Statistical multi-path exposure tool for realistic human body models

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INTRODUCTION

Quantifying the absorption in a human body in a realistic, multi-path exposure environment requires a statistical approach. The absorption needs to be determined for a large set of possible exposures (several thousands) in the investigated environment. In order to avoid thousands of time-consuming brute-force calculations using a finite-difference time-domain solver, a fast numerical method has been presented to determine the whole-body absorption in a spheroid human body model in a realistic exposure environment [1]. This method uses field distributions of a limited set of incident plane waves to calculate very fast (within seconds) the whole-body absorption for any single or multiple plane wave exposure. Only Tthis limited set of field distributions still needs to be computed using available 3D electromagnetic solvers. In this study, this fast method has been extended to realistic heterogeneous human body models such as the Virtual Family [2].

MATERIALS AND METHODS

The methodology of the fast method for a realistic human body phantom will be discussed for the Virtual Family Boy (VFB) [2] exposed to the GSM downlink frequency of 950 MHz. The dielectric properties for the various tissues of the body model has been taken from the Gabriel database [3]. The fast method assumes a far-field exposure condition and that there is no coupling between body and environment. Under these conditions, the exposure in a realistic environment is modeled as the superposition of multiple incident plane waves [4].

The method to calculate quickly the whole-body absorption in a human body is based on the linearity of Maxwell's equations and on the knowledge of the total fields on a closed surface around the human body for a limited set of single incident plane waves, denoted as basic field distributions (BFDs). A flow-chart of the method is shown in Figure 1.

The fast method for realistic heterogeneous human body models differs in several ways from the method for spheroid human body models. Due to the absence of rotation symmetry, the closed observation surface around the human body does not have to be a spheroid. Instead, a rectangular box around the human body is chosen allowing to reduce the overall simulation domain for the calculation of the basic field distributions using a brute-force 3D electromagnetic solver. Due to the absence of rotation and mirror symmetry, basic field distributions has have to be calculated all around the human body (azimuth and elevation direction). A cubic spline interpolation scheme limits the set of angles for which the basic field distributions have to be determined. In this study, the method has been validated and the whole-body averaged SAR (SAR_{wb}) in four different exposure environments has been determined.

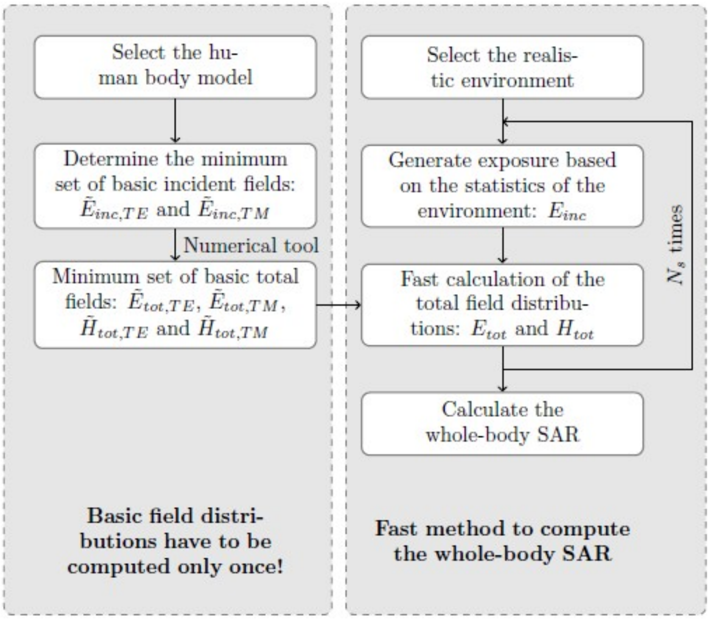

Figure 1: Flow-chart of the fast method to determine the whole-body SAR in a realistic environment.

RESULTS

The fast method has been validated with the results obtained by a 3D electromagnetic solver for 100 arbitrary exposure samples in an urban-macrocell environment [4]. The mean error equals 0.4 % for a spacing between the angles of incidence (for which a BFD is calculated) of 5° along the elevation and 10° along the azimuth direction. Figure 2 shows the cumulative distribution function (cdf) of the whole-body averaged SAR in the VFB in four realistic exposure environments. The incident power density equalled the ICNIRP reference level for general public exposure, i.e. 4.75W/m^2 at 950MHz [5]. The results for an E- and H-polarized frontal incident plane wave are indicated by markers. It is observed that the cdf of SAR_{wb} does not differ significantly between different environments at 950 MHz. The 95^{th} percentiles of SAR_{wb} are compliant with the basic restriction for general public exposure and vary from 0.068 W/kg to 0.069 W/kg for the different environments. It is very unlikely that the exposure in the four environments is not compliant with the basic restrictions as only Only about 0.26 % of the exposure samples in the four environments exceeded the basic restriction.

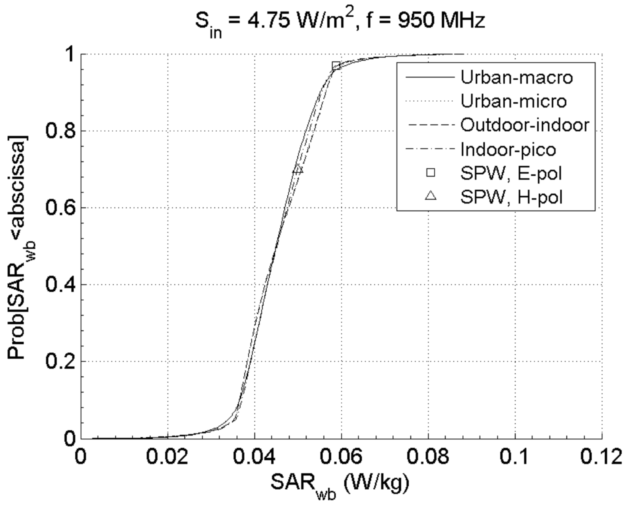

Figure 2: The cumulative distribution function of SARwb in VFB in four realistic environments exposed to electromagnetic fields from GSM downlink at 950MHz. The incident power density equalled the ICNIRP reference level for general public exposure, i.e. 4.75W/m2 at 950MHz. The results for an E- and H-polarized frontal incident plane wave is indicated by markers.

CONCLUSIONS

The fast method to determine numerically the whole-body SAR has been extended to realistic human body models. The method has been validated for the virtual family boy exposed to GSM downlink at 950 MHz; the relative error depends on the number of basic field distributions and can be less than 1 %. The fast method has been applied to investigate the whole-body SAR in the Virtual Family boy exposed to GSM downlink at 950 MHz in four different realistic environments for an incident power equal to the ICNIRP reference levels for general public exposure and 0.26 % of the realistic exposure samples in the four environments exceeded the basic restriction.. For these scenarios it is unlikely that the whole-body SAR exceeds the basic restriction.

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