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SAROTA: application of specific absorption rate (SAR) and over-the-air (OTA) data for the characterization of the real-life exposure due to mobile phones

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Abstract. The RF exposure level of a mobile phone is quantified by the measurement of the specific absorption rate (SAR) under laboratory conditions. The SAR which is measured while the mobile phone is operated at maximum power level does not reflect the real-life exposure scenario since the mobile phone typically re-adjusts its power level and frequency depending on the quality of the communication link with the nearest base station. The choice of a low RF exposure device based on the comparison of the relative SAR values of mobile phones can be misleading. The real-life RF exposure also depends on the over-the-air (OTA) performance of the mobile phone. Taken independently, the two sets of data do not allow a straightforward comparison of the global RF performance amongst mobile phones. A unique and simple parameter denoted as the SAROTA index is proposed for the characterization of mobile phones with regard to both RF exposure and OTA performance. The SAROTA index provides the real-life exposure index of the mobile phone.

1. Introduction

The RF exposure level of a mobile phone is currently quantified by the measurement of the specific absorption rate (SAR) averaged over a given mass of tissue. As required by international standards [1], the SAR is measured in the laboratory using a standard dosimetric test facility and the specific anthropomorphic mannequin (SAM) while the mobile phone is operated at the maximum power level using a base station emulator. De facto, the SAR value does not reflect the real-life RF exposure of the mobile phone since in real situations it will typically re-adjust its output power level as well as the communication frequency depending on the radio link conditions with the nearest base station antenna. In Europe mobile phones are considered to be compliant with regard to RF exposure when the peak 10 g average SAR value does not exceed 2 W/kg. This limit is based on well-established thermal effects of RF exposure below which it is considered that the temperature rise in the body cannot be measured. Since the general public is increasingly concerned about RF exposure, it may be tempting to select a mobile phone based on the comparison of the relative SAR values or indices, e.g. select the mobile phone with the lowest SAR value after all other criteria such as aesthetics, design, etc. of the desired mobile phone are fulfilled. This mode of selection is misleading because the mobile phone with the lowest SAR value will not necessarily produce the lowest RF exposure in real-life situations. Indeed the over-the-air (OTA) performance of the mobile phone is also an important criterion. Clearly, a mobile phone with a badly designed antenna will typically provide a poor OTA performance –eventually compensated by RF emission at relatively higher power levels than may be

required by a mobile phone with a better antenna design— as well as a low SAR value —that may be wrongly considered synonymous of a low RF exposure device. A test plan for the OTA characterization of mobile phones both with and without the SAM phantom has been already proposed by the Cellular Telecommunications and Internet Association (CTIA) [2]. However the exhaustive OTA measurement parameters —transmitter performance or total radiated power (TRP) and receiver performance or total isotropic sensitivity (TIS)— for each test configuration cannot obviously be provided to the untrained end-user. A unique and simpler parameter referred to as the SAROTA (SAR and OTA) index is proposed to characterize mobile phones with regard to both RF exposure and OTA performance [3]. The proposed index provides a better quantity for the comparison of the global RF performance amongst mobile phones and it additionally provides a real-life exposure index.

2. SAR compliance

The SAR measurement is typically performed inside a shielded anechoic chamber as shown in Figure 1. A six-axis robot is herein employed to scan for the electric field inside the SAM phantom filled with the appropriate tissue equivalent liquid. A base station emulator is employed to operate the mobile phone at the maximum power level. The SAR measurements are first performed for four intended use positions of the mobile phone against the SAM phantom —left/cheek, left/tilt, right/cheek and right/tilt— at the center frequency or traffic channel of the considered band, followed by two additional measurements carried out for the two extreme frequencies of the band for the worst-case phone/phantom position. This procedure is applied for all the operating frequency bands of the mobile phone and the SAR value ultimately provided to the end-user corresponds to the overall maximum value. Figures 2(a) and (b) show the results of the peak 10 g average SAR values of eleven dual-band mobile phones —numbered 1 to 11— obtained for the right/cheek position for the center frequencies of the Global System for Mobile (GSM) communication and Digital Communication System (DCS) frequency bands, respectively. Based on these SAR results, Phone No 7 would definitely be considered as a relatively higher RF exposure device, especially in the DCS frequency band. Based on SAR considerations, Phone No 10 would have been selected instead of Phone No 11 for both GSM and DCS frequency bands.



Figure 1. SAR measurement using a six-axis robot and the SAM phantom filled with tissue equivalent liquid. The SAR measurements are performed at the center frequency of a given band for four intended use positions of the mobile phone against the phantom. Two additional measurements are then performed at the two extreme frequencies of the band for the worst-case position.

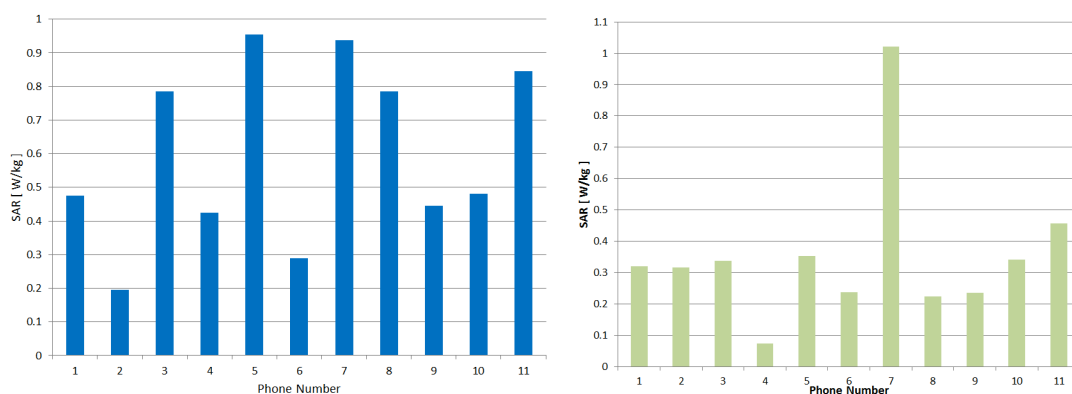


Figure 2. SAR values of eleven mobile phones for the right/cheek position: (a) GSM frequency band (left) and (b) DCS frequency band (right).

3. OTA performance

For the TRP measurements, the CTIA recommends the use of the traditional anechoic chamber antenna test facility. The mode-stirred reverberation chamber which is a good alternative for radiated power measurements of wireless communication devices is herein employed for the TRP measurements of the eleven mobile phones for the same configurations as those required for the SAR measurements i.e. same position and frequency (see Figure 3) [4]. Figures 4(a) and (b) show the results of the TRP values of the eleven mobile phones obtained for the right/cheek position for the center frequencies of the GSM and DCS frequency bands, respectively. Based on these TRP results, Phone No 2 would be considered as a relatively poor radiating device in the GSM frequency band. It is worth to note that this phone also showed a relatively low SAR value in the same frequency band. Based on TRP considerations, Phone No 11 would have been selected instead of Phone No 10 for both GSM and DCS frequency bands.



Figure 3. TRP measurement using a compact mode-stirred reverberation chamber. The TRP are measured for the same configurations (same frequency channel and use position) as those required for the SAR compliance of mobile phones.

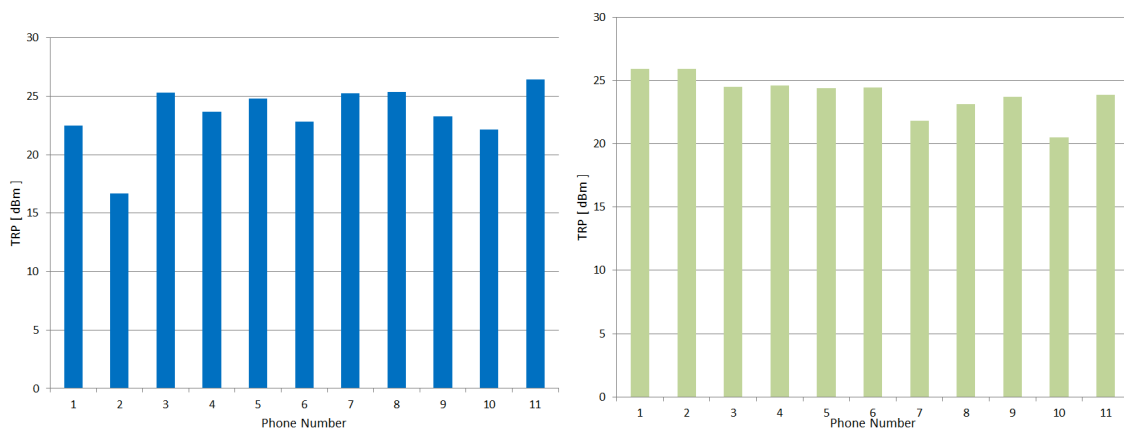


Figure 4. TRP values of the same eleven mobile phones for the right/cheek position: (a) GSM frequency band (left) and (b) DCS frequency band (right).

4. Real-life exposure: SAROTA index

Taken independently, the above sets of SAR and TRP data do not provide a straightforward indication about the mobile phone which offers the best compromise between RF exposure and OTA performance. The SAROTA index defined as the ratio between the SAR and the TRP values measured in the laboratory conditions for the same configuration, i.e. same maximum output power level, same position with respect to the head and same frequency channel, provides a simpler and easier quantification of both RF exposure and OTA performance. SAROTA is a measure of the power absorbed per kilogram of tissue per available power for communication, with units given in $W_{\text{absorbed}}/\text{kg}/W_{\text{available}}$:

$$SAROTA = \frac{SAR}{TRP} \quad (1)$$

Figures 5(a) and (b) show the SAROTA indices of the eleven mobile phones obtained for the right/cheek position for the center frequencies of the GSM and DCS frequency bands, respectively. Based on these indices, Phone No 4 provides relatively lower SAROTA values both for the GSM and DCS frequency bands. It is interesting to note that Phone No 2 provides the worst SAROTA index in the GSM frequency band. Furthermore, Phone No 7 provides relatively high SAR and low TRP values in the DCS frequency band which are reflected by a high SAROTA index. As expected, Phone No 11 offers the best SAROTA index as compared to Phone No 10, although the SAR index appeared to be favorable to Phone No 10. In real-life situation, if at a given location Phone No 10 has to emit at maximum power level in the GSM frequency band (i.e. about 23 dBm) to ensure a good communication link with the nearest base station, on average Phone No 11 will also emit at the same power level, i.e. the power will be lowered by about 3 dB with respect to the maximum that was measured in laboratory conditions (i.e. about 26 dBm). Consequently, the actual RF exposure or real-life SAR of Phone No 11 will be practically divided by two and found to be relatively lower than Phone No 10.

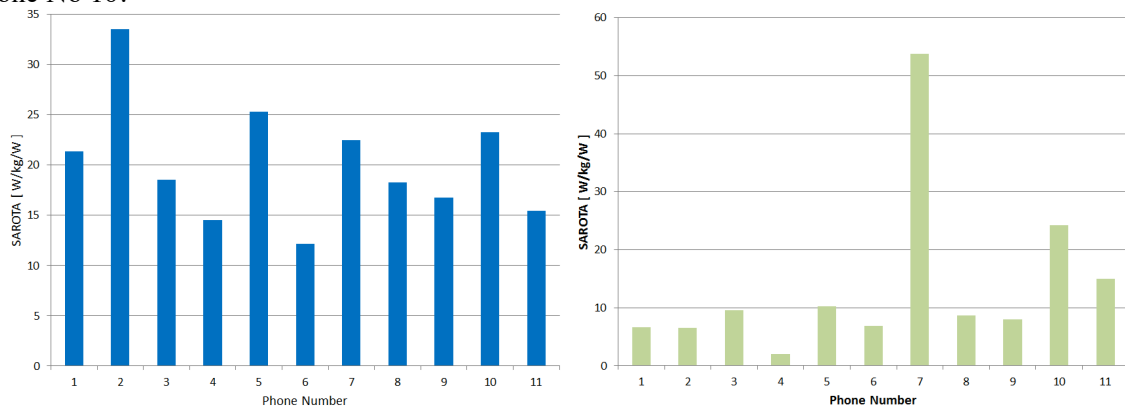


Figure 5. SAROTA indices of the same eleven mobile phones for the right/cheek position: (a) GSM frequency band (left) and (b) DCS frequency band (right).

5. Conclusion

Since SAR is measured under laboratory conditions while the mobile phone is operated at maximum power level, a comparison of the relative SAR values of mobile phones does not provide any indication about the real-life exposure. The latter depends on the OTA performance of the mobile. By taking into account both the SAR and OTA data measured under laboratory conditions, a real-life exposure index denoted as SAROTA is proposed. The SAROTA index is the ratio between the SAR and TRP values measured for the same configuration. It provides a simple quantity which aims to characterize a mobile phone with regard to both RF exposure and OTA performance.

6. References

- [1] IEC Standard 62209-1 2005 *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)*
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