Integrated Dual-Dipole Antenna for WiMax Operation in the Mini Laptop

Shun-Yun Lin[1], Yuan-Chih Lin[2], Jian-Rong Wu[1], Wen-Shyang Chen[1]
[1]Department of Electronics Engineering, Cheng Shiu University,
Kaohsiung County 83347, Taiwan R.O.C.
yun@csu.edu.tw
[2]Department of Mechanical Engineering, National Taipei University,
Taipei 10608, Taiwan, R.O.C.
linych@ema.ee.nsusi.edu.tw

1. Introduction

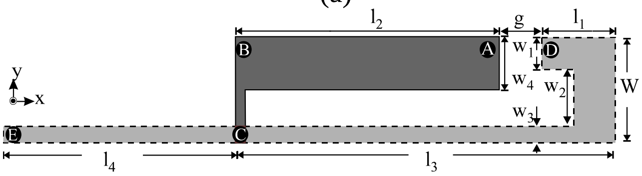
To meet the requirements of omnidirectional radiation, internal fabrication, and wideband/multi-band operation for laptop wireless, many kinds of antenna structure have been disclosed [1-3]. To achieve wideband/ multi-band operation, the techniques, including combination of the first two modes [1], multiple radiation elements [2], and introduction of additional resonant mode [3], were disclosed. Moreover, to fit in with the limited space of the panel edge for best integration [4], miniaturized antenna, especially the low profile, is critically demanded. The bended structures [1], quarter wavelength module [2-3] were used to reduce the occupied space. However, the antenna profile of most designs is too large to be suitable with the modern mini-laptop [4]. Also, note that all the mentioned patch antenna, monopole antenna, and slot antenna achieve the omnidirectional radiation by taking into that the ground plane is one portion of radiator. Therefore, remarkable variations in antenna performances, such as operation band, input impedance, and radiation characteristics, usually occur through the varied ground plane as the antenna integrates into the laptop. Comparatively, the horizontal polarized dipole antenna, which has properties of low profile, inherently omnidirectional radiation, and balance structure to dispense from the ground plane noise, is seen to be a good candidate for laptop wireless. To improve the inherent defects narrow bandwidth, additional modes or the high order modes to the half-wavelength mode were introduced by adding parasitic elements [5], integrated balun [6], and using offset feed [7].

In this article, a novel design of an integrated dual-dipole antenna for mini-laptop is proposed. A prototype that operates in the WiMax 3.5 GHz system was developed. The antenna occupies a dimension of 30×5 mm^2 and prints on an FR4 no-ground dielectric substrate of 0.4 mm thickness. The whole structure divides into a larger dipole and a shorter dipole, and respectively generates the half-wavelength mode. In this study, the two resonant modes are combined to 740 MHz (3.12 – 3.86 GHz) in bandwidth. Design considerations of the proposed antenna are described in the paper, and results for the fabricated prototype are presented and discussed.

2. ANTENNA DESIGN

A photo and a schema of the proposed antenna are shown in Figure 1 (a) and (b), respectively. The antenna was printed on a no-ground FR4 substrate with a thickness of 0.4 mm and a relative permittivity ε_r of 4.4. As shown in the figure, the antenna was fed at point C by a 50-Ω coaxial line. Note that SMA connector is too large to adapt to the design. The whole structure divides into a larger dipole (dipole 1, path ABCD, length $L_1 = l_1 + l_2 + l_3 + 2W$), and a smaller dipole (dipole 2, path ABCE, length $L_2 = l_2 + l_4 + W$). Each path dominates a half-wavelength mode, that is, L_1 and L_2 are the key factor to determine the operating band. In this study, we selected L_1 and L_2 to introduce two neighboring resonant modes to join together for a wideband operation. An inverted-L-shaped strip, which was printed on one substrate layer and connected to positive signal terminal, is the common arm of the dipoles. Other arms connected to the negative signal terminal were printed on the opposite substrate layer and joined together to be another inverted-L-shaped. Form the vertical view, the positive L-strip is seemingly embedded into the negative L-strip. Such fabrication reduces the occupied space of the design. The overall dimension of the structure is 30×5 mm^2, which allows it to be easily employed in the narrow space between the edges of the display panel and the case of the mini-laptop computer. All strip widths are mainly dominated on the coupling effect of dipole arms while w_3 is also a key factor on input impedance. For the limited antenna profile, all strip widths (w_1~w_4) have unnoticeable effects on impedance matching between the feed and dipoles for the desired operating band.

(a)



(b)

Figure 1: (a) Photograph, and (b) Configuration of the integrated dual-dipole antenna.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

For experiments, the operating frequency band was considered first. Figure 2 shows the measured and simulated S_{11} in frequency. Here, the simulations are performed with the commercial microwave software of Ansoft HFSS 10.0. Case 1 and case 2 are prototypes with and without feeding cable. The parameters were set as $w_1 = 1.5$, $w_2 = 2.8$, $w_3 = 0.7$, $w_4 = 2.5$, $l_1 = 2.5$, $l_2 = 12.5$, $l_3 = 18$, $l_4 = 12$ (unit: mm). As shown in the figure, the simulated very agrees with the measured of case 2 that two resonant mode are excited and combined to form a broad bandwidth. For Case 2, dipole 1 length (L_1 = 43 mm) is equal to $\lambda/2$ at the lower resonant frequencies (f_{r1}) of 3.5 GHz. However, dipole 2 length (L_2 = 29.5 mm) is much shorter than $\lambda/2$ at the upper resonant frequencies (f_{r2}) of 3.9 GHz. The characteristic is caused by the overflowing path into dipole's negative arm. On the other hand, difference between simulation and measurement of case 1 band is observed. The feeding coaxial line (length 87 mm), which parallels the path CE, equivalently lengthens the negative arm and shift whole operation band toward lower frequency. For the proposed antenna (case 1), two resonant modes, which combined together to introduce a 21.2% impedance bandwidth from 3.12 GHz to 3.86 GHz, is seen in measured result.

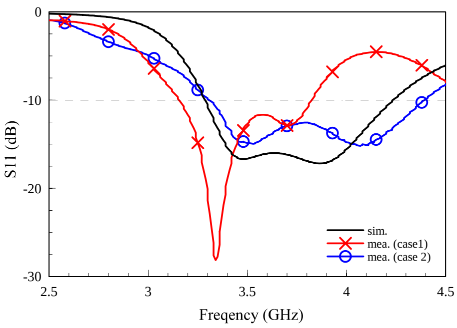


Figure 2: Simulated and measured S_{11} of the proposed antenna

In addition, the surface current distributions of the proposed antenna at f_{r1} and f_{r2} are respectively presented in Figure 3 (a) and (b). The arrows, which indicate the current direction on both arms, present a common mode current at f_{r1} distributes along path ABCD and the current nulls occur at point A and D. Also, the common mode current at f_{r2} mainly along path ABCE and the current nulls occur at point A and E. The features, which are similar to conventional dipole antenna, not only verify the formation of integrated dual-dipole antenna but also distinguish the contribution of each dipole.

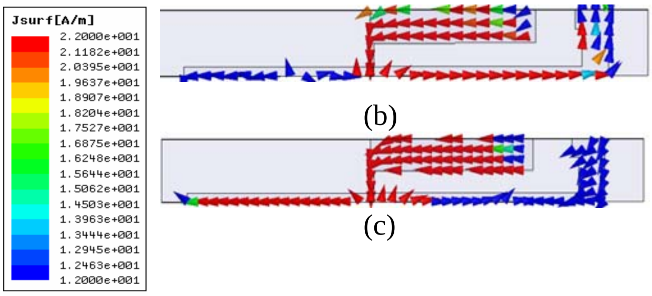


Figure 3: Current distribution of (a) conventional half-wavelength dipole antenna, and the proposed antenna at (b) f_{r1} of 3.3 GHz, and (c) f_{r2} of 3.7 GHz

Figure 4 shows the measured and simulated patterns at f_{r1} and f_{r2} for the proposed dual-dipole antenna (Case 1). To illustrate the effect of coaxial cable, the radiation characteristics of Case 2 that is without cable is also presented. For clear observation, only E-field in co-polarization is shown. From the experimental results, the simulation and the measurement of the Case 2 are in agreement on both planes at two resonant frequencies. However, the coaxial cable introduces some difference between simulation and measurement of Case 1. The exciting current, which periodically distributed on cable, causes a ripple-like pattern in E-plane. Also, the cable extends the negative arm and causes the pattern to tilt backward in H-plane. However, the nearly omnidirectional measured radiation in H-plane is still reasonable for wireless laptop application.

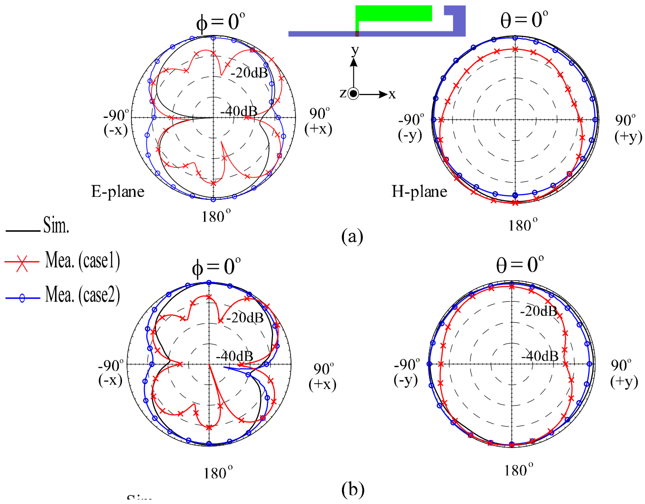


Figure 4: The measured pattern in coaxial cable and simulated radiation pattern at (a) f_{r1}, and (b) f_{r2}.

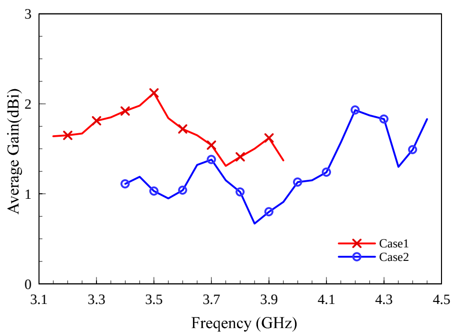


Figure 5: The measured average gain in frequency

The measured average antenna gains over operating band for both cases are presented in Figure 5.Although the antenna gain in H-plane is degraded by the omnidirectional radiation, for the proposed antenna (case 1), the measured average gain over the whole operating band is within 1.31 ~ 2.12 dBi.The gain variation is about 1.8 dB. It suggests that the antenna has good characteristics in stable gain within the operating band. The effect of coaxial cable on antenna gain is also studied in Figure 5. It is seen that the exciting current on feeding cable raise antenna gain in lower band. However, the enhancement is degraded by destructive current distribution along the cable in upper band.

The possible locations of antenna in a laptop computer are the spaces between the edges of the display panel. The locations are the preference for less electromagnetic interferences from the RF circuitry. For investigation, a large ground plane with 120×60 mm^2 dimension was being substituted for the circuitry of display panel. Although the operating bands are consequently shifted toward higher frequency, the characteristics, include dual-dipole modes, wideband operation, bandwidth for WiMax 3.5 GHz, are preserved from the integration.

Table 1: The corresponding data in frequency for Ref. (proposed antenna unintegrated into LCD panel), Ant. 1 and Ant. 2 are the proposed antennas integrated into LCD panel on top edge and side edge, respectively.

prototype	f_{r1} GHz	f_{r2} GHz	BW	Antenna gain @ f_{r1} dBi		Antenna gain @ f_{r2} dBi	
				Peak	Avg.	Peak	Avg.
Ref.	3.30	3.70	21.2%	4.60	1.81	5.38	1.54
Ant. 1	3.45	3.81	20.9%	0.87	-2.65	3.19	-2.47
Ant. 2	3.68	3.95	21.2%	2.88	0.42	3.08	0.40

4. CONCLUSIONS

A printed dual-dipole antenna with a compact dimension is proposed for WiMAX 3.5GHz applications. Two half- wavelength modes are successfully introduced and combined to develop the wideband operation. The proposed antenna was successfully implemented and its performance was verified. Its advantages include compact size, wideband performances, and nearly omnidirectional radiation patterns, and performance preservation from the integration into the laptop computer were obtained.

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