Experimental specific energy absorption rate assessment from absorption cross section measurement for far-field exposure at 2-3 GHz

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ABSTRACT

Rather than using such simulations, a measurement-based method is readily developed in this paper to assess the Absorption Cross Section (ACS) of humans in a realistic closed environment. From the ACS, it is hence easy to derive the whole body SAR [1].

INTRODUCTION

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) defines the Specific energy Absorption Rate (SAR) as a basic restriction for human exposure in the RF frequency band.
Various works based on numerical computations such as the Finite-Difference Time-Domain (FDTD) method have assessed the SAR, but whole body SAR remains a difficult quantity to measure in an actual human body. These computations are dependent on the accuracy of the phantom modeling, the used numerical code, etc. Therefore a measurement-based approach based on the absorption cross section is a suitable alternative.

MATERIALS AND METHODS

A network analyzer (Rohde & Schwarz ZVR) is used to measure the complex channel frequency response for a set of transmitting and receiving antenna positions. The channel is probed with the network analyzer in a 500 MHz measurement bandwidth for central frequencies of 2.3 GHz and 3 GHz. Both antennas are polarized vertically and positioned at a height of 1.8 m, and are moving along a uniform linear array (ULA) during measurements. At each of 51 (1×51×1×1) combinations of Tx and Rx positioning along the ULAs, the network analyzer measures the S_{21} scattering parameter ten times (i.e., 10 time observations), which we average to obtain an average power delay profile (APDP) per Tx-Rx location. The measurements are performed in an office environment in Ghent, Belgium. Three spatial locations for the Tx and one location for the Rx are selected.

The methodology is based on *Room electromagnetics* theory [2], which states that all the losses in a closed room can be described with a single parameter, called the reverberation time and is determined from the PDP. The reverberation time is only room dependent and is given by:

$$\tau = \frac{4V}{cA}$$

where V, c and A are the room volume, the velocity of light in vacuum and the effective area of the total absorbing surface.
We vary the room occupation to obtain the absorption area values as a function of the number of people (0, 2, 3, 7, 10, etc…), and then the absorption cross section is obtained by the determination of the slope of the linear regression of the points [2].

RESULTS

The measurement results in term of absorption cross section for the different locations and the two frequencies are summarized in Table 1. An illustration of the absorption area i.e., the total surface being absorbed as a function of room occupation is shown in Fig. 1.

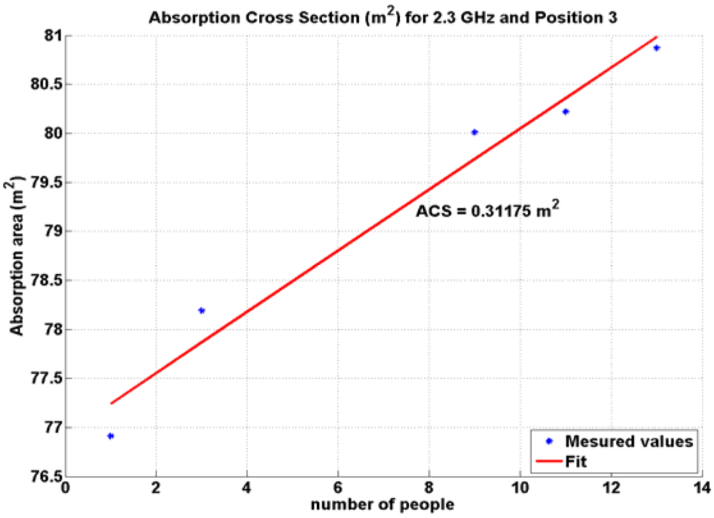

Figure 1: Absorption area as a function of room occupation

Absorption cross section (ACS) in $\mathbf{m^2}$		Positions
Frequency = 2.3 GHz	Frequency = 3 GHz	
0.41805	0.23697	Position 1 (AR1)
0.28144	0.43238	Position 2 (AR2)
0.31175	0.41857	Position 3 (AR3)
0.33708	**0.36264**	**Averaged over position 1, 2 and 3**

Table 1: Absorption cross section (ACS) from measurement

The average ACS at 2.3 GHz is about 0.34 m^2 and 0.36 m^2 at 3 GHz. We notice that the absorption cross section varies slightly according to the frequency (this variation is probably not statistically significant).

Assume that the mean weight and height of people under test are 68 kg and 176 cm respectively, and the power density is S=1 W/m^2.
Using the ACS from our measurement and [1], the whole body SAR at 2.3 GHz is about 0.005 mW/Kg and 0.0053 mW/Kg at 3 GHz, (These values are for an actual human).
From Fujimoto’s formula in [1], the phantom characteristics lead to a mean body surface area (BSA) of about 1.78 m^2, hence using the relation between the body surface area and the ACS at 2 GHz [1] we derive an ACS about 0.49 m^2 leading to a whole body SAR of 0.0072 mW/Kg.
In [3] a statistical tool is proposed to assess the SAR at 2.45 GHz with a spheroid average man as phantom, a mean whole body SAR of 0.0027 mW/Kg has been found. The relative “large” deviation from our “measured” whole body SAR may be explained by the difference in the phantom shapes and postures. For instance for the same body surface area of 1.785 m^2 the absorption cross section variation may reach 0.15 m^2 for two different phantoms shapes [1], resulting in a variation of 0.0022 mW/Kg in the whole body SAR. Moreover, the persons may not be exposed identically.

CONCLUSIONS

An easy and novel method to assess the ACS, and hence the whole body SAR has been proposed in this paper instead of the whole body SAR numerical computations. Measurement results of the ACS are in good agreement with the literature.

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