Efficient Implementation of SAR Averaging Techniques in Computational Dosimetry for Highly Detailed Human Models

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Abstract

This paper presents an efficient implementation of different techniques used in the computation of averaged Specific Absorption Rate (SAR). The main purpose of this work is to enhance the accuracy and speed in the prediction of SAR averaged values regarding highly detailed human models, which present a highly inhomogeneous medium. Following the recommendations of IEEE and ICNIRP standards, three different averaging schemes have been considered, namely using a cubical, contiguous and spherical volume. The resulting algorithms have been implemented and integrated into the advanced simulation platform SEMCAD X.

1. Introduction

Various organizations in the world have established safety guidelines for electromagnetic (EM) wave absorption. In particular, the regulations about near field exposure are based on spatial-peak values of averaged SAR. Nowadays, these quantities can be predicted by numerical simulation but its computation is expensive, specially if the medium is highly inhomogeneous and highly discretized.

In the process of SAR averaging, the adjustment of the averaging volume to a specific mass constitutes the major computational burden in the method. Actually, in the computation of large problems the time required for SAR averaging might even surpass that employed in the resolution of the EM problem itself. Previous techniques [1, 2] overcame this problem by using *approximations* on the averaging volumes that took advantage of the imprecision of the human models. In other cases, the problem was simply reduced to equivalent homogeneous models, where the process of averaging becomes trivial [8].

Nowadays, highly detailed models of human bodies are available [7]. Therefore, it would be desirable to develop algorithms that provide equivalent accuracy on larger models and without a loss in efficiency. In this line, we have develop an implementation that meets the following requirements:

- Performs an efficient and accurate computation on a range of averaging schemes: cubical (IEEE-compliant) [3], contiguous (ICNIRP-compliant) [4] and spherical.
- Suited for any arbitrary highly detailed human models (or equivalently, highly inhomogeneous structures) and for any averaging mass.
- Evaluation of SAR average on specific organ/tissue
- User-friendly interface for configuration and visualization.

2. Methods

The computation of SAR is based on the evaluation of the EM energy dissipated on the tissue due to an EM source. This is performed using an advanced implementation of the Finite-Difference Time-Domain (FDTD) technique [6] since this method is specially well suited for the computation of large and arbitrary highly inhomogeneous problems. Then, this result has to be integrated over a specific volume that is determined on a specific mass. The shape of this volume may be defined in several ways, leading to different possible schemes. We have focused this work on three of them.

The IEEE standard [3] proposes a cubic region of a specific mass (typically 1 or 10g) as the averaging volume. This shape can be easily fit in the FDTD grid which simplifies the averaging procedure. The cube fitting consist first in a fast "coarse" expansion based on the grid voxels [2]. Finally, the resulting cube is fine tuned in order to fit the exact mass, within a specified tolerance [5].

Another useful scheme consists of the so-called contiguous SAR averaging [4]. In this case, the shape of the averaging volume is not predefined. This is obtained connecting the tissue with maximum local SAR values until the required mass is reached. This procedure requires a higher computational effort with respect to the previous technique since the determination of the averaging volume shape implies the analysis of the entire problem instead of only the vicinity of the sampling point. Therefore a segmentation strategy is used in the optimization of this algorithm.

Finally, a spherical volume has also been implemented for comparison since it seems to be a natural shape for averaging. This shape has the inconvenient that it does not fit well the Cartesian grid provided in the FDTD method. This has been overcome by interpolating different volumes from the cubic scheme.

3. Results

The algorithm has been integrated into the post-processing unit of the simulation platform SEMCAD-X [6] which incorporates a number of advance tools for the visualization and treatment of simulation results.

In addition, SEMCAD provides all the features needed in order to generate and evaluate highly complex real world problems. It supports the generation of model specific, customizable non-homogeneous grid generation together with a fast voxelizer for material assignment. Advanced local refinement schemes enable enhanced modeling within FDTD, even for setups with a large ratio between smallest and largest extensions.

These algorithms have been applied to the computation of averaged SAR on a model of a six-years old child from the Virtual Family Project [7]. Fig.1 shows the results for the cubic scheme over the model's face together with a plot of the conductivity of the tissue in order get an insight about the degree of accuracy achieved even in a highly detailed human models.

Preliminary simulations show a clear increase of the computation speed with respect to previous implementations while providing higher accuracy. The three averaging schemes are being applied to realistic scenarios involving the EM exposure of human bodies, outlining performance of the methods as well as specific average SAR variations based on the chosen scheme.

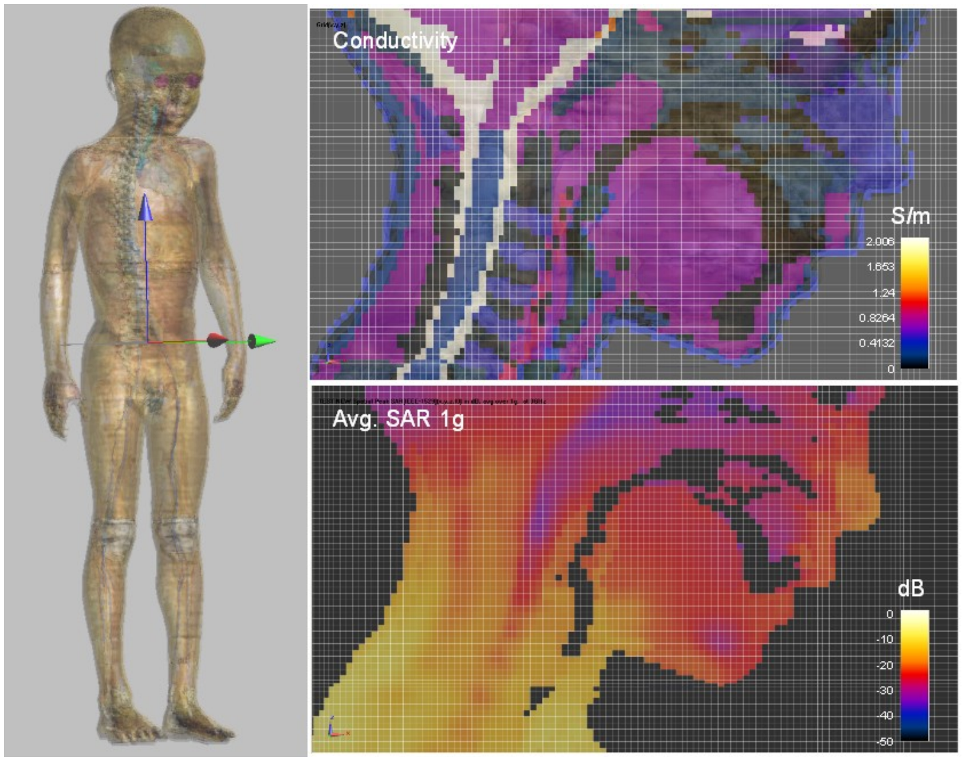

Fig. 1: Example of SAR computation on a 6-years old child model from the Virtual Family [7]. On the left side: a 3D view of the complete model. On the right: a representation of the tissue conductivity (top) and the SAR values averaged over 1g-cubic volumes @64MHz (bottom) relative to the maximum (3.58 mW/g)

4. Conclusion

Three SAR averaging schemes have been implemented to meet the requirements, in terms of efficiency and accuracy, in the computation of highly detailed human bodies. The cubical and contiguous schemes follow the recommendations of standardization groups of IEEE and ICNIRP, respectively. On the other hand, the spherical scheme provides an alternative averaging definition. These solutions have been successfully integrated into SEMCAD-X .

5. References

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