On Near-Field Radiation Characteristics of the Internal Handset Antenna with a Curved Metal Pattern

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1. Introduction

Near-field radiation characteristics of the internal handset antenna with a curved metal pattern are studied in this paper. We demonstrate that by using a smoothly curved metal pattern for an internal cellular handset antenna, the specific absorption rate (SAR) can be decreased, compared to a corresponding antenna with a metal pattern having right-angle or abrupt bendings. Results for a simple strip monopole for the GSM1800/1900 operation in the handset are presented and discussed. Related results obtained for corresponding strip monopoles with a right-angle bending or multiple-bendings are shown for comparison. The reason for decreased near-field radiation is because the excited surface currents on the strip monopole with a curved bending will experience a smooth variation on the surface current trace on the metal pattern of the antenna. On the other hand, the excited surface currents on the corresponding strip monopoles will experience relatively abrupt changes on the surface current trace of the antenna's metal pattern, which will result in strong near-field electric fields. It can be expected that the abrupt variations of the excited surface currents on the metal pattern of the antenna will cause sharp increase in the near-field radiation of the antenna. This behavior will lead to increased SAR values [1] and HAC (hearing-aid compatibility) values [2, 3] as well for the handset with such an antenna embedded therein.

2. Strip Monopoles for the GSM1800/1900 Operation

Figure 1(a) shows the geometry of the proposed internal cellular handset antenna with a curved metal pattern for the GSM1800/1900 operation. Corresponding internal GSM1800/1900 handset antennas with its metal pattern having a single bending (denoted as Ant1 in this study) or multi-bending (Ant2) are shown in Figure 1(b) and Figure 1(c). The three antennas (proposed, Ant1, and Ant2) are strip monopoles with different bendings and can be seen more clearly from the photos of the fabricated prototypes shown in Figure 2. The three antennas are all printed on the clearance region (10×60 mm^2) of the main circuit board of the handset, which is a 0.8-mm thick FR4 substrate of relative permittivity 4.4, loss tangent 0.024, and size 60×110 mm^2. On the back side of the main circuit board, a ground plane of size 60×100 mm^2 is printed. The lengths of the three strip monopoles are adjusted such that the obtained bandwidths cover the GSM1800/1900 bands in this study.

To confirm that the three antennas covered the desired operating bands, Figure 3(a) shows the measured return losses for the proposed antenna, Ant1, and Ant2. Based on 3:1 VSWR or 6-dB return loss, which is widely used as the design specification of the internal handset antenna for the WWAN operation, the operating bandwidths of the three antennas cover the GSM1800/1900 bands. The measured antenna efficiencies which include the mismatching loss for the three antennas are also shown in Figure 3(b). From the obtained results, it can be confirmed that the far-field radiation characteristics of the three antennas are about the same. This can ensure good accuracy of the following simulation study on the near-field radiation characteristics of the three antennas.

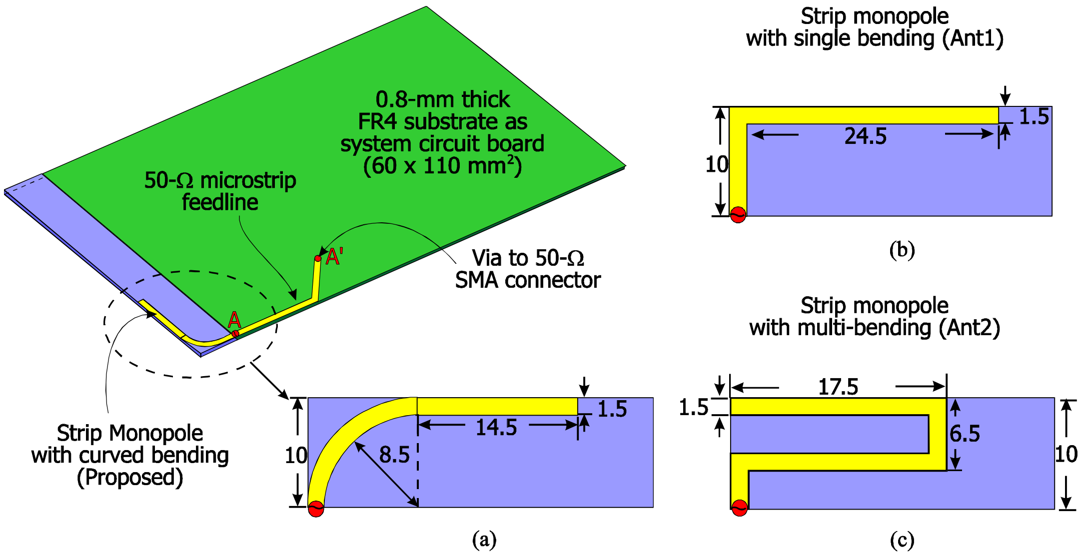


Figure 1: Geometry of the proposed internal cellular handset antenna with (a) a curved metal pattern, (b) a single bending, and (c) multi-bending for the GSM1800/1900 operation.

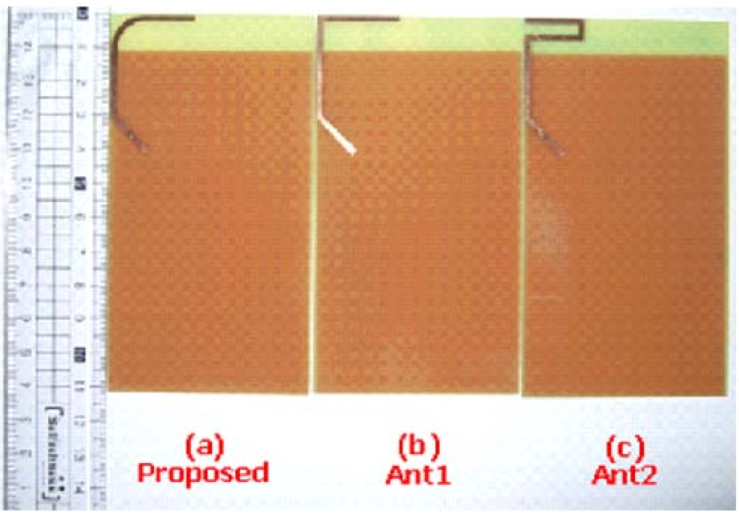


Figure 2: Photos of the fabricated prototypes of the proposed antenna, Ant1, and Ant2.

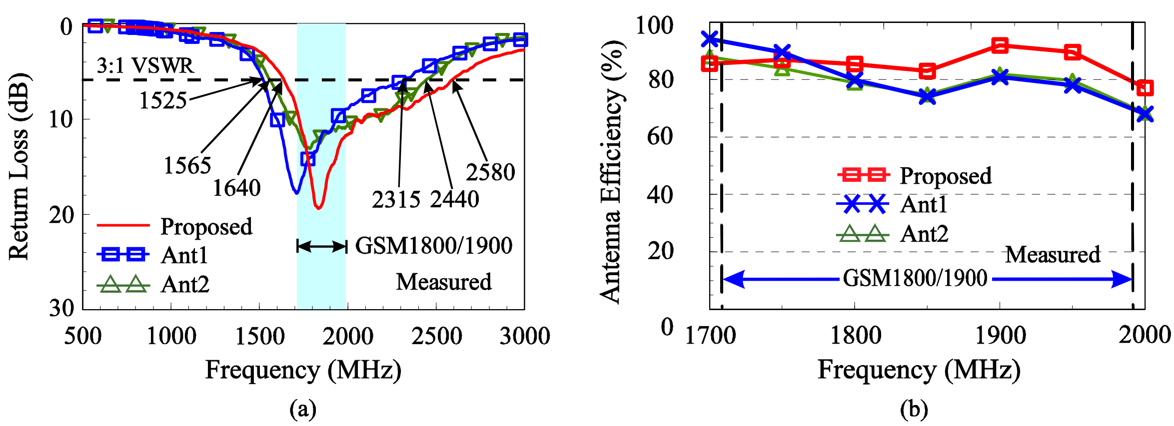


Figure 3: (a) Measured return losses and (b) measured antenna efficiencies.

3. Near-Field Radiation of the Studied Antennas

The SAR simulation models based on the SPEAG SEMCAD X version 14 are used in this study. For each case, the handset with the antenna embedded therein is attached to the phantom head with no tilt. The distance between the ear and the system ground plane is 5 mm only, and that between the palm center and the system ground plane is 30 mm.

Table 1: Simulated SAR values for 1-g and 10-g tissues for the proposed antenna, Ant1, and Ant2. The antenna is at the bottom edge of the handset.

Bottom edge		Proposed		Ant1		Ant2	
Frequency (MHz)		1795	1920	1795	1920	1795	1920
(A) 1-g SAR (W/kg)#	head only	0.50	0.51	0.65	0.67	0.65	0.68
	hand only	0.73	0.68	1.10	1.06	0.99	1.10
	head & hand	0.58 (0.48)	0.68 (0.50)	1.03 (0.62)	1.07 (0.64)	0.97 (0.61)	1.18 (0.63)
(B) 10-g SAR (W/kg)#	head only	0.36	0.36	0.42	0.43	0.40	0.42
	hand only	0.32	0.40	0.58	0.59	0.54	0.62
	head & hand	0.35 (0.33)	0.46 (0.34)	0.61 (0.41)	0.72 (0.42)	0.57 (0.39)	0.69 (0.40)

Bottom edge		Proposed		Ant1		Ant2	
Frequency (MHz)		1795	1920	1795	1920	1795	1920
(C) 1-g SAR (W/kg)	head only	0.40	0.47	0.60	0.67	0.59	0.65
	hand only	0.53	0.58	0.93	1.00	0.86	1.09
	head & hand	0.47 (0.38)	0.62 (0.45)	0.94 (0.57)	1.04 (0.63)	0.92 (0.58)	1.17 (0.63)
(D) 10-g SAR (W/kg)	head only	0.28	0.34	0.38	0.43	0.36	0.40
	hand only	0.23	0.34	0.50	0.56	0.47	0.59
	head & hand	0.28 (0.27)	0.41 (0.32)	0.55 (0.37)	0.70 (0.41)	0.54 (0.37)	0.69 (0.40)

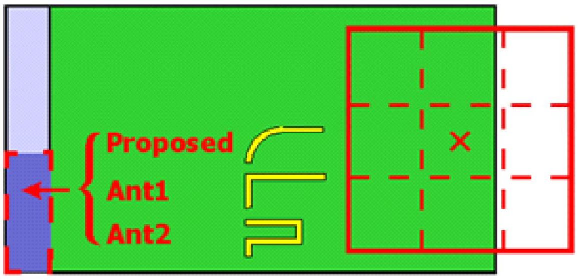
#: Considered under Perfect matching
( ): SAR value occurred at head for the head and hand condition

The simulated SAR values for 1-g and 10-g tissues for the proposed antenna, Ant1, and Ant2 are presented in Table 1, in which the results respectively for the antennas of the handset are presented. Results at representative frequencies of 1795 and 1920 MHz are shown. For fair comparison, the SAR results for the antennas with perfect matching condition (results with the # mark, part A and B in the table) are also shown. For the head only condition, the 1-g and 10-g SAR values are the smallest for the proposed antenna, while those for Ant2 are the largest. For the hand only condition, the SAR values for Ant2 are also the largest. For the head and hand condition, the behavior is similar to that for the head only condition, indicating that the head dominates the SAR behavior. Also note that the SAR values in the parentheses are occurred at head for the head and hand condition. When the values in the parentheses are smaller, it indicates that maximum power absorption in the head and hand condition is occurred at hand, not at head.

For the SAR results for the antennas with the mismatching condition considered (part C and D in the table), similar behavior as that observed for the perfect matching condition is seen. This also indicates that there are no large frequency shifts when the head and/or hand are in proximity to the three antennas in the study. This can also be seen from the return losses for the antennas in free space and three testing conditions shown in the figure. In general, it can be concluded that the antenna with multi-bending (Ant2) show increased SAR values, while the proposed antenna shows decreased SAR values. This observation is believed to be related to the near-field radiation characteristics of the antenna with smooth or abrupt bendings as discussed in the Introduction.

The SAR values for both Ant1 and Ant2 are also observed to be about the same and larger than those of the proposed antenna by at least 1 dB (25% larger) for the 1-g tissue case (for example, at 1795 MHz for the head only case in part A, 0.50 W/kg for the proposed antenna vs. 0.65 W/kg for Ant1 and Ant2). It is also seen that the obtained 1-g and 10-g SAR values are all less than the required limits (1.6 W/kg for 1-g tissue and 2.0 W/kg for 10-g tissue) for practical applications, with the proposed antenna having the lowest SAR values. This is also believed to be related to the near-field radiation characteristics of the antenna with smooth or abrupt bendings as discussed in the Introduction. The obtained results indicate that, by using a smooth or curved metal pattern for the internal handset antenna, the obtained SAR results can have decreased values.

The HAC simulation model based on the SPEAG SEMCAD X version 14 is also applied. Figure 4 shows the simulated HAC results for the three antennas. Based on the rule of ANSI C63.19-2007, the near-field E-field and H-field strengths at the HAC observation plane divided into 9 cells above the acoustic output are determined by excluding three consecutive cells along the boundary of the observation plane that have the strongest field strengths. From the obtained results, although the proposed antenna shows the smallest E-field and H-field strengths shown in Figure 4, the decrease in the E-field and H-field strengths is small, compared to the field strengths of Ant1 and Ant2. The different effects on the SAR and HAC behavior are largely because the SAR values are determined by the power absorption in a small-volume tissue (1-g or 10-g tissue). Hence, although the field variations may be small in view of the HAC behavior, the SAR variations could be relatively much larger as observed in Table 1.



Mismatching Considered

Frequency (MHz)	1795	1920
E-field (dB, V/m) (Proposed)	39.9	39.6
E-field (dB, V/m) (Ant1)	40.3	39.6
E-field (dB, V/m) (Ant2)	40.4	40.3
H-field (dB, A/m) (Proposed)	-10.6	-10.8
H-field (dB, A/m) (Ant1)	-10.4	-10.9
H-field (dB, A/m) (Ant2)	-10.5	-10.5

Figure 4: Simulated HAC results for the proposed antenna, Ant1, and Ant2.

4. Conclusion

The SAR and HAC results of the internal GSM1800/1900 handset antenna formed by a strip monopole with a curved bending, a right-angle bending, and multi-bendings have been studied. The antennas are all with good impedance matching and good antenna efficiencies for frequencies over the GSM1800/1900 bands. That is, similar far-field radiation characteristics have been obtained. However, from the obtained SAR results, the proposed antenna with a smooth or curved metal pattern can have decreased SAR values by at least 1 dB, compared to those of the corresponding antennas with right-angle bendings. This behaviour is believed to be related to the smooth variations of the excited surface currents on the curved metal pattern of the proposed antenna. For the HAC results, the proposed antenna with a smooth or curved metal pattern is still with decreased HAC values, although the decrease in the HAC values is much smaller than that in the SAR values. From the obtained results in this study, it can be concluded that simply by applying a smooth or curved metal pattern for the internal cellular handset antenna, it is very helpful to achieve decreased SAR values or decreased near-field radiation of the handset with the antenna embedded therein.

References

[1] Y. W. Chi and K. L. Wong, “Compact multiband folded loop chip antenna for small-size mobile phone,” *IEEE Trans. Antennas Propagat.,* Vol. 56, pp. 3797-3803, 2008.

[2] K. L. Wong and M. F. Tu, “Hearing aid-compatible internal penta-band antenna for clamshell mobile phone,” *Microwave Opt. Technol. Lett.,* Vol. 51, pp. 1408-1413, 2009.

[3] W. Y. Chen and K. L. Wong, “Wideband coupled-fed PIFA for HAC penta-band clamshell mobile phone,” *Microwave Opt. Technol. Lett.,* Vol. 51, pp. 2369-2374, 2009.