Comparison of Electromagnetic Absorption Characteristics in the Head of Adult and a Children for 1800 MHz Mobile Phones

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Abstract — **The Specific Absorption Rate (SAR) produced by mobile phones in the head of children is simulated using an algorithm based in the Finite Difference Time Domain (FDTD) method. A new model based on a 10 year old child computed tomographic images was used. The electromagnetic parameters were fitted to this age. The results are compared to the SAR calculated in the head of adults. Comparison also were made with SAR calculated in the children model when using adult human electromagnetic parameters values. It is shown that in similar conditions, the SAR calculated for the children is higher than that for the adults. When using the 10 years old child model, values around 80% higher than those for adults were obtained.**

Index Terms — **Children, Mobile Phones, Cell Phones, Specific Absorption Rate – SAR, Finite Difference Time Domain – FDTD.**

I. Introduction

THE use of mobile phone by adults, young people, children and the elderly has grown substantially in the last years. In parallel with this, an increased concern by the scientific community, the authorities and the population regarding the safety of these phones has arised.

Several authors have used the Finite Difference Time-Domain (FDTD) method to simulate the Specific Absorption Rate (SAR) in the cell phone user's head [1-10]. It is currently the most appropriate choice when highly non-homogeneous structures are involved for which boundary techniques have fundamental limitations. The SAR results estimated and measured show exposure levels close to (or even above) the limits of the available recommendations [11, 12].

Recently the use of cell phones by young and children has been strongly stimulated. Some authors have focused this, and different results were presented [10, 13-16]. In [10], the model of the children head was based on a scaled adult model and a SAR increase (compared with adult) of around 120 % has been obtained. In [13], the head model was based on MRI using similar electromagnetic parameters as those for adults, and no significant differences between adult and children SAR results were observed. In [15], the head model was approximated by spheres considering some variation of the electromagnetic parameters, and an increase of around 20 % in the calculated SAR was shown. In [16], using also scaled model for the children's head with adult electromagnetic parameters, no significant variation for the average SAR in the whole head was observed, and when considering the brain, an increase of around 35% in the SAR was calculated.

In this paper the FDTD method was used to simulate the SAR in the head of a child, and compared with the results simulated for the adults. A new model based on a 10 year old child computed tomographic images was used. The electromagnetic parameters were fitted to this age. Comparison also were made with SAR calculated in the children model when using adult human electromagnetic parameters values. Simulations were performed using CRAY T 94 supercomputer from CESUP [17].

All the SAR results were calculated using planar antennas.

The use of planar antennas with moderate directivity for mobile phones has been suggested previously [1,5,6]. These antennas radiate more in the direction opposed to the head, and they can be very low cost, resulting therefore in an interesting alternative to this application.

II. Antropomorphic Numerical Models

The geometric and the electromagnetic parameter differences between the adult and the child were considered in the simulations.

SAR simulations for the adult human are performed using a model based on [18] as in previous works [4-9]. In order to compare the SAR due to cell phones in adults and children a new model based on 102 computed tomographic images (Fig.1) from a healthy 10 years old child was developed.

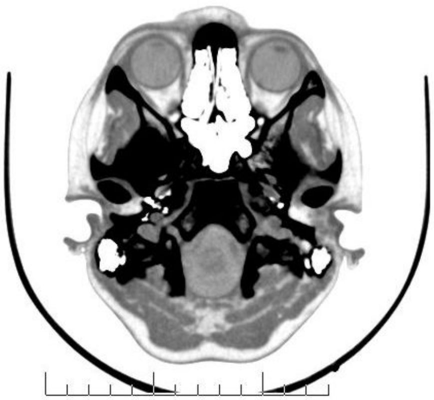

Fig.1. Computed tomographic image of the 10 years old child: coronal cut.

Both models were rotated to put the ear-to-mouth line vertically (Fig.2). This facilitate the cell phones antennas positioning.

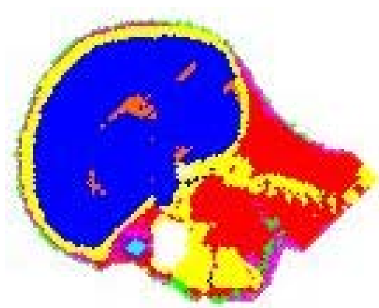

Fig.2. Saggital cut of the 10 years old child rotated model.

Three different simulation cases were implemented. In case A, the adult model and parameters [19] were used. In case B, the child model with adult electromagnetic parameters was used. In case C, the child model with fitted electromagnetic parameters was used. These were obtained from comparison with the results obtained for rats [20]. The electromagnetic parameters for adult human are well established, with an accuracy better than 5% [19]. However data for children are still not available. A study with rats [20] shows that conductivity and permittivity decrease with age. For 10 day and younger rats the values are around 20% higher than for sexually mature (adult) rats (e.g. 50 days). One reason for this could be the higher water concentration in the tissues of the young. The measured results for adult individuals in different animal species show that there is a parameter variation lower than 5% from animal to animal when considering the same type of tissue. This was the rationale, and using similar correspondence between parameters values and age for humans as for rats, we obtained the fitted parameters for the children. These values are shown in Table I.

TABLE I – PHYSICAL PROPERTIES FOR THE ADULT MAN AND FITTED FOR THE 10 YEARS OLD CHILD AT 1800 MHZ

Age		adult		10 years old	
Properties	$\rho(g/cm^3)$	ε_r	$\sigma(\Omega^{-1}/m)$	ε_r	$\sigma(\Omega^{-1}/m)$
Air	0.00	1.00	0.00	1.00	0.00
Average Skull	1.85	15.56	0.43	18.48	0.54
Skin (Wet)	1.01	43.85	1.23	54.63	1.53
Average Muscle	1.04	54.44	1.39	61.68	1.57
Average Brain	1.03	43.54	1.15	52.52	1.44
Vitreous Humour	1.01	68.57	2.03	81.81	2.47
Fat (Mean)	0.92	11.02	0.19	13.15	0.23
Eye Tissue (Sclera)	1.17	53.57	1.60	63.91	1.95
Brain Spinal Fluid	1.01	67.20	2.92	80.17	3.55
Nerve (Spinal chord)	1.04	30.87	0.84	36.83	1.02
Lens Nucleus	1.10	34.65	0.79	41.34	0.96

The cranial perimeters in both models were approximated from ellipsis. The calculated values are in close agreement with those shown in [13]. To adjust for the corresponding dimensions and in order to save memory, FDTD simulation were performed having different cell dimensions for each of the three cases [21,22]. Then, the distance between the antenna and the head are slightly different. These are shown in Table II.

TABLE II – SPATIAL DISCRETIZATION

Model	*Adult*	*10 years old*
Cases	*A*	*B and C*
Scale factor	*1*	*1*
Cranial perimeter (mm)	563.5	523.9
Δx (mm)	0.764	0.946
Δy (mm)	1.920	1.892
Δz (mm)	1.920	2.044
Antenna distance (mm)	14.51	14.19

III. ANTENNA MODELS

The cell phones were modeled using patch antennas to compare the SAR results with previous works [5,6]. The patch antennas were designed following the cavity models described by [23,24]. The antenna dimensions were adjusted according to the cell grid shown in Table II. Special care was taken to feed the antenna at the exact resonance frequency. For example, in the simulated cases B and C, the antenna dimensions were L = 55.19 mm, W = 32.17 mm, H = 1.89 mm, in accordance to the grid. Then the resonance frequency estimated using the cavity model should be f = 1832 MHz. However S_{11} simulations using FDTD and FFT show that the resonance frequency is f = 1807 MHz (Fig.3).

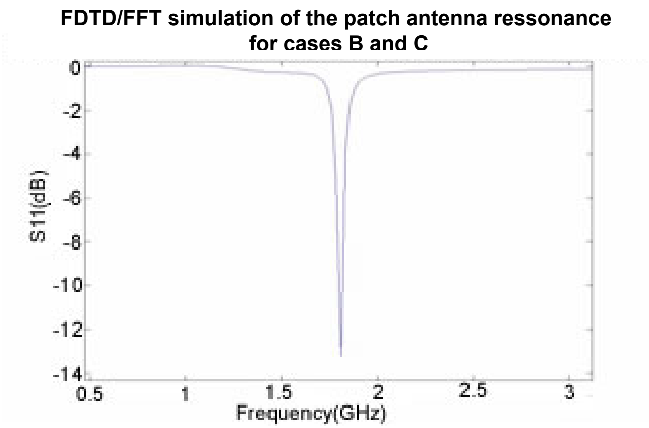

Fig.3. Simulated S_{11} for the patch antenna used in cases B and C.

This was the frequency used to feed the antenna with a normalized power harmonic signal. Then, even the feeding frequencies are slightly different from case to case, we ensure a high radiation efficiency in all the simulated cases.

The main objective of this work is to compare the child and adult exposures in three different situations (cases A, B, and C). Then the obtained SAR results are normalized for the adult (case A).

IV. RESULTS

In this section the peak SAR and average SAR (1 g and 10 g) are presented. The 1g-SAR and the 10g-SAR were calculated as spatial averages of boxes with 14Δx × 5Δy × 5Δz (1g-SAR, Case A), 28Δx × 11Δy × 11Δz (10g-SAR, Case A), 10Δx × 5Δy × 5Δz (1g-SAR, Cases B and C), 21Δx × 12Δy × 10Δz (10g-SAR, Case B and C). Since there is not a great variation in the densities of the different tissues, this can be considered a reasonably approximation.

Since the child and the adult head models were rotated in order to a better positioning of the cell phone, then the vertical and horizontal cuts do not correspond exactly to coronal and frontal cuts. Fig. 4 shows the SAR calculated in case A.

In order to make the necessary comparison, the values are normalised to the exposure limit recommended by the corresponding IEEE/ANSI standard [11], SAR = 1.6 W/kg for 1 g of tissue.

In Fig. 5, SAR results for the 10 years old child model with adult parameters (Case B) for the same six vertical and horizontal cuts and the same scale are shown.

In Fig. 6, SAR results for the 10 years old child model with parameters fitted to this age (Case C) for the same six vertical and horizontal cuts and the same scale are shown.

In Table III the maximum simulated SAR results in the brain for the three cases are shown.

The results were compared with that obtained for the 1 g average SAR in the adult (case A) assumed to be in the 1.6 W/kg SAR recommended IEEE/ANSI exposure limit [11].

It is observed that an increase of around 80% in the 1g-SAR was obtained for the children model with the fitted parameters (case C). Even when using adult parameters in the child model (case B), an increase of around 60% is observed. Hence, the results obtained for the child model when using the fitted parameters were around 9% higher than those when using adult parameters.

TABLE III – SAR

Model	*Adult*	*10 years old child*	
Electromagnetic parameters	*Adult parameters*	*Adult parameters*	*Children parameters*
Case	*A*	*B*	*C*
	Normalised values (W/kg)		
Peak SAR (one *voxel*)	1.704	3.356	3.636
1g-SAR	1.600	2.618	2.868
10g-SAR	1.319	1.984	2.119
	Percentage difference (increase/decrease)		
Peak SAR (one *voxel*)	+6.5%	+109.7%	+127.3%
1g-SAR	0%	+63.6%	+79.2%
10g-SAR	-18%	+24.0%	+32.5%

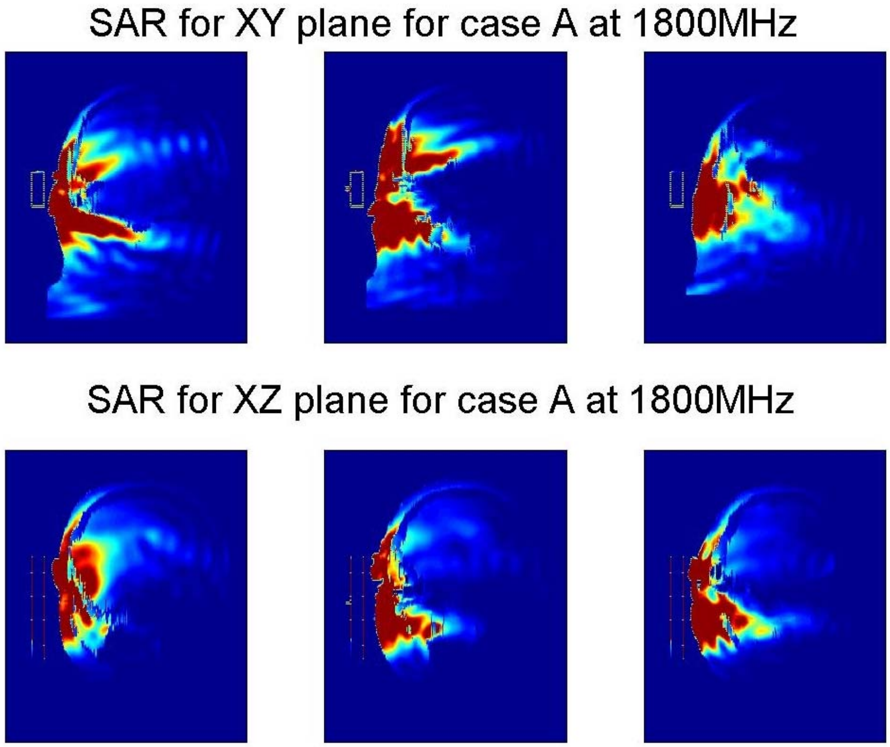

Fig.4. SAR for three vertical and horizontal cuts (Case A, adult). The color scale corresponds to 10 dB for each color. The same scale is used in Fig.5 and Fig.6.

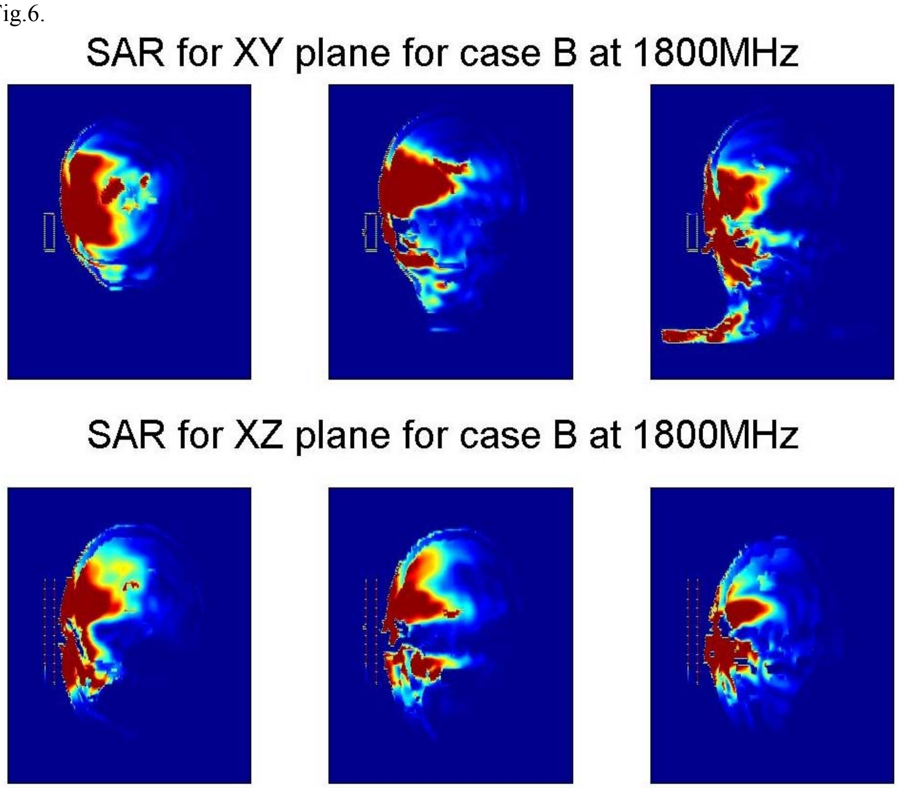

Fig.5. SAR for three vertical and horizontal cuts (Case B, child with adult parameters). The color scale corresponds to 10 dB for each color. The same scale is used in Fig.4 and Fig.6.

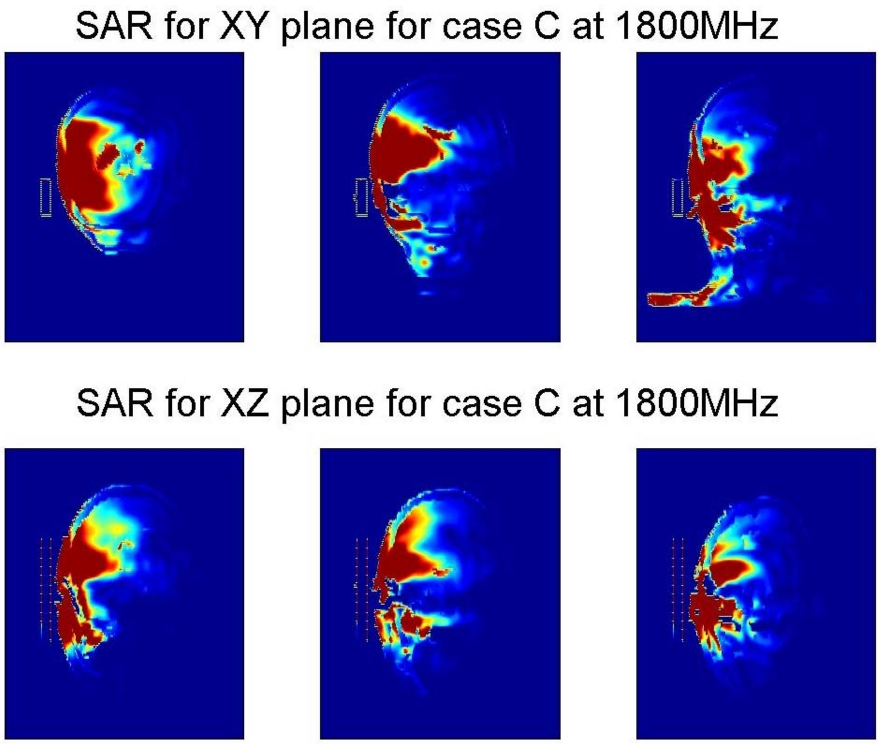

Fig.6. SAR for three vertical and horizontal cuts (Case C, child with fitted parameters). The color scale corresponds to 10 dB for each color. The same scale is used in Fig.4 and Fig.5.

V. DISCUSSIONS AND CONCLUSIONS

The SAR in the 10 years old child was calculated and compared to the results obtained for adult. SAR results around 80% higher than those for the adults were observed for the children. This is expected to be due to differences in dimensions and electromagnetic parameters, and is in accordance with the results obtained by other authors [10].

Due to the increase of the use of mobile phones by children, and since compliance tests use head phantoms based exclusively on adult data, the results shown in this paper may suggest that further theoretical and experimental research must be done in order to evaluate these issues aiming to reduce risks for the children. This is in accordance to the WHO – World Health Organization – effort, included in the WHO Children's EMF Research Agenda, recommending research studies relevant to the risk of adverse health effects in children from exposure to electromagnetic fields (EMFs) [25].

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