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Microstrip patch antenna loaded with Complementary Split Ring Resonator and Slots

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***Abstract*— This paper presents a compact microstrip patch antenna using metamaterials and slots for Global System for Mobile Communication (GSM), Worldwide Interoperability for Microwave Access (WiMAX) and C-band applications. The size of the proposed antenna is 20 x 20 x 0.5 mm³. The resonant frequency of WiMAX (3.3 GHz) is gained by introducing Complementary Split Ring Resonator on the ground plane. To achieve multiband characteristics for GSM (1.8 GHz), WiMAX (2.6 GHz) and C-band (4.2 GHz), two C-shaped slots are introduced in the patch. The extraction procedure of negative permittivity and refractive index for the proposed CSRR is discussed. The antenna is fabricated and designed using the Ansoft HFSS (High Frequency Structural Simulator).**

***Index Terms*— CSRR, Metamaterial, multiband, Negative permeability.**

I. Introduction

Multiband antenna plays an important role in the wireless technology due to their compactness, low cost, ease of integration and it can operate at various frequencies [1, 2]. Many researches have been done in the area of multiband antenna. Multiband frequency is achieved with a single radiating patch by introducing slots in the radiating element [3, 4], modified ground planes [5] and fractal geometry techniques [6, 7].

In recent years, metamaterials are used for acquiring multi resonant modes. The conventional metamaterial structures are SRR, CSRR, EC-SRR etc. The properties of metamaterial are not found in the nature. It exhibit negative permeability and negative permittivity. This property of CSRR is used to change the antenna performance, such as gain and enhancement of bandwidth [8, 9], multiband [10, 11] and size reduction [12, 13]. The geometrical parameters of these CSRR structures greatly affect the propagation of the electromagnetic waves [14].

In this paper, a compact half decagon monopole antenna with two C-shaped slots and a CSRR loaded ground plane is proposed for GSM (1.84–1.95 GHz), WiMAX (2.64–2.73 GHz, 3.23– 3.37 GHz), and C-band (4.12–4.26 GHz) applications. Permittivity characteristics and resonance frequency of the CSRR are extracted and validated. The proposed antenna has a compact size and also covers quad bands.

The organization of the paper is as follows, Section II presents design procedure of the proposed multiband antenna. Section III describes 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 multiband antenna geometry is shown in Figure 1. The proposed antenna consists of a half decagon monopole antenna with two C-shaped slots and a CSRR loaded ground plane. The geometry of the proposed antenna for quad band operation is illustrated in Figure 2. The dimensions of the antenna are listed in Table I.

The antenna structure consists of a half decagon monopole as the radiating element, a feed line (L2 x W3) and a ground plane (L x W). The main radiator is printed on commercially available FR-4 substrate with a dielectric constant of 4.4, thickness of 0.5 mm and a loss tangent of 0.02. The half decagon monopole antenna is designed in configuration A. In configuration B, CSRR is loaded on the left top corner of the ground plane at a distance of 10.5 mm from the bottom for achieving dual resonance. In configuration C, two C-shaped slots of are introduced to achieve multi resonant modes. Two C-shaped slots exhibit another two resonances at 2.6 GHz and 4.2 GHz.

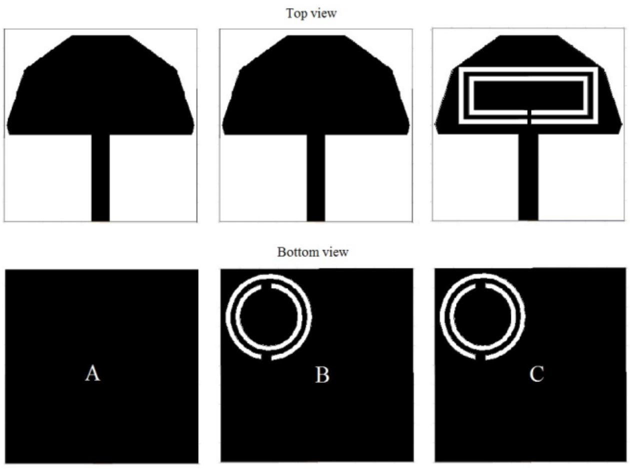

Fig. 1 Evolution of the proposed antenna

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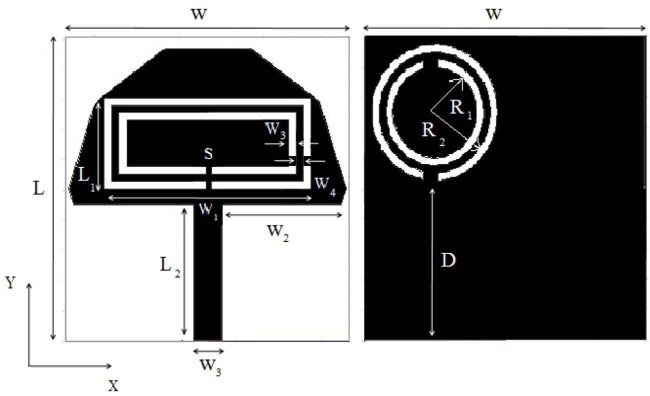

Fig. 2 Proposed antenna geometry and bottom view of the proposed antenna

Table. I Dimensions of the proposed antenna

Parameter	Dimensions (mm)
W	20
L	20
L_1	6
W_1	14.5
L_2	9
W_2	8.4
W_3	2
W_4	0.5
W_5	0.5
S	0.25
R_1	3
R_2	4
D	10.5

III. RESULT AND DISCUSSION

The photographs of the top and bottom view of the fabricated proposed antenna are given in Figure 3. The comparison of simulated return loss for all configurations is shown in Figure 4. From the Figure 4, it is clear that configuration A and configuration B is not giving any promising results. But configuration C has multi resonance at 1.8 GHz, 2.6 GHz, 3.3 GHz and 4.2 GHz. For determining the multiband resonance, the size of the two C-shaped slots and the CSRR plays an important role. It also improves the return loss at 1.8 GHz. The simulated return loss is less than -10dB at 1.8 GHz, 2.6 GHz, 3.3 GHz and 4.2 GHz which is suitable for GSM, WiMAX and C-band wireless applications respectively. The measured and simulated S parameter of the proposed antenna is given in Figure 5. The radiation patterns of the proposed antenna at 1.8 GHz and 4.2 GHz are shown in Figure 6 and Figure 7. It illustrates that omni-directional pattern for H-plane and bi-directional pattern for E-plane.

Surface current distribution of loaded and unloaded on the ground plane is simulated and shown in Figure 8(a) and 8(b). The current is concentrated along the patch and CSRR of the structure for the 3.3 GHz frequency band. The comparison of proposed antenna with existing antennas in the references is given in Table II.

Fig. 3 Photographs of top and bottom view of the fabricated proposed antenna

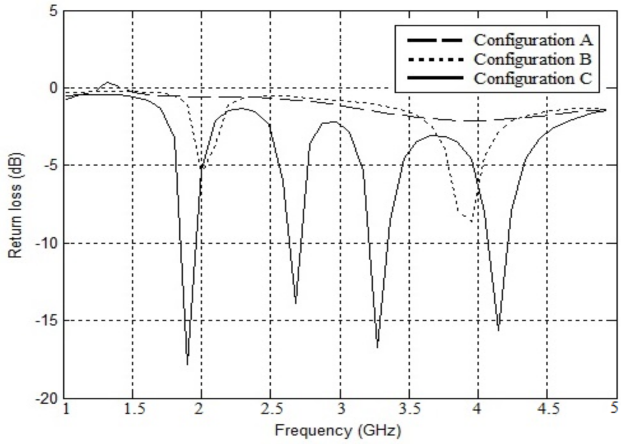

Fig. 4 Simulated return losses of the three different configuration of the proposed antenna

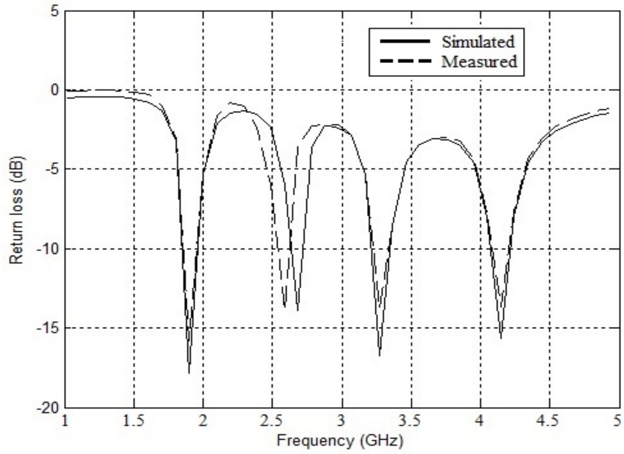

Fig. 5 Simulated and measured return loss of the proposed antenna

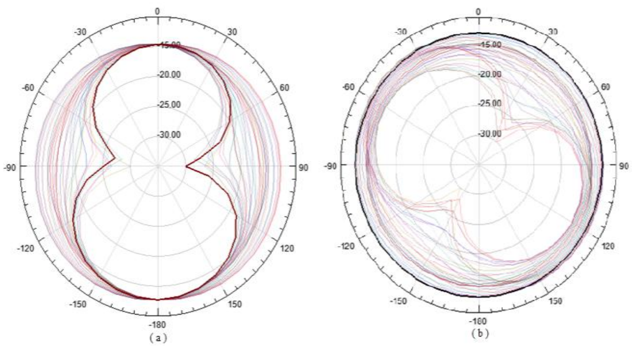

Fig. 6 Simulated far field radiation patterns of the proposed antenna at 1.8 GHz (a) for E-Plane (b) for H-Plane

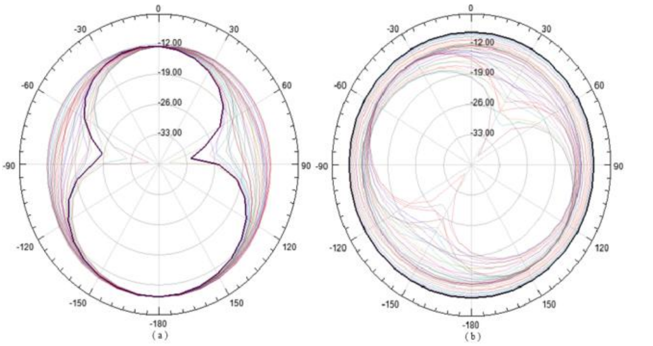

Fig. 7 Simulated far field radiation patterns of the proposed antenna at 4.2 GHz (a) for E-Plane (b) for H-Plane

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

Reference	Dimensions in mm^2	Number of frequency bands	Metamaterial property verification
[16]	56.4 x 56.4	4	Not Verified
[17]	30 x 40	3	Not Verified
[18]	31 x 30	3	Not Verified
[19]	40 x 70	4	Not Verified
Proposed antenna	20 x 20	4	Verified

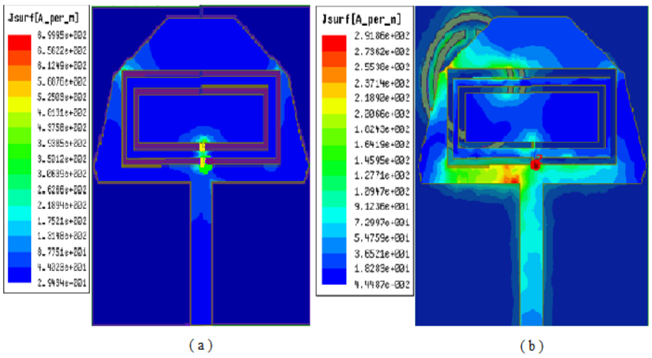

Fig. 8 Simulated surface current distribution of (a) unloaded ground plane and (b) CSRR loaded ground plane at 3.3 GHz

IV. EXTRACTION OF NEGATIVE PERMEABILITY

CSRR is a conventional metamaterial structure that shows the pass band characteristics. The CSRR is used to generate new resonance frequency (3.2 GHz) in order to achieve multiband. For CSRR, slit gap is one of the main parameter. If there is no slit gap, CSRR will not generate the resonance frequency. The CSRR consists of two rings. Radius of the inner ring is 3 mm and radius of the outer ring is 4 mm. Width of the metallic strip is 0.5 mm. Spacing between the rings is 0.5 mm and the slit gap is 1 mm. For better understanding of the pass band characteristics, transmission coefficient (S_{21}) and reflection coefficient (S_{11}) are simulated and compared.

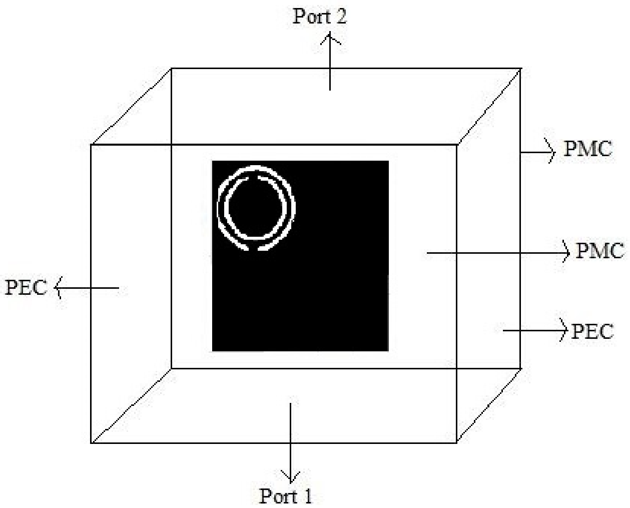

Fig. 9 Waveguide setup to extract S-parameters

The pass band performance of the proposed CSRR is extracted based on the waveguide setup as shown in the Figure 9. The metamaterial element CSRR is kept inside the waveguide along the appropriate axis. The perfect electric conductor (PEC) and perfect magnetic conductor (PMC) boundary conditions are assigned. The CSRR is excited electrically by electromagnetic wave to the input port (port 1), and the transmission and reflection coefficients are extracted from the output port (port 2) of the waveguide. Figure 10 shows the graphical representation of the simulated scattering parameters of proposed CSRR. It is observed that there is a pass band at 3.2 GHz.

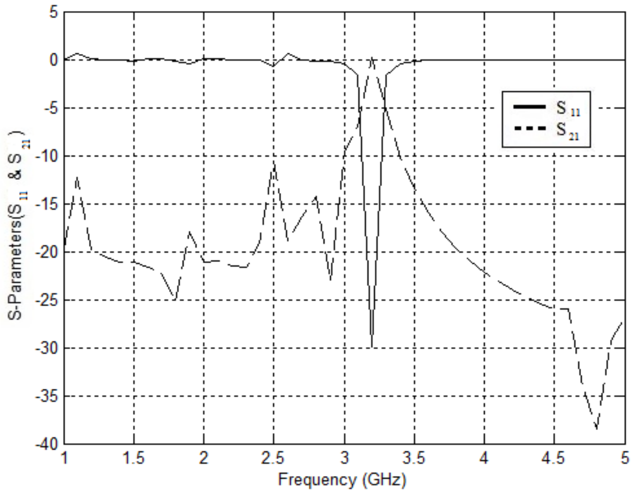

Fig. 10 Simulated S-parameters of the proposed CSRR

The extracted real and imaginary parts of permittivity of the CSRR are shown in the Figure 11. From the Figure 11, it is clear that negative permittivity occurred at 3.2 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.

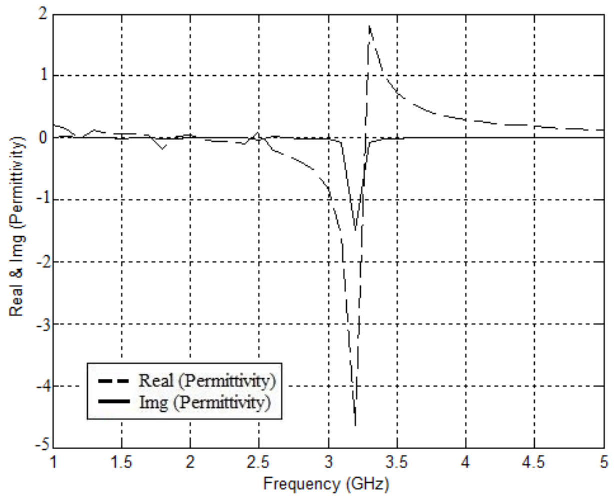

Fig. 11 Extracted negative permittivity of the proposed CSRR at 3.2 GHz

V. Conclusion

A quad band half decagon monopole antenna is proposed for GSM, WiMAX and C-band applications; with compact size of 20 x 20 x 0.5 mm³. The proposed antenna structure consists of a half decagon monopole with two C-shaped slots as the radiating element and a CSRR loaded ground plane. The metamaterial property of the CSRR is verified at 3.2 GHz. The proposed antenna is desirable for GSM (1.84–1.95 GHz), WiMAX (2.64–2.73 GHz) and (3.23– 3.37 GHz), and C-band (4.12–4.26 GHz) applications.

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