

Compact and Low Profile MIMO Antenna for Dual-WLAN-Band Access Points

Xinyao Luo*, Jiade Yuan, and Kan Chen

Abstract—A compact directional MIMO antenna operating in 2.4 and 5 GHz wireless local area network (WLAN) bands is presented. The compactness of the proposed multiple-input multiple-output (MIMO) antenna can be attained through using miniaturized antenna elements and meanwhile employing an extremely narrow edge-to-edge inter-element space (3 mm). Two novel miniaturized planar inverted-F antenna (PIFA) elements which share a common ground are designed, and each element has a dimension of 31 mm × 17 mm and a profile of 4.2 mm. By etching three slots on the ground, the port isolation can be significantly enhanced, which can even reach a maximum of 54 dB at 2.45 GHz. A desirable directional radiation pattern is obtained, and the calculated envelope correlation coefficient is better than 0.01.

1. INTRODUCTION

Multiple-input multiple-output (MIMO) technology has been widely used in wireless local area network (WLAN) to enhance the channel capacity and data rate without sacrificing additional spectrum or transmitted power in rich scattering environments [1–3]. Meanwhile, the tremendous growth of wireless communication services results in increasing demand for compact MIMO antennas, which can be installed against a wall or on a ceiling surface for indoor wireless access point (AP) applications [4–6]. In this case, a MIMO antenna having features of compactness, directional radiation, high port isolation and covering WLAN 2.4 GHz (2.4–2.485 GHz) and 5 GHz (5.15–5.85 GHz) bands is desired. Fortunately, MIMO antennas which almost possessing these characteristics mentioned above have been studied for WLAN applications in the past [4–11]. In [4], with polarization and pattern diversity method, the edge-to-edge distance between two antenna elements is about $0.126\lambda_{5.8}$. By utilising the same method, a co-located MIMO antenna with narrow edge to edge inter-antenna space of $0.008\lambda_{2.4}$ [7] and an E-shaped MIMO antenna with separation of $0.13\lambda_{5.8}$ [8] were proposed. In [9], a U-shaped microstrip was used for isolation improvement with edge-to-edge distance of around $0.312\lambda_{2.4}$ between the elements. An asymmetrical coplanar strip (ACPS) wall was proposed in [10] to suppress the mutual coupling between closely spaced antennas with edge-to-edge distance of $0.03\lambda_{5.8}$. However, some of them can only operate in the single WLAN 2.4 GHz band [7, 9] or 5 GHz band [4, 8, 10, 11]. In [5] and [6], the MIMO antennas can operate in both 2.4 and 5 GHz WLAN bands, whereas relatively large element size, wide edge-to-edge inter-element space and high profile were inevitable.

In this letter, we first design a directional dual-band planar inverted-F antenna (PIFA) element with a compact size of 31 mm × 17 mm and a low profile of 4.2 mm. Then two antenna elements which share a common ground are closely packed with edge-to-edge inter-element space of 3 mm. Three slots are etched on the ground to combat the port isolation deterioration caused by the compact structure proposed above.

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2. ANTENNA DESIGN

As shown in Figure 1, the proposed MIMO antenna is formed by two symmetrical dual-band PIFA elements which share a common ground. Each radiation patch, which consists of two pairs of inverted L-shaped metal arms and a central connecting metal patch, is printed on an FR4 substrate and placed above the ground plane at the height of h . Each slotted rectangular patch is shorted to the ground plane via a shorting wall of width L_8 and fed by a coaxial probe. The edge-to-edge inter-element space of the proposed MIMO antenna is only 3 mm.

As shown in Figure 1(b), a quarter-wavelength resonant mode at 2.4 GHz band with resonant path marked in R_1 and a half-wavelength resonant mode at 5 GHz band with resonant path marked in R_2 are generated, respectively, to obtain dual-band performance of the proposed antenna element. Therefore, the length of path R_1 and R_2 should be close to $0.25\lambda_{2.45}$ and $0.5\lambda_{5.5}$, respectively, where $\lambda_{2.45}$ and $\lambda_{5.5}$ are the free-space wavelength at 2.45 and 5.5 GHz. However, note that the ends of two inner L-shaped arms are coupled with the central connecting metal patch and then additional capacitance is provided to the input impedance of the proposed antenna element, which helps to decrease the required length for generating the quarter-wavelength resonant mode at 2.4 GHz band and the compact antenna element structure is obtained. Eventually, the size of the radiator is only $0.248\lambda_{2.45} \times 0.136\lambda_{2.45}$, which shows an average compactness of about 46% with respect to a conventional rectangular unslotted planar inverted-F antenna.

To reduce the mutual coupling, especially for the lower band, three slots arranged in a line are etched on the ground. In this way, a significant decreasing in $|S_{12}|$ as well as port isolation increasing is achieved over the lower operating band. On the premise of keeping the lower operating frequency located at 2.4 GHz band by adjusting parameters of antenna elements slightly, the performance of the decoupling design in the lower band is analyzed by varying lengths and width of three slots.

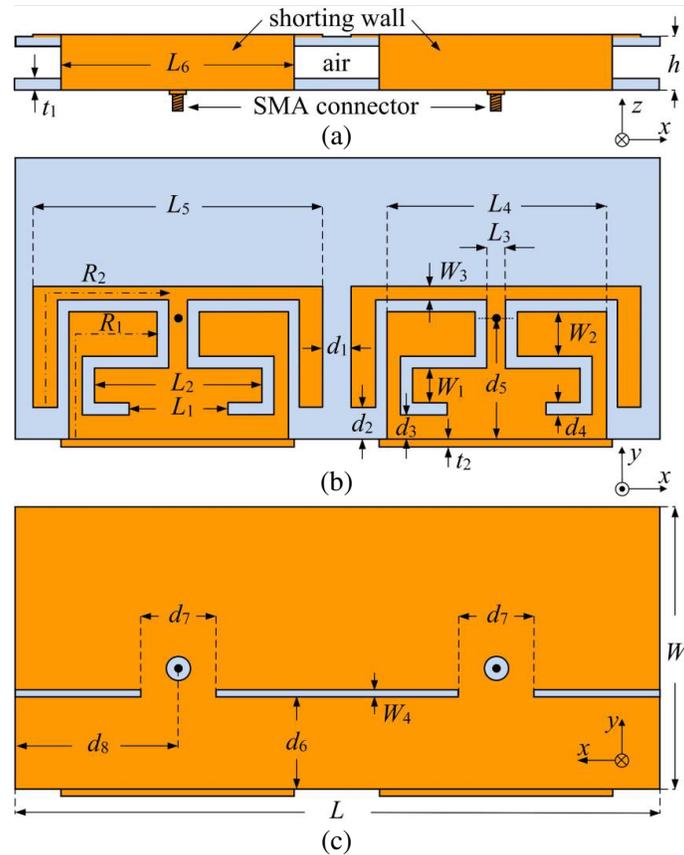


Figure 1. Geometry of the proposed antenna. (a) Side view. (b) Top view. (c) Bottom view.

shows that the parameter d_7 has an adjustment effect on the decoupling frequency. With d_7 increasing, the lengths of three slots become shorter accordingly and the decoupling frequency shifts to the left. Figure 2(b) shows that the parameter W_4 has little influence on decoupling frequency, but can control the decoupling depth. When W_4 is set to 0.5 mm, the isolation reaches a maximum of 54 dB. The optimized values of d_7 and W_4 are 8 and 0.5 mm, respectively.

In order to further understand the mechanism of the proposed technique, Figure 3(a) shows the surface current distribution on the common ground of the proposed design at the centre frequency of 2.45 GHz in the lower band, in which the right antenna element is excited and the left one is terminated with a 50-Ω load. Meanwhile, the case of the MIMO antenna without slots on the ground is also shown in Figure 3(b) for comparison. The current distribution around left port on the unslotted ground shown in Figure 3(b) is obviously stronger than that on the slotted ground shown in Figure 3(a). On one hand, this is because a large portion of surface current is trapped by three slots etched on the ground and less current flows to the left load. On the other hand, three slots produce additional coupling current paths for the coupling currents, and these additional current paths can cancel out a part of original coupling currents from the right excited feeding port to the left non-excited feeding port. Therefore, the current

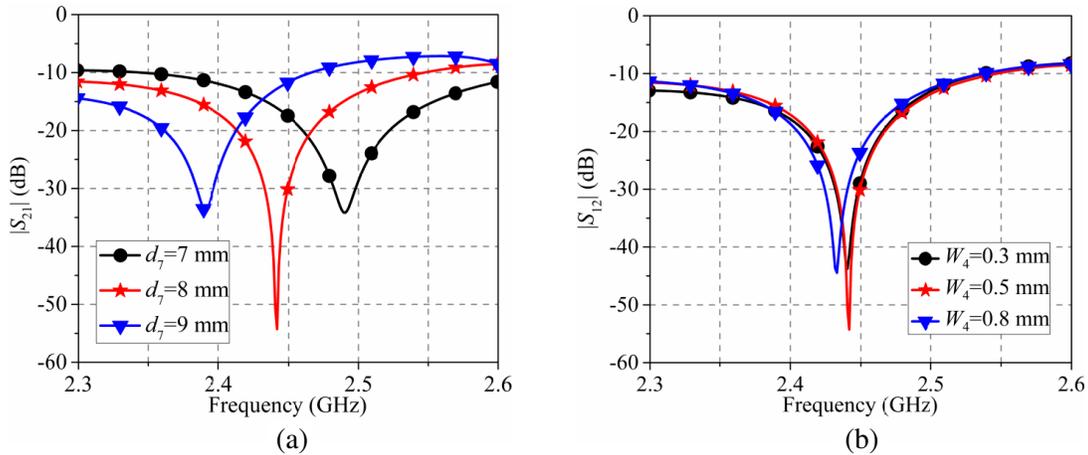


Figure 2. Isolation versus the parameter d_7 and W_4 : (a) versus d_7 , when $W_4 = 0.5$ mm, and (b) versus W_4 , when $d_7 = 8$ mm.

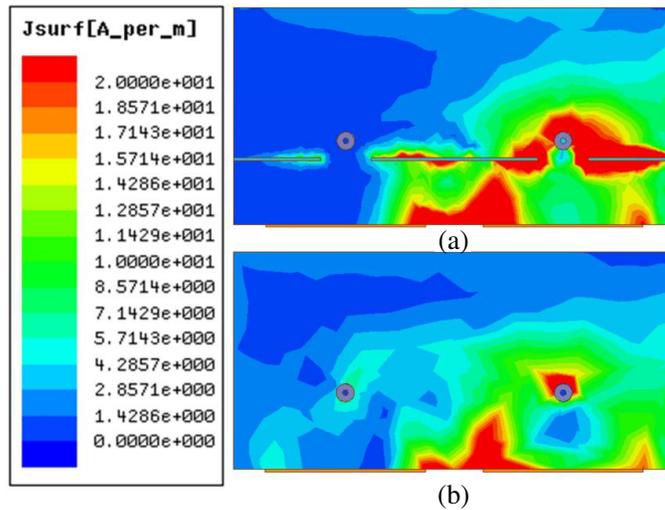


Figure 3. Current magnitude distributions at 2.45 GHz on (a) slotted ground and (b) conventional ground.

on slotted ground flowing from the right feeding port to the left feeding port is substantially reduced and mutual coupling between two elements is effectively reduced.

The performance of the proposed structure is simulated using simulation software Ansoft HFSS and the optimized design parameters are as follows (mm): $L = 69$, $W = 34$, $L_1 = 10.5$, $L_2 = 17.9$, $L_3 = 2$, $L_4 = 23.4$, $L_5 = 31$, $L_6 = 25$, $W_1 = 3.7$, $W_2 = 4.8$, $W_3 = 1.5$, $W_4 = 0.5$, $d_1 = 3$, $d_2 = 3.5$, $d_3 = 2.7$, $d_4 = 1.3$, $d_5 = 13.5$, $d_6 = 10$, $d_7 = 8$, $d_8 = 17.5$, $t_1 = 0.6$, $t_2 = 0.4$, $h = 4.2$.

3. RESULTS AND DISCUSSION

To verify the performance of the proposed antenna, a prototype is fabricated and measured, and a sample of fabricated antenna is shown in Figure 4. The S -parameters of the prototype are measured with an Agilent vector network analyzer E5071C and Figure 5 shows the measured and simulated impedance bandwidths ($|S_{11}| < -10$ dB) of the proposed antenna. Good agreements between simulation and measurement results are achieved. The results at both lower and upper bands are indicative of the MIMO antenna proposed with excellent return loss and isolation. The measured -10 dB impedance bandwidths ($|S_{11}|/|S_{22}|$) are 145 MHz (2.375–2.52 GHz) and 900 MHz (4.98–5.88 GHz), respectively, which can thus cover the 2.4 and 5 GHz WLAN operating bandwidths. Besides, the measured isolation between two elements is better than 20 dB in the lower band and no less than 18 dB in the upper band, note that, the ports' isolation has a dip of 54 dB at the center frequency of the lower band.

The far-field gain radiation patterns of the proposed antenna prototype measured at 2.45 and 5.5 GHz in an anechoic chamber are plotted in Figures 6(a) and 6(b), respectively. As shown in Figure 6, the simulated and measured radiation patterns agree in an acceptable level with the experimental ones.

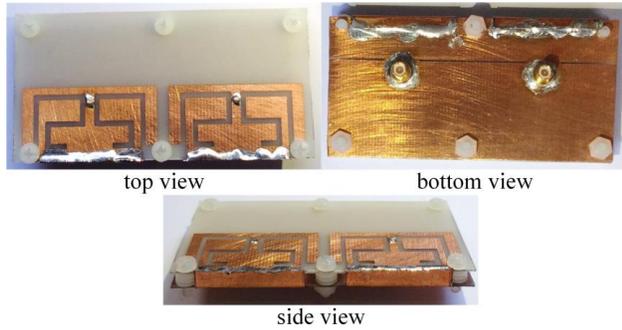


Figure 4. Fabricated prototype of proposed antenna.

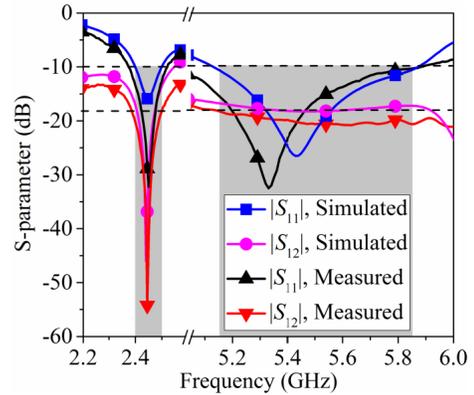


Figure 5. Simulated and measured S -parameters of proposed antenna.

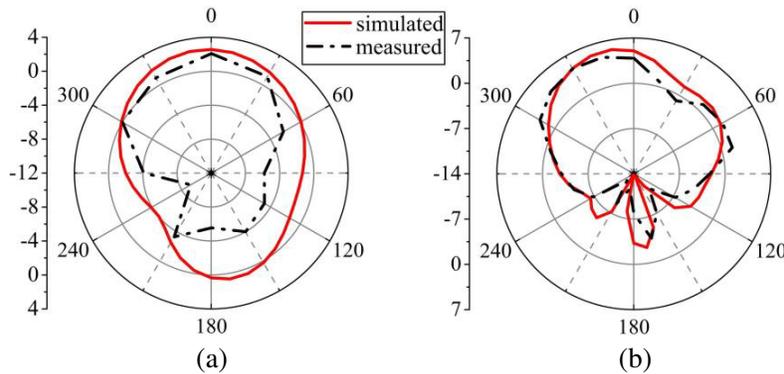


Figure 6. Measured and simulated radiation patterns for y - z plane at (a) 2.45 GHz and (b) 5.5 GHz.

Table 1. Comparison between the recently published directional MIMO antennas for WLAN applications.

Antenna structure	Radiation element dimension	Profile (mm)	Edge-to-edge spacing (mm)	Isolation at 2.45 GHz (dB)
Ref. [5]	40 mm × 20 mm	10	43	20
Ref. [6]	Φ 35 mm	10	11	20
Proposed	31 mm × 17 mm	4.2	3	54

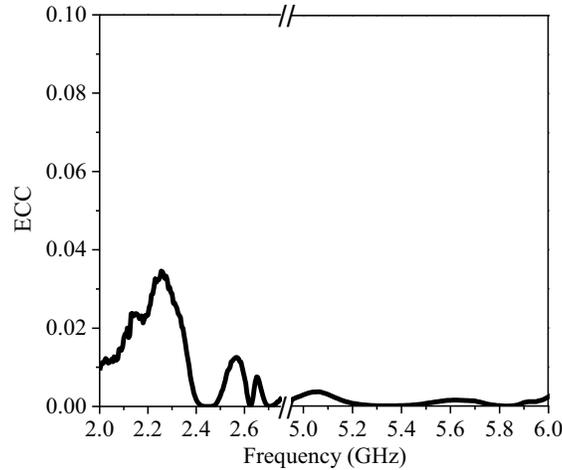


Figure 7. Measured envelope correlation coefficient (ECC).

The gain of the radiation patterns at 2.45 GHz is about 2.66 dBi. As for the radiation pattern measured at 5.5 GHz, a gain of 5.18 dBi is observed. The discrepancies between the simulated and measured plots may be attributed to the errors in the fabrication and measurement.

As shown in Table 1, from the comparisons to other recently published MIMO antennas which feature directional radiation patterns in both 2.4 and 5 GHz WLAN operating bands, it can be summarized that the proposed antenna has a more compact size, wider bandwidths and better isolation performance.

Envelope correlation coefficient (ECC) is used to find the correlation between signals received by antenna elements. For a two-antenna system, ECC can be calculated by substituting the S -parameters into the formula proposed in [12], which is shown in Equation (1). Figure 7 shows measured ECC curve of the proposed MIMO antenna. It is clear from the Figure 7 that the ECC is lower than 0.01 within both operating bands, which means a good performance of the MIMO antenna system.

$$ECC = \frac{|S_{11}^* S_{12} + S_{21}^* S_{22}|^2}{\left[1 - (|S_{11}|^2 + |S_{21}|^2)\right] \left[1 - (|S_{22}|^2 + |S_{12}|^2)\right]} \quad (1)$$

4. CONCLUSION

A compact directional dual-band MIMO antenna with total size of 69 mm × 34 mm × 4.2 mm is proposed and investigated in this letter. According to the measurement results, the dual-band bandwidths ($|S_{11}| < -10$ dB) are 2.375 to 2.52 GHz and 4.98 to 5.88 GHz, respectively. With a narrow edge-to-edge spacing of $0.0245\lambda_{2.45}$, the isolation is better than 18 dB over the bandwidths and a dip of 54 dB at 2.45 GHz is obtained. Moreover, the proposed antenna has excellent ECC values. Hence, the compact MIMO antenna proposed in this letter is suitable for dual-WLAN-band indoor wireless AP applications.

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