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DUAL-BAND FOLDED MONOPOLE ANTENNA WITH SLOTTED GROUND PLANE FOR WLAN APPLICATIONS

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Abstract—Study of a novel design of dual-band folded antenna with an L-shaped slot on the ground plane has been proposed for wireless local area network (WLAN) applications. The proposed antenna occupies a low profile above the ground plane. This characteristic makes it suitable for laptop PC applications. The proposed antenna can provide two impedance bands at 2.4 and 5.2/5.8 GHz, which satisfies WLAN applications. Details of the proposed antenna design and measured results are presented and discussed.

1. INTRODUCTION

Recently, there are appreciable attentions concentrated on the requirements of multi-band operations in wireless local area network (WLAN) applications, such as 2.45, 5.2 and 5.8 GHz bands for IEEE 802.11b/a standard. The antennas are designed in planar form, lightweight and compact size to be easily employing in the wireless communication devices. Many dual-band antennas using various impedance matching and feeding techniques for WLAN applications, especially for enhancing the upper-band bandwidth to cover both 5.2 and 5.8 GHz bands have been reported [1–9]. Such as a meandered grounded strip embedded in the annular-ring slot to connect the inner circular patch with the outer ground [1], adjustable the frequency ratio of the two operating frequencies through tuning the lengths of the loaded three arms [2], and placing three printed pairs of dipoles back to back on a dielectric substrate [3]. Furthermore, we also take the profile and area of the antenna into consideration due to the development

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of wireless communication device is trending to miniaturization of dimensions. For example, two CPW-fed monopole antenna with different dimensions of meandering strips, one is $15.4 \times 13.3\,\mathrm{mm}^2$ above the ground plane [4] and the other is $12.8 \times 11\,\mathrm{mm}^2$ above the V-shape notched ground plane [5]. Embedding a shorted parasitic element with $5 \times 37.5\,\mathrm{mm}^2$ above the metal frame [6], a CPW-fed G-shaped planar monopole antenna with $19.3 \times 27.2\,\mathrm{mm}^2$ above the ground plane [7], adding a C-shaped monopole with shorted parasitic on the opposite side of the substrate with $5.5 \times 25\,\mathrm{mm}^2$ above the ground plane [8], and using a capacitive coupling feed with $19 \times 23.3\,\mathrm{mm}^2$ above the ground plane are also discussed [9]. However, the above-mentioned researches still occupy large profile (more than 5 mm) above the ground plane.

In this paper, a novel dual-band folded monopole antenna with a cutting L-shaped slot on the ground plane is proposed for achieving 2.45 and 5.2/5.8 GHz bands for WLAN operation. The slot not only increases the current path at 2.45 GHz to shorten the length of the strip, but enlarges the bandwidth of the upper-band. This feature enables size reduction and lower profile (4 mm) above the ground plane. Moreover, large bandwidth improves the fabrication tolerance in practical applications. Consequently, the proposed antenna presents a desirable construction prototype for WLAN application owing to the simple structure and ease of impedance matching.

2. ANTENNA DESIGN AND EXPERIMENTAL RESULTS

Figure 1 shows the proposed geometry of a folded strip and an L-shaped slot cut on the ground plane for dual-band WLAN applications. The proposed antenna is printed on FR4 substrate with relative permittivity $\varepsilon_r = 4.4$, thickness $h = 0.8\,\mathrm{mm}$ and size dimensions of $50 \times 15\,\mathrm{mm}^2$. The antenna is fed by a $50\,\Omega$ coaxial line, consists of a central conductor connected to point A (the feeding point) and point B (the grounding point). Good impedance matching across a wide bandwidth can be achieved by adjusting feed position appropriately.

Figure 2 demonstrates the measured and simulated return loss against frequency with different lengths of cutting slot in the ground plane. Case 1 is conventional monopole without cutting slot in the ground plane, case 2 has cutting slot of $l_1 = 2\,\mathrm{mm}$ and $l_2 = 6\,\mathrm{mm}$, and case 3 has cutting slot of $l_1 = 2\,\mathrm{mm}$ and $l_2 = 12\,\mathrm{mm}$. The measured results are obtained using the R&S® ZVB 40 vector network analyzer. The simulated results are using the software High Frequency Structure Simulator (HFSS), and good agreement between the simulation and measurement is obtained. The proposed cutting slot has great effect

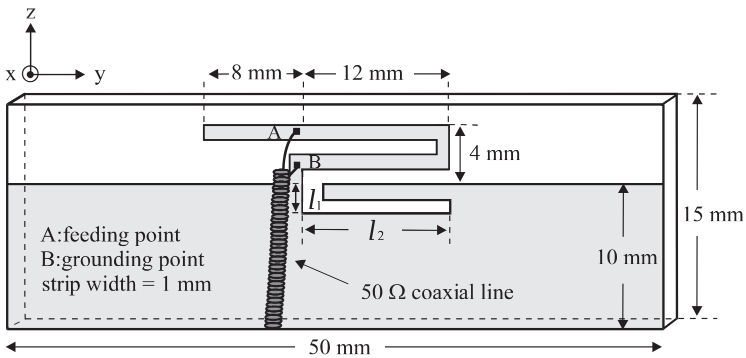

Figure 1. Geometry of the proposed folded antenna for WLAN application.

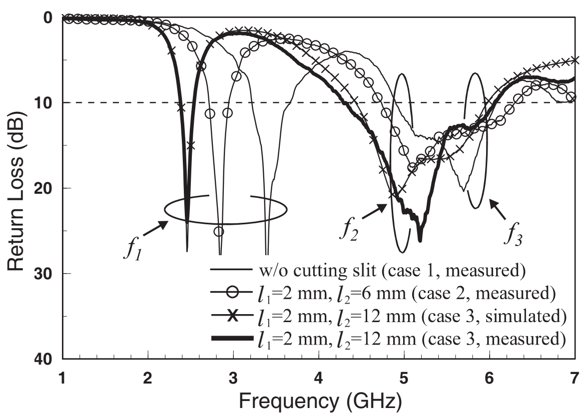

Figure 2. Measured and simulated return loss against frequency for the folded antenna with different cutting slot length.

on the impedance matching of both lower and upper bands. In case 1, the lower band has the center frequency at 3.4 GHz and upper band has an impedance bandwidth of 1168 MHz (4905–6073 MHz), which is not satisfied for WLAN 2.4/5 GHz applications. When the slot inserted, the extended length of l_2 results in the decreasing of the center frequency of the lower band f_1 and achieve better impedance matching in the upper band, f_2 and f_3. In case 3, the lower band of the proposed antenna has an impedance bandwidth of 158 MHz (2381–2539 MHz) which is almost two times the bandwidth requirement for the 2.45 GHz (2400–2484 MHz) WLAN application. Moreover, the upper band has an impedance bandwidth of 1766 MHz (4287–

6053 MHz), which is sufficient for the 5 GHz (5150–5825 MHz) WLAN application. The large bandwidths can relax the fabrication tolerance in practical applications.

The excited surface current distributions simulated from the software HFSS was used to present the operation modes of the three antenna cases. In Fig. 3(a) for case 1, the main current flow is $E \rightarrow B \rightarrow G \rightarrow H$ (25 mm), which is about $0.28\lambda_{c1}$ (λ_{c1} is the wavelength corresponding to 3.4 GHz). In Fig. 3(b), there exist two main current flows, $D \rightarrow A \rightarrow C$ (18 mm) and $G \rightarrow B \rightarrow E \rightarrow C$ (15 mm), which are about $0.33\lambda_{c2}$ and $0.27\lambda_{c2}$ (λ_{c2} is the wavelength corresponding to 5.5 GHz).

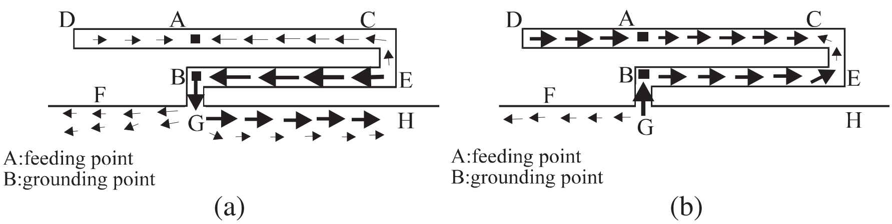

Figure 3. Simulated surface current distributions for case 1 in Fig. 2 at (a) 3.4 GHz, (b) 5.5 GHz.

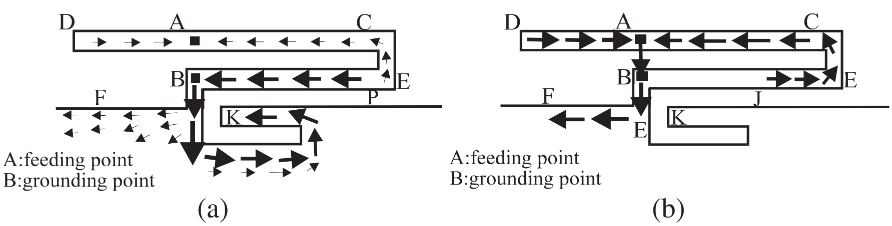

Figure 4. Simulated surface current distributions for case 2 in Fig. 2 at (a) 2.8 GHz, (b) 5.5 GHz.

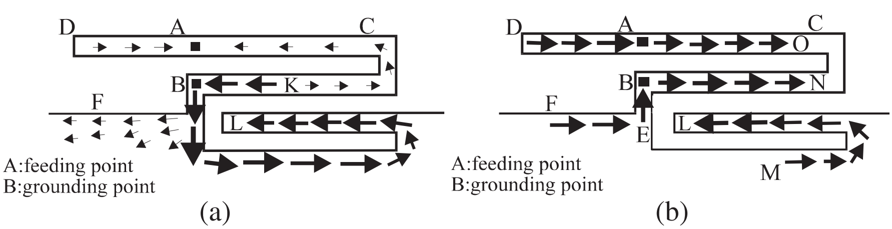

Figure 5. Simulated surface current distributions for case 3 (proposed) in Fig. 2 at (a) 2.45 GHz, (b) 5.5 GHz.

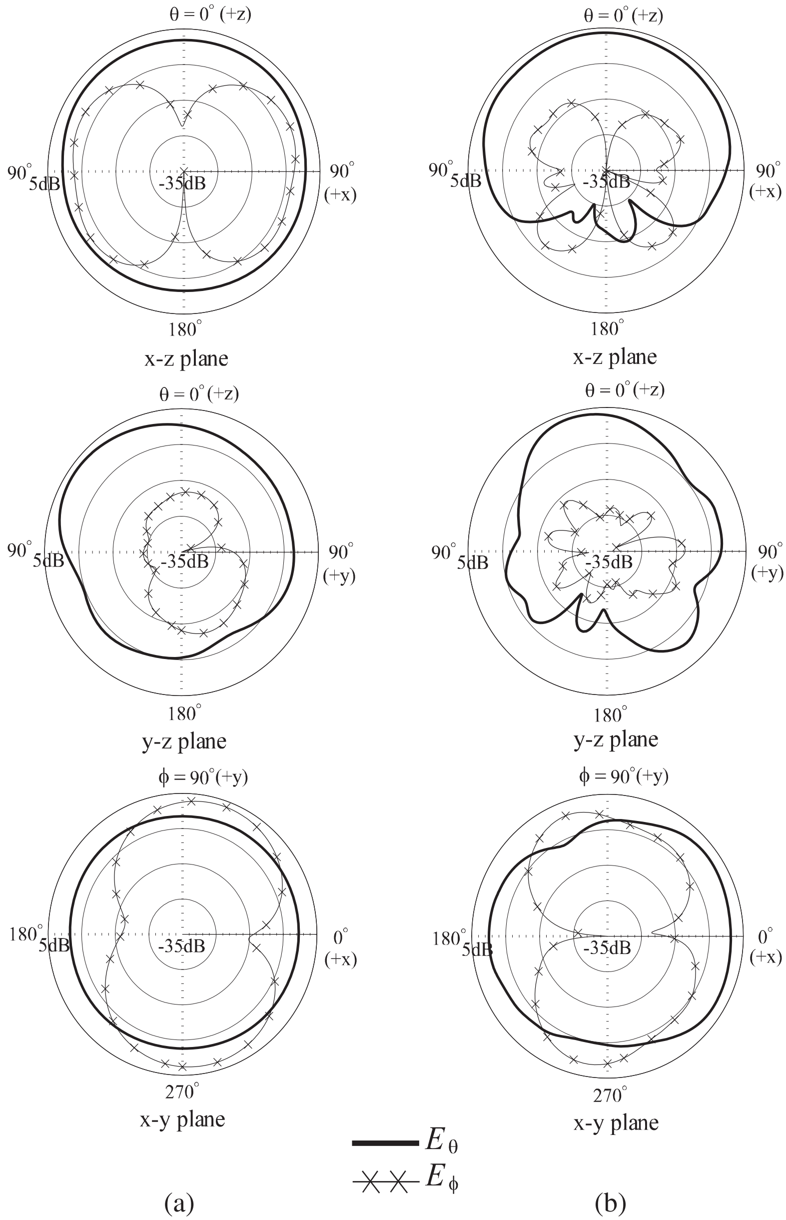

Figure 6. Measured radiation patterns for the proposed antenna in Fig. 2 at (a) 2.45 GHz, (b) 5.5 GHz.

Figure 4(a) illustrates the main current flow is $P \rightarrow B \rightarrow K$ (27 mm), which is about $0.25\lambda_{c3}$ (λ_{c3} is the wavelength corresponding to 2.8 GHz). Fig. 4(b) illustrates the main current flows are $D \rightarrow A \rightarrow B \rightarrow E \rightarrow F$ (17 mm) and $J \rightarrow E \rightarrow C \rightarrow A$ (18 mm), which are about $0.31\lambda_{c2}$ and $0.33\lambda_{c2}$.

Figure 5(a) illustrates the main current flow is $K \rightarrow B \rightarrow L$ (34 mm), which is about $0.28\lambda_{c4}$ (λ_{c4} is the wavelength corresponding to 2.45 GHz). Fig. 5(b) illustrates the three main current flows are $M \rightarrow L$ (17 mm), $D \rightarrow A \rightarrow O$ (18 mm) and $F \rightarrow E \rightarrow B \rightarrow N$ (19 mm), which are about $0.31\lambda_{c2}$, $0.33\lambda_{c2}$ and $0.35\lambda_{c2}$ respectively. According to the above mentioned current distributions, it is clearly seen that the variation in length l_2 leads to the variation in length of current flows of the antenna's lower band. With a larger length l_2, the lower band is shifted to lower frequencies. This is mainly because the larger length l_2 lengthen the current flows and result in the decreasing of the lower band frequency. For the upper band, the obtained bandwidths and the impedance matching levels are affected. In the upper bands of case 1 and 2, two main current flows provide similar bandwidths but ordinary impedance matching level. In case 3, three effective current flows provide sufficient bandwidth for WLAN 5 GHz operation and achieve good impedance matching simultaneously.

The measured radiation patterns at 2.45, 5.5 GHz are shown in Fig. 6. The radiation characteristic is stable in the azimuthal plane (x-y plane). E_θ component is roughly close to omnidirectional, which is advantageous to practical WLAN operation. Besides, it's noticed that both E_θ and E_φ components have comparable intensities. This property is advantageous for practical applications, especially for WLAN operations, because their wave propagation environment is usually complex.

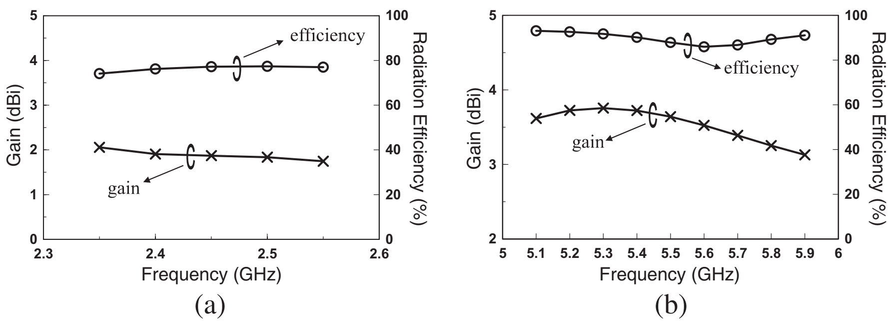

Figure 7. Measured maximum boresight antenna gain and radiation efficiency against for the proposed antenna in Fig. 2.

Figure 7 presents the measured antenna gain and radiation efficiency against frequency. The maximum boresight antenna gain is in a range of $1.75 \sim 2.06\,\mathrm{dBi}$ and the radiation efficiency is about 74% at the lower band in Fig. 7(a). For the upper band, the antenna gain varies in a range of $3.13 \sim 3.76\,\mathrm{dBi}$ and the radiation efficiency is about 90% in Fig. 7(b).

3. CONCLUSION

Design of a folded antenna with an L-shaped slot cutting on the ground plane for dual band WLAN applications has been proposed. This design can be obtained by embedding an L-shaped slot to lengthen the current path, thus it shorten the folded strip above the ground plane. The proposed antenna presents a low protruding profile of $4 \times 20\,\mathrm{mm}^2$ above ground plane and makes it suitable for integrated with the frame surrounding the display of the laptop PC or other compact wireless devices.

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