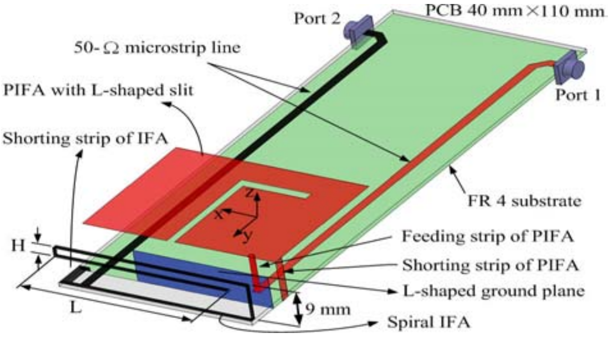
Multi-Band Antenna for Practical Handset Applications

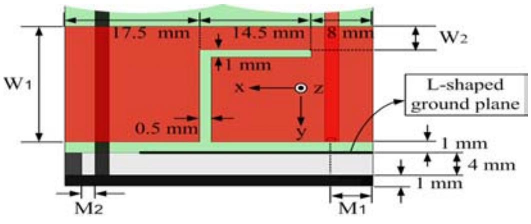
#C. W. Jang[1], Y. J. Sung[1], J. W. Baik[2] and Y.-S.Kim[2]
[1]Mobile Communication Division, Samsung Electronics Co., Ltd
416, Maetan-3dong, Yeongtong-gu, Suwon-si, Gyeonggi-do, Korea
[2]Department of Radio Sciences and Engineering, Korea University
1, 5-Ka, Anam-dong, Sungbuk-ku, Seoul, Korea
E-mail : wave_zzang@korea.ac.kr

Abstract

The two dual-band internal antennas which are located at the top portion of the printed circuit board (PCB) and 5 mm distance from each antenna element for practical handset applications are presented in this paper. A planar inverted-F antenna (PIFA) is designed as the main antenna of the handset to cover the US Cellular band (824 MHz~894 MHz) and the US PCS band (1850 MHz~1990 MHz). A rectangular spiral inverted-F antenna (IFA) is designed to cover the MediaFLO band (716 MHz~722 MHz) and the 1575.42 MHz non-simultaneous global positioning system (GPS) antenna. The location of two dual-band antennas is designed near the top portion of the PCB in order to minimize hand blockage. The L-shaped vertical ground plane between two antennas is proposed to improve the isolation performance and three-dimensional (3D) free-space radiation efficiency. It is acceptable in spite of the insufficient isolation performance as low as 10 dB at the non-simultaneous GPS and MediaFLO bands if radiation efficiencies are satisfied with the requirement. Numerical simulation and experiment results of return loss, isolation, radiation pattern and 3D free-space antenna gain are presented to demonstrate the effect of the L-shaped vertical ground plane.



(a)



(b)

Fig. 1. Configuration of the proposed two dual-band antennas.
(a) Bird's eye view. (b) Top view of radiating patch.

1. INTRODUCTION

In the current wireless communication industry, the mobile handset is no longer a voice-only device. Some additional applications have been expanded such as global positioning system (GPS) and Media Forward Link Only (MediaFLO) in the U.S. handset market. Enhanced 911 (E911) service for locating wireless subscribers has been mandatory since the year 2003. Recently, MediaFLO service has been prepared to delivery multimedia contents to millions of wireless handset subscribers in the U.S. To meet the multi applications in one handset, multi-antenna integration has become the trend for the handsets development [1]. We design two dual-band antennas according to each bandwidth, frequency distribution and application system. A dual-band planar inverted-F antenna (PIFA) using an L-shaped slit inserted beneath other antenna is designed to cover the US Cellular and US PCS bands [2, 3]. A dual-band rectangular spiral inverted-F antenna (IFA) locating the top portion of the PCB is designed to cover the MediaFLO and non-simultaneous GPS bands. Both the MediaFLO and non-simultaneous GPS applications are forward link only system with narrow bandwidth. This allows the implementations of small physical size and dual-band internal antenna. Because of the limited spaces available in a handset device, mutual coupling between two internal antennas could be large, especially for the case with closer operating frequencies and near location of each antenna [4, 5]. In general, increasing the distance of between two antennas reduces mutual coupling. However, there are other significant constraints on antenna locations such as hand blockage effect [6] and handset aesthetics in a small handset device.

In this paper, two dual-band internal antennas which are located at the top portion of the PCB and 5 mm distance from each antenna element for practical handset antenna design is proposed. The distance between the feed and short point of two antennas is maximized as far as possible for good isolation. In addition, the L-shaped vertical ground plane [7, 8] between two antennas is proposed to improve isolation performance and 3D free-space radiation efficiency. This L-shaped vertical ground plane can function as an effective shielding wall between two antennas. The isolation performance at the MediaFLO and non-simultaneous GPS bands is still insufficient as low as 10 dB because of the close antenna locations. The mutual coupling between two antennas may cause damage to hardware such as receiving modules and may also corrupt the received signals with noise. However, it is acceptable for the isolation performance to the non-simultaneous GPS antenna to be as low as 10 dB at the GPS band [9]. A non-simultaneous GPS means that signals are only received for approximately one second when location information is needed and both the US Cellular and US PCS modes are shut off during the GPS reception period. This reduces isolation requirement to the non-simultaneous GPS antenna since there are no emissions from the US Cellular or US PCS application. It is also acceptable for the isolation performance to the MediaFLO antenna to be as low as 10 dB at the MediaFLO band because the MediaFLO application is suspended during the activation of the US Cellular or US PCS application. However, the insufficient isolation does reduce the antenna efficiency at the GPS and MediaFLO bands. The antenna gain at the GPS and MediaFLO bands should be satisfied with the requirement for practical handset antenna design. The maximum RF input power of the MediaFLO band-pass filter should be below 15dBm at the US Cellular and US PCS bands. Therefore, the isolation at the US Cellular and US PCS bands must be over 10 dB [10]. Numerical simulation and measurement results of return loss, isolation, 3D antenna gain and radiation pattern are presented to demonstrate the effect of the L-shaped vertical ground plane between two antennas.

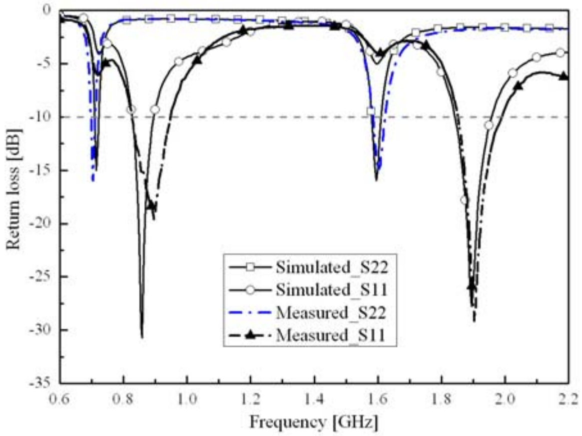


Fig. 2. Simulated and measured results of return loss.

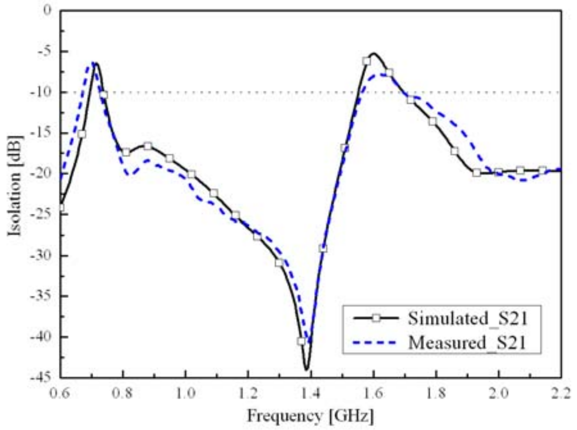


Fig. 3. Simulated and measured results of isolation.

2. THE PROPOSED ANTENNA DESIGN

Fig. 1 shows the geometry of the proposed antenna. Both dual-band internal antennas are located at the top portion of the PCB and 5 mm distance from each antenna element. The dimension of the PCB including with the area of IFA is a typical mobile phone size: 40 ×110 mm^2. Note that a 1 mm thick FR4 substrate is used for the PCB with a backside ground plane printed. Both 50-Ω microstrip line and SMA connector are used to feed each antenna. The dimensions of the larger and the smaller sub-patches on the PIFA can be designed to resonate as a quarter-wavelength structure to operate at the US Cellular and the US PCS band, respectively. The top patch of the PIFA is short-circuited at its upper side corner to the ground plane using a narrow strip (2 mm in width) and fed at the upper side to microstrip line using cylindrical feeding pin (1.2 mm in diameter). Note that the top patch of the PIFA is mounted above the substrate with a height of 9 mm. A dual-band rectangular spiral inverted-F antenna which is printed some part of radiation element including feeding and shorting strips on the PCB (FR4), and then bent in vertical to the PCB covers the MediaFLO and GPS bands. The distance between the radiation element of IFA and ground plane is only 4 mm and the width of the IFA radiation element is 1mm. Note that there is a region of about 40 ×4 mm^2 on the top portion of the PCB without ground plane. Therefore the total dimension of the spiral inverted-F antenna is 40 × 5 × 9 mm^3. In addition, to fine-tune the first two resonant frequencies of IFA to be about 720 and 1575 MHz, the resonant path of IFA starting from feeding point to the inner encircled open end is first selected to have a length of about one-quarter wavelength at 720 MHz, and then the dimensions of parameter L and H in Fig. 1(a) are varied to fine-tune the frequency ratio of the first two resonant frequencies. The shorting strip of IFA is located at the opposite side of the PIFA's shorting strip for isolation performance. The L-shaped vertical ground plane is electrically connected to the bottom ground of the PCB. The distance between the L-shaped ground plane and the patch edge of the PIFA is 1 mm. The dimension of L-shaped ground plane is 30 ×8 mm^2. Dimensions of the other parameters are presented in Table 1 including with or without the L-shaped vertical ground plane.

TABLE 1: DIMENSIONS OF THE UNKNOWN PARAMETERS IN FIG.1.
Unit : mm.

	With L-shaped ground plane	Without L-shaped ground plane
H	2.5	2.3
L	35	38
W1	31	29.5
W2	6.3	4.5
M1	5.4	9.5
M2	1	1.5

3. SIMULATION AND EXPERIMENT RESULTS

The designed antenna is simulated by the Ansoft HFSS 10™. Fig. 2 and Fig. 3 show the measured and simulated return loss (S11 for the PIFA, S22 for the IFA) and isolation (S21) results. Good agreement between the measurement and simulation is observed except the bandwidth difference (5.1 %) at the US Cellular band and isolations (2 ~ 3 dB) of the GPS and US PCS bands. The measured isolations are all fulfilled the application requirements. The measured minimum isolations are about 6.3 dB at the MediaFLO, 18.3 dB at the US Cellular, 7.8 dB at the GPS and 13.6 dB at the US PCS band, respectively. Fig. 4 and Fig. 5 show the effect of L-shaped vertical ground plane between two antennas. The L-shaped vertical ground plane could make the impedance matching of each antenna changed. The size of patch should be larger and the distance of the feeding pin and shorting strip should be closer for the impedance matching in the case of the L-shaped ground plane. Fig. 4 shows the measured return loss (S11 for the PIFA, S22 for the IFA) according to the existence of the L-shaped ground. The return loss at the MediaFLO band is almost same regardless of the existence of the L-shaped ground plane. However the difference of the GPS resonant frequency is about 50 MHz in spite of fine-tuning the impedance matching. Fig. 5 shows the effect of the L-shaped vertical ground plane. The improvement of isolations are about 3.3 dB at the MediaFLO, 4.1 dB at the US Cellular, 1.7 dB at the GPS and 2.4 dB at the US PCS bands, respectively. Fig. 6 shows the measured radiation patterns of the two antennas with the L-shaped vertical ground plane. The radiation patterns have omni-directional characteristics. The Cross-polarization level becomes alive at the GPS band in Fig. 6 (c). The measured maximum axial ratio with RHCP at 1575 MHz is below 1 dB. The 3D free-space antenna gains are summarized in Table 2. Gain represents maximum gain of combined vertical and horizontal polarization compared to an isotropic radiator. Efficiency is defined as power sent towards antenna structure compared to transmitted power from combined vertical and horizontal polarization measured over the entire sphere. The L-shaped vertical ground plane between two antennas improves 3.3 dB of the isolation performance and 8% of the 3D free-space radiation efficiency at the first resonant frequency from 700 MHz to 715 MHz.

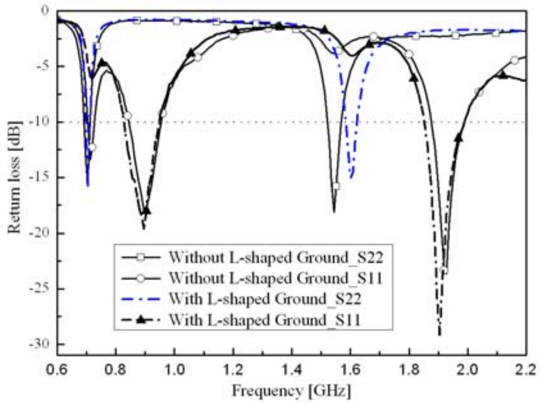


Fig. 4. Measured return loss with/without the L-shaped ground plane.

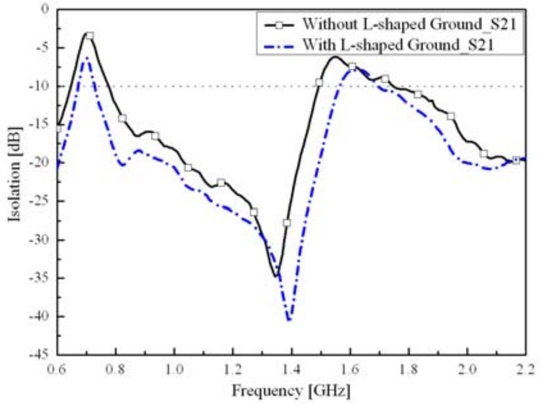
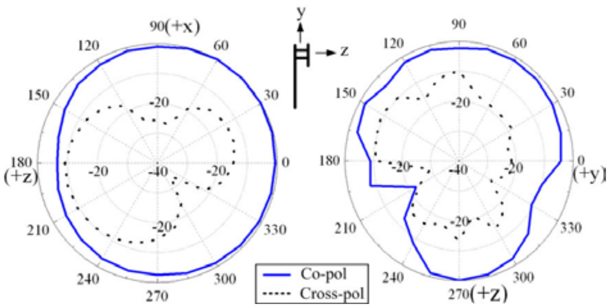
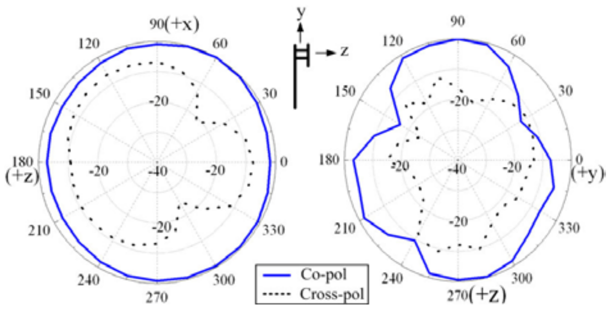


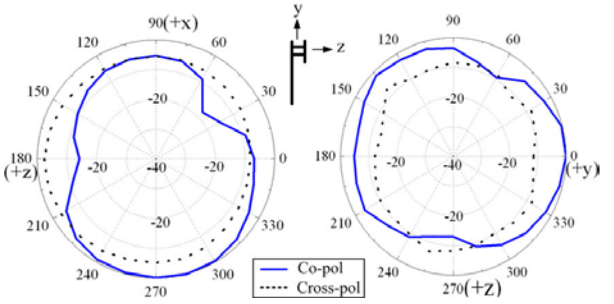
Fig. 5. Measured isolation with/without the L-shaped ground plane.



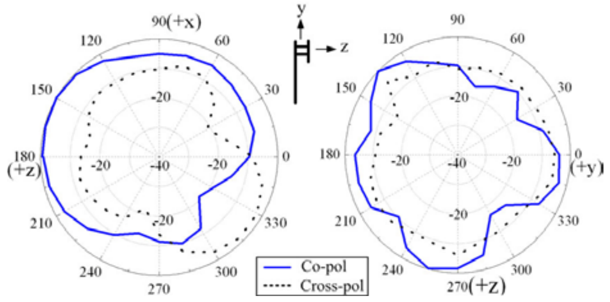
(a) x-z and y-z planes at 705 MHz.



(b) x-z and y-z planes at 894 MHz.



(c) x-z and y-z planes at 1575 MHz.



(d) x-z and y-z planes at 1910 MHz.

Fig. 6. Measured radiation patterns with the L-shaped ground plane.

4. CONCLUSIONS

In this paper, a multi-band antenna with an L-shaped vertical ground plane between two antennas has been proposed. This ground plane has an effect on the isolation performance and radiation efficiency. Two dual-band internal antennas are located at the top portion of the PCB in order to minimize hand blockage. It is suitable for practical applications to handset antennas due to the top location of the PCB with good performances.

TABLE 2: MEASURED THREE-DIMENSIONAL FREE-SPACE ANTENNA GAINS AND EFFICIENCIES WITH THE L-SHAPED GROUND PLANE.

	Without L-shaped Ground plane		With L-shaped Ground plane	
Frequency (MHz)	Gain (dBi)	Efficiency (%)	Gain (dBi)	Efficiency (%)
700	-2.6	30	-1.5	39
705	-2.0	33	-0.9	44
710	-3.3	27	-1.8	37
715	-3.6	25	-2.0	34
Average	**-3.1**	**28**	**-1.7**	**36**
1565	-0.5	39	-0.9	32
1575	-0.8	37	-0.2	38
1585	-1.9	27	0.4	41
Average	**-1.2**	**33**	**-0.3**	**37**
894	0.2	53	0.6	55
1910	3.9	68	4.2	75

REFERENCES

[1] Zhinong Ying and Johan Adersson, "Multi band, multi antenna system for modern mobile terminal," in Proc. Antennas Propagat. EM Theory, 6th Int. Symp., pp. 287-290, Nov. 2003.

[2] Kin-Lu Wong, *Planar antennas for wireless communications*, Willey, New York, 2003, pp. 26-28.

[3] Zhan Li and Yahya Rahmat-Samii, "Optimizaion of PIFA-IFA combination in handset antenna designs," IEEE Trans. Antennas and Propagat., vol. 53, pp. 1779-1778, May 2005.

[4] Chih-Ming Su, Chia-Luan Tang, Shih-Huang Yeh, and Kin-Lu Wong, "Optimized isolation between internal antennas for a dual-network wireless device," IEEE Antennas Propagat. Soc. Int. Symp., vol. 2B, pp. 523-526, July 2005.

[5] Zhinong Ying and Dan Zhang, "Study of the mutual coupling, correlations and efficiency of two PIFA antennas on a small ground plane," IEEE Antennas Propagat. Soc. Int. Symp., vol. 3B, pp. 305-308, July 2005.

[6] Zi Dong Liu, Peter S. Hall, and David Wake, "Dual-frequency planar inverted-F antenna," IEEE Trans. Antennas and Propagat., vol. 45, pp. 1451-1458, Oct. 1997.

[7] Saou-Wen Su, Kin-Lu Wong, Chia_Lun Tang, and Shih-Huang Yeh, "Internal shorted patch antenna for UMTS mobile phone," IEEE Trans. Antennas Propagat., vol. 53, Oct. 2005.

[8] F. R. Hsiao and Kin-Lu Wong, "A shorted patch antenna with an L-shaped ground plane for internal mobile handset antenna," Microw. Opt. Technol. Lett., vol. 33, pp. 314-316, May 2002.

[9] Qualcomm, *Handset antenna solution guidelines for CDMA-GPS-Bluetooth*, 80-V0978-1, March 2001.

[10] Qualcomm, *Forward link only design guidelines*, 80-V2166-5 Rev. A, July 2005.