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A Full Metal-Rimmed Antenna Using Capacitive Feed and Ground for LTE Mobile Handsets

Jae-Gon Lee*

Abstract

In this letter, a full metal-rimmed antenna using a capacitive feed and ground is proposed and designed for LTE mobile handsets. The full metal rimmed antenna can be structurally represented by a loop antenna formed along the metal rim and PCB ground. The capacitive feed decreases the large reactance seen at the half wavelength mode for the loop antenna, which leads to excitation of the half wavelength mode for the loop antenna and reduces the length of the proposed antenna. In addition, a gap-coupled ground is employed to obtain additional resonance in the high band. To verify its feasibility and performance, we simulated and measured the characteristics of the proposed antenna, such as the reflection coefficient, total efficiency, and far-field radiation patterns. The overall dimension of the metal rimmed antenna is 75 mm × 10 mm (length × width), and the total efficiencies are measured more than 60% in the quad-band.

Key Words: Full Metal Rimmed Antenna, Gap-Coupled Feed, LTE Mobile Handsets.

I. INTRODUCTION

Recently, the trend in mobile handsets has been a full display, multi-functionality, and a highly rapid network service. With these requirements, the wireless performance of mobile antennas may be degraded by the narrow bezel for the full display and the mobile antenna should have a broad bandwidth and multi-bands to improve communication speed. A metal-rimmed antenna could be one of the attractive candidates for improving wireless performance because the antenna is spaced a little farther away from the PCB ground and metallic components. In addition, a metal-rimmed antenna can increase the product's durability and improve its aesthetic design. The metal rimmed antennas applied to most mobile handsets have one or more slits at the top and bottom to obtain wireless performance in low bands [1–5]. However, this kind of metal-rimmed antenna may cause severe wireless performance degradation by the human body because the dominant radiation is generated in the slits located at the outermost part of the mobile handsets. Moreover, the metal-rimmed antenna with slits gives rise to a decline in product durability and an increased cost of bonding the metal rim and the dielectric.

To overcome the expected problems of metal-rimmed antennas with slits, this letter proposes a full metal-rimmed antenna without slits using a capacitive feed and ground for LTE mobile handsets. The capacitive feed and the capacitive ground are employed to reduce the length of the antenna and to obtain additional resonance in the high band. In Section II, the design procedure of the proposed antenna, including the input impedance and current distribution, is described. The simulated and measured results are discussed in Section III. Finally, the conclusions are presented in Section IV.

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Department of Electronic Engineering, Kyungnam University, Changwon, Korea.
*Corresponding Author: Jae-Gon Lee (e-mail: jaegonlee@kyungnam.ac.kr)

II. Design of Full Metal Rimmed Antenna

Fig. 1 shows the structure of a full metal-rimmed antenna with a capacitive feed and ground. The PCB ground, whose dimensions are chosen to be 75 mm in width and 130 mm in length, is printed on an FR4 substrate with a thickness 0.8 mm, relative permittivity of 4.4, and loss tangent of 0.02. The metal rim has a height of 5 mm and a thickness of 1 mm, and the ground clearance is 10 mm. The side metal rim is electrically connected to the main board electrically. To verify the effect of the capacitive feed and ground, we simulated the input impedance of the proposed antenna, as shown in Fig. 2. In the case of the direct feed, the length of the metal loop antenna is 120 mm, corresponding to one wavelength of 1.92 GHz considering the substrate. To design a half wavelength metal loop antenna in the low band without increasing the antenna length, the imaginary part of the input impedance should be moved to the capacitive region [6]. Thus, the capacitive feed is employed to generate a series capacitance in this letter, resulting in a half wavelength resonance at 880 MHz. The capacitive ground gives rise to an additional current path so that it is utilized to form resonance in the high band. The other resonance in the high band is a second resonance of the metal loop antenna, as shown in Fig. 2. As the gap distance increases, the capacitance value is reduced, and the imaginary part of the input impedance is moved to the inductive region. From this principle, the resonance frequency is down-shifted. In addition, as the gap distance between the feeding and ground line increases, the first resonance frequency in the high band is downshifted. To confirm the resonance modes at each resonant frequency, the simulated surface current distribution on the metal rim and PCB ground of the proposed antenna are presented in Fig. 3.

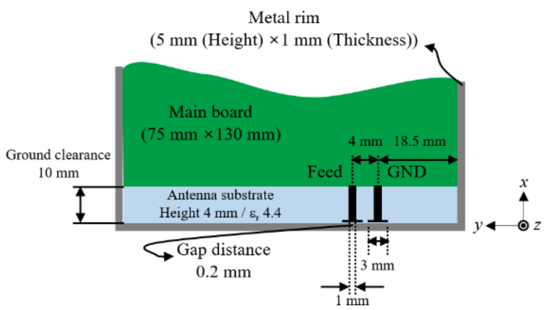


Fig. 1. Structure of the full metal-rimmed antenna with capacitive feed and ground.

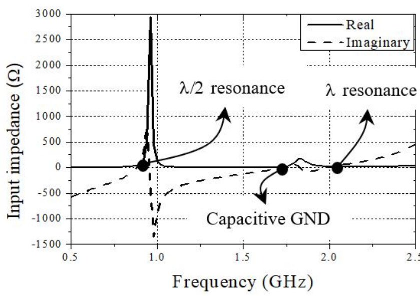


Fig. 2. Input impedance of the proposed metal rimmed antenna.

III. Experimental Results and Discussion

The fabricated full metal-rimmed antenna with its capacitive feed and ground is shown in Fig. 4. The gap distance between the feeding line and the metal rim is 0.2 mm. A metal stub with a length of 15.2 mm and a width of 3 mm connected inside the metal rim is added to obtain a broad bandwidth at the high band. The simulated and measured reflection coefficients of the proposed antenna are compared, as shown in Fig. 5. The measured results were obtained using an Agilent 8510C vector network analyzer (VNA). The −6 dB bandwidths in the low and high band are measured as 60 MHz (850–910 MHz) and 480 MHz (1,710–2,190 MHz), respectively. The simulated and measured results agree well with each other at the desired bands except for a shifted resonance frequency. It seems that the slight discrepancies are caused by manufacturing tolerance and the 50 Ω SMA connector. Total efficiency is measured in the full anechoic chamber system. The measured total efficiency of the proposed antenna is larger than 60% over the quad-band, including the GSM 850/1800/1900 bands and WCDMA 2100 band, as

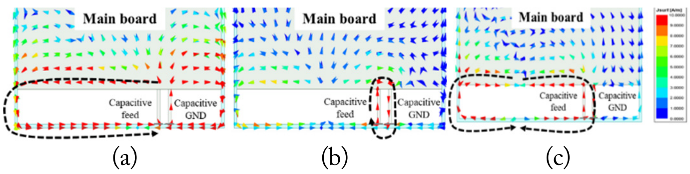


Fig. 3. Simulated surface current distributions on metal rim and PCB ground: (a) λ/2 resonance (880 MHz), (b) capacitive GND (1,780 MHz), and (c) λ resonance (2,020 MHz).

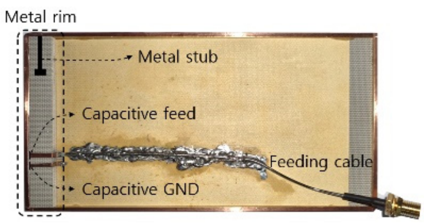


Fig. 4. Photograph of the fabricated antenna prototype.

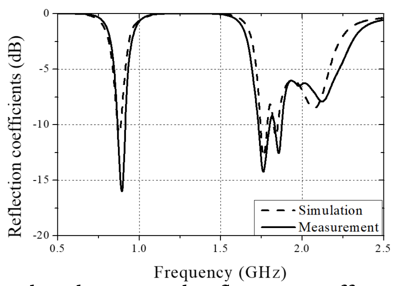


Fig. 5. Simulated and measured reflection coefficients of the proposed antenna.

shown in Fig. 6. Fig. 7 shows the measured far-field radiation patterns at resonant frequencies. The simulated and measured results agree well with each other at the desired bands. For a lower resonant frequency at 900 MHz, monopole-like radiation patterns are seen, and this pattern characteristic is similar to those observed on conventional internal mobile phone antennas at a low band. On the other hand, more variations are observed in the radiation pattern at 1,760 MHz, 1,860 MHz, and 2,120 MHz. This is because the length of the PCB ground is longer than the wavelength of the higher bands, and there are nulls of a surface current on the PCB ground. To demonstrate the performance of the proposed antenna, this work is summarized and compared with the performances of some recently published metal antennas in Table 1. Since the proposed antenna is a loop-type antenna without any slits, it is thought to be stronger in body effect than metal antennas with slits.

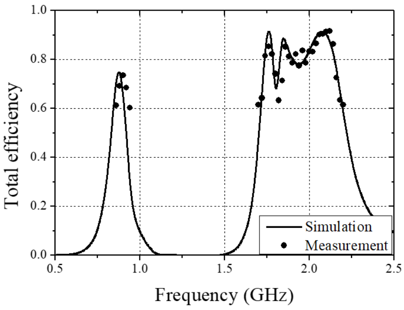
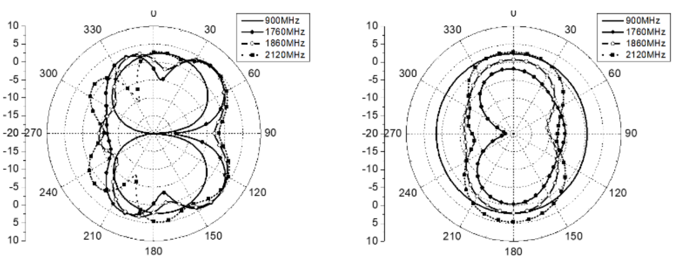


Fig. 6. Simulated and measured total efficiency of the proposed antenna.



(a) (b)

Fig. 7. Measured far-field radiation patterns at resonant frequencies: (a) xz-plane ($\phi = 0°$) and (b) yz-plane ($\phi = 90°$).

Table 1. Comparison of the performance of the proposed antenna with recently published designs

Study	Number of slit	Clearance (mm)	Efficiency[a] (%)
Liu et al. [1]	2	1	35/55
Wong and Huang [2]	1	7	50/60
Stanley et al. [3]	1	10	50/50
Chen and Zhao [4]	2	10	50/50
Choi et al. [5]	2	2	50/50
This work	None	10	60/60

[a]Values are presented as the lowest efficiencies at the lower/higher bands, respectively.

IV. Conclusion

A full metal-rimmed antenna using a capacitive feed and ground is proposed and designed for LTE mobile handsets in this letter. The proposed metal-rimmed antenna can be miniaturized by the capacitive feed and obtain broad bandwidth at high bands through the capacitive ground and metallic stub. The measured results, including the reflection coefficient and total efficiency, show that the proposed antenna can provide operation bands of 850–910 MHz and 1,710–2,190 MHz and indicate that the proposed antenna is one of solutions for full metal-rimmed mobile handsets.

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