Multiband Slot Loaded Uniplanar CPW-fed Monopole Antenna with Asymmetrical Arms

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***Abstract*—This paper presents a new approach for the design of a multiband uniplanar CPW-fed monopole antenna. The antenna consists of a fork like monopole strip to which is added an inverted U-shaped strip. The three branch fork like strip can create three resonant bands within the WLAN range while the placement of the inverted U-shaped strip provides a better impedance matching for the lowest resonant frequency band. Loading slot on the top of the U-shaped strip with asymmetric arms can add two further resonant frequency bands. This antenna can cover the frequencies of PCS, WiMAX and WLAN applications along with the major part of the C band. A prototype of the antenna is fabricated and tested. A good agreement is found between simulated and measured results.**

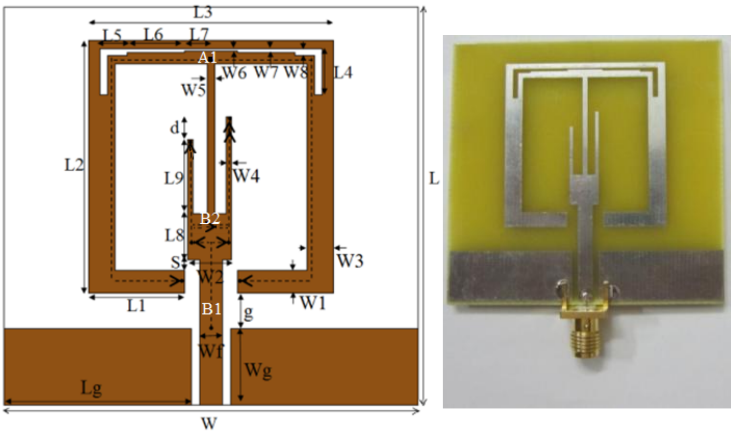
I. INTRODUCTION

Recently, wireless communication has become more and more widespread. The demand for the design of an antenna with multiband operation has increased since such an antenna is vital for integrating more than one communication standards in a single compact system to effectively promote the portability of a modern personal communication system.

In the literature many antennas have been reported for the WiMAX and WLAN applications with triple frequency bands. This includes: a microstrip antenna with defected ground plane [1], a fork shaped antenna with dual parasitic plane [2], a square slot antenna with dual L-strip [3] and a circular ring with a Y-shape like strip and a defected ground plane [4]. These antennas cannot fulfill the reception of the 1.9 GHz PCS band and 3.8 GHz C-band. Also, the coplanar waveguide (CPW)-fed antenna has become very popular owing to the simplest structure of a single metallic layer, wide bandwidth and easy integration with active devices or MMICs. In [5] a trident shape CPW-fed antenna is introduced but this antenna cannot cover the 3.5 GHz WiMAX band and the 3.8 GHz C-band. Thus, it seems that most of the recent works on printed multiband antennas cover only WiMAX and WLAN bands or cover one of these bands in addition to other frequency bands such as PCS.

To improve the capability of the antenna it is more interesting and useful to have an antenna that covers both WLAN/WiMAX bands and other frequencies such as PCS and C-bands. In this paper, a

Manuscript Received 4-June-2012 and revised 18-September-2012 *ISSN: 2322-3936*
Accepted on 1- December-2012



a *b*

Fig. 1. Configuration of the CPW-fed uniplanar monopole multiband antenna. (a) Top view of the proposed antenna and (b) the fabricated antenna

TABLE I. PARAMETERS OF THE PROPOSED ANTENNA IN (MM)

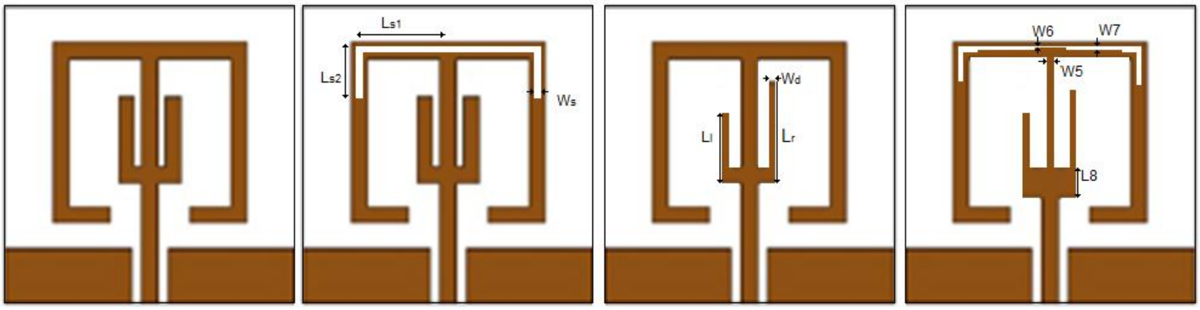
Parameter	**W**	**L**	**Lg**	**Wg**	**Wf**	**g**	**S**	**d**	
Value	54	52	24.4	10	3	4.6	1.4	3	
Parameter	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	
Value	3	5.8	3.5	0.7	1	0.25	0.5	0.8	
Parameter	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**
Value	12.5	33	32	6	3.5	7.5	3.5	6	9

penta-band uniplanar monopole antenna is proposed. The antenna can cover PCS (1.9 GHz), WLAN (2.4/5.2/5.8 GHz) and WiMAX (2.5/3.5/5.5 GHz) applications along with the major part of the C-band (3.7-4.2 GHz). The proposed antenna provides good radiation patterns and high gains. The antennas are simulated through commercially available software package HFSS.

II. ANTENNA DESIGN

The configuration of the proposed antenna is shown in *Fig*. 1. The antenna is printed on an FR4 substrate with relative permittivity ε_r = 4.4 and thickness h = 1 mm and is fed by a CPW transmission line with 50 Ω impedance.

The design evolution of the proposed antenna is presented in Fig. 2. The base structure has three branch fork like strip with an inverted U-shape strip on top of it [6]. The base structure is shown in Fig. 2a and the relevant current distribution shown in Fig. 3. As can be seen through the current distribution of Fig. 3, due to the presence of the three resonance paths, each close to one quarter-



antenna A antenna B antenna C antenna D

(a) (b) (c) (d)

Fig. 2. Design evolution of the proposed antenna

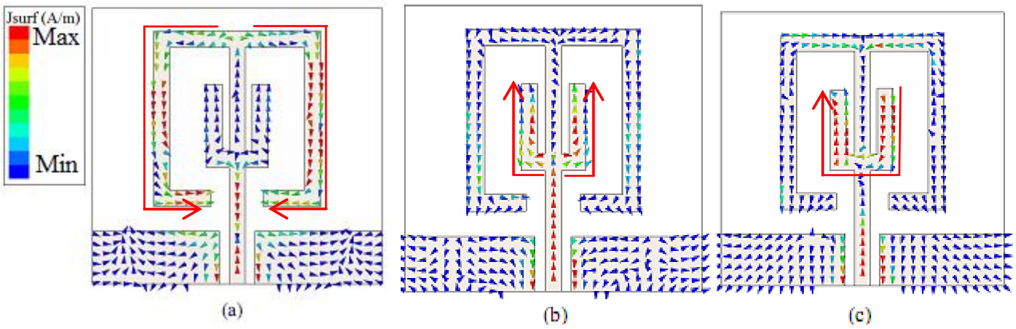


Fig. 3. Current distribution of the antenna A, at (a) 2.2 (b) 3.6 and (c) 5.5 GHz.

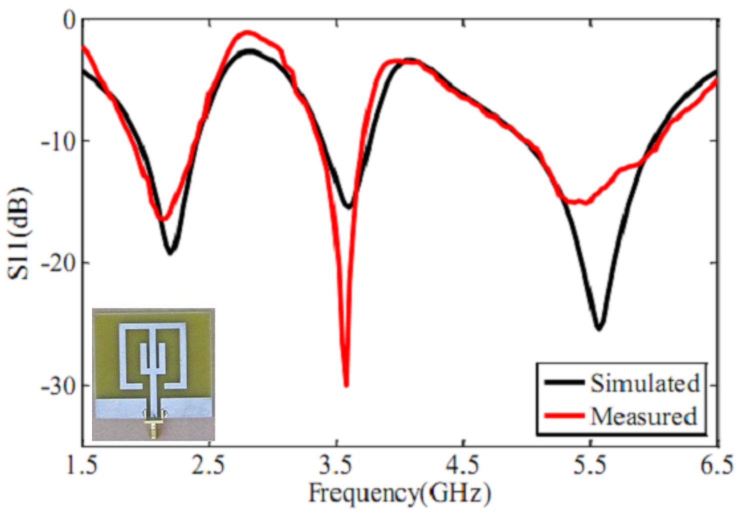


Fig. 4. The simulated and measured reflection coefficient of antenna A shown in Fig 2.

wavelength, the base antenna can provide three resonant bands at 2.4, 3.5 and 5.5 GHz. The simulated and measured reflection coefficient of this structure is shown in Fig. 4. This figure shows that the base antenna resonates in three frequency bands centered at 2.4, 3.5 and 5.5 GHz with reflection coefficient below -10 dB. Good agreement between simulated and measured results obtained.

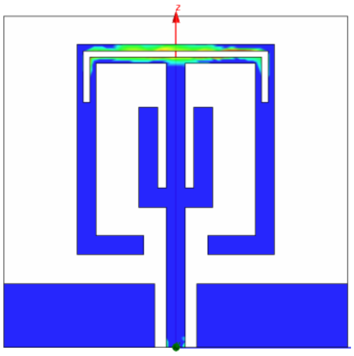


Fig. 5. Current distribution on the antenna B at stop band 2.1GHz

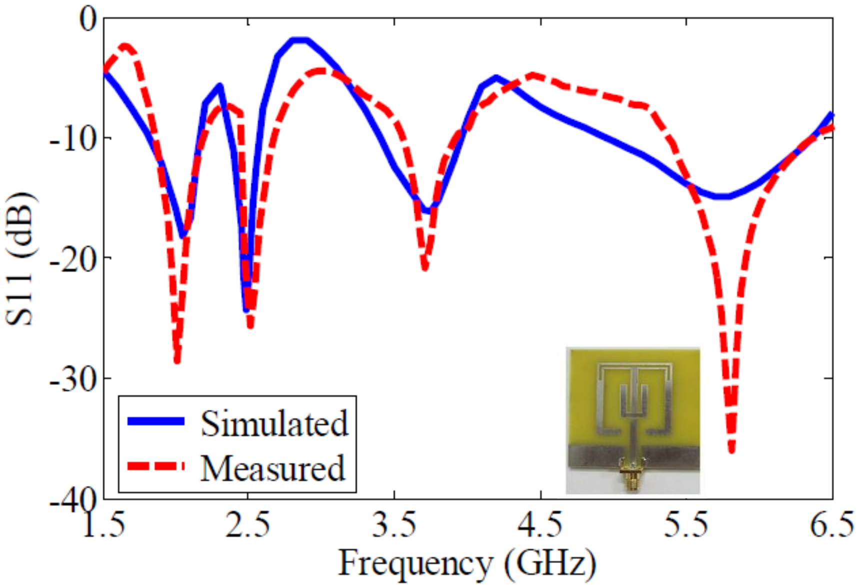


Fig. 6. Simulated and measured reflection coefficient of the antenna B.

By inserting a slot on the top of the inverted U-strip of the antenna A, antenna B is created [7] as shown in Fig. 2b. Figure 5 shows that when the top slot is added the current concentrates around the slot and divides the lowest band into two separate bands, thus creating another resonant band at 2.1 GHz, in this way one can increase the number of resonant bands into quad bands. Based on Fig. 2b one can relate the length to wavelength as $Ls(=2x(Ls1+Ls2))=\lambda/2$.

The simulated and measured reflection coefficient of the antenna B is shown in Fig. 6. As can be seen the proposed antenna resonates at 1.9, 2.4, 3.5 and 5.5 GHz that covers PCS, WiMAX and WLAN standards.

Reflection coefficient of the proposed antenna for various width of the slot is shown in Fig. 7. As can be seen, antenna without slot can create only three separate bands and inserting the slot can add another resonance. By increasing the width of the slot the impedance matching of the antenna at higher resonant bands can be improved.

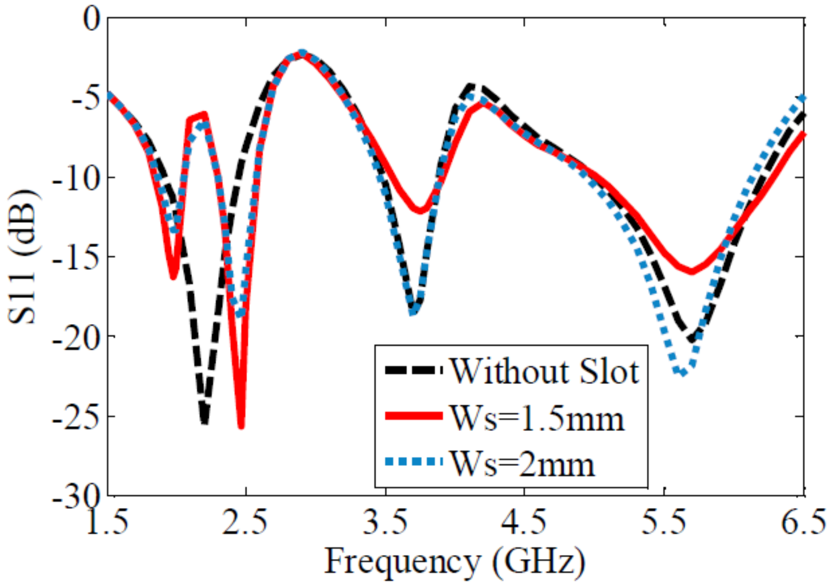


Fig. 7. Reflection coefficient of the antenna B for various W_S

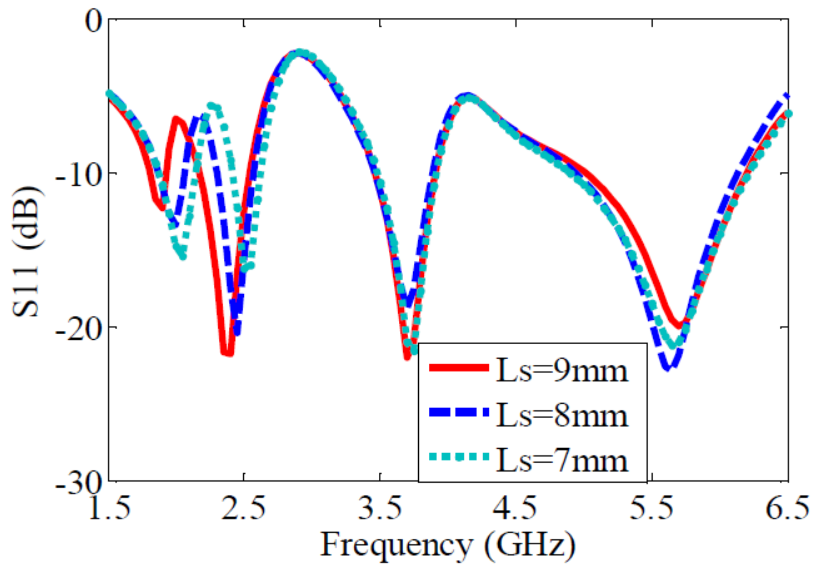
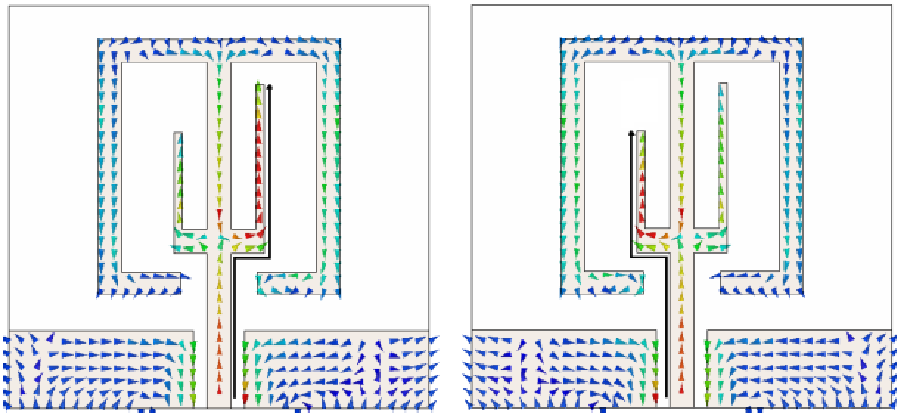


Fig. 8. Reflection coefficient of the antenna B for various L_S

Figure 8 shows the effect of the various length $L_S = 2\times(L_{S1} + L_{S2})$ of the slot shown in Fig. 2b. The length L_S affects the center frequency of the stop band that was created by the slot itself. Increasing the length L_S decreases the center frequency of the stop band and also causes a decrease in the center frequencies of the first and second bands.

Also by making the arms of the three branch fork like strips unequal, i.e. asymmetrical arms, (as shown in Fig. 2c), a new resonant band can be created. This is due to the creation of a new resonant path between the feed point and the unequaled arms. Figure 9 shows the current distribution of the



(a) (b)

Fig. 9. Current distribution of the antenna C, with asymmetrical arms at (a) 2 and (b) 3.5 GHz.

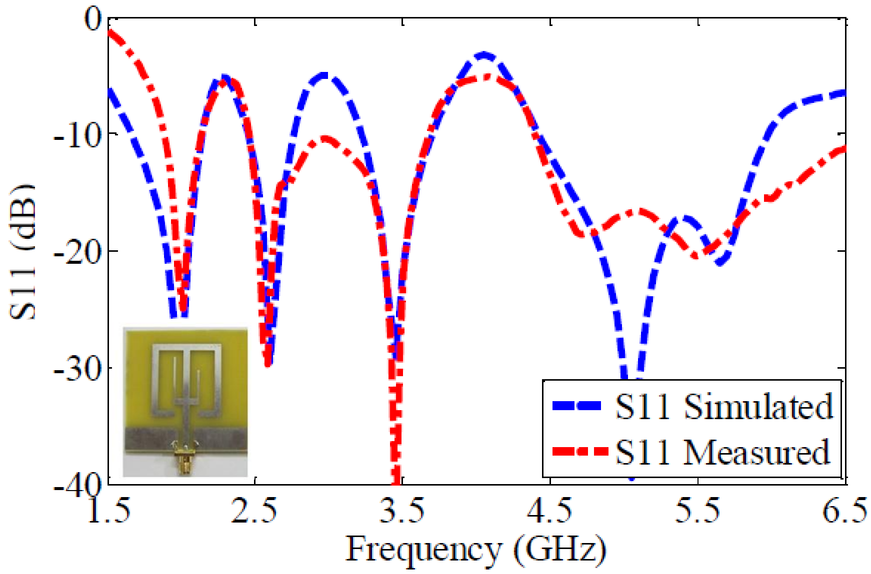


Fig. 10. Simulated and measured reflection coefficient of the antenna C shown in Fig. 2.

antenna C, at 2 and 3.5 GHz. As can be seen, the two arms with unequal size have two different resonance paths from feed point to end of the arm.

The simulated and measured reflection coefficient of the antenna C is shown in Fig. 10. This antenna resonates at quad frequencies including 2, 2.5, 3.5 and 5.5 GHz center frequencies. Good agreements between the simulated and measured results are noticed.

Figure 11 shows the effect of creating asymmetric arms on the reflection coefficient of the antenna C. This figure shows that if the difference between the left arm and the right arm ($d = L_l - L_r$) is zero, the antenna resonate in three resonant bands. By increasing this difference, d = 3 mm, a resonance at 2.7 GHz is created but it has low impedance matching with reflection coefficient of almost -10 dB at its center frequency. By using d = 6 mm, the center frequency of the created band decreases to 2.6 GHz and the impedance matching improves with reflection coefficient of -22 dB and also good impedance

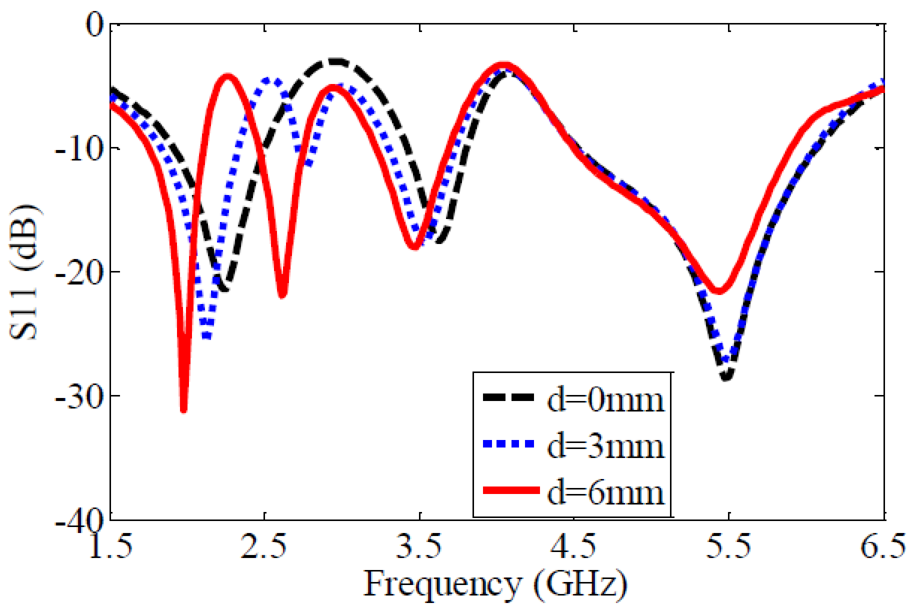


Fig. 11. Reflection coefficient for various *d* of antenna C.

matching in all the quad frequency bands. According to the evolution studied, the proposed antenna D, of Fig. 2, with slot and using unequal arms can create penta resonant bands and cover PCS, WiMAX, WLAN and C-band with frequencies of 1.9, 2.4, 3.5, 3.8 and 5.5 GHz. The optimal antenna dimensions are listed in Table. I.

III. RESULTS

Figure 12 shows the simulated return losses for various antennas involved in the design evolution process where a good penta-band performance can be seen from the proposed antenna D. It can be seen that the presence of the slot and also the three thin branch fork like strips improves the impedance matching of the proposed antenna. If the three branch forks like strips are made symmetrical with equal sizes, the 3.8 GHz band would not be excited. For the case with asymmetrical arms but without the slot, the 1.9 GHz for PCS band would not be covered. For the case without both the slot and the asymmetrical arms, three resonances are excited that cannot cover the 2.4 GHz band and the C-band.

The simulated and the measured return losses of the proposed antenna are shown in Fig. 13. It can be seen that the measured result reasonably agrees with the simulated results with an acceptable frequency discrepancy. The impedance bandwidth of the lower band centered at 1.9 GHz has a bandwidth from 1.80–2.05 GHz covering the PCS (1.85–1.99 GHz) band. The second band centered at 2.6 GHz with a bandwidth from 2.4–2.75 GHz determined by 10 dB return loss is good enough to cover the WLAN 2.4 (2.4-2.484 GHz) band. The third band centered at 3.5 GHz with the bandwidth of 3.4-3.6 GHz covers the WiMAX band. The fourth and fifth bands cover C-band with the bandwidth

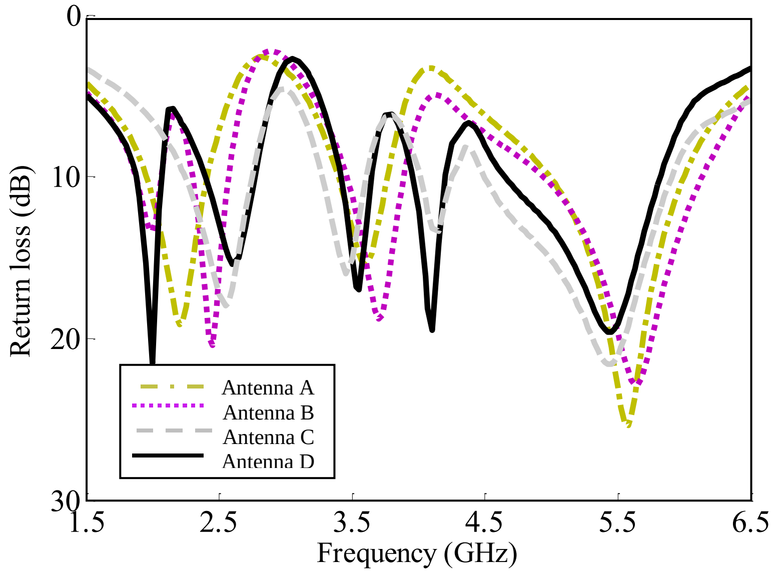


Fig. 12. Return loss of various antennas involved in the design evolution process

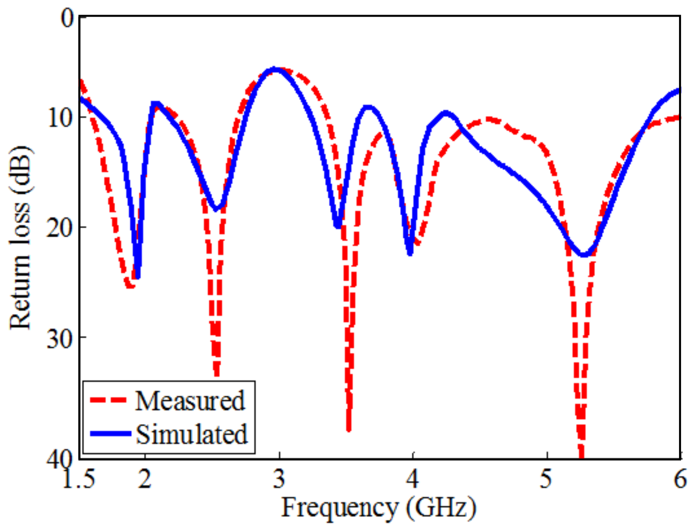


Fig. 13. Simulated and measured return loss for the proposed antenna

of 3.7-4.2 GHz and WiMAX/WLAN upper bands with the bandwidth of 4.75-5.88 GHz, respectively.

The effect of the parameter *W6* of the proposed antenna is shown in Fig. 14. As shown in this figure, the main effect of this parameter is on the impedance matching of the antenna, that by decreasing the value of *W6*, impedance matching can be improved.

Measured radiation patterns with co- and cross- polarization in the E- and H- planes are shown in Fig. 15. It is seen that the E-plane patterns are monopole-like for operation at all frequencies, while the H-plane patterns are nearly omnidirectional.

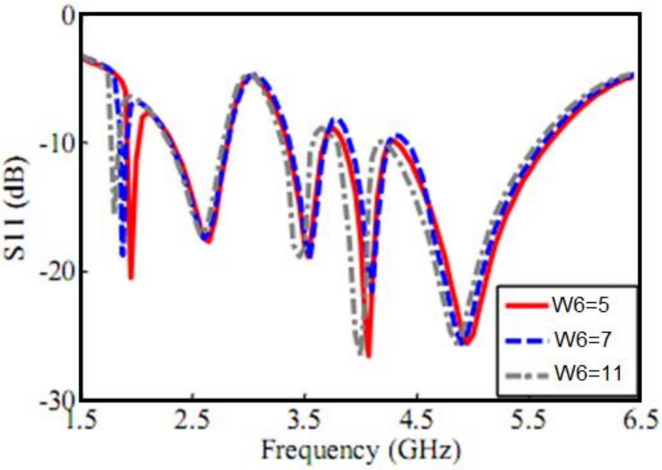


Fig. 14. Simulated reflection coefficient of the proposed antenna, Fig. 2D, for various W6.

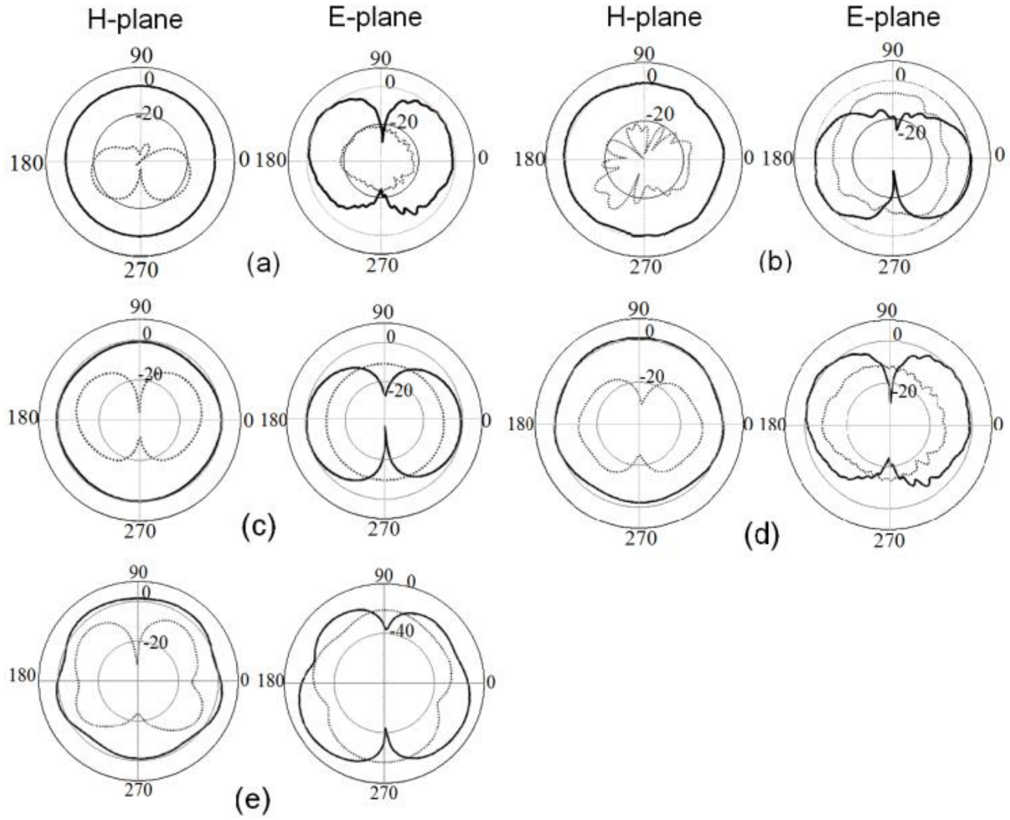


Fig. 15. Measured radiation patterns of the proposed antenna (Co-pol __ , Cross-pol …..) at frequencies of (a) 1.9 GHz, (b) 2.5 GHz, (c) 3.5 GHz, (d) 3.8 GHz, and (e) 5.5 GHz

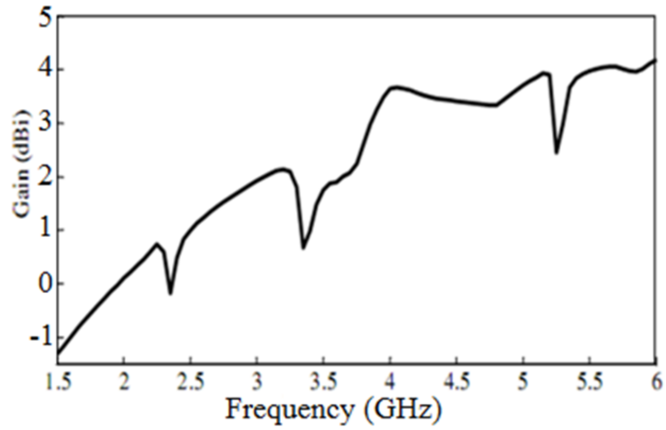


Fig. 16. Peak gain of the proposed antenna

TABLE 2. COMPARISON OF PROPOSED ANTENNA WITH OTHERS REPORTED IN THE LITERATURE

Multiband antennas		**Proposed**	**Reference [5]**	**Reference [4]**	**Reference [3]**	**Reference [8]**
Number of separated bands		5	2	3	3	2
Coverage bands	**C-band**	*	-	-	-	*
	Wimax	*	-	*	*	-
	WLAN	*	*	*	*	*
	PCS	*	*	-	-	-
Maximum Gain dBi		3.9	5.5	2.57	3.06	5.2
Dimention mm^2		52×54	54×52	25×38	32×28	32.5×25

Since the substrate size (L × W) of the proposed antenna is nearly one-half wavelength of the average resonant frequency [5], the peak gains can reach about -0.02, 0.96, 1.7, 1.85 and 3.9 dBi for the lower to upper bands, respectively, as shown in Fig. 16.

A comparison between the proposed antenna and the previous works reported in the literature is shown in table 2. Number of separated bands, the coveraged bands and the overall dimension of the relevant antennas are sorted in this table. As shown, the proposed antenna can cover C-band, PCS band, and both of the WLAN and WiMAX bands while the dimension of the antenna is acceptable in this situation. Other antennas [4-5] and [8] have lower dimensions but cannot cover the PCS band.

ACKNOWLEDGMENT

This work was supported by Research Institute for information and communication technology, ICT-ITRC.

CONCLUSION

A novel compact multi-band modified three branch fork like strip with inverted U-shape strip and loaded with slot for WLAN and WiMAX applications is proposed. In this design, a slot is used to excite the 1.9 GHz PCS band. By combining the structure with an asymmetrical forked-shaped strip, multiple resonant frequencies with frequencies of 1.9, 2.5, 3.5, 3.8 and 5.5 GHz are achieved. With its good return loss, gain and radiation pattern performances, the proposed antenna has potential in multi-band communication applications

REFERENCES

[1] W. Liu, C. Wu, and Y. Dai, "Design of triple-frequency microstrip-Fed monopole antenna using Defected Ground Structure," IEEE Antennas Wireless Propag. Letter., vol. 59, no.7, pp. 2457-2460, 2011.

[2] P. Xu, Z.-H. Yan, and C. Wang, "Multi-band modified fork-shaped monopole antenna with dual L-shaped parasitic plane," Electronics Letters, vol. 47, no. 6, pp. 364-365, 2011.

[3] W. Hu, Y.-Z. Yin, P. Fei, and X. Yang, "Compact Triband Square-slot antenna with symmetrical L-Strips for WLAN/WiMAX applications," IEEE Antennas Wireless Propag. Letter, vol. 10, pp. 462-465, 2011.

[4] J. Pei, A.-G. Wang, S. Gao, and W. Leng, "Miniaturized triple-band antenna with a Defected Ground Plane for WLAN/WiMAX applications," IEEE Antennas Wireless Propag. Letter, vol. 10, pp. 298-301, 2011.

[5] C. Wang, Z.-H. Yan, P. Xu, J.-B. Jiang, and B. Li, "Trident-shaped dual-band CPW-fed monopole antenna for PCS/WLAN applications," Electronics Letters, vol. 47, no. 4, pp. 231-232, 2011.

[6] M. Darvish and H.R. Hassani, "Multiband Uniplanar Monopole Antenna for MIMO Applications," 20^{th} ICEE conference, Tehran-IRAN, May 15-17, 2012.

[7] M. Darvish and H.R. Hassani, "Quad Band CPW-Fed Monopole Antenna for MIMO Applications," EUCAP conference, Prague, March 26-30, 2012.

[8] X. Yang, Y.Z. Yin, W. Hu and K. Song, "Dual-band planar monopole antenna loaded with pair of edge resonators," Electronics Letters, vol. 46, no. 21, pp. 1419 - 1421, 2010.