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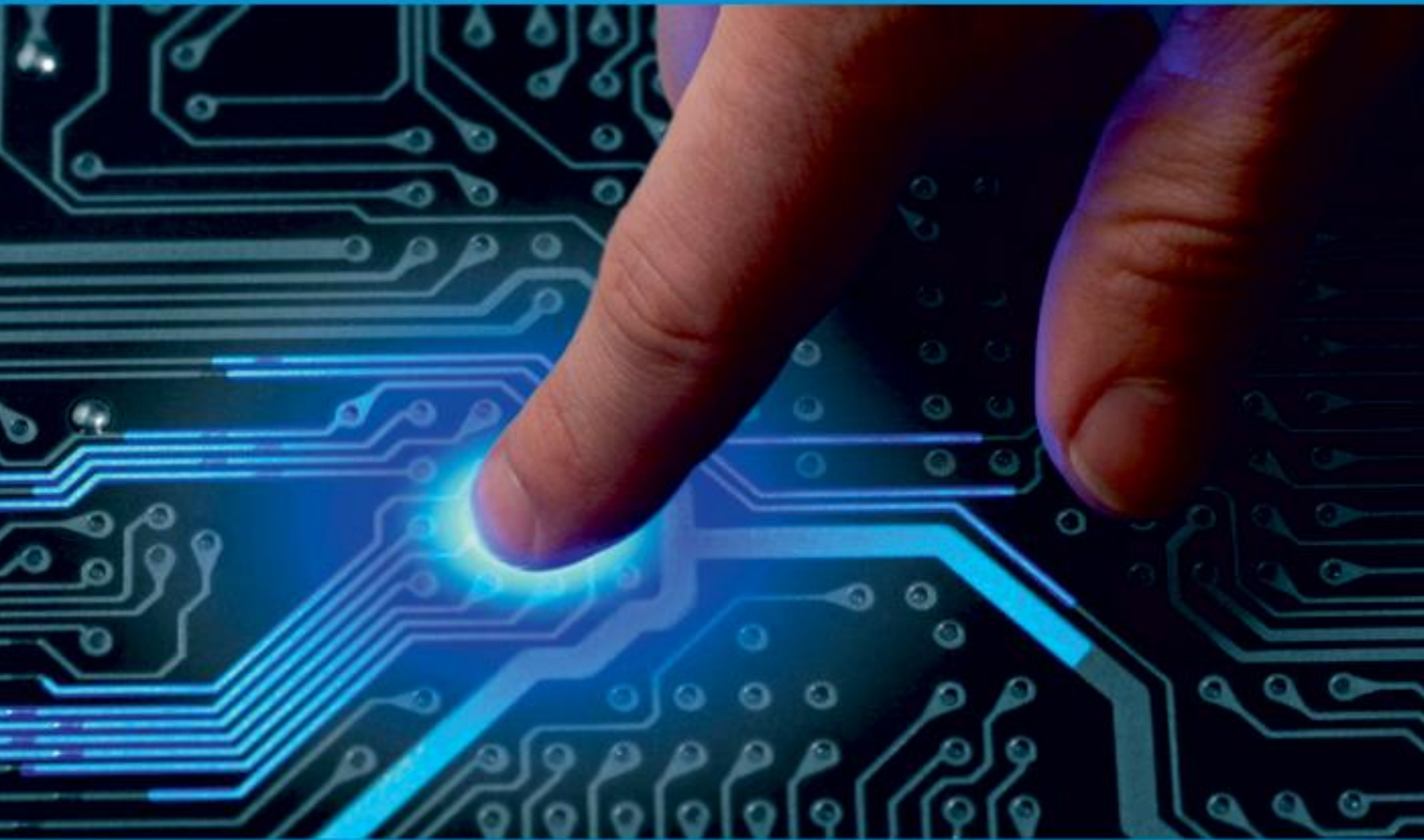

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Offset fed Metamaterial multiband antenna for wireless applications

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ABSTRACT: Objective to design a triband antenna with improved antenna characteristics namely gain VSWR. A miniaturized rectangle-shaped complementary split ring radiating element with an offset-fed microstrip line is reported for multiband operations. The fabricated antenna with a compact size of 19×19×1.6 mm3 is designed on an FR-4 substrate with loss tangent tan δ = 0.02 and dielectric constant (εr) of 4.4. Multiband and antenna miniaturization are achieved by a complementary split ring radiating element, and it produces an impedance bandwidth of 40 MHz resonance at 3.03 GHz, 40 MHz resonance at 3.66 GHz, and 1470 MHz resonance at 5.5 GHz. The passband behaviour of the complementary split ring radiating element is studied in detail for obtaining multiband abilities of the miniaturized antenna. The metamaterial property of the complementary split ring radiating element is analyzed, by which the negative permittivity (ε) existence and the new resonance frequency are confirmed. The fabricated antenna shows optimum performance at the measured radiation characteristics.

KEYWORDS: Multiband antenna, VSWR, Gain, Metamaterial, offset-fed.

I. INTRODUCTION

Metamaterial inspired antennas have been synthesized for multiband antenna design due to the verified extraordinary EM wave properties [1]. Metamaterial is a man-made homogenous structure composite to exhibit negative permeability (μ) and negative permittivity (ε) for performance enhancement of antenna [2]. Split Ring Resonator (SRR) exhibits negative value of permeability, and Complementary Split Ring Resonator (CSRR) exhibits negative value of permittivity.

Single Negative Metamaterial (SNG) is governed by either μ-negative material or ε-negative material, and Double Negative Metamaterial (DNG) is governed by both μ-negative material and ε-negative material [3]. Negative permittivity material is used to design new microwave components such as filters [4], power divider [5], branch line coupler [6], and multiband antenna design [7]. Due to the sub-wavelength resonator CSRR employs an antenna miniaturization [8] and bandwidth improvement [9]. The ε-negative metamaterial has spurred in millimeter wave frequency, such as phase shifter [10], circular polarization [11], and eliminates cross polarization [12]. Metamaterial absorber can be used for energy harvesting [13], multi-band polarization [14], and wide-band characteristics [15].

The objective of this paper is to investigate the performance of CSRR based radiating element with an offset-fed microstrip line for achieving multiband operation and 64% of antenna miniaturization. CSRRs passband behaviour and negative permittivity (ε) characteristics are discussed in detail for good understanding. The antenna is designed to operate in WiMAX (3.03/3.66 GHz) and WLAN (5.5 GHz) applications.

II. RELATED WORK

The complementary split ring radiating element generates the passband (S11) behaviour, which is examined by effective medium theory [16]. Here the radiating element is positioned inside a waveguide setup and is exposed to an EM wave along the input port of the waveguide. S-parameters S11 and S21 are measured through the output port of the waveguide. From these S-parameters, the values of permittivity (εr) and permeability (μr) are computed using Nicolson Ross Weir (NRW) equations [17].

$\varepsilon r = (2/jk0d) * (1 - V1)/(1 + V1)$ ......(1)

$\mu r = 2/(jk0d)*(1 - V2)/(1 + V2).$ ......(2)

where

V1 = S21 − S11

V2 = S21 + S11

k0 = Wave number of free space

d = substrate thickness

The passband (S11) characteristics of the rectangular radiating element and complementary split ring radiating element. It shows that the complementary split ring radiating element offers new passbands correlated with the rectangular radiating element. These passbands are responsible for obtaining multiband characteristics of the proposed antenna. The extracted negative permittivity (ε) of the proposed antenna. It describes that the negative permittivity is confirmed due to passband behaviour. The negative permittivity is observed for frequencies around 3 GHz, 3.66 GHz, and 6 GHz, and this is where the antenna has exhibited new resonance frequencies in the input reflection coefficient S11 (dB) characteristics. Thus, it is proved that the complementary split ring radiating element governs for attaining antenna miniaturization and multiband

III. PROPOSED ALGORITHM

The evolution steps of the proposed antenna design are shown in Fig. 1. The designed antenna is developed from a single resonance conventional monopole antenna as shown in evolution step (A) of Fig. 1. This conventional monopole antenna contributes a single resonance frequency of 5 GHz. In order to achieve a multiband and antenna miniaturization from this single band, the radiating element is reformed to arrange two pairs of complementary split rings as shown in evolution step (B) of Fig. 1

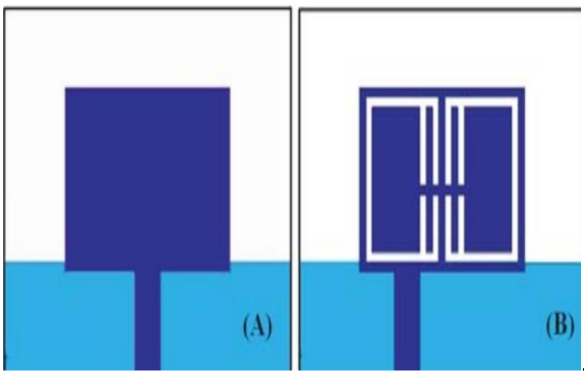

Figure 1. Evolution steps of antenna design

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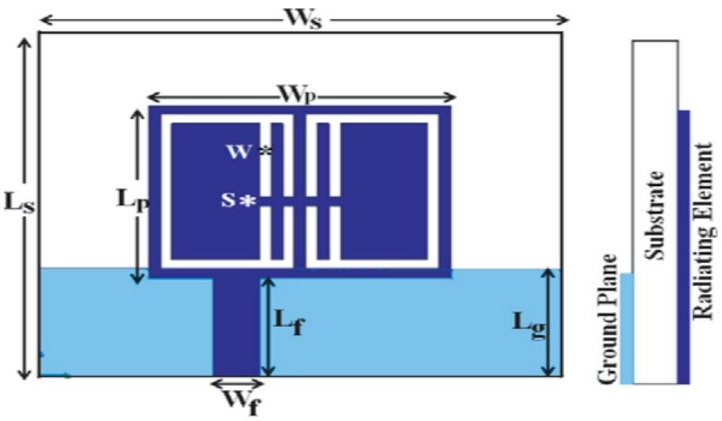

Figure 2. Antenna geometry and its side view.

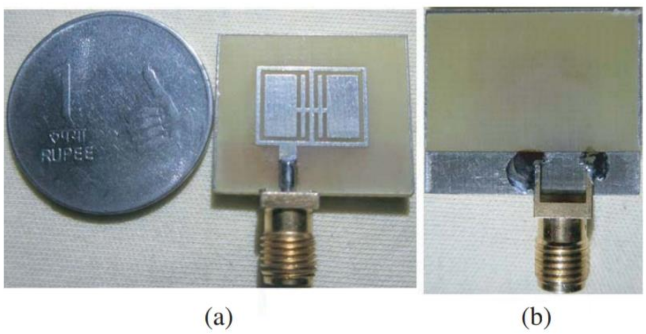

Figure 3. Fabricated antenna. (a) Top view. (b) Bottom view.

Parameter	Dimension (mm)
L_s	19
W_s	19
L_P	13.04
W_P	9.58
L_f	5.51
W_f	2
L_g	6
S	0.5
W	0.5

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IV. SIMULATION RESULTS

The simulated and measured reflection coefficients S11 (dB) of the antenna. Numerical values are displayed in Table 2. Experimental result matches simulated results perfectly. Measured S11 (dB) covers the impedance bandwidth of 40 MHz (2.98–3.02 GHz) centered at 3 GHz, 40 MHz (3.58–3.62 GHz) centered at 3.6 GHz, and 1470 MHz (4.93–6.4 GHz) centered at 5.5 GHz, which is useful for WiMAX and WLAN applications.

The far-field (R □ 2D2λ (Friis equation)) radiation patterns and antenna gains are measured in an anechoic chamber. Measured radiation patterns at 3 GHz, 3.6 GHz, and 5.5 GHz.. They exhibit the dipole pattern at elevation plane and omnidirectional pattern at azimuthal plane, which govern the significant directions for WiMAX and WLAN operating bands. The simulated and measured gain plots as a function of frequency are illustrated.Measured peak gains 2.4 dBi, 3.07 dBi, and 4.64 dBi are inferred at 3 GHz, 3.6 GHz, and 5.5 GHz, respectively.

Table 2. Numerical results of simulated and experimental values of the proposed antenna.

Proposed antenna	Resonance frequency (GHz)	S_{11} (dB)	Impedance bandwidth (MHz)
Simulated	3.03	−19	80
	3.66	−24	50
	5.5	−19	1640
Measured	3	−12	40
	3.6	−16	40
	5.5	−17	1470

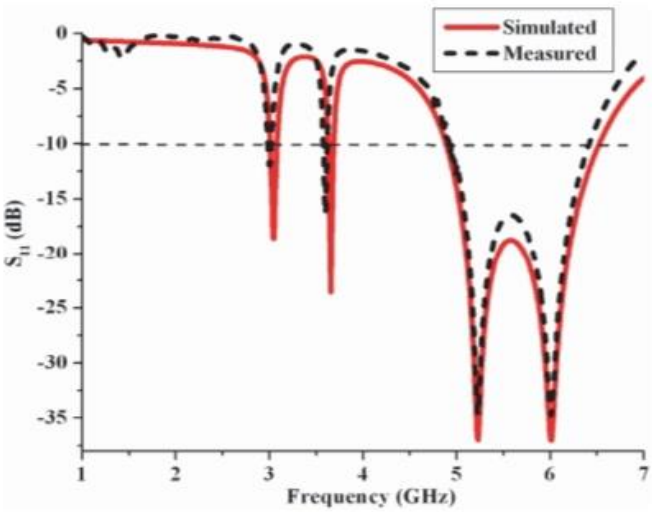

Fig.3: Simulated and experimental S11 (dB) characteristics.

V. CONCLUSION AND FUTURE WORK

A miniaturized CSRR based radiating element with offset-fed microstrip line is discussed for WiMAX and WLAN applications. The radiating element is reformed to arrange two pairs of complementary split rings, which also verifies negative permittivity presence, due to which new resonance frequencies are created. The parametric analysis of feed position, slit gap, and equivalent circuit of the proposed antenna has been studied for multiband abilities. The passband behaviour of the CSRR radiating element is explained by effective medium theory to validate the multiband

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characteristics. The measured input reflection coefficient, peak gain, and far-field patterns sufficient for the desired wireless applications

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