Improved Estimation of SAR Value of Biological Samples

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***Abstract*— The specific absorption rate of tissue samples in in-vitro exposure tests is one of the key parameters if one investigates possible damages to cells or their components by electromagnetic waves. While many other interactions were investigated, no non-thermal effects have ever been verified by reproducible and scientifically valid experiments.
While many different ways exist to estimate the SAR value of a sample, one more sophisticated method is to use the temperature change at the start of the heating and to employ a fitting algorithm. Based on this and applying an advanced fitting procedure to all measurement data, it is possible to avoid the assessment of material parameters, which are difficultly obtainable.

Keywords-SAR value, Numerical approximation

I. INTRODUCTION

We start with the Bio-heat equation

$$\nabla \cdot (K\,\nabla T) + A + \mathrm{Q} - RL - B(T_\mathrm{B} - T) = C\,\rho\,\frac{\mathrm{d}T}{\mathrm{d}t} \qquad (1)$$

The change of thermal energy per unit time and per unit volume inside a living body (left side) must be equal to the temperature change per unit time multiplied by the thermal capacitance of the tissue (right side) [7]. Here,

- T is the temperature,
- C is the heat capacity,
- ρ the specific density,
- K is the tissue thermal conductivity which represents the heat transfer through internal conduction,
- A denotes metabolic heat production,
- Q represents the net power influx from the external electromagnetic field,
- RL is the respiratory heat losses in the lungs,
- B stems from the thermal loss due to the difference between blood and tissue temperature ($T_\mathrm{B} - T$).

II. SOLUTION TO LDE

The equation is solved for in-vitro or in-vivo samples, under the assumption that the system is a thermal equilibrium and exchanges heat with its surrounding. The solution for the inhomogeneous LDE of first order is an exponential function with unknown parameters that can be estimated by fitting measured results to the data measured in an exposure test.

III. EXAMPLES

The proposed method was applied during an exposure test with 15 tests kits containing blood from 5 different donors in an open TEM cell. The TEM cell was excited by 900 MHz continuous wave with 10 W input power generating an electric field 140 to 150 V/m (parallel vector of 130 to 145 V/m) inside the Mini-TEM cell. Five test kits were exposed for 30 mins, five for 60 mins and five for 90 mins, respectively.

TABLE I. SAR VALUES FOR 5 DONORS, IN W/kg

	Donor 1	Donor 2	Donor 3	Donor 4	Donor 5
30 min	8.33±0.42	9.56±0.60		9.72±0.43	9.56±0.59
60 min	7.82±0.44	7.28±0.28	9.45±1.13	9.00±0.51	8.60±0.70
90 min	9.28±0.43	7.77±0.39	9.63±0.44	7.97±0.42	9.71±0.66

One exemplary resulting plot is displayed in Fig. 1: the blue dots are the measured temperature, while the red line is the resulting curve.

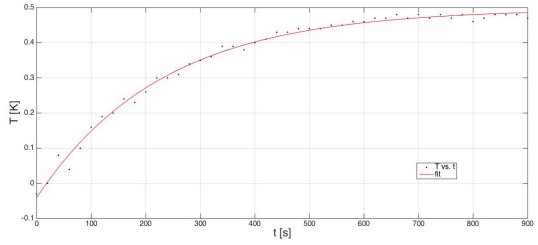

Figure 1. Exemplarily test of the fitting and SAR-calculation method with data generated by a given heat transfer, SAR-value.