Fetus RF exposure analysis. Preliminary results based on three realistic 3D digital models

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I Introduction

Mobile phones have been increasingly used over the 30 last years. The versatile use of personal Digital Assistant (PDA) is strengthening this tendency. In spite of existing protection limits (ICNIRP, IEEE) there is worldwide a public concern about the exposure to electromagnetic fields (EMF). Several expert groups have pointed out the need of research dedicated to children, pregnant women and fetus exposure. Recently the World Health Organization (WHO) has recommended the study of the EMF dosimetry on fetuses as a high-priority research topic. The estimation of the Radio frequency (RF) fetus exposure induced by wireless communication systems is complex since new technologies can be used in versatile ways and since the exposure depends on many parameters (usage, frequency, posture, age of fetus…).
The exposure assessment of fetuses is facing 3 major challenges. The first challenge is the limited number of existing anatomically corrects models of mother and fetus that can be considered reliable for the exposure assessment. The second challenge is the lack of tools allowing deforming the fetus and mother models in a correct anatomical way. The third challenge is the management of the complexity of this problem to assess the statistical distribution of the exposure and consequently the maximum exposure. The FETUS project, granted by ANR in France and JST in Japan, is dealing with these ambitious challenges. In this paper we present the works performed within this project to characterize the RF fetus exposure to far field exposure modeled using plane wave.

II Fetus and pregnant woman models

Prior to our project there were only few fetus models. To characterize the fetus exposure to EMF we developed three types of models. The first one is based on deformation of a non-pregnant woman heterogeneous model (Japanese woman) which was built from Magnetic Resonance Imaging (MRI) data, and in which a heterogeneous fetus model obtained from MRI data was inserted. The second type of model is based on a deformable synthetic woman (DSW) model composed of skin, fat, muscle, bone and a homogeneous tissue representing the other organs. In this DSW heterogeneous Uterus+Fetus models, built from the segmentation of 3D MRI data, were inserted; these models have various ages and postures. The last one is an MRI based model of a pregnant woman. In this case the images are limited to the thorax and abdomen of the pregnant woman.

Model 1:

In this model (see Figure 1) the fetus is a realistic model of a 26 weeks pregnancy fetus. The pregnant woman is based on the non-pregnant Japanese heterogeneous woman model Hanako that has been deformed to insert the fetus model.
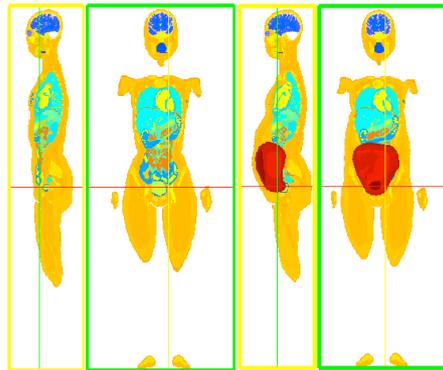

Figure 1. *Model 1 (left : non pregnant, right : pregnant)*

Model 2:

In a previous project called FEMONUM, antenatal images have been segmented at different stages of pregnancy. First these fetus models have been inserted in a completely homogeneous woman model coming from the software DAZ studio (www.daz3d.com) and called Victoria. To provide more realistic models, we developed in the ANR FETUS project a Deformable Synthetic Woman (DSW). This DSW is based on the initial homogeneous woman model with additional basic tissues such as skin, subcutaneous fat, muscles and bones in a realistic way, using physical properties (see Figure 2). The other organs are represented using a homogeneous tissue. The dielectric property of this tissue is determined using comparison with heterogeneous models. As shown in Figure 2 the deformation of this DSW allows inserting the Uterus+Fetus heterogeneous model.

Figure 2. *Fetus inserted in the deformable synthetic woman model*

Model 3:

As explained in the previous section, to compare to real configurations, pregnant woman images have also been segmented (see Figure 3). MRI images of a 19 weeks pregnant woman have been segmented and a 3D model has been created. Since these MRI were performed for medical diagnose there are limited to the fetus area. As a consequence and as shown in Figure 3, the model is truncated. But the distance from the border to the fetus is large enough to avoid spurious reflection if the frequency is above 900 MHz.
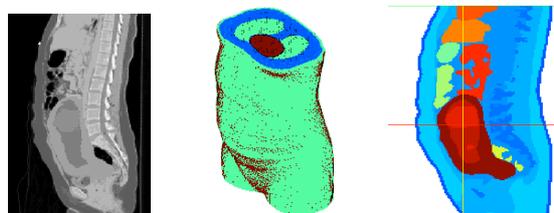

Figure 3. *Abdomen of a 19 weeks pregnant woman: 3D voxel model and sagittal view of the heterogeneous model*

III RF exposure analysis

The model 1 has been exposed to a frontal plane wave operating at 900 MHz (Figure 4). To do that a method based on finite difference (FDTD) has been used with plane wave excitation performed with a Huygens box.

The whole body absorption is almost the same for the pregnant woman than the non pregnant models as shown in Table 1. But as the pregnant woman is heavier, the whole body SAR of the pregnant woman is lower than for the non-pregnant woman. This result might be different for other incidences because the variations of highlighted surfaces might be more important by side for example than by front.
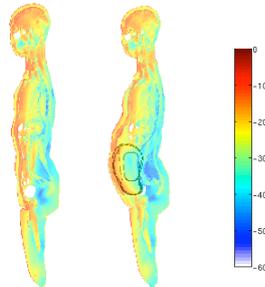

Figure 4 *Normalized SAR (color scaling in dB) induced in pregnant and non pregnant models by a frontal plane wave at 900MHz.*

The fetus absorbed about 0,1% of the whole power absorbed by the mother (Table 1). But this result might also change with the direction of arrival of the incident plane wave.

	Total power absorbed by the woman (mW)	WB SAR of the woman (mW/kg)	Power absorbed by the foetus (mW)	WB SAR of the foetus (mW/kg)
Non pregnant woman	1.304	0.025	×	×
pregnant woman (26 weeks)	1.301	0.022	1.36 10^{-3}	1,54 10^{-3}

Table 1 : Results in power and SAR for an incident plane wave at 900MHz with amplitude of 1V/m

The model 2 with homogeneous mother has also been exposed to a frontal plane wave. As shown in Figure 5 and Table 2, the fetus exposure is weak as it is with the previous model.
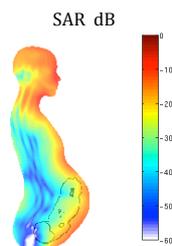

Figure 5 *Model 2 exposure to frontal plane wave operating at 900 MHz*

	Total power absorbed by the mother	WB SAR of the mother	Power absorbed by the foetus	WB SAR of the foetus
Homogeneous Pregnant Victoria (34 weeks)	0,997 mW	0,016 mW/kg	8,03 10^{-3} mW	2,99 10^{-3} mW/kg

Table 2 : Results in power and SAR for an incident plane wave at 900MHz with amplitude of 1V/m

To analyze the influence of the angle incidence the model 3 has been also exposed to plane wave having different angles. Figure 6 (a) shows the SAR in tissues in case of a frontal plane wave operating at 900 MHz, this figure shows that higher exposure tissues are located in the mother. The Figure 6 (b) shows also the normalized SAR induced in the fetus of the model 3 by a plane wave having different angle and

operating at three different frequencies (900, 1800 and 2450 MHz). The figure shows that the fetus exposure to plane wave depends on the incident angle. Of course, this result is also depending on the position of the fetus in the uterus of the mother.
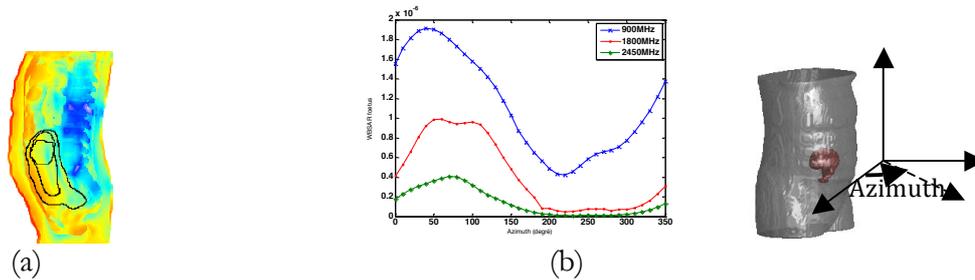

(a)   (b)

Figure 6. *Normalized SAR induced by a frontal plane operating a 900 MHz wave in model 3 tissues (a) and WBSAR induced in the fetus at three different frequencies and for different incident angles in an horizontal plane (b)*

IV Conclusion

The studies carried on in the FETUS project on various fetus and pregnant women models show that the fetus exposure depends on several parameters such as the fetus posture or the incident angle of the wave. This study also shows that the exposure (whole body averaged SAR) of the fetus is well below the mother one. These preliminary results will be extended in our future work.

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