International Journal of Control and Automation
Vol.9, No.2 (2016), pp.211-218
http://dx.doi.org/10.14257/ijca.2016.9.2.20

Design of the Twelve-bands MIMO Antenna for the Metal Cover Mobile Phone

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Abstract

A broadband MIMO antenna, using the metal cover which is one of the antenna radiators, is designed and implemented on the PCB. The antenna consists of a monopole and an IFA that is fed by the coupling structure and a metal cover radiator. Therefore, a monopole and an IFA with a metal cover radiator operate simultaneously through a hybrid form of operation. The proposed antenna satisfies VSWR 3:1(S-parameter -6dB) at the bands of LTE class 12 ~ 14, class 17, CDMA, GSM900, DCS, KPCS, USPCS, WCDMA, LTE class 40 and WiFi. The maximum ECC is 0.186 over the desire bands. The average gain and efficiency were measured from -5.14~-1.28dBi and 30.87~74.48%, respectively.

Keywords*: Mobile antenna, Hybrid antenna, Metal cover, MIMO, ECC*

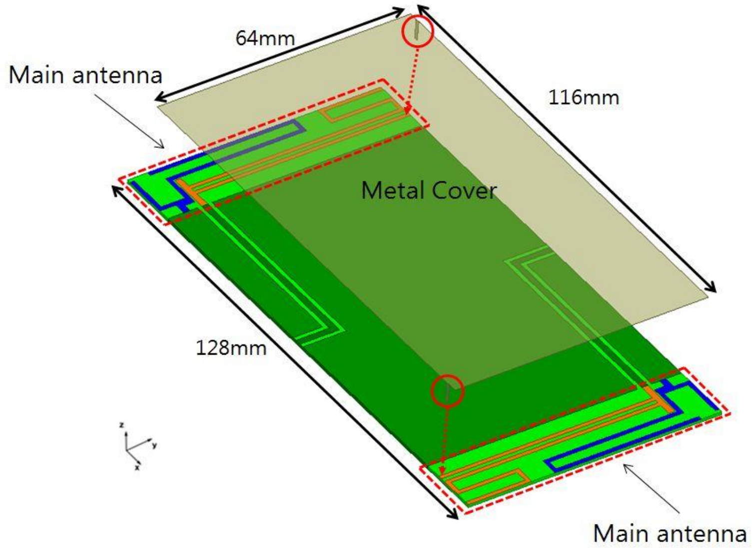
1. Introduction

Recent smart phones have been trends include big LCD screens and thinness. To avoid flexure due to the thinness of the phone, while still considering a state of the art design, the metal material is applied to the rear cover. The application of the metal cover gives many disadvantages to the antenna operation. However, the metal cover blocks the radiation of the antenna, and reduces the radiation efficiency due to small radiation resistance. The antenna of the smart phone has to be designed with multiband or wideband characteristics to cover both voice and data communication bands. For multiple input multiple output (MIMO) systems to obtain the diversity gain, the interference among several antennas makes a poor effect to the antenna characteristics. Therefore, many studies focused on increasing the antenna bandwidth with high efficiency [1-4] and improvement for the isolation between antennas [5, 6] are currently in progress.

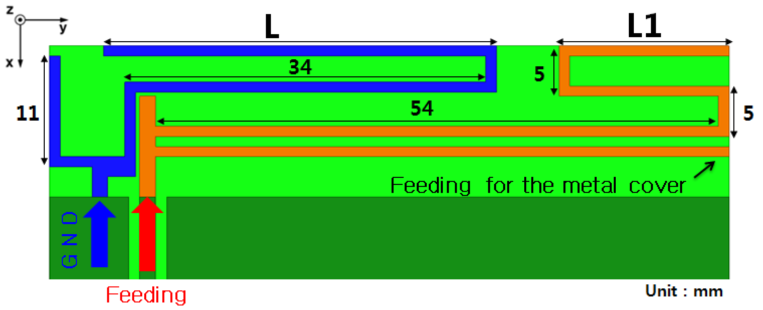
In this paper, a MIMO antenna that consists of a monopole and inverted F antenna (IFA) and metal cover radiator is designed, and implemented on the printed circuit board (PCB). The identical antennas are located on the top and bottom side of PCB, and are diagonally fed for the MIMO feeding system. The design bands are 12 mobile communication service bands of LTE class 12(698 ~ 746MHz), LTE class 17(704 ~ 746MHz), LTE class13(746 ~ 787MHz), LTE class14(758 ~ 798MHz), CDMA(824 ~ 894MHz), GSM(890 ~ 960MHz) for the low frequency band, and DCS(1710 ~ 1880MHz), KPCS(1750 ~ 1870MHz), USPCS(18550 ~ 1990MHz), WCDMA(1920 ~ 2170MHz), LTE class40(2300 ~ 2400MHz), WiFi(2400 ~ 2483MHz) for the high frequency band. The implemented proposed antenna measures the performances of both voltage standing wave ratios (VSWR) and radiation efficiency with antenna average gain.

ISSN: 2005-4297 IJCA

2. Antenna Design and Performance



(a) Perspective View

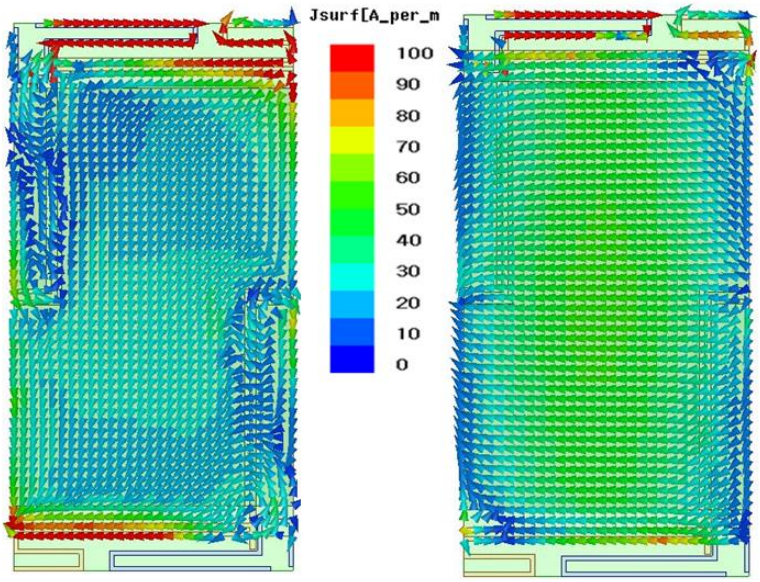


(b) Structure of the Main Antenna

(C) Feeding for the Metal Cover Element

Figure 1. Geometry of the Proposed Antenna

The proposed antenna was based on monopole + IFA hybrid antennas. Two hybrid antennas were laid at the top and bottom of the PCB, and have a common metal cover, 5mm high on the PCB as depicted in Figure 1(a). The structure of monopole + IFA hybrid antenna is shown in Figure 1(b). Detailed descriptions of the operation for the hybrid antenna are in references [2, 3] and [7, 8]. Figure 1(c) shows the feeding method to the metal cover. Therefore, the metal cover becomes a radiator for the antenna. The proposegd antenna is designed on a PCB of 64 mm by 126 mm FR4 substrate of relative dielectric constant = 4.4 with a thickness of h = 0.8 mm. The size of the metal cover is 64mm by 114mm. Two co-planer waveguide with ground (CPWG) feed lines are used for the antenna feeding.



(a) (b)

Figure 2. The Simulated Current Distribution on the Antenna Elements at Frequency of (A) 900 MHz (B) 2170 MHz

Figure 2 shows the simulated current distribution on the antenna elements for both the main antenna and the metal cover at frequency of (a) 960MHz (b) 2170MHz. For the simulations in this paper, Ansoft HFSS version 13 was used. The current on the IFA at 960MHz is continuous, and described operations of the frequency multiplication is at 2170MHz. However, it's proved that the metal cover is one of the antenna radiation elements.

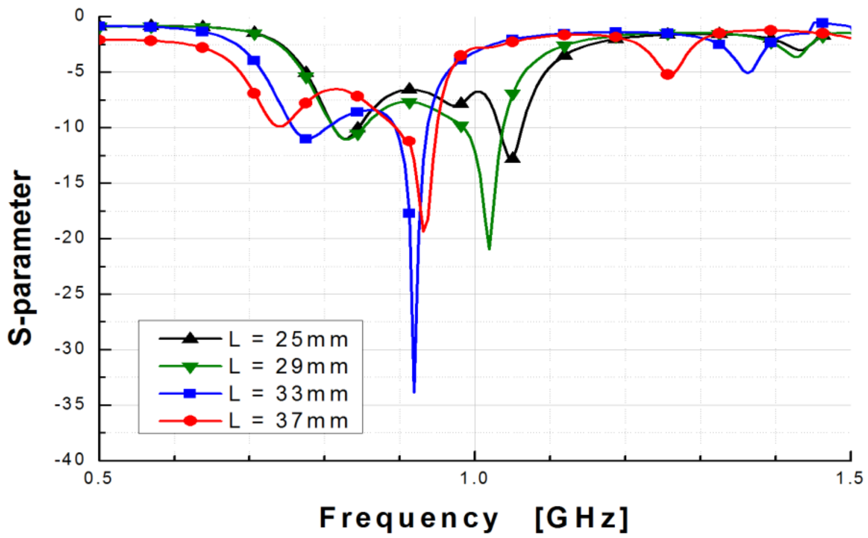


Figure 3. Variance of S-Parameter as a Function of the Length L

Figure 3 illustrates the simulated S-parameter of the element antenna as a function of the IFA length L in Figure 1(b). In Figure 3, tie position L was varied from 25mm to 37mm, in 4mm steps. The tie position affected the S-parameter in Figure 3 in lower band. When the lengths L are longer, the resonant frequencies at low frequency band move toward a low frequency.

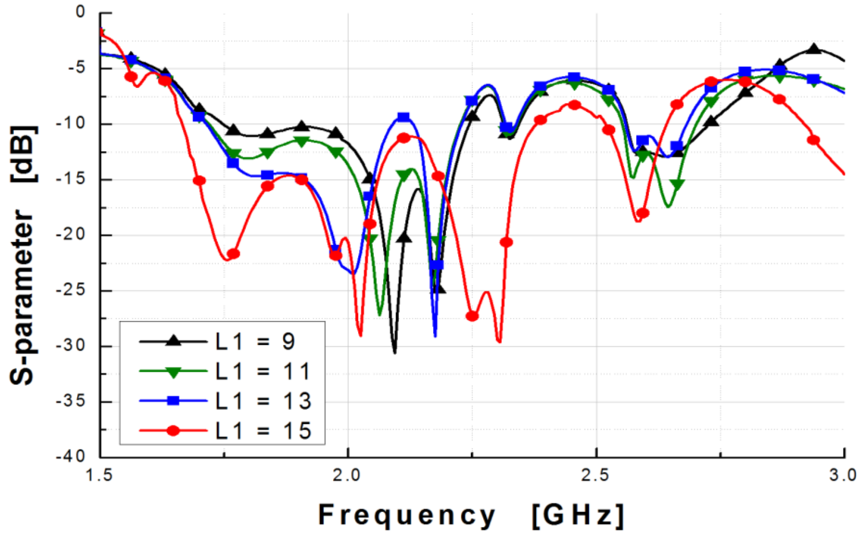


Figure 4. Variance of S-Parameter as a Function of the Length L1

Figure 4 illustrates the simulated S-parameter of the element antenna as a function of the Monopole length L1 in Figure 1(b). In Figure 4, tie position L1 was varied from 9mm to 15mm, in 2mm steps. The tie position affected the S-parameter in Figure 4 in high band. When the lengths L1 are longer, the resonant frequencies at high frequency band move toward a low frequency.

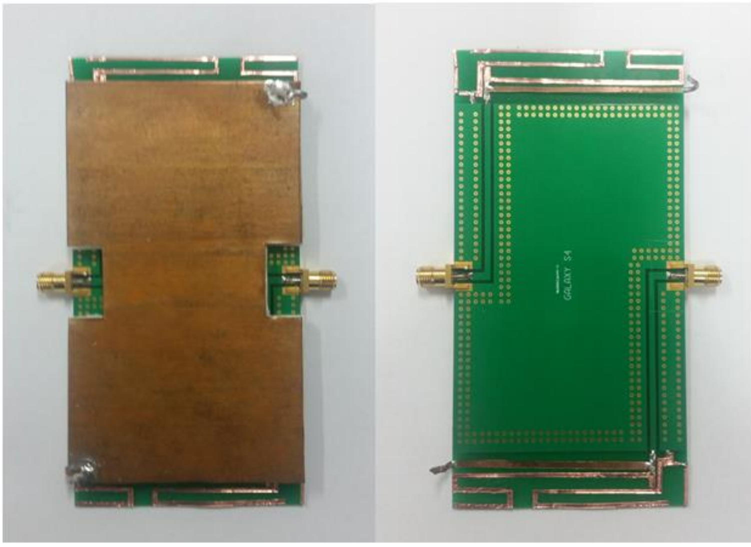
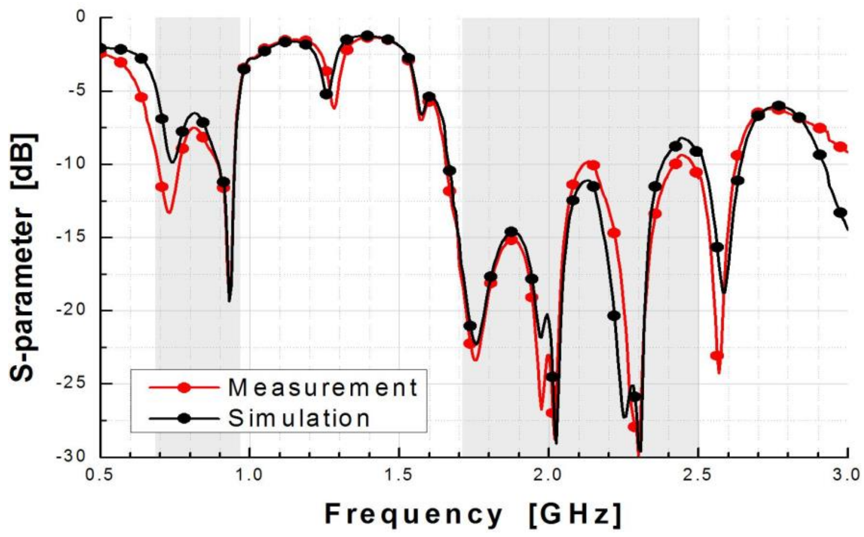
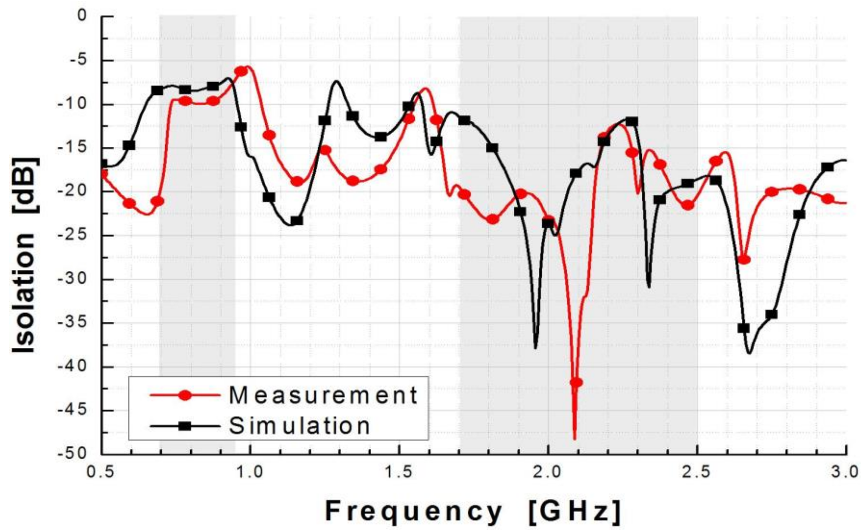


Figure 5. Proposed Metal Cover MIMO Antenna Implemented on a PCB

The proposed MIMO antenna, illustrated in Figure 5, was implemented and measured experimentally. The dimensions of the antenna and PCB are as depicted in Figure 1. Two SMA connectors were used at the feeding port of the co-planer waveguide with a ground (CPWG) feed line. The s-parameter was measured using the Agilent-E5062A two-port network analyzer.



(a)



(b)

Figure 6. Measured (A) S-Parameter and (B) Isolation.

The comparison between the simulation and the measurement of the S-parameter at port 1 and the isolation between 2 ports are shown in Figure 6. The measurements coincide well with the simulations. The S-parameter and the isolation are under -6dB (VSWR 3: 1) and 8.3dB maximum over the desire bands. Figure 7 shows the envelope coefficient correlation (ECC) of the proposed antenna.

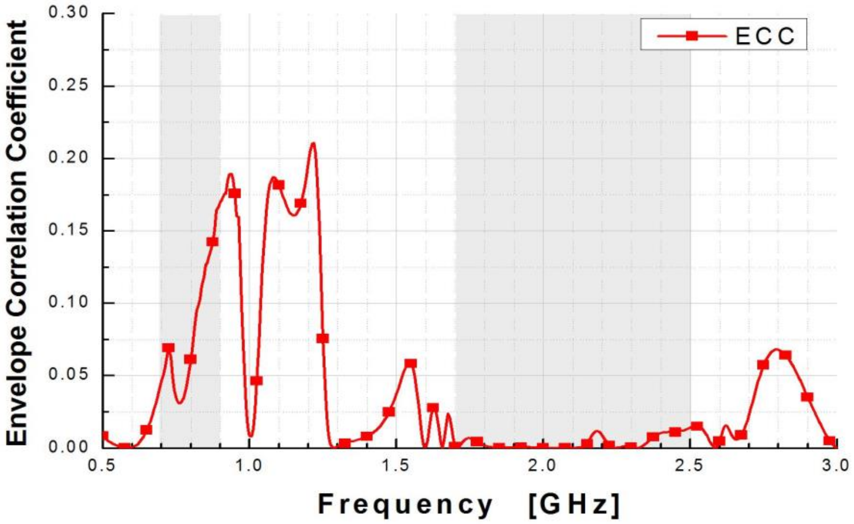
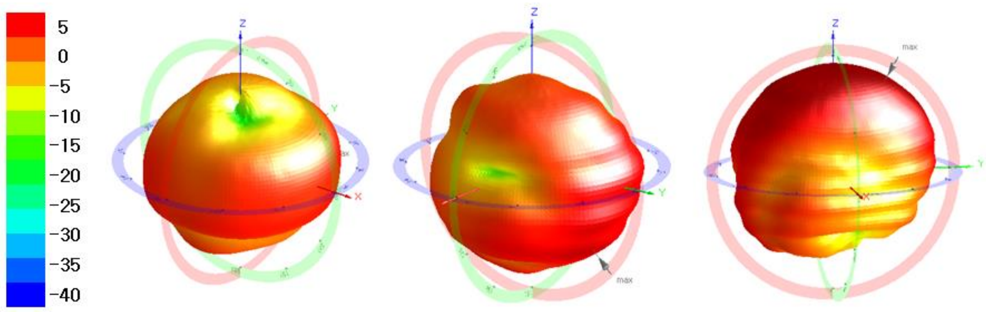


Figure 7. ECC of the Proposed Antenna.

The S-parameters that were measured are used to calculate the ECC [7], as in Figure 7, with the maximum ECC between the 2 ports over the entire design bands of 0.187. Therefore, this antenna can be applied as an antenna for the MIMO mobile communications.



(a) (b) (c)

Figure 8. Measured 3-Dimensional Radiation Patterns At Frequency Of (A) 824mhz (B) 1710mhz (C) 2500mhz

Figure 8 is the measured 3 dimensional (3D) radiation patterns at frequency of 824MHz, 1710MHz and 2500MHz. A CSCM anti-reflective anechoic chamber made by MTG Co. in KOREA was used for the radiation measurements of the antenna that was implemented. 3D patterns showed stable radiation patterns, and the proposed antenna had good radiation patterns for the mobile communication handset. However, some nulls were observed in the radiation pattern at 2500MHz.

Table 1. Measured Antenna Efficiency and Average Gian

	port 1		port 2	
Freq.[MHz]	Eff.[%]	Avg.[dBi]	Eff.[%]	Avg.[dBi]
746	30.87	-5.14	31.54	-5.06
780	44.87	-3.48	40.58	-3.92
840	48.08	-3.18	45.34	-3.44

900	61.39	-2.12	57.26	-2.42
960	74.48	-1.28	70.20	-1.54
1710	54.66	-2.62	48.70	-3.12
1950	64.22	-1.92	65.87	-1.81
2150	67.98	-1.68	73.00	-1.37
2310	59.53	-1.56	59.83	-2.23
2500	60.60	-2.18	59.33	-2.27

The measured antenna average gains and efficiencies over twelve band frequencies are summarized in Table 1. The average gains and efficiencies for the lower band of antenna 1 were measured as −5.14 ~ −1.28dBi and 30.87 ~ 74.48%, respectively. The average gains and efficiencies for the lower band of antenna 2 were −5.06 ~ −1.54dBi and 31.54 ~ 70.20%, respectively. The average gains and efficiencies for the upper band of antenna 1 were measured to be −2.62 ~ −1.68dBi and 54.66 ~ 67.98%, with -3.12 ~ -1.37dBi and 48.70 ~ 73.0% for antenna 2, respectively.

3. Conclusion

A metal cover mobile phone MIMO antenna that consists of one main antenna and a metal cover radiator was designed and implemented for the twelve bands mobile communication. The design of the main antennas is based on monopole + IFA hybrid operations. A metal cover is 5.0mm apart on the PC board, and fed from the feeding line. The antenna was implemented on the bare board and was measured. The VSWR and the maximum isolation between the antennas over the entire design band were less than 3:1 and -8.3dB, respectively. From the radiation pattern measurements, proposed antenna radiated almost omni-directionally, and had isotropy in 3-dimensional space. The average gains and efficiencies were measured -5.14~-1.28dBi and 30.87~74.48%, respectively. The maximum ECC from the S-parameters that were measured is 0.186 over the design bands.

Acknowledgments

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF), funded by the Ministry of Education (2015023260)

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