Computational Study on Temperature Elevation in Realistic Human Model for Whole-body Exposure

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Two international guidelines/standards for human protection from electromagnetic fields define the whole-body average specific absorption rate (WBASAR) as a metric for protection against prevent excessive core temperature rise. The international guidelines/standards have been revised in 2019 [1] and 2020 [2]. The upper frequency of WBASAR was revised from 10 GHz to 300 GHz in the revision of ICNIRP guidelines. In the revised IEEE standards, the upper frequency of WBASAR was set to 6 GHz, and the exposure reference levels (ERLs) for far-field exposure have been set up to 300 GHz. However, the rationale for this exposure restriction is unclear above 6-10 GHz due to the lack of the human modeling. The skin modeling would become important because electromagnetic power is mostly absorbed in the skin layer. If the effect of skin thickness on the whole-body average SAR and body core temperature elevation is clarified, it would be useful for setting the limit in the guidelines/standards.

This study computes the WBASAR and temperature elevation in the human body model for whole-body exposure at 1-30 GHz. The numerical human model used in this study [3] was fine-tuned into high resolution models with arbitrary skin thickness by mediating polygon model [4]. First, the SAR in the human model are computed using a finite-difference time-domain method. Then, temperature elevation is computed by solving the bioheat transfer equation [5] considering the thermoregulation. The effect of skin thickness on the whole-body average SAR is 20%. Additionally, we discuss that the difference in the body core temperature elevation due to the effect of skin thickness.

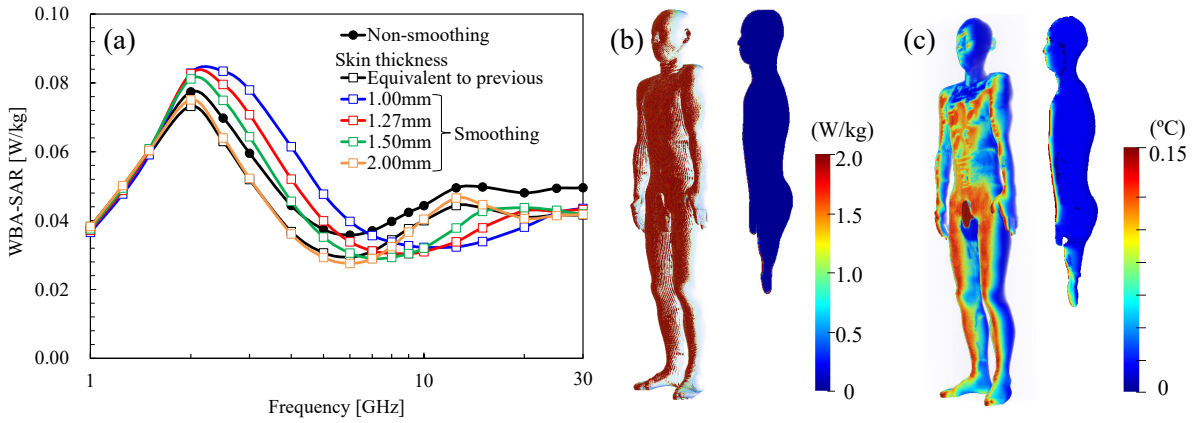

Figure 1. (a) Frequency-dependence of whole-body average SAR, and the distribution of (b) SAR and (c) temperature elevation at 30 GHz under the ICNIRP reference levels for general public.

References

[1] IEEE Std C95.1-2019, "IEEE standard for safety levels with respect to human exposure to electric, magnetic and electromagnetic fields, 0 Hz to 300 GHz," *IEEE Std*, 2019.

[2] ICNIRP, "Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)," *Health Phys.*, vol. 118, pp. 1–25, 2020.

[3] T. Nagaoka, S. Watanabe, K. Sakurai, et. al, "Development of realistic high-resolution whole-body voxel models of Japanese adult males and females of average height and weight, and application of models to radio-frequency electromagnetic-field dosimetry," *Phys. Med. Biol.*, vol. 49, no. 1, pp. 1–15, 2004.

[4] K. Taguchi, T. Kashiwa, and A. Hirata, "Development on high resolution human voxel model for high frequency exposure analysis," *Prog. Electromagn. Res. Symp. Abstr.*, p. 220, 2018.

[5] H. H. Pennes, "Analysis of tissue and arterial blood temperatures in the resting human forearm.," *J. Appl. Physiol.*, vol. 1, no. 2, pp. 93–122, 1948.