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Design of a Microstrip-Fed Quad-Band Slot Antenna for WLAN/WiMAX Application

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ABSTRACT
In this paper, a novel quad-band rectangular slot antenna for wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) applications in IEEE 802.11b/g/a and IEEE 802.16 systems is presented. The proposed antenna, fed by a 50Ω microstrip line, has size of 32mm × 28mm × 1.6 mm. By introducing a pair of U-shaped and inter digital strips, the proposed antenna can generate four separate impedance bandwidths. The prototype of the proposed antenna has been successfully constructed and tested. The low-band resonant frequency is located at about 2.4 GHz, with -10 dB impedance bandwidth from about 2.32 to 2.45 GHz. The second band resonant frequency is located at about 3.2 GHz, with -10 dB impedance bandwidth from about 3.14 to 3.26 GHz. The third band resonant frequency is located at about 3.9 GHz, with -10 dB impedance bandwidth from about 3.84 to 3.96 GHz. The high-band resonant frequency is located at about 5.6 GHz, with -10 dB impedance bandwidth from about 5.1 to 6.0 GHz. In addition, the measured results show good radiation characteristics at the two operating bands, proving the quad-band operation of the proposed antenna.

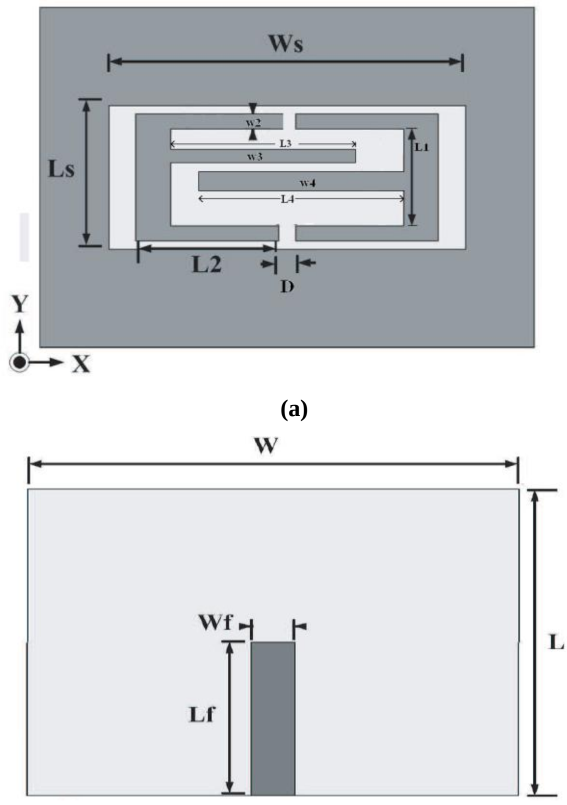
General Terms
Microstrip antenna, WLAN, WiMAX

Keywords
Microstrip line fed antenna, Slot antenna

1. INTRODUCTION
Rapid progress in wireless communication technology has sparked the need for developments in antenna designs. Some applications of the wireless communication system such as cellular phones, laptops, PC wireless cards, and various remote-sensing devices require miniaturized antennas. For these applications, the slot antenna has special advantages because of its simple structure. The slot antenna fed by the microstrip line is one type of microstrip antenna which has advantages such as low profile, lightweight, simple structure and easy fabrication [1]. For WLAN/ WiMAX systems, some slot antennas have been proposed by using a slot-ring antenna with a narrow rectangular slot [2], parasitic element [3], or stair-shaped slot antenna [4]. However, these slot antennas mentioned above have larger dimension and are not good candidates for WLAN/ WiMAX applications that require miniaturized antennas. Moreover, to adapt to various WLAN environments, a WLAN/WiMAX antenna should be capable of operating at quad frequency bands [5-8].

In this paper a novel design of microstrip-fed slot antenna with dual-band characteristics is proposed. The proposed antenna has advantages such as simple structure, compact size and easy fabrication. By introducing a pair of U-shaped and inter digital strips to the antenna, quad-band operation and good radiation performance suitable for the WLAN/ WiMAX systems can be achieved. 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 DESIGN AND STRUCTURE
The configuration of the proposed slot antenna with a pair of U-shaped inter digital strips is shown in Figure 1.



(a)

(b)

Figure 1. Geometry of the proposed rectangular-slot antenna for dual-band operation (a) Top view (b) Bottom view

The rectangular slot (Ls - Ws) antenna is etched on an low-cost FR4 substrate with dielectric constant of 4.4 and thickness of 1.6 mm. A 50 microstrip line with width of 3.2mm and length of 14mm is used for feeding the antenna. A pair of U-shaped strips is embedded symmetrically along the center line of the rectangular slot antenna. The dimensions of the strips are L1, L2, W1 and W2. The spacing between the two U-shaped strips is denoted as D here. A pair of interdigital strips is embedded within U-shaped slots. The dimensions of the strips are L3, L4, W3 and W4. In our study, due to the presence of the two U-shaped strips, a new resonant mode close to the second resonant mode of the rectangular slot antenna can be easily excited in order to obtain the desired quad-band operation. These geometry parameters were all carefully adjusted and then obtained for achieving good impedance matching over two wide bandwidths suitable for 2.4/5.2 GHz WLAN operation and for 3.2/3.9 GHz WiMax operation.

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 as follows: L = 28 mm, Lf = 14 mm, Ls = 11.8 mm, L1 = 8 mm, L2 = 10.4 mm, L3 = 14mm, L4 = 14.5mm, W = 32 mm, Wf = 3.2 mm, Ws = 26 mm, W1 = 2.5 mm, W2 = 1.2 mm, W3 = 1mm, W4= 1.5mm

3. EXPERIMENTAL RESULTS AND DISCUSSION

The prototype of the proposed antenna with optimal geometrical parameters as shown in Fig. 1 was constructed and tested. The picture of a physically realized module is shown in Figure 2.

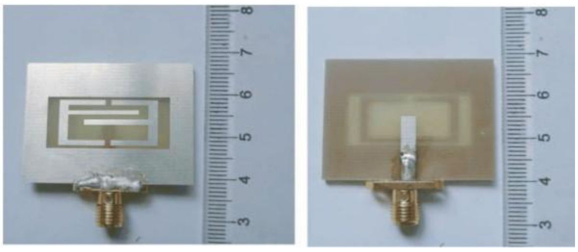


Figure 2. Physically realized module of the proposed antenna

The return loss was measured with an R&S vector network analyzer. Fig. 3 shows the measured return loss of the proposed antenna, together with the simulated one.

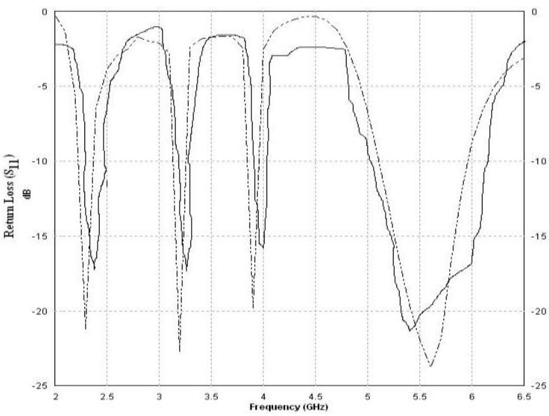
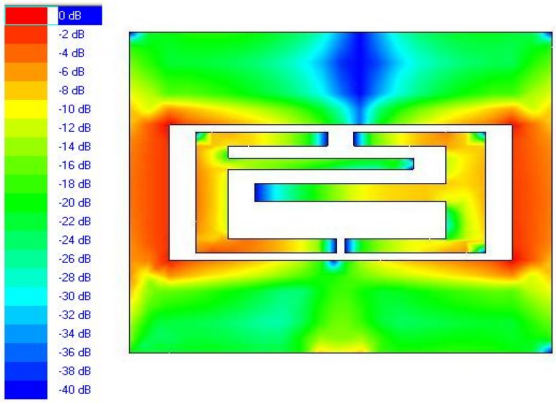
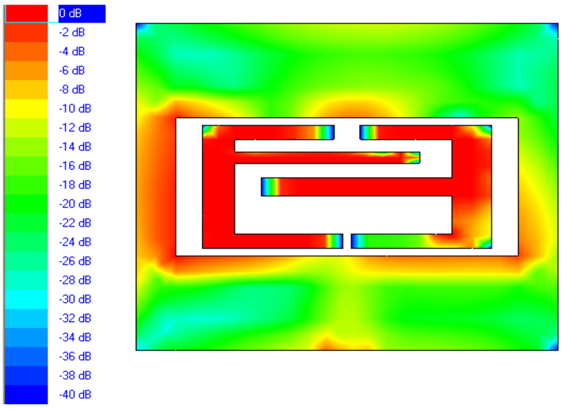


Figure 3. Simulated and measured return loss of the proposed antenna

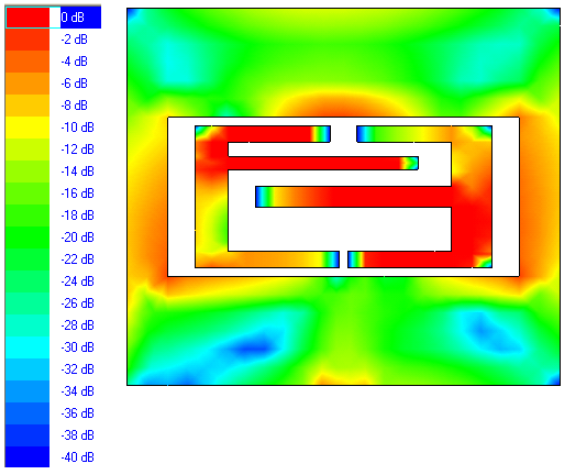
As can be seen, there is a reasonable agreement between the measured and simulated results. The low-band resonant frequency is located at about 2.4 GHz, with -10 dB impedance bandwidth from about 2.32 to 2.45 GHz. The second band resonant frequency is located at about 3.2 GHz, with -10 dB impedance bandwidth from about 3.14 to 3.26 GHz. The third band resonant frequency is located at about 3.9 GHz, with -10 dB impedance bandwidth from about 3.84 to 3.96 GHz. The high-band resonant frequency is located at about 5.6 GHz, with -10 dB impedance bandwidth from about 5.1 to 6.0 GHz. Fig. 4 shows the surface-current distributions of the proposed dual-band rectangular slot antenna operating at 2.4, 3.2, 3.9 and 5.2 GHz.



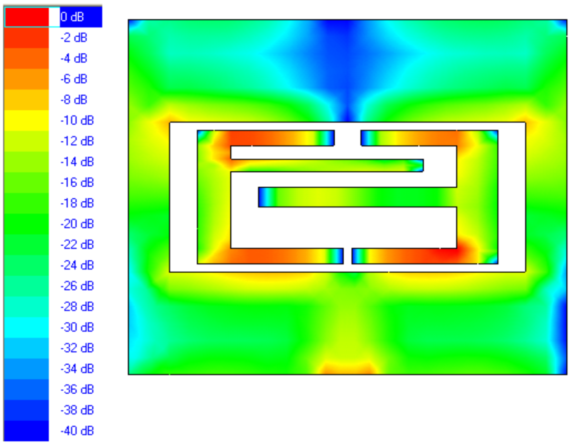
(a) 2.4GHz



(b) 3.2GHz



(c) 3.9GHz



(d) 5.6 GHz

Figure 4. Simulated surface-current distributions for the antenna: (a) 2.4GHz; (b) 3.2GHz; (c) 3.9GHz; (d) 5.2GHz

The cases for the various dimensions of Ws and Ls have been investigated. Fig. 5 shows the tuning effect of varying the rectangular slot width as Ws = 24, 26, and 28mm with a fixed Ls of 11.8mm on the impedance characteristic. It can be seen from Fig. 5 that with increasing length of Ws, the lower resonant frequency shifts down, while the bandwidth of the upper band changes slightly.

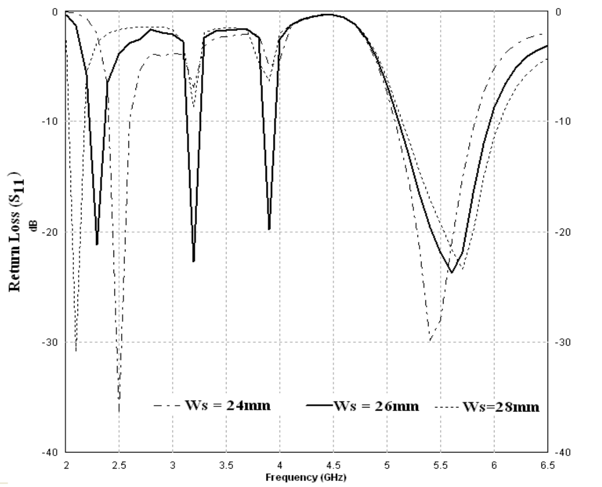


Figure 5. Simulated return loss against frequency for the proposed antenna with various length Ws.

The simulated return loss curves with width *Ws* of 26mm and different length *Ls* of the rectangular slot are plotted in Fig. 6.

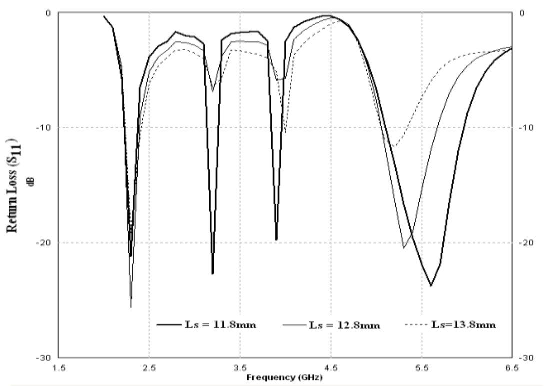
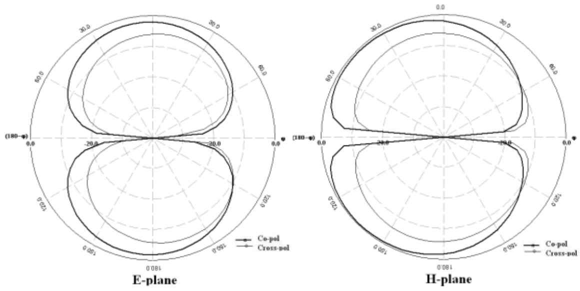


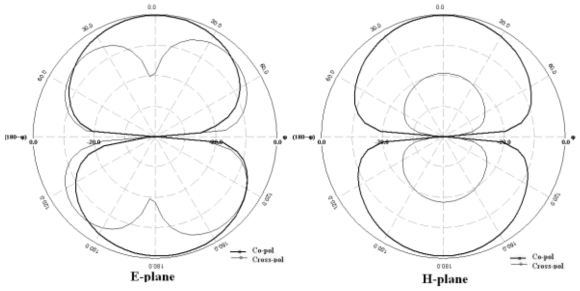
Figure 6. Simulated return loss against frequency for the proposed antenna with various length Ls.

It can be observed that the impedance characteristic of the upper band is improved with decreasing Ls. This is prerequisite because the surface current paths can be extended by increasing Ws or Ls.

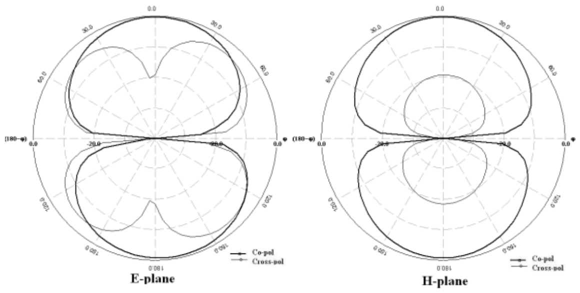
The radiation characteristics are also investigated. Fig. 7 presents the measured far-field radiation patterns of both co- and cross- polarizations for the designed antenna at 2.4, 3.6, 4.8 and 5.2 GHz.



(a) 2.4GHz



(b) 3.2GHz



(c) 5.6 GHz

Figure 7. Measured radiation patterns for the proposed antenna at (a) 2.4 GHz; (b) 3.2GHz (c) 5.6 GHz.

The measured results show that the radiation patterns of the antenna are bidirectional in the E-plane. The radiation pattern becomes conical for 3.2GHz and 5.6GHz in H-plane due to excitation of higher order modes. The peak antenna gains for the proposed antenna are shown in Fig. 8.

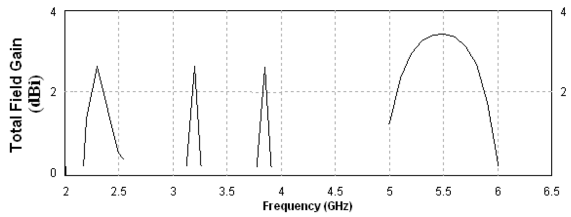


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Figure 8. Simulated antenna gains for the proposed antenna.

The obtained average gains are 2.2 dBi (1.8-2.4 dBi) at lower band and 3.98 dBi (3.7-3.9 dBi) at higher band.

4. CONCLUSIONS

A novel microstrip-line-fed rectangular slot antenna for 2.4/3.2/3.9/5.6 GHz quad-band operation has been proposed and implemented. By introducing a pair of U-shaped and interdigital strips to the antenna, the proposed antenna can generate separate impedance bandwidths. Omni-directional radiation performance and sufficient antenna gain of operating frequencies across the four bands can also be obtained.

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