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Compact Uni-Planar Monopole Antenna for 2.4/5 GHz WLAN Operation for Laptop Applications

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1. Introduction

For achieving 2.4/5 GHz (2400~2484/5150~5350/5725~5825 MHz) WLAN (Wireless Local Area Network) operation, the shorted T-shaped monopole antenna or planar inverted-F antenna (PIFA) has been widely applied in the laptop computer [1]-[10]. These antennas generally comprise two directly-driven metal strips of about one-quarter wavelength at 2.45 and 5.5 GHz, and they usually show a total length of larger than 30 mm. Recently, in order to accommodate more antennas in the limited space in the laptop computer for other new communication systems, there are great demands in size reduction for the internal 2.4/5 GHz WLAN antennas. For this purpose, we present here a new uni-planar dual-band monopole antenna having a compact area of 6×20 mm^2 and capable of generating two wide bands for 2.4/5 GHz WLAN operation.

The proposed antenna has a simple uni-planar structure and is very suitable to be printed on an inexpensive FR4 substrate, making it easy to fabricate with a low cost. The antenna comprises a driven inverted-L strip and a coupled strip to be short-circuited to the supporting metal plate of the display of the laptop computer. With the selection of a proper coupling gap between the driven and coupled strips, good excitation of two operating bands centered at about 2.45 and 5.5 GHz can be obtained, yet the antenna shows a simple and compact structure with a length of 20 mm only. Detailed design considerations of the antenna are described in the paper, and results for the constructed prototype are presented and discussed. Effects of major parameters on the antenna performances are also analyzed.

2. Antenna Design

Fig. 1(a) shows the geometry of the proposed compact uni-planar monopole antenna for 2.4/5 GHz WLAN operation in the laptop computer. In the study, the antenna is printed on a 0.8-mm thick FR4 substrate, and the antenna has a small height of 6 mm, which allows it to be easily employed in the narrow space between the top edge of the display panel and the casing of the laptop computer. The antenna also shows a small length L of 20 mm, which is believed to be about the smallest among the existing uni-planar internal laptop antennas for 2.4/5 GHz WLAN operation. Further, through the short-circuiting of the antenna at point C (the shorting point) to the ground plane or supporting metal plate of the laptop display, the antenna can be firmly integrated within the laptop computer. Also note that the ground plane in the study is selected to be 260 mm in length and 200 mm in width, which are reasonable dimensions for general laptop computers. A picture showing the proposed antenna mounted on a laptop (the display portion only) for practical application is shown in Fig. 1(b). With the presence of the display, the measured results are about the same as those presented in Section 3. No special distinctions were observed.

The proposed antenna comprises a driven strip and a coupled strip. Both of the two strips are with an inverted-L shape and face to each other. In between the open ends of the two strips, there is a coupling gap of t (length 0.3 mm in this design), which plays an important role in the excitation of the antenna's lower and upper bands. When operating at higher frequencies at about 5.5 GHz, the coupling gap will function like an open circuit, thus the driven strip alone contributes to the excitation of the antenna's upper band. For this reason, the length of the driven strip (about 11 mm here) is selected to be about one-quarter wavelength at 5.5 GHz.

On the other hand, for operating at lower frequencies at about 2.45 GHz, the coupling gap will function as a short circuit. In this case, the antenna will be operated as a shorted monopole antenna with a length determined by the total length of the driven strip, the coupling gap, and the

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coupled strip. This total length (about 31 mm here) is selected to be about one-quarter wavelength at 2.45 GHz such that a lower band for covering the 2.4 GHz WLAN operation can be generated. The detailed dimensions of the antenna are shown in the figure; note that widened widths (3 mm) of w_1 and w_2 of the horizontal or open-end portions of the driven and coupled strips are selected for the preferred dimensions in the study. With increasing widths of w_1 and w_2, good coupling between the driven and coupled strips can be expected for lower-frequency operation at about 2.45 GHz, hence leading to good excitation of the antenna's lower band. Wider bandwidths with increasing widths of the driven and coupled strips are thus obtained; this behavior is similar to that observed for wider radiating strips in [11]. Detailed effects of the major parameters t, w_1, and w_2 on dual-band operation of the antenna were studied, and the results are presented in Figs. 3-5. Related discussion is given in the next section.

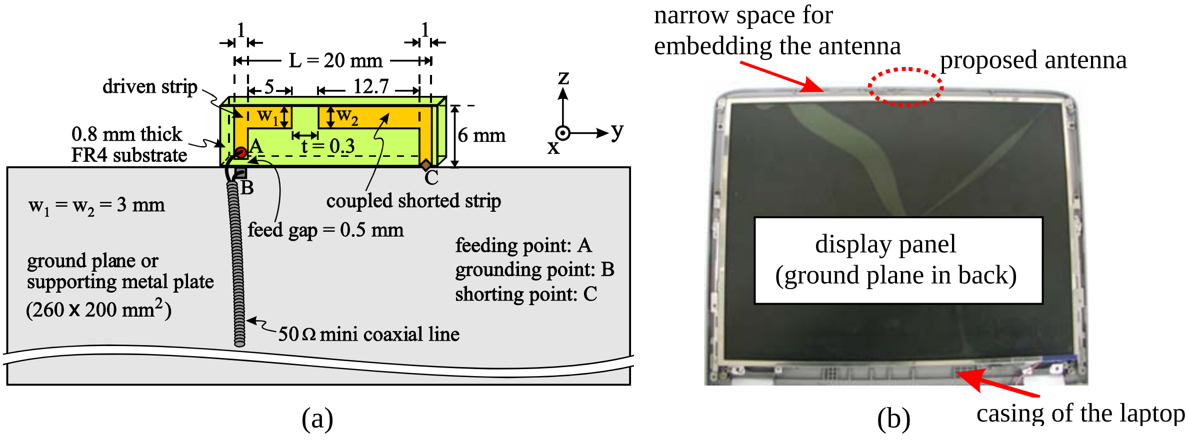

Figure 1: (a) Geometry of the proposed compact uni-planar monopole antenna for 2.4/5 GHz WLAN operation. (b) Picture showing the proposed antenna mounted on a laptop (the display portion only) for practical application.

3. Results and Discussion

Based on the design dimensions given in Fig. 1, the antenna was fabricated and tested. A 50-Ω mini coaxial line is used across the antenna's feed gap (width 0.5 mm) in the experiment, whose central conductor and outer grounding sheath are connected to the feeding point (point A) and the grounding point (point B), respectively. Fig. 2 shows the measured and simulated return loss for the fabricated prototype. The simulated results are obtained using Ansoft simulation software HFSS (High Frequency Structure Simulator) [12], and agreement between the simulation and measurement is obtained. Two operating bands centered at about 2.45 and 5.5 GHz are excited with good impedance matching. The lower band has a 10-dB return-loss bandwidth of 200 MHz (2390~2590 MHz), which allows the antenna to easily cover the 2.4 GHz band for WLAN operation. The upper band shows a much wider bandwidth of 1050 MHz (4940~5990 MHz) and also easily covers the 5.2/5.8 GHz band for WLAN operation.

Effects of the parameters t, w_1, and w_2 on the dual-band operation of the antenna are studied in Figs. 3~5 with the aid of Ansoft simulation software HFSS. The simulated return loss as a function of the length t of the coupling gap is shown in Fig. 3. Results of the length t varied from 0.3 to 1.2 mm are presented. Note that with other parameters fixed as given in Fig. 1, the variation in the length t also leads to the variation in the length L of the antenna. From the results, major effects are seen in the antenna's lower band. With a smaller length t, the lower band is shifted to lower frequencies. This is largely because a smaller length t can lead to better coupling between the driven and coupled strips, and a larger effective length of the driven and coupled strips together can thus be obtained. The larger effective length will then result in the decreasing of the center frequency of the lower band. For this reason, the length t is selected to be 0.3 mm in this study. Since it is not easy to achieve good accuracy in the fabrication of the antenna for the dimension smaller than 0.3 mm in the experiment, the length t smaller than 0.3 mm is therefore not considered here.

Fig. 4 shows the simulated return loss as a function of the open-end width w_1 of the driven strip. Results for w_1 varied from 1 to 4 mm are presented. For the upper band, the obtained bandwidths are generally about the same, although the impedance matching levels are affected. Conversely, large effects are seen in the antenna's lower band. The width w_1 should be larger than 2 mm for achieving good excitation of the lower band. Fig. 5 shows the effects of the open-end width w_2 of the coupled strip, and results for w_2 varied from 1 to 4 mm are presented. Results indicate that increasing width w_2 can effectively shift the lower band to lower frequencies. This is helpful for achieving a smaller total length of the antenna. Based on the obtained results, the widths of w_1 and w_2 are both selected to be 3 mm in this design.

Radiation characteristics of the fabricated prototype were also studied. The measured radiation patterns over the impedance bandwidth of the antenna are similar to those of the conventional dual-band flat-plate antenna for the laptop computers [2]. In the azimuthal plane (*x*-*y* plane), near-omnidirectional radiation patterns for E_θ component (vertical polarization) are obtained. In addition, the amplitude of E_ϕ component (horizontal polarization) is comparable to that of E_θ component. This radiation characteristic is advantagous, because the wave propagation environment is usually complex for WLAN operation in practical applications. Fig. 6 presents the measured antenna gain and HFSS simulated radiation efficiency. For the lower band shown in Fig. 6(a), the antenna gain varies from about 2.8 to 3.9 dBi, and the radiation efficiency is larger than about 84%. For the upper band shown in Fig. 6(b), the antenna gain varies from about 5.0 to 5.9 dBi, and the radiation efficiency is all better than 92%.

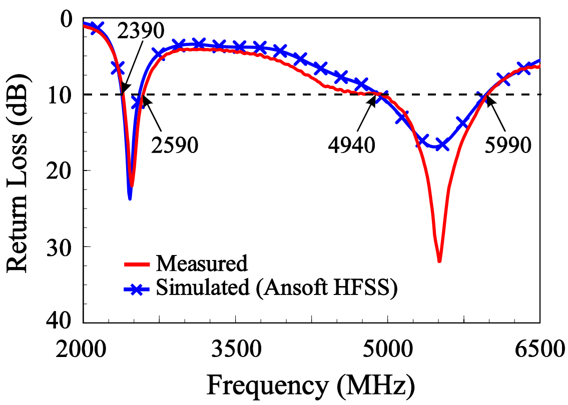

Figure 2: Measured and simulated return loss for the proposed antenna.

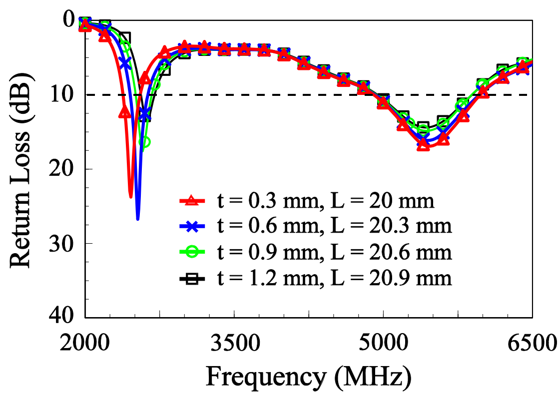

Figure 3: Simulated return loss as a function of *t*, the length of the coupling gap.

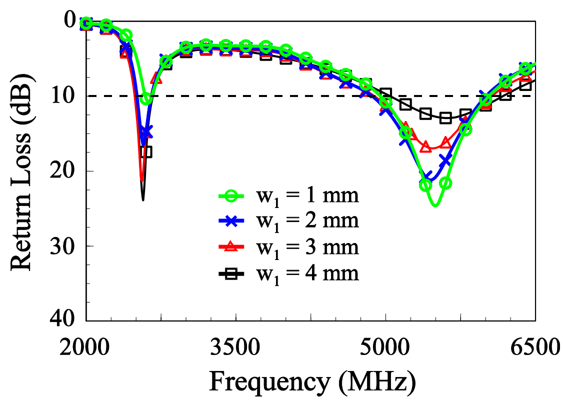

Figure 4: Simulated return loss as a function of w_1, the open-end width of the driven strip.

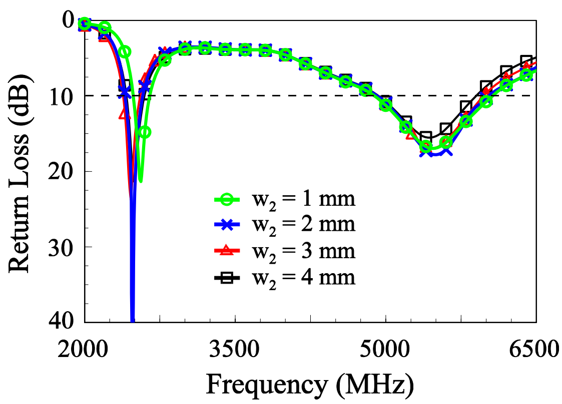

Figure 5: Simulated return loss as a function of w_2, the open-end width of the coupled strip.

4. Conclusion

A new and simple compact uni-planar monopole antenna suitable for laptop computer application has been proposed. The antenna has a simple structure consisting of a driven strip and a coupled strip, and is easy to fabricate with a low cost by printing on an FR4 substrate. The antenna also occupies a small area of 6×20 mm^2 in this study, and it can generate two wide bands for 2.4/5 GHz WLAN operation. Prototypes of the proposed antenna have been successfully implemented, and agreement between the measured and simulated results has been obtained. Good radiation characteristics for frequencies over the antenna's two operating bands have also been observed. The antenna is very promising to operate as a small-size internal laptop antenna for 2.4/5 GHz WLAN operation.

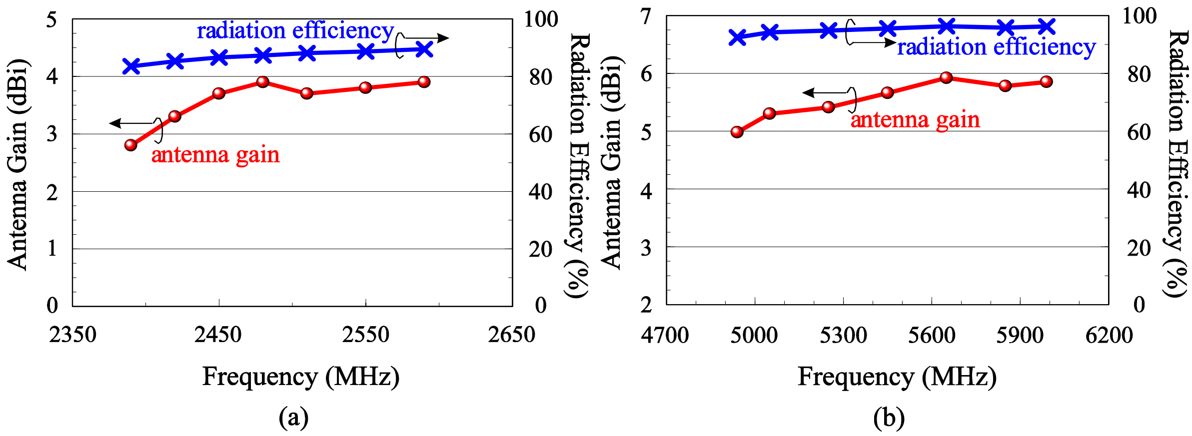

Figure 6: Measured antenna gain and simulated radiation efficiency for the proposed antenna. (a) The lower band. (b) The upper band.

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