Influence of the ear's morphology on Specific Absorption Rate (SAR) Induced in a Child Head using two source models.

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***Abstract* — In this paper, an investigation is elaborated for the Specific Absorption Rate (SAR) induced in the head of 12 years old children having different ear dimensions. Two types of sources are employed : a mobile phone and a dipole. Both the average SAR over a mass of 10g and 1g in the head and the power budget are determined in each tissue using the Finite Difference Time Domain (FDTD) method. The differences between the results for different ear dimensions are given at 900MHz and 1800MHz. The mean and standard deviation about the SAR and power budget are also given for this age class.**

***Index Terms* — FDTD, Dosimetry, Child RF exposure, Mobile phone.**

I. INTRODUCTION

The wireless communications operators use more and more systems based on the transmission and reception of electromagnetic waves. Nowadays many questions are raised on a public level related to the interference of these waves with existing electronic systems as well as others related to the possible biological effects associated to these electromagnetic waves. With the increase number of children using a mobile phone there is a public concern about the nature and degree of absorption of electromagnetic waves by this public class as a function of their age and their morphology. At the international level, the WHO (World Health Organization) recommended that studies have to be undertaken on this subject.

Previous studies have been carried out [1-4] to analyze the energy absorption of radiofrequency (RF), induced in the head with a mobile phone. This energy deposition has been compared to the energy absorption observed for adults.

This paper presents a study of the influence of the child ear morphology on the obtained SAR (Specific Absorption Rate) values. For this purpose, a comparison is performed between the different ear dimensions for the same head of a 12 years old child (Fig. 1) concerning the SAR and the power budget. In each case, the head is exposed firstly to a dual band mobile phone and secondly to a reference dipole. The results are obtained using an electromagnetic field solver employing the Finite difference Time Domain (FDTD) method [5].

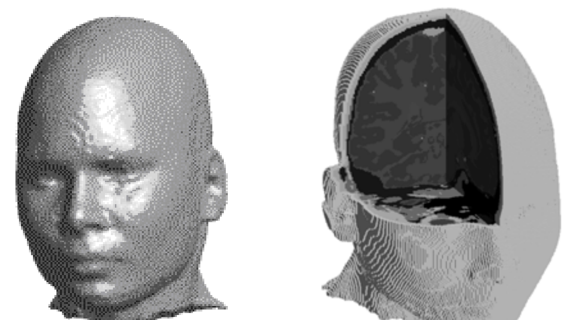

Fig. 1. Morphological description of the child head model

II. MODELING THE HEAD OF A 12 YEARS OLD CHILD

The model that we employed is a real heterogeneous 12 years child head obtained from a 3D magnetic resonance image (MRI). This image is segmented to identify the various biological tissues, which form the human head [9]. Once these tissues are identified, they are labeled in order to associate each tissue to its corresponding dielectric characteristics. The child head bounding box has a size of 175x205x241 mm^3 and the ear is contained in a parallelepiped of volume 18x39x59 mm^3. The ear's dimensions are given in Table I. It worths mentionning that some differences can be observed between the ear dimensions in the 12 years age class (Fig. 2).

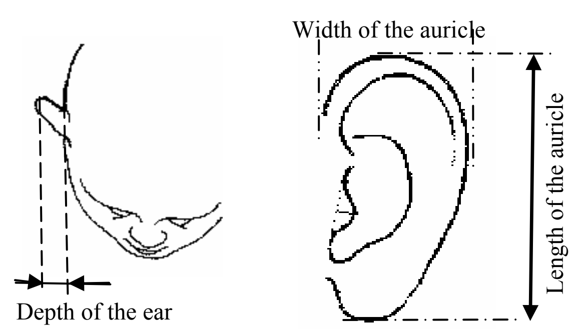

Fig. 2. Morphological description of the model ear

These differences have been studied [6] and statistical characteristics (mean and standard deviation) have been published (Tab. I).

TABLE I
EAR DIMENSIONS OF 12 YEARS OLD CHILD HEAD AND STATISTICS FOR THIS AGE CLASS

Ear	Length of the auricle	Width of the auricle	Depth of the ear
12 y. old Child head	59 mm	33 mm	10 mm
12 years age class	59,6 ± 3,6 (mm)	35,3 ± 2,3 (mm)	6 ± 4 (mm)

The different ear dimensions used in this study are given in Table II. Case 1 corresponds to an extreme compression of the ear while in case 5 no compression is applied (the normal ear of the child head).

TABLE II
DIFFERENT EAR DIMENSIONS

Ear dimensions	Length auricle (mm)	Width auricle (mm)	Depth ear (mm)
Case 1	56	33	2
Case 2	58	35	4
Case 3	60	37	6
Case 4	63	38	8
Case 5	59	33	10

For the two operating frequencies of 900 MHz and 1800 MHz, the dielectric characteristics of human living tissues are not the same, but the tissue permittivities and conductivities are the same as those for the adult head [7].

III. THE TWO SOURCE MODELS

The first source model is a dual-band mobile phone, which is characterized using the FDTD method. It is composed of the basic elements shown in Fig. 3, namely a battery, a patch antenna, a ground plane and a plastic layer surrounding the handset. Each of these elements has an influence on the antenna adaptation and its radiation pattern.

The second source model is a dipole. The antenna has a length of 0.5λ and a square section of $1mm^2$. The distance between the dipole and the head is the same whatever be the width of the ear. This distance is taken 2 cm.

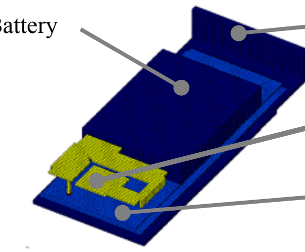

Fig. 3: The mobile phone model

IV. DOSIMETRIC COMPARISON

The source model is positioned close to the ear of the head. For each case of exposure, the absorbed power is calculated. This allows us to evaluate the power budget. The local SAR is defined as:

$$SAR = \frac{\sigma . E^2}{2\rho} \quad (1)$$

where E is the amplitude of the electrical field in the body tissue (V/m), σ is the tissue conductivity (S/m) and ρ is the tissue density (Kg/m^3). The "SAR10g" is the maximum SAR value averaged on 10g obtained by averaging the SAR around each point in the volume and adding the nearest points till an averaging mass of 10g with a resulting volume having the shape of a portion of sphere. The "contiguous SAR10g" is estimated by averaging the local maximum SAR, adding the highest SAR volume in a given tissue till a mass of 10g is reached.

The power budget for the different source models (Tab. III and IV) is approximately the same for all the studied cases at 900MHz. At this frequency, the injected power is distributed roughly as: 60% radiated and 40% absorbed, except for case 1 (small ear) using the mobile phone. On the other hand, for the handset and at 1800MHz, the phenomenon is reversed. This is due to the space distribution of the power density, in free space, which is different for the two frequencies [4]. At the frequency of 1800MHz for the dipole, the injected power is distributed as half absorbed and half radiated. Except for case 5, the results at 900MHz are similar to the mean ones obtained when using the handset.

TABLE III
POWER BUDGET FOR HANDSET

Handset	900 MHz		1800 MHz	
Case	**Absorbed Power**	**Radiated Power**	**Absorbed Power**	**Radiated Power**
Case 1	68 %	32 %	41 %	59 %
Case 2	60 %	40 %	36 %	64 %
Case 3	64 %	36 %	40 %	60 %
Case 4	56 %	44 %	35 %	65 %
Case 5	59 %	41 %	37 %	63 %
Mean result	61 ± 5 %	39 ± 5 %	38 ± 3 %	62 ± 3 %

TABLE IV
POWER BUDGET FOR DIPOLE

Dipole	900 MHz		1800 MHz	
Case	**Absorbed Power**	**Radiated Power**	**Absorbed Power**	**Radiated Power**
Case 1	62 %	38 %	44 %	56 %
Case 2	63 %	37 %	49 %	51 %
Case 3	62 %	38 %	52 %	48 %
Case 4	63 %	37 %	56 %	44 %
Case 5	65 %	35 %	61 %	39 %
Mean result	63 ± 1 %	37 ± 1	52 ± 7	48 ± 7

In our simulations, the calculated local SAR is lower than the limit of 2 W/kg given by ICNIRP (International commission on Non-Ionising Radiation Protection) [8]. The influence the ear's morphology on SAR values over 10g depends on the utilized antenna. At 900 MHz with a dipole, the SAR values are practically the same (Fig. 5). On other hand, at 1800 MHz the phenomenon is different. The SAR values increase with the increase of the width of the ear. When using the handset the opposite happens, i.e. the SAR values over 10g do not vary significantly at 1800MHz while they vary with the ear's morphology at 900MHz (Fig. 4).

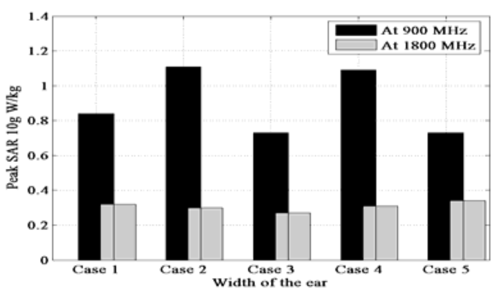

Fig. 4Peak SAR over 10g using a handset

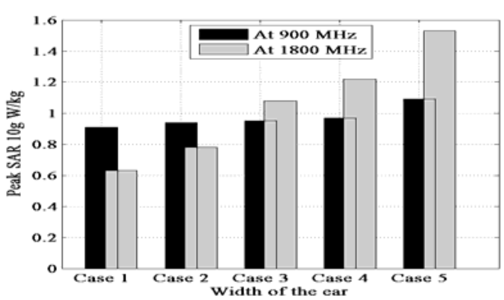

Fig. 5. Peak SAR over 10g using a dipole

When using the dipole, the SAR variation over 1g in skin or in brain at 1800 MHz is slightly higher than that at 900 MHz (Fig. 7 and 9). While when using a handset, the SAR variation in the skin and brain depends on the handset positioning and the ear morphology (Fig. 6 and 8).

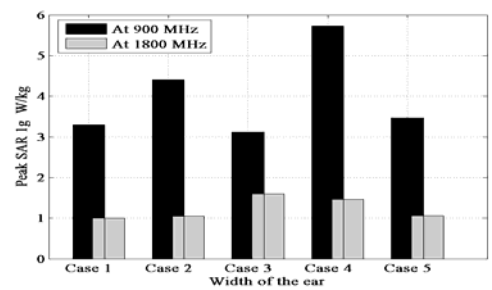

Fig. 6. Peak SAR over 1g contiguous in skin "Handset"

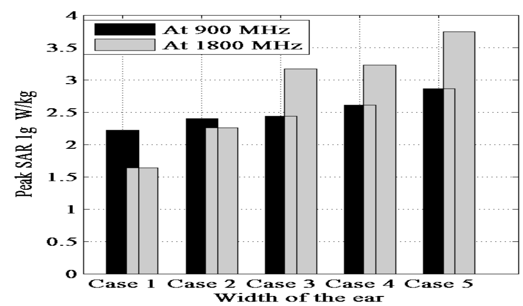

Fig. 7. Peak SAR over 1g contiguous in skin "Dipole"

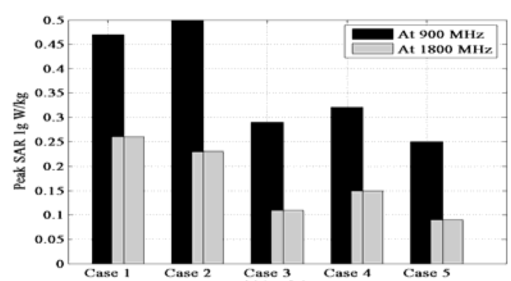

Fig. 8. Peak SAR over 1g contiguous in brain "Handset"

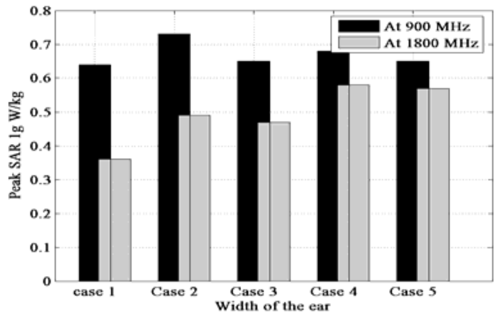

Fig. 9. Peak SAR over 1g contiguous in brain "Dipole"

CONCLUSION

A comparison of Specific Absorption Rates (SAR) induced in a child head with different ear dimensions is performed employing two source models: a dual band mobile phone having a patch antenna and a dipole. Both the average SAR over a mass of 10g in the head and the power budget are determined in each case, using the Finite Difference Time Domain (FDTD) method. The differences between the results for different ear dimensions are given at 900MHz and 1800MHz.

It is found that the power absorption in the brain of the child head depends on the ear's morphology (auricle's dimensions and ear's width) and on the used source, while it remains at a weak level of exposure.

In the case of a dipole at 900 MHz, no important difference in the SAR values over 1g in brain is found, between the different ear's dimensions, but when using a handset, the SAR values over 10g or 1g depend on the ear's morphology, and the positioning of the mobile with respect to the head.

It is important to put these results into their context and note that they are valid only for specific cases (specific model of source and child head with different ear's dimensions) and that the different models for the studied ears are built by deformation of a real ear of a 12 years old child.

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