WWAN Loop Antenna Integrated with U-shaped System Ground Plane for Handset Application

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Abstract

An internal WWAN loop antenna suitable to be applied in the mobile handset having a U-shaped system ground plane is presented. With the antenna disposed in the dented region of the U-shaped system ground plane, decreased near-field radiation and good far-field radiation efficiency can both be obtained.

Keywords : Internal handset antennas, multiband antennas, loop antennas, WWAN antennas

1. Introduction

In this paper, we present an internal penta-band WWAN antenna suitable to be disposed in the dented region of a U-shaped system ground plane of the mobile handset. The U-shaped ground plane is formed by adding two protruded grounds at two corners of the main ground plane of the handset, which is usually of a simple rectangular shape. The U-shaped ground plane studied here is different from the studies on which the system ground plane has a protruded ground only and is of an L-shape [1]. With the presence of the two protruded grounds nearby the antenna, there are usually large effects on the impedance matching and bandwidth of the antenna. To achieve the desired bandwidth with a limited antenna size, the proposed antenna is formed by a monopole strip and a parasitic loop strip encircling the same. The monopole strip capacitively excites the loop strip which supports a longer loop resonant path for the antenna. Additionally, the monopole strip is also a part of the radiator, and a shorter loop resonant path is supported by the monopole strip and a portion of the parasitic loop strip. The longer loop path contributes a 0.5-wavelength resonant mode [2] , [3] at about 900 MHz to form the antenna's lower band and a higher-order resonant mode at about 2050 MHz. The shorter loop path contributes a 0.5-wavelength resonant mode at about 1700 MHz to combine with the resonant mode at about 2050 MHz to form the antenna's upper band. The obtained lower and upper bands of the antenna can respectively cover the desired 824~960 and 1710~2170 MHz band for penta-band WWAN operation.

It is also noted that the presence of the two protruded grounds in the U-shaped ground plane can attract some strong excited surface currents that are originally on the main ground plane when the protruded ground is not present. This feature can lead to decreased surface current distribution on the main ground plane away from the dented region where the antenna is located. Hence, by disposing the antenna at the bottom of the handset, decreased near-field emission near the top portion of the handset can be expected. This can make it easy for the handset to meet the SAR and HAC [4]-[6] requirements for practical applications.

2. Proposed Antenna

Fig. 1 shows the geometry of the proposed WWAN handset antenna with a U-shaped system ground plane. Note that the plastic casing made by 1-mm thick plastic slab of relative permittivity 3.0 and loss tangent 0.02 to simulate the casing of a practical handset is not shown in the photos. Also note that for achieving decreased SAR and HAC results required for practical applications, the dented region of the U-shaped ground plane is placed at the bottom of the handset. The antenna occupies a volume of $42 \times 10 \times 5$ mm^3 and is disposed in the dented region (size 10×42 mm^2) of the U-shaped ground plane, which is formed by adding two protruded grounds (size 10×9 mm^2) at two corners of the main ground plane (size 60×100 mm^2) of the handset. The

protruded grounds are large enough to accommodate associated electronic elements such as a USB connector [1]. Both the two protruded grounds and the main ground plane are printed on the back surface of the system circuit board, which is an 0.8-mm thick FR4 substrate of size 110 × 60 mm^2, relative permittivity 4.4, and loss tangent 0.02 in this study. The selected dimensions of the system circuit board are reasonable for practical smartphones.

There are two loop resonant paths provided in the proposed antenna. The loop strip with its two ends short-circuited through two 1-mm wide shorting strips at point B and C to the main ground plane supports a longer loop resonant path (loop BEC) of about 155 mm, which is close to 0.5-wavelength at about 900 MHz. The loop strip encircles the open end of the monopole strip and is parasitically excited by the monopole strip through the coupling gaps of gap1 (0.5 mm) and gap2 (0.8 mm). The longer loop resonant path can support a 0.5-wavelength resonant mode to form the antenna's lower band for the GSM850/900 operation. Further, the longer loop resonant path can contribute a higher-order resonant mode at about 2050 MHz. The shorter loop resonant path (loop ADEB) has a length of about 75 mm and is formed by the monopole strip and a portion of the parasitic loop strip. The loop ADEB can contribute a 0.5-wavelength loop resonant mode at about 1700 MHz, which combines with the resonant mode at about 2050 MHz to form the antenna's upper band for the GSM1800/1900/UMTS operation.

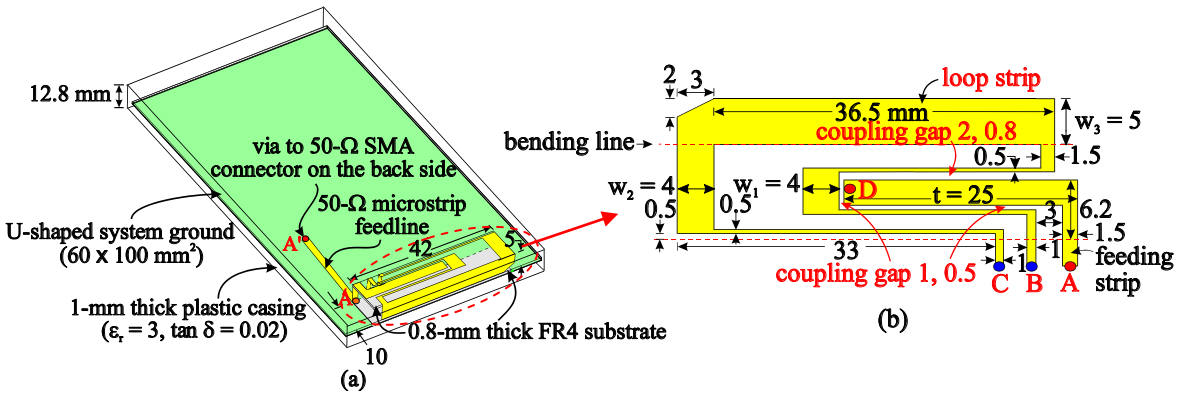


Fig. 1. (a) Geometry of the proposed WWAN handset antenna with a U-shaped system ground plane. (b) Dimensions of the antenna's metal pattern.

3. Result and Discussion

Fig. 2 shows the measured and simulated return loss for the fabricated antenna and the photos of the fabricated antenna. Simulated results are obtained using ANSYS simulation software HFSS (high frequency structure simulator) version 12. Agreement between the simulation and measurement is seen. The obtained antenna's lower and upper bands, with impedance matching defined by 3:1 VSWR (6-dB return loss) which is widely used as the design specification for the internal WWAN handset antenna, cover the desired 824~960 and 1710~2170 MHz bands.

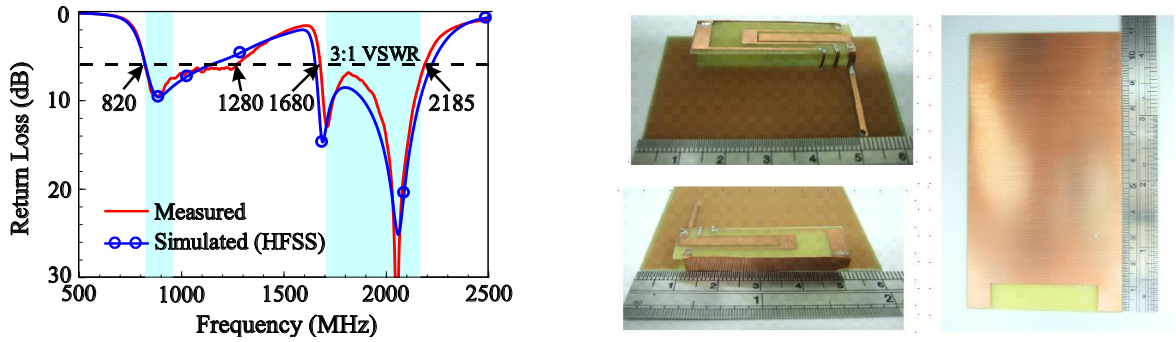


Fig. 2. Measured and simulated return loss for the proposed antenna and the photos of the fabricated antenna (handset casing not included in the photos).

To analyze the operation principle of the antenna, the results shown in Fig. 3 in which a comparison of the simulated return loss for the proposed antenna and the reference antenna with the loop path ADEB is presented, it can be concluded that the resonant mode at about 1700 MHz for the proposed antenna is mainly contributed by the loop path ADEB as discussed in Section 2.

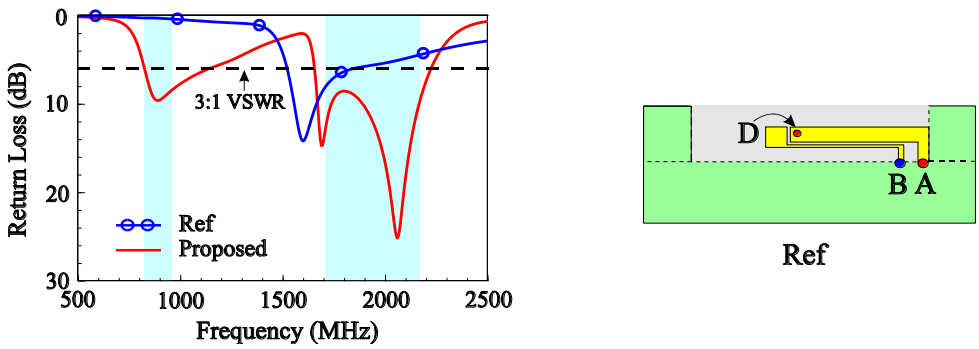
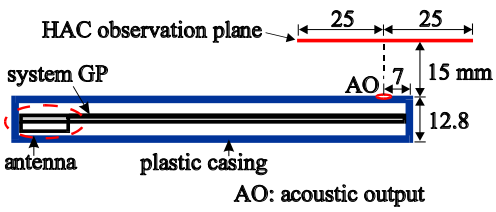


Fig. 3. Simulated return loss for the proposed antenna and the reference antenna with the loop path ADEB. Other parameters are the same as in Fig. 1.

The antenna efficiency (mismatching loss included) of the fabricated antenna are measured in a far-field anechoic chamber. The antenna efficiency varies from about 55 to 75% for frequencies over the lower band, while that over the upper band varies from about 70 to 94%. The SAR results for the proposed antenna are also studied. The simulation model is provided by the simulation software SEMCAD X version 14. The obtained SAR values for 1-g head tissue are all well below the limit of 1.6 W/kg , indicating that the antenna is promising for practical handset applications.

Fig. 4 shows the simulated HAC results for the proposed antenna based on the HAC simulation model provided by SEMCAD X version 14 complying with the standard ANSI C63.19-2007 [5]. In the study, the input power is 33 dBm (2 Watt continuous input power) at 859 and 925 MHz, and 30 dBm at 1795 and 1920 MHz (1 Watt continuous input power). Results show that the proposed antenna at the five testing frequencies is rated to be M3 or M4 category [5], and can be considered as a hearing-aid compatible handset meeting ANSI C63.19-2007. In addition, note that the obtained near-field E-field and H-field strengths are weaker by about 0.5~2.1 dB for the proposed antenna with a U-shaped ground plane than the corresponding case with a simple rectangular ground plane (no protruded grounds). This behavior is related to the presence of the two protruded grounds, which can attract some strong excited surface currents that are originally on the main ground plane when the protruded ground is not present. This can be seen more clearly from the excited surface current distributions at 925 and 1920 MHz shown in Fig. 5. Also note the fine-adjustment of the antenna dimensions ensures the impedance matching of the antenna in the corresponding case better than 6-dB return loss required for practical applications.



Frequency (MHz)	859	925	1795	1920	2045
E-field (dBV/m) (U-shaped ground)	47.8 (M3)	48.2 (M3)	38.4 (M3)	36.9 (M3)	27.3 (M4)
E-field (dBV/m) (w/o protruded grounds)	48.9 (M2)	48.7 (M2)	40.1 (M2)	38.8 (M2)	29.4 (M4)
ΔE (dBV/m)	-1.1	-0.5	-1.7	-1.9	-2.1
H-field (dBA/m) (U-shaped ground)	-8.4 (M4)	-7.4 (M4)	-12.5 (M3)	-13.3 (M3)	-21.9 (M4)
H-field (dBA/m) (w/o protruded grounds)	-7.2 (M4)	-6.7 (M3)	-11.1 (M2)	-12.6 (M3)	-21.3 (M4)
ΔH (dBA/m)	-1.2	-0.7	-1.4	-0.7	-0.6

ΔE = E-field (U-shaped ground) – E-field (w/o protruded grounds)
ΔH = H-field (U-shaped ground) – H-field (w/o protruded grounds)

Fig. 4. HAC simulation model and the simulated HAC results for the proposed antenna.

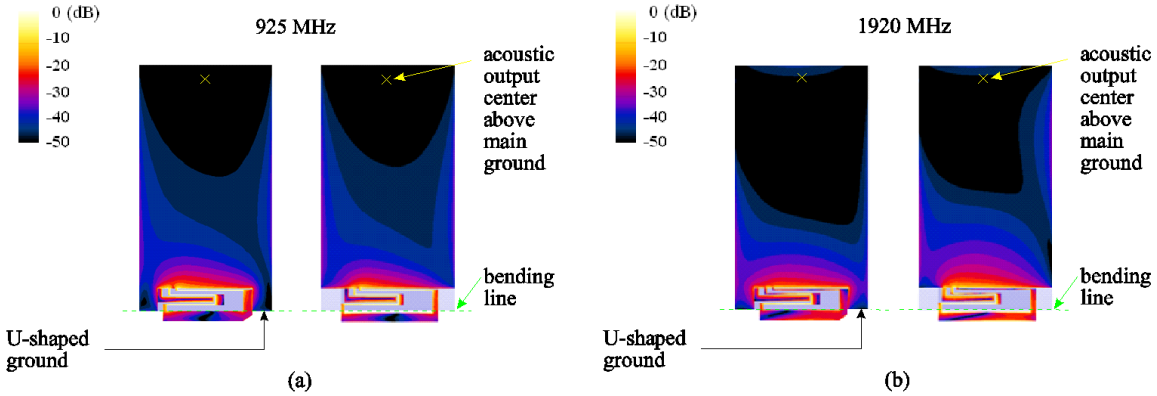


Fig. 5. Simulated surface current distributions excited on the U-shaped ground plane and on the ground plane without two protruded grounds (simple rectangular ground plane). (a) f = 925 MHz. (b) f = 1920 MHz.

4. Conclusion

An internal penta-band WWAN antenna especially suitable to be applied in the mobile handset having a U-shaped system ground plane has been proposed and studied. The antenna is to be disposed at the dented region of the U-shaped system ground plane and can provide two wide operating bands to respectively cover the GSM850/900 and GSM1800/1900/UMTS bands. Good radiation characteristics of the antenna have also been observed. The antenna also meets the 1-g SAR values to be less than 1.6 W/kg and the HAC standard to be rated in the M3 category. The obtained results make the antenna promising for practical applications.

Reference

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