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COMPACT DUAL-BAND SLOT ANTENNA FOR 2.4/5 GHZ WLAN APPLICATIONS

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Abstract—This paper presents a compact dual-band slot antenna for 2.4/5 GHz WLAN applications. The radiating elements of the proposed antenna are composed of a square ring slot and a circular ring slot, operating at 2.4 GHz and 5 GHz bands respectively. The antenna size is very compact (40 mm × 40 mm × 1 mm), and can be integrated easily with other RF front-end circuits. It is demonstrated that the proposed antenna can completely cover the required bandwidths of IEEE 802.11b/g (2.4–2.485 GHz) and IEEE 802.11a (5.15–5.825 GHz) with satisfactory radiation characteristics. Good agreement is achieved between the simulated and measured results.

1. INTRODUCTION

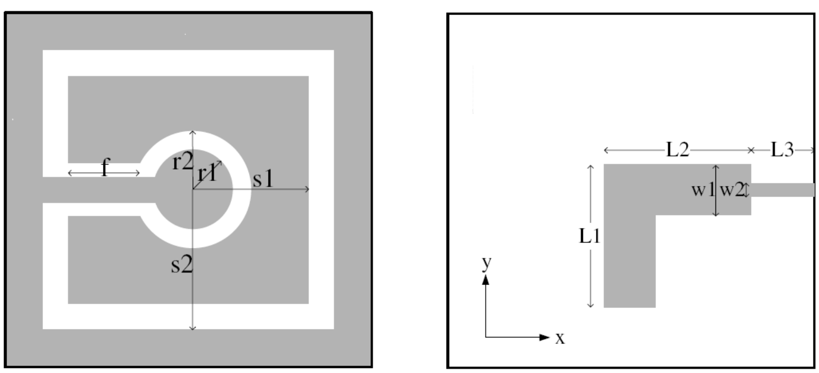
Rapid developments of various Wireless Local Area Network (WLAN) protocols have sparked the requirements for miniaturized multi-band antennas. Today, the most wide spread WLAN protocols are IEEE 802.11b/g, which utilizes the 2.4 GHz ISM band (2.4–2.485 GHz), and IEEE 802.11a which employs the 5 GHz U-NII band and ISM band (5.15–5.825 GHz). For system flexibility and feasibility, antennas that have the ability to operate in both of the specified operation bands are highly desired. A slot antenna has special advantages because of its simple structure, such as wider bandwidth, less conductor loss, and better isolation between the radiating element and feed network [1–4]. It can also provide the merits of low profile, low cost, small size, easier integration with other circuits and conformability to a shaped surface.

Numerous slot antennas for 2.4/5 GHz operations have been reported in the past few years [5–8]. In [5] and [6], the proposed slot antennas only cover a part of the 2.4/5 GHz bands. The proposed antennas in [7] and [8] can wholly cover the 2.4/5 GHz bands, but are not very compact and will cause inconvenience when integrated with other circuits. Based on a recent investigation of broadband [10–16, 18, 27] and dual-band antenna [9, 17, 19–26], we propose a compact dual-band ring slot antenna. It can completely cover the WLAN operation bands and can be easily integrated with other RF front-end circuits in a PCB.

This paper is organized as follows. In Section 2, the geometry of the proposed antenna is presented. In Section 3, we present the simulated and measured results of the proposed antenna. Concluding remarks are given in Section 4. The simulations are carried out using finite element method (FEM) software "High Frequency Structure Simulator" HFSS Ver.11.0.

2. ANTENNA GEOMETRY

The geometry of the proposed antenna is shown in Fig. 1. The ground plane lies at the bottom side of the antenna with a compact size of 40 mm × 40 mm. The radiation elements of the proposed antenna consist of a square ring slot and a circular ring slot, operating at 2.4 GHz and 5 GHz bands respectively. The two ring slots are cut at the center of the ground plane and are electromagnetically fed by an L-shaped microstrip line at the top side of the board. The substrate material is FR4, which is used in most of the practical applications. The corresponding antenna parameters are given in Table 1. r_1 and r_2 represent the radius of the inner and outer circular ring slots. s_1 and s_2 represent the radius of the inner and outer square ring slots. The



(a) Bottom View (b) Top View

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

Table 1. Parameters of the proposed dual-band slot antenna.

Antenna Parameters	Values/mm
r_1	4.5
r_2	7
s_1	11
s_2	15
f	3.4
L_1	13
L_2	13
L_3	9
w_1	4
w_2	1.8

length of rectangular slot between the square and circular ring slots is marked as f. The length and width of the L-shaped microstrip line are described by L_1, L_2, L_3, w_1 and w_2 as shown in Fig. 1(b).

3. EXPERIMENTAL RESULTS AND DISCUSSION

In order to validate the simulated results, a prototype of the proposed antenna was implemented and fabricated on FR4 substrate ($\varepsilon_r = 4.50$, $\tan\sigma = 0.02$). The picture of a physically realized module is shown in Fig. 2. The return loss was measured using an Agilent 8722ES vector network analyzer and the radiation patterns were tested in the anechoic chambers at the Electromagnetic Academy of Zhejiang University.

3.1. Impedance Bandwidth

Figure 3 shows the simulated and measured return loss of the proposed dual-band slot antenna. It is clearly indicated that the proposed antenna has a dual-band characteristic. The simulated result shows that the low-band resonant frequency locates at about 2.4 GHz, with the −10 dB impedance bandwidth from about 2.3 GHz to 2.6 GHz, covering the whole 2.4 GHz ISM band (2.4–2.485 GHz). The high-band resonant frequency locates at about 5.5 GHz, with the −10 dB impedance bandwidth from 5.15 GHz to 5.9 GHz, wholly covering the 5 GHz ISM and U-NII band (5.15–5.825 GHz). The low-band resonant frequency is mainly effected by s_1 and s_2. The high-band resonant

Figure 2. Physically realized module of the proposed dual-band slot antenna.

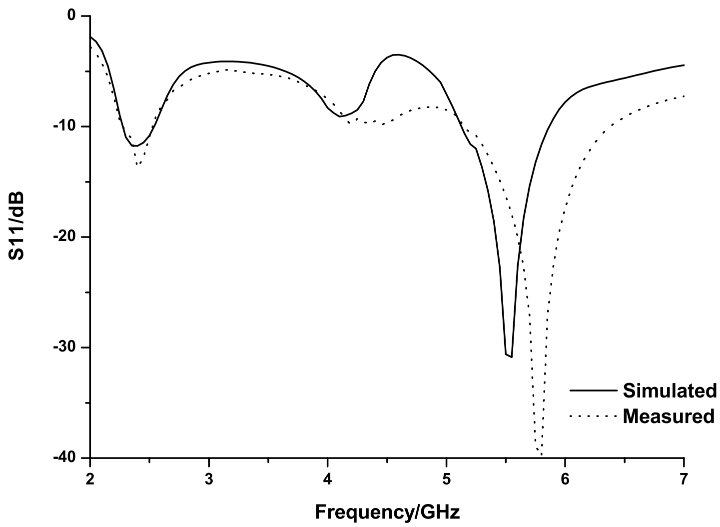
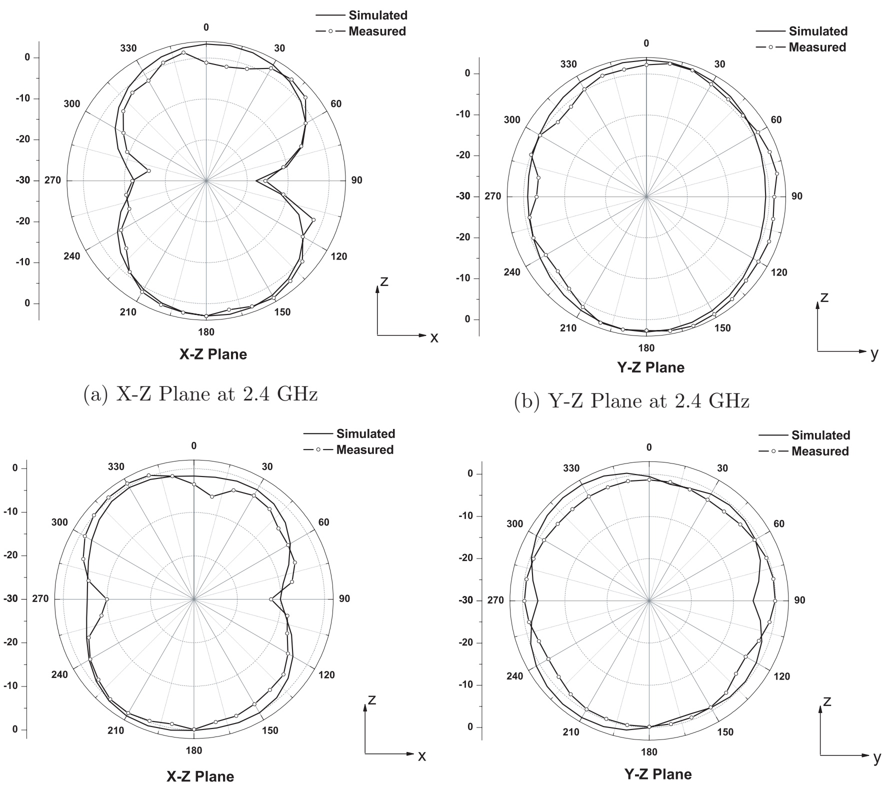


Figure 3. The return loss of the proposed dual-band slot antenna.

frequency is mostly effected by r_1 and r_2. L_1, L_3 and w_2 have a great effect on the impedance matching of the proposed antenna. Compared with the simulated result, the measured result shows good agreement with it at the low band. The simulated and measured resonant frequency and bandwidth are nearly the same. At the high band, the measured result displays larger bandwidth and the resonant frequency shifts to a higher frequency. This may be caused by the little differences of the FR4 substrate between the practical and simulated models. In addition, the dielectric constant and dissipation factor are not stable when the frequency increases. In general, good agreement is observed between the measured and simulated results. The simulation costs about 25 minutes CPU time when selecting 100 points from 2 GHz to 7 GHz with 2 GHz Intel Pentium Dual Core CPU and 2 G DDR SDRAM.



(a) X-Z Plane at 2.4 GHz

(b) Y-Z Plane at 2.4 GHz

(c) X-Z Plane at 5.5 GHz

(d) Y-Z Plane at 5.5 GHz

Figure 4. Radiation patterns of the antenna at 2.4 GHz and 5.5 GHz.

3.2. Radiation Pattern

Figures 4(a)–(d) indicate the simulated and measured radiation patterns of the proposed dual-band slot antenna at 2.4 GHz and 5.5 GHz. In the X-Z plane, as shown in Figs. 4(a) and (c), the radiation pattern is nearly bidirectional. It radiates broadly along the Z axis and the shapes of the simulated patterns correspond well to the measured results. In the Y-Z plane, as shown in Figs. 4(b) and (d), the radiation patterns is nearly omni-directional. The measured Y-Z plane

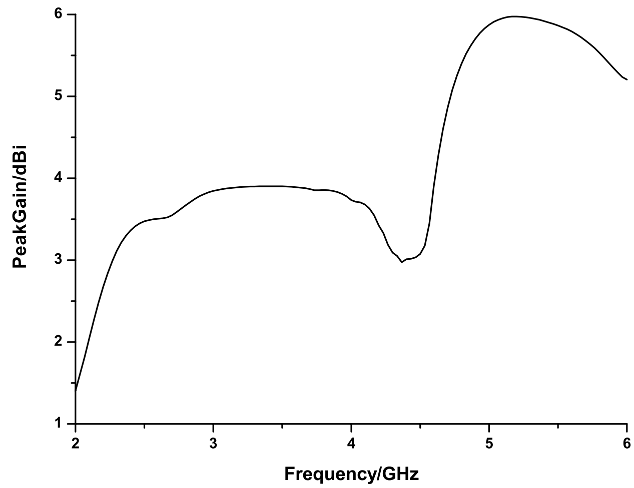


Figure 5. The peak gain of the proposed dual-band slot antenna.

patterns follow the styles of the simulated ones, though the agreement is not as good as the X-Z plane patterns. There are some ripples and distortions in the measured radiation patterns, which are mainly caused by the feed cable and connector. The radiation mechanism of the ring slot antenna has been illustrated in A.Balanis's book [28], so it is not explained here in detail.

3.3. Peak Gain

Figure 5 presents the peak gain of the proposed dual-band slot antenna. In the 2.4 GHz band, the peak gain is about 3.2 dBi with less than 0.5 dBi of gain variation. In the 5 GHz band, the peak gain is about 5.5 dBi and the gain variation is less than 1 dBi. It can fulfil the requirements of indoor wireless applications very well.

4. CONCLUSIONS

A compact dual-band slot antenna for 2.4/5 GHz WLAN operations is presented. The proposed antenna has a compact size of 40 mm $\times$ 40 mm $\times$ 1 mm, so it can be easily integrated with other RF front-end circuits. Computer simulations and measurements have shown that it can effectively cover WLAN operation bandwidth (2.4–2.485 GHz, 5.15–5.825 GHz) and the gain of the proposed antenna can fully meet the requirements of indoor wireless applications.

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