Circular Slot Loaded Miniaturized Triple-band Antenna for WLAN/WiMAX Applications

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ABSTRACT
The design of a simple miniaturized triple band antenna for wireless local area net-work (WLAN) covering 2.7/5.5-GHz operating band and worldwide interoperability for microwave access (WiMAX) application covering 3.6-GHz operating band is presented in this paper. The proposed printed-type antenna is based on a 1.6 mm-thick FR4 epoxy substrate with dimensions 25mm × 38 mm. It has a circular split-ring slot enclosed inside a rectangular patch. The inclusion of the split-ring slot and the H-shaped slot in the partial ground plane gives resonance at two additional frequencies. The characteristics of the proposed antenna have been calculated using simulation software IE3D. Simulated results are verified with measurements. Good agreement between measured and simulated results is achieved.

General Terms
Microstrip antenna, WLAN, WiMAX
Keywords
Circular slot, H-shaped slot, Partial ground.

1. INTRODUCTION
Recently, with the wireless communications, such as the WLAN, WiMAX having evolved at astonishing rate, it has been well known that the future communication technology pressingly demands integration of more than one communication system into a limited equipment space. To meet the miniaturization requirement, the antennas employed in mobile terminals must have compact size accordingly. Various WLAN antennas have been investigated to fit in the limited equipment space having dual band or wideband operation capabilities. 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. In this paper, the antenna presented is capable of working on triple-frequency bands, for the two different applications, WLAN and WiMAX. In [1-10] several printed antenna designs for both WLAN and WiMAX applications have been presented. In [1-3], the triple-band characteristic is designed by etching two narrow slots with different lengths on a wideband monopole antenna. In [4,5], a triple-band coplanar antenna is presented. In [6], a Meander T-shape with a long and a short arm are used to achieve multi-band frequency. Through the development of antenna design, slot structures have been proposed to reduce the size of the multi-band antennas. For WLAN/ WiMAX systems, some slot antennas have been proposed by using a slot-ring antenna with a narrow rectangular slot [7], parasitic element [8], or stair-shaped slot antenna [9]. In [10] 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 circular slot along with hexagonal patch enclosed inside a rectangular patch and etching an H-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. Details of the antenna design are described, and both simulated and measured results such as return loss, radiation patterns, and antenna gains are presented and discussed.

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 circular slot along with hexagonal patch enclosed inside of it. The proposed printed-type antenna is fabricated on a 1.6 mm-thick FR4 epoxy substrate with dimensions 25mm × 38 mm, fed by a 50Ω microstrip feed line with a width of 3mm and a length of 12 mm. The partial ground plane is located on the backside of the dielectric substrate, shown in Figure 1(b), where H-shaped slot is illustrated. The antenna shape and dimensions were first searched by using the software Zealand's IE3D, which is based on the Method of Moment (MoM), and then the optimal dimensions were determined from experimental adjustment which are listed in Table 1.

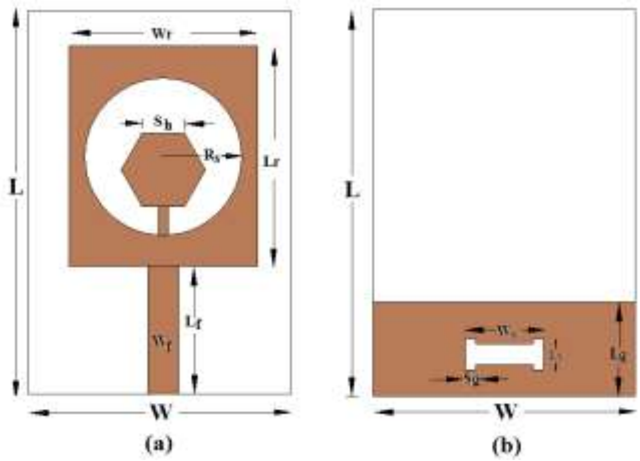


Figure 1: Geometry of the proposed antenna. (a) Top view, (b) bottom view.

Table 1: The antenna dimensions (in mm).

Parameter	Size	Parameter	Size
L	38	S_h	4
W	25	R_s	7.5
W_f	3	W_s	7.5
L_f	12	L_s	3
W_r	18	S_g	1
L_r	22	L_g	10

Figures 2(a-e) represent the design evolution of the proposed antenna. The corresponding simulated reflection coefficient (S_{11}) and resonance curves are shown in figure 3(a) and (b) respectively.

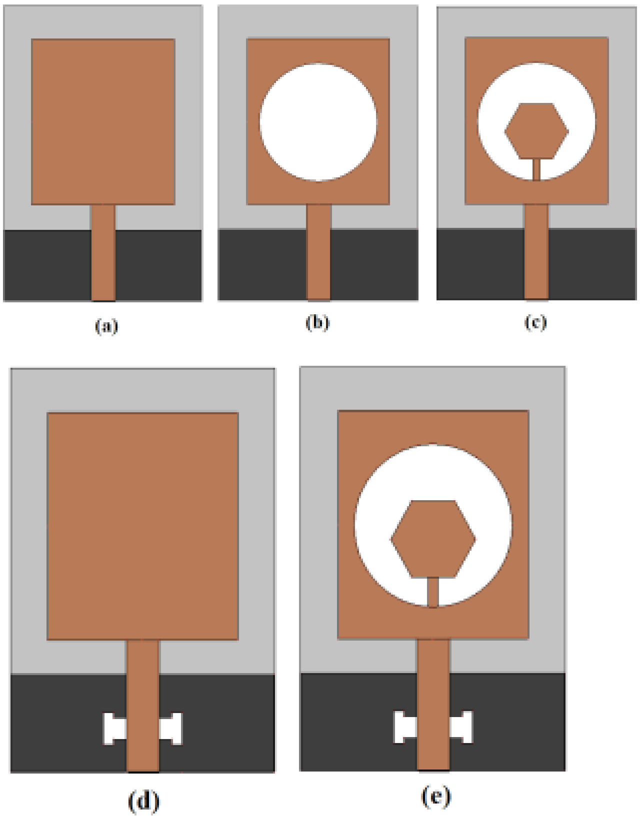


Figure 2: (a-e) the evolution of the antenna design.

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 5.3 GHz. The inclusion of the circular slot in rectangular patch, Figure 2(b), leads to lowering the resonant frequency of 1st mode slightly and increasing the input impedance at the resonant frequency of the 2nd mode as shown in Figure 3(b), without increasing the size, where the current will be divided between the rectangular patch and the circular slot giving two resonance frequencies. In Figure 2(c) the hexagonal patch having side length of 2mm is added inside the circular slot which leads to the excitation of another mode at around 3.4GHz as shown in Figure 3(b). The H-shaped slot is etched in the ground plane, as shown in Figure 2(d), gives resonance in the 3.4 and 5.3-5.6 GHz bands. Finally, in Figure 2(e), the two slots were added to the design to achieve resonance in the three frequency bands, 2.6-2.8, 3.4-3.5, 5.3-5.6 GHz, as shown in Figure 3(b).

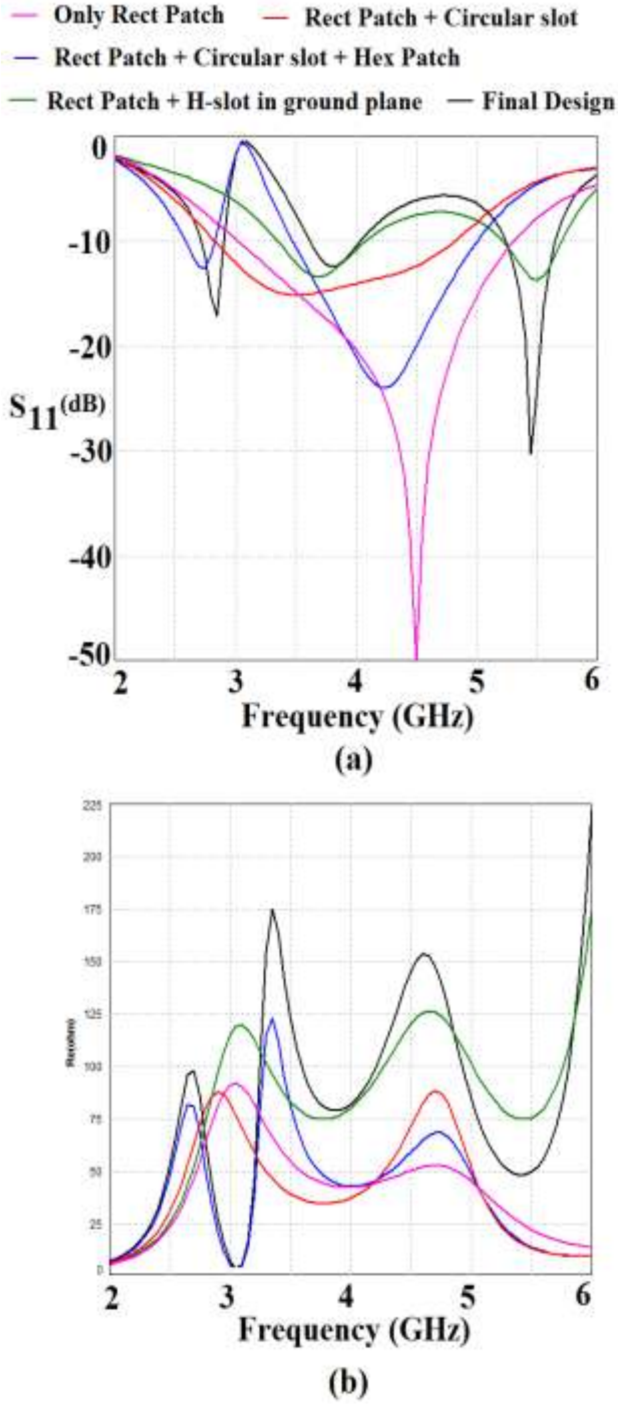


Figure 3: (a) Simulated reflection coefficient of each design and (b) resonance plot for each design

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

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

(a) (b)

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

The return loss (S_{11}) was measured with an R&S vector network analyzer (ZVH-8). Fig. 5 shows the measured return loss plot of the proposed antenna, together with the simulated one. As can be seen, there is a reasonable agreement between the measured and simulated results. Some errors in the resonant frequencies occurred due to tolerance in FR4 substrate and poor manufacturing in the laboratory.

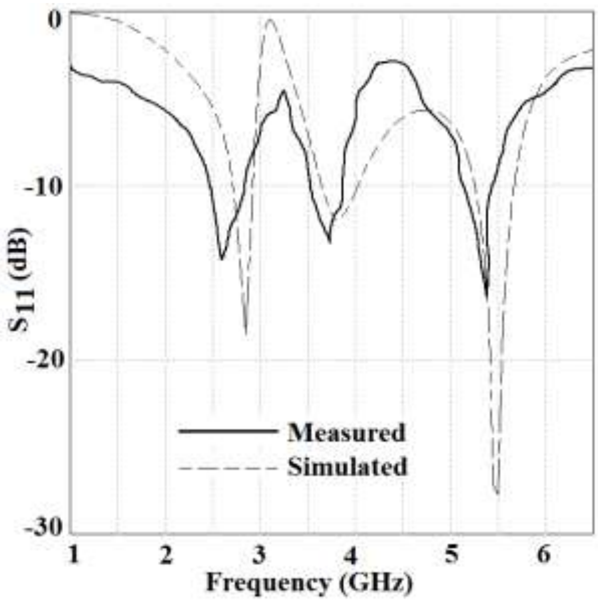
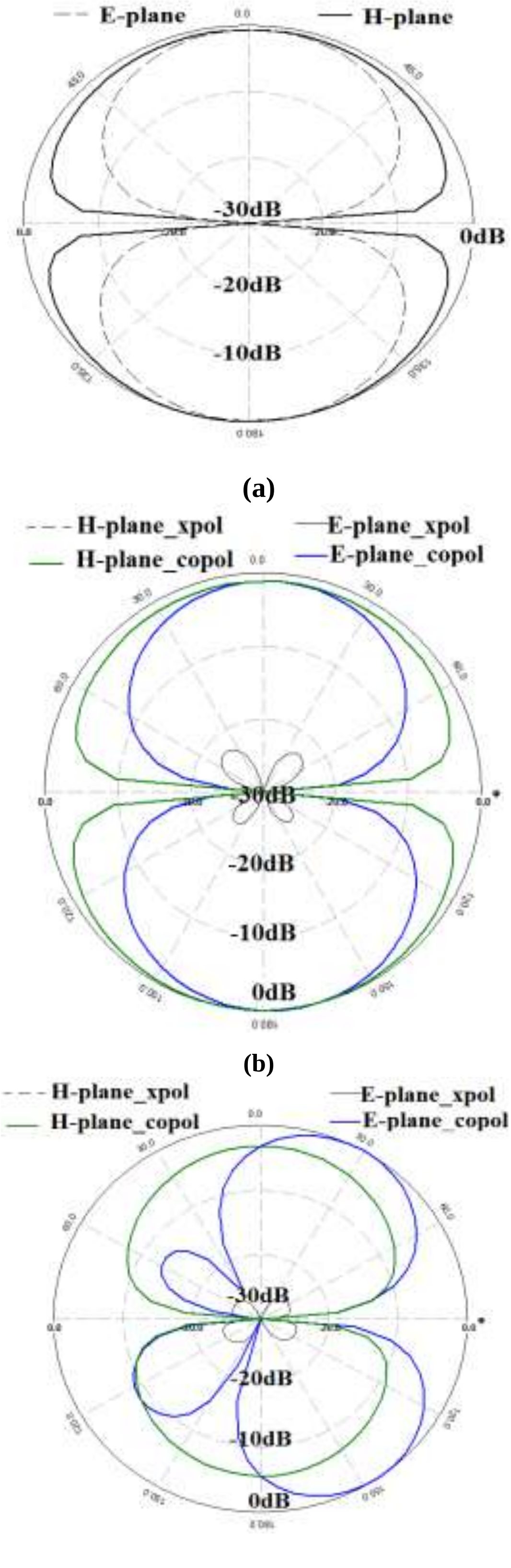


Figure 5. Simulated and measured return loss (S_{11}) of the proposed antenna

From the measured results it is seen that the antenna covers three frequency bands, 2.5-2.65, 3.5-3.6, and 5.2-5.45 GHz bands, making it suitable for WLAN operating in the 2.4 and 5.2 GHz bands, and WiMAX networks operating in the 3.6 GHz band.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 (a-c) for the 2.5, 3.6, and 5.5 GHz frequencies. 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). In the higher band the pattern becomes conical due to excitation of higher order modes.



(c)

Figure 6: Simulated radiation patterns in the E-plane and H-plane at (a) 2.5GHz (b) 3.6GHz and (c) 5.5GHz.

The antenna gain computed at 2.5-2.65, 3.5-3.6, and 5.2-5.45 GHz is shown in Figure 7. As shown, the gain of the proposed antenna within the operating bands satisfies the requirement of several wireless communication terminals.

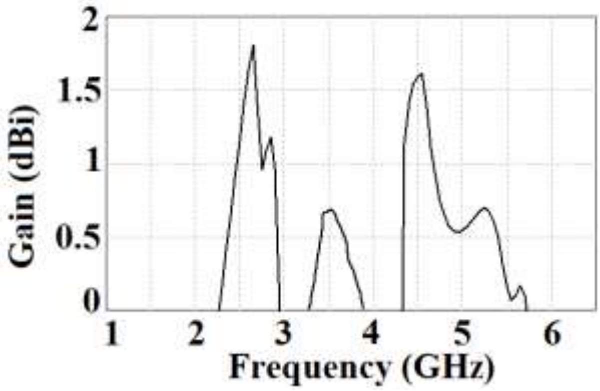


Figure 7. Simulated gain plot for the proposed antenna

4. CONCLUSIONS

A novel triple-band antenna suitable for WLAN/WiMAX applications is proposed in this paper. Using a circular slot implanted in the rectangular patch and a H-shaped slot etched partial ground plane, three resonant modes with excellent impedance performance is 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, 2.5-2.65, 3.5-3.6, and 5.2-5.45 GHz. By incorporating parasitic patches the gain in the operating band can be increased further.

5. REFERENCES

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