Microstrip-Fed Monopole Antenna with Triple Band Performance for WLAN/WiMAX Applications

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Abstract **─** In this paper, a printed monopole antenna is presented for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The desired resonant frequencies are obtained by cutting four L-shaped slits in both sides of square radiating patch and an H-shaped slot around the slits. Prototypes of the proposed antenna have been constructed and studied. The measured impedance bandwidth for l0 dB return loss is from 2.23 GHz to 2.60 GHz (15.0 %), 3.05 GHz to 4.10 GHz (29.3 %) and 5.02 GHz to 5.86 GHz (15.2 %), covering the 2.4/3.5/5.5 GHz for WLAN/WiMAX applications. Simulated and experimental results obtained for this antenna show that the proposed antenna has a good radiation behavior within the 2.4/3.5/5.5 GHz frequencies.

Index Terms **─**Microstrip-fed monopole antenna, L-shaped slit, triple-band, and ultra-wideband (UWB) systems.

I. INTRODUCTION

In the last few years, there have been rapid developments in wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The 2.4/5.2/5.8 GHz (2.4 GHz-2.84 GHz / 5.15 GHz-5.35 GHz / 5.725 GHz-5.825 GHz) and 2.5/3.5/5.5 GHz (2.500-2690/3400-369/5250-5850 MHz) bands are demanded in practical WLAN and WiMAX applications, respectively. During the last years, there are various antenna designs, which enable antennas with low-profile, light weight, flush mounted and WLAN/WiMAX devices. These antennas include the planar inverted-F antennas [1], the chip antennas [2], and the planar dipole and monopole antennas [3-4].

In this paper, a multiband printed antenna is proposed. The size of the designed antenna is smaller than that of the antennas [1-4] for WLAN/WiMAX application. By cutting four L-shaped slits and an H-shaped slot, we can tune frequency bands. Details of the antenna design are described, and prototypes of the proposed antenna for WLAN/WiMAX operations at the 2.4 GHz, 3.5 GHz, and 5.5 GHz frequencies have been constructed and tested.

II. ANTENNA DESIGN

The proposed monopole antenna fed by a microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 1.6 mm, and permittivity 4.4. The proposed antenna configuration comprises pairs of L-shaped slits and an H-shaped slot cut on the square radiating patch. The basic monopole antenna structure consists of a square patch, a feed line, and a ground plane. The triple-band performance of the proposed antenna is significantly affected by using the modified radiating patch on top layer of the substrate.

In order to design a multi-band antenna in the first step, two L-shaped slits in the bottom corners of the antenna radiating patch are used to perturb a

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new resonance. By cutting another pair of L-shaped slits in the top corners of the radiating patch the antenna can create the second resonant frequency in individual resonant radiation band.

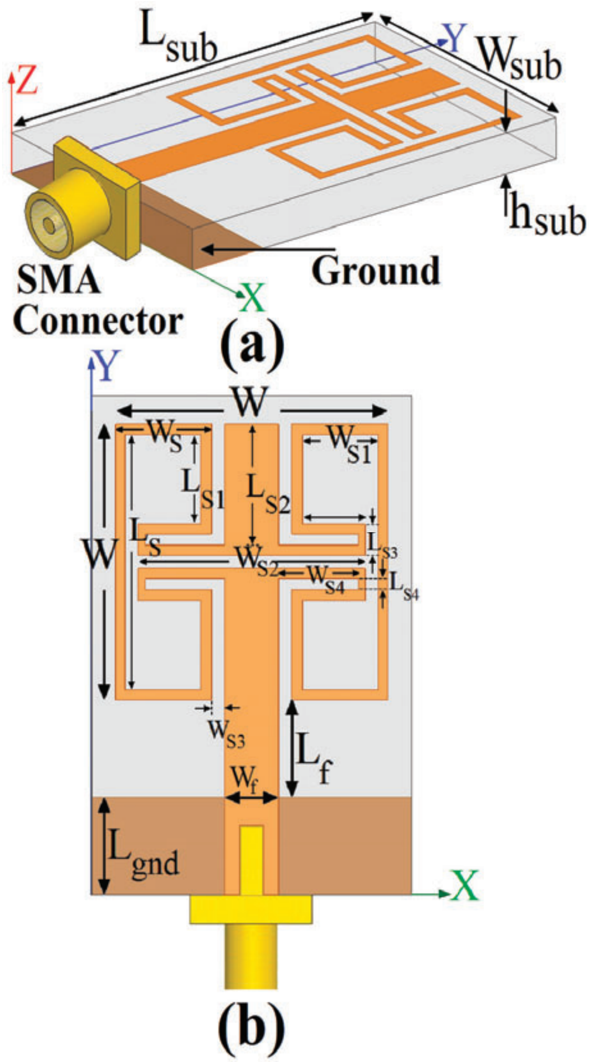


Fig. 1. Geometry of the proposed monopole antenna, (a) side view and (b) top view.

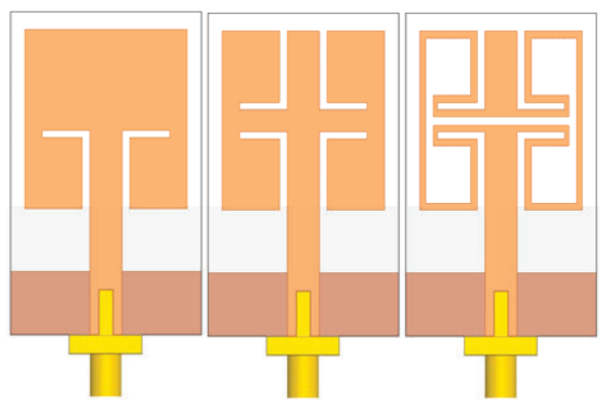
By creating these modified slits additional current paths are provided on the radiating patch. Moreover, these structures change the inductance and capacitance of the input impedance, which in turn leads to change the bandwidth. Therefore, by cutting four L-shaped slits at the square radiating patch and carefully adjusting its parameters, extra frequency resonances are exited and dual-band performance can be achieved. In the proposed configuration the modified H-shaped slot is playing an important role in the multi band characteristics of this antenna, because it can creates another additional surface current path in the antenna therefore additional (third) resonance is excited.

The dimensions of the proposed antenna are as follows: W_{Sub} = 12 *mm*, L_{Sub} = 18 *mm*, h_{Sub} = 1.6 *mm*, W = 10 *mm*, W_f = 2 *mm*, L_f = 3.5 *mm*, W_S = 3.5 *mm*, L_S = 9.5 *mm*, W_{S1} = 3 *mm*, L_{S1} = 3.5 *mm*, W_{S2} = 8.5 *mm*, L_{S2} = 4.5 *mm*, W_{S3} = 0.5 *mm*, L_{S3} = 1 *mm*, W_{S4} = 3 *mm*, L_{S4} = 0.5 *mm*, and L_{gnd} = 3.5 *mm*.

III. RESULTS AND DISCUSSIONS

In this section, the monopole antenna with various design parameters was constructed. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [5].

Figure 2 shows the structure of the various antennas used for triple-band performance simulation studies. Return loss characteristics for ordinary square monopole antenna with two L-shaped slits, with four L-shaped slits, and the proposed antenna (simulated and measured results) are compared in Fig. 3.



(a) (b) (c)

Fig. 2. (a) Ordinary square antenna with two L-shaped slits, (b) with four L-shaped slits, and (c) the proposed antenna structure.

In Fig. 3, the square antenna with two L-shaped slits resonates single band 3.5 GHz. The square antenna with four L-shaped slits on the radiating patch produces dual-band 3.5 GHz / 5.5 GHz. Finally, by cutting a modified H-shaped slot in the radiating patch a triple-band is achieved that covering all the 2.4/3.5/5.5GHz.

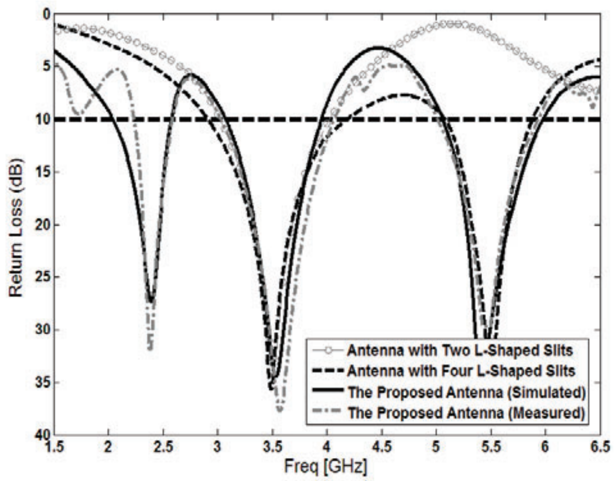


Fig. 3. Return loss curves of three antennas shown in Fig. 2.

In order to understand the phenomenon behind this additional resonance performance, the simulated current distributions on the radiating patch for the ordinary square antenna with two and four L-shaped slits on the radiating patch at 3.5 GHz and 5.5 GHz are presented in Fig. 4 (a) and (b), respectively. It is found that, the current flows are more dominant around of the L-shaped slits at these frequencies [9-11].

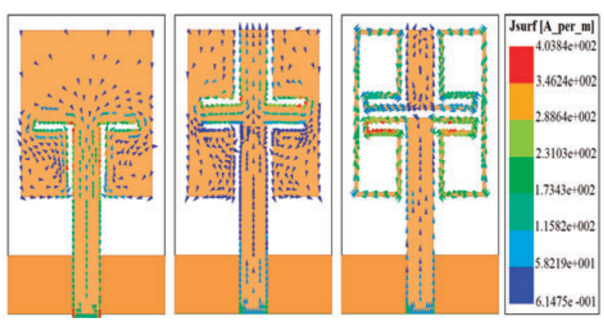


Fig. 4. Simulated surface current distributions for the ordinary square patch antenna with two and four L-shaped slits, and the proposed antenna at (a) 3.5 GHz, (b) 5.5 GHz, and (c) 2.4 GHz.

Another important design parameter of this structure is a modified H-shaped slot on the radiating patch. Figure 4 (c) present the simulated current distributions on the radiating patch of the proposed antenna at the first resonance frequency (2.4 GHz). As shown in Fig. 4 (c), at 2.4 GHz, the current flows are more dominant around of the H-shaped slot.

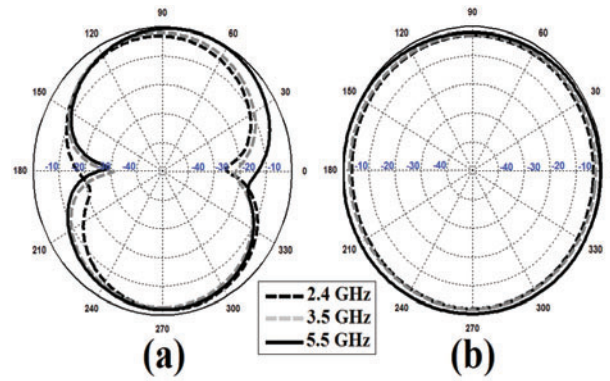


Fig. 5. Measured radiation patterns of the proposed antenna, (a) E-plane and (b) H-plane.

Figure 5 depicts the measured radiation patterns of the proposed antenna including the co-polarization in the H-plane (x-z plane) and E-plane (y-z plane). It can be seen that quasi-omnidirectional radiation pattern can be observed on x-z plane over the whole operation bands. The radiation patterns on the y-z plane display a typical figure-of-eight, similar to that of a conventional dipole antenna. It should be noticed that the radiation patterns in E-plane become imbalanced as frequency increases because of the increasing effects of the cross polarization [12-15].

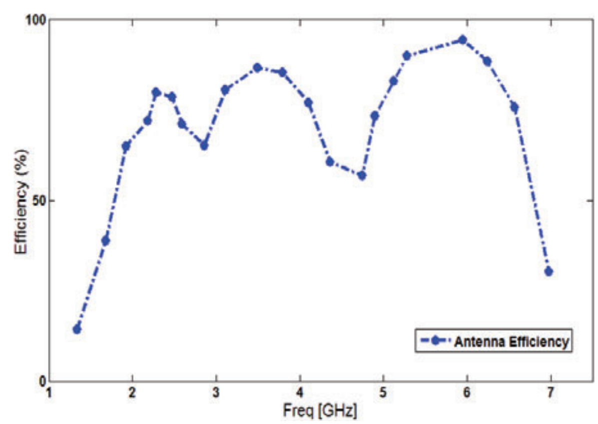


Fig. 6. Simulated radiation efficiency values of the proposed monopole antenna.

The simulated radiation efficiency characteristic of the proposed antenna is shown in Fig. 6. Results of the calculations using the software HFSS indicated that the proposed antenna features a good efficiency, being greater than 75 % across the entire radiating bands. The measured maximum gains of the proposed antenna are presented in Fig. 7. As seen, the proposed antenna has a gain that is low at 2 GHz and increases with frequency. The proposed antenna has sufficient and acceptable gain level in the operation bands [8].

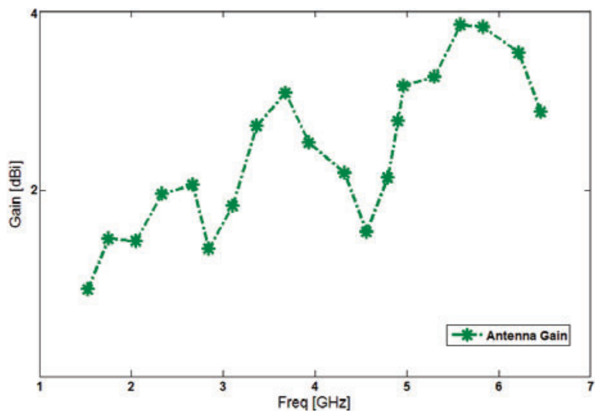


Fig. 7. Measured maximum gain property of the proposed antenna.

Table I summarizes the previous designs and the proposed antenna. As seen, the proposed antenna has a compact size with very wide bandwidth in compared the pervious works. In addition, as the proposed antenna has symmetrical structure, in compared with previous multi-band antennas, the proposed antenna displays a good omnidirectional radiation pattern even at lower and higher frequencies. Also the proposed microstrip-fed monopole antenna has sufficient and acceptable radiation efficiency and antenna gain levels in the operation bands.

Table I: Comparison of previous designs with the proposed antenna.

Ref.	Operation	Size (mm)	Gain (dBi)
[1]	Dual-band	33×33	2.5~3.5
[2]	Single-band	4×12	1~2
[3]	Dual-band	80×20	1~2
[4]	Dual-band	48×60	1.8-4.1
This Work	*Tri-band*	*12×18*	*1.8~3.9*

IV. CONCLUSION

In this letter, a novel multi-band printed monopole antenna for simultaneously satisfying wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications is presented. The desired resonant frequencies are obtained by using four L-shaped slits and an H-shaped slot in the radiating patch of the proposed antenna. The size of the designed antenna is smaller than the antennas for WLAN/WiMAX applications that reported recently.

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