Calculation of SAR and Temperature in Pregnant Female Models for a Half-Wavelength Dipole Antenna at 900 MHz and 2 GHz

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***Abstract* - We calculated the specific absorption rate (SAR) and temperature in pregnant female models exposed to a half-wavelength dipole antenna at 900 MHz and 2 GHz. In this calculation, we used Japanese pregnant female models with gestational ages of 13, 18, and 26 weeks. We placed the antenna at the position 10 mm ahead of the abdomens of the maternal bodies. The feeding points of the antenna were the heights of the centers of the fetus heads in the pregnant female models. From the calculation results, we found that the peak 10-g-averaged SARs of the fetuses were considerably lower than those of the maternal bodies, the peak 10-g-averaged SAR and the peak temperature elevations in the fetuses tended to increase with fetal growth, and the temperature elevation in the fetuses was markedly affected by the placenta.**

***Index Terms* — EMF safety, Fetus, Specific absorption rate, Temperature elevation, FDTD method.**

1. Introduction

With the progress of wireless communication technology, the range of use of wireless communication equipment has diversified, and the electromagnetic environment surrounding us has changed considerably. On the other hand, there is concern about the safety of electromagnetic fields (EMFs).

In this study, we present the specific absorption rates (SARs) and temperature elevation in female models exposed to EM waves from a half-wavelength dipole antenna at 900 MHz and 2 GHz at three different stages of pregnancy.

2. Computational Models of Pregnant Humans

We used Japanese pregnant female models at 13, 18 and 26 weeks of pregnancy [1], as shown in Fig. 1. The pregnant female models were developed by combining a model fetus including gestational tissues, constructed on the basis of abdominal magnetic resonance imaging data acquired from a healthy female at 26 weeks of pregnancy and that of a Japanese adult female [2] deformed the abdomen by applying the free-form deformation algorithm [3]. Gestational tissues such as the fetus and placenta including the pregnant female models are represented on the basis of International Commission on Radiological Protection (ICRP) anatomical reference data [4]. These models are composed of voxels of 2 × 2 × 2 mm^3 and divided into 56 different tissues including gestational tissues (fetal body, fetal brain, fetal eyes, amniotic fluid, and placenta).

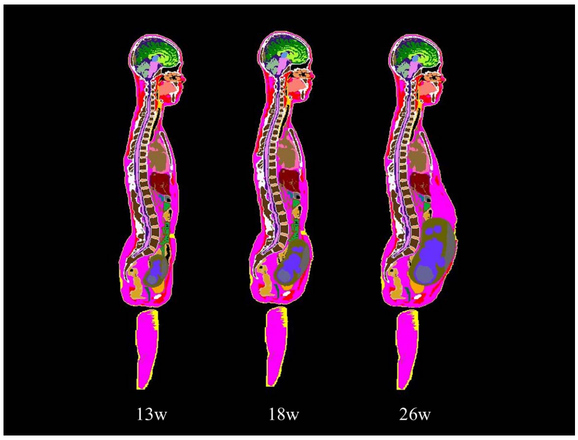

Fig. 1. Pregnant female models.

3. Calculation Model

We placed the half-wavelength dipole antenna at the position 10 mm ahead of the abdomens of the maternal bodies. The feeding points of the antenna were the heights of the center of the fetal head in the pregnant female models. The output power of the antenna was assumed to be 0.25 W. We calculated the SAR by the finite-difference time-domain (FDTD) method and employed a perfectly matched layer (eight layers) as the absorbing boundary condition. The cell size for the calculation was 2 × 2 × 2 mm^3. Furthermore, we solved the bio-heat transfer equation by assuming the SAR as an external heat source and estimated the temperature elevation. The electrical and thermal constants of the organs and tissues in the pregnant female models are obtained from a previous paper [5].

4. SAR and Temperature Calculation

(1) SAR

Fig. 2 shows the peak 10-g-averaged SARs in the pregnant female models for both frequencies. The SARs in the fetuses are lower than half of those of the maternal body and increase with fetal growth.

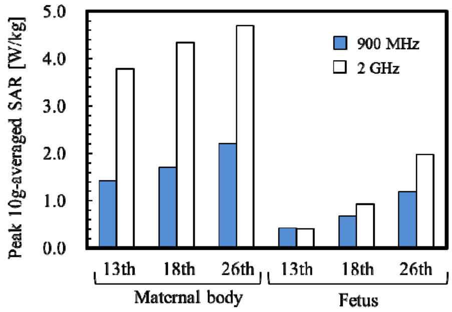

Fig. 2. Peak 10-g-averaged SARs.

(2) Temperature Elevation

Figs. 3 and 4 show the SAR and temperature elevation distributions on the fetuses at 26 weeks and the peak temperature elevation in the fetuses, respectively. The temperature elevation distribution differs from the SAR distribution. The peak temperature elevation in the fetuses trended to increase with fetal growth, similarly to the result of the SAR. The peak temperature elevation is lower than 0.2 ℃

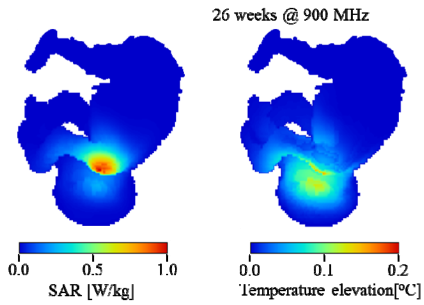

Fig. 3. SAR and temperature elevation distributions.

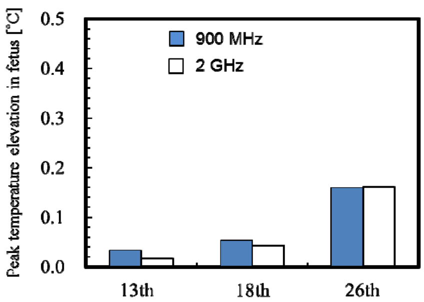

Fig. 4. Peak temperature elevations.

(3) Impact of Placenta

The placentas in the Japanese pregnant female models are ventral midline. The SARs in the fetuses are high near the placenta, which provides cooling due to blood flow. The position of the placenta varies with the individual. We may have underestimated the temperature elevation in the fetuses. Therefore, we evaluated the effect of the presence or absence of the placenta on the SAR and the temperature elevation in the fetus. In this evaluation, we replaced the placenta in the pregnant female models with amniotic fluid. The SAR and temperature elevation distributions with and without the placenta are shown in Fig. 5. The temperature elevation distributions were significantly different between the cases with and without the placenta, while the SAR distributions were similar. The peak temperature elevation in the fetuses without the placenta was up to approximately 6 times higher than that with the placenta.

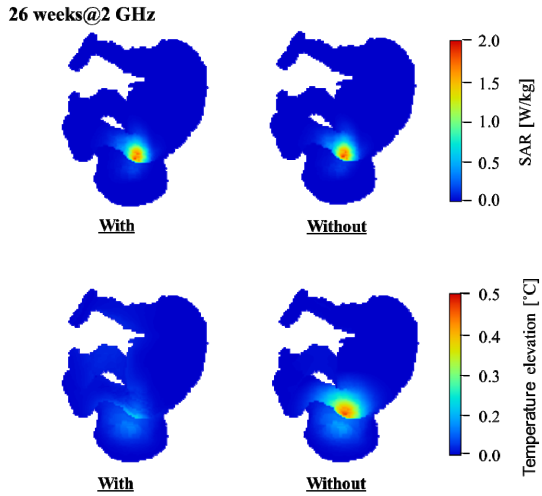

Fig. 5. Comparison between cases with and without placenta.

5. Conclusions

We calculated the SARs and temperature elevations in pregnant female models with gestational ages of 13, 18, and 26 weeks exposed to a half-wavelength dipole antenna at 900 MHz and 2 GHz. We found that the peak 10-g-averaged SARs in the fetuses were considerably lower than those of the maternal bodies, the peak 10-g-averaged SAR and the peak temperature elevations in the fetuses trended to increase with fetal growth, and the temperature elevation in the fetuses was markedly affected by the placenta.

References

[1] T. Nagaoka, K. Saito, M. Takahashi, K. Ito, S. Watanabe, "Anatomically realistic reference models of pregnant women for gestation ages of 13, 18, and 26 weeks," *Proc. 30th Ann. Intl. Conf. of the IEEE EMBS*, pp. 2817-2820, 2008.

[2] T. Nagaoka 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, pp. 1–15, 2004.

[3] T.W. Sederberg, S.R. Parry, "Free-form deformation of solid geometric models," *ACM Siggraph Conference Proceedings*, 1986.

[4] A. Tateno et al., Specific absorption rate and temperature elevations due to wireless radio terminals in proximity to a fetus at gestation ages of 13, 18 and 26 weeks," *IEICE Trans. Commun.,* vol. E97-B, no. 10, pp. 2175-2183, 2014.

[5] ICRP, "Basic anatomical and physiological data for use in radiological protection: reference values," ICRP Publication 89, 2002.