Triple Bands Inverted-U Shaped Monopole Antenna for Application in ISM, WiMAX, and UNII

Yih-Chien Chen [#1], Hong-Mine You [#2]

[#]Department of Electrical Engineering, Lunghwa University of Science and Technology, Gueishan Shiang, Taoyuan County, Taiwan

[1]ycchenncku@yahoo.com.tw

[2]cancer206@yahoo.com.tw

Abstract—**In this paper, the simulation and measured results of CPW-fed inverted-U shaped monopole for application in ISM, WiMAX, and UNII bands are presented. The proposed antenna has good agreement between the measured and the simulation results. The proposed antenna has a 6 dB return loss with bandwidth 596 MHz (2,208-2,804 MHz) in the lower band, 381 MHz (3,327-3,708 MHz) in the middle band, and 647 MHz (5,236-5,883 MHz) in the higher band. The proposed triple-band CPW-fed inverted-U shaped monopole covered the ISM, WiMAX, and UNII bands.**

Keywords—**inverted-U monopole, bandwidth, radiation, gain.**

1. INTRODUCTION

Many commercial applications, including mobile radio and wireless communications, use monopole antenna. The monopole antenna is used extensively because it is reasonably compact, good efficiency, and is very simple [1-2]. Conventional planar monopole antenna is a straight shape of quarter-wavelength. Instead of a straight shape monopole antenna, an inverted L-shape monopole antenna is researched and it owns the advantage of low profile. Recently, multiband monopole antennas for application in WLAN (wireless local area network, 2.4-2.484 GHz), ISM (Industrial, Scientific, Medical) and Bluetooth at low band and UNII (Unlicensed National Information Infrastructure, 5.725-5.825 GHz) applied at high band are implemented. Simultaneously, associating with the rapid development of WiMAX (worldwide interoperability for microwave access, 2.5-2.69, 3.4-3.6, and 5.25-5.85 GHz), there is an increasing demand for antennas suitable for WLAN/WiMAX simultaneously. Multiband monopole antennas are realized by employing a parasitic or shorted element to the monopole [3-6]. The multiband monopole antennas are fed with microstrip line, the structure of the antennas has two metal layers. Via holes are employed to connect the parasitic or shorted element on the front side to the ground plane on the back side of the substrate. However, this has increased the manufacturing cost and difficulty in fabricating. Numerous studies on the patch antennas fed with coplanar waveguide (CPW) are carried out [7-10]. CPW allows the realization of series connections as well as easy mounting of shunt lumped elements or active devices on one side of the planar substrate avoiding via holes as for microstrip line.

Combination the advantages of CPW feed line and monopole antenna, a CPW-fed inverted-U shaped monopole fabricated on FR4 substrate operated in ISM, WiMAX, and UNII bands simultaneously, is proposed. The proposed antenna is simple in manufacturing because of single dielectric substrate, single metal layer, and without via holes. The proposed antenna is capable of operating in the ISM, WiMAX, and UNII bands. The design considerations and experimental results for the proposed antenna are presented and discussed.

2. ANTENNA DESIGN

The geometry and parameters of CPW-fed inverted-U shaped monopole antenna are shown in Fig. 1. The CPW-fed inverted-U

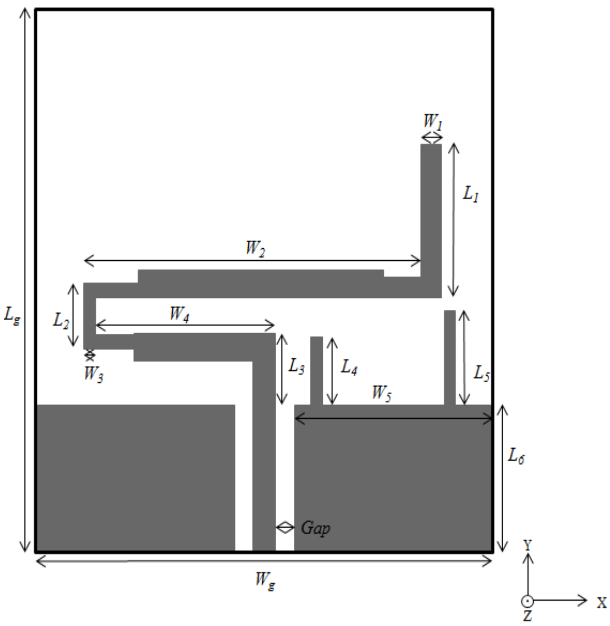
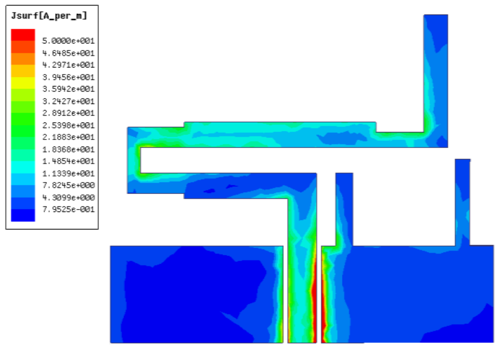
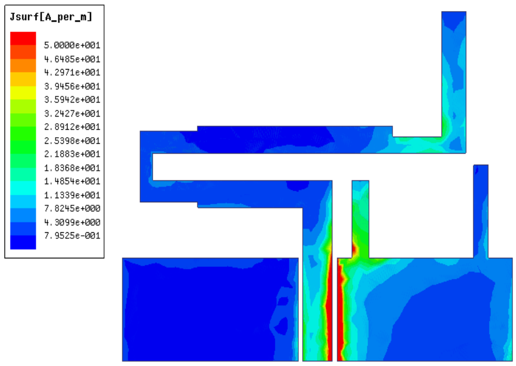


Fig. 1 Configuration of the proposed CPW-fed inverted-U shaped monopole antenna on FR4 substrate.

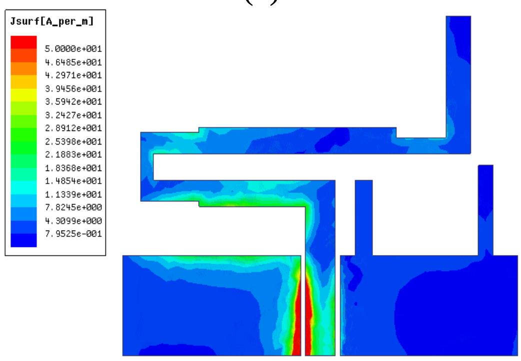
shaped monopole antenna is realized on FR4 substrate of 1.6 mm in thickness, 40 mm × 37 mm in dimension, 4.4 in relative permittivity, and loss tangent of 0.024. A 50 ohm CPW feedline is used to feed the inverted-U shaped monopole antenna, while the other side is without any metallization. The inverted-U shaped monopole antenna and CPW feedline are printed on the same metal layer of the substrate. Dimensions of the CPW feed line are calculated by close-form formulas given in [11], assuming infinite ground plane and finite dielectric thickness. The CPW feed line dimensions are chosen to be compatible with a subminiature version (SMA) connector. The diameter of dielectric core of conventional SMA connector is about 4.5 mm. The CPW feed line dimensions are confirmed by AWR Microwave Office. Gap, width, and length of CPW are 0.5, 2.5, and 9.5 mm, respectively. Two finite ground planes with the same dimensions of length *Lg* and width *Wg* are designed to be 9.5×18.0 mm^2. The two finite ground planes are designed symmetrically on each side of the CPW feed line. The proposed CPW-fed inverted-U shaped monopole antenna, which leads to three resonant modes.



(a)



(b)



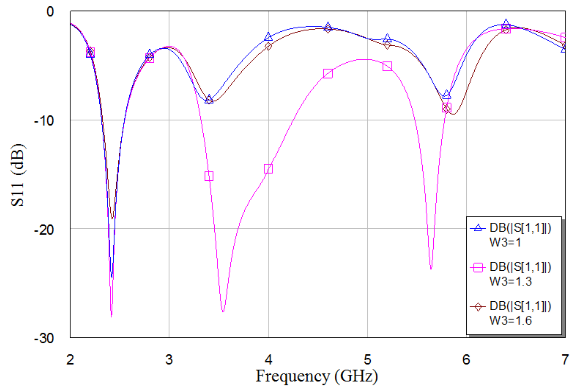
(c)

Fig. 2 Simulation electric field distribution of the proposed monopole antenna at (a) first, (b) second, and (c) third resonant frequencies.

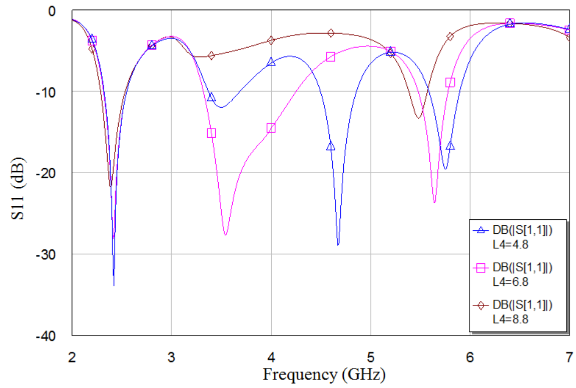
Fig. 2 shows the simulation electric field distribution of the proposed antenna at three resonant frequencies. The electric field distribution of the proposed antenna is studied to understand the behavior of the proposed antenna. As shown in Fig. 3, the the resonant frequencies can be obtained through following formulas. The first resonant length can be calculated from the following formula.

$$L_3 + W_4 + L_2 + W_2 + L_1 = 3\lambda_{g1}/4 \qquad (1)$$

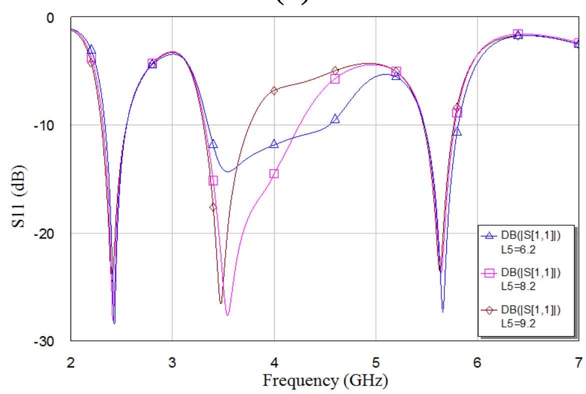
The resonant length is nearly equal to three quarters of the guided wavelength excited in the radiating structure. The second and the



(a)



(b)



(c)

Fig. 3 Simulation return loss of the inverted-U shaped monopole antenna with different lengths of (a) W_3, (b) L_4, and (c) L_5.

third resonant frequencies can be obtained from the following formulas, respectively.

$$L_3 + W_4 + L_2 + W_2 + L_1 = 5\lambda_{g2}/4 \qquad (2)$$

$$L_3 + W_4 + L_2 + W_2 + L_1 = 7\lambda_{g3}/4 \qquad (3)$$

where λ_{g1}, λ_{g2}, and λ_{g3} are the corresponding guided wavelength in the radiating structure at first, second, and third resonant frequency, respectively.

The effects of W_3, L_4, and L_5 on the bandwidth are studied to understand the behavior of the CPW-fed inverted-U shaped monopole.

Fig. 3 (a) shows the simulation return losses of the CPW-fed inverted-U shaped monopole with different widths of W_3. The bandwidth of second resonant mode increases from 0.48 to 1.34 GHz as W_3 increases from 1.0 to 1.3 mm and decreases from 1.34 to 0.44 GHz as W_3 increases from 1.3 to 1.6 mm. The bandwidth of third resonant mode increases from 0.28 to 0.57 GHz as W_3 increases from 1.0 to 1.3 mm and decreases from 0.57 to 0.43 GHz as W_3 increases from 1.3 to 1.6 mm. Fig. 3 (b) and (c) show the simulation return losses of the CPW-fed inverted-U shaped monopole with different lengths of L_4 and L_5, respectively. The bandwidth of second resonant mode increases from 0.85 to 1.34 GHz as the L_4 increases from 4.8 to 6.8 mm. The bandwidth of third resonant mode increases from 0.67 to 0.42 GHz as the L_4 increases from 4.8 to 8.8 mm. The longer the L_4 enables the wider the bandwidth of the second and third resonant modes. The bandwidth of second resonant mode decreases from 1.69 to 1.09 GHz as L_5 increases from 6.2 to 9.2 mm. Thus, the use of a parasitic strip in the protruding stub of the ground plane can lead to wide impedance matching to obtain broadband. The lengths of L_4 and L_5 significantly affect the impedance performance in the second and third modes and were optimized by simulation. However, the influence of W_3, L_4, and L_5 on the bandwidth of the first resonant mode in the lower band is not evident. The optimal parameters of CPW-fed inverted-U shaped monopole antenna on FR4 substrate is set as follows: L_1= 12 mm, L_2= 6.5 mm, L_3= 14.0 mm, L_4= 6.8 mm, L_5= 8.2 mm, L_6= 9.5 mm, W_1= 2.5 mm, W_2= 29.6 mm, W_3= 1.3 mm, W_4= 19.7 mm, and W_5= 18.0 mm.

3. RESULTS

Fig. 4 shows the measured and simulation return loss of the proposed antenna. The simulation resonant frequencies are 2.41, 3.52, and 5.62 GHz. The measured resonant

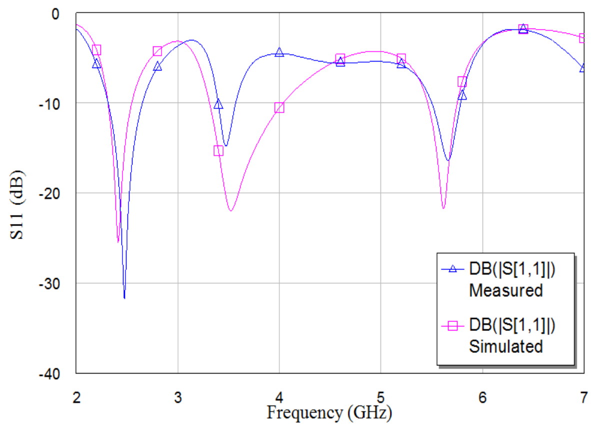


Fig. 4 Measured and simulation return losses of the proposed monopole antenna.

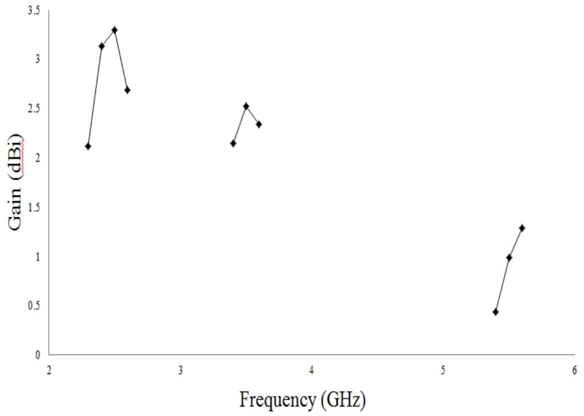


Fig. 6 Peak gains of the proposed antenna in ISM band, WiMAX, and UNII bands.

frequencies are close to the simulation resonant frequencies. The return losses are -31.7, -14.8, and -16.4 dB at 2.47, 3.48, and 5.66 GHz, respectively. Furthermore, there is a 6 dB return loss bandwidth of 596 MHz (2,208-2,804 MHz) in the lower band, 381 MHz (3,327-3,6708 MHz) in the middle band, and 647 MHz (5,236-5,883 MHz) in the higher band. The bandwidth of the proposed antenna is sufficient for the ISM band from 2.40 to 2.484 GHz. It is also sufficient for the UNII band from 5.725 to 5.825 GHz.

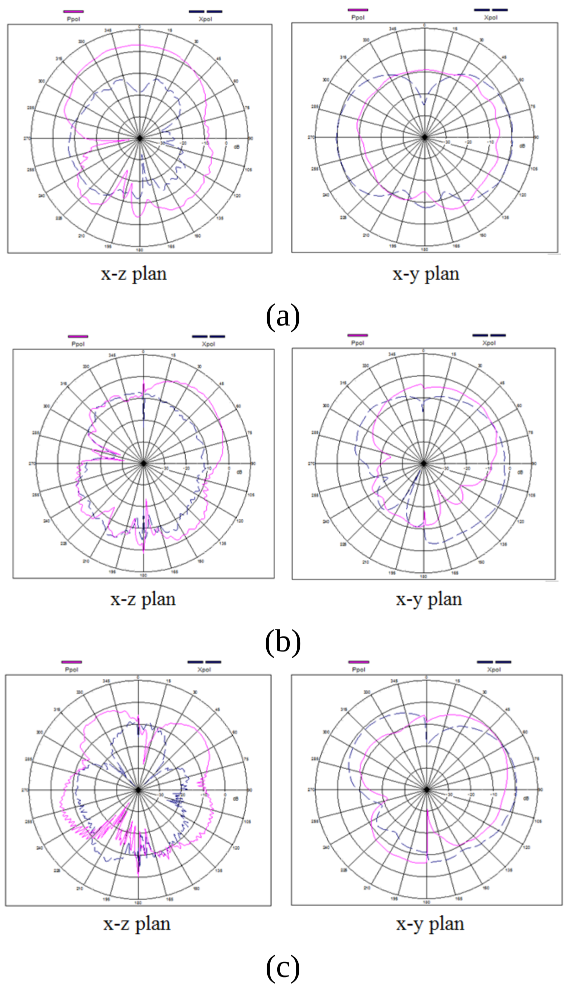


Fig. 5 Radiation patterns of the proposed antenna at resonant frequencies of (a) 2.5, (b) 3.5, and (c) 5.5 GHz.

Fig. 5 displays the radiation patterns in the azimuth plane (x-z plane) and the elevation planes (x-y plane) at frequencies of 2.5, 3.5, and 5.5 GHz. The radiation patterns are similar to that of a monopole antenna. Large cross-polarization is observed. Although large cross-polarization was observed, it became an advantage for practical applications. The wave propagates with multiple reflections between the transmitter and receiver, especially in indoor applications.

Fig. 6 displays the gain of the proposed antenna for operating frequencies in the ISM, WiMAX, and UNII bands. The peak gains are 3.29, 2.52, and 1.29 dBi in the lower and higher bands, respectively. The gain variations are 1.17, 0.37, and 0.85 dBi for frequencies within the lower, middle, and higher bands, respectively.

4. CONCLUSIONS

A CPW-fed inverted-U shaped monopole antenna fabricated on FR4 substrate is successfully realized. The inverted-U shaped monopole antenna and the CPW feedline are printed on the same metal layer of the substrate. The structure of the proposed antenna is simple and easily manufactured. The return loss is -31.7, -14.8, and -16.4 dB at 2.47, 3.48, and 5.66 GHz, respectively. The proposed antenna has a 6 dB return loss with bandwidth 596, 381 and 647 MHz in the lower, middle, and higher bands, respectively. The 6 dB S_{11} bandwidth of the proposed antenna covered ISM, WiMAX, and UNII bands.

REFERENCES

[1] Jiang H., Arai H.: 'FDTD Analysis of low profile top loaded monopole antenna' *IEICE Trans. Commun.,* 2002, E85-B, (11), pp.2468-2475.

[2] Itoh J., Hung T., Morishita H.: 'Analysis of decoupling method between J-shaped folded monopole antennas for IEEE 802.11 b/g on handset' *IEICE Electron. Expre.*, 2010, 7, (18), pp. 1359-1363.

[3] Jan Y.C., Tseng L.C.: 'Small planar monopole antenna with a shorted parasitic inverted-L wire for wireless communications in the 2.4-, 5.2-, and 5.8-GHz bands' *IEEE Trans. Antennas Propag.,* 2004, 52, (7), pp. 1903-1905.

[4] Mohammad N.M., Rousta H., Virdee B.S.: 'Compact UWB planar monopole antenna' *IEEE Antennas Wireless Propag. Lett.,* 2009, 8, pp. 1382-1385.

[5] Thomas K.G., Sreenivasan M.: 'A simple ultrawideband planar rectangular printed antenna with band dispensation' *IEEE Trans. Antennas Propag.*, 2010, 58, (1), p. 27-34

[6] Lu J.H., Lee Y.Y.: 'Planar C-shaped monopole antenna with multi-band operation for WiMAX system' Proc. IEEE *Antennas and Propag. Soc. Int. Sym.,* July 2010, pp. 1-4.

[7] Menzel W., Grabhert W.: 'A microstrip patch antenna with coplanar feed line' *Microw. Guided Wave Lett.,* 1991, 1, pp. 340-342.

[8] Kormanyos B.K., Harokopus Jr. W., Katehi L.P.B., Rebeiz G.M.: 'CPW-fed active slot antennas' *IEEE Trans. Microw. Theory Techniques*, 1994, 42, pp. 541-545.

[9] Liu H.C., Horng T.S., Alexopoulos N.G.: 'Radiation of printed antennas with a coplanar waveguide feed' *IEEE Trans. Microw. Theory Techniques,* 1994, 42, pp. 541-545.

[10] Giauffert L., Laheurte J.M., Papiernik A.: 'Study of variuous shapes of the coupling slot in CPW-fed microstrip antennas' *IEEE Trans. Antennas Propag.*, 1997, 45, pp. 642-647.

[11] Gupta K.C., Garg R., Bahl I., Bhartia P.: 'Microstrip lines and slotlines', (2en ed., ArtecHouse, Norwood, MA, 1996).