A New Design of Printed Monopole Antenna with Multi-Resonance Characteristics for DCS/WLAN/WiMAX Applications

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Abstract **─** In this paper, a new printed monopole antenna is presented for simultaneously satisfying DCS, wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The operating frequencies of the proposed antenna are 1.8 GHz, which covers DCS operations, 2.4/5.2/5.8 GHz for WLAN system and 2.5/3.5/5.5 GHz for WiMAX system. The desired first and second resonant frequencies are obtained by adjusting the length of the L-shaped slits. Also by cutting an inverted Γ-shaped slot in the radiating patch; multi band performance can be produced. Prototypes of the proposed antenna have been constructed and studied experimentally. The measured results show good agreement with the numerical prediction and good multiband operation.

Index Terms **─** L-shaped structure, monopole antenna, and multi-resonance characteristics.

I. INTRODUCTION

The evolution of the mobile communication system has required simple configuration, light and easy integration with monolithic microwave integrated circuits (MMICs) and multiband antennas for the widespread system application. For such reasons, numerous designs of multiple-band microstrip antenna have been developed for DCS applications [1-3]. Also in the last few years, there have been rapid developments WLAN/WiMAX applications, thus there are various antenna designs, which enable antennas with low-profile, lightweight, flush mounted, and WLAN/WiMAX devices. These antennas include the planar inverted-F antennas [4], the chip antennas [5, 6], and the planar slot antennas [7, 8].

In this paper, a compact wideband microstrip-fed monopole antenna is designed to satisfy all the system requirements for DCS1800 (1.71 GHz – 1.88 GHz), DCS1900 (1.85 GHz – 1.99 GHz), WiBro (2.3 GHz – 2.39 GHz), WLAN (2.4 GHz – 2.483 GHz), and WiMAX (2.5 GHz, 3.5 GHz, and 5.5 GHz), simultaneously. By cutting two L-shaped slits in the square radiating patch, we can tune frequency bands for 1.8/2.4/5.2/5.8 GHz. Also by cutting an inverted Γ-shaped in the radiating patch, a new resonance at 3.5 GHz can be created. Details of the antenna design are described, and prototypes of the proposed antenna have been constructed and tested. The size of the designed antenna is smaller than the antennas for DCS/WLAN/WiMAX applications that reported recently [1-8].

II. ANTENNA DESIGN

The current design (Fig. 1) was performed for FR4 substrate of thickness 1.6 mm, permittivity 4.4, and loss tangent 0.018. The antenna comprises a pair of L-shaped slits and an inverted Γ-shaped cut on the square radiating patch. The basic monopole antenna structure consists of a square patch, a feed line, and a ground plane. In this study, two L-shaped slits in the radiating patch are

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used to perturb a new resonance. In the proposed configuration the inverted Γ-shaped is playing an important role in the multi band characteristics of this antenna, because it can creates additional surface current paths in the antenna therefore additional resonance is excited [5, 6].

The optimal dimensions of the designed printed monopole antenna are as follows: W_{sub} = 14 mm, L_{sub} = 22 mm, h_{sub} = 1.6 mm, W = 12 mm, L = 13 mm, W_f = 2 mm, L_f = 3 mm, W_S = 3 mm, L_S = 12 mm, W_{S1} = 6 mm, L_{S1} = 5 mm, W_1 = 7.5 mm, L_1 = 10 mm, W_2 = 6.5 mm, L_2 = 9.25 mm, W_3 = 0.5 mm, and L_{gnd} = 5 mm. It is found that the designed antenna satisfies all the requirements in the desired frequency band.

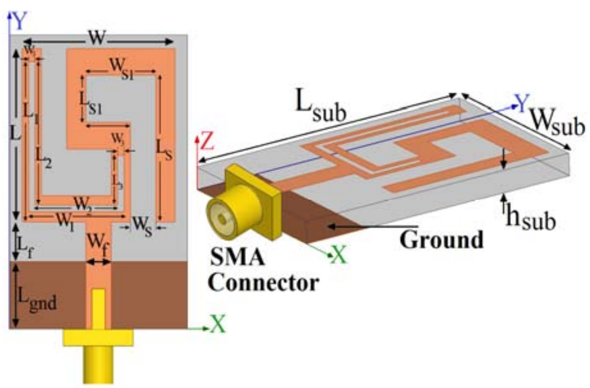


Fig. 1. Geometry of the proposed antenna, (a) top view and (b) side view.

III. RESULTS AND DISCUSSIONS

In this section, the printed monopole antenna was constructed. Both numerical and experimental results of the input impedance and the radiation characteristics are presented and discussed. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [9].

The configuration of the presented monopole antenna was shown in Fig .1. The return loss characteristics for the ordinary square antenna with an L-shaped slit in the radiating patch (Fig. 2 (a)), with two L-shaped slits in the radiating patch (Fig. 2 (b)), and the proposed antenna structure (Fig. 2 (c)) are compared in Fig 3. As shown in Fig. 3, it is observed that the lower frequency bandwidth is affected by using two L-shaped slits and by cutting an inverted Γ-shaped in the radiating patch, a new resonance at 3.5 GHz can be created. Also the input impedance of the proposed antenna, on a Smith chart is shown in Fig. 4.

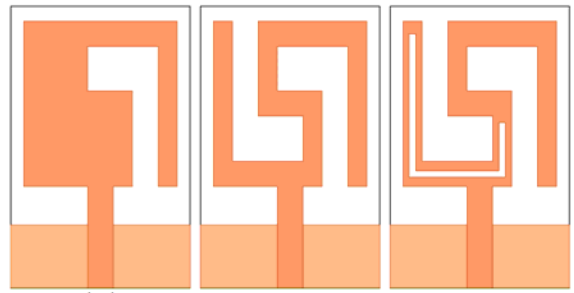


Fig. 2. (a) The ordinary square antenna with an L-shaped slit in the radiating patch, (b) the antenna with a pair of L-shaped slits in the radiating patch, and (c) the proposed antenna.

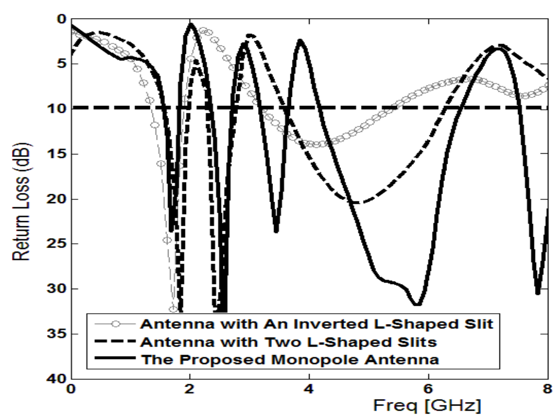


Fig. 3. Simulated return loss characteristics for the antennas shown in Fig. 2.

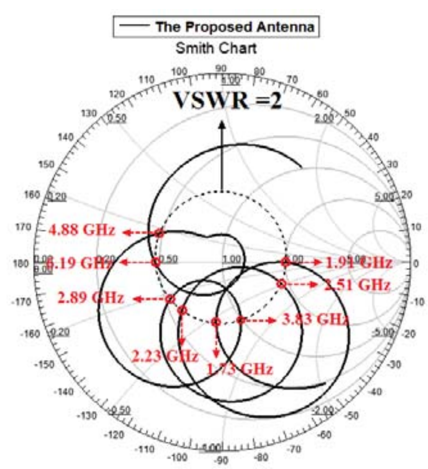
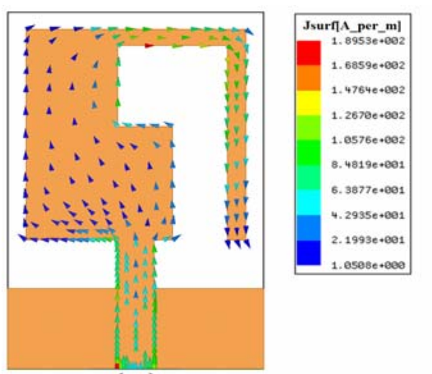
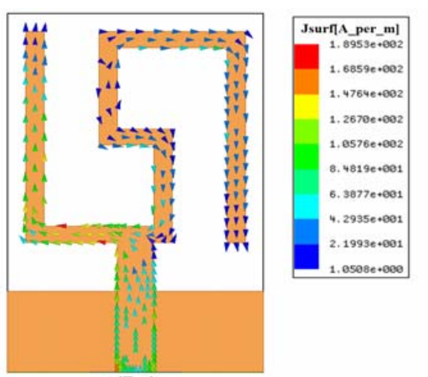


Fig. 4. Smith chart demonstration of the simulated input impedance for various monopole antenna structures, shown in Fig. 2.

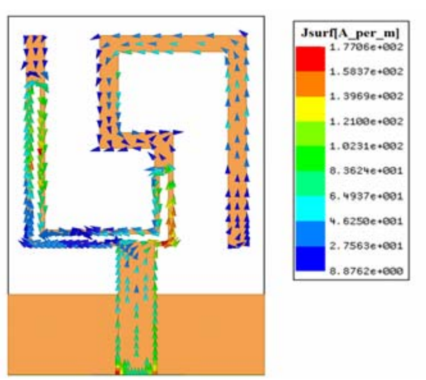
Moreover, the input impedance of the proposed antenna, on a Smith chart is shown in Fig. 4. In order to understand the phenomenon behind this multi-resonance performance, the simulated current distributions for various square slot antenna structures shown in Fig. 2, at new resonances frequencies 1.8 GHz, 2.4 GHz, and 3.5 GHz are presented in Fig. 5, respectively.



(a)



(b)



(c)

Fig. 5. Simulated surface current distributions on the radiating patch for antennas shown in Fig. 2 at (a) first resonance frequency (1.8 GHz), (b) second resonance frequency (2.4 GHz), and (c) third resonance frequency (3.5 GHz).

It can be observed that in Fig. 5 (a) and (b), that the current concentrated on the edges of the interior and exterior of the L-shaped slits at 1.8 GHz and 2.4 GHz. Therefore, the antenna impedance changes at these frequencies due to the resonant properties of the L-shaped slits [8]. Another important design parameter of this structure is the inverted Γ-shaped slot used in the radiating patch. Figure 5 (c) presents the simulated current distributions on the radiating patch of the proposed antenna at 3.5 GHz. As shown in Fig. 5 (c), at the third resonance frequency the current flows are more dominant around of the inverted Γ-shaped slot structure.

The proposed antenna with optimal design was built and tested. The measured and simulated return loss characteristics of the proposed antenna are shown on Fig. 6. The fabricated antenna has the frequency band from 1.73 GHz – 1.91 GHz, 2.23 GHz – 2.51 GHz, 2.89 GHz – 3.83 GHz, and 4.88 GHz – 6.19 GHz, that satisfy all the system requirements for DCS1800 (1.71 GHz – 1.88 GHz), DCS1900 (1.85 GHz – 1.99 GHz), WiBro (2.3 GHz – 2.39 GHz), WLAN (2.4 GHz – 2.483 GHz), and WiMAX (2.5 GHz, 3.5 GHz, and 5.5 GHz), simultaneously. As shown in Fig. 6, there exists a discrepancy between the measured and simulated results. In order to confirm the accurate return loss characteristics of the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully. In conclusion, as the monopole is a short radiator, the SMA connector can modify its impedance matching.

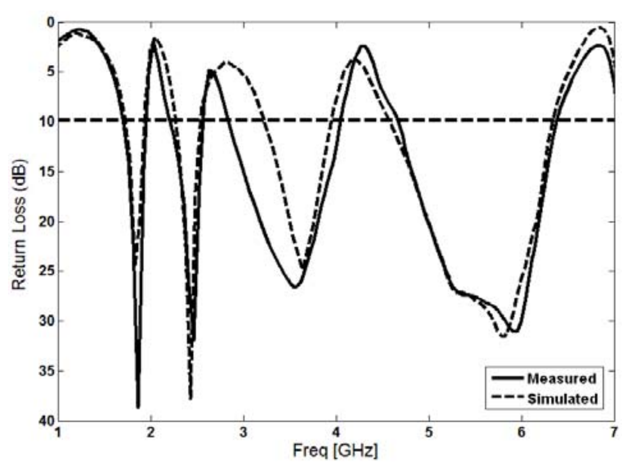


Fig. 6. Measured and simulated return loss for the proposed antenna.

The simulated radiation efficiencies and the measured maximum gains of the proposed antenna are shown in Figs. 7 and 8, respectively. Results of the calculations using the software HFSS indicated that the proposed antenna features a good efficiency, being greater than 62 % across the entire radiating band, as shown in Fig. 7. Also, the measured maximum gains of the proposed antenna are presented in Fig. 8. As shown in Fig. 8, the proposed antenna has a gain that is low at 1 GHz and increases with frequency.

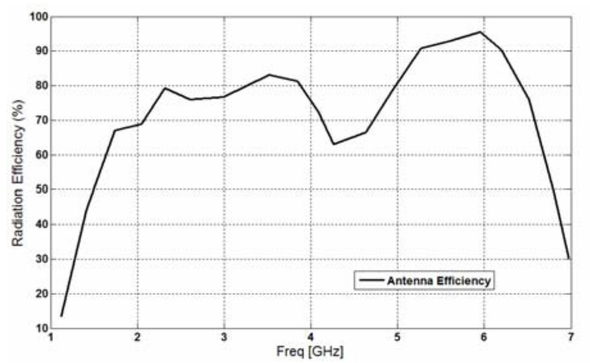


Fig. 7. Simulated radiation efficiency values of the proposed monopole antenna.

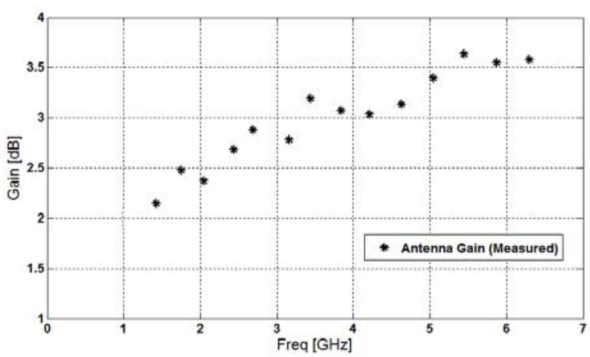


Fig. 8. Measured maximum gain and simulated radiation efficiency values of the proposed monopole antenna.

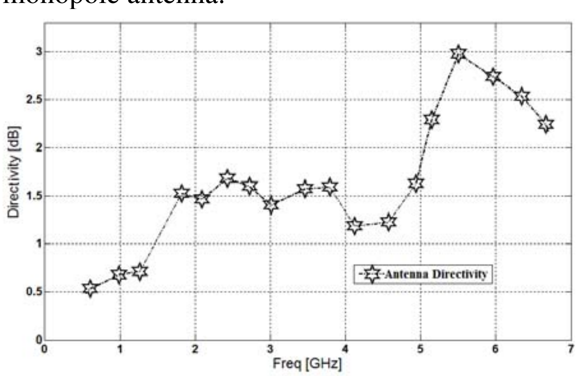


Fig. 9. Simulated directivity characteristics of the proposed monopole antenna.

The simulated directivity characteristic for the proposed antenna is shown in Fig. 9. As shown in Fig. 9, the directivity characteristics of the proposed monopole antenna have a variation similar to other monopole antennas directivity at DCS/WLAN/ WiMAX frequencies bands [7]. Figures 10 and 11 show the measured radiation patterns at resonance frequencies including the co–polarization and cross–polarization, in the H–plane (x–z plane) and E–plane (y–z plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a multi frequency band. It can be seen that the radiation patterns in *x–z* plane are nearly omni–directional even at higher frequencies, and also the cross–polarization level is low for the five frequencies.

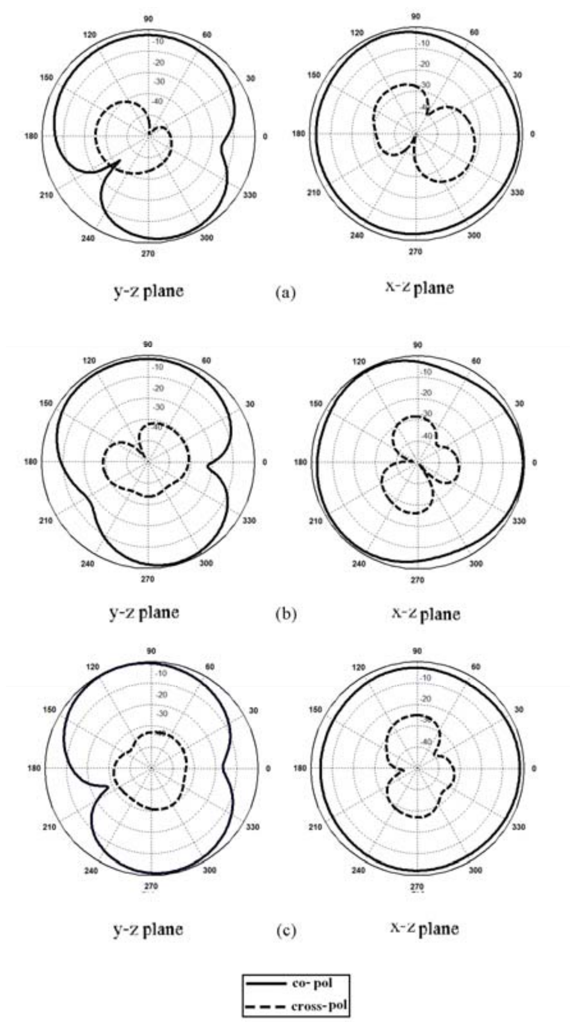


Fig. 10. Measured radiation patterns of the proposed antenna at (a) 1.8 GHz, (b) 2.4 GHz, and (c) 3.5 GHz.

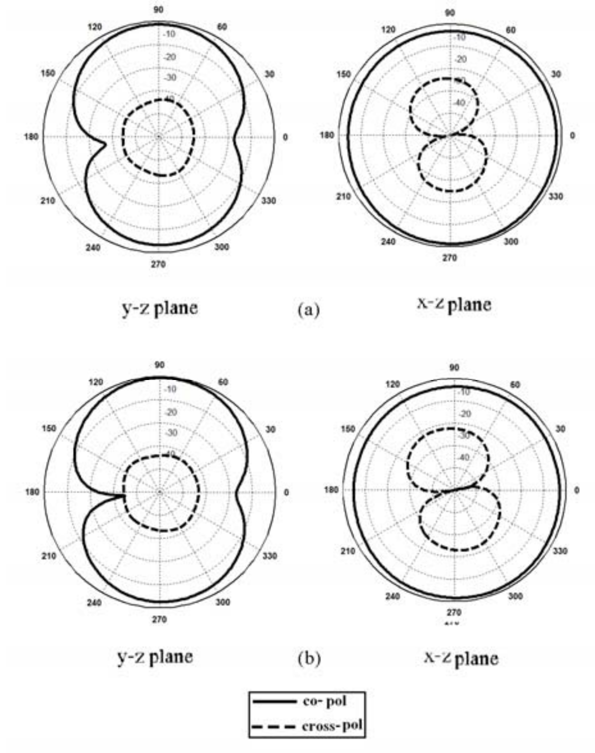


Fig. 11. Measured radiation patterns of the proposed antenna at (a) 5.2 GHz and (b) 5.8 GHz.

IV. CONCLUSION

In this paper, a new multi-resonances printed monopole antenna by using a pair of L-shaped slits and an inverted Γ-shaped is presented for satisfying DCS operations at the 1.8 GHz frequency, WLAN operations at the 2.4 GHz, 5.2 GHz, and 5.8 GHz frequencies and also for WiMAX operations at the 2.5 GHz, 3.5 GHz, and 5.5 GHZ frequencies. Prototypes of the proposed antenna have been constructed and studied experimentally. The measured results showed good agreement with the numerical prediction. By adjusting the L-shaped slits the desired first and second resonant frequencies are obtained by adjusting the length of L-shaped slits. Also by cutting an inverted Γ-shaped slot in the radiating patch, a new resonance at 3.5 GHz can be created. Prototypes of the proposed antenna have been constructed and studied experimentally

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