters L4, Wg and Lg, the peak absorption characteristics remains unchanged but the bandwidth increases in the UWB.

## V. FIELD (E & H) DISTRIBUTIONS AND SURFACE CURRENT DISTRIBUTIONS

The absorption mechanisms are studied through the Magnetic field, Electric field and Surface current distributions for the proposed absorber. From Fig. 6A, it is understood that the concentration of the surface currents are concentrated more at the edges of the E shaped split rings. These surface currents at the edges create strong resonance in the metamaterial surface.

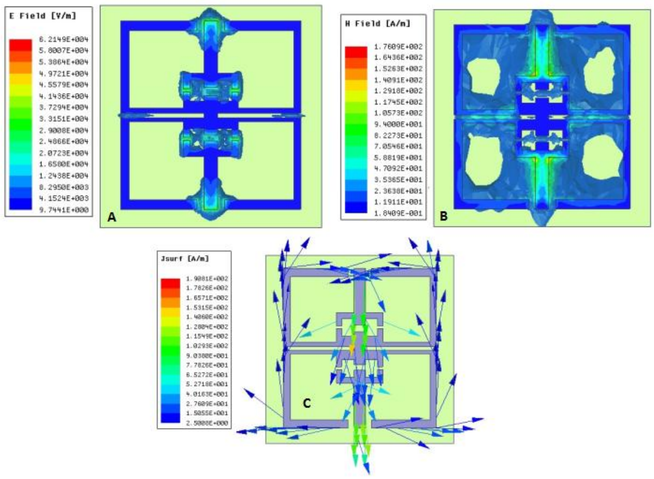


**Fig.6. (A) E Field distributions, (B) H Field distributions and (C) Surface current distributions**

## VI. POLARISATION INSENSITIVITY

To study the polarization insensitivity behavior, the absorber is analyzed through various angles of the incident wave. Fig. 7 shows the simulated absorptivity responses for different polarization angles. From the figure, for the various incident angles ϴ = $0^0$, $30^0$, $45^0$, $90^0$ there is not much variation in the absorptivity curves. This confirms that the absorber remains polarization insensitive throughout the various angles of incident wave unlike the previous works [14-15]. The symmetrical nature of the E-shaped metamaterial absorber may also be the reason for polarization insensitivity nature of the absorber. Therefore, the absorber is good candidate for UWB applications.

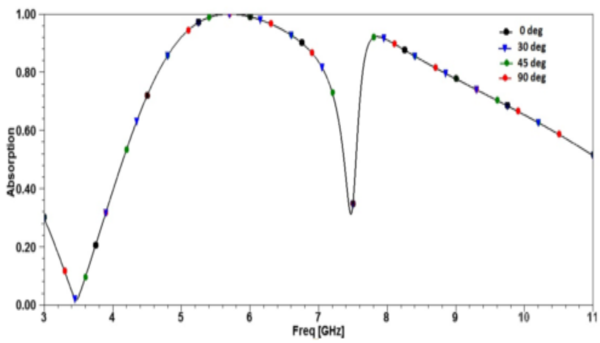


**Fig.7. Absorptivity performances for various angles of polarization**

## VII. CONCLUSION

An Ultra-wide band E-shaped metamaterial absorber of thickness 1.6mm with respect to FR4 substrate has been proposed. The proposed absorber shows dual band characteristics, with one band of frequency from 4.3GHz to 7.3GHz having peak absorption of about 99% at 5.8GHz and another band of frequency from 7.6GHz to 8.6GHz having peak absorption of 92% at 7.8GHz. The E field distribution and H field distribution curves are plotted and the surface current distribution is also studied.

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The absorber proves to be a good candidate through its polarization insensitivity nature. The structure proves to be simple, compact and also shows dual band characteristics in the UWB frequency range.

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Mr. J. John Paul, received his B.E degree in Electronics and Communication Engineering from Anna University, Master degree in Power Electronics and Drives from PSG college of Technology and he is pursuing his PhD in Karunya University. His area of interest includes Energy harvesting, Internet of things, Metamaterial absorbers and Sensor technology. He has a rich teaching experience of 10 years in prestigious Engineering Colleges. Currently, he is working as an Assistant Professor in the Department of ECE, Karunya Institute Technology and Sciences. To his credit, he has published several research papers in reputed national, International journals and conferences. He is also a life member of Institute of Engineers (IE). He has also organized many National level workshops, Symposiums and attended Faculty Development Programs, Seminars, Workshop and Conferences.

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