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Research paper

Metamaterial inspire multiband monopole antenna with defected ground structure

B T P Madhav*, K Thirumalarao, M Venkateswara Rao, V N V Saiteja, J Kranthi Kumar, P N V S Reavanth

Department of ECE, Koneru Lakshmaiah Education Foundation, Andhra Pradesh, India-522502
**Corresponding author E-mail: btpmadhav@kluniversity.in*

Abstract

This article represents the design and analysis of a compact antenna of size 34mmX18mmX1.6mm on FR-4 substrate material. The designed antenna is having a slot at the partial ground for all iterations are observed and it is analysed with the help of ANSYS 17 Electronics Desktop. A new unit cell design which exhibits the metamaterial property is also analyzed with the help of unit cell analysis. The negative permittivity value is extracted, and that unit cell is implemented in the proposed antenna. The enhanced results have been carried out with comparing iteration wise. The proposed antenna has radiation efficiency of 94%, it works in the range of for LTE (33-37) band at 1.95-2.04 GHz, WiMAX band 2.87-3.76 GHz and LTE (43-44) bands 5.92-7.2 GHz.

Keywords: *Band Notch Antenna, Defected Ground (DGS), WiMAX, Unit cell.*

1. Introduction

Now a day's metamaterials engineered to show various properties which does not exhibit in nature. their varying structures plays a vital role in the electromagnetic environment. Silva et.al proposed an antenna where resonating arrays of microstrip patch antenna loaded with the splitting resonator. the change in the electromagnetic behaviour due to split ring resonator have been observed in the [1]. A pair of splitting resonators loaded on the sides of the feed has been observed in [2] later another pair of the antenna added, and a multiband behaviour of the antenna is observed. Raghavan et.al [3] proposed an antenna which is loaded with split ring resonator for WLAN and WiMAX applications. A measurement of dielectric constant is carried out by Jackson in [4]. Kumar et.al proposed a dual band antenna which of a circular split ring resonator type of a patch covering the bands if WIFI and WiMAX and Bluetooth applications in [5]. In [6] jawed et.al proposed a notch UWB antenna with the help of split ring resonator which are placed on the backside of the antenna. With the multiple split ring resonator on the backside it gives multiple resonance. A reconfigurable loaded split ring resonator CPW antenna have been seen in [7]. A compact multiple notch band antenna which are loaded with the stepped impedance resonators and split ring resonators are observed in [8] Zheng proposed antenna works in the multiband areas. Planar monopole antenna which covers the bands of WiMAX and Bluetooth have been observed in the [9] proposed antenna. In [10] Yadav et.al proposed antenna which is having a triple notch bands in the ultra-wideband range. The proposed antenna is analysed according to the S shaped slot in the feed and CSRR on the patch and mirror split ring resonators at the either ends of the feed. Due to this a triple notch band is occurred at the circular patch antenna.it is observed that measured and simulated results are correlated with each other. In Yang [11] proposed a filtenna with the help of split ring resonator and complimentary split ring resonator. He clearly differentiates the difference in the split and complementary split ring resonators for this proposed model the lower cut off frequency is said to be at 3. 7GHz.A band notched ultra-wide band printed monopole antenna have been designed and analysed through the HFSS is observed in [12]. Madhav et al proposed multiple antenna models with defected ground and metamaterial concept [13-21].

In this article a compact antenna is designed with unit cell which is placed on the proposed model to enhances the performance of the antenna. The proposed antenna works at the bands LTE 33-37, WIMAX, LTE 43-47. The proposed antenna designed and analysed using commercially equipped tool ANSYS electronic desktop 17. Results of the proposed antenna with iterations have been exhibited. The result analysis of the antenna has been discussed in subsequent sections

2. Antenna design

2.1 Unit cell analysis

The approach for design of split ring resonator have been introduced in the below design. The splits in the ring produces wavelength much larger than the normal rectangle. The second split ring resonator which is oriented towards the first rectangular resonator produces the large capacitance. It is because of the gap between the rectangular split ring resonators.

The unit cell analysis is carried by applying the perfect electric conductor on the split side and magnetic conductor as towards the top side of the box. A wave guide port is assigned to remaining ends of the unit cell. The following equation number 3 states the relation between effective dielectric constant and resonant frequency where L_{eff} effective length of the microstrip line. F_{SRR} is the resonant frequency of the split ring resonator and L_{SRR} is the total inductance of the ring as shown in Equation 1. The formula for capacitance of split ring resonator is also explained. Through this analysis fig:2 clearly shows the negative permittivity has been obtained.

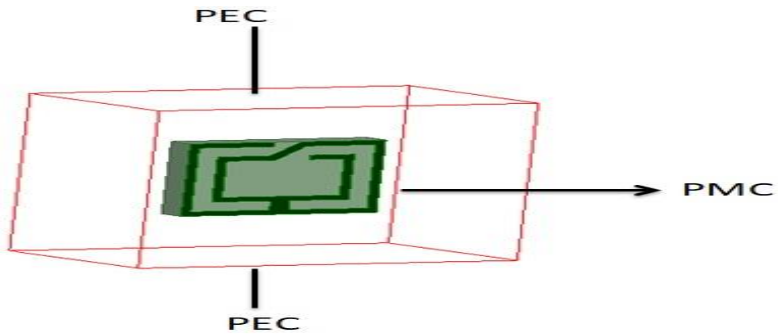


Fig. 1: unit cell analysis view

$$F_{SRR} = \frac{1}{\pi\sqrt{L_{SRR} \times C_{SRR}}} \quad (1)$$

$$C_{SRR} = P \times C_{PUL} \quad (2)$$

$$f_R = \frac{C}{\sqrt{\epsilon_{eff}}} \frac{1}{\sqrt{L_{eff}}} \quad (3)$$

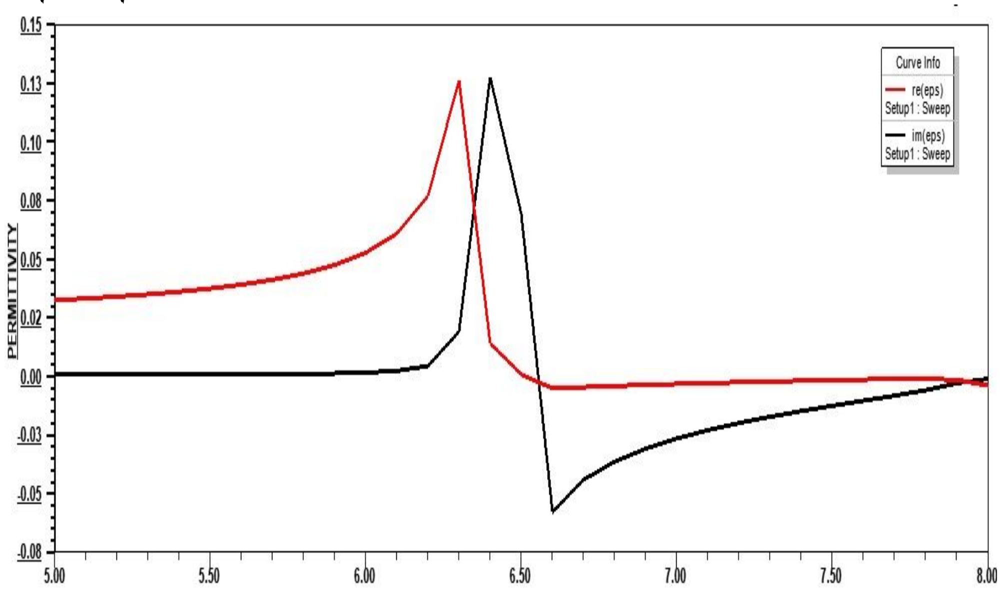
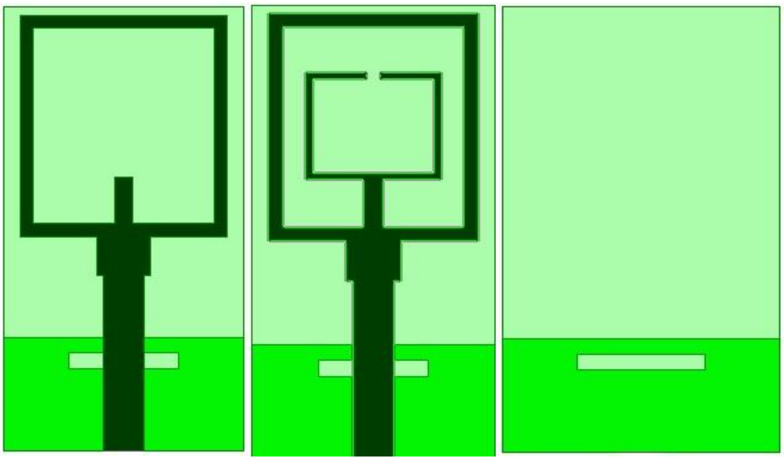


Fig. 2: permittivity vs frequency of the unit cell

2.2 Antenna design and analysis

A Compact antenna is designed of length 34mm and width 18mm on FR4 material having dielectric constant of 4.4 with thickness of 1.6mm is analysed using ANSYS ELECTRONIC DESKTOP 17. The partial ground of an antenna is cut with a slot which gives the notch characteristics. A microstrip feed of 50-ohm characteristic impedances is connected through a SMA connector. Proposed model has been extracted from 3 iterations. Model 1 explains a simple design. Model 2 consists of a split ring resonator which is connected to the split ring resonator A new approach of metamaterial split ring design is taken on the opposite side of the feed to extract the metamaterial properties. This approach gives good measurements than other two iterations. The proposed antenna dimensions and measurement table with iterations have seen in the below diagram Fig 3. shows the iterations of the antenna and Fig 4. shows the proposed antenna with parameters the dimensions of the proposed antenna has been shown in table 1



(a) (b) (c)

Fig. 3: (a) and (b) model 1 and model 2 front view (c) common flip view of all models

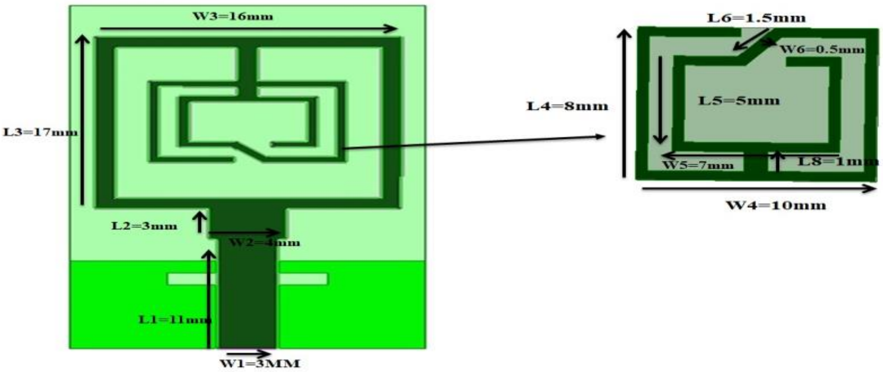


Fig. 4: Proposed Antenna

Table 1: Dimensions of the proposed antenna

Ls	34mm	W6	0.5mm
Ws	18mm	L7	3.4mm
L1	11mm	W7	1mm
W1	3mm	w5	7mm
L2	3mm	H	1.6mm
W2	4mm	a	1mm
l3	17mm	G1	1.75mm
W3	16mm	Lg	8.5mm
L4	8mm	Wg	18mm
W4	10mm	Ws1	8.2mm
L5	5mm	Ls1	1.2mm
L6	1.5mm	L8	1mm

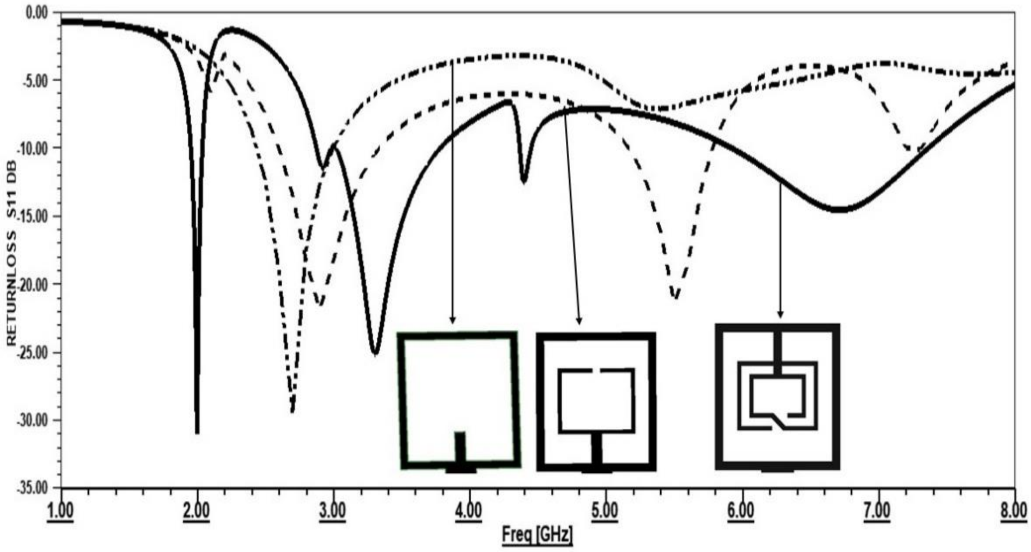
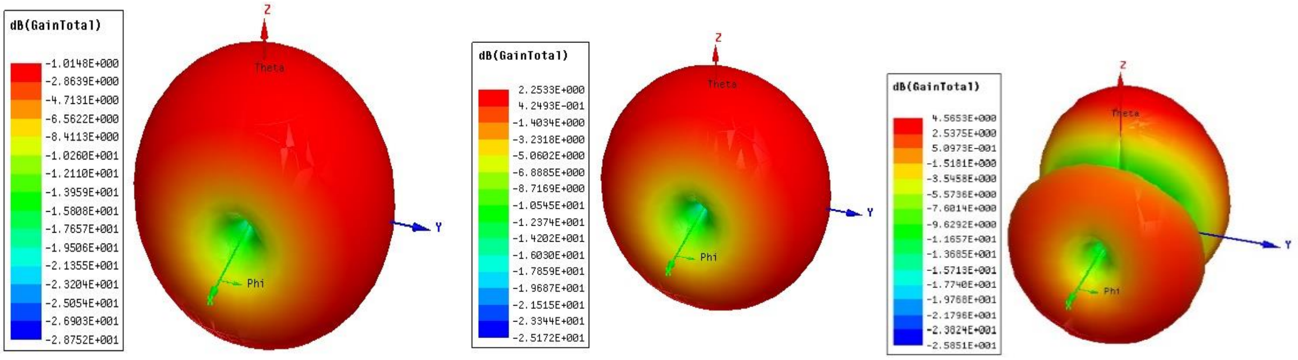
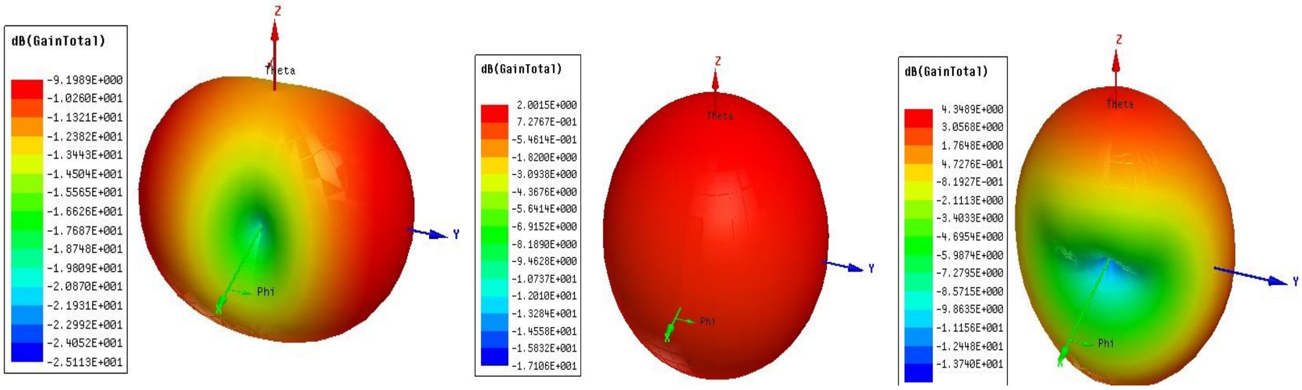


Fig. 5: Return loss of all antennas

Fig 3 shows the return loss characteristics of the three antennas. Model 1 shows the return loss at 2.44 to 3 GHz with a maximum return loss of -30db.Where as the model 2 shows the dual band characteristics at 2.6 to 3.3 GHz and 5.1 to 5.8GHz with maximum return loss of -25db.A new metamaterial design approach has been taken for the proposed model it shows the graph varied at the multiple bands with considerable return loss having a maximum at 2GHz of 30db.proposed antenna works in LTE bands and WiMAX.



(a)2 GHz (b) 3.3 GHz (c) 6 GHz



(d) 2.2 GHz (e) 4.3 GHZ (f) 5.4 GHz

Fig. 6: Gain at working bands (a)2GHz (b)3.3GHz (c)6GHz, notch bands (d)2.2GHz (e)4.3GHz (f)5.4GHz

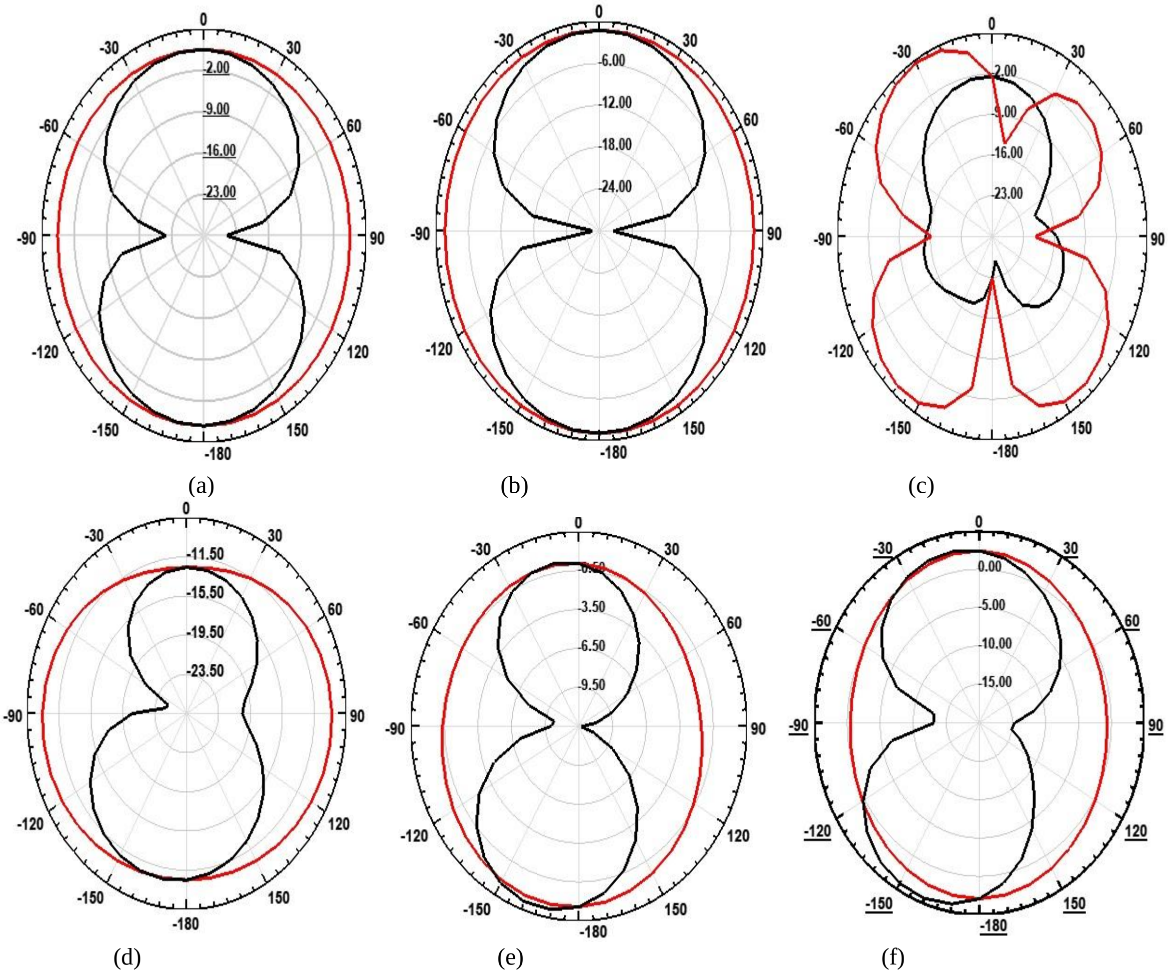


Fig. 7: Radiation patterns at working bands (a)2GHz (b)3.3GHz (c) 6GHz, notch bands (d) 2.2 GHz, (e)4.3 GHz, (f) 5.4 GHz

The fig 6 and 7 shows the gain and radiation patterns at both the working band and notch band. At working band, the gain is almost maintained stable at 3 dB whereas at notch band the gain depicts to -9db and for another bands also the gain is negative. The radiation patterns indicate a omni directional patterns on the H-plane and dipole type of patterns in the E-plane at the working bands. A variation is observed in the radiation patterns at the notch bands when compared to the working band. Table 1 shows the iteration wise application and band range and maximum return loss of the antenna. For proposed antenna a maximum gain of 4.5db with average gain of 2.5db is noticed

Table 2: comparing working bands of iteration models and its applications with proposed model

Models	Max return loss	Bands	Applications
Model 1	-28db	2.44-2.80	WLAN
Model 2	-25db	2.60-3.3, 5.17-5.78	Upper WLAN
Proposed model	-30db	1.95-2.04, 2.87-3.76, 5.92-7.20	LTE33-37, Wi MAX, LTE 43-44

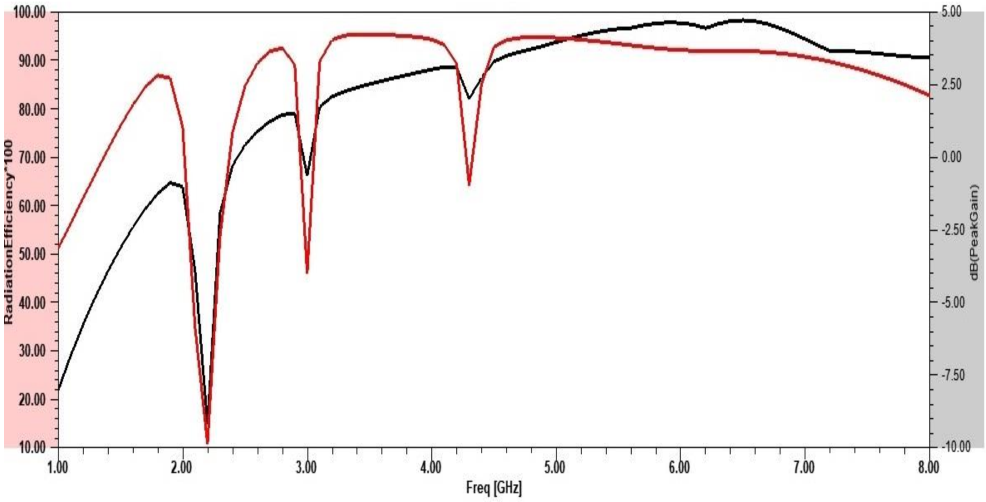


Fig. 8: Radiation efficiency/gain vs frequency of the proposed model

Fig 8 shows the radiation efficiency and gain with respect to frequency of the proposed antenna. Figure clearly indicates that at notch bands both radiation efficiency and the gain are less.at 2.2GHz the radiation efficiency is below 20percent and gain is -9db.The notch band characteristics of the antenna shows good rejection at those bands. Average of 3.5 dB gain is maintained throughout the band at the proposed antenna and an average of 94% radiation efficiency is observed in the graph

Fig 10 and Fig 11 shows parametric analysis of the proposed antenna. Fig 10 shows the width of the feedline. Figure shows the exact characteristics have been obtained at 4mm only. Fig 11 shows the parametric analysis of the slit gap.at 1mm the curve shows exact characteristics when compare to other values.i.e.,0.6mm and 0.8mm

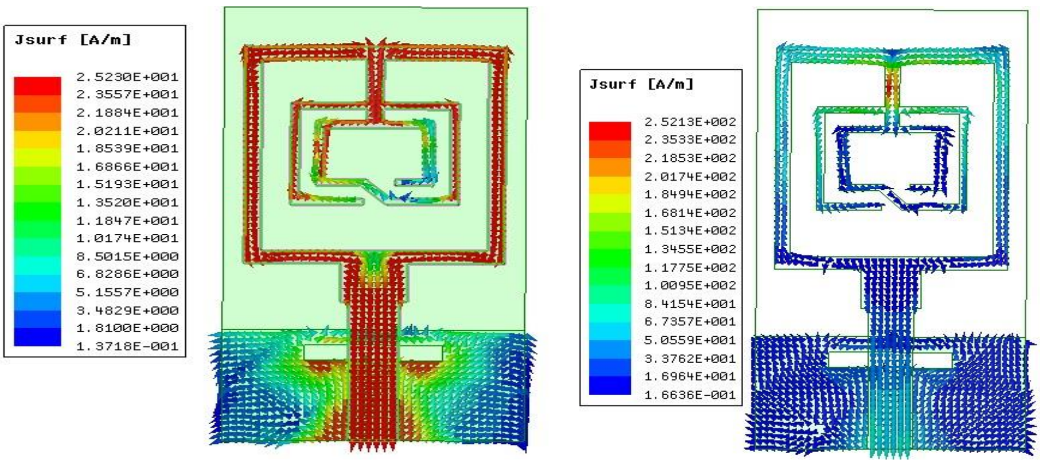


Fig. 9: Current distribution at working band (2 GHz) and at notch band (2.2 GHz) Parametric study

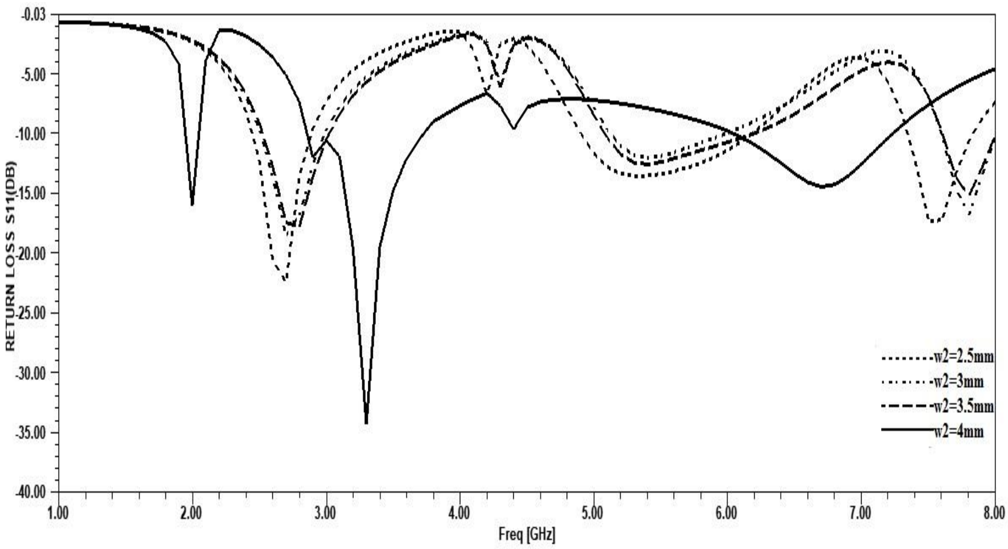


Fig. 10: width(w2) varying parametric analysis.

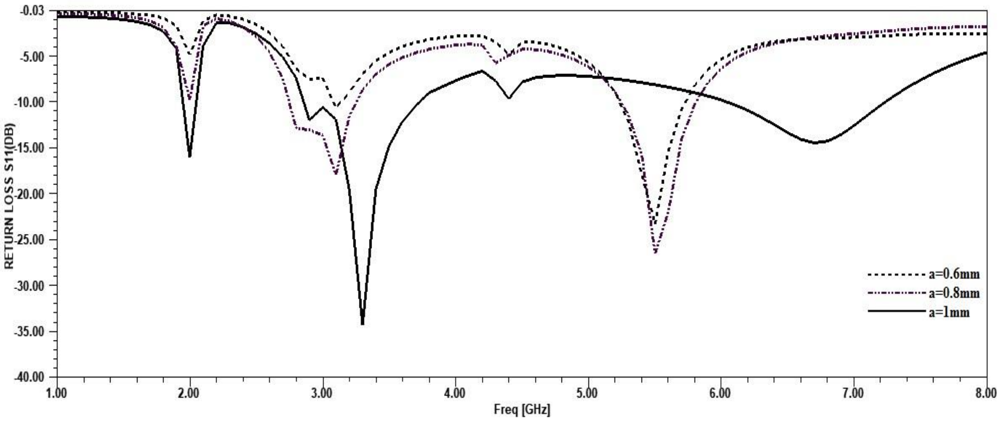


Fig. 11: Parametric analysis by varying Slit Gap of the proposed antenna

Table 3: comparison table of proposed work with other works

References	dimensions	Max Gain at notch bands	No of Notches	Ɛr	Metamaterial property
[12]	46x30	NA	1	6.15	No
[6]	50x50	-8	1	2.33	No
[7]	50x50	NA	1	2.2	No
[8]	47x52	-8	3	3	No
[9]	38.5x46.4	-8	2	2.65	no
Proposed model	34x18	-9	3	4.4	yes

3. Conclusion

This paper shows simple compact antenna loaded with new metamaterials design approach. By placing the metamaterials unit cell, triple notch characteristics are obtained and depth in the resonant frequency has been observed. The parameters like gain, radiation pattern and return loss are analysed and parametric analysis is presented for optimization of the antenna. Average of 3.5 dB gain is maintained throughout the band and an average of 94% radiation efficiency is observed from the current model.

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