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Design & Development of Compact Met Material Based Antenna for WLAN/WiMAX Applications

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Abstract- **This project presents a compact triple band antenna for the frequency bands 5.5/6.7/9 GHz, These bands are assigned to the IEEE 802.11g and IEEE 802.16e standards. The resonant modes for WLAN, WiMAX bands are achieved by employing a rectangular slot and a met material inspired split ring structure. Also Ultra-wideband (UWB) systems have attracted significant research attention since the Federal Communication Commission (FCC) released a band of 7.5 GHz (3.1-10.6 GHz) as UWB in 2002. The proposed antenna with a compact size of 35 mm × 35 mm is fabricated and tested. The triple band antenna yields a −10 dB impedance bandwidth of about 18.6%, 4.3% and 40.3% in 5.5, 6.7 and 9 GHz bands respectively. Stable radiation patterns with low cross polarization and high average antenna gain of 6 dBi are observed for the operating bands.**

Keywords **- Met materials, Negative permeability, Split ring resonator, Reconfigurability, WiMAX, WLAN**

I. INTRODUCTION

Electromagnetic metamaterials were first investigated by the Russian physicist Victor Veslago [1]. Recently, there is a great interest from electromagnetic waves community in investigating metamaterial structures. Specifically, a great interest has been paid on studying the characteristics of using these artificially constructed metamaterials in possible RF/microwave circuit applications. The studies show that these materials have unique electromagnetic properties at microwave frequency bands which are not found using conventional materials.

Because of the rapid development of the mobile communication systems such as the wireless local area network (WLAN) and the Worldwide Interoperability for Microwave Access (WiMAX), antennas having compact size, multiband operation, low cost, and ease of integration are urgently needed. Several techniques such as using meander line, fractal geometries, various shape slots [2]–[5], or embedding chip inductors in the monopole antennas [6], [7] have been adopted to achieve compact size. Some antennas having multiband performance have also been investigated in [8]–[16].

In Wireless applications, low profile, compact planar antennas are preferred. Moreover, they should be characterized by simple design, and omni-directional radiation pattern. The conventional microstrip patch antenna In this paper we introduce a compact band metamaterial antenna for WiMAX upper bands applications, (5.8 GHz band). The designed antenna has the compactness advantage. Its overall size is only (only 35 X 35) mm2. Moreover, its radiator patch length is only 60% 5.8 GHz. In other words, the antenna length has reduced by more than 75% compared to conventional antenna.

The theoretical explanation of the designed antenna is introduced. The performance of the proposed antenna is evaluated using the electromagnetic full wave simulations. The commercial software HFSS was employed. All radiated antenna parameters were extracted.

II. ANTENNA DESIGN

Fig. 1 shows the design of the proposed antenna. The antenna with the monopole only, the monopole, rectangular patch and SRR, and Fig. 2 shows the design evolution for proposed antenna.

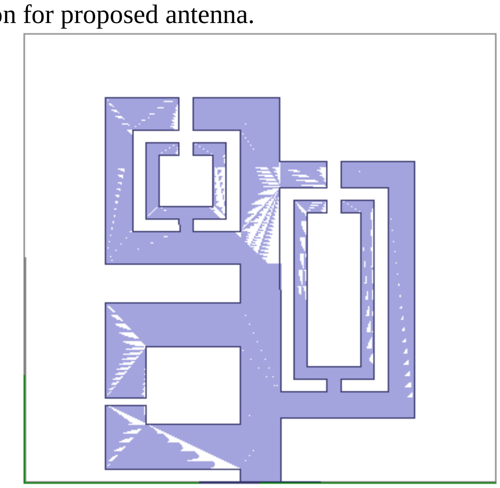

Figure 1. The layout of the initial design dual band antenna

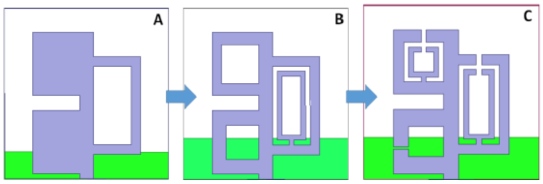

Figure 2. Evolution of the proposed split ring monopole antenna

The geometry and the dimensions of the proposed antenna as shown in configuration 'C' in Fig. 2 is further illustrated in Fig. 3 with details and a side view. The proposed antenna is fabricated on a low cost FR4 substrate with dielectric constant $\varepsilon_r = 4.4$ as shown in Fig. 3. The thickness, h, of the substrate is 1.6 mm and loss tangent, tan is about 0.018. The dimensions of the proposed antenna, after due optimisation, are listed in Table 1.

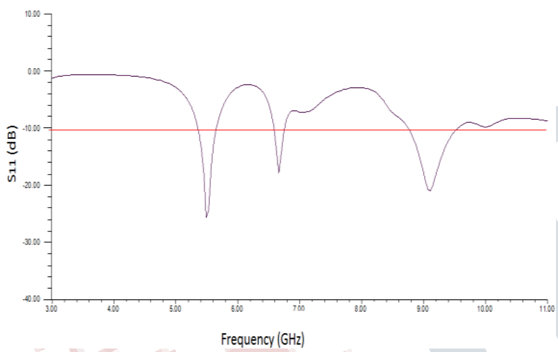

Figure 4. The simulated Return loss of the final designed metamaterial antenna at intrinsic variation freq. of 5 GHz

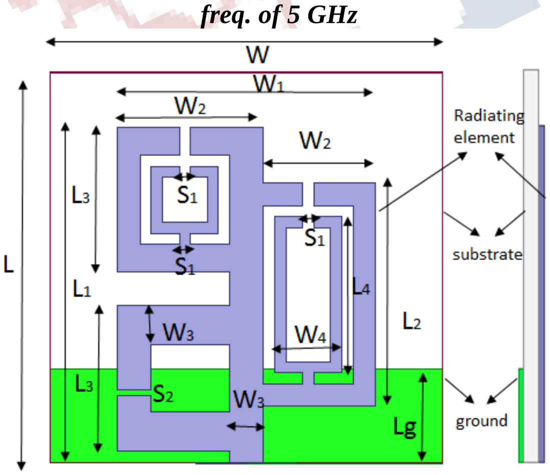

Figure 3. Geometry of Proposed Antenna Configuration

III. RESULTS AND DISCUSSION

All the simulations have been carried out on finite element method (FEM) numerical technique based Ansoft High Frequency Structure Simulator (HFSS) [24].

Table 1
Dimensions of the proposed antenna illustrated in Fig. 3

Parameter	L	W	L_1	L_2	L_3	L_4	W_1	W_2	W_3	W_4	Lg	S_1	S_2
Dimensions	35	35	30	20	13	14	23	10	3	6	8.4	1	0.5

The variation of return loss with frequency is shown in Fig. 4. In a triple band system, the measured first resonant frequency occurs at 5.5 GHz with an impedance bandwidth of about 240 MHz (5.38–5.62 GHz) , the second resonant frequency occurs at 6.7 GHz with a wide impedance bandwidth of about 200 MHz (6.6–6.8 GHz) and the third resonant frequency occurs at 9 GHz with a wide impedance bandwidth of about 900 MHz (8.6–9.5 GHz). The simulation results from the Ansoft HFSS are in good agreement.

Fig. 5. shows the comparative simulated S-parameter of the Ant. A, Ant. B and Ant. C at intrinsic frequency of 5 GHz. Simulated radiation pattern of a proposed antenna is shown in Fig. 6. The peak realised antenna gain of 6 dBi is observed from Fig. 7.

Fig. 9. shows the surface current distributions of the proposed antenna at different frequencies (5 GHz, 7 GHz, and 9 GHz). It is observed that at lower frequency maxicmum surface current is concentrated near bottom side of the radiating patch but as frequency increases the current distribution starts to flow towards the top section of the patch. Therefore, it can be concluded that at lower frequency side the radiation become more prominent from bottom section of radiating structure while as frequency increases the top section of radiating element contributed in radiation.

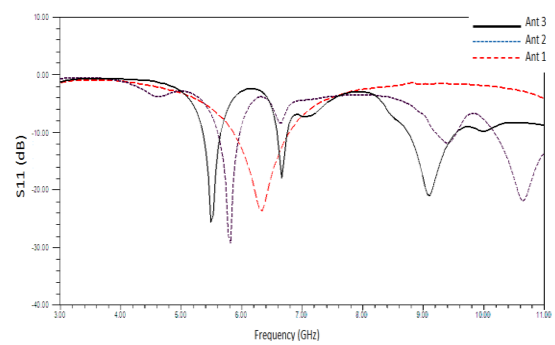

Figure 5. The simulated Return loss of the various designed metamaterial antenna at intrinsic variation freq. of 7 GHz

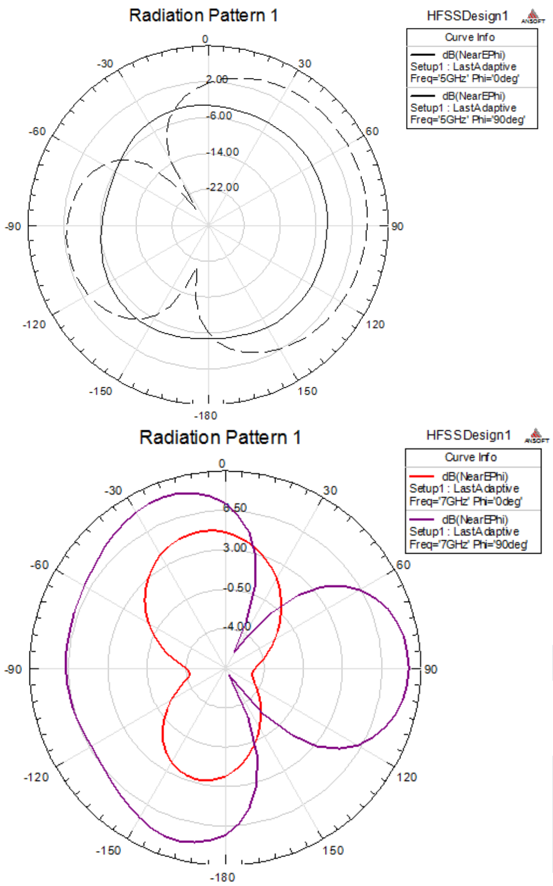

Figure 6. Simulated radiation pattern of the proposed antenna at (a) 5 GHz, (b) 7 GHz,

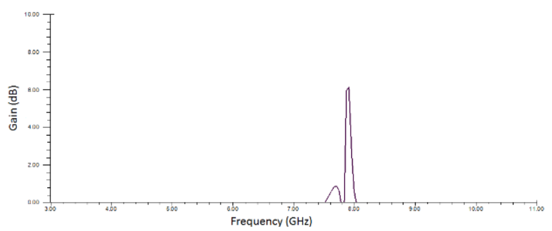

Figure 7. The simulated Gain of the final designed metamateria antenna at intrinsic variation freq. of 7 GHz.

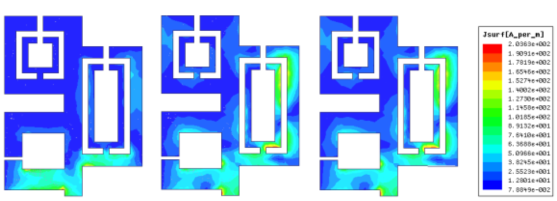

Figure 8. Simulated results of the surface current distribution for the proposed antenna at 5 GHz, 7 GHz and 9 GHz

To extract the permittivity and permeability of an antenna we required the parameters refractive index (n) and impedance (z). The values of refractive index (n) and impedance (z) are determined using the Eqs. (1) and (2) as proposed by [21,23].

$$n = \frac{1}{kd}\cos^{-1}\left[\frac{1}{2S_{21}}\left(1 - S_{11}^2 + S_{21}^2\right)\right] \text{---------------(1)}$$

$$z = \sqrt{\frac{(1+S_{11})^2 - S_{21}^2}{(1-S_{11})^2 - S_{21}^2}} \text{----------------(2)}$$

The value of effective permittivity ε and effective permeability μ then may be computed as $\varepsilon_{eff} = n/z$ and $\mu_{eff} = n * z$.

The condition Im{n}≥0 fix the choice for sign of 'n'. Similarly the condition Re{z}≥0 fixes the choice for sign of 'z'. An improved parameter retrieval method given in (Liu and Wang, 2012) is as follows:

$$n = \frac{ln\left(\frac{S_{21}}{1 - S_{11}\frac{z-1}{z+1}}\right)}{ikd}$$

Till now we got only S11 parameter, to get S21 parameter we required to 2 port antenna. By extending the antenna to upper boundary and then adds another port to the antenna we got two port antenna and both the ports are excited by wave port excitation. So we can got the remaining parameter as shown.

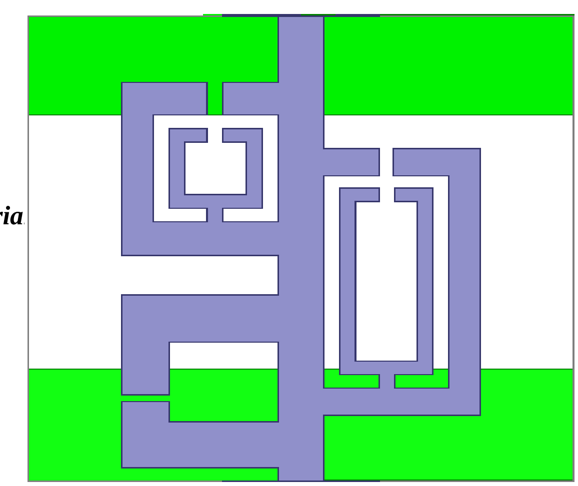

Figure 9. Two port proposed antenna.

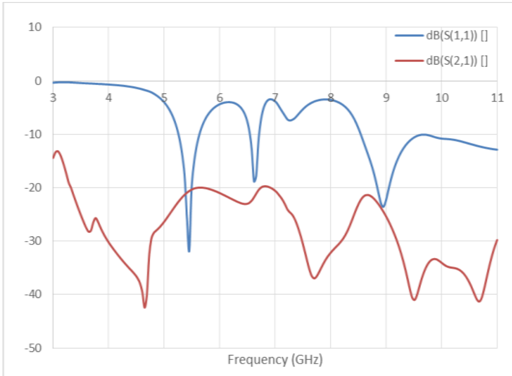

Figure 10. The simulated S-parameter of two port antenna at intrinsic variation freq. of 7 GHz

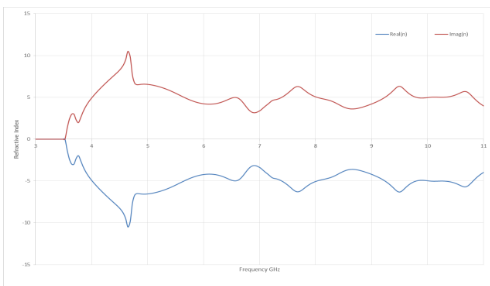

Figure 11. Refractive index Vs Frequency

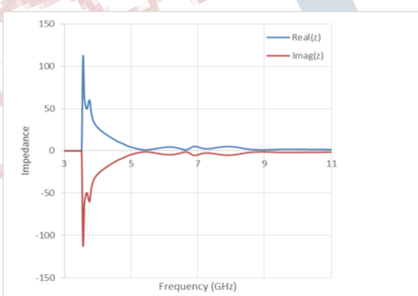

Figure 12. Wave Impedance Vs Frequency.

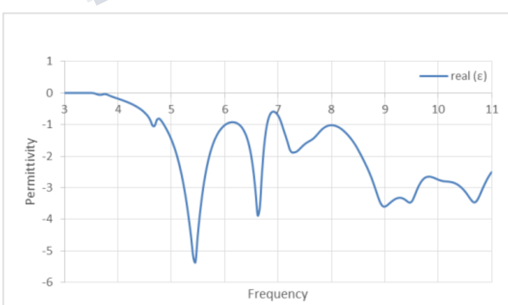

Fig. 13. Extracted negative permeability characteristics of the proposed

IV. CONCLUSION

A Compact triple band metamaterial antenna for upper 5.8 GHz WiMAX and 5.2 GHz WLAN frequency bands has been presented. The antenna design and performance has been introduced using electromagnetic full wave simulations. The results illustrate that the proposed antenna can demonstrate better than 15 dB return loss at the operating bands. Also, antenna demonstrate almost typical omni-directional radiation pattern at the operating frequencies with better than 15 dB difference in co polarized and cross polarized component. Finally, the proposed antenna has been miniaturized up to 75% compared to conventional patch antenna.

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