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A Compact Metamaterial Inspired Quad band Antenna for C-Band Applications

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Abstract: **- This paper presents a compact microstrip patch antenna for the frequency bands 3.2, 4.5, 6.2 and 7.1 GHz. The resonant modes for WiMAX and C-band applications are achieved by using metamaterial inspired split ring structure and complementary split ring structure. The proposed antenna with a compact size of 27 mm × 25 mm is designed. The extraction procedure of negative permeability for the proposed metamaterial structure is discussed.**

Index Terms: **- CSRR, Metamaterial, Negative permeability, SRR.**

I. INTRODUCTION

Multiband antenna plays a major role in wireless communication systems. When designing a multiband antenna the main challenges are miniaturization, low cost impedance matching and integration with RF circuits. Nowadays several dual-band, multiband, wideband and ultra-wideband (UWB) antennas are developed [2]. Many dual-band antennas are proposed for WLAN frequency band. These antennas are limited to only WLAN applications [2-6]. Multi-resonant modes can be achieved by introducing strips and slots in the ground and patch planes. Antenna limits its applications because of its large size [7-12]. In recent years, metamaterials are commonly used for implementing compact multiband antennas. Metamaterials is an artificial electromagnetic structure with properties that cannot found in the nature. Its special property is negative permeability and negative permittivity. Commonly used metamaterial structures are split ring resonator (SRR) and complementary split ring resonator (CSRR). The metamaterial inspired antennas are mainly focused on optimum bandwidth, miniaturization and better radiation performance [13-16]. SRR and CSRR are loaded substrates and SRR loaded radiating patch are used to design metamaterial antenna. In this paper, a rectangular SRR and circular CSRR are introduced in the radiating patch to achieve the WiMAX frequency band. Two CSRR are introduced in the partial ground plane to obtain the frequency bands suitable for C-band applications. The negative permeability characteristics are extracted and discussed. A compact metamaterial inspired multiband antenna is proposed for WiMAX (2.95-3.25 GHz) and C-band applications (4.25-4.6 GHz, 6.05-6.15 GHz and 6.95-7.2 GHz).

The organization of the paper is as follows section II presents design procedure of the proposed antenna. Section III contains result and discussion. Extraction of negative permeability and discussions are given in section IV. This paper is concluded in section V.

II. PROPOSED ANTENNA CONFIGURATION

The design evolution of the proposed antenna is shown in the figure 1. The proposed antenna consists of CSRR loaded patch and ground plane. The geometry of the proposed quad band antenna is illustrated in figure 2. The dimensions of the antenna are given in the table I.

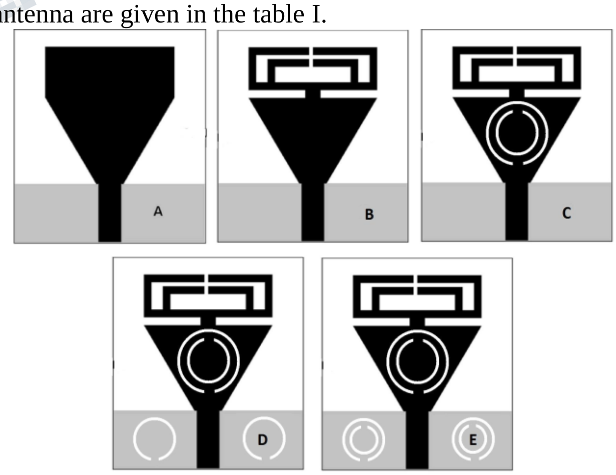

Fig. 1Evolution of the proposed antenna

Initially the antenna structure consists of a trapezoidal monopole as a radiating patch, a feed line (Fw × FL), and a partial ground plane (W × Lg). The radiating element of the antenna is printed on a low cost FR-4 substrate with dielectric constant 4.4. The thickness of the substrate is 1.6

mm and loss tangent is 0.018. The rectangular SRR is introduced in the patch without increasing the outer dimensions as shown in configuration 'B' (Figure 1). In configuration C, a CSRR structure is integrated to the patch to obtain dual band antenna. Then two single ring CSRR structure is introduced in the partial ground plane as shows in configuration D. These add another band to the existing dual band antenna system. Finally the single ring CSRR in the ground plane is modified to double ring CSRR. These modifications provide a quad band antenna.

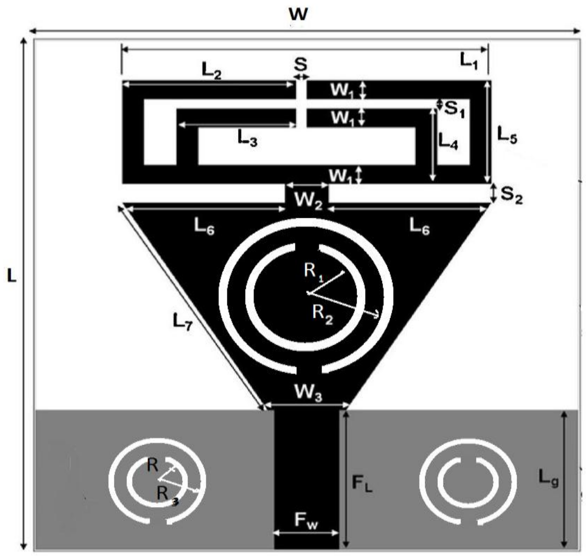

Fig. 2 Geometry of the proposed quad band antenna

Table. I Dimensions of the proposed antenna

Parameter	*Dimension (mm)*
W	25
L	27
L_1	17
L_2	8
L_3	5.5
L_4	4
L_5	5.5
L_6	7.5
L_7	11
W_1	1
W_2	2
W_3	3.6
L_g	7.4
F_L	7.4
F_w	3
S	0.5
S_1	0.5
S_2	1
R	1.5
R_1	2.5
R_2	3.5
R_3	2.5

III. RESULT AND DISCUSSION

The comparison of simulated return loss for different configurations is shown in figure 3. From the figure 3, it is clear that configuration A has a resonance at 4.9 GHz and configuration B has a resonance at 3.9 GHz. This shifting of the first resonance towards lesser frequency proves a better antenna performance. But configuration C has dual bands at 3.5 GHz and 4.5 GHz. Configuration D provides triple bands at 3.2 GHz, 4.5 GHz and 7.1 GHz. Configuration E adds an another band to the existing antenna at 6.2 GHz. The CSRR in the patch and ground plane plays an important role to obtain the multiband resonance. It also improves the return loss at 6.2 GHz. The simulated return loss is less than -10dB at 3.2 GHz, 4.5 GHz, 6.2 GHz and 7.1 GHz which is suitable for WiMAX and C-band applications respectively. The radiation patterns of the proposed antenna at 3.2 GHz for E-plane and H-plane is shown in figure 4. The radiation patterns exhibit dipole like radiation pattern in E-plane and omnidirectional radiation pattern in H-plane. Table II is given the comparison of the proposed antenna with the existing antennas.

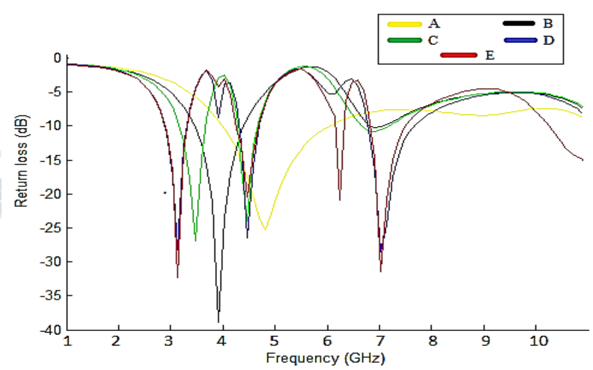

Fig. 3 Simulated return losses of different configuration of the proposed antenna

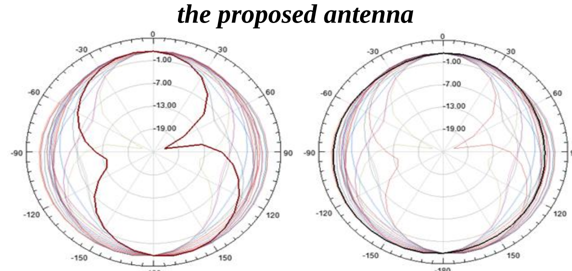

Fig. 4 Simulated far field radiation patterns of the proposed antenna at 3.2 GHz (a) for E-Plane (b) for H-Plane

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Table. II Comparison of the existing antennas with the proposed antenna

Reference	Dimensions in mm	Number of frequency bands	Metamaterial property verification
[13]	43.5 x 43.5	1	Not Verified
[14]	60 x 60	3	Not Verified
[15]	55 x 55	3	Not Verified
[16]	30 x 52.6	3	Not Verified
Proposed antenna	25 x 27	4	Verified

IV. EXTRACTION OF CSRR PARAMETERS

Nicholson–Ross–Weir (NRW) method is adapted to determine negative permeability. Figure 5 shows the waveguide setup used in the HFSS to obtain the transmission and reflection coefficients of the proposed CSRR. The boundary conditions are assigned to perfect electric conductor (PEC) and perfect magnetic conductor (PMC). An electro-magnetic wave is incident through one port and the corresponding transmission (S21) and reflection coefficients (S11) can be measured that shown in the figure 6. The transmission and reflection coefficients are used to extract the negative permeability. The real and imaginary part of permeability of the CSRR extracted is shown in the figure 7. The figure 7 shows that negative permeability has occurred at 2.5 GHz and also satisfies the metamaterial property. Hence, the CSRR loaded ground plane is used to generate a new resonance frequency to obtain the multiband modes.

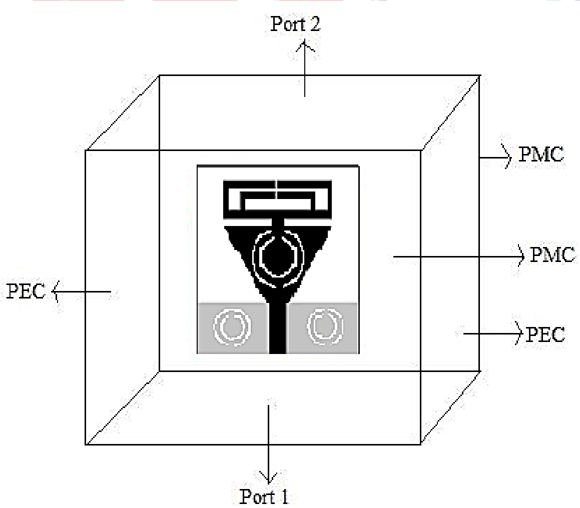

Fig.5 Waveguide setup to retrieve S-parameters

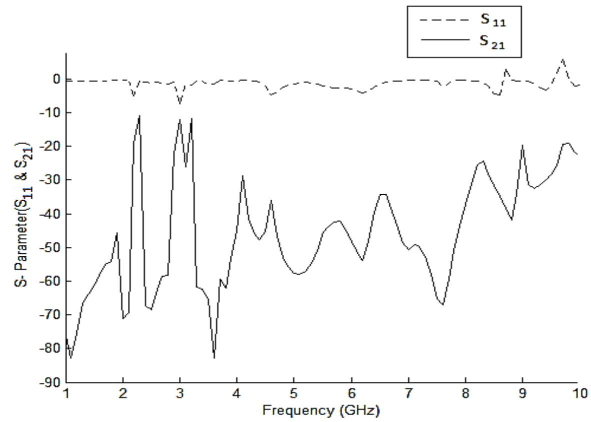

Fig. 6 Simulated S-parameters (S11 & S21)

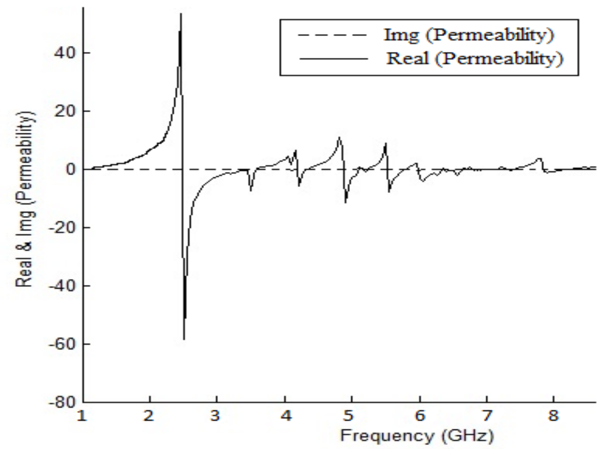

Fig. 7 Extracted negative permeability of the proposed CSRR at 2.5 GHz

V. CONCLUSION

A compact CSRR loaded quad band antenna fed by a microstrip line with compact size of 27 mm × 25 mm × 1.6 mm is designed and simulated. The operating bands of the proposed antenna are 3.2, 4.5, 6.2 and 7.1 GHz, which meets WiMAX and C-band requirements. The CSRR structure is loaded in the radiating element and ground plane. The metamaterial property is satisfied at 2.5 GHz. The proposed antenna is suitable for WiMAX (2.95 - 3.25 GHz) and C-band applications (4.25 - 4.6 GHz, 6.05 - 6.15 GHz and 6.95 - 7.2 GHz).

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