Effects of PCB Ground Plane and Case on Internal WLAN Patch Antenna

H. T. Kim*, J. K. Heo*, K. J. Jeong*, and S. W. Hwang*★

Abstract

We demonstrate that the effect of the PCB ground length and the cover is important in the performance of 2.4 GHz patch antennas. The Center frequency in the return loss shifts as much as 0.5 GHz, when the length of the PCB ground increases from 30 to 85 mm. The position of 10-dB bandwidth accordingly shifts to lower frequency region. Finally, the resonance at 2.4 GHz becomes stronger when the top cover exists. The radiation pattern of the patch antenna is also strongly affected by the ground structure and the existence of the top cover. In both the return loss and the radiation pattern, 3-dimensional simulations are shown to be an efficient tool.

Keyword : Antenna, PCB, Case, WLAN, Internal

I. Introduction

Patch antenna have been widely used in wireless systems due to their small sizeand simultaneous integration into printed circuit boards (PCBs). So far, various printable antennas such as planar inverted F antenna (PIFA) [1], monopole patch antenna [2], dipole patch antenna [3], slot antenna [4], and loop antenna [5] have been proposed and actively studied. However, most of the previous studies have been concentrating only on antennas themselves. The patch antenna printed on a PCB inherently has finite ground effects and is easily affected by neighboring structures. Usual way of overcoming these difficulties is by tuning the shape of the antenna using trials and errors. In this paper, we *quantitatively*analyze the effect of finite grounds and other neighboring structures on the performance of a patch antenna for 2.4 GHz WLAN applications. The resonant frequency and the radiation pattern of the patch antenna with the grounds of various sizes are calculatedusing three-dimensional field simulation. Those antennas are fabricated and their characteristics are measured. The results of simulation and the measured characteristics are compared.

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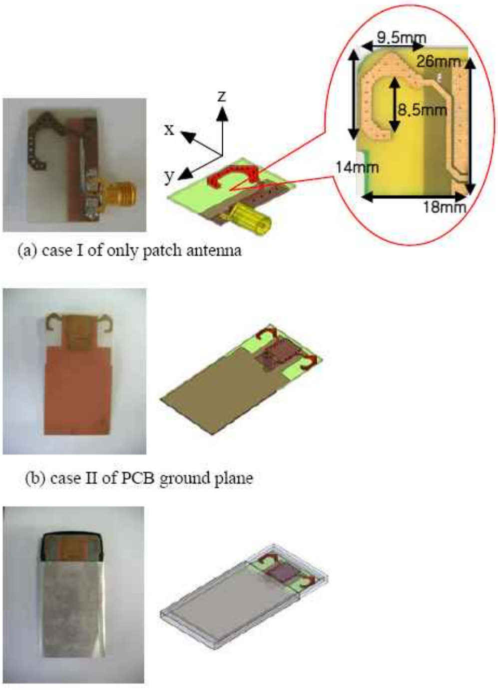
II. WLAN Hook Antenna Simulation and Measurement

We focus on a commonly used PCMCIA (personal computer memory card international association) type WLAN patch antenna. It is compatible with IEEE 802.11b standard with 13 channels and the frequency ranging from 2.412 to 2.472 GHz.

Figure 1 shows three different cases of patch antenna implementation to verify the effect of neighboring structures. The right column shows the schematics used in 3D simulations, and the left column shows the photos of the fabricated patch antennas. The inset of Fig. 1(a) shows detailed dimensions of the patch antenna. The first case (case I) shown in Fig. 1(a) is a monopole hook antenna without PCB ground. The second case (case II, Fig. 1(b)) is double hook antenna on the PCB with the usualsize of WLAN card. A ground plane is formed on the PCB surface. The third case (case III, Fig. 1(c)) is the same as the second case except the card is covered by a case consisting of metal andplastic. The PCB area is covered by metal and the antenna is mainly covered by plastic.



(a) case I of only patch antenna

(b) case II of PCB ground plane

(c) case III of PCB ground plane and cover

Fig.1 Photos and Simulation models of three Cases

Figure 2 shows the return loss (S_{11}) measured from the fabricated patch antennas shown in Fig. 1 (solid lines) and the results of 3D simulation (dotted lines). PCB Ground length of Case II and Case III is 85mm in simulations and measurements. For all three cases, the simulation data are in agreement with the measured data within3%. In the case I, the center frequency occurs at the 3.1 GHz, and in the case II, there are large frequency shift of 600MHz. And in the case III, center frequency is slightly shifted to 2.4GHz form 2.5GHz. The 10dB bandwidth also changes according to theshift of the center frequency. The 10dB bandwidth of the case I, case II, and case III are 2.6 to 3.5 GHz, 2.3 to 3.3GHz, and 2.2 to 3.3GHz, respectively. This result clearly suggests that the design of patch antennas for a certain target frequency must consider the shape of the PCB ground and the case.

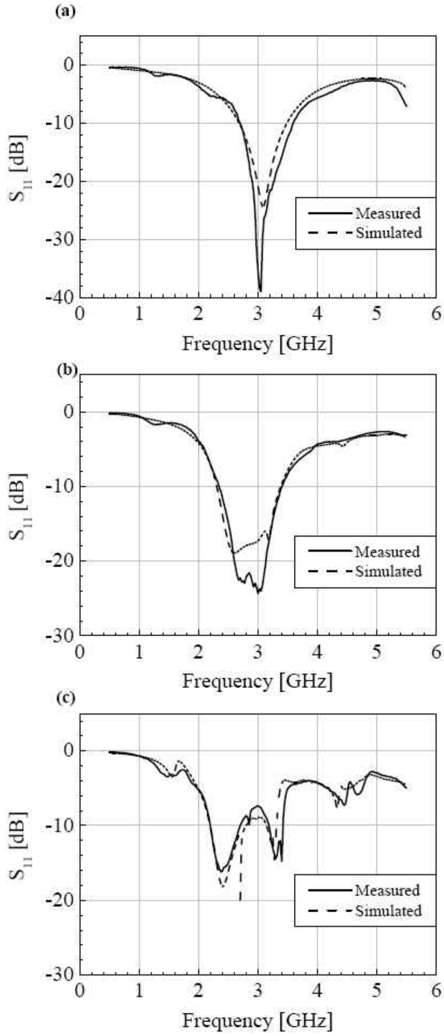


Fig.2 The simulated and measured return losses of the antenna: (a) case I of only patch antenna, (b) case II of PCB ground plane, and (c) case III of PCB ground plane and cover

In order to know effect of the PCB length, PCB ground plane length is varied. Figure 3 shows schematics of three patch antennas mounted on PCBs with three different ground lengths (30, 45, 60 mm). The length of the ground is defined from the strip line feeding point to the other end of the PCB. The case II of Fig. 1 corresponds to the case of the PCB with a 85 mm long ground.

Figure 4 shows the center frequency variation according to PCB ground plane length. There is large difference of the resonance frequency as the length of the ground increases.

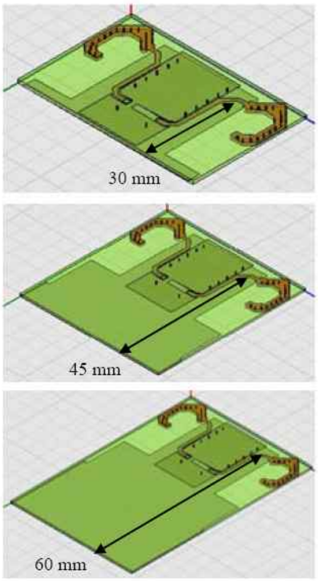


Fig.3 PCB Ground Plane Length Variation.

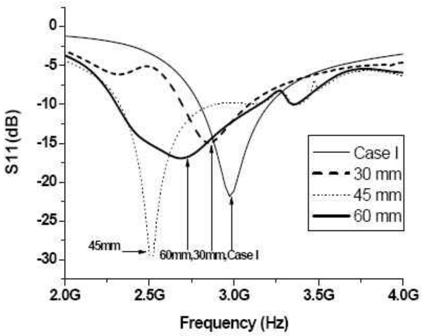
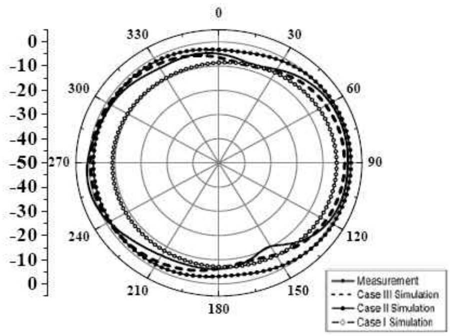
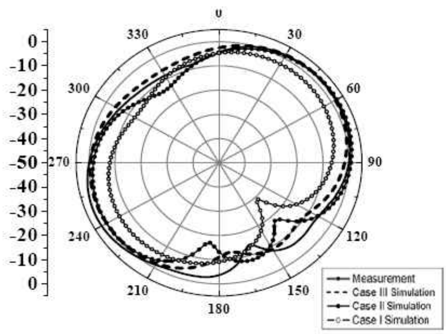


Fig.4 Variation of resonant frequency according to PCB ground length variation.

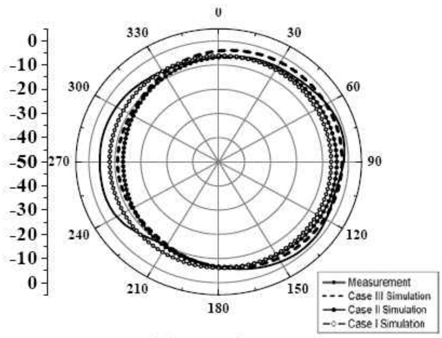
Figure 5(a), (b), and (c) show the radiation patterns of various situations in the xz, yz, and xy plane, respectively. The solid lines denote the radiation pattern measured from the fabricated prototype of the case III (Fig. 1(c)).The dashed lines, dark circle symbol lines, and empty circle symbol lines denote the simulated radiation pattern of the case III, II, and I, respectively. Table I summarizes the maximum, minimum, and the average deviation of the simulated radiation gain from the measured data. The discrepancy of the average gain is the largest for the case I, and the smallest for the case III. The results of Fig. 5 suggest that our 3D field simulation gives realistic results and suggest that the radiation pattern is strongly affected again by the PCB grounds and cases.



(a) E_ϕ, xz plane



(b) E_ϕ, yz plane



(c) E_ϕ, xy plane

Fig.5 Radiation patterns of measurement and simulations

Table 1. Max, Min, and Ave. radiation gains in reference plane

Reference planes	Case	E_{Φ} Gain (dBi)		
		Max.	Min.	Average
xz plane	Case I	-8.99	-13.03	-10.82
	Case II	-1.41	-12.6	-6.75
	Case III	-1.02	-9.61	-4.74
yz plane	Case I	-9.98	-13.50	-11.53
	Case II	2.28	-4.96	-1.23
	Case III	1.05	-10.40	-3.48
xy plane	Case I	-6.45	-24.71	-12.45
	Case II	2.18	-19.85	-5.41
	Case III	2.18	-14.27	-2.89

Conclusion

We analyze the effect of the PCB ground length and the cover on the return loss and the radiation pattern of 2.4 GHz patch antennas. The center frequencyshifts from 3.1 GHz to 2.4 GHz as the length of the PCB ground increases from 30 to 85 mm. The position of 10dB bandwidth also shifts to lower frequency region with the increase of the ground length. The existence of the top case deepens the resonance at 2.4 GHz. The measured radiation pattern is in best agreement with the simulated radiation pattern of the case III, suggesting that the radiation pattern is also a strong function of the PCB structures.

Acknowledgments

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