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Near-Field Reduction Techniques in the Speaker Area of Slide Mobile Phones for Improved HAC Performance

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Introduction

It is well known that mobile phones can cause electromagnetic interference with hearing aids. The near field (NF) energy in the speaker area of the mobile phone can be received by a hearing aid and thus result in an audible buzzing noise [1, 2]. Typically, this problem can be partly alleviated by tilting the phone, but the noise may not be completely eliminated. For this reason, the hearing aid compatibility (HAC) must be taken serious into account in the design of mobile phones. From 2008, the Federal Communications Commission (FCC) requires that about 50% of all mobile phone models offered by a manufacturer or carrier for the use in the USA should meet the HAC requirement of category M3 or better [3, 4].

So far, the research has concentrated on the modeling, evaluation, and measurement of HAC [1, 2, 5] and rarely on the possible solutions to the problem [4]. This paper shows how to efficiently reduce the electromagnetic energy around the speaker area of mobile phones in order to fulfil the HAC standard [3]. Since a mobile phone is more likely to fulfil the HAC requirements below 960 MHz than at higher frequencies [4], the main focus of this paper is on reducing the NFs above 960 MHz. In particular, devices operating in the Personal Communications System (PCS) band is considered. The transmit band (1850 – 1910 MHz) of PCS (PCSTX) is the most critical for HAC. At these frequencies, the category M3 defines an electric field $|E| < 84.1\,\mathrm{Vm}^{-1}$ and a magnetic field $|H| < 0.254\,\mathrm{Am}^{-1}$ [3].

Method

The investigations are carried out on slide mobile phones in open state, i.e., talk position only. The Printed Wire Board (PWB) in this kind of phone is divided in two parts. One part is the Display PWB (DPWB), which typically contains the display and the loudspeaker. The other is the Engine PWB (EPWB) that includes the antenna and the main circuitry (see Figure 1).

The HAC reduction technique presented in this paper mitigates the NF in the speaker area of a mobile phone. The means is a quarter-wave parasitic resonator, i.e., an Inverted-L Parasitic Element (ILPE) that is connected to the DPWB. Such resonators manipulate the NF emissions on the DPWB by choking the surface currents in the speaker area. The ILPE is tuned to resonate at 1880 MHz, i.e., the center frequency of the PCSTX. In free space, this results in a total physical length (length

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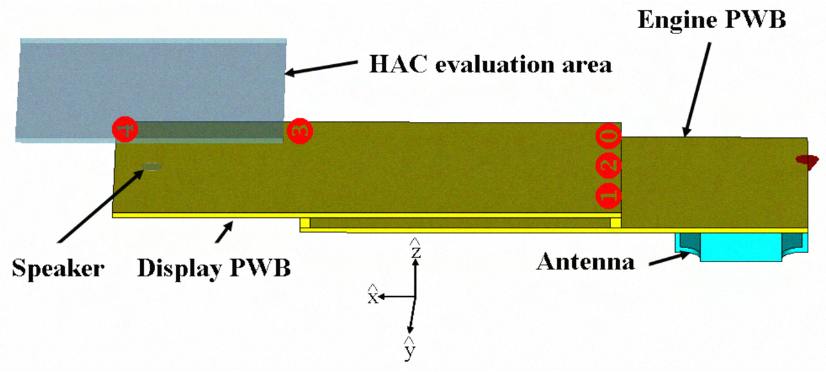


Figure 1: Simulation model that shows the different positions of the ILPEs on the DPWB: The Position ”0” in the x̂ direction ($P^0_{\hat{x}}$); $P^1_{\hat{x}}$; $P^2_{\hat{x}}$; $P^0_{\hat{x}}$ and $P^1_{\hat{x}}$; $P^0_{\hat{x}}$, $P^1_{\hat{x}}$, and $P^2_{\hat{x}}$; $P^0_{\hat{y}}$; $P^0_{\hat{y}}$ and $P^1_{-\hat{y}}$; $P^3_{-\hat{x}}$; $P^3_{\hat{y}}$; and finally, $P^4_{-\hat{x}}$. The best HAC results are achieved by the configuration with three or two ILPEs directed in the x̂ direction.

l and height h) of the ILPE $l + h = 39.8\,\mathrm{mm}$. However, traditional antenna design or matching techniques can reduce the size of the ILPE as desired and allow the fabrication as a Surface-Mount Device (SMD) (see Figure 2 (c)). Nevertheless, this technique could also be integrated in the DPWB by allowing L-shaped arms on the DPWB (see Figure 2 (d)).

(a) Simulation.

(b) Prototype.

(c) Molex HAC antenna (SMD).

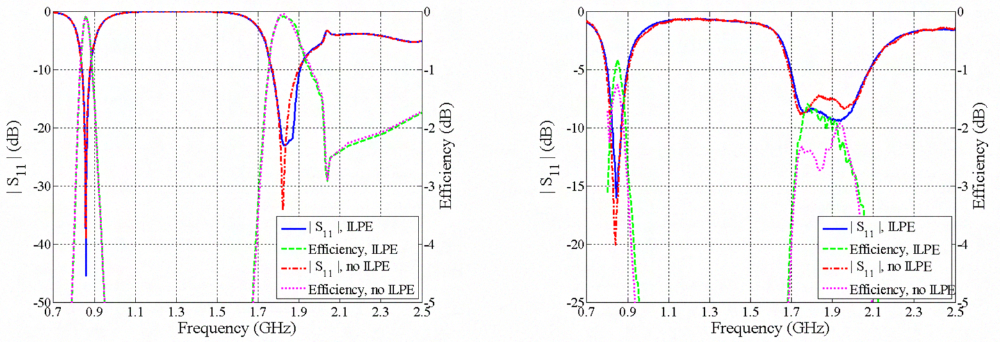
(d) ”Flat” ILPE.

Figure 2: Implementation of the field reduction technique. (a) Simulation model, (b) prototype, (c) ILPE as SMD, and (d) ILPE integrated in the DPWB. With reference to Figure 1, the implemented solution corresponds to $P^0_{\hat{x}}$ and $P^1_{\hat{x}}$ (see Figure 1).

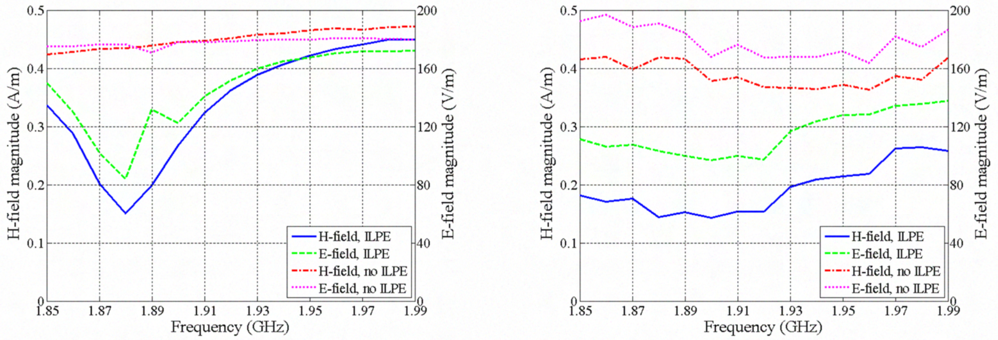
Different positions were explored during the simulation phase (see Figure 1) in order to find the optimal configuration. However, only the solution that presents the largest NF reduction, provided by one ILPE on each side of the DPWB, as shown in Figure 2 (a)–(b), was prototyped.

Results

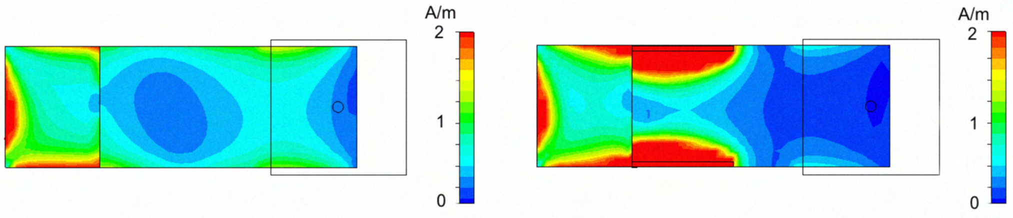
A model of the phone, including antenna and PWBs, was initially implemented and the simulation results were verified by prototyping the ILPE on a commercial phone. The effect of the ILPEs was first estimated by simulations and passive measurements of the reflection coefficient, efficiency, HAC, and surface currents (Figure 3). Then, the behavior of the phone with and without ILPE was verified by active measurements in the middle channel of PCSTX (1880 MHz) of Total radiated power (TRP), Total Isotropic Sensitivity (TIS), and NFs (Table 1). All simulations and measurements were carried out according to the directives in [3].



(a) Simulated performance. (b) Measured performance.



(c) Simulated near-fields. (d) Measured near-fields.



(e) Simulated surface currents without ILPE. (f) Simulated surface currents with ILPE.

Figure 3: The effect of the ILPE on the passive performance. (a) Simulated and (b) measured reflection coefficients and efficiencies. (c) Simulated and (d) measured peak values of the electric and magnetic near fields. Simulated surface currents (e) without and (f) with ILPEs at 1880 MHz.

Table 1: Active measurement of TRP, TIS, and NFs at 1880 MHz, i.e., the middle channel of the PCSTX.

	TRP (dBm)	TIS (dBm)	E-field (Vm^{-1})	H-field (Am^{-1})
Without ILPE	25.7	−104.7	100.8	0.212
With ILPE	25.6	−104.6	60.2	0.124

Notice, the ILPEs have minor effect on the reflection coefficient, efficiency, TRP, and TIS (see Figure 3 (a)-(b) and Table 1). However, they reduce dramatically the NFs in the speaker area at 1880 MHz of up to 45.9% and 65.6% for the measured passive (see Figure 3 (c)-(f)) and up to 40.3% and 41.5% for the measured active near E- and the H-fields (see Table 1), respectively. With the ILPEs, the measured phone fulfills the FCC's HAC requirements [3,4].

Conclusions

This paper presents a method to improve the HAC of slide mobile phones. Although, the technique is demonstrated with a given commercial phone and for PCS band only, it could be adapted to other phones and bands as well. Simple antenna design and matching techniques can allow multi-band operation as well as high dimension flexibility. In the investigated cases, the two ILPE that are connected to the DPWB results in a reduction in excess of 45.9% for passive NF and of 40.3% for active NF at the resonant frequency of the ILPEs.

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