

A Novel CPW-Fed Multiband Planar Monopole Antenna for GSM/ WLAN/ WiMAX Applications

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Abstract

A novel CPW-fed multiband planar monopole antenna is designed and investigated in this paper. The proposed antenna is fabricated on FR4 substrate and has a compact size of $26 \times 45 \times 1.6 \text{ mm}^3$. A prototype is fabricated and then measured. The simulated and measured results exhibit that the operating bandwidth with a reflection coefficient of less than -10 dB is about 150 MHz ($1700\text{--}1850\text{MHz}$), 310 MHz ($2.38\text{--}2.69 \text{ GHz}$), 520 MHz ($3.23\text{--}3.75 \text{ GHz}$), and 820 MHz ($5.09\text{--}5.91 \text{ GHz}$). These frequency ranges meet the bandwidth requirement for GSM 1800MHz , WLAN $2.4/5.2/5.8 \text{ GHz}$ and WiMAX $2.5/3.5/5.5 \text{ GHz}$ bands. Also, almost omnidirectional radiation patterns and peak gains of 2.1dBi at 1.8 GHz , 2.21dBi at 2.4 GHz , 2.8dBi at 3.5 GHz , and 4.98dBi at 5.5 GHz are obtained. The proposed antenna with small size, planar structure, good impedance bandwidth and omnidirectional radiation patterns is very suitable for GSM/ WLAN/ WiMAX applications.

Keywords: GSM/ WLAN/ WiMAX, multiband antenna, omnidirectional radiation pattern, coplanar waveguide

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1. Introduction

Recently, fast growth in wireless communications has increased the demands for mobile terminals offering multiple features. Global system for mobile communication (GSM), worldwide interoperability for microwave access (WiMAX), and wireless local area network (WLAN) are very popular wireless communication systems and have been widely applied in mobile devices [1–3]. In order to meet GSM ($1770\text{--}1840 \text{ MHz}$), WLAN ($2.4\text{--}2.48$, $5.15\text{--}5.35$, and $5.72\text{--}5.85 \text{ GHz}$) and WiMAX ($2.5\text{--}2.69$, $3.40\text{--}3.69$, and $5.25\text{--}5.85 \text{ GHz}$) standards simultaneously, multiband antennas with good performance are required. The performance of the antenna which includes the reflection coefficient, radiation pattern, gain and efficiency are considered enough to meet the requirement of the multiband communication systems. Many antennas have been introduced to achieve multiband characteristics. A CPW-fed monopole antenna with double rectangular rings and vertical slots in the ground plane is presented for WLAN/WiMAX applications [4]. Also, a CPW-fed triple-band antenna with metamaterial resonators is presented for wireless communications [5]. A miniaturized triple band monopole antenna with a toothbrush-shaped patch, a meander line and an inverted U-shaped patch is reported for WLAN/WiMAX operations [6]. Triple-band antenna with defected ground structure is proposed for WLAN/WiMAX applications [7]. In [8], the antenna with two branches of curved strips is proposed for vehicle communication applications with four resonant frequency bands. Multi-bands circular ring monopole antenna with double L-shape for WLAN/WiMAX applications is presented in [9]. In [10], multiband monopole antenna with meander line has been presented for wireless communications. In [11], wide CPW-fed multiband wearable monopole antenna with extended grounds is presented for GSM/WLAN/WiMAX applications. However, some of these reported multiband antennas are not sufficient to cover the entire frequency band for GSM/WLAN/WiMAX operations. Meanwhile, some of them are large in size and have complex structures. In this paper, a novel CPW-fed monopole antenna with quadruple band characteristic is proposed for wireless communication application. The proposed antenna operates at $1.8/2.4/3.5/5.2/5.5/5.8 \text{ GHz}$ bands. The performances of the proposed quadruple band antenna are investigated by using the CST Microwave Studio software. Simulated and measured results show that the proposed antenna has quad-band characteristics and good omnidirectional radiation patterns which make it suitable for GSM/WLAN/WiMAX communication applications. The paper is organized in the following sections. Antenna design is presented in section 2. In section 3, the simulated and measured results are discussed. Subsequently, section 4 concludes the paper.

2. Antenna design

The geometric configuration of the proposed antenna and photograph of the fabricated prototype are shown in Fig. 1(a) and (b), respectively. The proposed antenna is printed on an FR4 substrate with relative permittivity of $\epsilon_r = 4.4$, loss tangent

of $\tan \delta = 0.02$, a thickness of $h = 1.6$ mm and dimensions of 26×45 mm². The antenna is fed by a CPW line which is designed for 50Ω characteristic impedance. A signal strip width of a 50Ω CPW transmission line is 3 mm and a gap distance is 0.3 mm. Two ground planes of the CPW line with dimensions of 11.2×11 mm² are situated symmetrically on either side of the CPW line. A SMA connector is connected to the 50Ω CPW line to feed the antenna.

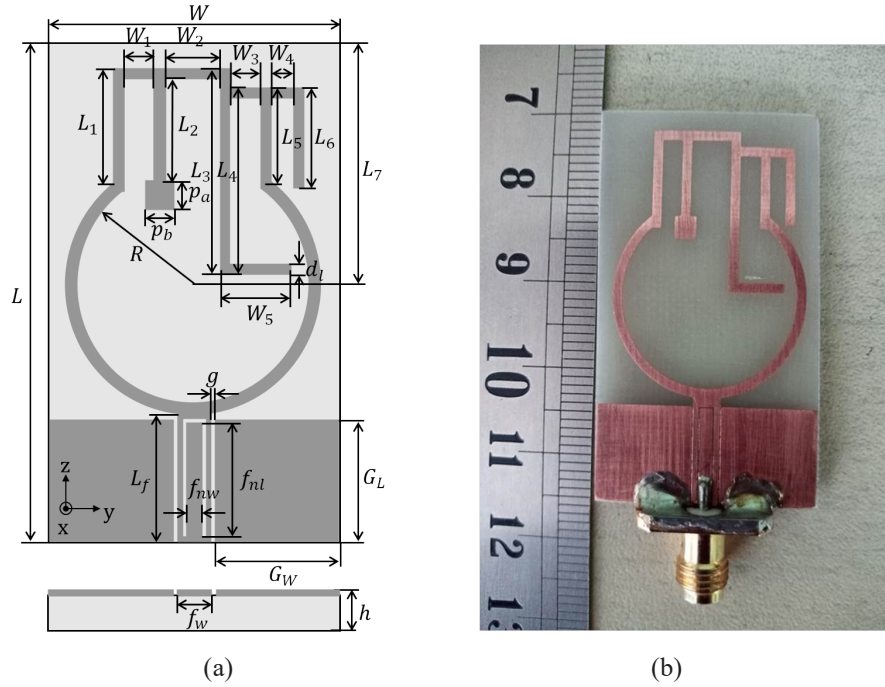


Fig. 1: Geometry of the Proposed Antenna
(a) Structure, (b) Photograph

The antenna consists of a circular-shaped strip, a Π -shaped strip connected with an inverted L-shaped strip, an inverted T-shaped strip and a L-shaped strip within Π -shaped strip, and a Π -shaped slot etched on the CPW feed line. The antenna consists of a single-layer metallic configuration for the simple fabrication, which is etched onto one side of the substrate. In order to sufficiently understand the proposed multiband antenna, the key parameters L_2 , L_3 , L_6 and f_{nl} are selected to investigate their effects on the impedance bandwidth. Fig. 2(a) shows the effects of L_3 on the reflection coefficient of the proposed multiband antenna. It is observed from the figure that the center frequencies of the first band near 1800MHz and the second band near 2.4GHz move to lower frequency side with an increase of L_3 ranging from 14.5 mm to 16.5mm. In this case, the other resonance frequencies are slightly changed. Fig. 2(b) shows the effect of the parameter L_2 . As shown in Fig. 2(b), it is observed that, the parameter L_2 has an important effect on the bands near 3.5GHz and 5.5GHz. When parameter L_2 increases from 7 mm to 9 mm, the resonance frequencies of the third band near 3.5GHz and fourth band near 5.5GHz move to lower frequency side. In this case, the other resonance frequencies are almost invariable. Fig. 2(c) shows the effects of L_6 on the reflection coefficient of the proposed antenna. As shown in Fig. 2(c), it is observed that, the parameter L_6 has an important effect on the fourth band near 5.5GHz. As L_6 increases from 7 mm to 9 mm, the center frequency of fourth band near 5.5GHz moves to lower frequency side. At the same time, the other frequency bands are slightly changed. Fig. 2(d) shows the effects of f_{nl} on the impedance bandwidth of the proposed antenna. A Π -shaped slot etched on the CPW feed line is used to reject an unwanted resonance at around 4.5 GHz. When the parameter f_{nl} increases from 8.3 mm to 10.3 mm, the resonance frequencies of the notched band near 4.5GHz move to lower frequency side. From the discussion above, center resonance frequencies can be adjusted by changing the dimensions of a L-shaped strip, an inverted T-shaped strip, an inverted L-shaped strip, and a Π -shaped slot to make them suitable for GSM/WLAN/WiMAX communication applications. The proposed multiband antenna has been investigated and optimized by the CST Microwave Studio software. The optimized parameters of the antenna are listed as follows: $W_1 = 2.5$, $W_2 = 4.9$, $W_3 = 2.6$, $W_4 = 2$, $W_5 = 6.5$, $L_1 = 9.98$, $L_2 = 9$, $L_3 = 18.5$, $L_4 = 16.7$, $L_5 = 7.18$, $L_6 = 9$, $L_7 = 21.5$, $G_w = 11.2$, $G_L = 11$, $f_w = 3$, $f_{nw} = 1.4$, $f_{nl} = 10.3$, $L_f = 12.1$, $d_t = 1$, $R = 11.5$, $h = 1.6$, $L = 45$, $W = 26$, $g = 0.3$. Here all dimensions are in mm.

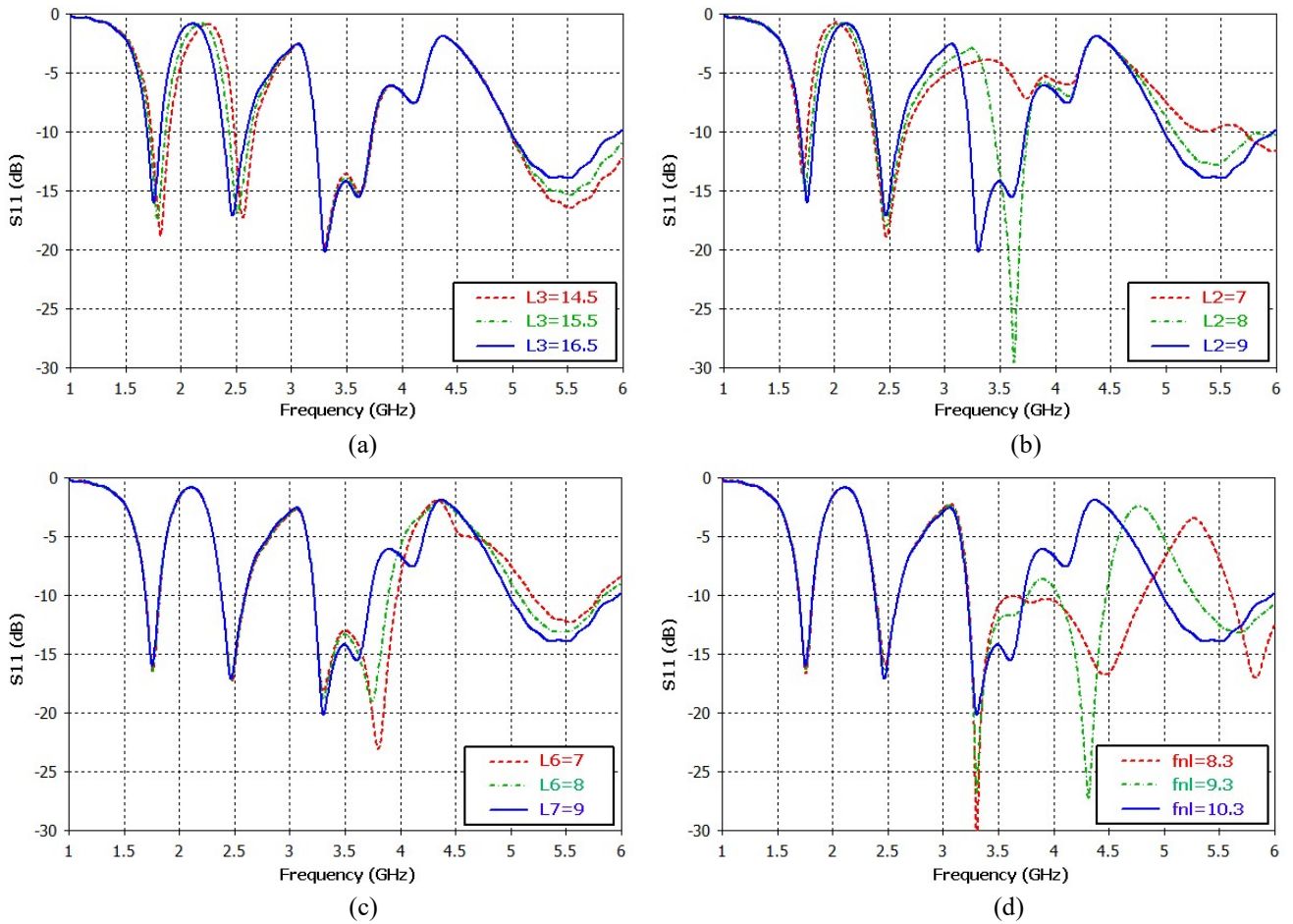


Fig. 2: The Simulated Reflection Coefficients of the Proposed Antenna with Different Values of L_3 , L_2 , L_6 and f_{nl}
 (a) L_3 , (b) L_2 , (c) L_6 , (d) f_{nl}

3. Results and discussions

Fig. 3 shows the simulated and measured reflection coefficients of the proposed multiband antenna with the optimized parameters, and good agreement between simulation and measurement is observed. The measurement of the fabricated multiband antenna is performed with Agilent FieldFox N9918A vector network analyzer. As shown in Fig. 3, the proposed antenna has four different resonance frequencies at 1800MHz, 2.4 GHz, 3.5 GHz, and 5.5 GHz, which can cover 1800MHz GSM, 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/5.5 GHz WiMAX operational bands with reflection coefficient of less than -10dB. The measured bandwidths of the proposed antenna at the desired four different operating bands are 150 MHz (1700–1850 MHz), 310 MHz (2.38–2.69 GHz), 520 MHz (3.23–3.75 GHz), and 820 MHz (5.09–5.91 GHz), respectively.

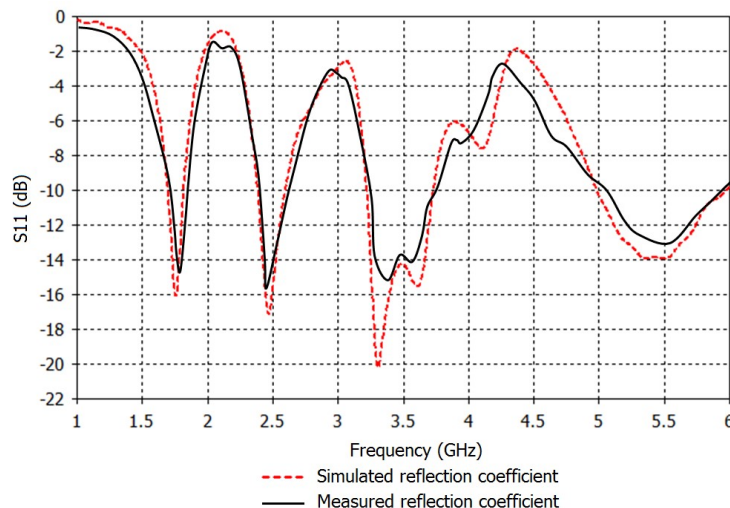


Fig. 3: The Simulated and Measured Reflection Coefficient of the Proposed Antenna

The simulated current distributions of the proposed antenna at the four different resonance frequencies are shown in Fig 4. The larger current distribution is indicated in red, and the smaller one is indicated in blue. As shown in Fig. 4, current distributions of the four different resonance frequencies are different from each other. As can be seen from the Fig 4(a), current distribution at first frequency band (1800MHz) mainly focuses on the circular-shaped strip and L- shaped strip within Π -shaped strip. Similarly, as can be seen from the Fig. 4(b), current distribution at second frequency band (2.4GHz) mainly concentrates on the L- shaped strip within Π -shaped strip. As can be seen from the Fig. 4(c) and Fig. 4(d), the current distributions at third frequency band (3.5GHz) and fourth frequency band (5.5GHz) mainly appear on the inverted T- shaped strip within a Π -shaped strip and an inverted L- shaped strip.

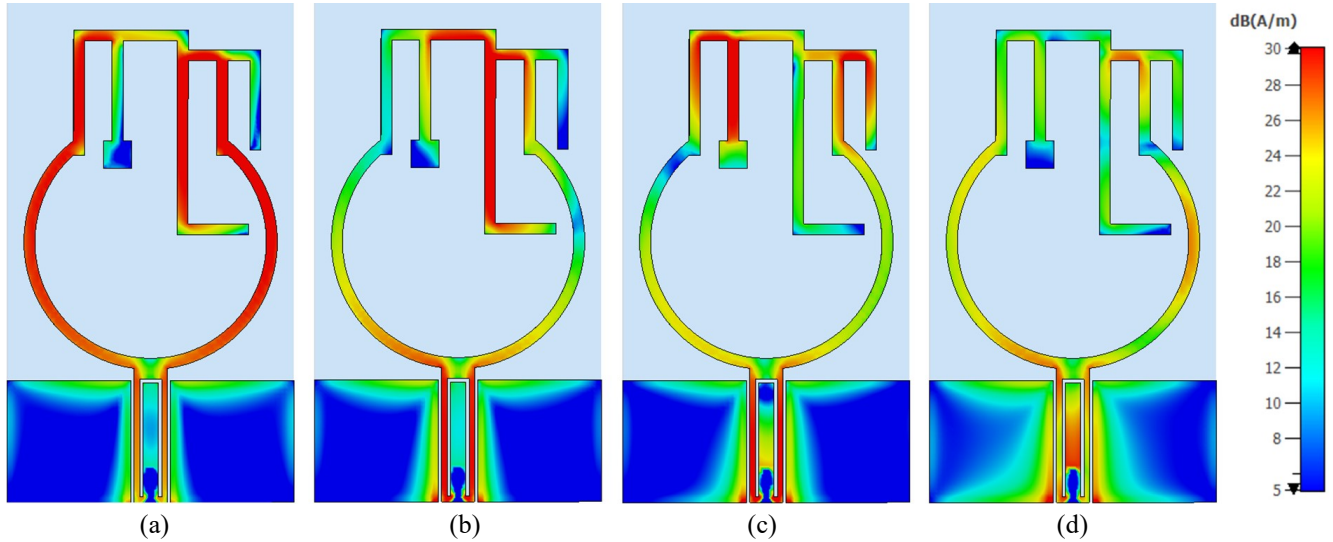


Fig. 4: The Simulated Current Distribution of the Proposed Antenna
 (a) 1.8GHz, (b) 2.4GHz, (c) 3.5GHz, (d) 5.5GHz

The radiation patterns of the proposed multiband antenna are shown in Fig. 5. It can be seen from Fig. 5(a) and 5(b) that the proposed antenna has good omnidirectional radiation patterns in H -plane (X - Y plane) and bidirectional patterns in E -plane (X - Z plane). The peak gain of the proposed multiband antenna is shown in Fig. 6. It is found that the peak gain of the antenna at 1800MHz, 2.4 GHz, 3.5 GHz and 5.5 GHz are about 2.1dBi, 2.21dBi, 2.8dBi and 4.98dBi, respectively.

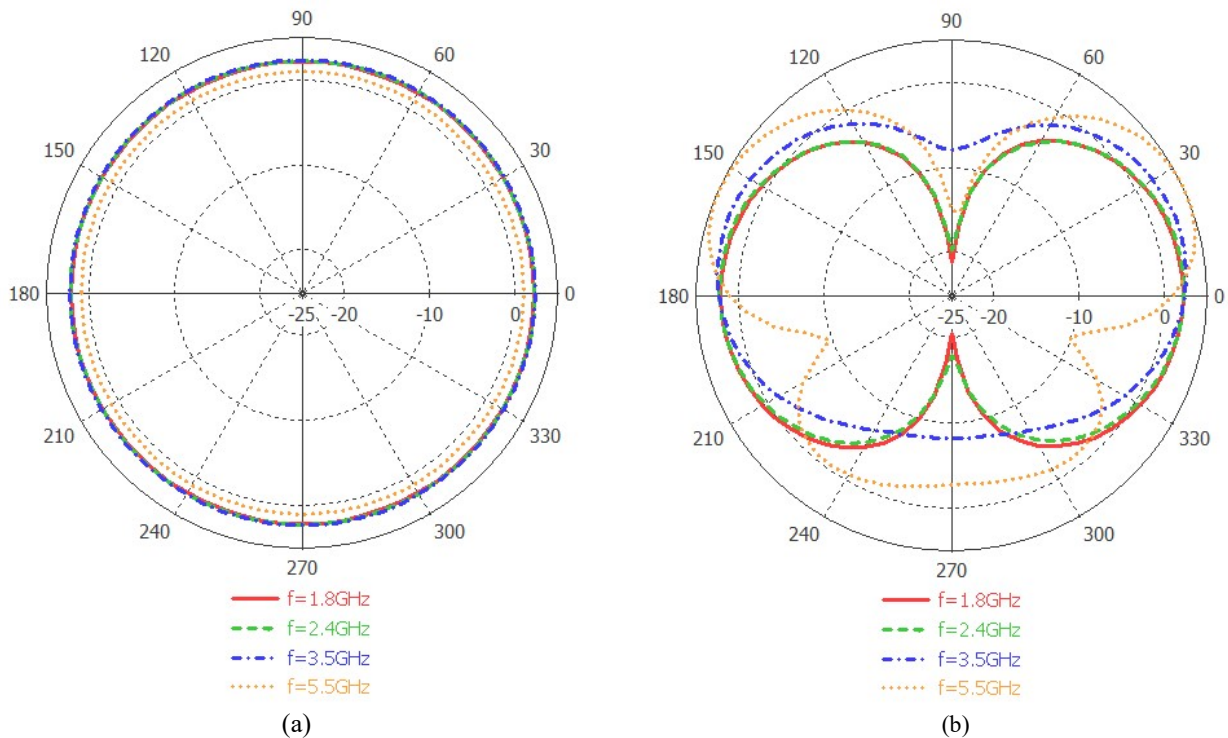


Fig. 5: Radiation Patterns of the Proposed Antenna
 (a) H -Plane (X - Y Plane), (b) E -Plane(X - Z Plane)

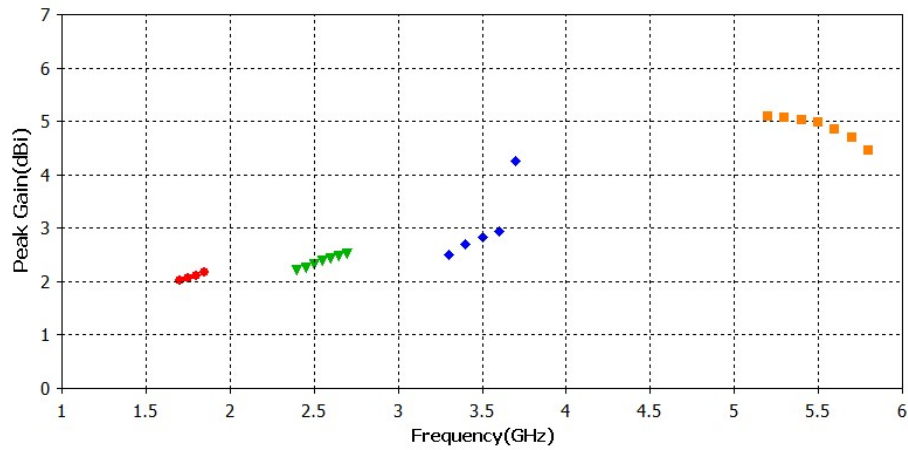


Fig. 6: Peak Gain of the Proposed Antenna

Comparisons between the proposed antenna and some existing multiband antennas are shown in Table 1. From the Table 1, the proposed antenna with an excellent multiband performance has a smaller size than previously proposed quadruple antennas in [11, 12]. Although previously reported antennas in [13-15] have smaller sizes than our designed antenna, they cannot cover all the above mentioned operating bands.

Table 1: Comparisons of several existing multiband antennas.

References	Sizes (mm ²)	Operating bands
[11]	45.5×85	1.8/2.4/3.6/5.5
[12]	70 × 70	1.78/2.4/3.46/5.26
[13]	28×41	2.4/3.5/5.8
[14]	35×25	2.4/3.5/5.8
[15]	14.6×17.5	2.4/3.5/5.8
This work	26×45	1.8/2.4/3.5/5.2/5.5/5.8

4. Conclusion

In this paper, a novel CPW-fed multiband planar monopole antenna with quadruple band characteristic has been presented. The proposed antenna is fabricated on a low-cost FR4 substrate with dimensions of 26 mm × 45 mm × 1.6 mm. The proposed antenna with planar structure and small size is designed to cover the 1800 MHz GSM, 2.4/5.2/5.8 GHz WLAN, and 2.5/3.5/5.5 GHz WiMAX bands. The measured -10 dB impedance bandwidths are about 150 MHz (1700-1850 MHz)/ 310 MHz (2.38–2.69 GHz)/ 520 MHz (3.23–3.75 GHz) /820 MHz (5.09–5.91 GHz). The peak gains are 2.1dBi at 1800MHz, 2.21dBi at 2.4GHz, 2.8dBi at 3.5GHz, and 4.98dBi at 5.5GHz. Also, the good omnidirectional radiation patterns in *H*-plane are obtained. The proposed multiband monopole antenna with a compact size, planar structure, low cost, ease to manufacture, omnidirectional *H*-plane radiation patterns, and good impedance bandwidths is well suitable for GSM, WLAN and WiMAX communication applications.

5. References

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