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Design of Human-Skin Equivalent Phantom for Evaluating the Surface Temperature Elevation due to Millimeter Wave Exposure

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Use of Millimeter wave (MMW) frequencies in 5G and WiGig wireless devices will increase the public concerns on human safety for electromagnetic fields exposure. Major health effects due to MMW exposure are the local temperature elevation on the skin surface. To evaluate the heating effects caused by wireless devices employing MMW frequencies, it is essential to develop a human-skin equivalent phantom to represent the required surface temperature elevation on a multi-layer skin model.

In this study, we propose a design method of human-skin equivalent phantom at MMW frequencies. We focused on a typical semi-solid agar phantom comprised of water and glycerin [1]. Firstly, we derived the relative complex permittivity ε_{r} of the phantom using the Cole-Davidson model, which is a dispersion model for representing the standard liquid, e.g., ethanediol, as expressed by the following equation,

$$\varepsilon_{\mathrm{r}}(f,u) = \varepsilon_{\infty}(u) + \frac{\Delta(u)}{\left\{1+\left(i\frac{f}{f_r(u)}\right)\right\}^{\beta(u)}}, \qquad (1)$$

where u and f denote the water content and frequency, respectively. f_r and ε_{∞} indicate the relaxation frequency and the relative permittivity at $f \gg f_r$, respectively. Δ and β are the magnitude of the dispersion and the distribution parameter, respectively. Here, we investigated the correlation between the parameters and u based on the measured dielectric data of several phantoms using a coaxial sensor from 1 to 100 GHz [2]. The phantoms utilized in the experiment have different water contents from 40 % to 80 %. We found that the dielectric data obtained by (1), in which parameters are represented by polynomial functions, showed a good agreement with the measured data. Secondly, the composition of the human equivalent phantom was determined.

Here, we aimed to obtain the same steady-state temperature elevation by MMW exposure to the skin tissue [3]. To do this, one-dimensional heat conductance equation was analytically solved for plane-wave exposure to a flat phantom. The required composition of the phantom u was determined at each frequency from 6 to 90 GHz. Furthermore, the result was demonstrated by comparing the computational simulation and measurement for the exposure using a standard horn antenna at 60 GHz. It is expected that the proposed phantom feasibly estimates the surface temperature elevation at steady states by the exposure from 6 to 90 GHz.

1. K. Ito, K. Furuya, Y. Okano, and L. Hamada, “Development and Characteristics of a Biological Tissue-Equivalent Phantom for Microwaves”, *Electronics and Communications in Japan*, **84**, 4, Dec. 2001, pp. 67–77.
2. K. Sasaki, Y. Ishimura, K. Fujii, K. Wake, S. Watanabe, M. Kojima, and O. Hashimoto, “Dielectric Property Measurement of Ocular Tissues up to 110 GHz Using 1 mm Coaxial Sensor,” *Physics in Medicine and Biolgy*, **60**, August 2015, pp. 6273-6288.
3. K. Sasaki, M. Mizuno, K. Wake, and S. Watanabe, “Monte Carlo simulations of skin exposure to electromagnetic field from 10 GHz to 1 THz,” *Physics in Medicine and Biolgy*, **62**, July 2017, pp. 6993-7010.