Simulation of Wireless Communications Induced SAR for Interlaboratory Comparison

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Abstract — This paper involves the numerical modeling and simulation of the electric field generated by a mobile phone and estimation of the specific absorption rate (SAR) induced in human brain tissue equivalent liquid. The Transmission Line Modeling (TLM) method is used to model and simulate the electric field source, and then a standard procedure is applied to determine the SAR for hand-held devices used in close proximity to the ear within the frequency range of interest. Results were compared to measured ones obtained through standardized measurements procedures.

I. INTRODUCTION

Research on the effects of mobile communication devices on human tissue have grown over the last years. The Specific Absorption Rate (SAR) is the most common used measure of the energy amount absorbed by a biological tissue. International standards establish specific SAR limit values for various applications. Other standards, such as [1], provide guidance in how to estimate or compute the SAR for mobile telecommunications operating at maximum power, within the 300 *MHz* – 3 GHz frequency range, which are within the interest of this paper.

This work intends to model and simulate the distribution of the E-field generated by a mobile phone using the Transmission Line Modeling (TLM) method. To validate the numerical model, the canonical example described in [1] is developed, then, the model is applied to simulate and compute SAR induced into human brain tissue due to a cellular telephone operating at the frequencies of 900 *MHz* and 1800 *MHz* and the results are compared.

II. METHODOLOGY

The methodology basically consists in comparing measured results with the simulation to validate the numerical model and then to apply it to the desired problem. Sections A and B describe the measurements and the simulation setup used for this validation and section C describes the model applied to the human head problem.

A. Measurement System Setup

Assuming acceptable to evaluate the influence of cellular telephones and electronic devices in biological tissue using induced SAR [2], it can be defined as the time derivative of the incremental energy absorbed by an incremental mass contained in a volume element of a given mass density. SAR is expressed in (*W/kg*), and it is related to the E-field at a point by:

$$SAR = \sigma \left| E^2 \right| / (2\rho) \tag{1}$$

where E (in *V/m*) is the RMS E-field strength, ρ (in kg/m^3), and σ (in *S/m*) are the volumetric mass density and electric conductivity of the tissue, respectively.

Specific SAR limit values are defined in [3]. The evaluation of the SAR as in [1] is performed by measuring the E-field induced in a human tissue equivalent liquid inside a partially filled phantom with a dielectric probe, subsequently applying (1) and adding the liquid mass up to a cubic volume of 1 g or 10 g, containing the peak E-field.

The measuring procedure consists of a robotic arm moving an E-field isotropic probe in order to sweep the area of interest. The standard recommends that a first rough area scan is done to roughly locate the peak E-field, and consequently SAR. Following, finer resolution volume scans in that region are taken to evaluate the peak spatial-average SAR values for 1 g or 10 g cubes [6].

The example applied to validate the TLM implemented code can be depicted from Fig. 1.

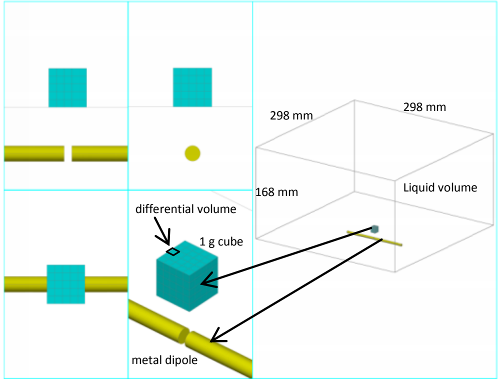


Fig. 1. Measuring and Simulation setup: three basic views (top, bottom and side) and perspective view with zoom in 1-g cube.

A large volume recipient is filled with brain tissue equivalent liquid and a dipole is positioned below it. The recipient's thickness is 2 *mm* and the liquid filled height is 150 *mm*. The amount of liquid is considered enough in order not to interfere with the measure results. The dipoles used for excitation were SPEAG [4] models D900V2 for 900 *MHz* and D1800V2 for 1800 *MHz*.

The measuring system was the SPEAG DASY4, with isotropic probe models ES3DV3 and EX3DV3 for 900 and 1800 *MHz* respectively. System probes were calibrated as per [5]. Table I presents the materials electrical parameters.

B. Numerical Method and Validation Setup

The chosen method was TLM, due to reduced space, the description of the method and more details were omitted, but those may be found in [7]. The model validation simulation setup was shown in Fig. 2. The energy source was an electric dipole of 146 *mm* for 900 *MHz* and 78 *mm*

TABLE I

MEASURED MATERIAL ELECTRICAL PROPERTIES

	900 MHz			***1800 MHz***		
	μ_r	ε_r	σ [S/m]	μ_r	ε_r	σ [S/m]
phantom	1.0	3.7	0	1.0	3.7	0
liquid	1.0	41.27	0.99	1.0	39.58	1.34

for 1800 *MHz*. It was modeled by one node of thickness in square format, which is 2 *mm* for both cited frequencies, and the characteristics of the simulation are on Table II.

TABLE II

SIMULATION PROPERTIES

	900 MHz	**1800 MHz**
Excitation Power	1 W peak	1 W peak
Dipole length	146 mm	78 mm
Distance dipole - liquid	16 mm	10 mm
Differential volume (node size)	8 mm^3	8 mm^3
Boundary type	Simple ABC	Simple ABC

The phantom shell thickness used is 2 *mm* for both 900 *MHz* and 1800 *MHz*, and the main electric properties employed on the simulation are on Table III.

TABLE III

SIMULATED MATERIAL ELECTRICAL PROPERTIES

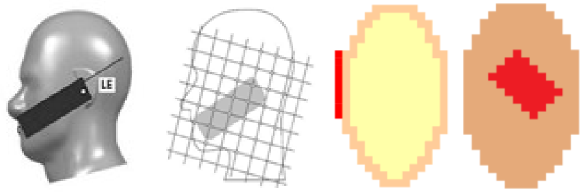
	900 MHz			***1800 MHz***		
	μ_r	ε_r	σ [S/m]	μ_r	ε_r	σ [S/m]
air	1.0	1.0	0.0	1.0	1.0	0.0
dipole	1.0	1.0	5.81×10^7	1.0	1.0	5.81×10^7
phantom	1.0	3.69	0.0093	1.0	3.69	0.018
liquid	1.0	41.5	0.97	1.0	40.0	1.4

Since the peak E-field is most probably located at the edge or within the subsurface of the phantom human tissue, the mesh was defined so that the center of the lowest node was located as close as possible to this surface.

After simulating the E-field and finding the peak, the 1 g and the 10 g volumes are obtained as follows. With the peak E-field, compute SAR for a large region near the surface where the peak is found. Then define the differential volume to be added according to the node size and, starting at the node of the peak E-field, add one differential volume at a time, until the 1 g and 10 g mass are achieved. Divide the total by the amount of differential volumes and normalize the values to the input power of 1 W. The acceptable tolerance is tested against target values from [1] and [3]. Then, the model is applied to the real problem.

C. Numerical Model Application

The TLM model setup used in the application to this specific problem is shown in Fig. 2.



(a) (b) (c)

Fig. 2. Cellular telephone test and simulation position: (a) Left ear setup for 900 and 1800 MHz. (b) Recommended grid for data acquisition [1]. (c) Front and side rough view of the modeled mesh.

The energy source is a cellular telephone operating at maximum output power in 900 *MHz* and 1800 *MHz*, which is close to 40 mW or 16 dBm. To model this source, the E-field is measured according to the recommended grid from Fig. 2. The cellular is modeled as a plane of E-field sources. The phantom shell thickness used is 2 *mm*, the liquid depth is 15 cm and the distance of the source to the shell is 0.5 *mm* for both frequencies. The electric properties used for the same chosen for the validation simulation. Again, after simulating the E-field and finding the peak, the 1 g and the 10 g volumes are obtained. Results are on next section.

III. PRELIMINARY RESULTS

Similar behavior is observed for the measurement and simulation in the validation and application, for both 900 *MHz* and 1800 *MHz*. The SAR values are on Table IV.

TABLE IV

RESULTS SUMMARY

		Validation		**Application**	
		900 MHz	**1800 MHz**	**900 MHz**	**1800 MHz**
SAR 1-g	***IEEE Std 1528***	10.8	38.1	10.8	38.1
	Measurement	10.4	36.9	10.9	37.3
	Simulation	13.8	32.8	12.5	36.8
SAR 10-g	***IEEE Std 1528***	6.9	19.8	6.9	19.8
	Measurement	6.7	19.3	7.0	19.4
	Simulation	6.6	19.8	6.3	17.9

IV. CONSIDERATIONS

The induced SAR expected in the human head under normal use of a cellular telephone operating at maximum output power in 900 *MHz* and 1800 *MHz* was modeled using TLM method and the estimate of the peak spatial-average induced SAR was compared to standards and experimental values. Considering the tolerance from [1], the simulation results are satisfactory when compared to the measured and to the recommended values presented on [1].

In the full paper, more detail is given to the modeling and measuring procedures, as well as detailed results.

V. REFERENCES

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