Met material Loaded Rectangular Monopole Antenna with Ultra-Wideband Applications

M. Venkateswara Rao, B T P Madhav, T Naveen, N Sai Prashanth, B Niharika

Abstract*: A planar-rectangular monopole antenna with split ring resonators (SRR) is presented in this article. The objective of the proposed antenna is to obtain the frequency notch characteristic in the wide operating band. Frequency notch characteristics are attained by placing, split ring resonators and the defected ground structure (CSRR) on the top and bottom sides of the FR4 substrate respectively. The proposed antenna works in the band between 2.5-9.5GHz and 12.58-20GHz and remaining band is notched. This metamaterial loaded antenna and its analysis is carried out through unit-cell analysis and the characteristics such as permittivity and permeability have been plotted. The proposed antenna shows the characteristics of high gain, size reduction and high radiation efficiency.

Index Terms*: Rectangular SRR (Split-ring resonator), CSRR (Complementary Split-ring resonator), Rectangular Monopole Antenna (RMA).

I. INTRODUCTION

Now a days the design of the ultra-wideband antenna with and without specific notch band performance have seen a quick lift towards the modern-day communication systems. Such band notch characteristics can be obtained by alteration in radiating structures and by incorporating the defected ground structures which are available in the known literature. The design proposed in [1] exhibits the UWB frequency response over 3-12 GHz with the trident shaped radiating patch. The bandwidth of the elliptical and rectangular monopole antennas has been increased in [2] by using the ground plane in a tapered step configuration and placing the EBG structure in the antenna design which leads a stable antenna gain and efficiency.

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The tapered steps introduced at the bottom side of the antenna radiating structure in [3] played a key-role in enhancing the antenna bandwidth to work across UWB spectrum. A Bluetooth/WLAN-2.4/Zigbee compatible antenna with bow-tie shape designed on liquid crystal substrate is exhibits with omni directional radiation patterns which is discussed in [4].

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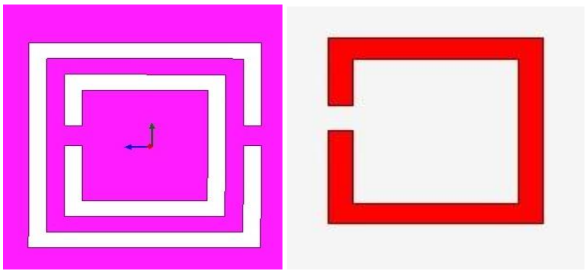
based antenna design is presented in [7] by incorporating a notch filter at 2.45GHz in the printed log-periodic dipole antenna design. The enhancement of the bandwidth for EBG structured Sierpinski fractal radiator proposed in [8] is achieved by the critical variation in the radius to period ration of the patterns of fractal design. A trapezoidal monopole antenna in [9] is modified to obtain the notch band in the S-band by etching U-slot in the radiating structure. Other techniques for band notched characteristics are presented in [12]. The effects due to the substrate permittivity changes are discussed in [13,14]. Antenna with dual feed mechanism to cater X-band applications with dual band operation in [15], broadband antenna with circularly polarized radiation in [16] and multiband antenna characteristics with slotted aperture configuration [17] and array elements based in Liquid crystal substrate are demonstrated in [18].

In this article a novel metamaterial loaded rectangular antenna having wide band characteristics and increased gain has been proposed. In respect to that the metamaterial behavior of the rectangular split-ring resonator and rectangular-structuredCSRR is also studied with respect to unit cell analysis.

II. ANTENNA DESIGN AND ANALYSIS

2.1 Unit Cell Analysis



(a) (b)

Fig. 1 Unit-cell structure (a) Rectangular CSRR (b) Split-ring resonator (SRR)

In enhancing the metamaterial characteristics, the SRR structures play the key role. In this design, SRR and CSRR structures are placed on the top and bottom sides of the substrates respectively. The magnetic field connected opposite to the plane that of the other planes contains the SRR units. The currents will flow on the ring structure of rectangular geometry of the SRR, and the dispersal of these currents gives that change of inverse sign accumulated over the holes. This structures a substantial conveyed capacitance, which thus brings about delivering very high positive and negative of effective permeability at the region of the magnetic plasma frequency in which SRR resonates. The configuration of SRR structure consists of two rectangular turn which is made of metal like copper, and can be treated as perfect electric material

The extracted parameters like permeability and permittivity of the circular SRR are simulated from the S_{11} and S_{21} parameters. Given below are the equation for determining the effective permittivity, permeability and the calculation of inductance, capacitance, and the resonant frequency of the SRR are also included.

$$n = \pm \frac{1}{kd} \frac{\cos^{-1}(1 - S_{11}^2 + S_{21}^2)}{2S_{21}} \quad (1)$$

$$z = \sqrt{\frac{(1+S_{11})^2 - S_{21}^2}{(1-S_{11})^2 - S_{21}^2}} \quad (2)$$

$$\in_{eff} = n/z \quad (3)$$

$$\mu_{eff} = nz \quad (4)$$

Where 'n' can be considered refractive index

$$c_t = \frac{1}{c_s + c_g + c_c} \quad (5)$$

$$L = \mu_0 r(\log(\frac{2r}{w}) + 0.9 + 0.2(\frac{w}{2r})^2) \quad (6)$$

$$W_0 = \frac{1}{\sqrt{(L_s + 4L_M)(C_s + C_c + C_G)}} \quad (7)$$

where

L_S = Self Inductance, L_M = Mutual Inductance, C_S = Surface Capacitance, C_c =Coupling Capacitance, C_G = Gap Capacitance.

For finding absorption loss in the numerical calculation transfer matrix method is utilized.

$$A = 1 - (S_{11}^2 - S_{21}^2) \quad (8)$$

From Fig. 3, we observe that CSRR has negative permeability occurs at the resonance frequency and negative permittivity is obtained with the Floquet mode setup

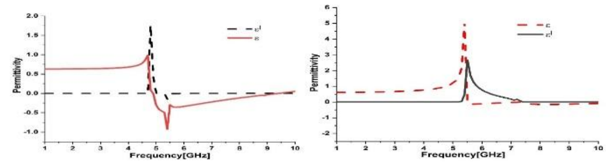


Fig. 2 Relative Permittivity versus frequency of SRR and CSRR

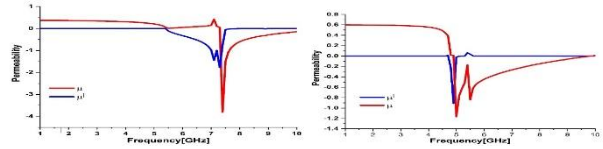
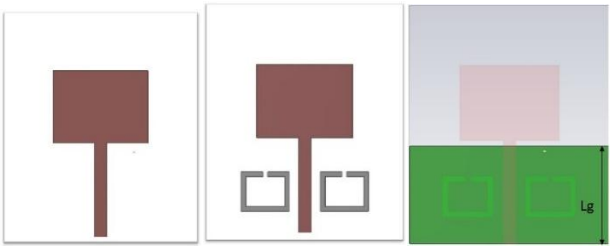


Fig. 3 Permeability versus frequency of SRR and CSRR

2.2 ANTENNA DESIGN

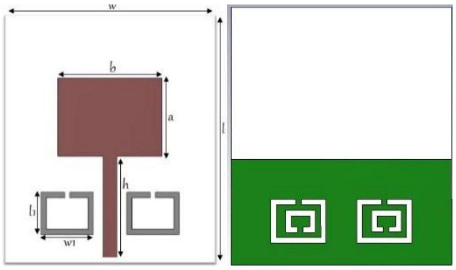
Iteration 1 consists of the monopole antenna which is shown in the below Fig. 1. Iteration-2 consists of monopole antenna along with the partial ground are placed on the geometry of the antenna which is illustrated in the Fig. 2. In iteration 3 rectangular SRR'S are placed in the front side as shown the Fig.3. Fig.4 illustrates about the Iteration-4 which consists of the rectangular SRR'S along with the partial ground. The rectangular monopole is having dimensions of 48x40mm^2 and the dimensions of the defected ground plane is 19.3mm. The suggested SRR and CSRR based antenna model holds the dimensions of 47x40mm^2 on FR4 substrate with thickness of 0.6mm. The slotted gap for the SRR is 0.5mm. Rectangular CSRR is introduced in the partial ground plane of the antenna. The rectangular monopole antenna is analyzed and after that a pair of rectangular SRR is added to the either sides of the feedline and in the third iteration, ground is slotted with the CSRR is observed as shown in figure. The resonance frequency can be determined with the equivalent circuit model by considering complete inductance and circulated capacitance between the conducting path of SRR. The resonance frequency of the rectangular SRR is



(a) (b)

Fig. 4 Rectangular monopole SRR Antenna models

(a) rectangular monopole, (b) rectangular monopole with SRR and CSRR



(a) (b)

Fig. 5 Rectangular monopole with SRR and CSRR , (a) SRR on top , (b) CSRR on bottom

$$f_0 = 1/2\pi\sqrt{1/L_T C_{eq}} \quad (9)$$

In Eq (9), the total equivalent capacitance is denoted by'C_{eq}'which is due to the distributive capacitance existing between the rings of SRR structure whereas the total inductance is denoted by 'L_T'.

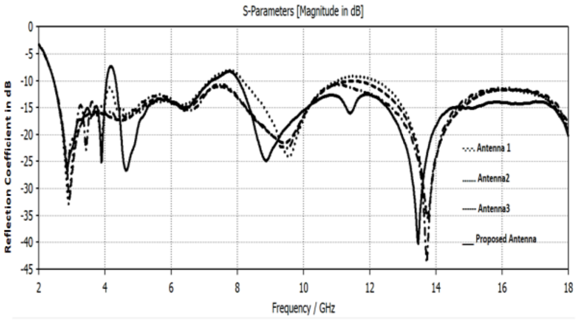
The design parameters with dimension values of the antenna are presented in Table 1.

Table 1 Antenna dimensions in mm

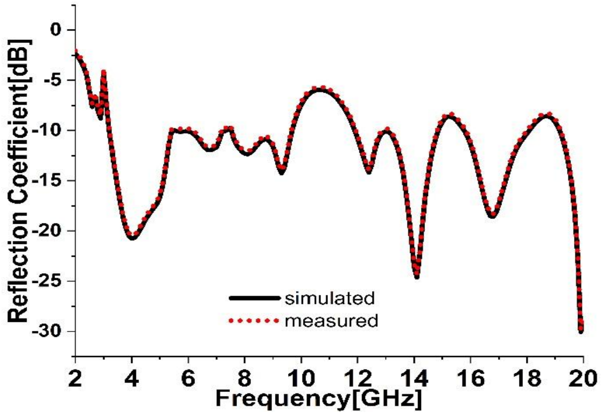
Parameter	h	l	w	l1	w1	l2	w2	lg
Dimension	20.3	47	40	8	10	6	9	19.3

III. RESULTS & DISCUSSION

The proposed antenna is discussed in 4 different iteration. Where proposed antenna simulated and measured results have benn shown in Fig (6) .The antenna alomost works in the wideband band characterstics and with a average gain of 3.8GHz.it is also suitable for the high gain applications.

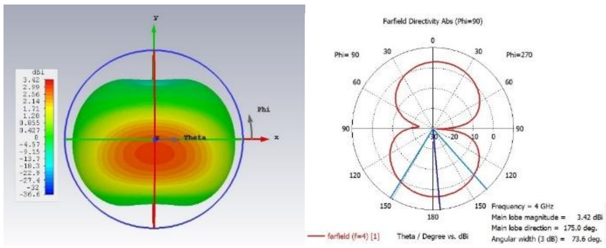


(a)

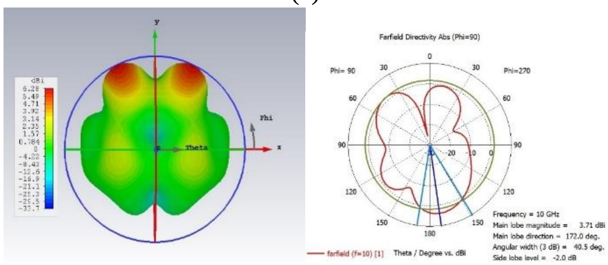


(b)

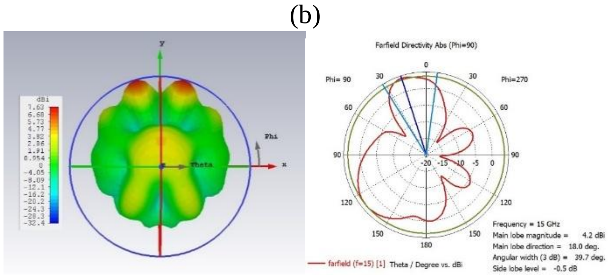
Fig. 6 (a) S_{11} (dB) of proposed antenna (b)Simulated and measured reflection coefficient of proposed antenna



(a)



(b)



(c)

Fig. 7 Radiation Pattern of the proposed antenna. a band at 5GHz, b at 10GHz , c at 15GHz

Fig. 7 shows the gain and radiation pattern of the proposed antenna at 3 different working resonant frequencies here we can conclude that due to the metamaterial behaviour the antenna gain is enhanced.In figure 8 the radiation efficieny and gain with respect to frequency is plotted as shown below

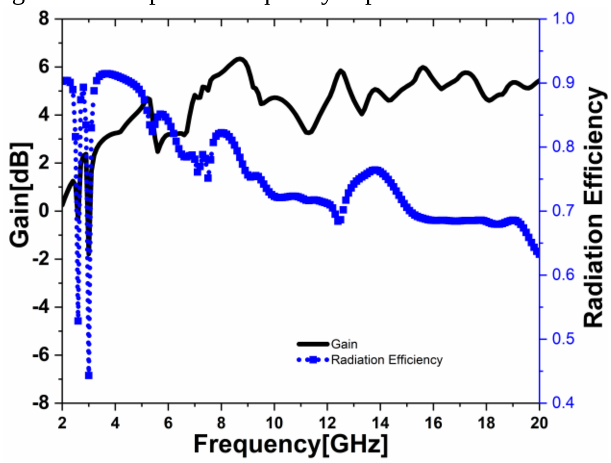


Fig. 8 Gain/Radiation Efficiency VS Frequency of the proposed antenna

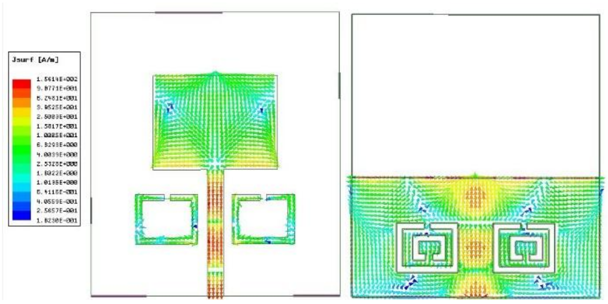


Fig.9 Surface current flow on the patch and ground of the proposed antenna at 4.1GHz

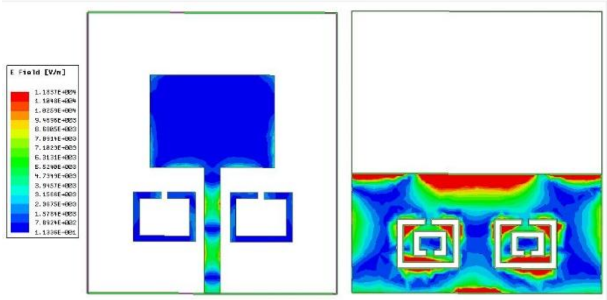


Fig.10 E-Field distribution of on the patch and ground of the proposed antenna at 4.1GHz

The current distribution and electric field distribution of the proposed antenna is seen in Fig. 9 and Fig. 10. The plots states that the intensity of the proposed antenna carries with the metamaterial inspired splitring resonators and complimentary splitring resonators.

PARAMETRIC ANALYSIS:

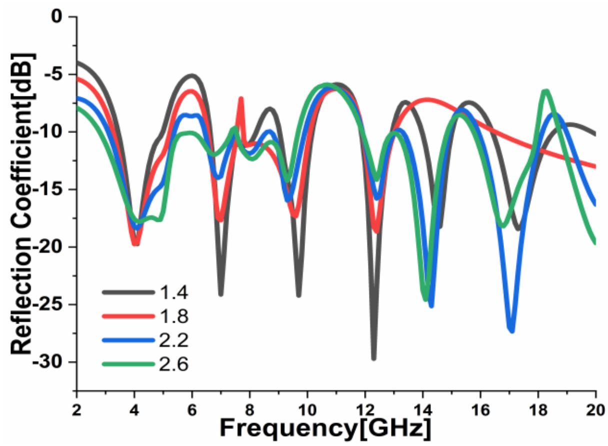


Fig.11 parametric analysis by varying width of the feed

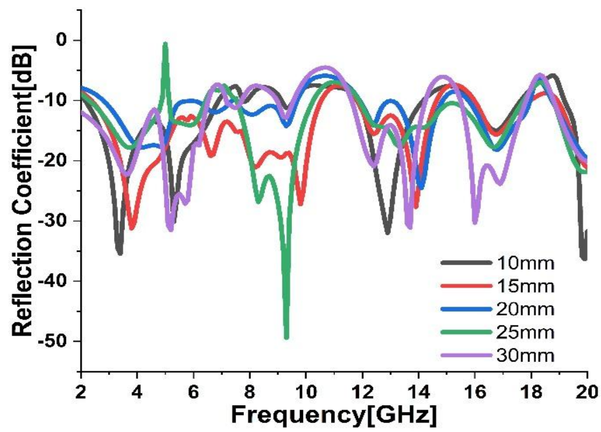


Fig.12 parametric analysis by varying width of the patch

IV. CONCLUSION

A rectangular monopole antenna which is loaded with a pair of SRRs on the front side of the substrate and a pair of complementary SRRs on the back side is proposed in this article. The proposed antenna works in a wide band, over a bandwidth of 16GHz and average gain of 3.8dB with efficiency of 79%. The proposed antenna is best suitable for the modern ultrawideband applications. With respect to the antenna analysis the metamaterial analysis of the antenna makes the proposed antenna a strong candidature for the ultra-wideband and high gain applications

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