Split Ring Resonator BASED Multi-Band Antenna FOR Wimax, Wlanand Gsm

Ajay Kumar Gangwar[1], Sudhakar Singh[2]

[1] Department of Electronics and Communications, HMR ITM, New Delhi,India
[2] Department of Biomedical Engineering, LPU, Phagwara, Punjab, India

akgangwarr@gmail.com[1], sudhakarsingh86@gmail.com[2]

Abstract- A miniaturized monopole multi-band antenna using two split ring resonators is proposed for WiMAX, WLAN and GSM applications. The antenna multi-band characteristic is realized by the splits rings, which further justified with the current distribution. The electrical behavior of antenna in term of lump components is implicit with the equivalent circuit. The antenna return loss and 2D radiation patterns are verified with experimental. The radiation patterns are exhibited omnidirectional and bidirectional at the H and E-plane respectively. The multi-band antenna is superior (in term of size, gain as well as modelling of equivalent circuit) with respect to published works in literature.

1. Introduction

In modern communication miniaturized size multi-band antenna is most widely used that replaced many antennas by single one. That technique (i.e. Multi-band antenna design technique) does not only reduce the size but also reduce production time. For the multiband antennas design different techniques are used such as cutting slots, shorting pin and using the parasitic elements [1] but in the present scenario metamaterial utilizes for improving the performance of the antennas [2]-[3]. it is a kind of a material with electromagnetic properties not found in nature and the size of the metamaterial cell are quarter of wavelength [4]. Many antenna researchers implemented metamaterial in to antenna due to its extraordinary electromagnetic properties. By using metamaterial structures different multiband antennas have been designed such as: The split and closed ring resonator based antenna was designed, which was resonated at 2.6 and 3.6 GHz frequencies [4] and in similar way complementary split ring resonator is one of the popular metamaterial, which was utilized in [5]-[6] for multiband antenna design. However, in [7] dual band metamaterial based antenna was designed by the used of resonators for WiMAX, WLAN and RFID applications. Therefore, in these published work multiband antennas were complex designed but all these antennas are large in size and not understand its electrical behavior in term of equivalent circuit model.

Aminiaturized size split ring resonator based multi-band antenna has beendesigned for WiMAX, WLAN and GSM applications and further electrical behavior of multi-band antenna is understood by equivalent circuit.The components of equivalent circuit namely resistance (R), capacitance (C) and inductance (L) are calculated by themethod [8]-[9] and the components values are optimized using ADS [10] software for required results .

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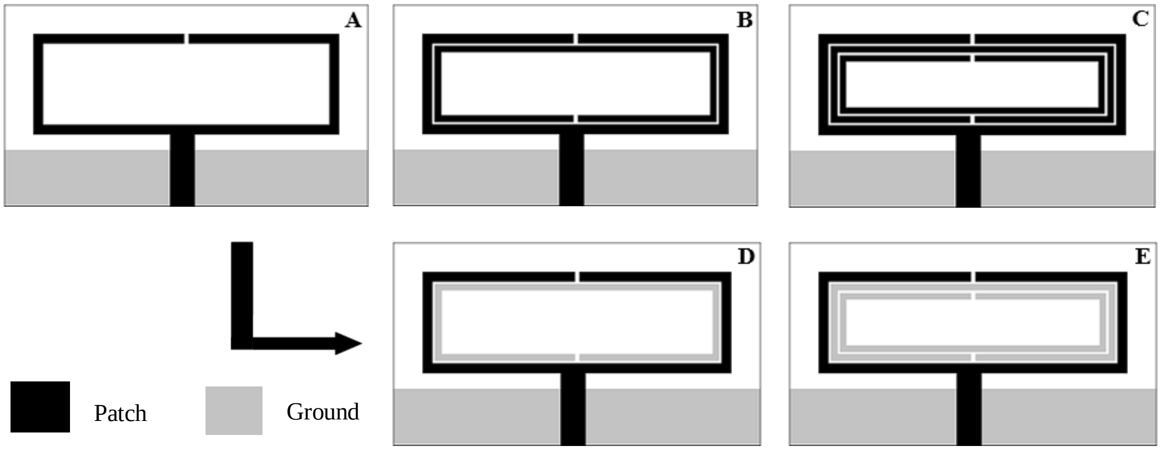

Fig. 1. Evaluation of resonator based antenna.

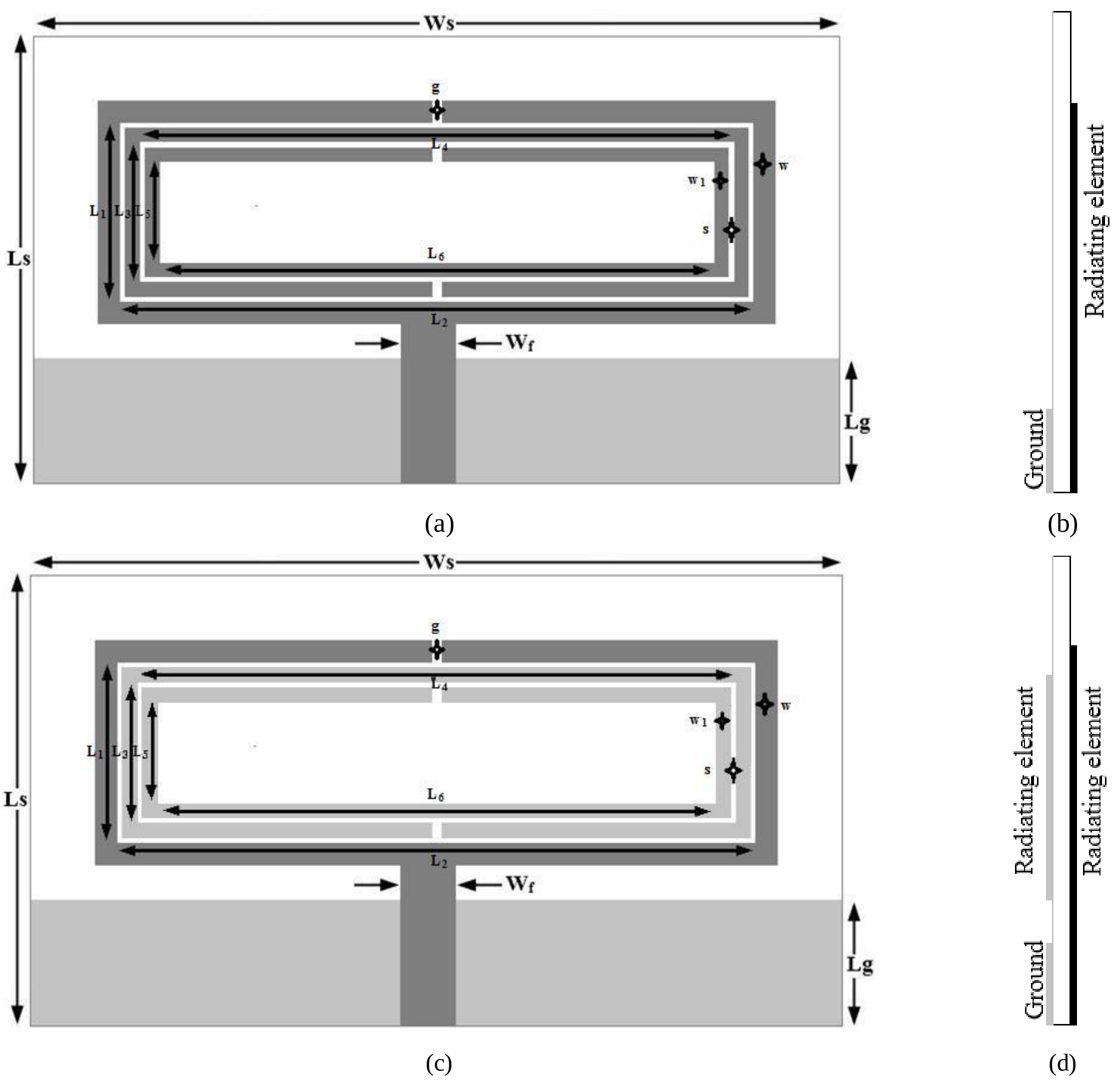

Fig. 2. Proposed antenna (a) Antenna C configuration (b) antenna C configuration (side view) (c) Antenna E configuration (d) antenna E configuration (side view).

2. Antenna Design Process

The design procedure of multi-band antennas is given in Fig. 1. In these antennas configurations, C antenna and E antenna are the final structures, the geometries of these antennas are expressed in Fig. 2.

2.1. Proposed Antenna 1

The proposed antenna 1 is a configuration Cantenna. It is designed by monopole antenna with split rings,the monopole antenna is resonated at 2.5 GHz as shown in Fig. 3. From single band to dual band antenna design, one split ring is added inside the split ring monopole (See configuration B), it is resonated at 2.06 GHz and 3.1 GHz as illustrate in Fig. 3. The single band monopole antenna (B), 2.06 and 3.1 GHz resonance is occurred due to outer and inner rings. Further for triband antenna designed, one additional split ring is added inside the previous ring then the whole structure is resonated at 2.05, 2.59 and 3.44 GHz. These three resonance are achieved due to outer monopole, middle and inner split rings, respectively. The antenna 1dimensions are given in Table I. The resonances of antenna1 are understood by current distribution as revealed in Fig. 4.

2.2. Proposed Antenna 2

The configuration E is considered as antenna 2 designed by monopole antenna (configuration A) with split rings, which is resonated at 2.5 GHz as shown in Fig. 5. From single band to dual band antenna design, one split ring is inserted on the ground plane of single band antenna (antenna (A)) than it is resonated at 2.02 GHz and 3.2 GHz (See Fig. 5). That dual band antenna (D), 2.02 GHz resonance is occurred due to monopole and 3.2 GHz resonance is occurred due to inner split ring. For design a triband antenna (Antenna E), one additional split ring is added on the ground plane of the antenna D than it is resonated at 1.95, 2.59 and 3.43 GHz. In antenna 1 and antenna 2 all the geometries are remaining same but only difference is that in antenna 1 two spilt rings are placed inside the antenna A but in antenna 2 the same split rings are positionedon the ground plane. In antenna 2 two split rings are placed ground plane than the coupling between monopole antenna to split rings at ground plane are less, which reveals in the return loss as shown in Fig. 5. In this paper author main focused on antenna1.

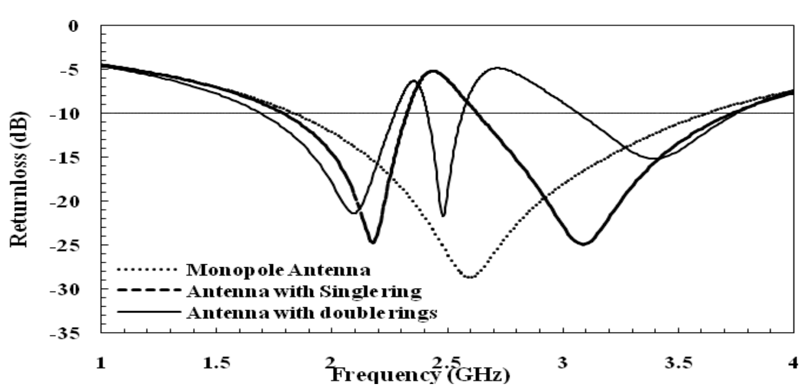

Fig. 3. Return loss of antenna 1 (Configuration C).

TABLE I

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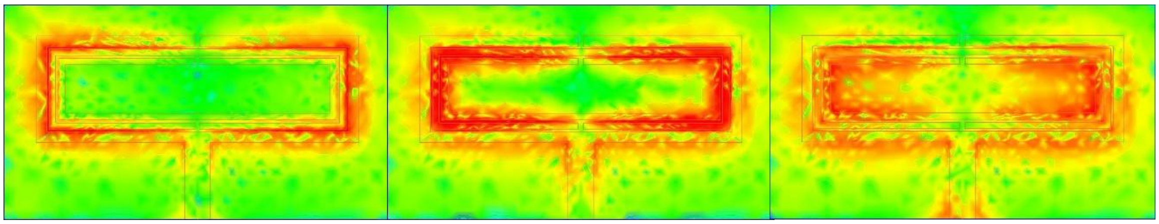
ANTENNA DESIGN PARAMETERS

Design parameters	W_F	g	w	W_1	s	L_1	L_2	L_3	L_4	L_5	L_6	Lg	Ws	Ls
Values (mm)	2.6	0.5	1.0	0.65	0.3	8.7	30.5	6.8	28.6	4.9	26.7	6.0	32.5	24



(a) (b) (c)

Fig. 4. Current distribution of the antenna 1 at (a) 2.06 GHz (b) 2.55 GHz (c) 3.38 GHz.

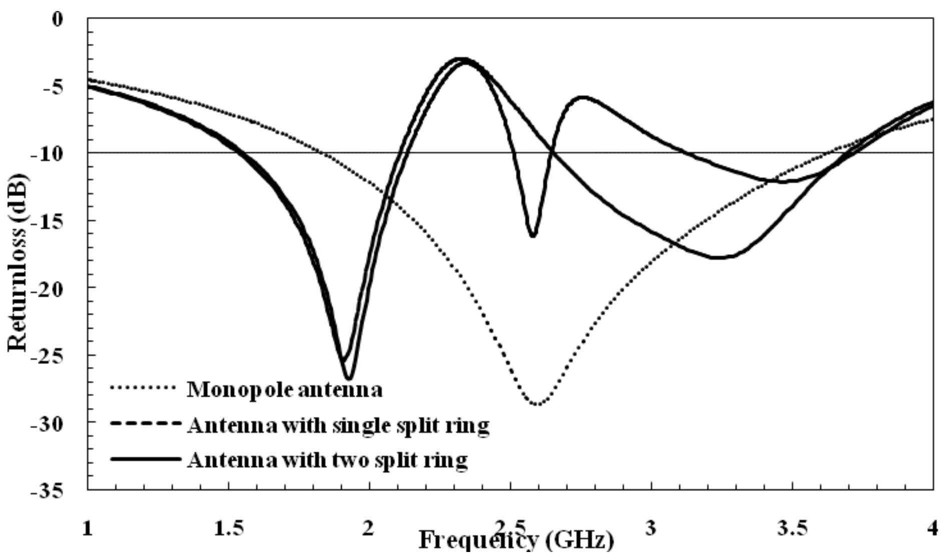


Fig. 5. Return loss of antenna 2 (Configuration E)

3. Antenna Equivalent Circuit

The electrical behavior and the occurrence of resonance of the antenna can be understand with the help equivalent circuit. The input impedance (Z_{IN}) of proposed antenna 1can be represented by using foster representation [11] expressed as:

$$Z_{IN} = \underbrace{\sum_{n=1}^{3} \frac{j\omega}{C_n\left(\omega_n^2 - \omega^2\right)}}_{1st} + \underbrace{j\omega L_M}_{2nd} + \underbrace{\frac{1}{j\omega C_s}}_{3rd} + \underbrace{j\omega L_s}_{4th} \quad (1)$$

In this equation 1st section indicates three resonances, which are represented by parallel LCcircuit, the 2nd sectionof the equation indicates the inductive coupling among the split rings and 3rd section indicates the asymptotic behavior at lower resonance frequency while the 4th term of the equation counter balanced effect at higher frequencies. If in the above equation losses are incorporated than resistance is associated with tank (L, C) circuit, these resistances are shown as R_1, R_2 and R_3 with corresponding tank circuits (See Fig. 6). In Figure 6 lower resonance frequency is represented by R_1, L_1 and C_1 tank circuit and in form of impedance (Z_1), it is expressed as:

$$Z_1 = \frac{j\omega R_1 L_1}{\left(R_1 - \omega^2 R_1 L_1 C_1\right) + j\omega L_1} \tag{2}$$

Similar the second tank circuit (R_2, L_2 and C_2) is represented the second resonance (Middle split ring) and the third resonance is represented by the third tank circuit (R_3, L_3 and C_3) due to inner split ring and the impedance due to tank circuits are represented as Z_2 and Z_3, respectively. And the inductive coupling of the split rings is modelled by the impedance $Z_4 = j\omega L_M = (j\omega L_{M12} + j\omega L_{M23})$. The third term in equation (1), capacitance Cs indicates the impedance $Z_s = 1/j\omega C_s$ account the asymptotic behavior of input impedance at low frequencies, while the fourth and last term indicates the inductance L_s counter balanced the influences of higher frequencies with impedance $Z_s = j\omega L_s$ [12]. Now by including all the impedance, the reformed input impedance expression is Z'_{IN} expressed as:

$$Z'_{IN} = Z_1 + Z_2 + Z_3 + j\omega L_M + 1/j\omega C_s + j\omega L_s \tag{3}$$

The equivalent circuit components (R, L and C) of equation (1) can be determined by [13] and it is further optimized with the Key sight ADS [10] for the desire results. The optimum values of the components are summarized in Table. II. The compare return loss of equivalent circuit and the antenna are presented in Fig. 7.

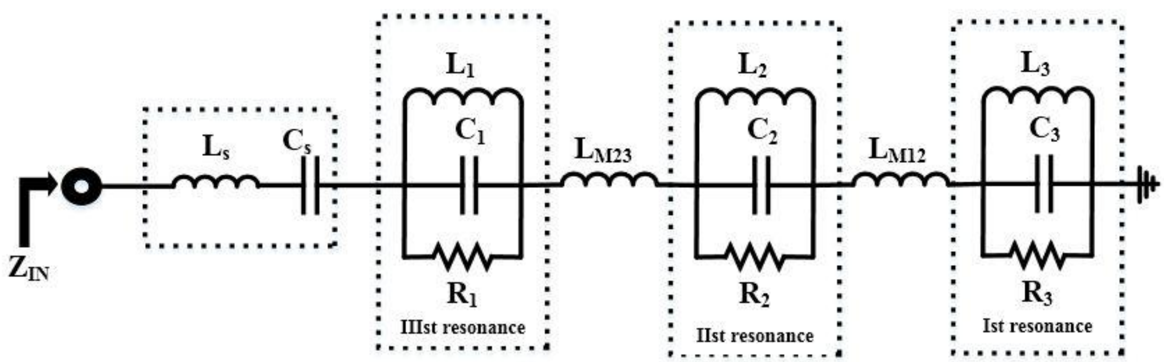


Fig. 6. Equivalent circuit of proposed multi-band antenna.

TABLE II
CIRCUIT COMPONENTS

Circuit components	**R_1**	**L_1**	**C_1**	**R_2**	**L_2**	**C_2**	**R_3**
Values	113.0 Ω	1.56nH	1.88 pF	182.53 Ω	0.71nH	2.25 pF	116.56 Ω
Circuit components	**L_3**	**C_3**	**L_S**	**C_S**	**LM12**	**LM23**	
Values	0.81nH	7.15 pF	0.40nH	0.69 pF	1.26nH	1.13nH	

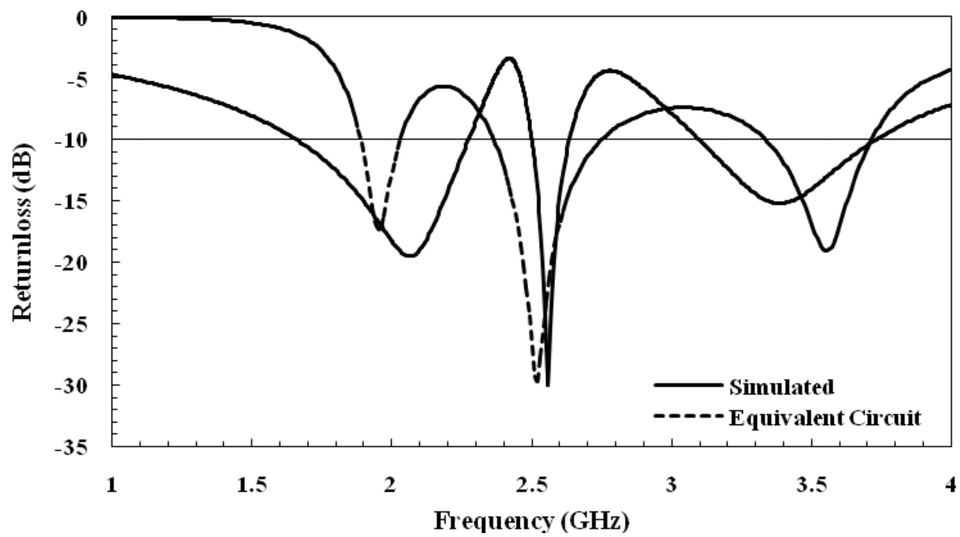


Fig. 7. Return loss of the antenna and its equivalent circuit.

4. Input Impedance Matching

In antenna design input impedance matching is an important part for maximum power transfer to the radiating patch. When the input impedance matches to the characteristic impedance of the feedline, maximum power is transferred to the patch but if they are differ (i.e. $Z_{IN} \neq Z_0$), then power is reflected back to the input terminal, The reflected power is quantified as:

$$S_{11} = \frac{Z_{IN} - Z_0}{Z_{IN} + Z_0} \quad (4)$$

Due to impedance mismatch at input, some power is loosed at input terminal, the impedance mismatch loss (IML) is calculated as:

$$IML(dB) = 10\log(1 - |S_{11}|^2) \quad (5)$$

Ideally, IML should be ideally zero but in this multi-band antenna the optimum values of IML are summarized in Table III.

TABLE III
IML PERFORMANCE AT RESONANCE FREQUENCIES

Frequency	Return loss	Reflection coefficient	$\lvert Z_{IN} \rvert$	IML
2.06 GHz	-19.49	0.106	53.98 Ω	0.049 dB
2.55 GHz	-30.12	0.031	46.99 Ω	0.004 dB
3.38 GHz	-15.20	0.174	68.43 Ω	0.133 dB

5. Results discussion

The multi-bandantenna is designed using Keysight ADS and for design of the antenna FR4 substrate is used. For validation of simulation results to the measurement using vector network analyzer. The hardware measured results and simulated results are compared at 2.06, 2.55 and 3.38 GHz as shown in Fig. 8 and Fig. 9. The return loss in

Fig.8 covered required bandwidth ($S_{11} \leq -10$) for GSM, WLAN and WiMAX applications. From the fig. 9, it is observed that the antenna offersbi-directional and omni-directional radiation pattern in the E and H-plane, respectively. From the Fig. 9, it is visualized that there are some small discrepancies between measured and simulated results, these errors are mainly manufacture and human errors. The gain, efficiency vs frequency graph is given Fig. 10.

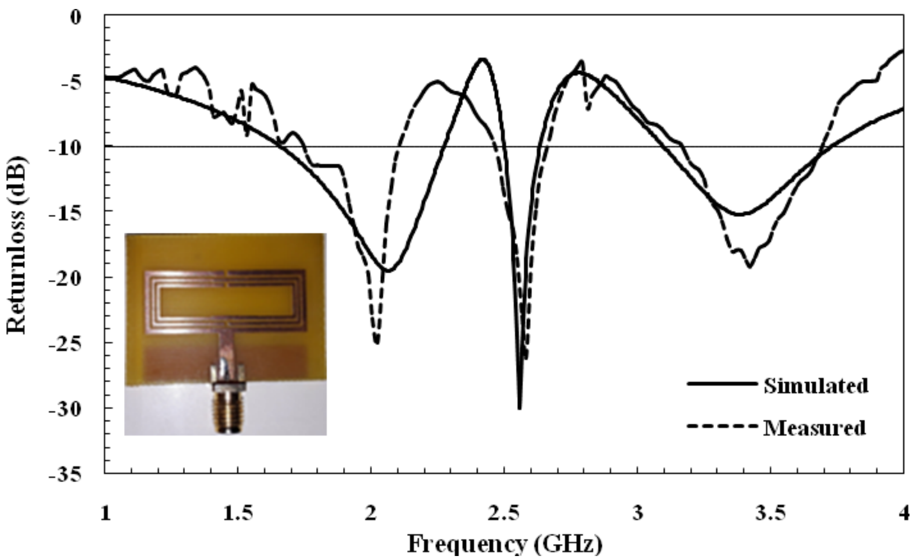
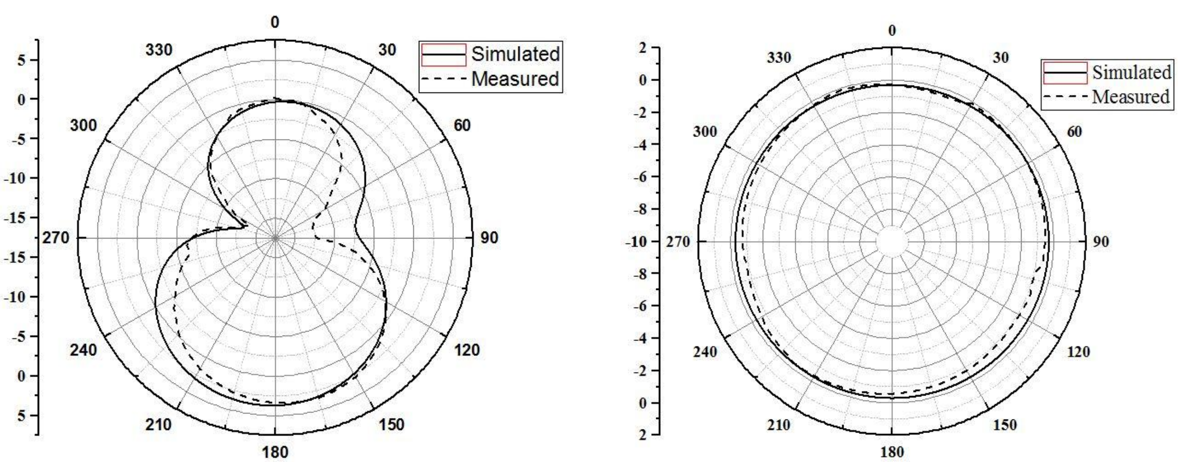
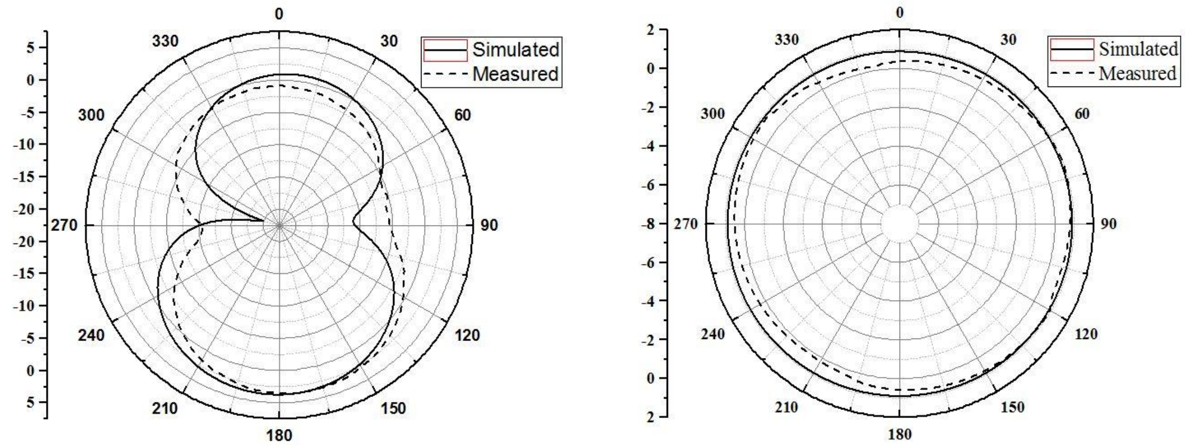


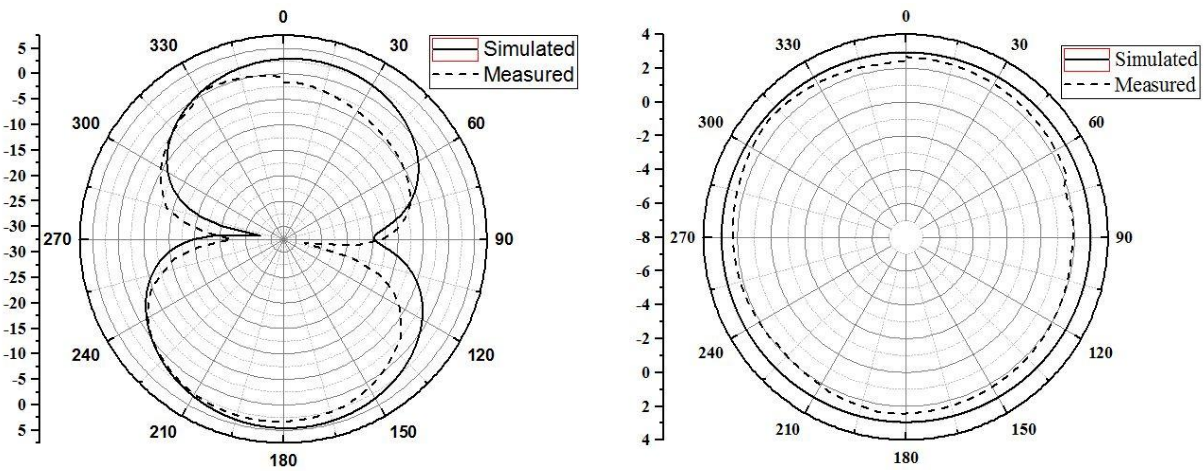
Fig. 8. Measured and simulated return loss S_{11}.



(a)



(b)



(c)

Fig. 9. The bidirectional (E-plane) left hand side and omnidirectional (H-plane) right hand side radiation patterns (a) 2.06 GHz (b) 2.55 GHz (c) 3.38 GHz.

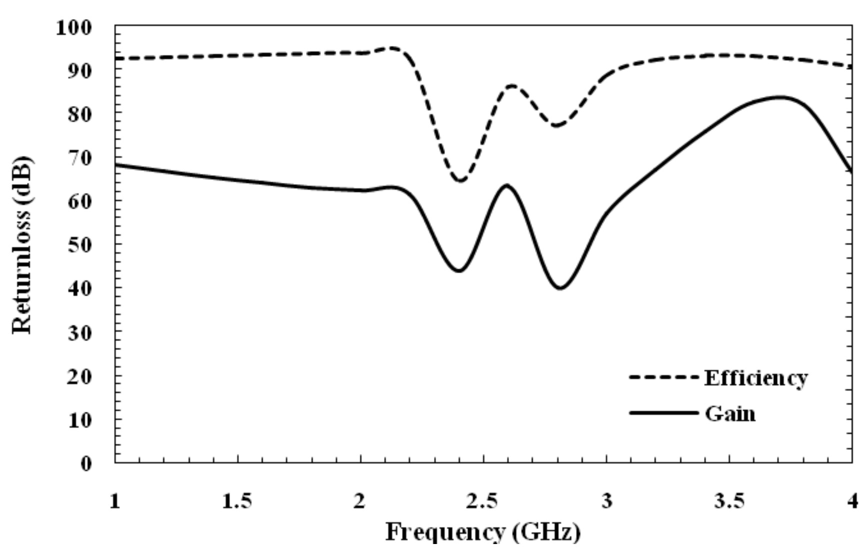


Fig. 10. Simulated gain and efficiency of antenna.

6. Conclusion

The multi-band resonator based antenna has been designed for. The antenna consists of one monopole with two split rings, which are resonated at 2.06, 2.55 and 3.38 GHz frequencies. The gain (efficiency) performance of the antenna has been found as 3.76dBi (93.94%), 3.67dBi (86.95%) and 4.60dBi (93.39%) at 2.06, 2.55and 3.38 GHz, respectively.Further resonance behavior of antenna is observed with the equivalent circuit and its components values is optimized for required resonance frequencies. The measured results are validated with the simulated makes its suitable for WiMAX, WLAN and GSM applications.

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