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A compact metamaterial loaded monopole antenna with offset-fed microstrip line for wireless applications

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ABSTRACT

A compact metamaterial loaded monopole antenna with offset-fed microstrip line is proposed for Universal Mobile Telecommunication System (UMTS), Worldwide interoperability for Microwave Access (WiMAX), and Wireless Local Area Network (WLAN) wireless applications. The proposed antenna is printed on a $19.18 \times 22.64 \times 1.6\ mm^3$ FR-4 substrate having a dielectric constant (ε_r) of 4.4. The antenna radiating element consists of split ring structure and CSRR for generating multiband characteristics, which is fed by offset microstrip line. A split in the outer vertical arm creates a lower order resonance at 2.1 GHz and the Complementary Split Ring Resonator (CSRR) in the monopole antenna is used to generate a new resonance frequency of 3.45 GHz. The precise equivalent circuit design equations are used to analyze the CSRR resonance frequency. Also, the band characteristics of a split ring structure and CSRR are enlightened in detail to verify the metamaterial property. Simulated results are verified with measured results. The measured azimuthal plane (H-Plane) exhibits omnidirectional radiation pattern and elevation plane (E-plane) represents a bidirectional radiation pattern.

1. Introduction

Several printed monopole antennas have been designed for multiband operations. This can be achieved by truncated radiating patch [1], fractal structures [2], introducing slots [3], and meandered monopole [4]. Apart from multiband, the antenna requires compact, efficient and cost effectiveness. Recently, electromagnetic metamaterials have got great attention in multiband antenna design because of their extraordinary electro-magnetic properties. These unusual material properties have been used to improve the performances of antenna such as good impedance matching [5], bandwidth improvement [6], and miniaturization [7]. The Split Ring Resonator (SRR) and Complementary Split Ring Resonator (CSRR) are the basic elements of metamaterials that exhibit negative permeability and negative permittivity, respectively. The geometrical parameters of these structures greatly affect the orientation of the EM wave propagation and create a new resonant frequency [8,9]. Generally, SRR is used for designing small antennas due to quasi-static resonant nature, so the wavelength of resonant frequency is smaller than its own size. Dual band antenna was designed by loading SRR to achieve wide bandwidth [10]. CSRR embedded ground plane was used to achieve multiband [11] and gain enhancement [12]. Multiband antenna was designed using bulky size, complicated structure and poor impedance matching.

In this paper, a compact multiband antenna is designed using simple radiating structure and with good impedance matching. The size miniaturization is achieved by using metamaterial elements such as split ring structure and CSRR. The negative permeability characteristics of split ring structure and negative permittivity characteristics of CSRR are studied for generation of new resonance frequencies. The proposed antenna has a compact size compared with already existing antenna [9–10,13–17].

2. Proposed antenna geometry and simulated results

The design steps of proposed antenna are shown in Fig. 1. Configuration A shows an inverted U-shaped slot embedded monopole antenna with a partial ground plane. It is fed by a 50 Ω, offset-fed microstrip line, which is used to create a higher order resonance around 5 GHz. In configuration B, a split is introduced at the center of the outer vertical arm, which is used to induce magnetic resonance and in turn creates a lower resonance frequency of 2.1 GHz, due to its capacitance effect of split ring structure. As shown in configuration C, CSRR is introduced inside the monopole antenna, to achieve middle resonance frequency of 3.45 GHz,

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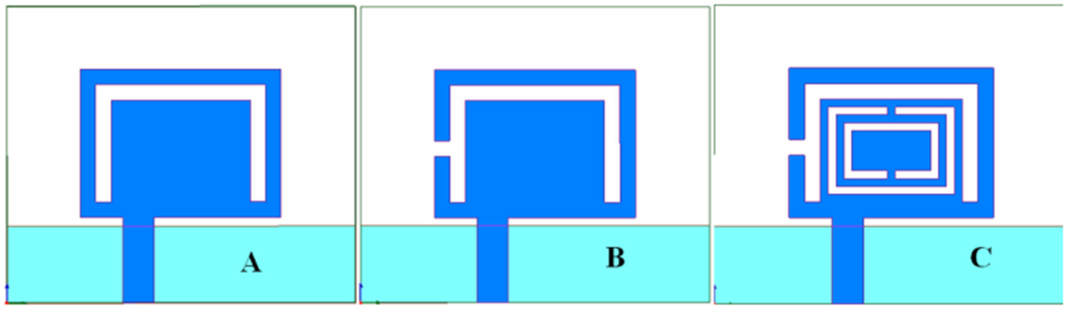

Fig. 1. Design steps of proposed antenna.

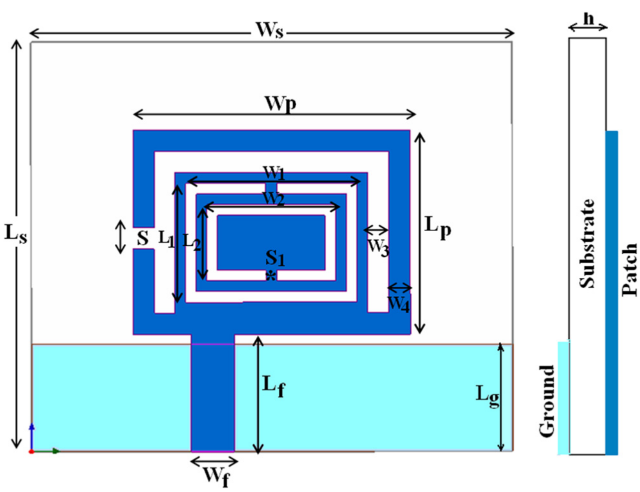

Fig. 2. Proposed antenna geometry and its side view.

Table 1
Parameters of the proposed antenna.

Parameter	Dimension (mm)	Parameter	Dimension (mm)
W_s	22.64	W_3	1
L_s	19.18	W_4	1
W_p	13.04	L_1	5.58
L_p	9.58	L_2	3.58
W_f	2	S	1
L_f	5.51	S_1	0.5
W_1	8.04	L_g	5
W_2	6.04		

corresponding to the CSRR geometrical parameters. The geometry of the proposed antenna for triple band operation is shown in Fig. 2. The parameters of the antenna are listed in Table 1. The snapshot of the fabricated antenna is shown in Fig. 3.

The simulated return loss characteristics of the three configurations is shown in Fig. 4. As figure shows, configuration A has a single band resonance at 5 GHz with an impedance bandwidth of 490 MHz (4.78–5.27 GHz). The split ring structure (configuration B) changes the monopole current path and in turn creates a lower resonance at 2.1 GHz. Also, it shifts the resonance frequency of 5–5.17 GHz. In configuration C, CSRR is introduced at the center

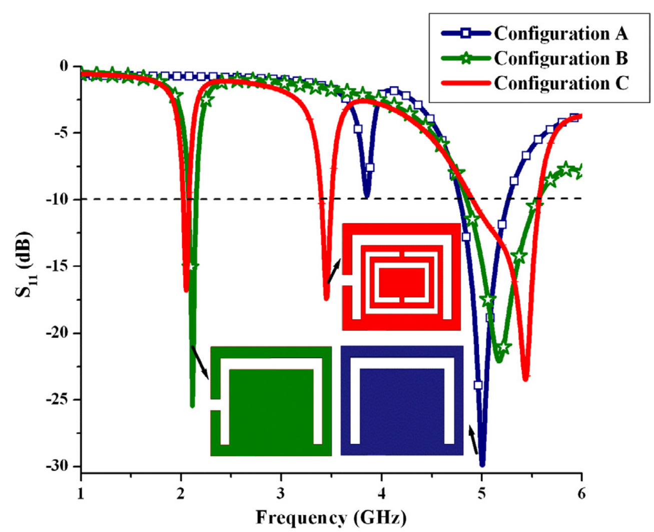

Fig. 4. Simulated return loss characteristics of the three different configuration of proposed antenna.

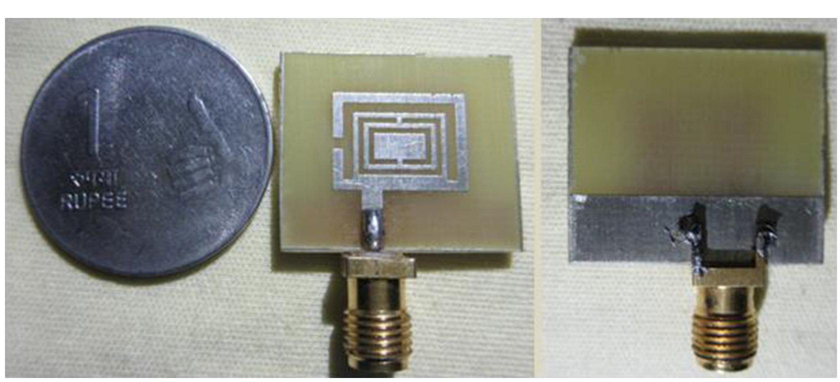

Fig. 3. Snapshot of the fabricated proposed antenna (top view and bottom view).