A Study on the Evaluation of the Electromagnetic Exposure in the Human Fetus Model at 150 MHz

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Abstract – Many researchers have been conducted on the estimation of the SAR in the human body at many situations. However, little is known about the EM exposure in the human fetus, which is caused by the radiation from mobile communication devices. Therefore, in this paper, we investigate the EM exposure in the human fetus model, which is calculated by the FDTD method using three types of fetus models close to the 0.18λ dipole antenna at 150 MHz. As a result, it has been confirmed that the local SARs and the SAR distribution in the body of pregnant women are hardly due to the fetus size. Moreover, the increase in the local SARs at the fetus are proportional to the increase in the fetus size. Furthermore, the local 10 g average SAR in the fetus is 0.13 W/ kg at the maximum size when the input power of the antenna is 1.0 W.

I. Introduction

In the past few years, the personal communication devices, which are usually used in the vicinity of the human body, become popular. Hence, the need for evaluating the interaction between the human body and the electromagnetic (EM) field is increasing. In the radio frequencies, the primary dosimetric parameter for the evaluation of EM exposure is the specific absorption rate (SAR).

Portable radio terminals for business purposes at 150 MHz are usually used in a radio set attached to the human abdomen [1]. In addition, the EM waves at 150 MHz can penetrate into the human body more easily than those at the frequencies of cellular phones. Therefore, it is important to evaluate the SAR in the organs, to confirm the EM-safety problem by use of the portable radio terminals at 150 MHz. In particular, the precision evaluation of the SAR at the fetus in pregnant women is indispensable.

In this paper, we investigate the EM exposure in the fetus models, which is caused by the radiation from antennas of the portable radio terminals at 150 MHz. For one thing, three types of fetus models, composed of a layered spherical uterus and a cylindroid body of pregnant women, are proposed. For another, the local SARs and the SAR distributions in the fetus models are calculated by the FDTD method.

II. Numerical Models and FDTD calculations

A. Numerical Models

Figure 1 shows a 0.18λ dipole antenna close to a cylindroid human model. The human model has an elliptical cross section with a major axis of 260 mm (0.13λ) and a minor axis of 180 mm (0.09λ), and it has a height of 500 mm (0.25λ) at 150 MHz. This model simulates the body figure of average Japanese women in their twenties [2].

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The 0.18λ dipole antenna replaces same axial length of the small radio terminals at 150 MHz [1]. Here, the antenna is attached close to the side of the abdomen, because it is difficult to the fixation of the terminals in front of the body for the pregnant women. In addition, the distance between the antenna and the surface of the human model is constantly 60 mm, to realize the actual situation. Moreover, the origin is directly under the feed point, which is on the phantom surface.

Figures 2 (a), (b), and (c) describe the structure of the fetus models. This model is composed of a layered spherical uterus and a cylindroid body of the pregnant women. The size of these models is referenced from the fetus weight in the fourth, sixth, and tenth month of pregnancy [3]. The uterus has the layered structure with the amniotic fluid and the fetus. The radiuses of the layered sphere, R_1, R_2 and R_3, are as shown in Table 1. Here, the center of the layered spheres in the z direction is constant. In addition, the inner edge of the uteruses is fit to the center of the human model.

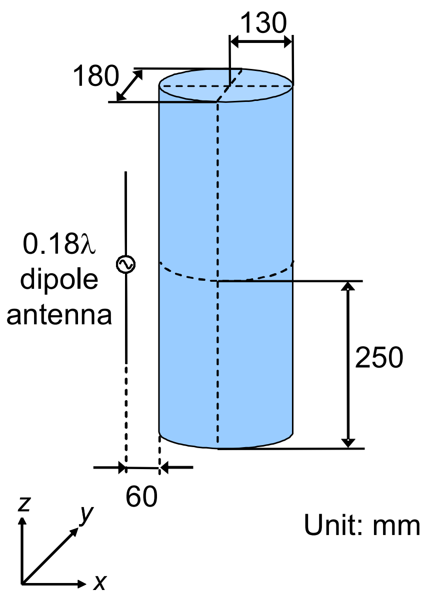

Fig. 1 Calculation model.

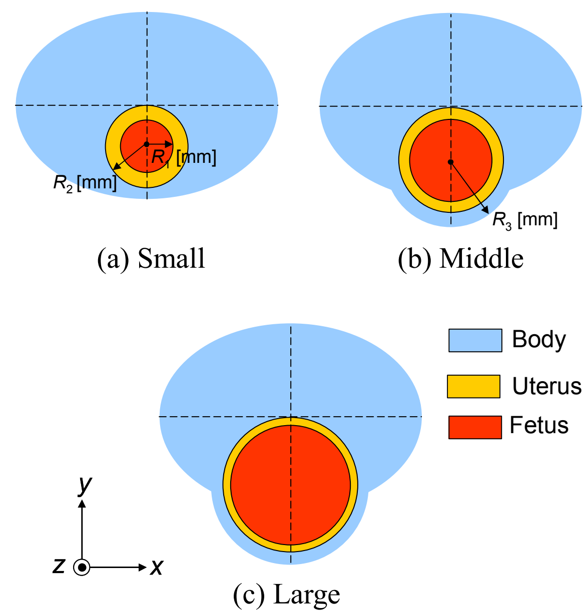

Fig. 2 Structure of fetus models (x-y plane, z=0).

Table 1 Size of fetus models.

Size	Small	Middle	Large
R_1 [mm]	30.0	52.5	90.0
R_2 [mm]	42.5	62.5	95.0
R_3 [mm]	-	72.5	105

B. Numerical Technique

The FDTD method is used for the SAR calculations in the human models. The parameters of the FDTD calculations are as follows: the FDTD space is 390 × 250 × 540 mm^3; the minimum cell size is 2.5 mm; the absorbing boundary condition is PML (eight layers); the time step of the FDTD calculations is 4.82 ps; the calculation time is 9 periods at 150 MHz, to get converged results.

Table 2 shows the parameters of the tissues. Here, the electrical properties of the human body are as a mixture of the human body tissues [5]. In addition, ε_r and σ of uterus are used the measurement data of the deionized water as the amniotic fluid, because the amniotic fluid is composed by the water over 98 % [3]. Moreover, the dielectric constants of the fetus are employed the brain, because the brain is the heaviest tissue in the fetus [3].

Table 2 Parameters of tissues.

Tissue	Body	Uterus	Fetus
ε_r	42.1	80.0	60.2
σ [S/m]	0.514	0.003	0.479
ρ [kg/m^3]	1,000	1,000	1,000

III. Results and Discussion

Figures 3 (a), (b), and (c) represent the SAR distributions in the fetus model on the *x-y* plane at $z = 0$. From now on, the input power of the antenna is normalized to 1.0 W. As can see from Fig. 3, it has been confirmed that the peak SAR and SAR distribution in the body of the pregnant women are hardly due to the variation in the fetus size. In addition, the SAR in the fetus is strongly attenuated at each model.

Table 3 describes the calculation results of the local SARs, which are the local peak SAR and 10 g average SAR, in the body of the pregnant women and the fetus. Here, the results of the local SARs in the uterus are omitted, because the SAR in the uterus is less than 10^{-3} W/kg. From Table 3, the increase in the local SARs at the fetus is almost proportional to the increase in the fetus size. Moreover, the local 10 g average SAR in the fetus is 0.13 W/kg at the maximum size. Furthermore, the local SARs in the fetus are less than 13% of that in the body at each model.

From Fig. 3 and Table 3, we could confirm that the EM exposure in the fetus is strongly attenuated by the distance between the feed point of the antenna and the surface of the fetus at each size.

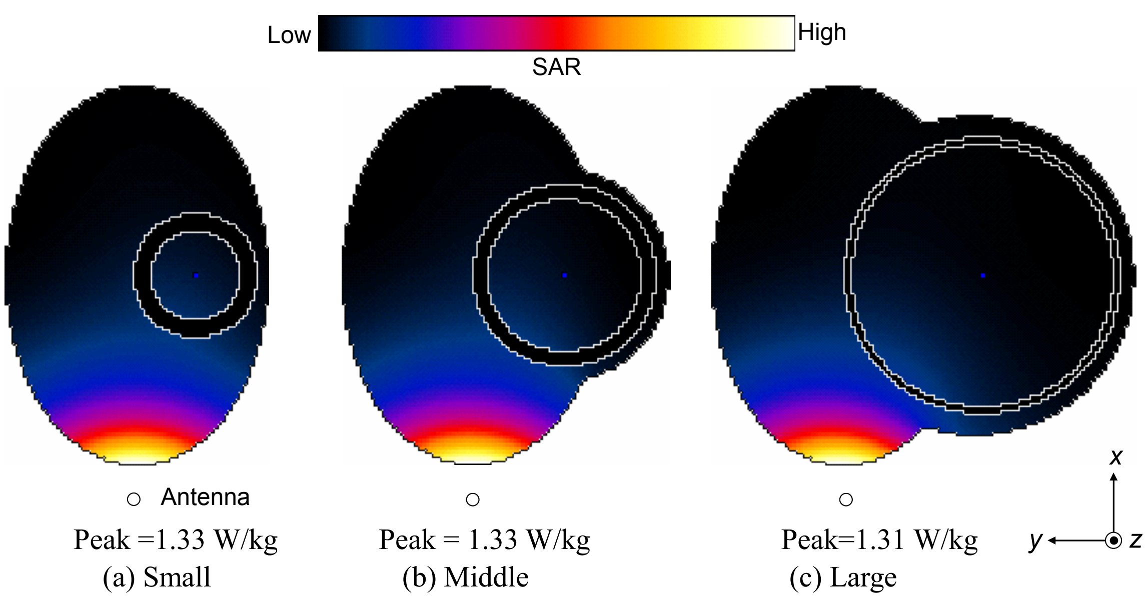

Fig. 3 SAR distributions in fetus models (*x-y* plane, *z*=0).

Table 3 Local SAR values in the body of pregnant women and the fetus.

Tissue		Body	Fetus
Peak SAR [W/kg]	Small	1.33	0.11
	Middle	1.33	0.13
	Large	1.31	0.17
10 g average SAR [W/kg]	Small	1.00	0.09
	Middle	1.00	0.11
	Large	0.96	0.13

IV. Conclusions

We have investigated the EM exposure in the fetus models, which is caused by the radiation from the portable radio terminals at 150 MHz. For one thing, the three types of fetus models, which were composed of the layered spherical uterus and the cylindroid body of pregnant women, were proposed. For another, the local SARs and the SAR distributions in the fetus models were calculated by the FDTD method. As a result, it has been confirmed that the local SARs and the SAR distribution in the body of the pregnant women are hardly due to the variation in the fetus size. Moreover, the increase in the local SARs at the fetus are almost proportional to the increase in the fetus size. Furthermore, the local 10 g average SAR in the fetus is 0.13 W/kg at the maximum size when the input power of the antenna is 1.0 W. From these results, we may conclude that the EM exposure in the fetus is strongly attenuated by the distance between the feed point of the antenna and the surface of the fetus at each size.

As a further study, the same investigation as above should be done using more realistic models and at higher frequencies.

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