WHOLE-BODY AVERAGED SAR MEASUREMENTS FOR POSTURED HUMAN USING EXTERNAL ELECTRIC-FIELD SCANNING

TAKASHI HIKAGE[1], YOSHIFUMI KAWAMURA[1], TOSHIO NOJIMA[1], ALLY Y. SIMBA[2], TOMOAKI NAGAOKA[2], and SOICHI WATANABE[2]

[1] GRADUATE SCHOOL OF INFORMATION SCIENCE AND TECHNOLOGY, HOKKAIDO UNIVERSITY, JAPAN
{hikage, kawamura, nojima}@wtemc.ist.hokudai.ac.jp
[2] NATIONAL INSTITUTE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY, JAPAN

Abstract

In this paper, measurement data of whole-body averaged specific absorption rate (WB-SAR) for postured physical human phantom under 2GHz far-field exposure are presented. Based on the cylindrical field scanning technique, we developed an experimental WB-SAR measurement system for UHF far-field exposure. A key characteristic of the measurement system is that it can be easily applied to human phantoms that have different postures or sizes, because it is not necessary to determine the electromagnetic components distributed inside of the phantom. The physical postured human phantoms used in this paper were made from enhanced high-resolution numerical human models. The phantoms were composed of 2/3 muscle-equivalent tissue and the material consisted of carbon nanotubes embedded in silicone rubber. The measurement results of WB-SARs for postured male adult and child human phantom were, under ICNIRP reference level exposure condition, comparable with the numerical calculation results.

Introduction

A basic metric used as the reference value of biological effects is the whole-body averaged specific absorption rate (WB-SAR). The International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronic Engineers (IEEE) have separately issued advice notices [1,2]. In Japan, a telecommunications technology council report also included advice [3]. These guidelines are based on established adverse effects for human exposure to electromagnetic fields and include safety margins.

The relationship between the reference level of the guidelines and the WB-SAR in human due to plane-wave exposure was established mainly based on numerical calculations for highly simplified human modelling [4]. Recently, many dosimetry estimations for human exposure including high accuracy numerical phantom models have been reported [5]. Dosimetry estimations using numerical analysis exhibit some variations due to differences in program code and so on. In order to confirm the validity of computer results, it is important to conduct experiments. However, due to the difficulty of measuring WB-SAR, few investigations have used realistically shaped human models.

Previously, we proposed a new WB-SAR estimation method based on electric power consumption based on the cylindrical field scanning technique [6,7]. In the method, absorbed power due to a human is obtained by estimating both the outward radiated electric power from a cylindrical closed area including the human body and the power of the exposure plane-wave. The WB-SAR can be derived from the absorption power and the weight of the human. A key characteristic of the proposed method is that it can be easily applied to human phantoms that have different postures or sizes, because it is not necessary to determine the electromagnetic components distributed inside of the human phantom.

In this paper, we develop postured physical human phantoms made of tissue-equivalent material based on Japanese numerical human models [8]. And, measured results of WB-SAR of the standing and sitting phantoms for 2GHz far-field exposure are shown.

Experimental setup for WB-SAR measurement

The block diagram of the experimental set-up for WB-SAR estimation is shown in Fig. 1. This set-up assumed that human exposed to a 2 GHz E-polarized plane-wave. The power density of the plane wave was 1 mW/cm^2. To estimate plane-wave exposure at mobile radio frequencies on the human body, the direct approach is to use a

full-size model. Instead, this set-up used a scaled model to minimize the estimation space requirements for measurements. In an evaluation that includes lossy materials such as the human phantom, both the electric constant and the scale of the lossy material should be changed. In this study, a 1/2 scale model was used. Then, the object sizes were reduced by a half and the antenna radiation frequency is 4.0 GHz.
In order to expose a uniform plane wave, a plane-wave radiation system was used (Fig.2). A dielectric lens was designed and set in front of the horn antenna. The dielectric lens aligns the amplitude and phase of the electric field.
The physical postured phantoms were made based on enhanced high-resolution Japanese human model [7]. The male adult and the 6-year old male child models were used, as shown in Fig. 3. The human phantoms were composed of 2/3 muscle-equivalent tissue [9]. The phantom material consisted of carbon nanotubes embedded in silicone rubber [10]. The phantom parameters are summarized in Table I.
The experimental set-up for the sitting male child phantom in the anechoic chamber is shown in Fig. 4. The human phantom is separated by 0.5 m from the lens of the exposure equipment. The radiation power from the cylindrical closed surface is obtained by electric field distribution measurement using 3-axis optical field sensor. The sampling interval of cylindrical scanning is 20 mm in height and 1 degree in circumference. The input and output power of the closed area is obtained using Poynting vector based on the electromagnetic field distributions measured on the boundary surface. In order to include areas not usually considered, such as the upper and lower parts of the cylinder, the absorbed power is subtracted from the radiation power when the lossy material is in the scanning surface as well as when the material is not in the scanning surface [6].

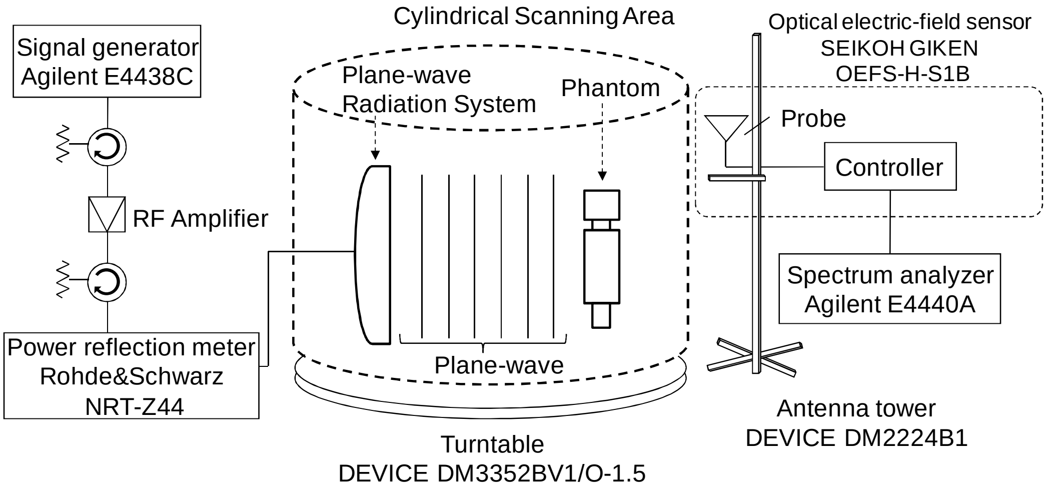

Figure 1. Experimental Set-up for WB-SAR Measurement

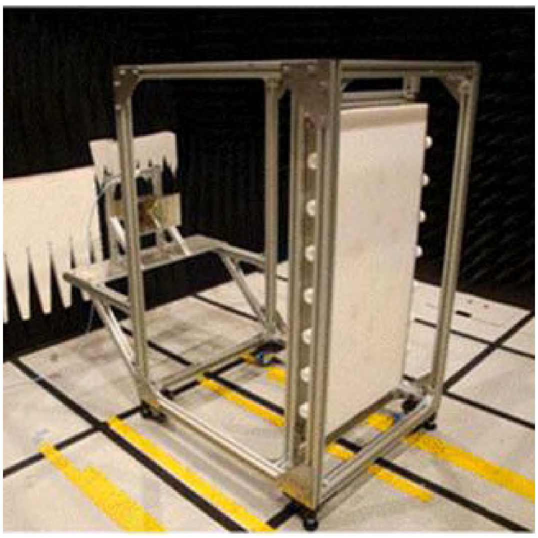

Figure 2. Plane-wave Exposure Equipment

Results

The electric power of the plane-wave radiation system was 23 dBm. Then, the averaged electric power density of the plane wave excitation space of the radiation system is 0.154 W/m^2. The Poynting vector on cylindrical surface was derived from the electric field data. The measured WB-SAR for the male adult and male child models are shown in Fig. 5 compared with FDTD calculated results. The WB-SARs were evaluated using the weight of the numerical human phantom models. Each of the absorbed power was normalized for the power density of exposed plane-wave of 1 mW/cm^2. The measured WB-SAR for the standing male adult was 0.058 W/kg. A numerical estimated WB-SAR for the standing adult model exposed to ideal plane-wave was 0.059 W/kg obtained by calculation. The measured results agree well with calculated results of whole-body averaged SAR for both of the adult and child phantom cases.

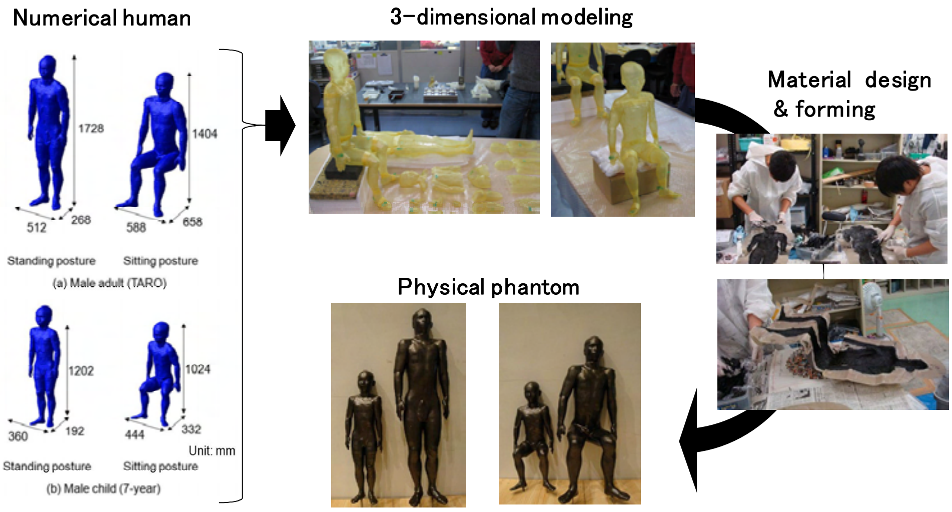

Figure 3. Postured Phantoms Based on Numerical Data

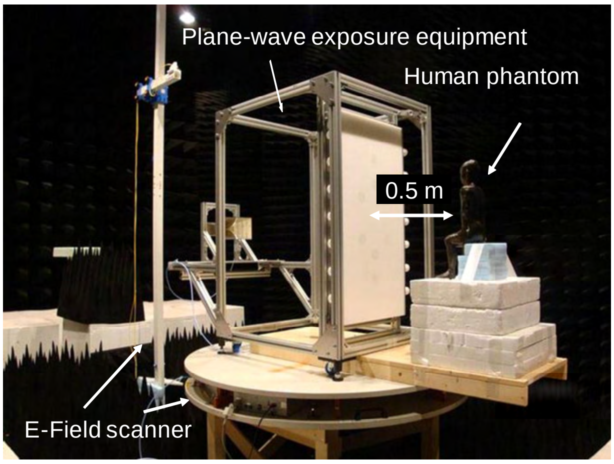

Figure 4. Measurement for Postured Phantom

Table 1 Phantom Parameters

Type	Male adult		Male child	
Body Height (1/2 scaled)	Standing	Sitting	Standing	Sitting
	86 cm	70 cm	60 cm	51 cm
Body Weight	62 kg		21 kg	
Tissue	(half scale, 2/3 equivalent Muscle) $\varepsilon_r = 36$, $\sigma = 2.1\,S/m$			

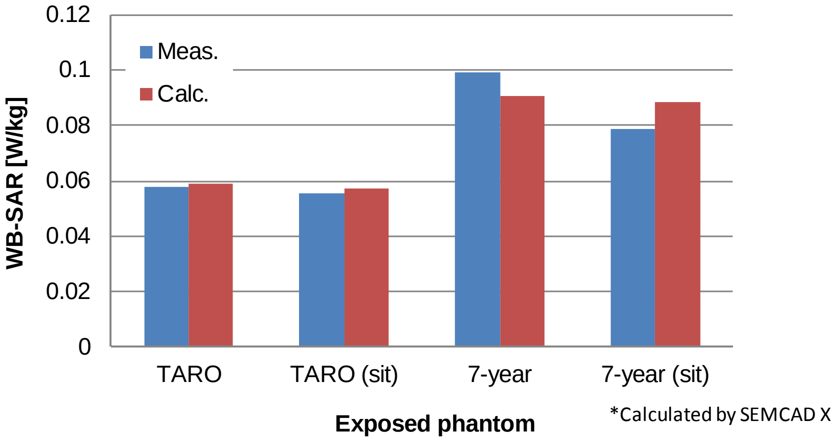

Figure 5. WB-SAR Measurement Results and IEEE 1528a Calculation Results for Postured Phantoms

Summary

In this paper, based on the cylindrical field scanning technique, WB-SAR measurements for postured human phantoms were conducted. Measured results of WB-SAR of standing and sitting Japanese human phantom for 2GHz far-field exposure were, under ICNIRP reference level exposure condition, comparable with the numerical calculation results.

Acknowledgement

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