Internal Handset Antenna Integrated with USB Connector for WWAN/LTE Operation

#Fang-Hsien Chu and Kin-Lu Wong
Department of Electrical Engineering, National Sun Yat-Sen University
Kaohsiung 804, Taiwan, chufh@ema.ee.nsysu.edu.tw

Abstract

A coupled-fed dual-loop antenna capable of covering WWAN/LTE operation and integrating with a USB connector in the handset is presented. The antenna integrates with a protruded ground, which is extended from the main ground of the handset to accommodate a USB connector functioning as a data port of the handset.

Keywords : Mobile antennas, handset antennas, coupled-fed loop antennas, WWAN antennas, LTE antennas, USB connector

1. Introduction

Several internal mobile handset antennas capable of covering eight-band WWAN/LTE operation in the 704~960 and 1710~2690 MHz bands have recently been demonstrated [1], [2]. In order to provide wideband operation and low SAR (specific absorption rate) values to meet the limit of 1.6 W/kg for 1-g head tissue, these WWAN/LTE handset antennas are generally disposed on the no-ground portion at the entire bottom edge of the system circuit board [3], [4]. In this case, the integration of such an antenna with nearby electronic elements such as a USB (universal series bus) connector, which is usually mounted at the bottom edge of the handset and used as a data port for external devices, becomes a challenging problem. This is because the presence of the USB connector, which is a conducting object, is generally not considered in the antenna design. Hence, when the USB connector is placed very close to the antenna, some undesired coupling will usually occur to cause degrading effects on the impedance matching of the antenna, thereby greatly decreasing the bandwidth of the antenna. Many traditional internal WWAN handset antennas also have a similar problem, which causes a limitation in achieving compact integration of the internal antenna with associated electronic elements inside the handset.

To overcome the problem, we present in this paper a promising coupled-fed dual-loop handset antenna to integrate with a USB connector (typical size 9 × 7 × 4 mm^3 for mini USB connector) and cover eight-band WWAN/LTE operation which includes the LTE700/GSM850/900 bands and the GSM1800/1900/UMTS/LTE2300/2500 bands. The antenna is mounted above a protruded ground extended from the main ground plane of the handset, while there is a USB connector mounted on the protruded ground. The antenna is further short-circuited to the protruded ground, and the presence of the USB connector on the protruded ground is included in the antenna design. Details of the proposed antenna are described in the paper. With the presence of the protruded ground below the antenna, the design considerations for achieving two wide operating bands to cover the desired 704~960 and 1710~2690 MHz bands are addressed. A parametric study of the major parameters of the antenna is also conducted. The obtained results including the antenna's radiation characteristics and its SAR values for 1-g head tissue are also presented.

2. PROPOSED ANTENNA

Fig. 1(a) and (b) shows the geometry of the proposed coupled-fed dual-loop mobile handset antenna integrated with a USB connector. Detailed dimensions of the antenna's metal pattern are shown in Fig. 1(c). Note that a USB connector is mounted on the protruded ground of size 10 × 10 mm^2 extended from the main ground plane of size 55 × 105 mm^2. The protruded ground and main ground plane are both printed on the back surface of a 0.8-mm thick FR4 substrate of size 55 × 115 mm^2, relative permittivity 4.4 and loss tangent 0.02 in the study, which is treated as the main circuit board of a practical smartphone. The selected dimensions of the main circuit board are reasonable for practical smartphones.

The antenna is centered above the protruded ground. A meandered shorting strip of length 17.8 mm and width 0.5 mm (section BB′) short-circuits the antenna to the protruded ground. The short-circuiting integrates the USB connector mounted on the protruded ground with the antenna. Further, by using a meandered shorting strip, additional inductance is expected to be contributed to the antenna’s input impedance. This causes shifting of the excited resonant modes to lower frequencies, which is helpful in achieving decreased size of the internal antenna for eight-band WWAN/LTE operation.

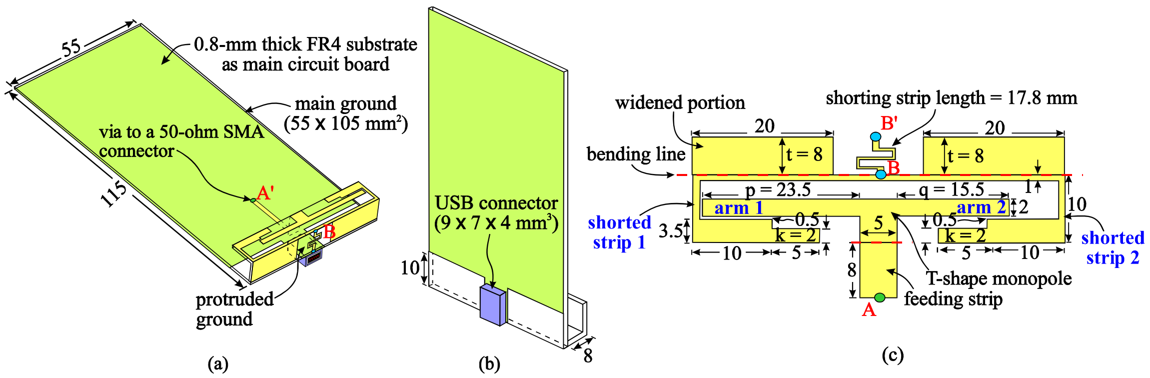


Fig. 1: (a) Geometry of the proposed coupled-fed dual-loop mobile handset antenna integrated with a USB connector. (b) A USB connector mounted on the protruded ground. (c) Dimensions of the antenna’s metal pattern.

To achieve two wide operating bands for the desired WWAN/LTE operation, the antenna is composed of two separate shorted strips and a T-shape monopole encircled therein as a coupling feed and a radiator as well. The two shorted strips (strip 1 and 2) are of the same dimensions and are short-circuited to the protruded ground through the meandered shorting strip. Each arm (arm 1/arm 2) of the T-shape monopole couples to the open end of each shorted strip (strip 1/strip 2) through a coupling gap of 0.5 mm. By tuning the length p and q of the two arms (one is 23.5 mm and the other is 15.5 mm), two separate quarter-wavelength loop resonant modes can be excited to form a wide lower band to cover the desired 704~960 MHz band. With the successful excitation of the quarter-wavelength loop resonant mode [3], which is different from the traditional internal loop handset antennas operated at the half-wavelength resonant mode as the fundamental or lowest-frequency mode. This leads to the size reduction of the internal loop handset antennas for the WWAN/LTE operation.

3. RESULTS AND DISCUSSION

Based on the dimensions given in Fig. 1, the measured and simulated return loss for the proposed antenna and the photo of the fabricated antenna was shown in Fig. 2. The simulated results are obtained using HFSS (high frequency structure simulator) version 12, and agreement between the measured data and simulated results is seen. Two wide operating bands have been obtained for the antenna. The lower band is formed by two resonant modes which are contributed by the two coupled-fed loop resonant paths provided by the antenna. Based on the bandwidth definition of 3:1 VSWR (6-dB return loss), which is widely used as the design specification of the internal WWAN/LTE handset antenna, the lower band covers the desired 704~960 MHz band. The upper band is formed by three resonant modes and shows a bandwidth of larger than 1 GHz to cover the desired 1710~2690 MHz band.

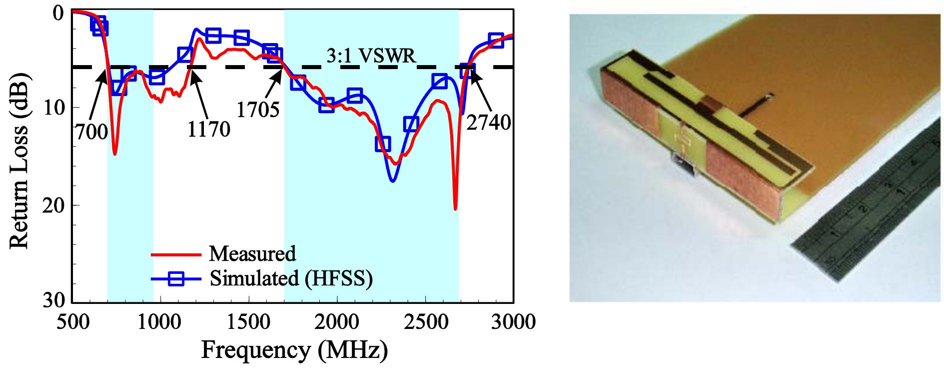


Fig. 2: Measured and simulated return loss for the proposed antenna and the photo of the fabricated antenna.

Fig. 3(a) shows the simulated return loss for the proposed antenna and the case with the T-shape monopole only (Ref1). It is seen that without the two shorted strips, the lower band cannot be excited. On the other hand, a wide operating band formed by two resonant modes (the first one at about 2.15 GHz contributed by arm 1 and the second one at about 2.7 GHz contributed by arm 2) is obtained for the case with the T-shape monopole only (Ref1). This indicates that the T-shape monopole is also an efficient radiator in the proposed antenna.

The simulated return loss for the proposed antenna and the case with the coupled-fed loop on the left-hand side (arm 1 and shorted strip 1) only (Ref2) is also shown in Fig. 3(b). It is seen that only a resonant mode is excited at about 800 MHz and is far from covering the desired lower band. An additional resonant mode at about 2.7 GHz, which is a higher-order mode contributed by shorted strip 1, is excited to enhance the bandwidth of the antenna's upper band. It is also noted that when arm 2 is not present, the second resonant mode in the antenna's upper band cannot be excited.

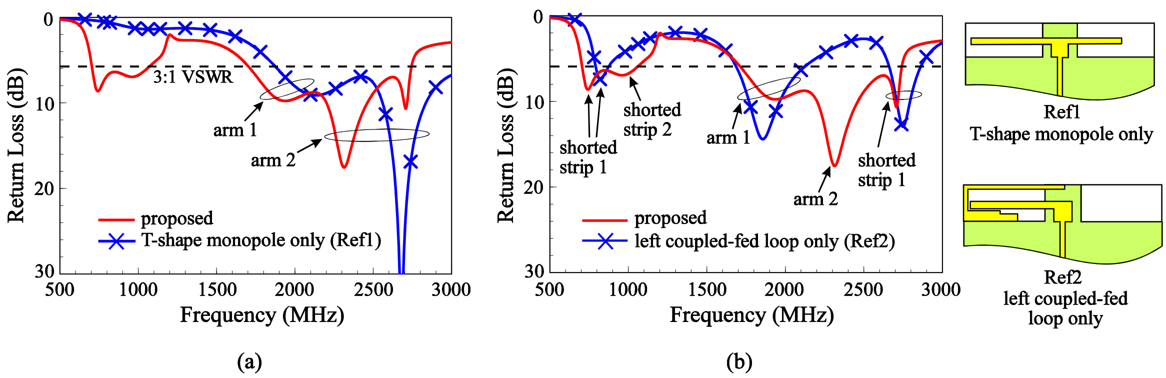
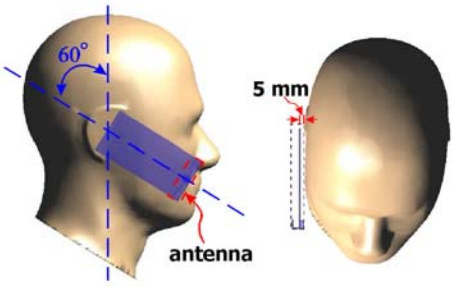


Fig. 3: Simulated return loss for (a) the proposed antenna and the case with the T-shape monopole only (Ref1), and (b) the proposed antenna and the case with the coupled-fed loop on the left-hand side (arm 1 and shorted strip 1) only (Ref2).

In addition, for practical applications, the SAR values of the antenna should be less than 1.6 W/kg for 1-g head tissue. To analyze the SAR results, Fig. 4 shows the SAR simulation model and the simulated SAR values for 1-g head tissue for the antenna. In the simulation model, the typical parameters of the head phantom liquid are $\varepsilon_r = 41.5$, $\sigma = 0.97$ (S/m) at 900 MHz, and $\varepsilon_r = 40$, $\sigma = 1.4$ (S/m) at 1800 MHz. The simulated results are obtained using the SPEAG simulation software SEMCAD X version 14. The main circuit board with the antenna mounted at the bottom is placed close to the head phantom with a 5-mm distance to simulate the thickness of the handset housing. At each testing frequency (central frequencies of the eight operating bands), the SAR values are tested using input power of 24 dBm for the GSM850/900 (859, 925 MHz) system and 21 dBm for the GSM1800/1900/UMTS (1795, 1920, 2045 MHz) and LTE700/2300/2500 (740, 2350, 2595 MHz) systems. The return loss given in the table shows the impedance matching level at the testing frequency. The obtained SAR values are well below the SAR limit of 1.6 W/kg, indicating that the antenna is promising for practical handset applications.



Frequency (MHz)	Testing power (dBm)	SAR (W/kg)	Return loss (dB)
740	21	0.54	8.7
859	24	1.01	5.6
925	24	1.11	6.2
1795	21	0.70	14.1
1920	21	0.57	15.1
2045	21	0.47	11.2
2350	21	0.66	22.0
2595	21	0.62	7.6

Fig. 4: SAR simulation model and the simulated SAR values for 1-g tissue for the proposed antenna.

Furthermore, the measured results show that the radiation efficiency is all larger than 50% over the WWAN/LTE operating bands, which is good for practical applications. Detailed measured results and discussions on parametric studies of the proposed antenna will be given in the presentation.

4. CONCLUSION

A promising internal eight-band WWAN/LTE antenna integrated with a USB connector at the bottom edge of the mobile handset has been proposed. The antenna is mounted above a protruded ground extended from the main ground plane of the handset, which allows the antenna to integrate with a USB connector disposed on the protruded ground. Further, two coupled-fed loop resonant paths capable of generating quarter-wavelength modes have been provided by the antenna. The proposed design makes the antenna not only capable of WWAN/LTE operation but also suitable to integrate nearby associated elements such as a USB connector at the bottom edge as the data port of the handset. Good far-field radiation characteristics for frequencies over the eight operating bands have also been observed. Acceptable near-field emission of the antenna with its SAR values for 1-g head tissue well less than 1.6 W/kg has been obtained. From the results shown in this study, the proposed antenna is promising for practical applications in a smartphone for eight-band WWAN/LTE operation.

References

[1] F. H. Chu and K. L. Wong, “Simple planar printed strip monopole with a closely-coupled parasitic shorted strip for eight-band LTE/GSM/UMTS mobile phone,” IEEE Trans. Antennas Propagat., vol. 58, pp. 3426-3431, Oct. 2010.
[2] C. T. Lee and K. L. Wong, “Planar monopole with a coupling feed and an inductive shorting strip for LTE/GSM/UMTS operation in the mobile phone,” IEEE Trans. Antennas Propagat., vol. 58, pp. 2479-2483, Jul. 2010.
[3] Y. W. Chi and K. L. Wong, “Quarter-wavelength printed loop antenna with an internal printed matching circuit for GSM/DCS/PCS/UMTS operation in the mobile phone,” IEEE Trans. Antennas Propagat., vol. 57, pp. 2541-2547, Sep. 2009.
[4] K. L. Wong and S. C. Chen, “Printed single-strip monopole using a chip inductor for penta-band WWAN operation in the mobile phone,” IEEE Trans. Antennas Propagat., vol. 58, pp. 1011-1014, Mar. 2010.