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Specific absorption rate and temperature increase in pregnant women at 13, 18, and 26 weeks of gestation due to electromagnetic wave radiation from a smartphone

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Abstract: Nowadays, mobile communication technology has become essential; thus, it is important to consider the effect of electromagnetic radiation from mobile terminals such as smartphones on the human body. In this study, we calculated the specific absorption rate (SAR) and temperature increase in pregnant women exposed to a smartphone's radiation at 13, 18, and 26 weeks of gestation. The results indicate that the SARs were much lower in fetuses than in pregnant women under all of the calculation settings in this study. Moreover, the maximum temperature increases in fetuses were half of those in pregnant women.

Keywords: specific absorption rate, temperature increase, smartphone
Classification: Electromagnetic Compatibility (EMC)

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1 Introduction

With the continuous expansion of mobile communication networks and the development of new mobile terminals such as smartphones and tablet PCs, people's lives have improved. We have previously used mobile terminals for voice calls. However, we frequently used novel mobile terminals not only for voice calling but also for data communication. If pregnant women perform data communications near the abdomens using the novel mobile terminals, the distance between the fetuses and the terminals become very close. In this kind of environment, the numerical dosimetry for fetuses during pregnancy is one of the most important issues in electromagnetic (EM) field safety [1, 2]. Tateno et al. consider SARs and temperature rises in bodies during pregnancy radiated by simplified EM source such as a dipole antenna [3]. Chiaramello et al. evaluating SARs in a fetus body radiated by tablet PC, but they did not consider the temperature increase [4]. Therefore, in this study, we estimate SARs and temperature increase by using high-resolution computational smartphone model.

2 Calculation models

In this study, we used computational whole-body pregnant woman models for gestational ages of 13, 18, and 26 weeks [5, 6], and a computational smartphone model [7]. Fig. 1(a) shows the pregnant woman model at 26 weeks of gestation. The pregnant woman models are composed of 56 types of tissues and organs. The abdominal dimensions of the models for each week of pregnancy are adjusted to those of average Japanese pregnant women. Masses of fetal tissues are also adjusted to anatomical reference data [8]. Fig. 1(b) shows the smartphone model

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that was developed on the basis of an actual smartphone sold in Japan. The validity of the smartphone model was confirmed by comparing the SAR distributions between the smartphone model and the actual equipment [7].

The calculation model is shown in Fig. 1(c), (d). The smartphone model was placed horizontally at the front of the navel of the pregnant woman model. The shortest distance between the surface of the body and the edge of the smartphone was fixed at 10 mm. A perpendicular bisector of the short side of the smartphone is orthogonally crossed to the midsagittal plane of the body. Operating frequencies of the smartphone were 900 MHz and 2 GHz, and the maximum radiated power was fixed at 0.25 W in consideration of the maximum power of the third-generation mobile communication system. We calculated SARs and temperature increases in the calculation models using XFdtd ver. 7.5 (Remcom Inc., State College, PA, USA). The calculation region was divided into approximately 200 million cuboids varying from 0.2 to 1 mm for each edge. The tissue properties of the pregnant woman models were described by Tateno *et al.* [3]

3 Results and discussion

The peak 10-g-averaged SARs in the pregnant women models are shown together with the SARs in non-pregnant woman model [7] in Table I(a). The SARs were higher at 900 MHz than at 2 GHz in the fetuses, although the SARs in the pregnant women were higher at 2 GHz. The reason for this difference can be explained by penetration depth of the EM waves. For example, penetration depth of the muscle at 900 MHz and 2 GHz are 42 and 26 mm, respectively. Thus, the penetration depths of the anatomical tissues at 2 GHz are shallower than those at 900 MHz. Therefore, EM energy at 2 GHz were mainly absorbed in the maternal body, whereas the EM energy at 900 MHz could reach the fetal body more than 2 GHz.

The SARs in the pregnant women increased with the progress of pregnancy regardless of the operating frequencies of the smartphone. On the other hand, the SARs in the fetuses showed tendencies different from those in the pregnant women, and they were the highest at the gestational age of 18 weeks. In this study, the placement of the smartphone was determined on the basis of the navel of the pregnant women. In the case of 18 weeks of gestation, the distance between the smartphone and the fetus was the closest. Therefore, the SARs in the fetuses are the highest at 18 weeks of gestation. However, the highest fetal SAR was much lower (approximately up to one-fourth) than the maternal SAR under the same configuration and operating frequency. We also confirmed that the SARs in pregnant women and fetuses were much lower than the basic restriction of the general public recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [9].

We compared the 10-g-averaged SARs of this study with the results by simplified sources, namely, dipole antennas and planar inverted-F antennas (PIFAs) with a metallic case [3]. The peak maternal SARs due to EM radiation from the dipole antennas and the PIFAs were 4.70 and 1.66 W/kg, respectively. Moreover, the peak fetal SARs were approximately 1.88 and 0.83 W/kg, respectively. In the previous study [3], the positions of the wave sources were determined in relation to

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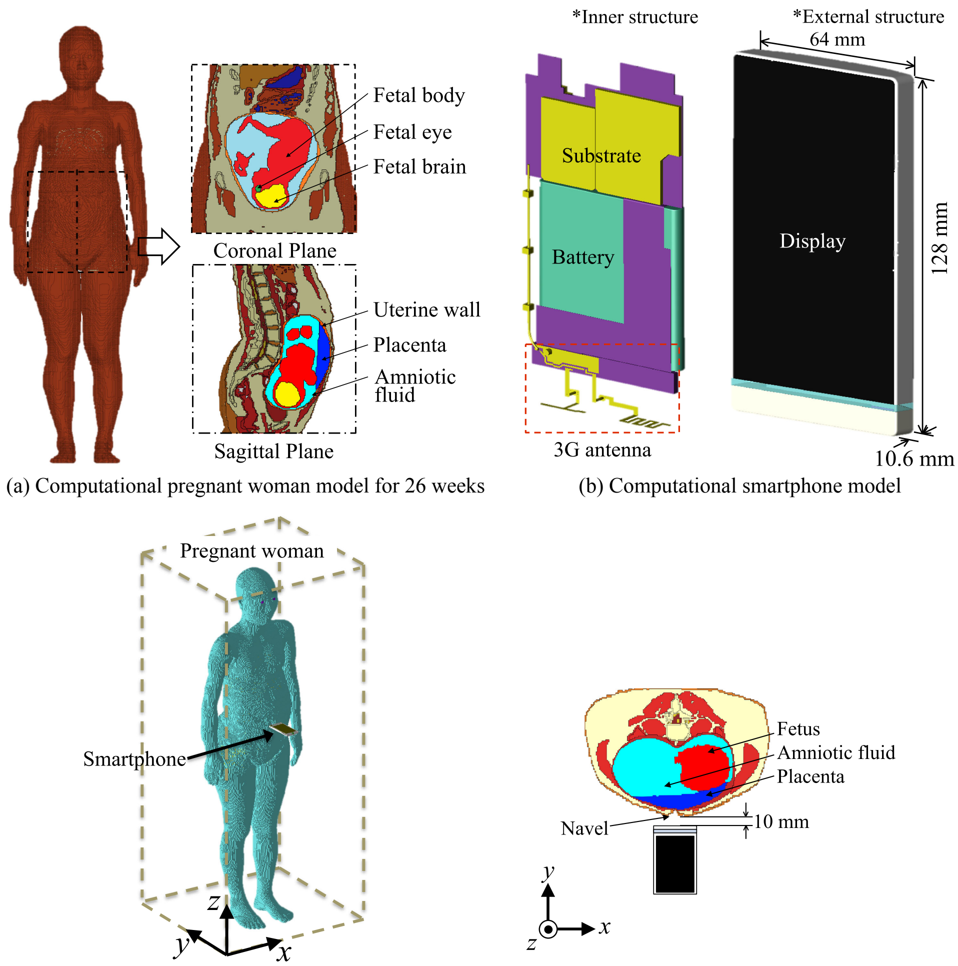

(a) Computational pregnant woman model for 26 weeks (b) Computational smartphone model

(c) Overall view of the calculation model (d) Transverse plane of the calculation model

Fig. 1. Calculation model intended for using the smartphone for data communication.

the position of the fetal head. The peak 10-g-averaged SARs when the smartphone model was placed in the same condition as [3] are shown in Table I(b). The SARs in the pregnant women and the fetuses for the smartphone radiation were the highest at 26 weeks of gestation, like the results for simplified sources. Moreover, the SARs in the pregnant women and the fetuses for the smartphone were much lower than those for the simplified sources. This is because of the difference in the near field pattern between the simplified sources and the smartphone.

Table I(c) shows peak temperature increases in the pregnant women and the fetuses. The temperature increases in the fetuses as well as the SAR results were highest at 18 weeks of gestation, and the maximum increase was 0.017 K. Therefore, the temperature increases in the fetuses were significantly less than temperature increase (1 K) which is known to cause adverse health effects such as growth retardation for the fetuses of many animals [10]. We also confirmed that the temperature increases in the fetuses were less than half of those in the pregnant women.

Fig. 2 shows the distributions of temperature increases on the midsagittal plane of the pregnant women at 18 and 26 weeks of gestation due to EM exposure from the smartphone operated at 2 GHz. We confirmed that the temperature increases

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Table I. Peak values of SAR and temperature increase in pregnant women and fetuses

(a) Peak 10-g-averaged SAR [W/kg] in the case:
smartphone was placed at the front of the maternal navel

@ Mother (@ Fetus)	Non-pregnant [7]	13 weeks	18 weeks	26 weeks
900 MHz	0.12 (–)	0.12 (0.004)	0.13 (0.035)	0.15 (0.012)
2 GHz	0.19 (–)	0.26 (0.001)	0.22 (0.025)	0.33 (0.006)

(b) Peak 10-g-averaged SAR [W/kg] in the case:
smartphone was placed in the same condition as [3]

@ Mother (@ Fetus)	13 weeks	18 weeks	26 weeks
900 MHz	0.15 (0.011)	0.11 (0.024)	0.35 (0.051)
2 GHz	0.18 (0.005)	0.18 (0.018)	0.41 (0.060)

(c) Peak temperature increase [K] in the case:
smartphone was placed at the front of the maternal navel

@ Mother (@ Fetus)	13 weeks	18 weeks	26 weeks
900 MHz	0.025 (0.002)	0.030 (0.013)	0.017 (0.006)
2 GHz	0.053 (0.001)	0.057 (0.017)	0.043 (0.007)

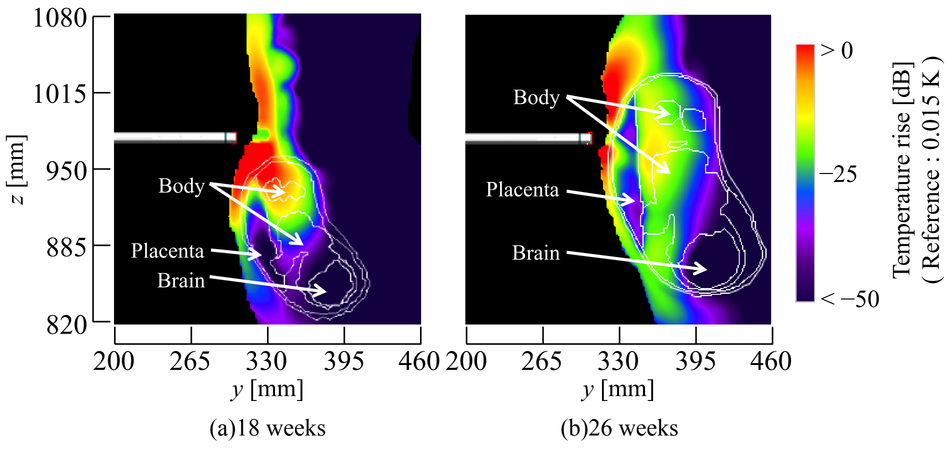

Fig. 2. Distributions of temperature increase on the midsagittal plane of pregnant woman models.

were suppressed in the placenta due to a large amount of blood flow. It is suggested that the placenta provides a strong cooling effect for both the maternal body and the fetus. Therefore, when we evaluate the temperature increases in a fetus, the positional relationships among the smartphone, the placenta, and the fetus are of considerable importance. We also confirmed that the temperature increases in

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pregnant women and fetuses were much lower than the value (1 K) known to cause possibly adverse effects.

4 Conclusions

In this study, we estimated the SARs and temperature increases in the pregnant women and their fetuses when they use a smartphone close to the abdomen. Results showed that the 10-g-averaged SAR in the maternal body increased with gestational progress. The SARs in the fetus changed depending on the positional relationship between the smartphone and the fetus, and they were highest at 18 weeks of gestation in this study. Moreover, we confirmed that the temperature increases in the maternal and fetal bodies were higher at 18 weeks of gestation than at 26 weeks of gestation, because the placenta provided a strong cooling effect for both the maternal body and the fetus. This indicates that the positional relationship among the smartphone, the placenta, and the fetus is of considerable importance. We also confirmed that the SARs for the smartphone radiation were the much lower than those for the simplified sources radiation.

Finally, we confirmed that the 10-g-averaged SARs in pregnant women were much lower than the basic restriction of the general public recommended by the ICNIRP. We also found that the temperature increases in fetuses were significantly less than the value (1 K) known to cause possibly adverse effects.

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