A Compact Metamaterial Inspired Triple BandMonopole Antenna for Wireless Applications

Chetan.S[1]
Scholar, Asst. Professor
Dept. of E&CE, SJMIT
Chitradurga, India
chetansjmit@gmail.com

Dr.Chandrappa D. N[2]
Assoc. Professor
Dept.of E&CE, EPCET
Bengaluru, India
karanthc@gmail.com

Dr.Yogesh G S[3]
Professor and Head
Dept. of E&CE, EPCET
Bengaluru ,India
hodece.epcet@eastpoint.ac.in

***Abstract* —** This paper proposes and discusses a triple band printed monopole antenna loaded with metamaterial unit cells. The antenna proposed is planned to cover applications for Wi Fi/WLAN/Satellite. The structure is made of printed strip line and two rectangular split ring resonator unit cells of different sizes mounted on opposite sides of the patch. Each unit cell exhibit a negative permeability over the resonant frequency at 2.4GHz and 5.5GHz which produces magnetic coupling with the antenna. The proposed structure was fabricated and measured. The measured -10dB bandwidth for the reflection coefficient is from 2.32GHz - 2.47GHz, 5.1GHz to 5.7GHz and 7.1 to 7.7GHz which are suitable for Wi-Fi, WLAN and satellite band applications.

***Index Terms*—** *Metamaterials, Split Ring Resonator.*

I. INTRODUCTION

In the development of wireless communication systems, a multiband antenna has great importance to cover several applications such as WIFI, Bluetooth and WLAN/WiMAX bands. To meet the requirement of multi-band, a printed monopole antenna is an attractive candidate due to its low profile, easy fabrication, simple structure, low cost and omnidirectional radiation pattern. In order to achieve multiband operations, several techniques are used. Multibranched radiators [1], slotted monopoles [2, 3], meander monopoles [4] and fractal shapes[5] are few among them. Recently, an electromagnetic metamaterial is used to improve the antennas performances (gain, bandwidth and size reduction). Metamaterials are artificial materials that exhibit simultaneously negative values of electric permittivity and magnetic permeability over a frequency band[6], Due to the special physical properties that natural materials do not exist, nowadays, the metamaterials are very attractive materials and are applied in many areas of life, such as the microwave invisibility cloaks, the invisible submarines, the revolutionary electronics, the negative refractive-index lenses, the microwave components, as the filters, compact, and efficient antennas[7]. Applying metamaterials to design of antennas is one of its most important applications[8, 9]. Metamaterials have been implemented in the resonant antennas to achieve multi-band applications as well as to improve the radiation performances. Several works have been established on metamaterial loaded antennas [10, 11] making the metamaterial unit cell close to the radiating structure [11, 12]. The basic idea behind this approach is that the radiating element is sensitive to the presence of the resonator due to coupling. The presence of the resonating structure improves the antenna radiation characteristics and optimizes the geometric dimensions so that we can obtain an electrically small antenna operating at wireless communication frequencies. The main purpose of this paper is to use a split ring resonator metamaterial unit cell in order to design a multiband antenna. Two split ring resonator unit cells of different sizes are positioned near the patch to create two additional operating bands. The effect of introduction of the two unit cells is investigated and studied.

II. METAMATERIAL UNIT CELL

Fig. 1 shows a split ring resonator unit cell deposited on FR4 epoxy dielectric substrate. The other side of the dielectric material is free from metal. The dielectric material has relative permittivity of ε_r=4.4, dielectric loss tangent of $tan\delta$=0.0017 and a thickness of h=1mm. Geometrical parameters of the split ring resonator metamaterial is shown in Table 1 for 5.5GHz wireless application.

Table. 1 Dimension of SRR

Parameters	Value
Lsub	7mm
Wsub	7mm
L1	1.5mm
L2	5mm
g	1mm

The proposed unit cell is designed to get the resonance at 5.5GHz, WLAN application. The unit cell has been designed and simulated using ANSYS HFSS (High Frequency Structure Simulator) software. The unit cell simulation setup is presented in Fig. 2. The metamaterial unit cell is placed between two waveguide ports situated

on each side of y axis. A perfect electric conductor (PEC) and perfect magnetic conductor (PMC) boundary conditions are applied along perpendicular to x axis and z axis respectively.

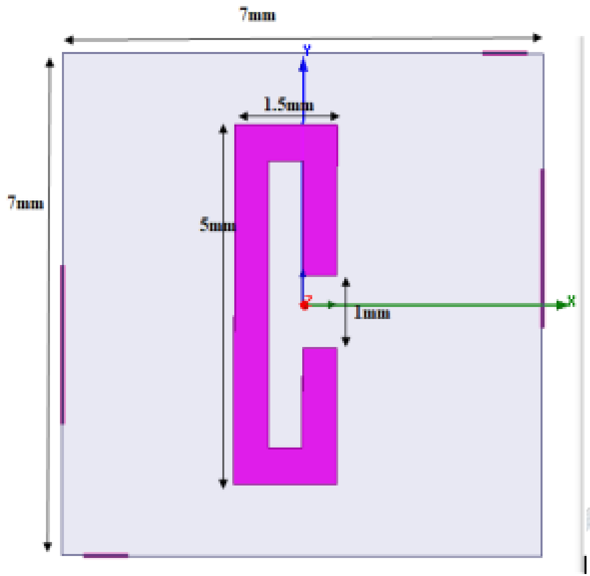


Fig. 1 Proposed metamaterial unit cell

The S-parameters so obtained are substituted in the equation given in [13].

$$n = \frac{1}{k_0 d}\left[\left[\left\{\ln\left(e^{ink_0 d}\right)\right\}'' + 2m\pi\right\} - i\left[\ln\left(e^{ink_0 d}\right)\right]'\right] \quad (1)$$

$$\varepsilon = \frac{n}{z} \quad (2)$$

$$\mu = nz \quad (3)$$

Where k_o is the wave vector.

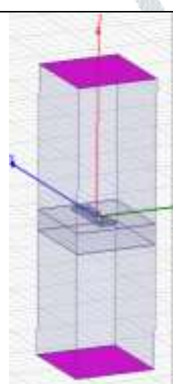
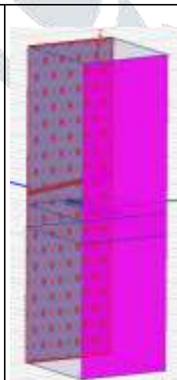
		
Perfect Electric boundary condition	Perfect Magnetic boundary condition	Unit element excitation: Waveport

Fig. 2 The metamaterial structure between two waveguide ports transmission coefficient (S_{21}) is less than -10dB at around 5.5GHz. This means that theresonant frequency of the metamaterial is 5.5GHz.

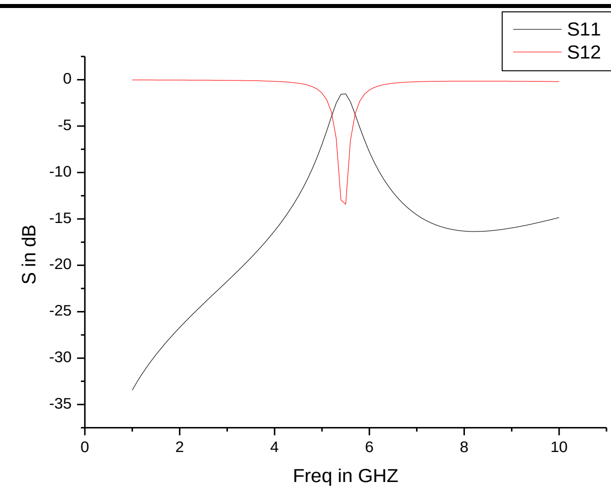


Fig. 3 Transmission coefficient (S_{21}) plot

The S-parameters obtained from simulations with HFSS are given to MATLAB tool as input. Fig. 4, 5 and 6 shows permittivity, permeability and refractive index of metamaterial unit cell formed by square split ring resonator. In the desired frequency range, permittivity, permeability and refractive index are negative. This shows the metamaterial behaviour of square split ring resonator.

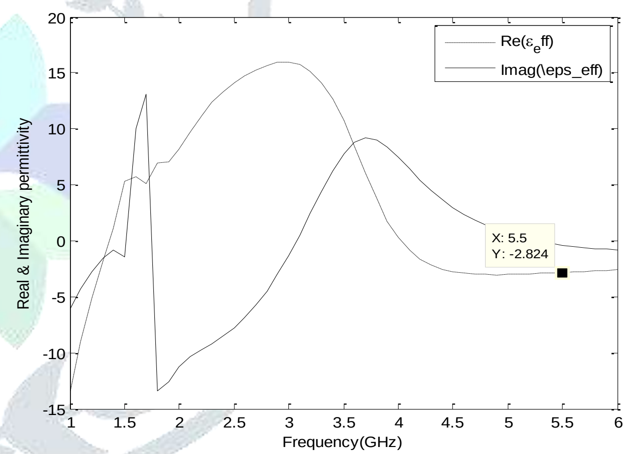


Fig. 4 Permittivity plot of metamaterial unit cell formed by square split ring resonator

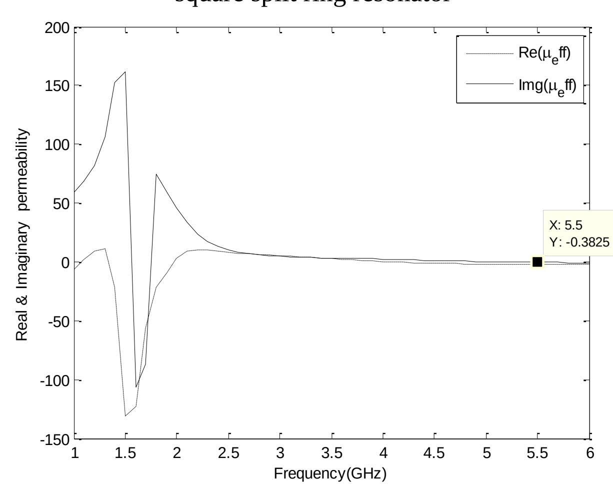


Fig. 5 Permeability plot of Metamaterial unit cell formed by square split ring resonator

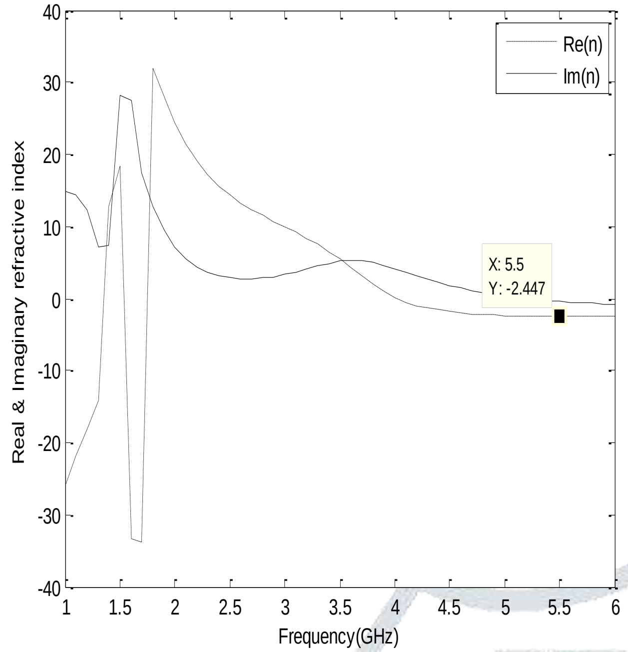
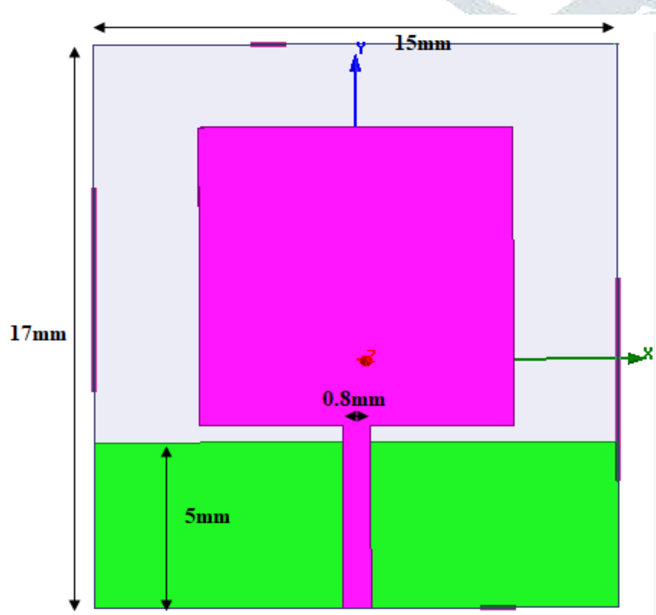


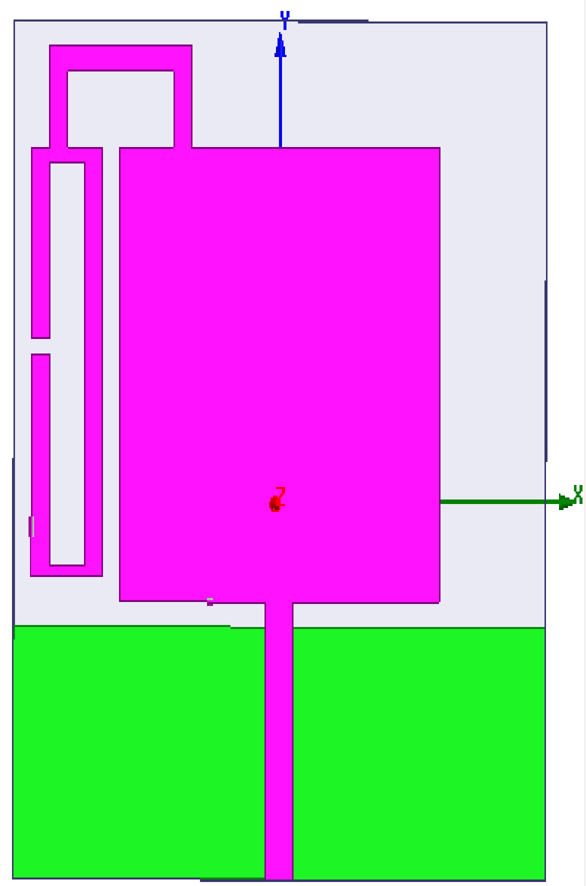
Fig. 6 Refractive Index plot of metamaterial unit cell formed by square split ring resonator

III. PROPOSED ANTENNA DESIGN

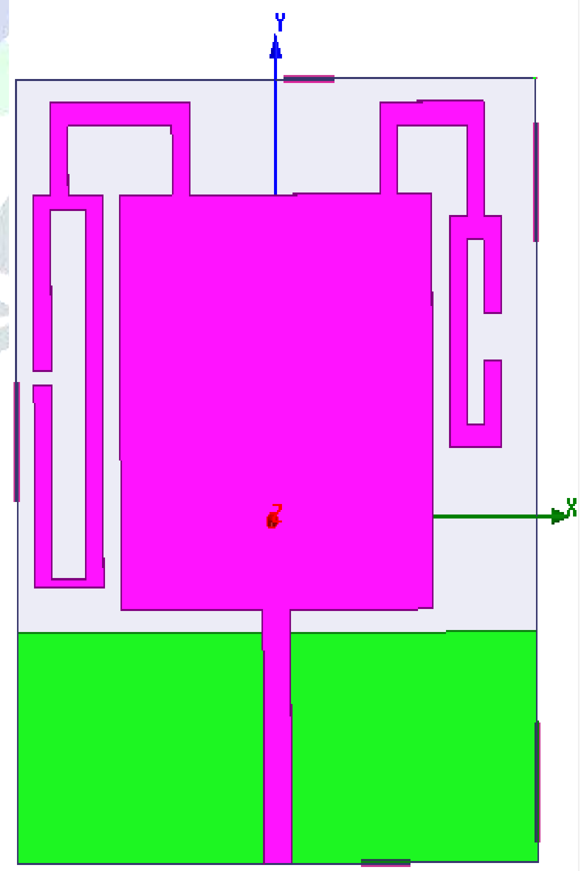
The proposed compact metamaterial loaded monopole antenna with its design evolution stages are illustrated in Fig. 7 and Fig. 8 respectively. Initially a rectangular monopole antenna with dimension 9mm x 9mm x 1mm is designed as shown in Fig. 7. Next a rectangular split ring resonator is included on the left side of stage 1 design to obtain dual resonance at 2.4GHz and 7.5 GHz. By loading another rectangular split ring resonator on the right side of the conventional monopole antenna asshown in Fig. 1 triple band atWiFI/WLAN/Satellite standards (2.4/5.5/7.5)GHz are obtained as shown in Fig. 8.



Stage 1



Stage 2



Stage 3

Fig. 7 Stages of antenna configuration

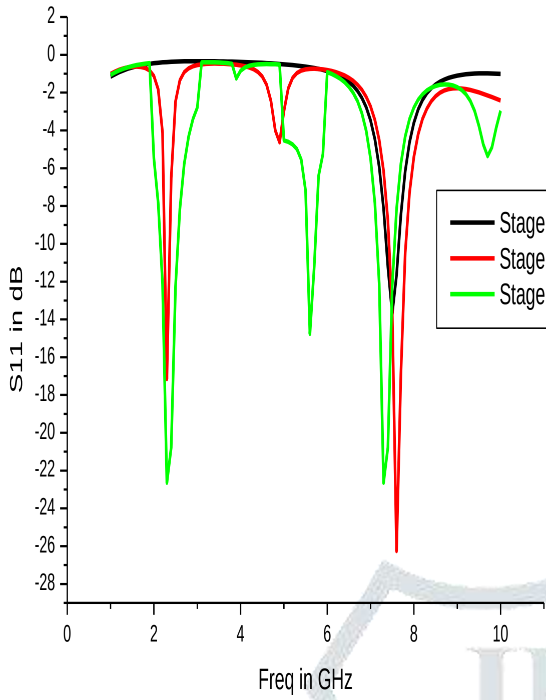


Fig. 8 Simulated S11 for antenna configurations 1/2/3

In stage 2 a single rectangular split ring resonator whose dimension is shown in Table. 1 is loaded on the left side of the patch antenna. The inclusion of the metamaterial is said to increase the current path length in the antenna structure and thereby making the antenna configuration in stage to operate at two resonant frequencies at 2.4GHz and 7.5 GHz for wireless

application WiFi and satellite communication respectively as shown in Fig. 8. In order to obtain a triple operating band an additional metamaterial is added. Whose dimension is shown in Table. 2 is loaded to the antenna configuration in stage 2. In this stage 3 configuration proposed design operate at three frequency bands at 2.4GHz, 5.5GHz and 7.5GHz covering WiFi, WLAN and satellite applications. The conducting current passing through the SRR rings is liable to create magnetic response to generate an additional resonant band.

TABLE 2: Dimensions of loaded Metamaterial 2.

Parameters	Value
Lsub	7mm
Wsub	7mm
L1	2mm
L2	8.5mm
g	0.3mm

The proposed design layouts are printed on FR4 epoxy substrate ($\varepsilon_r = 4.4$) with compact dimensions of 15mm x 17mm x 1mm fed with a 50ohm microstrip feed line. The simulation of the antenna design is performed using ANSYS HFSS.

The operational behaviour of the proposed design can be better understood by analysis of the simulated surface current distributions at wireless standards WiFi/WLAN/Satellite communications. As seen in Fig. 9. The maximum current of surface current is seen along the periphery of left SRR unit cell at 2.4GHz (WiFi band) and along right SRR cell at 5.5GHz(WLAN band). Comparison of the proposed work with previous in the literature is presented. As seen from Table 3, the proposed design possesses compact size and operates at three different frequencies.

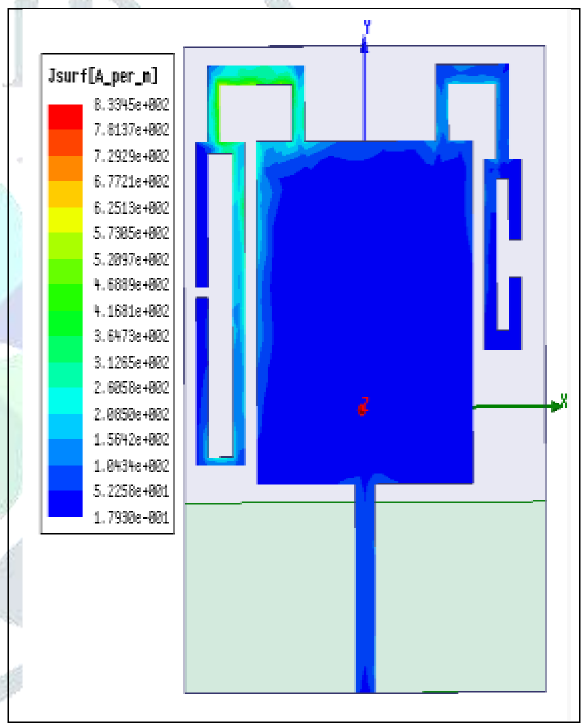


Fig. 9 Surface current distributions

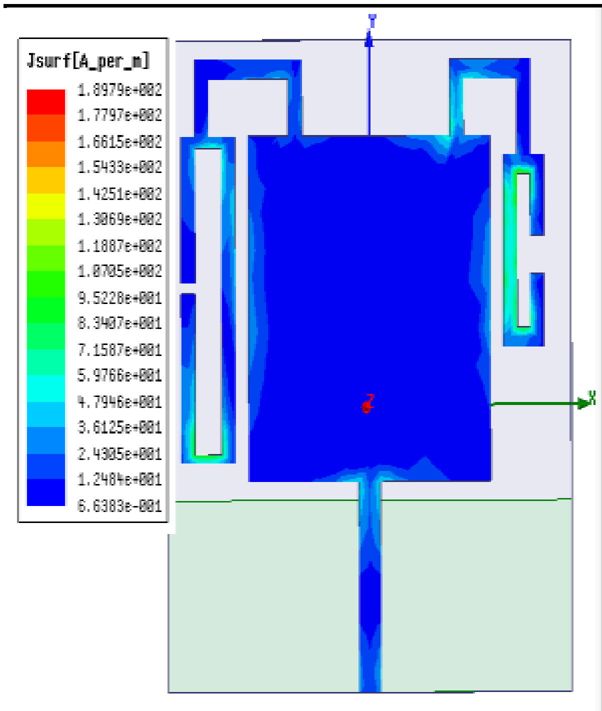


TABLE 3: Comparison with previous works

Reference	Frequency range in GHz	Dimension L x W mm^2	Shape of MTM
[12]	2.45,5.35,6.5	28.6 x 26.6	Rectangular
[15]	1.22-1.23,3.5-4.1,4.4-5.2	33x30	Rectangular
[18]	2.47-2.51, 3.59-3.69,5.3-7.2	23x 26.6	Triangular
Proposed work	2.4,5.5,7.5	15 x 17	Rectangular

IV. CONCLUSION

A tri band metamaterial loaded multiband antenna for WiFi, WLAN and satellite applications is presented. Then the verification of the properties or characteristics of metamaterial on the proposed structure was carried out. The aim was to explore the proposed structure to insert on the monopole patch antenna to get multi-band for WiFi/WLAN/Satellite applications and to reduce the size of antenna. By loading rectangular split rings resonator on the left and right side of the patch triple band was achieved. In future the antennas may be fabricated and tested in real time environments.

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