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DESIGN OF A NOVEL MICROSTRIP-FED DUAL-BAND SLOT ANTENNA FOR WLAN APPLICATIONS

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Abstract—In this paper, a novel dual-band rectangular slot antenna for wireless local area network (WLAN) applications in IEEE 802.11b/g/a systems is presented. The proposed antenna, fed by a $50\,\Omega$ microstrip line, has size of $32\,\text{mm} \times 28\,\text{mm} \times 1.6\,\text{mm}$. By introducing a pair of U-shaped strips, the proposed antenna can generate two 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 2.3 to 2.5 GHz. The high-band resonant frequency is located at about 5.7 GHz, with -10 dB impedance bandwidth from about 4.9 to 6.0 GHz. In addition, the measured results show good radiation characteristics at the two operating bands, proving the dual-band operation of the proposed 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 systems, some slot antennas have been proposed by using a slot-ring antenna with a narrow rectangular

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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 applications that require miniaturized antennas. Moreover, to adapt to various WLAN environments, a WLAN antenna should be capable of operating at dual frequency bands [5–8]. For instance, these frequency bands may cover 2.400–2.484 GHz (specified by IEEE 802.11b/g) and 5.150–5.350/5.725–5.825 GHz (specified by IEEE 802.11a).

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 strips to the antenna, dual-band operation and good radiation performance suitable for the WLAN 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 strips is shown in Fig. 1. The rectangular slot ($L_s \times W_s$) antenna is etched on an low-cost FR4 substrate with dielectric constant of 4.4 and thickness of 1.6 mm. A 50 Ω microstrip line with width of 3.2 mm and length of 14 mm is used for feeding the antenna. A pair of U-shaped strips are embedded symmetrically along the center line of the rectangular slot antenna. The dimensions of the two strips are L_1, L_2, W_1 and W_2. The spacing between the two U-shaped strips is denoted as D here. 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 dual-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.

The antenna shape and dimensions were first searched by using the software Ansoft HFSS, which is based on the finite-element method (FEM), and then the optimal dimensions were determined from experimental adjustment as follows: $L = 28$ mm, $L_f = 14$ mm, $L_s = 11.8$ mm, $L_1 = 8$ mm, $L_2 = 10.4$ mm, $W = 32$ mm, $W_f = 3.2$ mm, $W_s = 26$ mm, $W_1 = 2.5$ mm, $W_2 = 1.2$ mm.

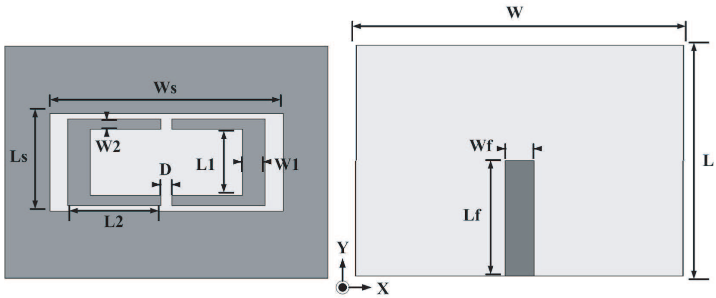


Figure 1. Geometry of the proposed rectangular-slot antenna for dual-band operation.

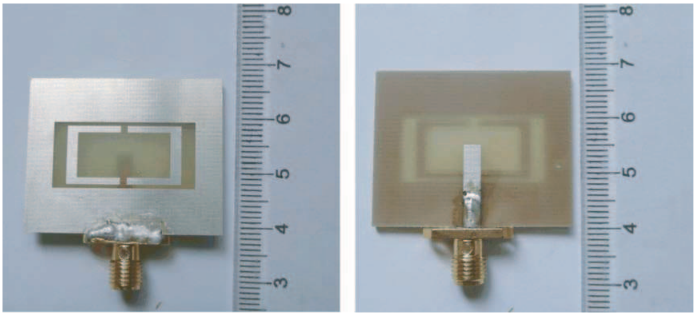


Figure 2. Physically realized module of the proposed antenna.

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 Fig. 2. The return loss was measured with a Wiltron 37269A network analyzer and the radiation patterns were tested in the anechoic chamber at the National Key Laboratory of Antennas and Microwave Technology, Xidian University. Fig. 3 shows the measured return loss of the proposed antenna, together with the simulated one. 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 2.3 to 2.5 GHz. The high-band resonant frequency is located at about 5.7 GHz, with −10 dB impedance bandwidth from about 4.9 to 6.0 GHz. Fig. 4 shows the surface-current distributions of the proposed dual-band rectangular slot antenna operating at 2.4/5.2 GHz.

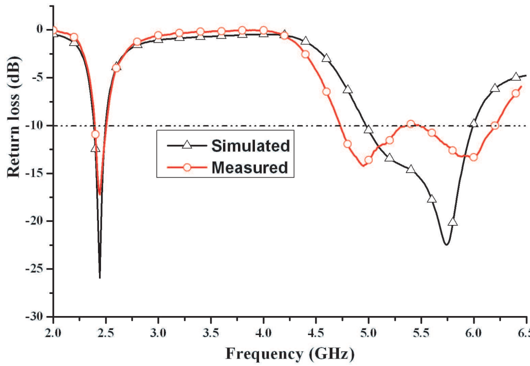
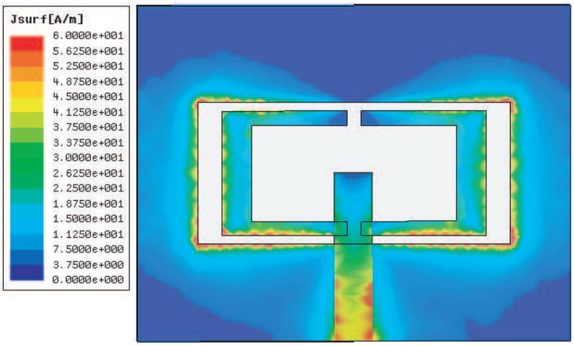
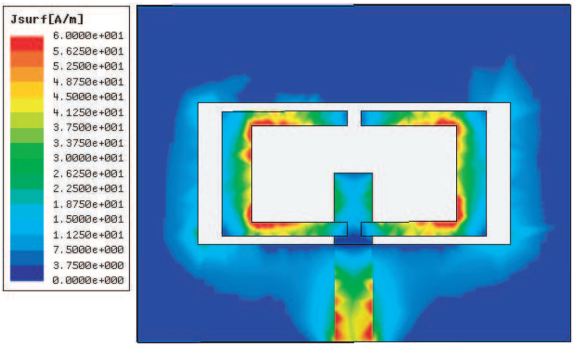


Figure 3. Simulated and measured return loss of the proposed antenna.



(a) 2.4 GHz



(b) 5.2 GHz

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

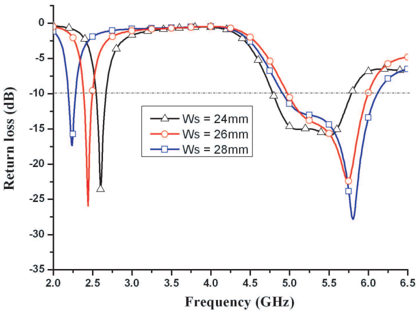


Figure 5. Simulated return loss against frequency for the proposed antenna with various length W_s.

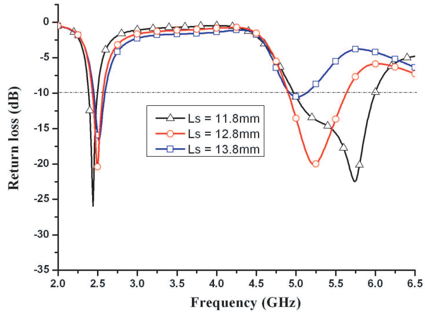


Figure 6. Simulated return loss against frequency for the proposed antenna with various length L_s.

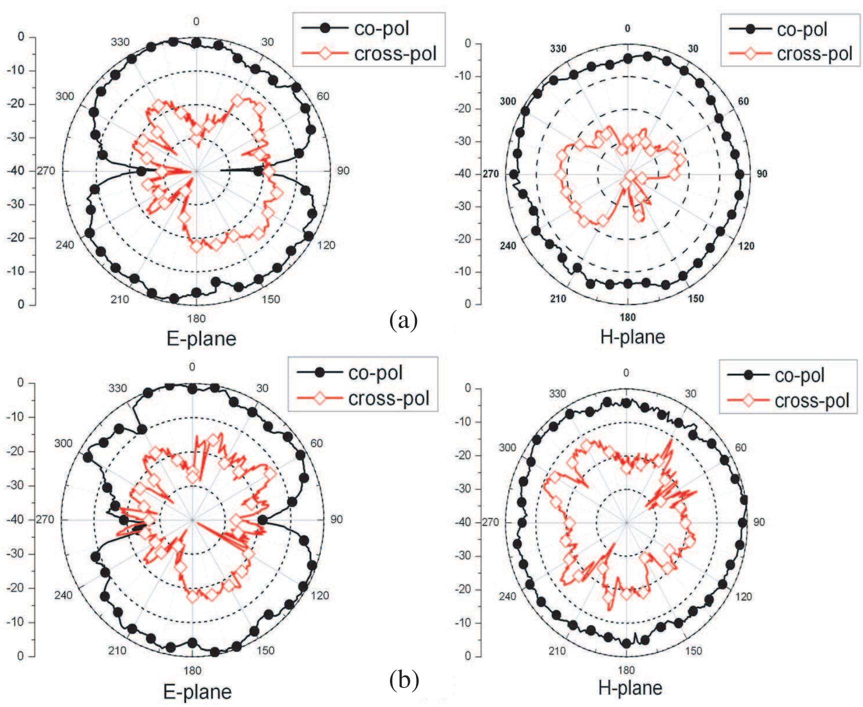


Figure 7. Measured radiation patterns for the proposed antenna at (a) 2.4 GHz; (b) 5.2 GHz.

The cases for the various dimensions of W_s and L_s have been investigated. Fig. 5 shows the tuning effect of varying the rectangular slot width as $W_s = 24$, 26, and 28 mm with a fixed L_s of 11.8 mm on the impedance characteristic. It can be seen from Fig. 5 that with increasing length of W_s, the lower resonant frequency shifts down, while the bandwidth of the upper band changes slightly. The simulated return loss curves with width W_s of 26 mm and different length L_s of the rectangular slot are plotted in Fig. 6. It can be observed that the impedance characteristic of the upper band is improved with decreasing L_s. This is prerequisite because the surface current paths can be extended by increasing W_s or L_s.

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 and 5.2 GHz. The measured results show that the radiation patterns of the antenna are bidirectional in the E-plane and nearly omnidirectional in the H-plane. The peak antenna gains for the proposed antenna are measured and shown in Fig. 8. The obtained average gains are 2.2 dBi (1.8–2.4 dBi) and 3.98 dBi (3.7–4.1 dBi), respectively.

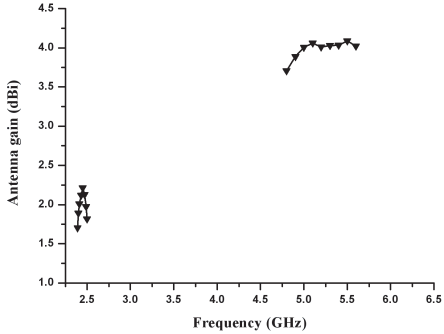


Figure 8. Measured antenna gains for the proposed antenna.

4. CONCLUSION

A novel microstrip-line-fed rectangular slot antenna for 2.4/5.2 GHz dual-band operation has been proposed and implemented. By introducing a pair of U-shaped strips to the antenna, the proposed antenna can generate two separate impedance bandwidths for the 2.4 and 5.2 GHz bands. Omni-directional radiation performance and sufficient antenna gain of operating frequencies across the two bands can also be obtained.

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