A Compact Triple Band Antenna for Bluetooth, WLAN and WiMAX Applications

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Abstract **─** In this paper, we propose a compact triple band microstrip antenna, whose performance is discussed and investigated by using full-wave simulation and measurements. To achieve expected triple-band characteristics, three nested loop radiation elements are presented and a rectangular stub connected to the feed line is also introduced. Our proposed antenna has a size of 28 mm×41 mm and a thickness of 1.5 mm, which is fed by a coplanar waveguide (CPW). The simulated and measured results show that the proposed antenna provides a tri-band characteristic that covers 2.1-2.8 GHz, 3.3-4.0 GHz and 5.5-5.8 GHz. The center frequencies of the designed triple bands can be controlled by adjusting the dimensions of the nested loop elements. As a result, the designed tri-band antenna has a good impedance matching characteristic and omnidirectional radiation patterns, which make the proposed antenna could be a favorable candidate for Bluetooth, WiMAX and WLAN applications.

Index Terms **─** Bluetooth; CPW feeding; nested loop radiation elements; tri-band antenna; WiMAX and WLAN applications

I. INTRODUCTION

In recent years, wireless communication technology has been extensively studied and used for many portable devices like smartphone, laptop and other personal terminals. As a wireless equipment, an antenna plays an important role in transmitting and receiving electromagnetic wave signals. Furthermore, microstrip antennas have gotten more and more attentions in recent decades due to the rapid development of wireless communications and their advantages of low cost, easy of fabrication and conformability [1-6]. Wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) based on IEEE 802.11 and 802.16 standards are two most widely studied wireless technologies. Also, WLAN and WiMAX have been used in our daily life, and operate at 2.4-2.484 GHz, 5.15-5.35 GHz, 5.725-5.825 GHz and 2.5-2.7 GHz, 3.3-3.69 GHz and 5.25-5.85 GHz. After that, many research articles have been published to make an effort to design WLAN and WiMAX antennas [7-10]. Meanwhile, Bluetooth, a short distance transmission technology, has also been widely integrated into a smart phone, a smart watch, a wireless headset and an on-ear headphone [11]. The Bluetooth is also operating in the band from 2.4 GHz to 2.483 GHz. Thus, multi-band design is needed for developing a wireless device by sharing only one antenna, which has an advantage of high efficiency and low cost [12]. Then, many methods have been presented to design an antenna with good multi-band characteristics, including etching slots on the patch or ground [13-14], loading the shorted pins and walls [15], adding stubs to the ground and patch [16], using metamaterials [17] and EBG [18], and so on. However, designing an antenna to cover Bluetooth, WiMAX, and WLAN bands is still a challenging work today. Most of the mentioned antennas cannot be integrated into portable devices because of their large size or complex structure.

We present, in this paper, a compact CPW feed triple band microstrip antenna for Bluetooth, WLAN and WiMAX applications. By using three nested loops and a rectangular stub connected to the feed line, three resonance bands can be achieved to operate at 2.1-2.8 GHz, 3.3-4.0 GHz and 5.5-5.8 GHz, which can be used for Bluetooth, WiMAX at 2.5/3.5/5.5 GHz and WLAN at 2.4/5.8 GHz. By adjusting the dimensions of the antenna, the center frequencies of these three operating bands are tunable, which makes it flexible for practical fabrication. The full-wave simulation and measurement results have verified that our proposed antenna has not only a triple-band achievement but also a good impedance matching characteristic and omnidirectional radiation patterns at three operating bands, which make it suitable for Bluetooth, WLAN and WiMAX communication applications. The numerical

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full-wave simulation results and optimized dimensions of the proposed tri-band microwave antenna are obtained by using the commercial software package high frequency structure simulator (HFSS).

II. ANTENNA CONFIGURATION

The configuration of the proposed triple-band antenna is depicted in Fig. 1. The proposed antenna is fabricated on a substrate with a relative permittivity of 3.5, a loss tangent of 0.002 and a thickness of 1.5 mm. The antenna has a total size of 28×41 mm^2. Our proposed antenna is comprised of a CPW-fed structure, which includes a CPW ground plane and a 50-Ohm feed signal line whose width is W0=4 mm, three nested loop radiation elements and a rectangular stub connecting to the feeding feed line. The three operating bands are generated by the presented three nested loops so that the center frequencies of three operating bands can be adjusted by selecting the dimension of the loops. The distance M1, M2 and M3 between the centers of the three loops and the end of the feeding point are 22 mm, 25.5 mm and 28.5 mm, respectively. The end of the feeding point is the connecting point of the loops and the feeding line. The rectangular stub is used to improve the efficiency. The structure of the antenna is very simple in which the CPW fed structure has the advantage of easy to integration with the radio-frequency front-end. The proposed antenna is investigated and optimized by using the Ansoft High Frequency Structure Simulator (HFSS) Version 13, and the optimized parameters of the antenna are listed in Table 1.

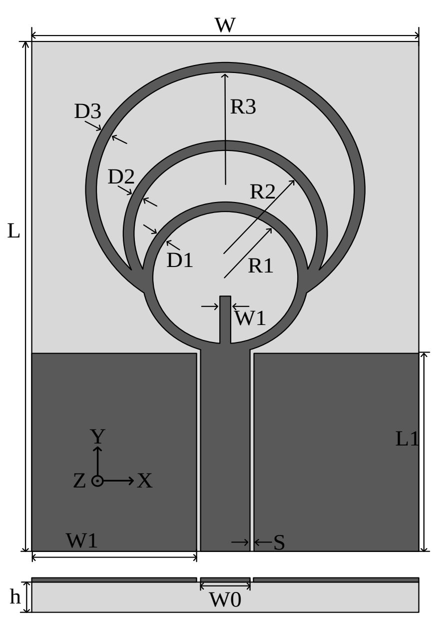

Fig. 1. Geometry structure of the proposed antenna.

Table 1: Optimized parameters of the antenna

L	41 mm	R1	5.5 mm	D3	1 mm
L1	15.5mm	R2	7 mm	S	0.4 mm
W	28 mm	R3	10 mm	M1	22 mm
W0	4 mm	D1	1 mm	M2	25.5 mm
W1	1 mm	D2	1 mm	M3	28.5 mm

III. PERFORMANCE ANALYSIS

For the design of the antenna, three nested loops are used to generate the expected resonance frequencies. Each nested loop is initially set to be about quarter wave length corresponding to the resonance frequency. Then, the antenna is modeled and optimized by means of the HFSS to obtain the optimal dimensions. To sufficiently investigate the performance of the proposed triple-band antenna, the key parameters are selected to investigate the antenna performance. Here, R2, R3 and D1 are chosen to discuss their effects on the antenna impedance. The effects of R2 on the reflection coefficient of the proposed antenna are shown in Fig. 2. It is observed from Fig. 2 that, R2 has an important effect on the highest operating band while the center frequency of the highest band moves to low frequency with an increment of the R2 from 7 mm to 8 mm. And the bandwidth of the middle band is slightly narrowed while the center frequency and bandwidth of the lowest band are almost invariable.

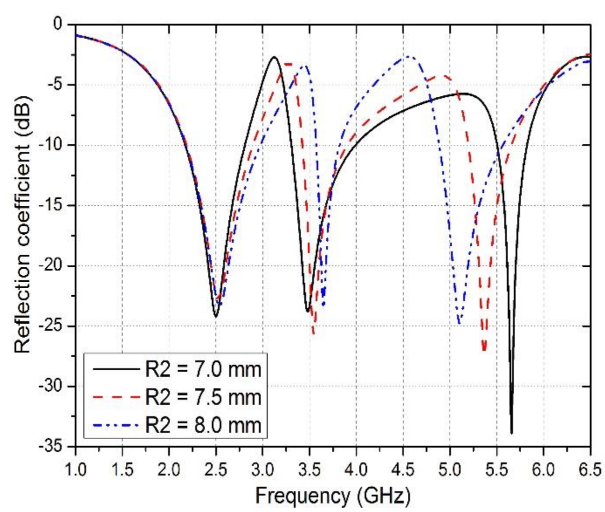

Fig. 2. Effects of the parameter R2 on the reflection coefficient.

Figure 3 depicts the parameter effects on the reflection coefficient of the proposed antenna with variation of R3. It can be found from Fig. 3 that the resonance frequency at 3.5 GHz for WiMAX moves towards the high frequency with the reduction of R3 from 10 mm to 9 mm. At the same time, the bandwidth of the lowest band is improved, while the bandwidth and the center frequency keep constant.

In Fig. 4, the effect of parameter D1 is presented. We can find from the figure that the center frequency of the highest band moves to high frequency with the increment of D1, while the middle band and the lowest band are almost invariable. Thus, we can conclude that the center frequencies of the three operating bands can be controlled by adjusting the dimensions of the loops.

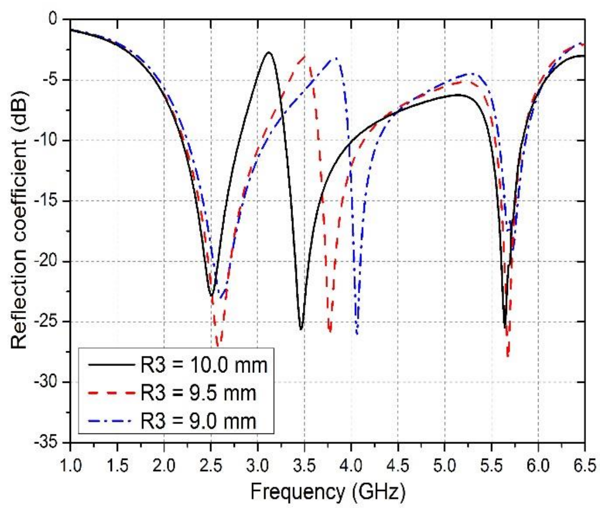

Fig. 3. Effects of the parameter R3 on the reflection coefficient.

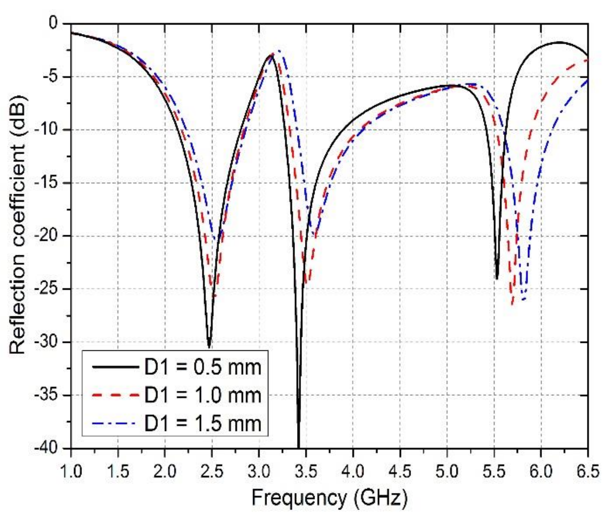

Fig. 4. Effects of the parameter D1 on the reflection coefficient.

From discussions above, we can see the radius and the width of the designed nested loop radiation element have important effects on the impedance bandwidth. The effect of the rectangular stub on the reflection coefficient is depicted in the Fig. 5 from which it can be found that the proposed antenna without the stub can operating at 5.5 GHz to 6.3 GHz. By using this stub, we remove the unwanted bandwidth that is out of the WLAN band. Thus, we can conclude that the proposed antenna with stub can effectively suppress the out-of-band radiation, and help the proposed antenna to improve the efficiency.

The impedance characteristic of the proposed triple bands is illustrated in Fig. 6, in which the black line is the real and the red line is the imaginary. It is found that the real part of the antenna impedance at the three operating bands is around 50 Ohm and the imaginary part is about zero, which means that the proposed triple-band antenna has a good impedance matching characteristic at the three operation bands.

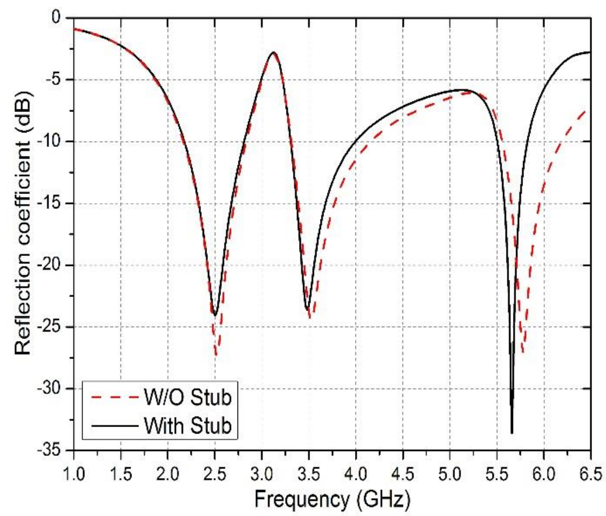

Fig. 5. Reflection coefficient of proposed antenna with and without stub.

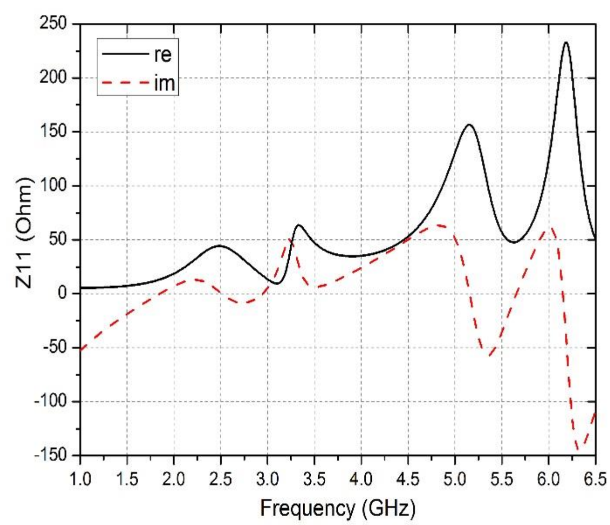

Fig. 6. Impedance characteristic of proposed tri-band antenna.

In order to verify the performance of the proposed CPW-fed triple-band antenna, the optimized antenna is fabricated and antenna performance is measured. The phototype of the fabricated antenna is shown in Fig. 7. The measured and simulated reflection coefficients of the designed antenna are shown in Fig. 8, where the measured result is obtained by using Agilent N5224A vector network analyzer. We can observe that the measurement result in a good agreement with the simulated one, which can help verify the effectiveness of the simulation. As is noted, there are some discrepancies between the measurement and the simulation, which may be caused by the fabrication tolerances and experimental conditions. From Fig. 8, we can find that our proposed antenna has three operation bands at 2.5 GHz, 3.5 GHz and 5.6 GHz in terms of the reflection coefficient less than -10 dB. The bandwidth of the lowest band, middle band and highest band are 0.7 GHz, 0.7 GHz and 0.3 GHz, respectively. The three resonance frequencies can be used for Bluetooth, WLAN 2.4GHz, WiMAX 3.5 GHz and WLAN 5.8 GHz.

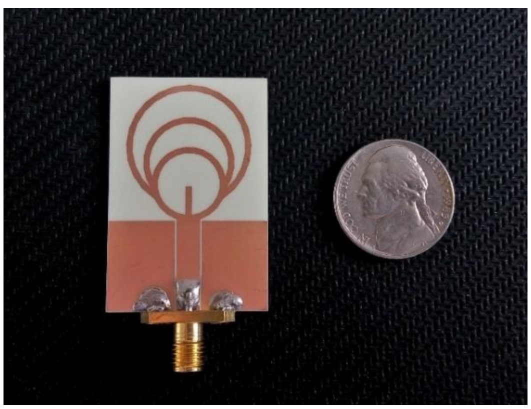

Fig. 7. Fabricated tri-band antenna.

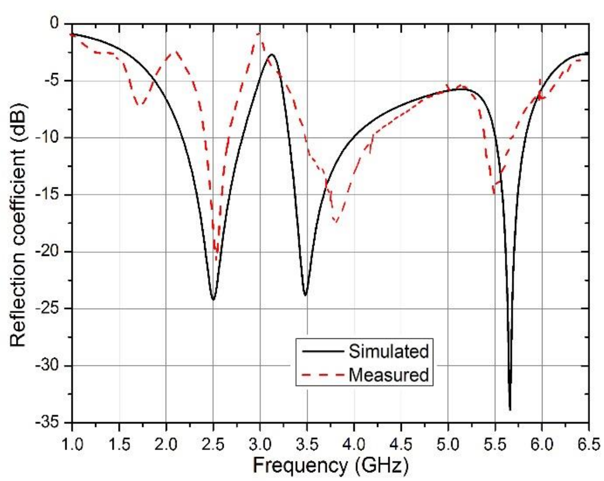

Fig. 8. The measured and simulated reflection coefficients of antenna.

Current distribution of the proposed tri-band antenna in Fig. 9 at 2.5 GHz, 3.5 GHz and 5.65 GHz are also studied to get a further understanding of the principle. From the figure, we can see that the current distribution at 2.5 GHz mainly focuses on the feed line. The current distributions concentrate on the both feed line and second loop at 3.5 GHz. Similarly, a large current appears on the both first and second loop at 5.65 GHz.

Figure 10 shows the gain and the efficiency of proposed antenna. It is found that the gain of the antenna are 1.8 dBi, 1.8dBi and 5dBi at 2.5 GHz, 3.5 GHz and 5.6 GHz, respectively, which are higher than zero in the operating bands. The efficiency is higher than 90% in most of the operating bands.

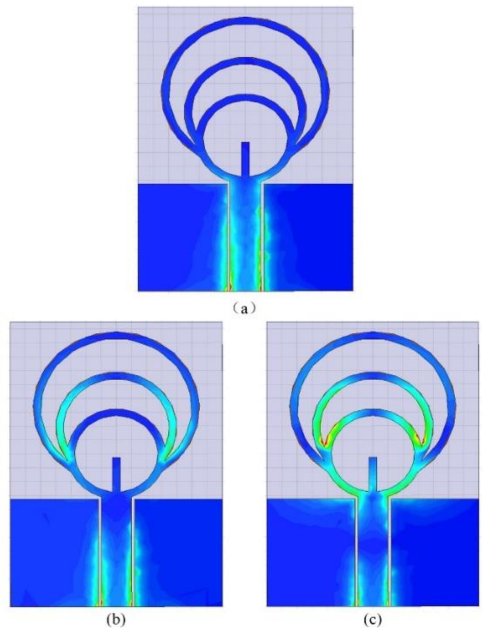

Fig. 9. Current distribution of antenna: (a) 2.5 GHz, (b) 3.5 GHz, and (c) 5.65 GHz.

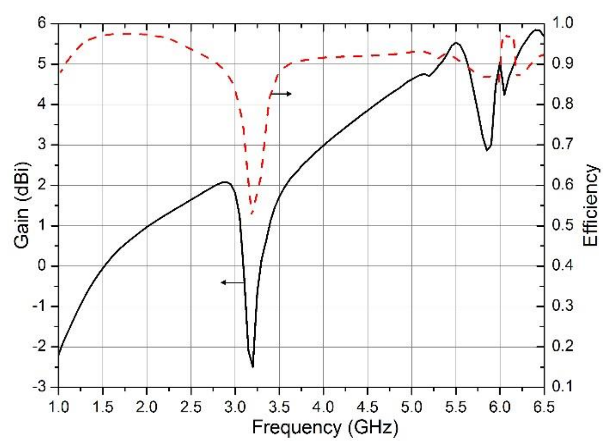

Fig. 10. Gain and radiation efficiency of the proposed antenna.

The radiation patterns at 2.5 GHz, 3.5 GHz and 5.65 GHz of proposed antenna are obtained in a chamber, which are shown in Fig. 11. It can be found from the figure that our designed tri-band antenna has a nearly omnidirectional radiation patterns in the H-plane, and a figure-of-eight radiation patterns in E-plane, which can meet the requirement for the above designated wireless communication applications.

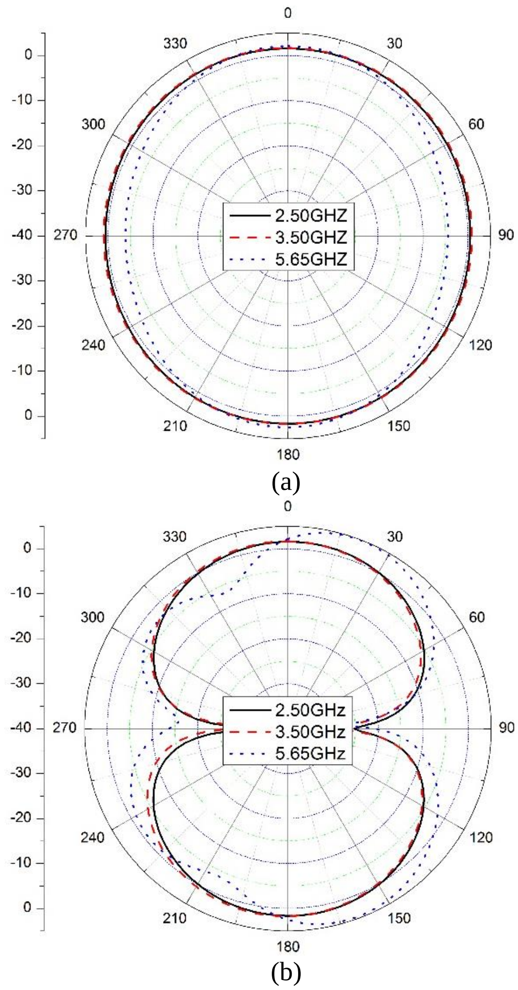

Fig. 11. Radiation patterns of the proposed antenna: (a) H-plane and (b) E-plane.

IV. CONCLUSION

A compact triple-band microstrip antenna has been proposed and its performance has been investigated by the simulation and measurement. Three nested loops and a rectangular stub have been employed to realize the desired triple-band characteristics at 2.5 GHz, 3.5 GHz and 5.6 GHz, which are used for Bluetooth, WLAN and WiMAX wireless communication applications. The proposed antenna has a size of 28 mm × 41 mm, a simple structure. Furthermore, the simulated and experimental results demonstrated that our designed triple-band antenna has a tunable frequency characteristics and good omni-directional radiation patterns, rendering it suitable for multi-band wireless communication system applications.

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