A Compact CPW-Fed Triple Band Monopole Antenna with Simple Structure for WLAN/WiMAX Applications

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Abstract

In this paper, a new compact coplanar waveguide (CPW)-fed triple band monopole antenna with dual circular rings and two L-shaped parasitic strips on the ground plane is presented. The fabricated antenna with new simple structure has a compact size of 26 mm × 34 mm. The proposed antenna has impedance bandwidths of 2.39-2.69 GHz, 3.21- 4.12GHz and 5.08 -5.86GHz with a reflection coefficient of less than -10dB. The measured performances are compared with the simulated results and show good agreement. The proposed triple band monopole antenna also has good omnidirectional radiation patterns and available gain. The simple structure, ease of implementation, compact size and good performances make the proposed antenna an excellent candidate for WLAN and WiMAX applications.

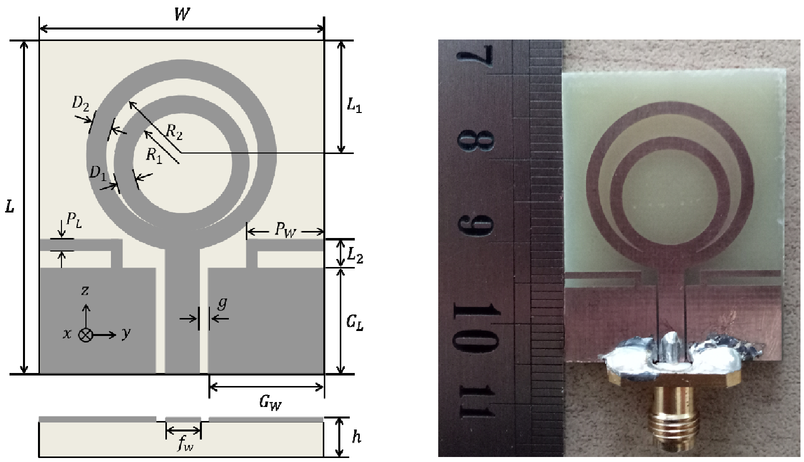
Keywords: monopole antenna, WLAN, WiMAX, multiband antenna, parasitic strip, coplanar waveguide.

1. Introduction

The rapid growth in wireless techniques has increased the demands for developing antennas employing multiple frequency bands in mobile devices. Wireless local area network (WLAN) and Worldwide interoperability for microwave access (WiMAX) are very popular wireless communication systems and have been widely applied in mobile devices. The ranges of resonant frequencies for WLAN are from 2.412- 2.484 GHz, 5.15- 5.35GHz and 5.725-5.825 GHz bands and WiMAX are from 2.4- 2.69GHz, 3.4-3.69GHz and 5.25- 5.85GHz bands. Recently, WLAN and WiMAX have been simultaneously used in the same mobile device. Thus, it is necessary to design multiband antennas with simple configuration, small size, light weight and good performance. Several multiband antenna designs have already been presented, including an antenna loaded with metamaterial and slots [1], CPW-fed planar monopole antennas [2, 3], a monopole antenna with a split ring [4], a circular ring monopole antenna with double L-shape [5], antennas with etching slots on the patch or ground [6-8], antennas with meander lines [9-11], a fork shaped antenna [12], an antenna with double rectangular rings and vertical slots [13] and so on. However, some of these presented multiband antennas are not easy to be used for portable devices due to their large sizes or complex configurations. In this paper, a compact CPW-fed triple band monopole antenna with simple structure for WLAN/WiMAX applications is proposed and investigated in detail. By using dual circular rings and two L-shaped parasitic strips on the ground plane, three resonance frequencies are obtained to operate at 2.4/3.5/5.2/5.5/5.8 GHz bands. The parameter effects on the impedance bandwidth are simulated and optimized using CST Microwave Studio software. Simulated and measured results show that the designed antenna has controllable triple band and good omnidirectional radiation characteristics which make it suitable for WLAN and WiMAX applications. This paper is organized into four sections. In Section 2, antenna design is presented. The simulation and measurement results are discussed in Section 3 and concluding explanations of this paper are given in Section 4.

2. Antenna design

Fig. 1(a) shows the geometric configuration of the proposed compact CPW-fed triple band monopole antenna. The proposed antenna is fabricated on a low-cost FR-4 substrate with the thickness of 1.6 mm, the relative permittivity of 4.4, and loss tangent of 0.02. The proposed antenna consists of dual circular rings, a CPW line and two L-shaped parasitic strips on two ground planes of the CPW line. The proposed antenna has a single-layer metallic configuration for ease of implementation. The proposed antenna with new structure has a compact size of 26×34 mm^2. A signal strip width of a 50 Ω CPW transmission line is 3 mm and a gap distance is 0.3 mm. A SMA connector is connected to the 50Ω CPW line to feed the antenna. A parametric study is carried out in order to sufficiently investigate the performance of the proposed triple band antenna. The key parameters R_1, R_2 and P_W are selected to investigate their effects on the antenna impedance bandwidth. Fig. 2(a) shows the effects of R_2 on the reflection coefficient of the proposed triple band antenna. As shown in Fig. 2(a), it is observed that, the parameter R_2 has an important effect on the upper and the lower frequency bands.

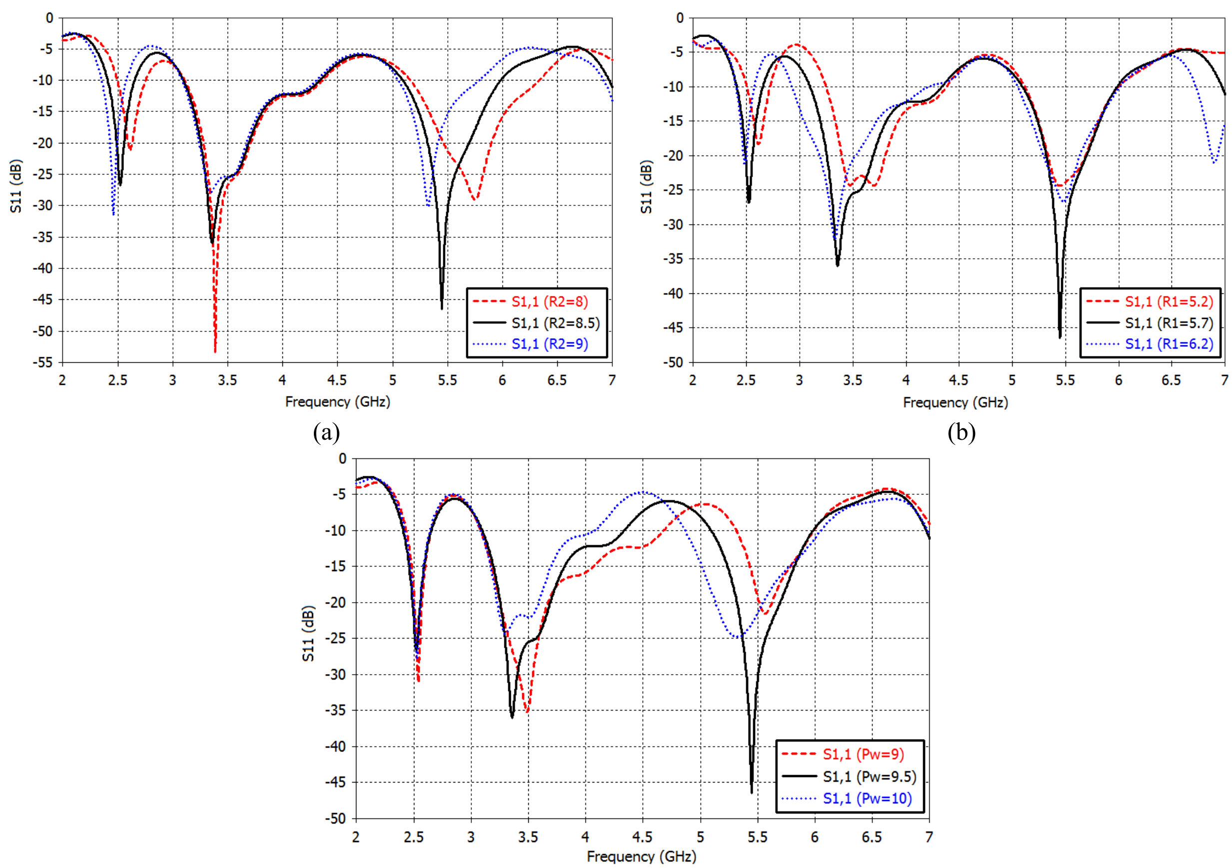


(a) (b)

Fig. 1: *Geometry of the Proposed Antenna*

(a) *Structure*, (b) *Photograph*

When parameter R_2 increases from 8 mm to 9 mm, the resonance frequencies of the upper and the lower bands move to lower frequency side. In this case, the resonance frequency of the middle band is slightly changed. It is observed from the Fig. 2(b) that the resonance frequency of the middle band moves to lower frequency side with an increase of R_1 from 5.2 mm to 6.2 mm. At the same time, the upper and the lower frequency bands are slightly changed. The effect of parameter P_W is shown in Fig. 2(c). It can be seen from Fig.2(c) that the resonance frequency of the upper band moves to lower frequency side with an increase of P_W from 9 mm to 10 mm, while the lower and the middle band are almost invariable.



(a) (b)

(c)

Fig. 2: *The Simulated Reflection Coefficients of the Proposed Antenna with Different Values of* R_1, R_2 *and* P_W

(a) R_2, (b) R_1, (c) P_W

From the discussion above, we can control the resonance frequencies of the three operating bands and it can be adjusted by changing the dimensions of the circular rings and L-shaped parasitic strips. Through simulations with CST Microwave Studio software, the optimized parameters of the designed antenna are listed as follows: $L = 34$, $W = 26$, $h = 1.6$, $fw = 3$, $g = 0.3$, $G_W = 11.2$, $G_L = 9$, $R_1 = 5.7$, $R_2 = 8.5$, $P_L = 0.8$, $P_W = 9.5$, $L_1 = 13.1$, $L_2 = 1.8$, $D_1 = D_2 = 1.8$. Here all dimensions are in mm.

3. Results and discussions

To verify the design of the proposed antenna, a prototype of the triple band antenna is fabricated and measured. The photograph of the fabricated triple band antenna is shown in Fig. 1(b) and the measurement is taken with an Agilent FieldFox N9918A vector network analyzer. Fig. 3 shows the simulated and measured reflection coefficients of the proposed antenna with the optimized dimensions, and good agreement between simulated and measured results is observed. As shown in Fig. 3, the proposed antenna has three different resonance frequencies at 2.4 GHz, 3.5 GHz, and 5.5 GHz, which can cover 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/5.5 GHz WiMAX operational bands with a reflection coefficient of less than -10dB. The measured bandwidths of the proposed antenna at the desired three different operating bands are 300 MHz (2.39-2.69 GHz), 910 MHz (3.21-4.12 GHz), and 780 MHz (5.08-5.86 GHz), respectively. The simulated current distributions of the proposed antenna at the three 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, the current distributions of the three different resonance frequencies are different from each other. As can be seen from the Fig 4(a), the current distribution at lower frequency band (2.4GHz) mainly focuses on the outer and inner circular ring. As can be seen from the Fig. 4(b), the current distributions at middle frequency band (3.5GHz) mainly concentrate on the inner circular ring and two L-shaped parasitic strips on the ground plane. Similarly, as can be seen from the Fig. 4(c), current distributions at upper frequency band (5.5GHz) mainly appear on the outer circular ring and two L-shaped parasitic strips on the ground plane.

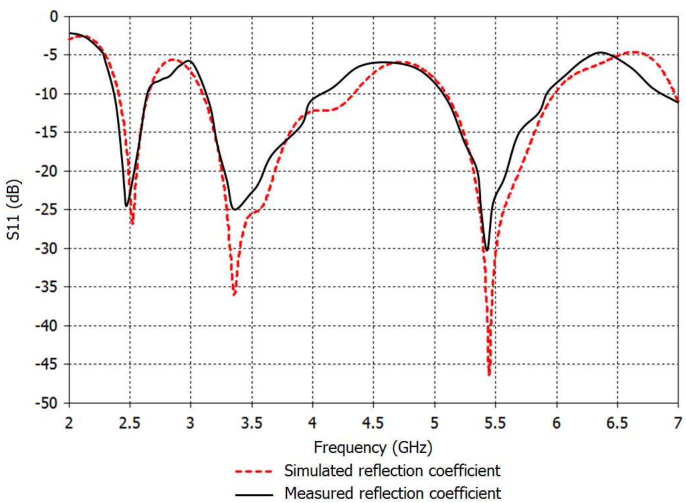
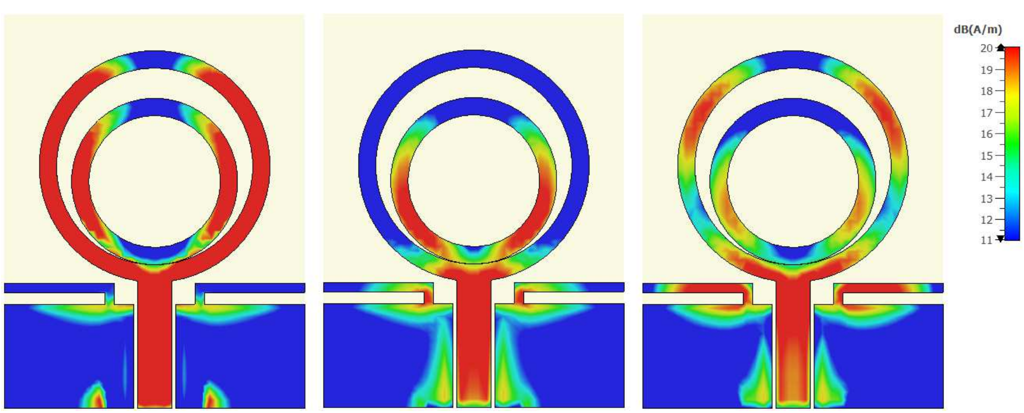


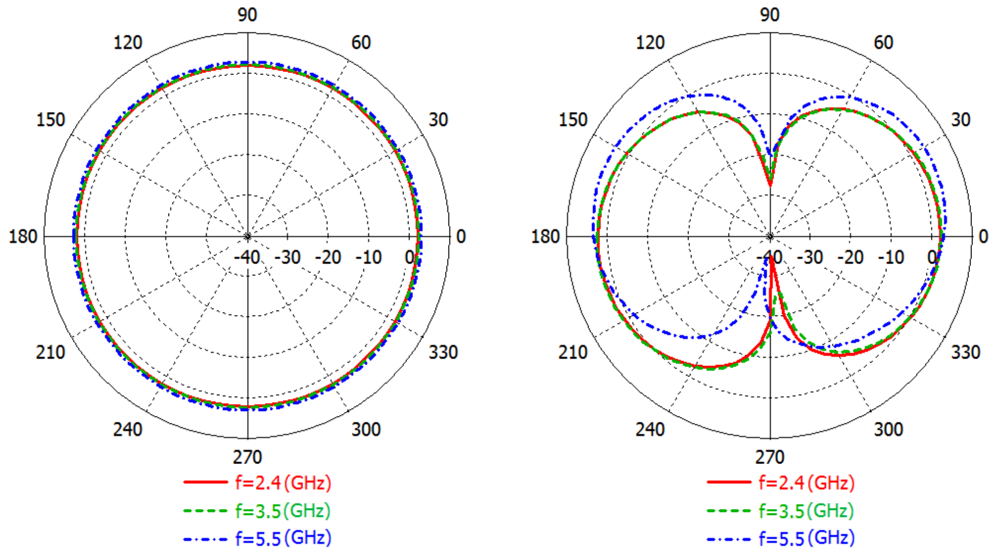
Fig. 3: *The Simulated and Measured Reflection Coefficient of the Proposed Antenna*



(a) (b) (c)

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

The radiation patterns of the proposed triple band 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 figure of eight radiation patterns in *E*-plane (x-z plane). The Realized gain of the proposed triple band antenna is shown in Fig. 6. It is found that the peak realized gain levels of the antenna at 2.4 GHz, 3.5 GHz and 5.5 GHz are about 1.99dBi, 2.06dBi and 3.34dBi, respectively.



(a) (b)

Fig. 5: *Radiation Patterns of the Proposed Antenna*
(a) *H-Plane(x-y Plane),* (b) *E-Plane(x-z Plane)*

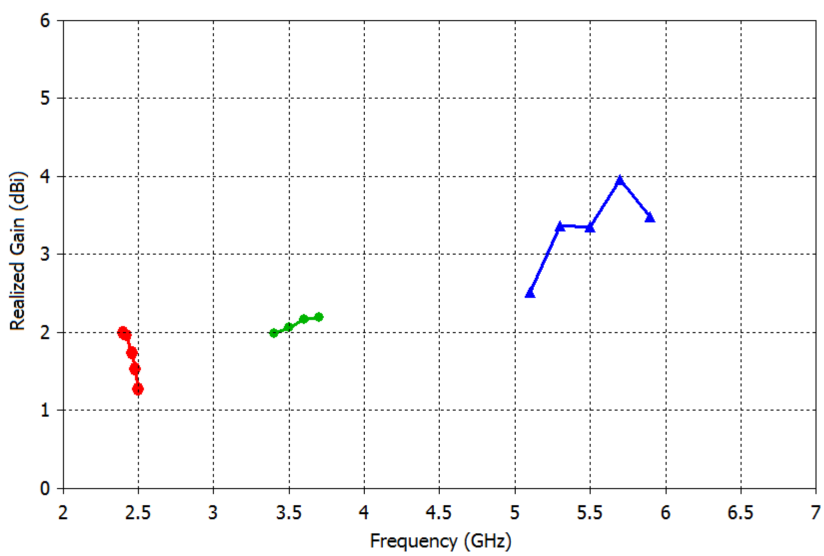


Fig. 6: *Realized Gain of the Proposed Antenna*

Comparisons between the proposed antenna and some existing multiband antennas are shown in Table 1. From the Table 1, we note that some of the early reported antennas can provide three operating bands to cover the 2.4/3.5/5.2/5.5/5.8 GHz.

Table 1: Comparisons of several existing multiband antennas.

References	Size (mm^2)	Operating bands
[14]	14.6×17.5	2.4/3.5/5.8
[15]	20×35	2.4/5.5/5.8
[16]	40×40	2.4/3.5/5.2/.5.5/5.8
[17]	35×25	2.4/3.5/5.8
[18]	27.1×38.8	2.4/3.5/5.2/.5.5/5.8
[19]	28×41	2.4/3.5/5.8
This work	26×34	2.4/3.5/5.2/.5.5/5.8

Although previously reported antennas in the literature have smaller sizes than our designed antenna [14, 15], they cannot cover all the above mentioned operating bands and also have a complex structure. The proposed antenna with an excellent multiband performance has a smaller size and simple structure than previously proposed triple antennas in [16-19].

4. Conclusion

In this paper, a novel compact CPW-fed triple band monopole antenna with simple structure is proposed and investigated. The dual circular rings and two L-shaped parasitic strips on the ground plane have been used to generate the desired three individual resonance frequencies at 2.4 GHz, 3.5 GHz, and 5.5 GHz. The multiband antenna is fabricated on FR4 substrate and has a compact size of 26 mm × 34 mm × 1.6 mm. The measured -10 dB impedance bandwidth of the proposed multiband antenna covers the frequency ranges 300 MHz (2.39-2.69 GHz), 910 MHz (3.21-4.12 GHz), and 780 MHz (5.08-5.86 GHz), which meets the specifications of WLAN 2.4/5.2/5.8 GHz and WiMAX 2.5/3.5/5.5 GHz frequency bands. Also, the good omnidirectional radiation patterns in *H*-plane and realized gain levels of the proposed antenna of 1.99dBi at 2.4 GHz, 2.06dBi at 3.5 GHz, and 3.34dBi at 5.5 GHz are also obtained. The simple structure, compact size, ease of manufacture and good characteristics of the proposed antenna make it an excellent candidate for WLAN and WiMAX communication applications.

5. References

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