A CPW-Fed Elliptically Curved Antenna Design for Multiband Operation with Metamaterial Loading

M Purna Kishore, B T P Madhav, M Venkateswara Rao

Abstract*: In this article, a multi elliptical structured antenna is designed in which its ground plane is etched with different radius of elliptical SRR. The antenna size is 44×40×1.6mm^3, the substrate used is FR-4 substrate which is having a dielectric constant of 4.4. The proposed antenna approach is determined using four iterations achieve the maximum radiation performance. The antenna is working under 1.96GHz -3.74GHz, 3.95GHz – 7.48GHz, 8.42GHz – 11.47GHz and 13.41GHz – 18.93GHz bands, the antenna can work for the WLAN, Wi-Fi & Wi-MAX applications. The design and analysis of the proposed radiating structure is carried out using ANSYS EM desktop and metamaterial unitcell setup validation is carried out is an added advantage to the proposed antenna

***Index Terms*: CPW, metamaterial loading, elliptical split ring, unit cell.**

I. INTRODUCTION

The wireless communication technology has been emerging since past and expanded providing numerous technologies that may have variation in their applied techniques. The wave propagation among the antenna systems in the wireless medium is an important aspect for an efficient communication system. Efficient antennas that support the multi-standard communication technologies are beneficial and there are many techniques to develop such antennas which is available in literature. The parallel study of substrates and the electrodynamics [1] helps to enrich the metamaterial technology which supports further development in the antenna design to yield desired improvements. Usually the multiband operation in the planar antennas are achieved by the perturbation of currents through the surrounding the etched slots. In [2], a CPW fed quasi-yagi antenna obtains the multiband operation by the odd-mode E-fields caused by the CPW-to-CPS transition. There are some effects occurred due to the metamaterial-H-shaped loading within the antenna structure which can be interpreted in [3] causing the beam tilting and a reactive metamaterial loaded in the monopole antenna yields multiband phenomenon in [4,18] by shifting of resonant frequency towards low end. Metamaterials are spreading their applications in bolometers, thermal imaging by developing the absorber to detect the polarization of wave as demonstrated in [5]. These structures impart miniaturization when used as rectangular CSRR in [6] in combination with L and T-shaped slot and multiband characteristics, and can provide notch bands to the antennas by SRR resonators within a circular ring monopole as in [7]. Other techniques to enhance the obtained bandwidth are mentioned in [8] by using the trident shaped structure, tapered ground with EBG structure in [9], implementing asymmetric DGS in [11]. Few designs with liquid crystal polymer material are reported in [10,25]. The notch band characteristics within the wideband response of the antenna techniques are discussed in [12-14, 16], with the array configuration in [19] by sequential rotation concept. Few designs are reported with different defected ground structures and feeding methods such as coplanar feeding for achieving the multiband and broadband are discussed in [20-24].

In this article the metamaterial loaded elliptical antenna is studied and analyzed to get multiband characteristics. SRR slots are etched in the CPW ground plane in three levels. The design approach is explained in Section-II with unit-cell analysis, which is continued with results discussed in Section-III with the field distributions. The parametric effects discussed in Section-IV and finally concluded in Section-V.

II. ANTENNA DESIGN

A. UNIT-CELL ANALYSIS

The metamaterial unit cell analysis is carried using the Floquet mode of analysis. In This setup includes that at the slit side is generated with the perfect electric conductive material and those edges are connected with the waveguide port assignment. Other two sides of the box are connected to the magnetic fields of the antenna.

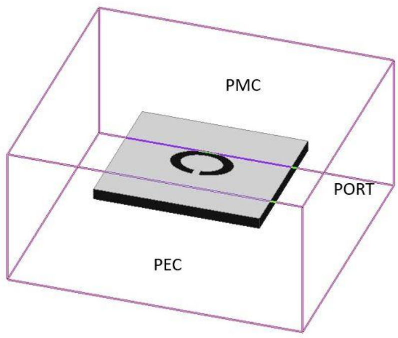

Fig 1: Elliptical unit-cell

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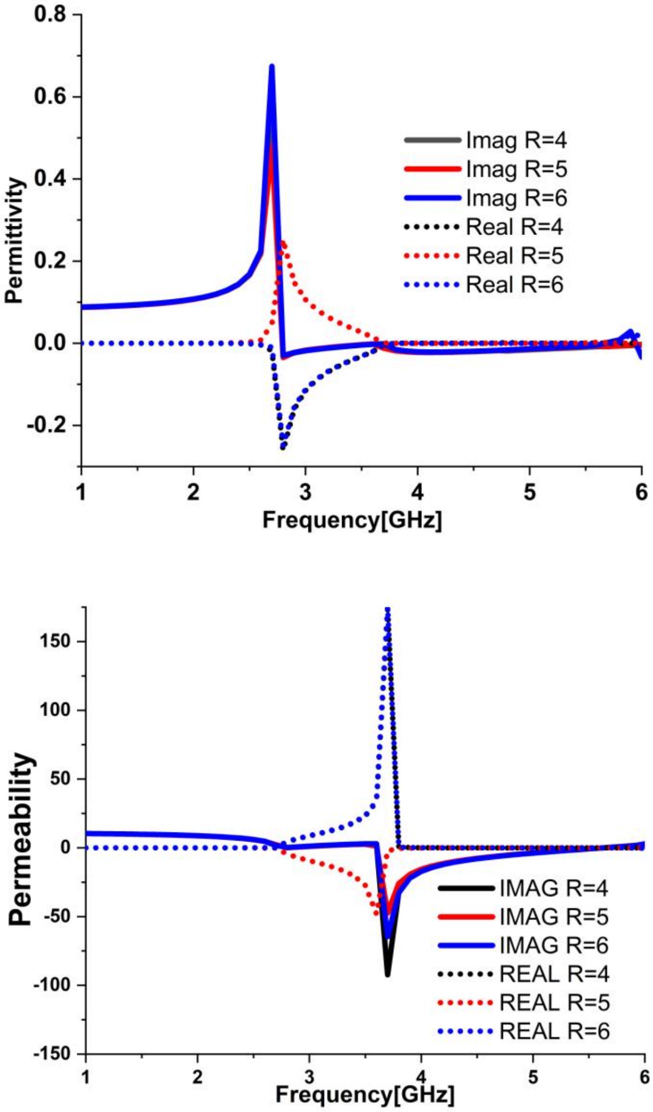
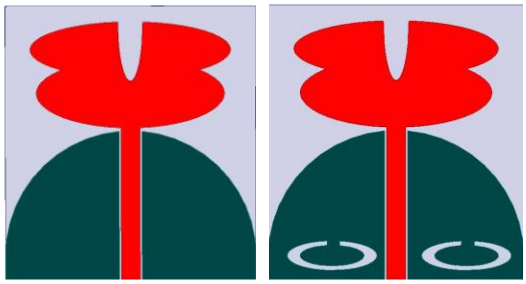


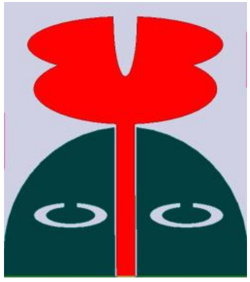
Fig 2. permittivity and permeability vs frequency response of the proposed elliptical unitcell with by varying its radius

B. ANTENNA DESIGN APPROACH

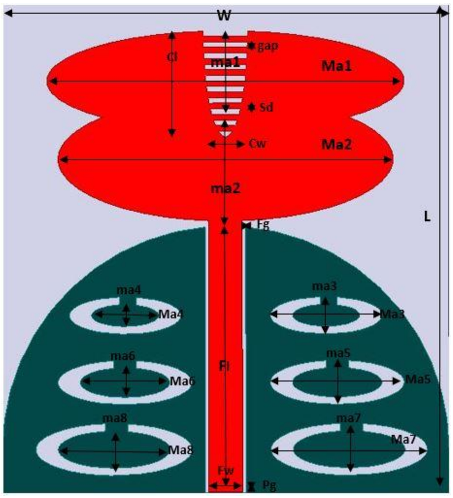
The proposed work consists of an antenna which is in the form of replicative ellipse structures. To achieve the final antenna, the basic antenna was iterated which is in the form of a carnivorous plant with a cut and without the teeth structure with a large elliptical ground. In the second iteration the antenna undergoes etching by an elliptical ring inside the elliptical ground at the bottom of the patch. In the third iteration the antenna undergoes same etching process, but the elliptical ring is removed in the middle of the elliptical ground. In the final iteration the antenna has six elliptical rings etched on the elliptical ground of the patch, three on one side and other three on other side of the feed along with the teeth structure placed in between the cut that was made on the top of the middle patch. So, the final antenna is achieved after four iterations of the basic antenna model designed. The antenna proposed is the final antenna where the required results are achieved. The antenna is fabricated using FR-4 substrate of height 1.6mm and having a dielectric constant of 4.4. The dimensions of antenna are 44×40x1.6mm^3.



(a) Iteration-1 (b) Iteration-2



(c) Iteration-3



(d) Proposed design

Fig 3. Design Iterations of the antenna

Table 1: Dimensions of proposed antenna (UNITS: in mm)

W	40	Cw	4
L	44	Ma1	32
FL	24.3	mA2	7.5
Fg	0.3	mA3	30
Pg	0.1	Ma4	10
Gap	0.5	Ma5	3.1
Sd	0.5	Ma6	6
CL	9.4	Ma7	14

The proposed antenna is constructed using the following equations.

The operating wavelength 'λ_0' of the proposed antenna is calculated as given in equation (1),

$$\lambda_0 = c / f_r \quad (1)$$

Where, 'c' is the velocity of light in free space
'f_r' is the resonant frequency.

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The thickness of the substrate (h_s) is given by:

$$h_S \leq \frac{0.3\times c}{2\pi f_r\sqrt{\varepsilon_r^{\,2}+1}} \qquad (2)$$

where, ε_r is relative dielectric constant.
The width of the strip (w_s) is given by:

$$w_S = \frac{C}{2f_r}\sqrt{\frac{2}{\sqrt{\varepsilon^2+1}}} \qquad (3)$$

The effective length (ΔL) due to effective dielectric constant is:

$$\Delta L = 0.412 h_S \left\{\frac{\varepsilon_r+0.3}{\varepsilon_r-0.258}\right\}\left\{\frac{\frac{w_S}{h_S}+0.264}{\frac{w_S}{h_S}+0.813}\right\} \qquad (4)$$

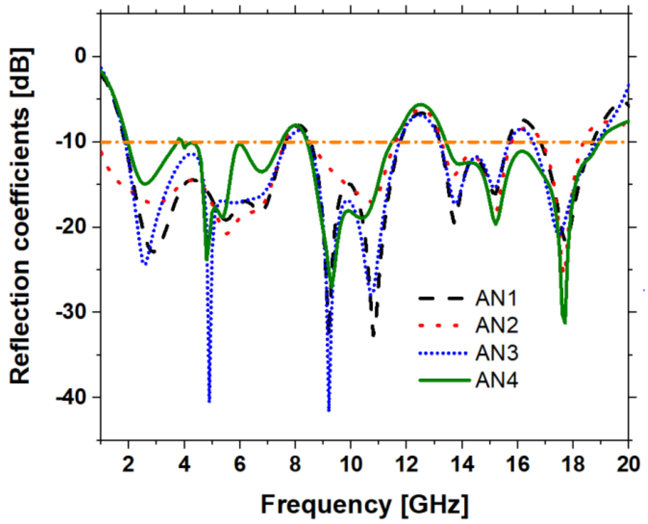
The length of the patch (L_d) is:

$$L_d = \left\{\frac{C}{2f_r\sqrt{\varepsilon_{reff}}}\right\} - 2\Delta L$$

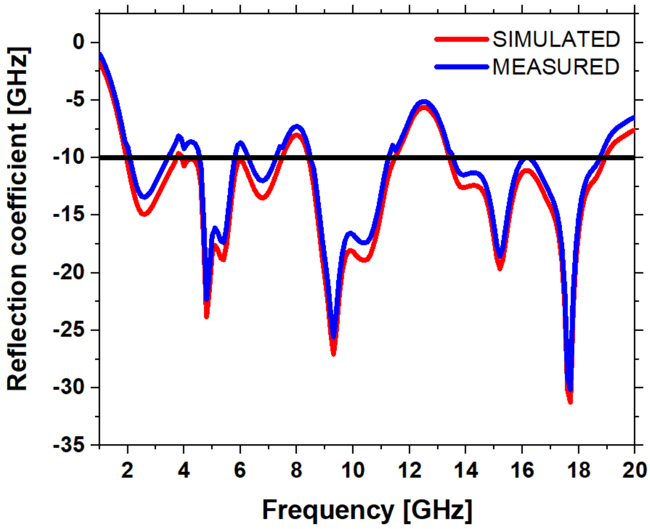
Fig 1(a) shows the basic antenna designed, where the antenna consists of a repetitive elliptical design, where the antenna works under the 1.86GHz – 7.63GHz, 8.56GHz – 11.76GHz, 13.21GHz – 15.65GHz, 16.82GHz -18.68GHz bands. Fig 1(b) shows the basic antenna designed, where the antenna consists of a repetitive elliptical design with an elliptical SRR ring at the bottom of the elliptical ground, where the antenna works under the 1.0GHz – 7.61GHz, 8.51GHz – 11.6GHz, 13.25GHz – 15.79GHz, 16.86GHz -18.35GHz bands. Fig 1(c) where the antenna consists of a repetitive elliptical design with an elliptical SRR ring at middle of the elliptical ground, where the antenna works under the 1.86GHz – 7.70GHz, 8.48GHz – 11.74GHz, 13.19GHz – 15.70GHz, 16.55GHz -18.84GHz bands. Fig 1(d) shows the fourth iteration where the antenna consists of a repetitive elliptical design with six elliptical SRR rings three on one side of the feed line and other three on other side of the feed line on the elliptical ground with teeth structure at the cut, where the antenna works under 1.96GHz -3.74GHz , 3.95GHz – 7.48GHz, 8.42GHz – 11.47GHz and 13.41 GHz – 18.93GHz bands. the graphical representation of the return loss values for all the iterations of the antenna is shown in the Fig 3.

III. RESULTS AND DISCUSSION

The proposed antenna is fabricated on the FR4 substrate and tested using Anritsu combinational analyzer. Return loss antenna describes how much energy is reflected and it describes about the antenna performance, does the antenna work or not with good efficiency. The S_{11} values are shown graphically in a given Fig 2 where the return loss of all the iterations are plotted.



(a)

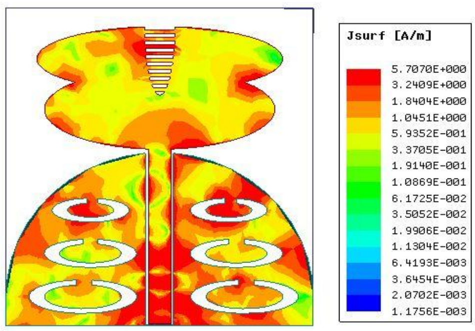


(b)

Fig 4 (a) reflection coefficient of iteration of the antenna (b) simulated and measured reflection coefficient of proposed antenna

CURRENT DISTRIBUTIONS

The current distributions of the proposed antenna are shown figure below at different frequencies at 2.8/4.8/9.3 GHz.



(a)

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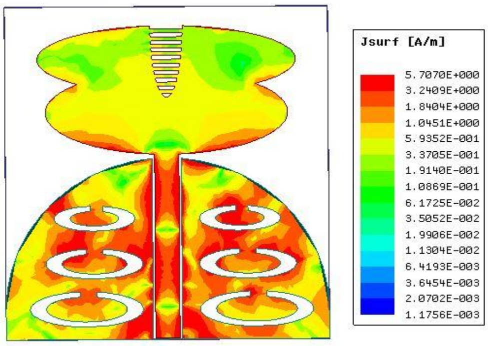
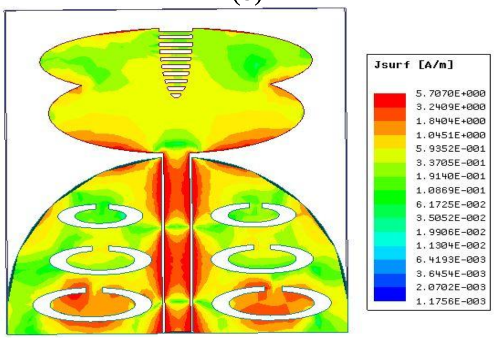
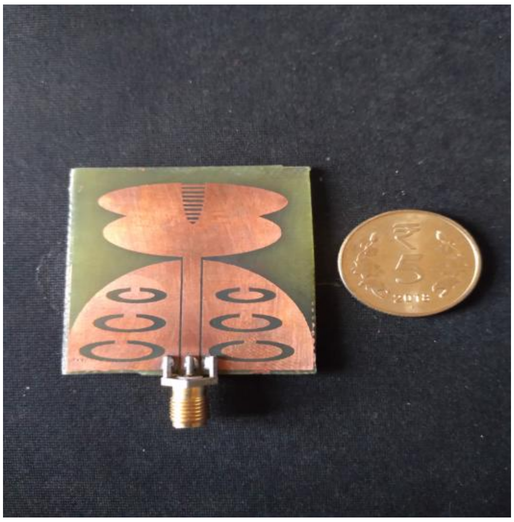


(b)



(c)

Fig 5 Current distributions of the proposed antenna at different frequencies (a) at 2.6GHz, (b) at 4.8GHz, (c) at 9.3GHz



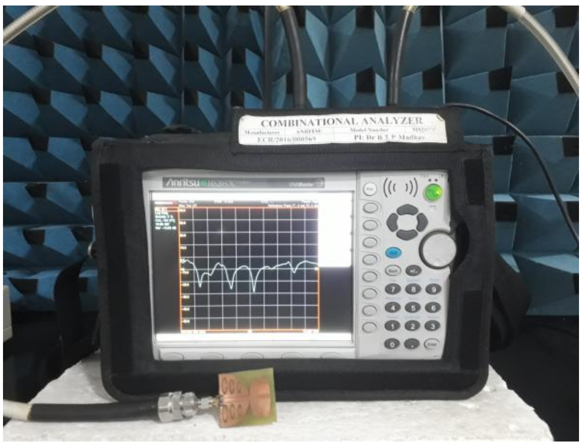
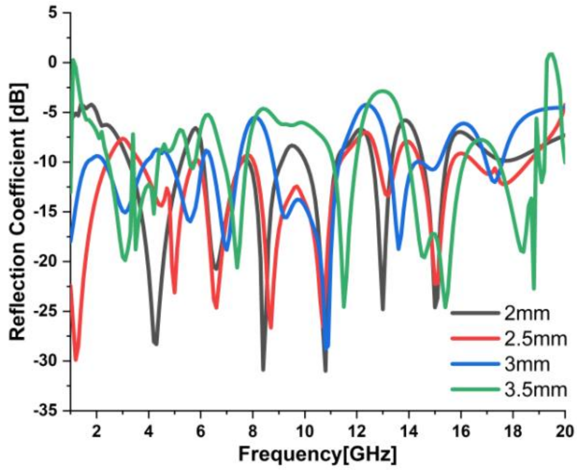
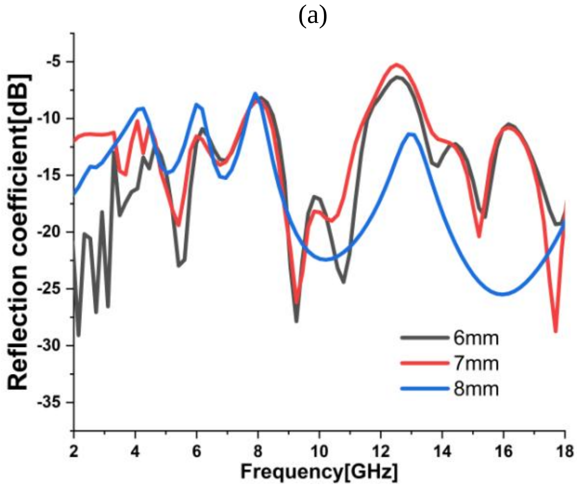


Fig 6 (a) prototype image and (b) measurement of proposed antenna

IV. PARAMETRIC ANALYSIS

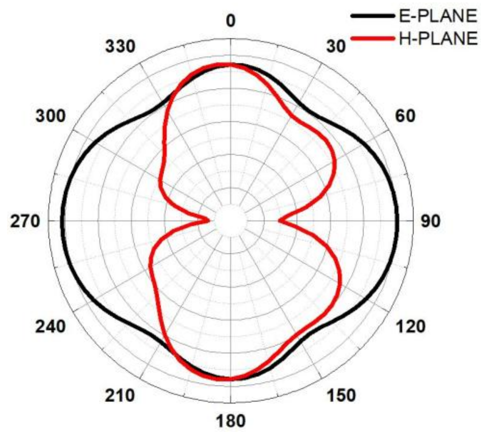


(a)



(b)

Fig 7 (a) parametric by varying width of the feed (b) parametric variance by changing radius of the ellipse



(a)

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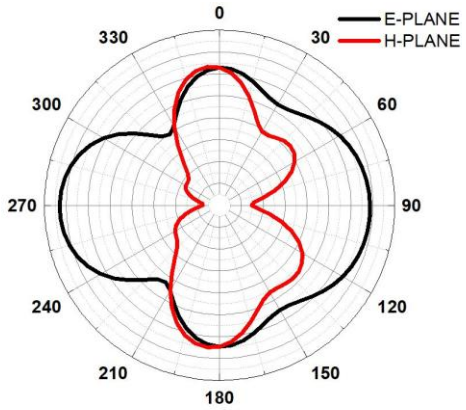
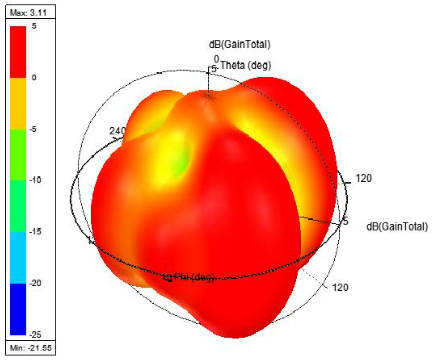


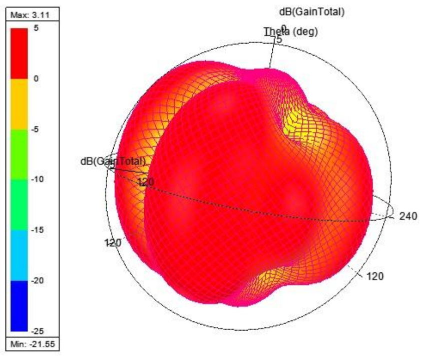
(b)

Fig 8 Radiation patterns (a) at 2.5 and (b) 4.8GHz

3D -POLAR PLOT



(a)



(b)

Fig 9 3D gain (a) at 2.5GHz and (b) 4.8GHz

Table 2 Comparison of Proposed antenna with other proposed antennas in literature

Ref. No.	Total Area (mm^2)	No. of Bands	Operating bands	Gain(dBi) at the operating bands	Metamaterial property
[6]	55x50	3	2.54/3.55/5.7	5.71/6.16/6.48	No
[7]	40x40	4	3.04/3.83/4.83/5.76	2.36/1.43/2.11/2.39	No
[8]	56x44	3	3.1/5.52/7.31/9.72	1.35/1.0/1.07/1.75	No
[9]	40x50	2	3.5/5.2	2.84/0.16	No
Proposed Antenna	44x40	6	2.5/2.7/3.5/3.8/4.3/5.6	2.5/3.4/3.2/3.5/4	Yes

V. CONCLUSION

The proposed elliptical patch antenna which is loaded with the metamaterial. behaves in multiband applications works in almost modern commercial wireless applications. The antenna is fabricated and etched on the FR4 substrate and antenna measurements have been carried out to find the variance between the simulated and measured. The dimensions of the antenna are optimized and prototyped antenna is tested on Aniritsu combinational analyzer for validation and the obtained measurement results are providing good matching with respect to the simulation results

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