Evaluation of the Real Life Exposure due to GSM Mobile Phones

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Abstract

The radio frequency (RF) exposure due to mobile phones is currently characterized by measuring the specific absorption rate (SAR) under laboratory conditions with the mobile phone operating at the maximum power level. Under typical operating conditions, the network operators optimize the transmit level of a mobile phone by implementing a power control mechanism based on the channel characteristics such that the mobile phone does not always transmit at the maximum power level. This implies that the real life exposure experienced by the user for a given mobile phone use configuration will depend on the power transmitted by the mobile phone averaged over the duration of the call. In this study we propose a method to evaluate the real life exposure for a mobile phone in a given indoor environment. This is achieved by characterizing the received signal level (RX_LEV) and quality (RX_QUAL) of the traffic channel (TCH) for which the actual power control mechanism is implemented by the network operator and also taking into account the SAR and over the air (OTA) performance of the mobile phone. The measurements are performed by placing actual calls on hardware and/or software modified mobile phones that are capable of recording various radio resource parameters.

1. Introduction

International standards such as IEEE1528 [1] and IEC62209-1 [2] currently provide the measurement procedures for the specific absorption rate (SAR) compliance test of mobile phones. Briefly, the specific anthropomorphic mannequin (SAM) head phantom, filled with the appropriate tissue equivalent liquid, is employed for the measurement of the SAR while the mobile phone is operated at the maximum power level using a base station emulator. The measurements are performed for four intended use positions of the mobile phone against the SAM phantom: right/cheek, right/tilt, left/cheek and left/tilt at the center frequency of a given operating band. The peak spatial-average SAR –either 1g or 10g– is calculated for each use position and two additional measurements are then performed for the two extreme frequencies of the considered band for the position that yielded the maximum value. The same procedure is applied for all the operational frequency bands of the mobile phone and ultimately the maximum value obtained from all these configurations should not exceed 2 W/kg averaged over 10g of tissue according to current European SAR regulations [3]. This unique peak spatial-average SAR value is usually provided by the mobile phone manufacturer or network operator e.g. in the user manual. Actually, in France, a national decree requires that this SAR value should be clearly displayed for the information of the general public e.g. inside shops or in TV commercials [4].

Although all marketed mobile phones are expected to be SAR compliant i.e. less than 2 W/kg, there could be a tendency of the general public to buy a mobile phone based on the relative SAR values. However, since a mobile phone experiences power control during real life communication, the effective SAR or the real life exposure would be typically much lower than the value measured at maximum power level under laboratory conditions. The actual implementation of the power control algorithm depends on several parameters and may vary from one network operator to another but an intrinsic constraint is the over-the-air (OTA) radio frequency (RF) performance of the mobile phone i.e. the total radiated power (TRP) and the total isotropic sensitivity (TIS) [5]. The TRP provides information about the amount of power available to ensure the radio communication link between the mobile phone and the nearest base station antenna whereas the TIS provides information about the robustness of the link in a multipath environment. Clearly, if two different mobile phones having the same SAR value but differing TRP values are placed in the same electromagnetic environment i.e. same position from the base station antenna, same network operator and same use condition, it is expected that the mobile phone with the higher TRP value will be requested to emit at a relatively lower power level than the other i.e. it will have a lower real life exposure. Considering both the SAR and OTA characterization, a real life exposure index called SAROTA was previously proposed [6] and an experimental evaluation of the applicability of the SAROTA index was performed under laboratory conditions wherein the power control algorithm was implemented artificially [7].

Herein the investigation is extended to a real life scenario wherein the actual base station dictates the power control mechanism applied to the mobile phone. A set of Global System for Mobile (GSM) communication mobile phones with modified hardware and embedded software is employed to collect the received and transmit data during the radio communication between the base station and the mobile phone. The paper is organized as follows: Section 2 presents the essential features of the power control algorithm and its effect on the real life exposure assessment, Section 3 describes the measurement methodology, Section 4 presents the measurement results and Section 5 provides a conclusion.

978-1-4673-5225-3/14/$31.00 ©2014 IEEE

2. Effect of Power Control on Real Life Exposure

The RF power control mechanism implemented by a network operator determines the transmit power level of the mobile phone and the transmit power level employed by the base station subsystem (BSS). The power control level to be implemented in each case will depend on the periodic measurement results reported by the mobile phone and the base station and the various cell and channel parameters. However, the exact power control strategy to be implemented will be determined by the network operator [8-9] and it will usually vary from one network operator to another. The actual power control depends on several network parameters and it is difficult to determine the type of power control that will be implemented by the different network operators. Nonetheless, the location of the mobile phone with respect to the base station antenna and the associated received signal level (RX_LEV) and received quality (RX_QUAL) along with the considerations of interference primarily determine the extent of power control that should be applied [10]. The power control can be applied for both the downlink and the uplink but since we are herein interested in the real life exposure due to the mobile phone, only the uplink power control mechanism will be considered.

If the traffic channel (TCH) characteristics are such that both RX_LEV and RX_QUAL are degraded then the mobile phone will tend to transmit at a higher power level (TX_LEV) and in extreme conditions the TX_LEV may be at the maximum power level i.e. similar to the laboratory conditions for the SAR and OTA measurements. On the other hand, if the channel conditions are such that both RX_LEV and RX_QUAL are satisfactory then the TX_LEV of the mobile phone will be lowered till the communication may be sustained with an accepted level of speech quality. This also results in reduced interference towards the neighboring devices and optimization of the battery power consumption. Since the power control regulates the mobile phone TX_LEV, the analysis of the implemented power control can give an insight into the real life exposure experienced by the user. Indeed, knowing the characteristics of the power amplifier of the mobile phone –usually linear operation– and the TX_LEV, one can deduce the emitted power and the real life SAR. Measurement and observation of the downlink and uplink RXLEV and RXQUAL, inter-cell and intra-cell handover is required to estimate the communication link characteristic and investigate the possible reasons for the implementation of a given power control.

The uplink TX_LEV as well as the downlink RX_LEV and RX_QUAL may be obtained using specific hardware and/or software modified mobile phones capable of monitoring the network parameters. The real life exposure, SAR_{real_life}, may be obtained using the SAROTA index as follows:

$$SAR_{real\_life} = SAROTA \times TRP_{real\_life} \quad (1)$$

where TRP_{real_life} is deduced from the real life TX_LEV measurement, and the SAROTA index is given by:

$$SAROTA = \left\lfloor \frac{SAR_{\max}}{TRP_{\max}} \right\rfloor_{Configuratio} \quad (2)$$

where SAR_{max} and TRP_{max} are, respectively, the peak spatial-average SAR and TRP values measured under laboratory conditions at the maximum power level using a base station emulator for the same configuration i.e. same phone/phantom position and TCH. In the above, SAR_{real_life} and TRP_{real_life} are, respectively, the averaged peak spatial-average SAR and TRP values observed in real life scenario with the actual power control mechanism enforced by the base station.

3. Measurement Methodology

The main objective of the study is to characterize the power control mechanism in a real life scenario. Since in a given environment the power control will vary from one mobile phone model to another, it is important to use mobile phone models with rather similar RF characteristics. A set of four samples of the same mobile phone model is herein used for the measurement of the downlink RX_LEV, RX_QUAL and the uplink TX_LEV. The investigation of the power control mechanism is conducted for the speech mode of operation for the GSM 900 MHz frequency band. The mobile phones, herein referred to as M1, M2, M3 and M4, were previously characterized for both SAR and OTA for the lower, middle and upper TCH using a standard dosimetric test facility and a compact reverberation chamber, respectively. The similarities of the SAR and OTA performance of the four mobile phones were confirmed within the measurement uncertainty of the two test systems.

Since the power control will also be highly dependent on the network conditions, it is important to select the same network operator and as much as possible a relatively stable electromagnetic environment for all the real life measurements. Herein the measurements are performed in an indoor environment for both the free space and the right/cheek configuration of the mobile phone positioned against the SAM phantom. The indoor environment is an empty room with its outer facing wall consisting almost entirely of glass windows. The phone and the phantom are placed on a wooden table located in-between the center of the room and the outer facing wall.

The mobile phones are configured to operate only on the GSM 900 MHz band with an audio uplink function which simulates a voice call by playing a recorded audio file to prevent the mobile phone from going into discontinuous transmission (DTX)-mode. The recorded audio file is played on repeat mode which helps simulating short and long call durations thereby eliminating the need for any separate audio device and other intrusions. Following a preliminary analysis of the RX_LEV, RX_QUAL and TX_LEV measurement data where the call duration was varied in sets of 3, 5, 15 and 30 minutes over a period of several days at different times, it was observed that a duration of at least 30 minutes is required to reliably average out the effects due to unexpected instantaneous variations in the measured parameters. For each measurement it is ensured that the mobile phone battery is fully charged.

The indoor environment is characterized for the selected channels available for a given network, N1, by measuring the corresponding received and transmit parameters. It is observed that from the available traffic channels for N1 at this given location, there are four specific channels referred to as TCH A, TCH B, TCH C and TCH D that are allotted for majority of the calls initiated during the measurements. These channels were characterized by configuring the mobile phones to operate at the selected channel during the entire duration of the call. The network operators are chosen such that they operate in the lower, middle and upper channels herein referred to as N1, N2 and N3 (not in specific order). The measurements are performed in three sets such that for set I, the mobile phones are configured to operate on GSM 900 where the network operator allots the TCH. For set II, the mobile phones are configured to operate on GSM 900 and the traffic channel locked at TCH A. The measurements for sets I and II are performed for the same network operator N1 with M1 calling M2, and M3 calling M4. For set III, the mobile phones are locked at GSM 900 for network operators N1, N2 and N3.

4. Measurement Results

Figure 1 and Figure 2 show the results for a specific sample of the measurements performed for set I. From Figure1 it is observed that the TX_LEV for TCH A is considerably lower than that at TCH B while the RX_QUAL for both channels is 0 (0 being the best and 7 being the worst quality). The RX_LEV for both channels was at an average value of -75 dBm with +/-4 dB variation. For 1 in 5 cases the above described trend was found to be interrupted with the same TCH being allotted to the calling and the receiving phone, in this case TCH A is allotted for both M3 and M4. The TX_LEV of both phones when at TCH A is comparable, indicating the same level of power control with M4 experiencing a degradation in RX_QUAL. The corresponding effect on the real life SAR is described in Figure 2 where the real life exposure is considerably lower at TCH A than at TCH B. The effect of both mobile phones placed in the same room being allotted the same TCH was investigated in measurement set II and it was confirmed that the TX_LEV for both phones is comparable within +/- 1dB variation with one of the mobile phones (either caller or receiver) experiencing a degradation in RX_QUAL averaged at 4 with a +/- 1 unit variation. In this case the real life exposure is found to be comparable since the channel being the same with the RX_LEV comparable within +/- 2 dB for the caller and the receiver mobile phones and the degradation in the link quality being at accepted level.

Table1 provides the results for set III, where the effect of channel characteristics at the given indoor location for the three different network operators is examined. It also describes three different levels of power control observed with respect to the RX_LEV and RX_QUAL characteristics for N1, N2 and N3. Maximum level of power control is observed for N1 with the combination where both the received signal level and the quality are satisfactory. For N2, it is observed that the effect of the power control mechanism is negligible since the RX_QUAL is highly degraded indicating the presence of heavy interference in combination with the RX_LEV being worse than that for N1 and N3. It is obvious that for this case the mobile phone will transmit at a higher power level for a longer duration to avoid call failure. For N3, an intermediate level of power control is observed in spite of the RX_LEV being better than for N1 and N2 with a noticeable degradation in the RX_QUAL. The difference in the level of power control implemented by each network operator is dependent on various factors that are yet to be comprehensively investigated.

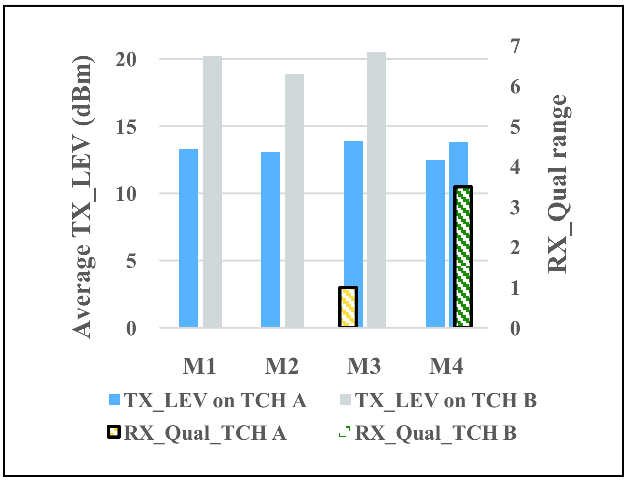

Figure1. Comparison between TX_LEV for the allotted TCH

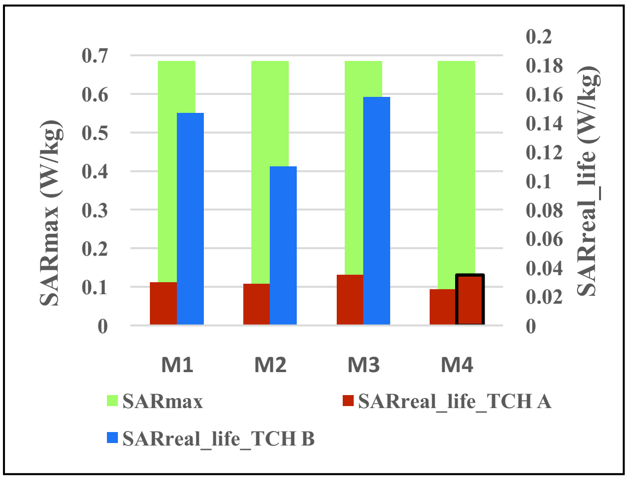

Figure2. Comparison between SARmax and SARreal life for the allotted TCH

Table 1: SARreal life evaluation from averaged values of TRPreal life for the four mobile phones for a given position.

Network Operator	SARmax (W/kg)	TRPmax (dBm)	TRP real life (dBm)	Average RX_QUAL	Average RX_LEV (dBm)	SAR real life (W/kg)
N1 at TCH A1	0.685	26.87	13.1	1	-75	0.029
N2 at TCH A2	0.692	25.69	25.6	6	-83	0.688
N3 at TCH A3	0.633	26.49	19.2	3	-68	0.118

5. Conclusion

With the use of hardware and/or software modified mobile phones capable of recording the radio resource parameters, a given indoor environment was characterized for its on-call received signal level (RX_LEV) and quality (RX_QUAL) for a given network operator at GSM 900 MHz. The observed power control mechanism implemented by the network operator is found to vary depending on the allotted traffic channel (TCH). For a given mobile phone placed at the same position in a given indoor environment, the average TX_LEV and, consequently the real life exposure experienced by the user, are affected. In some cases mobile phones operating at closely spaced locations are allotted the same TCH wherein they exhibit nearly similar average TX_LEV although degradation in RX_QUAL was observed. Furthermore, the real life exposure due to the same mobile phone can vary considerably when operating on closely spaced TCH. The study will be extended to GSM 1800 MHz and Universal Mobile Telecommunications System (UMTS) to gain a comprehensive understanding of the effect of power control in order to evaluate the real life exposure using the SAROTA index.

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