

# Internal Penta-Band Printed Loop-Type Mobile Phone Antenna

Wei-Yu Li and Kin-Lu Wong

Department of Electrical Engineering, National Sun Yat-Sen University  
Kaohsiung 804, Taiwan

**Abstract-** A novel internal mobile phone loop-type antenna for GSM850/GSM900/DCS/PCS/UMTS penta-band operation is presented. The antenna comprising a driven monopole and a coupled strip is very suitable to be printed on the system circuit board of the mobile phone and short-circuited to the system ground plane to form as a loop-type structure. The antenna provides two wide bands at about 900 and 1900 MHz to cover the GSM850/900 and DCS/PCS/UMTS bands, respectively. The lower band is generated by the driven monopole and coupled strip operated together as a half-wavelength loop resonant structure. The upper band is formed by two resonant modes: the first one is the driven monopole operated alone as a quarter-wavelength monopole and the second one is contributed from the driven monopole and coupled strip operated together as a one-wavelength loop resonant structure.

## I. INTRODUCTION

The internal mobile phone antenna with a loop structure is attractive for practical application owing to its balanced one-wavelength resonant mode that can result in small excited surface currents on the ground plane of the mobile phone [1, 2]. With this characteristic, when the mobile phone is held by the user's hand, small effects on the performances of the antenna can be obtained [3]. To utilize this advantageous property, promising loop antennas capable of dual-band or multiband operation in the mobile phone have been reported in the literature [3-6]. However, among the available designs, the penta-band loop antennas that can cover the major existing mobile communication bands including the global communication system (GSM850, 824-894 MHz and GSM900, 890-960 MHz), the digital communication system (DCS, 1710-1880 MHz), the personal communication system (PCS, 1850-1990 MHz) and the universal mobile telecommunication system (UMTS, 1920-2170 MHz) are still very few.

In this paper we present a printed loop-type antenna capable of penta-band operation in the mobile phone. The antenna is suitable to be printed on the system circuit board of the mobile phone and short-circuited to the system ground plane to form as a loop-type structure. Design considerations of the proposed antenna are described in the paper. Results of the constructed prototype are presented and discussed.

## II. ANTENNA DESIGN

Fig. 1 shows the geometry of the proposed loop-type antenna for penta-band operation in the mobile phone. The antenna is printed on the top no-ground portion ( $45 \times 20 \text{ mm}^2$ ) of a 0.8-mm thick FR4 substrate of relative permittivity 4.4, which is treated as the system circuit board of the mobile phone. A ground plane of size  $45 \times 95 \text{ mm}^2$  as the system ground plane of the mobile phone, which does not cover the top no-ground portion of the substrate, is printed on the back surface of the FR4 substrate.

The antenna is mainly comprised of a driven monopole and a coupled strip. The driven monopole is of an inverted-L shape, and its feeding point (point A) is connected to a 50- $\Omega$  microstrip line printed on the FR4 substrate. The driven

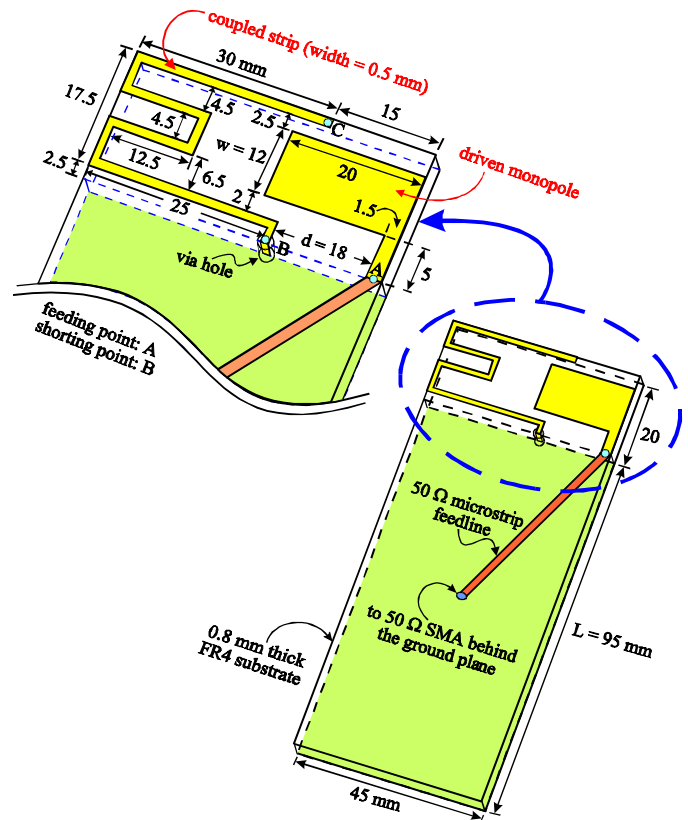


Figure 1. Geometry of the printed loop-type mobile phone antenna for penta-band operation.

monopole alone (that is, the coupled strip is not present) can support a resonant path of about 35 mm, thus providing a quarter-wavelength resonant mode at about 1800 MHz. With the end portion of the driven monopole widened to be 12 mm ( $w$ ), the excited resonant mode can have a wide bandwidth to cover the DCS/PCS bands. Effects of the width  $w$  on the performance of the antenna are also studied, and the results are shown in Fig. 4 for detailed discussion in the next section.

The coupled strip has a narrow width of 0.5 mm and is meandered in its middle section to achieve a longer resonant length inside the limited region of the top no-ground portion of the substrate. From point B, which is short-circuited to the ground plane, to point C (the open end), the length of the coupled strip is about 100 mm in this design. In addition, the open end of the coupled strip is extended toward the driven monopole, and there is a small gap of 2.5 mm in between the two end portions of the driven monopole and coupled strip. Through the small gap, the coupled strip is electromagnetically coupled to the driven monopole, thus a loop-type structure is formed. In this case, the total length of the loop-type structure starting from point A to point C then to point B is about 135 mm, which is close to about a half-wavelength of the frequency at 900 MHz. This loop-type structure leads to the excitation of a half-wavelength loop resonant mode at about 900 MHz and a one-wavelength loop resonant mode at about 1900 MHz.

The antenna's lower band is formed by the excited half-wavelength loop resonant mode, which shows a wide bandwidth to cover the GSM850/900 bands. That is, the lower band is generated by the driven monopole and coupled strip operated together as a half-wavelength loop resonant structure. For the antenna's upper band, it is formed by two resonant modes: the first one is the quarter-wavelength resonant mode generated by the driven monopole alone, and the second one is the one-wavelength loop resonant mode [7-10] contributed from the driven monopole and coupled strip operated together as a loop-type structure. This upper band has a wide bandwidth to easily cover the DCS/PCS/UMTS bands. Thus, with the wide lower and upper bands obtained for the proposed antenna, penta-band operation is achieved.

### III. RESULTS AND DISCUSSION

The proposed antenna shown in Fig. 1 was first fabricated and tested. Fig. 2 shows the measured and simulated return loss for the constructed prototype. The simulated results are obtained using Ansoft HFSS (High Frequency Structure Simulator) [11], and good agreement between the simulation and measurement is obtained. A wide lower band having an impedance bandwidth (3:1 VSWR or 6-dB return loss) of 370 MHz (810 ~ 1180 MHz) is excited, which easily covers the GSM850/900 bands and is mainly contributed from the driven monopole and coupled strip operated together as a half-wavelength loop resonant mode as discussed in Section II. This behavior can be explained more clearly from the results

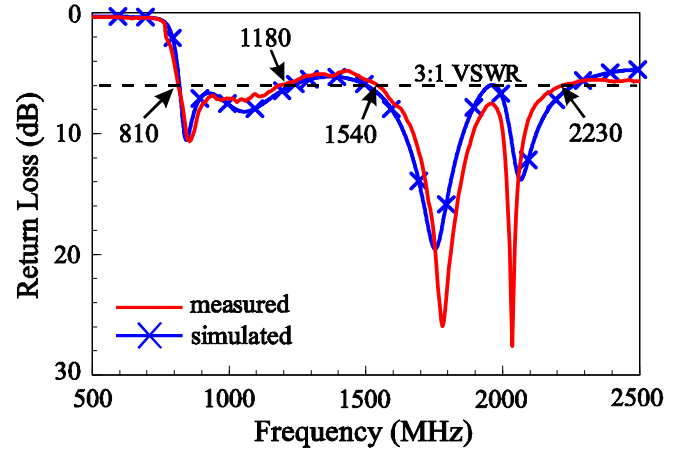


Figure 2. Measured and simulated return loss for the antenna with dimensions given in Fig. 1.

of the proposed antenna and the case with the driven strip only (the coupled strip not present) shown in Fig. 3. When the coupled strip is not present, the lower band can not be excited.

For the upper band, it has a bandwidth of 690 MHz (1540 ~ 2230 MHz) and also easily covers the DCS/PCS/UMTS bands. The upper band is formed by two resonant modes. The first one is contributed from the driven strip alone operated as an inverted-L monopole. This behavior can also be explained clearly in Fig. 3, in which there is only one resonant mode excited at about 1800 MHz when the coupled strip is not present. For the second mode in the upper band, it is generated by the driven monopole and coupled strip operated together as a one-wavelength loop resonant mode as discussed in Section II.

Fig. 4 shows the simulated return loss as a function of the width  $w$  of the driven monopole, and other dimensions are the same as in Fig. 1. Results show that only when the width  $w$  is large enough (12 mm here), the obtained bandwidth of the first mode of the upper band contributed by the driven monopole alone can be enhanced to be wide enough to cover the DCS/PCS bands. That is, wider bandwidth with increasing widths of the driven monopole is obtained; this behavior is

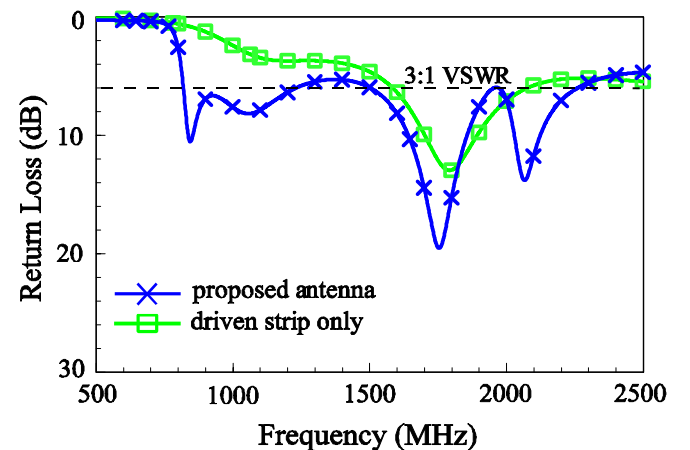


Figure 3. Simulated return loss for the proposed antenna and the case with the driven monopole only.

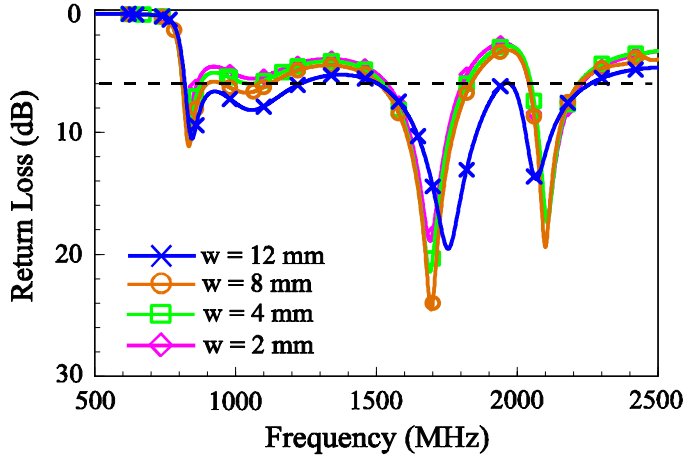


Figure 4. Simulated return loss as a function of  $w$  of the driven monopole; other dimensions are the same as in Fig. 1.

similar to that observed for the monopole with a wider radiating strip [12]. The second mode of the upper band is also found to have a wider bandwidth, which covers the UMTS band. The larger width  $w$  can also result in improved impedance matching of the antenna's lower band, thus providing a wide bandwidth to cover the GSM850/900 bands.

The radiation characteristics of the constructed prototype are also studied, and the measured radiation patterns at 860 and 925 MHz (center frequencies of the GSM850 and GSM900 bands) are plotted in Fig. 5. Similar radiation patterns

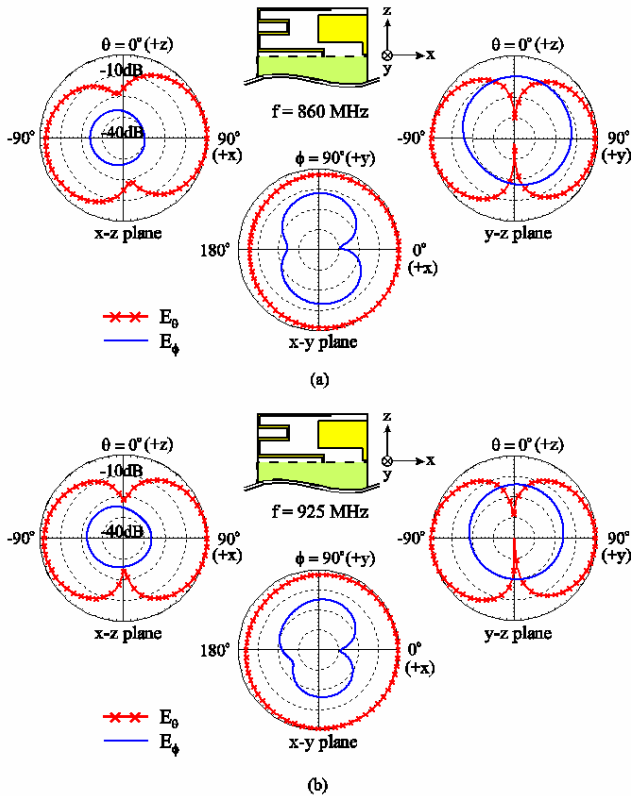


Figure 5. Measured radiation patterns at (a) 860 MHz and (b) 925 MHz for the antenna.

at 860 and 925 MHz are observed, which suggests that stable radiation characteristics are obtained over the antenna's lower band. The radiation patterns are also seen to be similar to that of the general internal mobile phone antenna [13]. This behavior is mainly because the half-wavelength loop resonant mode excited for the lower band is an unbalanced mode. In this case the excited surface currents on the system ground plane are large and thus dominate the radiation performance in the 900 MHz band.

Fig. 6 plots the measured radiation patterns at 1795, 1920 and 2050 MHz (center frequencies of the DCS, PCS and UMTS bands). Similar radiation patterns at 1795 and 1920 MHz are seen, which indicates that stable radiation performance is obtained over the band. This behavior is mainly because the operating bands of DCS and PCS are covered by the

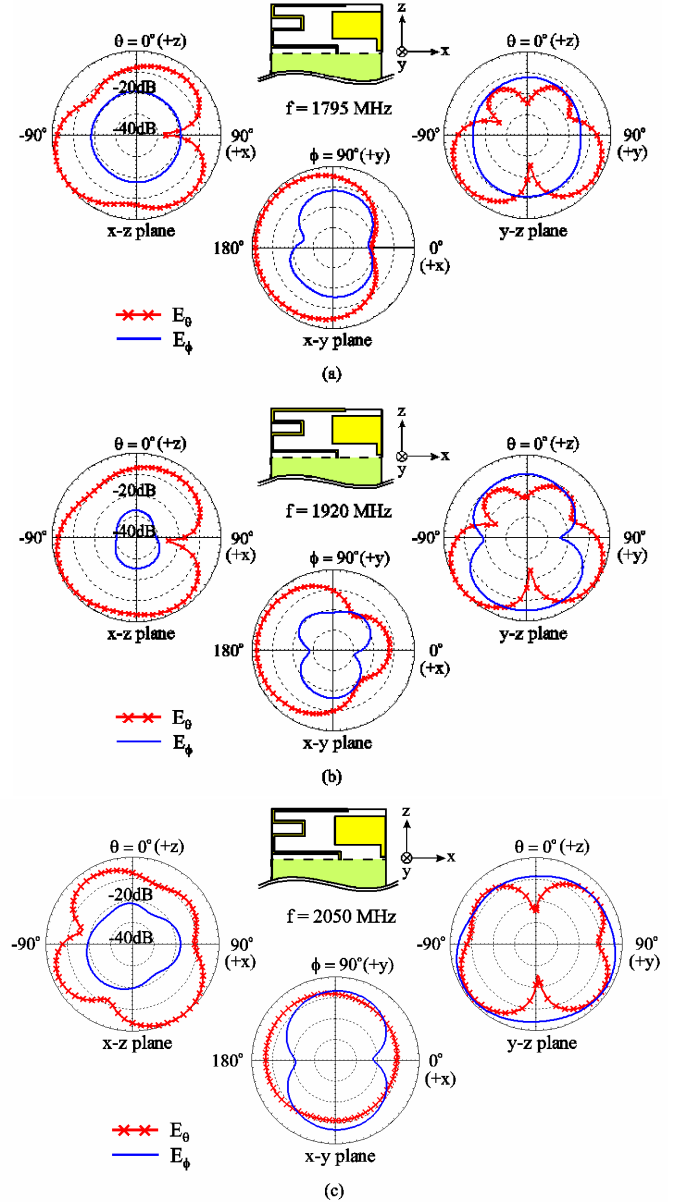


Figure 6. Measured radiation patterns at (a) 1795 MHz, (b) 1920 MHz and (c) 2050 MHz for the antenna.

resonant mode contributed from the driven strip alone operated as an inverted-L monopole. In addition, owing to the driven strip asymmetrically located at the top no-ground portion, asymmetric radiation patterns at 1795 and 1920 MHz are also seen. At 2050 MHz, more symmetric radiation patterns are seen, different from those at 1795 and 1920 MHz. This behavior is because the resonant mode covering the UMTS band is generated by the driven monopole and coupled strip operated together as a one-wavelength loop resonant mode as discussed earlier.

Fig. 7 shows the measured maximum antenna gain and simulated radiation efficiency. As shown in Fig. 7(a), stable antenna gain of about 0.4 dBi over the GSM850/900 bands is seen. Small variations in the radiation efficiency are also obtained. The efficiency over the GSM850 band is about 62 ~ 81%, while that over the GSM900 band is about 72 ~ 76%. Results for the DCS/PCS/UMTS bands are shown in Fig. 7(b). More variations in the antenna gain and radiation efficiency are seen. Over the DCS and PCS bands, the antenna gain is about 3.6 ~ 4.1 dBi and 2.2 ~ 3.8 dBi, respectively. Over the UMTS band, it is about 2.2 ~ 3.0 dBi. For the efficiency, it is

larger than 85% over the DCS band and about 64 ~ 90% over the PCS bands. Over the UMTS band, the efficiency is about 62 ~ 80%.

#### IV. CONCLUSION

A printed loop-type antenna suitable for application in the mobile phone has been proposed and studied. The antenna can be operated in the planar structure with an area of  $20 \times 40 \text{ mm}^2$  to cover the penta-band operation. The antenna is easy to fabricate at lost cost and integrate with the system circuit board of the mobile phone to operate as an internal antenna. Good radiation characteristics over the operating bands have also been obtained.

#### REFERENCES

- [1] H. Morishita, Y. Kim and K. Fujimoto, "Design concept of antennas for small mobile terminals and the future perspective," *IEEE Antennas Propag. Mag.*, vol. 44, pp. 30-43, Oct. 2002.
- [2] H. Morishita, H. Furuuchi and K. Fujimoto, "Performance of balanced-Fed antenna system for handsets in the vicinity of a human head or hand," *IEE Proc-Microw Antennas Propag.*, vol. 149, pp. 85-91, 2002.
- [3] C. I. Lin and K. L. Wong, "Internal meandered loop antenna for GSM/GPRS/DCS/PCS multiband operation in a mobile phone with the user's hand," *Microwave Opt. Technol. Lett.*, vol. 49, pp. 759-765, Apr. 2007.
- [4] B. Jung, H. Rhyu, Y. J. Lee, F. J. Harackiewicz, M. J. Park and B. Lee, "Internal folded loop antenna with tuning notches for GSM/GPRS/DCS/PCS mobile handset applications," *Microwave Opt. Technol. Lett.*, vol. 48, pp. 1501-1504, Aug. 2006.
- [5] B. K. Yu, B. Jung, H. J. Lee, F. J. Harackiewicz and B. Lee, "A folded and bent internal loop antenna for GSM/DCS/PCS operation of mobile handset applications," *Microwave Opt. Technol. Lett.*, vol. 48, pp. 463-467, Mar. 2006.
- [6] Y. W. Chi and K. L. Wong, "Internal compact dual-band printed loop antenna for mobile phone application," *IEEE Trans. Antennas Propag.*, vol. 55, 2007, in press.
- [7] C. C. Lin, G. Y. Lee and K. L. Wong, "Surface-mount dual-loop antenna for 2.4/5 GHz WLAN operation," *Electron. Lett.*, vol. 39, pp. 1301-1302, Sep. 2003.
- [8] K. L. Wong, A. C. Chen and F. S. Chang, "Planar diversity loop antenna for wireless PCMCIA card," *Microwave Opt. Technol. Lett.*, vol. 39, pp. 488-490, Dec. 2003.
- [9] T. Adachi, A. Hirata and T. Shiozawa, "Folded-loop antennas for handset terminals at the 2.0-GHz band," *Microwave Opt. Technol. Lett.*, vol. 40, pp. 272-275, Feb. 2004.
- [10] S. Hayashida, T. Tanaka, H. Morishita, Y. Koyanagi and K. Fujimoto, "Built-in folded monopole antenna for handsets," *Electron. Lett.*, vol. 40, pp. 1514-1516, Nov. 2004.
- [11] <http://www.ansoft.com/products/hf/hfss/>, Ansoft Corporation HFSS.
- [12] Y. L. Kuo and K. L. Wong, "Printed double-T monopole antenna for 2.4/5.2 GHz dual-band WLAN operations," *IEEE Trans. Antennas Propag.*, vol. 51, pp. 2187-2192, Sep. 2003.
- [13] K. L. Wong, *Planar Antennas for Wireless Communications*, Wiley, New York, USA, 2003.130

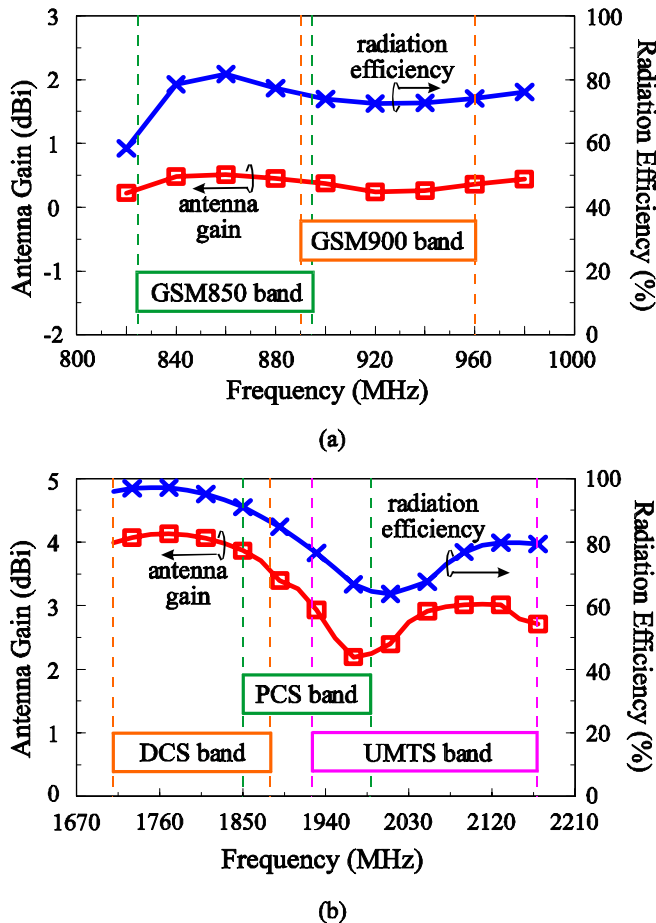


Figure 7. Measured maximum antenna gain and simulated radiation efficiency over (a) GSM850/900 bands and (b) DCS/PCS/UMTS bands.