A Simple Miniaturized Triple-band Antenna for WLAN/WiMAX Applications

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Abstract— The design of a simple small-size multi-band antenna for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) application is presented in this paper. The antenna covers the 2.4/5.2/5.8-GHz WLAN operating bands and the 2.5/3.5/5.5-GHz WiMAX bands. The proposed printed-type antenna is based on a 1.6 mm-thick FR4 epoxy substrate with dimensions 25 mm × 38 mm. It has a rectangular split-ring slot enclosed inside a rectangular patch. The inclusion of the split-ring slot and the U-shaped slot in the partial ground plane gives resonance at two additional frequencies. The dimensions of the patch, the ground, and the two slots are optimized to obtain these desired functional frequency ranges.

1. INTRODUCTION

Due to the rapid and wide development of wireless communications, the design goal is heading towards the desired features of compact, lightweight, multi-band and low cost antennas. UWB antennas have the advantage of covering a very wide frequency range. In [1], a UWB antenna operational over the 2–11 GHz range is presented. However, UWB antennas are prone to noise from unwanted frequencies, which could degrade the original message. On the other hand, reconfigurable antennas are designed to be able to control the resonance of the antenna and limit the disadvantage of UWB antennas. A frequency reconfigurable antenna is proposed in [2]. Though very robust, reconfigurable antennas are complex as they require the use of switching elements and their biasing lines, or other complicated reconfiguration mechanisms. Multi-band antennas can be thought of as an intermediate solution combining simplicity and multi-frequency operation.

The advantage of the multi-band antennas is to be able to integrate several frequency bands on one single antenna, making it useful for several frequency ranges. These multi-band antennas could contain frequency ranges from several wireless applications. [3, 4] represent two antennas working on multi-frequency bands. In this paper, the antenna presented is capable of working on triple-frequency bands, for the two different applications, WLAN and WiMAX.

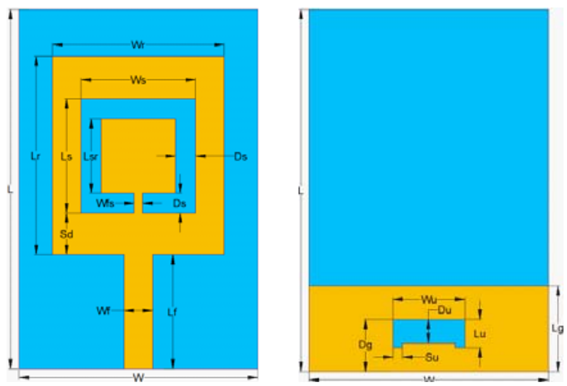
In [5–18] several printed antenna designs for both WLAN and WiMAX applications have been presented. In [5–7], the triple-band characteristic is designed by etching two narrow slots with different lengths on a wideband monopole antenna. In [8], the design uses a trapezoidal ground to achieve the triple-band frequencies of WLAN/WiMAX applications. In [9], a triple-band unidirectional coplanar antenna is presented, but with a large size of $100 \times 60\,\text{mm}^2$. Usually, to meet the requirements of mutli-band frequency range, a various types of configurations could be used. In [10], a meander T-shape with a long and a short arm are used to achieve multi-band frequency. A multifractal structure is used in [11]. In [12, 13], a flared shape with V-sleeve or Y-shape is implemented to realize the multi-band operation. However these antennas have a large size comparing to the limited space of mobile wireless terminals. Through the development of antenna design, slot structures have been proposed to reduce the size of the multi-band antennas. In [14], the use of U-slots with a combination with an L-probe feed is used to produce dual and multi-band characteristics. A triangular-slot loaded multi-band antenna excited by the strip monopole is presented in [15]. In [16], the adjustment of the size of the slots on the radiating patch improves the performance of the coplanar waveguide-fed monopole antenna, but with a low antenna gain. Meandering slot antennas, in [17, 18], could also be used as well with different slots to generate two resonant modes. However, the complex structures of these antennas make them unsuitable for the practical applications. In [19] a miniaturized multi-frequency antenna is proposed using circular ring, a Y-shape-like strip, and a defected ground plane.

In this paper, using a split-ring slot enclosed inside a rectangular patch and etching a U-shaped slot in the partial ground plane are the two techniques used to achieve not only triple-band operation performance, but also smaller size and simpler structure. By using the three different resonant frequencies, the proposed antenna can generate three resonant modes to cover three desired bands for WLAN and WiMAX applications. The geometry and the design guidelines of the proposed antenna structures are presented in Section 2. Experimental results are presented in Section 3. In Section 4 a brief conclusion is given.

2. ANTENNA STRUCTURE AND DESIGN

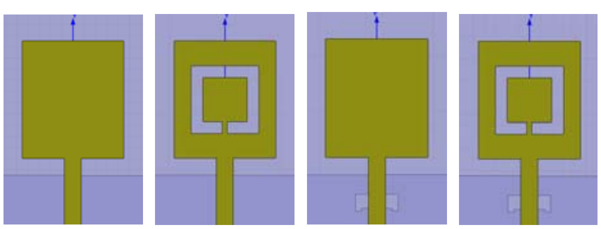
The configuration of the proposed triple-band antenna is shown in Figures 1(a)–(b). The rectangular patch is the main radiating element of the antenna combined with split-ring slot enclosed inside of it. The proposed printed-type antenna is based on a 1.6 mm-thick FR4 epoxy substrate with dimensions 25 mm × 38 mm, fed by a 50 Ω microstrip feed line with a width of 3 mm and a length of 12.06 mm. The partial ground plane is located on the backside of the dielectric substrate, shown in Figure 1(b), where a U-shaped slot is illustrated.

Figures 2(a)–(d) and Figure 3 represent the design evolution of the proposed antenna and its corresponding simulated reflection coefficient. Initially, the antenna in Figure 2(a) consists of a rectangular patch in addition to a partial rectangular ground. As shown in Figure 3(a), there is one operating band from 3 to 5 GHz. The inclusion of the split-ring slot, Figure 2(b), leads to the excitation of an additional coverage of the 2.4–2.5 GHz band, shown in Figure 3(b), without increasing the size, where the current will be divided between the rectangular patch and the split-



(a) (b)

Figure 1: Geometry of the proposed antenna. (a) Front view, (b) back view.



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

Figure 2: (a)–(d) The evolution of the antenna design.

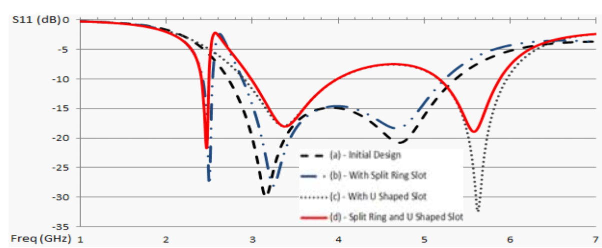
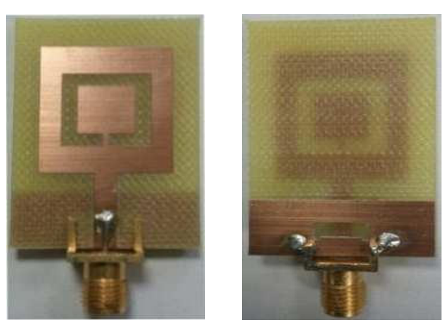


Figure 3: Simulated reflection coefficient of each design.



(a) (b)

Figure 4: The fabricated antenna. (a) Font view, (b) back view.

ring slot giving two resonance frequencies. In Figure 2(c) and under the 50 Ω microstrip feed line, the ground plane is defected by etching a U-shaped slot without adding a split-ring slot in the rectangular patch. The U-shaped slot, as shown in Figure 3(c), gives resonance in the 3–4 and 5.2–5.9 GHz bands. Finally, in Figure 2(d), the two slots were added to the design to achieve resonance in the three frequency bands, 2.4–2.5, 3–4, 5.2–5.9 GHz, as shown in Figure 3(d). The dimensions of the patch, the ground, and the two slots are optimized to obtain these desired functional frequency ranges using Ansoft HFSS.

Figures 4(a)–(b) show the fabricated antenna, with the dimensions shown in Table 1 for both upper and lower part.

3. RESULTS AND DISCUSSION

The computed and measured reflection coefficient plots are given in Figure 5, where good analogy is revealed.

From the measured results it is seen that the antenna covers three frequency bands, 2.4–2.5, 3–4, and 5.4–5.9 GHz bands, making it suitable for WLAN operating in the 2.4, 5.2 and 5.8 GHz bands, and WiMAX networks operating in the 2.5, 3.5 and 5.5 GHz bands.

Due to its geometry as a printed monopole, and the use of the partial ground plane, the antenna has omnidirectional radiation patterns, as shown in Figure 6 for the 2.4, 3.5, and 5.8 GHz frequen-

Table 1: The antenna dimensions (in mm).

Parameter	Size (mm)	Parameter	Size (mm)	Parameter	Size (mm)
W	25	Ws	12	Lg	9
L	38	Ls	12.10	Wu	7.5
Wf	3	Ds	2.10	Lu	3
Lf	12.06	Lsr	7.9	Du	2.5
Wr	18	Wfs	0.9	Dg	5.5
Lr	21	Sd	4.4	Su	1

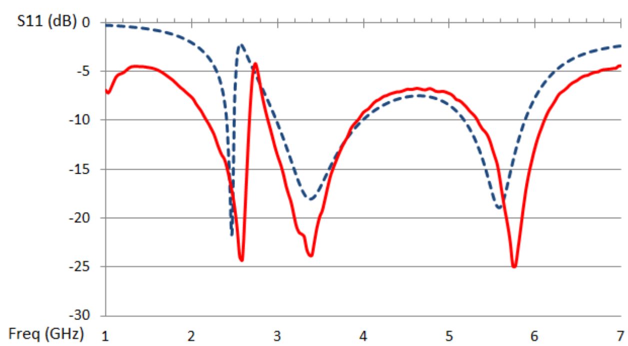


Figure 5: Simulated (dashed line) and measured (solid line) reflection coefficient.

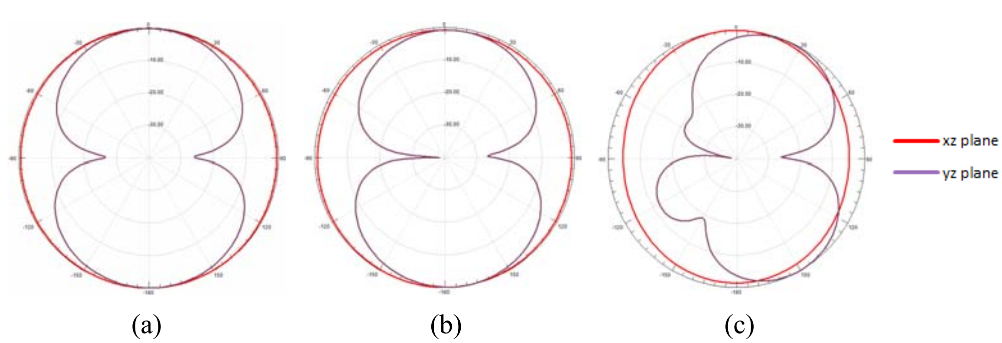


Figure 6: The antenna gain computed at (a) 2.4, (b) 3.5 and (c) 5.5 GHz in the XZ plane (H-plane) and YZ plane (E-plane).

Table 2: Simulated antenna gain at the frequencies of operation.

Frequency (GHz)	Gain (dB)	Frequency (GHz)	Gain (dB)
2.40	1.8811	4.00	2.0398
2.45	1.7991	5.20	2.0568
2.50	1.6529	5.50	1.8904
3.00	1.7120	5.80	1.3232
3.50	1.8529	5.90	1.4112

cies. These simulated patterns reveal an equal gain in the XZ plane (H-plane), and a pattern with the shape of digit 8 in the YZ plane (E-plane).

The antenna gain computed at 2.4–2.5, 3–4, 5.2–5.9 GHz is given in Table 2. As shown, the gain of the proposed antenna within the operating bands satisfies the requirement of several wireless communication terminals.

4. CONCLUSION

A novel triple-band antenna suitable for WLAN/WiMAX applications is proposed in this paper. Using a split-ring slot implanted in the rectangular patch and a U-shaped slot etched partial ground plane, three resonant modes with excellent impedance performance are achieved.

The compact size, triple-band frequency, excellent radiation patterns, good gain and a simple structure makes this antenna suitable for practical wireless communication systems, working on WLAN and WiMAX networks, in three different frequency bands, 2.4–2.5, 3–4, 5.2–5.9 GHz.

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