INVESTIGATION ON SPECIFIC ABSORPTION RATE (SAR) INDUCED IN A CHILD HEAD AND A CHILD-LIKE HEAD USING TWO SOURCE MODELS.

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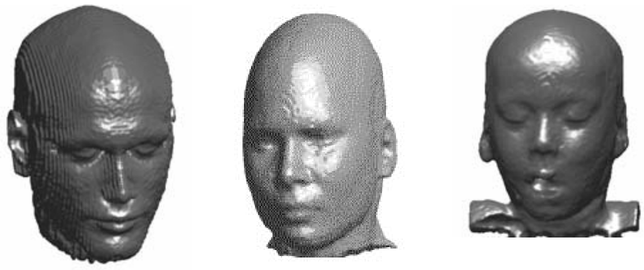
I. Introduction:

Nowadays the wireless communications operators use more and more systems based on the transmission and reception of electromagnetic waves. The increase of number of children using a mobile phone develops many questions about the nature and degree of absorption of electromagnetic waves by this category of public as a function of their age and their morphology. For this reason the World Health Organization (WHO) has recommended that studies have to be undertaken on this subject. In France the research program on dosimetric analysis of third generation mobile phone ADONIS [1] is investigating this question.

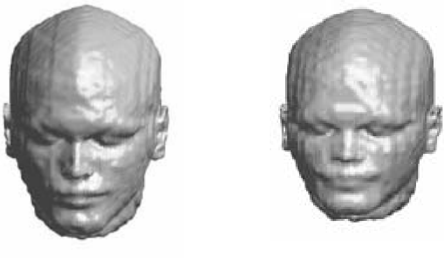
In this paper, we present a study contributing to answer this question. For this purpose, a comparison is performed concerning the Specific Absorption Rate (SAR) and the power budget between a real child head obtained from a 3D Magnetic Resonance Image (MRI) [2] and what is called Child-Like (CL) [3] head corresponding to an anisotropic scaling of an adult head. The results are obtained using an electromagnetic field solver employing the Finite Difference Time Domain (FDTD) method [4].

II. Modelling of a child head:

For this study, three head models are used namely: that of an adult, a 12 years and 4 years old (Fig.1). The utilized head model follow the human morphology and are heterogeneous. In the first case, the used models of child head for two age classes, 12 and 4 years old, are obtained from MRI. In the second case, the Child-Like (CL) head is built by morphing deformation of an adult head. Through the literature, the external shape of human heads and their transformation versus age have been analyzed [5]. The head has been divided into specific volumes having specific ratios (depending on the age) with respect to the adult one (Fig. 1. a). Using these ratios, an adult head has been resized by parts using relevant parameters and the head corresponding to 12 and 4 years old children have been built (Fig. 2). The real and CL heads have the same dielectric characteristics as the adult one.



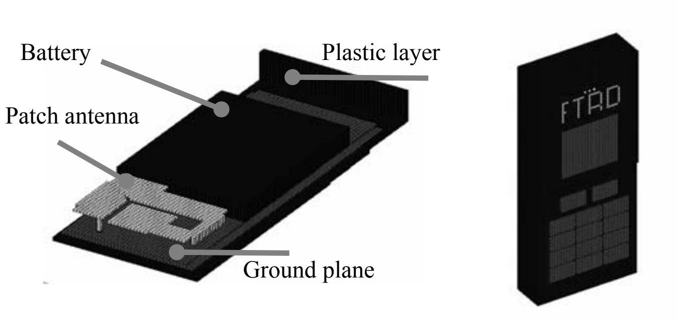
a. Adult head b. 12 years old head c. 4 years old head
Fig. 1. Morphological description of the human head.



a. CL 12 years old b. CL 4 years old
Fig. 2. Morphological description of the human CL

III. Modelling of the sources:

Two mobile phone models have been used. The first model is a tri-band mobile phone and is contained in a parallelepiped of 44 x 16 x 103 mm^3, which is characterized using the FDTD method, is composed of the basic elements shown in Figure 3 a., namely a battery, a patch antenna, a ground plane and a plastic layer surrounding the handset (Fig. 3. b). Each of these elements has an influence on the antenna matching and its radiation pattern. The antenna is designed to have a good return loss and a nearly omnidirectional radiation pattern at the frequencies of 900 MHz, 1800 MHz and 2100 MHz. To achieve this objective, a parametric study has been performed which enabled us to achieve a compromise between the elements dimensions and the distances separating them, valid for the three frequencies.



a. Inside view b. Outside view
Fig. 3. The Tri-band mobile phone model

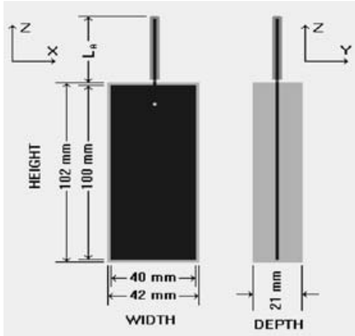


Fig. 4. The IEEE mobile phone model

The second one is the "IEEE" mobile phone (model proposed by Food and Drug Administration (FDA) for international a comparison study), which is composed of a solid plastic body 102 mm high, 42 mm wide, and 21 mm thick. An 1 mm thick, of perfect electrical conductor material is embedded in the body of the "IEEE" mobile phone (Fig. 4). The length of the antenna is 71 mm for the one utilized at 835 MHz and 36 mm for the one utilized at 1900 MHz [6].

This investigation is carried out firstly for the three frequencies, 900MHz, 1800MHz and 2100MHz using the Tri Band mobile phone and secondly for the two frequencies 835MHz and 1900MHz using the "IEEE" mobile phone. At each frequency, the dielectric characteristics of human living tissue constituting the head are set up according to [7], thus a simulation is carried out for each studied frequency.

The mobile phone is firstly analyzed in free space. Then it is positioned adjacent to the ear of each head models (Fig. 5). The presence of the head in front of the mobile phone modifies the radiation pattern of the mobile phone and its input impedance (Tab. 1). Figure 6 presents the radiation patterns at 835 and 1900MHz, for the standard "IEEE" mobile phone, in free space and in presence of the head. At 835MHz, in free space the radiation pattern is omnidirectional, while at 1900MHz, the radiation pattern is strongly attenuated in the plane transverse to the dipole.

For the Tri band mobile phone the radiation pattern in free space changes: it is omnidirectional at 900MHz, more directive at 1800MHz and less directive at 2100MHz (Fig. 7).


Fig. 5. Mobile phone is positioned against the ear.

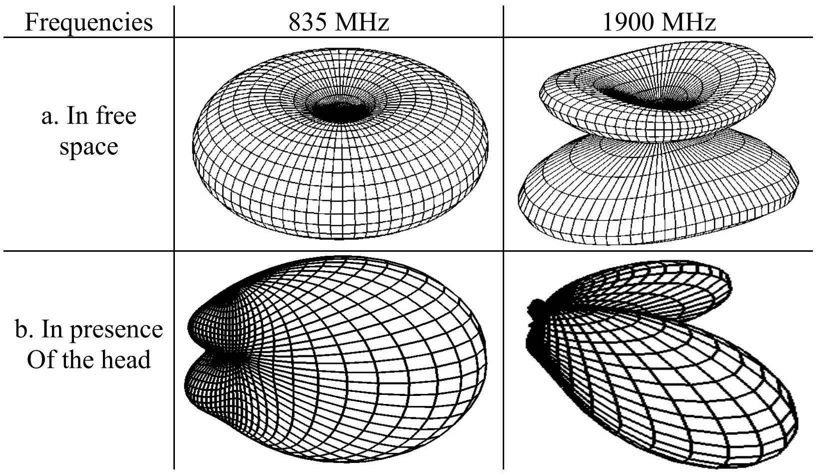


Fig. 6: Radiation pattern of mobile phone "IEEE". a. In free space and for each frequency. b. In presence of the head and for each frequency

Table I: phone input impedance for each simulation

Frequencies	900MHz	1800MHz	2100MHz	835MHz	1900MHz
	Impedance (Ω)	Impedance (Ω)	Impedance (Ω)	Impedance (Ω)	Impedance (Ω)
Free space	18 – 5 i	66 + 4 i	46 – 5 i	119 – 42 i	34 + i
Adult head	13 – 14 i	60 + 5 i	41 + 13 i	90 – 32i	64 + 11 i
CL 12 years old	14 – 13 i	63 + 10 i	49 + i	82 – 37 i	58 + 9 i
CL 4 years old	13 – 12 i	59 + 6 i	43 + i	89 – 25 i	65 + 10 i
Child 12 years old	11 – 13 i	54 + 2 i	90 – 43 i	85 – 38 i	72 + 8 i
Child 4 years old	14 – 13 i	57 + 4 I	40 + 16 i	77 – 41 i	55 + 15 i

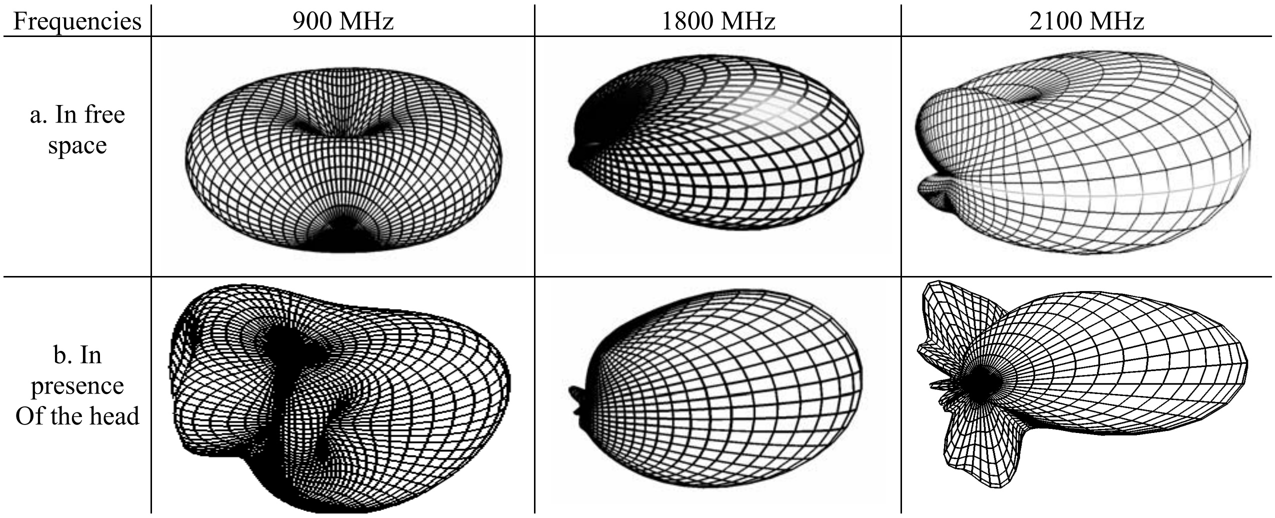


Fig. 7 Radiation pattern of mobile phone with patch antenna.
a. In free space and for each frequency. b. In presence of the head and for each frequency.

IV. Dosimetric calculations

The source model is positioned adjacent to the ear of each studied head. For each case of exposure, the absorbed power is calculated. This makes it possible to perform a power budget. The local SAR is defined as:

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

where E is the peak 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 SAR over a mass of 10g and 1g in the head and the power budget are determined in each tissue using the FDTD method. The differences between the results for different age classes are given for each frequency for each studied child head model. The "SAR 10g" is the maximum SAR value averaged on 10g which is obtained by averaging the SAR around each point in the volume and adding the nearest points till an average mass of 10g is reached with a resulting volume having the shape of a portion of sphere. The "contiguous SAR 1g" is estimated by averaging the local maximum SAR, adding the highest SAR volume in a given tissue till a mass of 1g is reached.

At 835 and 900MHz, the power absorption budget indicates that more than half of the power is absorbed by the head (Tab. 2). The input power is distributed roughly as: 1/3 is radiated and 2/3 is absorbed. On the other hand, at 1800MHz the phenomenon is reversed. This is due to the space distribution of the power density, in free space, which is not completely the same for the two frequencies. The radiation pattern in free space of the Tri band mobile phone is more directive at 1800MHz, the main lobe is more directed opposite to the head, than at 900MHz (Fig. 7). Absorption at 1800, 1900 and 2100MHz is more superficial than at 835 and 900MHz, due to the effect of the skin depth. As the brain is nearer to the mobile phone in the case of a 4 years old child, one finds that the power absorption in the brain of the 4 years old child is slightly more significant than that for child of 12 years old and adult head (Fig. 9)

Table 2: Power absorption budget

Head model Freq. (MHz)	Adult Head	CL 12 y. old	Child 12 y. old	CL 4 y. old	Child 4 y.old
900	58 %	59 %	53 %	55 %	58 %
1800	32 %	34 %	32 %	28 %	36 %
2100	42 %	45 %	40 %	42 %	46 %
835	55 %	51 %	60 %	53 %	60 %
1900	35 %	37 %	44 %	30 %	50 %

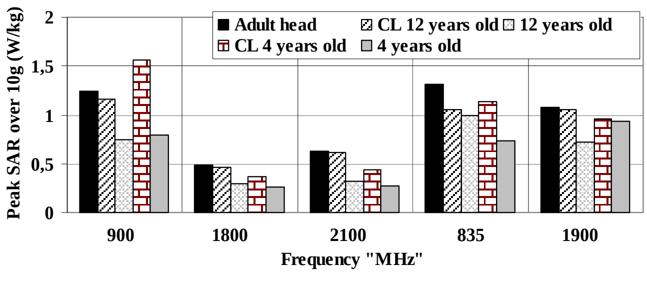


Fig. 8: SAR over 10g for each simulation and in each head model

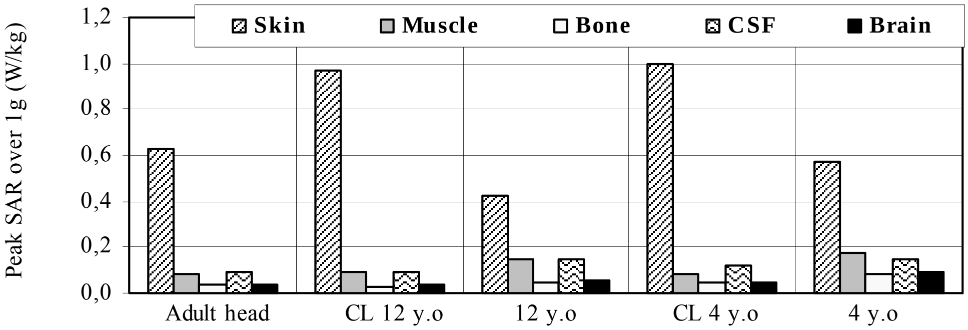


Fig. 9: Peak SAR contiguous over 1g in each head at 900 MHz (Normalized vs peak SAR over 1g in Skin for CL 4 y.o.)

The technique of the CL head has been used to obtain two child heads of different ages namely 4 and 12 years. The absorbed power percentage in the CL model is lower than that in the real model of a child head built from IRM imaging, especially for the 4 years old child (Tab. 2). On the other hand, the SAR values over 10g in a CL head are higher than that in a true child head model (Fig. 8). Only at 900 MHz and in the case for adult head and child like one, the peak SAR over 10g of CL 4 years old is increased approximately 15 % than the adult head. But the comparison with the true child heads obtained by MRI imaging, the SAR values gives always lower values than those of the adult head and the CL head.

The comparison between the two models of children heads enables us to observe the sensitivity of the dosimetry to the child head morphology and to the mobile phone model.

It worths mentioning that in all 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].

V. Conclusion:

A comparison of Specific Absorption Rate (SAR) induced in child-like and real child head using two source models (Tri-band mobile phone having a patch antenna and IEEE mobile phone), is made through the use of different child head models for each age class. Both the average SAR over a mass of 10g in the head and the power budget are determined using the Finite Difference Time Domain (FDTD) method. The differences between the results for the different head models are given at 900MHz, 1800MHz and 2100MHz. The power budget between two child head models for each age class is compared. It is found, that the SAR values over 10g in a CL head are higher than that in a true child head model.

It is important to put these results into perspective owing to the fact that they are valid only for specific cases (specific models of mobile phone and child head models).

VI. Bibliographie:

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