Statistical whole-body averaged SAR in indoor microenvironments by cellular communication and indoor signals

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SHORT ABSTRACT

We calculated the statistics of the whole-body SAR induced by cellular communication systems and indoor wireless sources in indoor microenvironments. The 95th percentile of the whole-body SAR ranged from 15 µW/kg to 33 µW/kg in Belgium, and from 28 µW/kg to 145 µW/kg in Greece and were below the ICNIRP basic restrictions of 0.08 W/kg for general public. The whole-body absorption induced by indoor sources can become larger than the values induced by outdoor sources if the indoor wireless sources are approached.

INTRODUCTION

Within the SEAWIND project, funded by the European Union's seventh framework program, we measured in-situ the exposure in indoor microenvironments [1]. In this study we estimated numerically the whole-body SAR in a human body in these indoor microenvironments by applying the statistical multipath exposure (SME) method of Vermeeren et al [2, 3].

MATERIALS AND METHODS

We determined the statistics of the whole-body absorption induced by cellular communication systems and indoor wireless radio-frequency (RF) sources in sensitive indoor microenvironments using the statistical multipath exposure (SME) method of Vermeeren et al. [2, 3]. The cellular communication systems were GSM 900, GSM 1800, and UMTS. The indoor signals were DECT (digital cordless phones and baby phones) and Wi-Fi 2G. Within the SEAWIND project, we measured in-situ the incident electromagnetic fields in four indoor microenvironments (in Belgium and Greece): at home, school, day nurseries, and offices [1].

From every measured incident field value, the SME method calculated the range of whole-body averaged SAR values that can be induced by 4000 different exposures with a field level equal to the measured field strength. From this range of whole-body averaged SAR values we selected the 95th percentile to obtain a single SAR value for each measured field level.

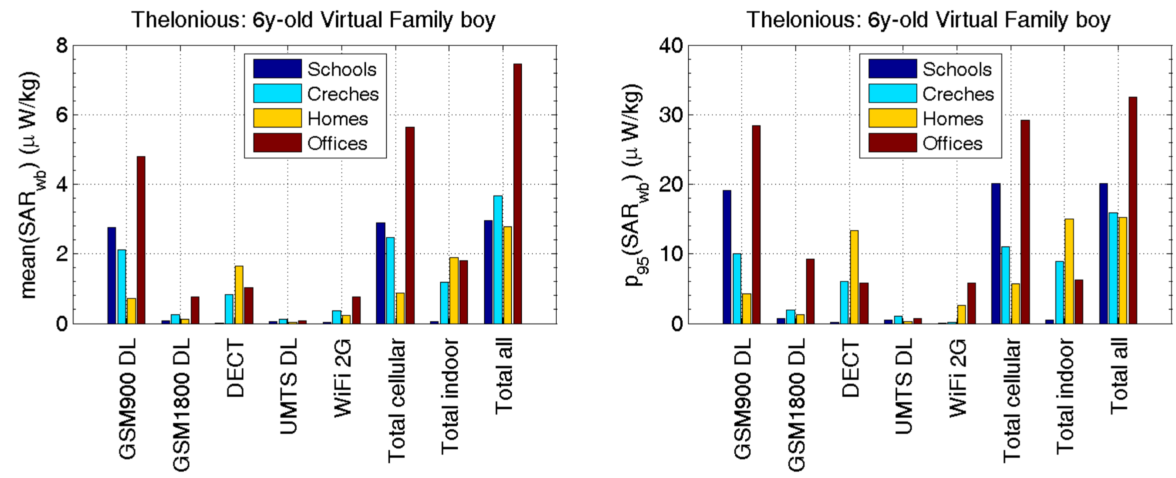
We selected the 6-year-old boy Thelonious and the 34-year-old Duke from the virtual family [4] as the human body models. These models consist of 81 different tissues. The tissues of the model are mapped to the tissues available in the Gabriel database for which the dielectric properties have been determined experimentally [5].

The SME method is a fast alternative for 3D full-wave electromagnetic computations. In this study we limited the angles of incidence for which the total fields are pre-computed and mapped every incident plane wave to the nearest pre-computed plane wave. The pre-computed fields were calculated in elevation at every 5 degrees from -10 to +10 degrees from the horizontal plane and in azimuth at every 30 degrees.

RESULTS

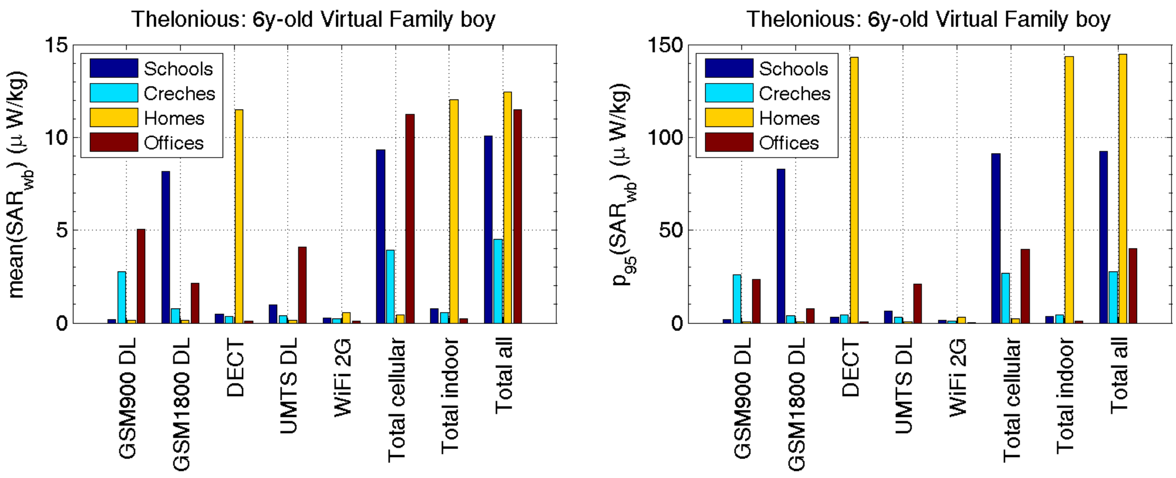
By mapping each incident plane wave of a random exposure on a pre-computed incident-plane wave, the error on the whole-body SAR induced by this random exposure can increase by more than 10 %. But, the error on the statistics of the sample (all 4000 exposures) remains small: the deviation on the 95th percentile is less than 5 % at 950 MHz.

Figure 1 and Figure 2 present the whole-body averaged SAR (SAR_{wb}) induced in Thelonious by wireless cellular communication systems and indoor radio-frequent sources in Belgian and Greek indoor microenvironments. The vertical axis shows the mean or the 95th percentile of the whole-body SAR for the 95th percentile of the measured incident field for each of the signals as well as for the total of cellular, indoor, and all signals.



(a) (b)

Figure 1: The (a) mean and (b) 95th percentile of the estimated whole-body averaged SAR induced in Thelonious by the exposure from cellular communication networks and indoor RF sources for the investigated indoor microenvironments in Belgium.



(a) (b)

Figure 2: The (a) mean and (b) 95th percentile of the estimated whole-body averaged SAR induced in Thelonious by the exposure from cellular communication networks and indoor RF sources for the investigated indoor microenvironments in Greece.

In general, the values for the whole-body absorption reflect the results of the incident-field exposure. For frequencies above resonance (70 MHz – 150 MHz), the whole-body absorption depends mainly on the incident power density or the incident field strength.

The mean values of the total absorption are comparable in Belgium and Greece, but the 95th percentiles were one order of magnitude larger in Greece. In Belgium, the total absorption induced by the measured field strengths ranged from 3 µW/kg to 7 µW/kg for the mean and from 15 µW/kg to 33 µW/kg for the 95th percentile. The total absorption was the highest in Belgian offices. In Greece, the total absorption varied from 5 µW/kg to 12 µW/kg for the mean and from 28 µW/kg to 145 µW/kg for the 95th percentile. The peak value of 145 µW/kg was caused by DECT because the field strength at one location was measured at a distance of 0.5 m from the DECT base station. The total absorption was the lowest in crèches and the highest in homes.

All calculated whole-body SAR values were below the basic restriction of 0.08 W/kg for general public specified by the International Commission on Non-Ionizing Radiation Protection [6].

In Belgium, GSM900 contributes the most to the absorption induced by cellular communication systems. GSM900 induced the highest absorption in offices – offices were mainly located in urban areas – and the lowest in homes – most of the homes were located in rural environments. In Greece, the highest total absorption induced by cellular systems was observed in schools and offices. Cellular systems induced the lowest absorption in homes.

From the indoor signals, DECT contributed the most to the total absorption in both countries and peaked in houses. In Belgian schools, DECT and Wi-Fi 2G induced the lowest absorption indicating that this technology was less used in schools. Absorption due to Wi-Fi 2G was mainly encountered in Belgian offices and Greek homes.

CONCLUSIONS

In this study, we estimated the whole-body SAR in an adult and a child using the statistical multipath exposure tool. The numerical error on the statistics of the sample (all 4000 exposures) remains small: the deviation on the 95th percentile is less than 5 % at 950 MHz.

We estimated numerically the whole-averaged SAR in the 6y-old Virtual Family boy (Thelonious) if he would be exposed to the incident field values measured in Belgian and Greek indoor environments. The 95th percentile of the whole-body SAR ranged from 15 µW/kg to 33 µW/kg in Belgium, and from 28 µW/kg to 145 µW/kg in Greece and were below the ICNIRP basic restrictions of 0.08 W/kg for general public. The whole-body absorption induced by indoor sources can become larger than the values induced by outdoor sources if the indoor wireless sources are approached.

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