An Effect of Skin Modeling on Temperature Elevation by Millimeter-Wave and Terahertz-Wave Exposure Using a Two-Dimensional Forearm Model

Kensuke Sasaki and Soichi Watanabe
National Institute of Information and Communications Technology, Tokyo, Japan

Extended Abstract

The continuous growth of wireless data traffic is expected with the development of high-speed wireless communication technologies using millimeter wave (MMW) and terahertz (THz) wave bands. Thus, research and development using these frequency bands are recent topics. As an example, a wireless LAN system using the 60 GHz band (called WiGig or IEEE802.11ad) is now commercially available. Furthermore, the use of MMW frequencies is expected in 5th generation (5G) mobile and wireless communications technologies. The expansion of these new technologies will increase the public exposure to MMWs and THz waves; thus, an assessment of the safety of exposure to electromagnetic waves is a high priority.

Thermal hazard of the skin is the dominant health effects of exposure to MMW and THz frequencies. This is because energy absorption concentrates over surface tissues on the body and elevates the surface temperature; the penetration depth of electromagnetic fields into the skin is approximately 4 mm at 10 GHz and decreases to 0.1 mm order with increasing frequency. Therefore, a dosimetric study is necessary to clarify the relationship between the exposure and the temperature elevation at the skin surface. Modeling of the skin is expected to be important for precise assessment; the skin has a laminated structure comprising the epidermis and dermis[1]. Alekseev and Ziskin suggested the effect of blood flow to temperature elevation caused by the skin exposure to MMW using a multilayer plane model[2]. A remarkable fact is that there are no blood vessels inside the epidermis; thus, it may work to suppress the diffusion of heat. From this background, in this study, we aim to clarify the effect of skin modeling on temperature elevation by electromagnetic wave exposure at frequencies from 10 to 1000 GHz. For this purpose, temperature elevation due to the exposure was assessed using the measured dielectric properties of the tissues composing the skin. Here, the dielectric properties of the tissues were updated from those in previous works, and temperature elevations were quantified by the numerical calculation of the bioheat equation[3] using a two-dimensional arm model.

In this study, we firstly summarize dielectric properties of tissues in previous studies, and then dielectric properties were measured for the tissues with no data, namely, the dermis, subcutaneous tissue, and muscle. Secondly, temperature elevations were estimated using the two-dimensional forearm model. Here, two steps were taken to derive the temperature elevation by the exposure; energy absorption by the skin was quantified by electromagnetic field analysis, and the bioheat equation[3] was solved numerically using the result of the electromagnetic field analysis. Two skin models were used for the temperature elevation analysis. In one model, the skin is composed of epidermal and dermal regions, whereas homogeneous skin is assumed in the other model. The difference between the two skin modes is that blood circulation is not considered in the epidermal region of the model with the epidermis. The results indicated that the epidermis affects to increase the temperature elevation compared with that obtained using the homogeneous skin model. However, the effect of the skin model is not remarkably high; the discrepancies in the temperature elevations between the skin models are lower than 10%. This finding suggests that the homogeneous skin model can be used for the assessment of the temperature elevation over the surface of the body by exposure to MMW and THz frequencies.

Acknowledgement

This work was supported by the Ministry of Internal Affairs and Communications, Japan.

References

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