Specific Absorption Rate (SAR) in the head of Tablet user's

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Abstract—**Wireless communication devices such as tablets are increasing and developing rapidly. The effects of the electromagnetic (EM) waves in the human body from the wireless communication devices have been paid attention. It is well known that the absorption of electromagnetic waves on the human head for a certain period of time may lead to health problems such as headaches, or even worse, significantly increased risk of brain cancer. In this paper, the Specific Absorption Rate (SAR) in the head of tablet user's is simulated for three different head models and compared with available international recommendations. The models used are the Specific Anthropomorphic Mannequin (SAM) and two realistic models of human head (a 34 years old adult and a 6 years old child). The simulations were performed using the finite difference time domain (FDTD) method and the frequency used to feed the antenna was 2.45 GHz. All the results are below the safety recommendations set up by the International Commission Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Committee (FCC). Among the heterogeneous models, the highest peak spatial Specific Absorption Rate (psSAR) values are estimated for the children. For 1 g psSAR the child heterogeneous model shows highest value in comparison to the SAM model.**

Keywords—Tablets; Specific absorption rate; Specific anthropomorphic mannequin; Finite-difference time-domain method

I. INTRODUCTION

SAR evaluations in the human body from a tablet computer is increasing in recent year. A substantial concern has risen regarding the possible adverse effects on human health [1]-[2] due to the user's electromagnetic (EM) energy absorption for long periods of time. Several safety standards have been defined [3]–[5] in order to prevent harmful effects in human beings exposed to non-ionizing radiation (NIR). The Specific Absorption Rate (SAR) is a unit to indicate the amount of power absorbed per unit mass of human biological tissue when exposed to electromagnetic radiation. The SAR is defined using the following equation (1):

$$SAR = \int \frac{\sigma(r)\,|E(r)|^2}{\rho(r)}\, d(r) \qquad (1)$$

where σ is the electrical equivalent conductivity of the sample (S/m), ρ is the density of the sample (Kg/m³), and *E* is the RMS electric-field (V/m).

The exposure limit recommended by ICNIRP and FCC are psSAR lower than 2 W/Kg for any 10 g of tissue or psSAR lower than 1.6 W/Kg for any 1 g of tissue respectively.

This paper will focus on the impact of the radiation on the SAR values produced by Tablet devices in realistic adults and children head models and in the SAM Phantom. The simulations are based on the Finite Difference Time Domain (FDTD) method. The commercial software SEMCAD-X [6] was used for the SAR simulations.

The paper is organized as follows. Section II shows the modeling and the device used. In section III the relevant international recommendations limits for the SAR are described. Section IV shows the computational resources. Simulated results are discussed in section V and the in section VI the conclusions are presented.

II. MODELING

A. Tablet case model

Fig. 1 shows the tablet model with 134.7 × 200.1 × 9.34 mm³ size. A popular tablet shape model was selected from Grabcad database [7] and then imported into the SEMCAD X software where it was adapted and the antenna was included. The relevant case parameters are included in Table I.

B. Antenna model

Fig. 2 shows some details of the Planar Inverted F antenna (PIFA). A suitable antenna from the Antenna Magus Software database [8] was selected and imported into the SEMCAD X software. After this, its dimensions and shape were adjusted to fit the requirements of this project. The antenna was designed to operate in the 2.45 GHz Wi-Fi communication band and tested, showing good performance in the mid-band (see Table II). It was positioned in the upper right side of the tablet. The relevant antenna parameters are included in Table II.

C. SAM phantom

The SAM phantom is an available [9] adult human head model made of plastic shell, with ear spacers in two sides of the head and a homogeneous liquid inside the shell, elaborated with electrical parameters close to the average head tissues dielectric parameters. Table III contains the dielectric properties of the SAM phantom [9]. The SAM phantom with the Tablet is shown on Fig. 3.

D. *Adult and children head models*

Two available [10] realistic head models were used in these simulations. They are heterogeneous and reproduce approximately the human head tissue morphology. These models were obtained from magnetic resonance imaging (MRI) and are available at the Virtual Family [10].

These models are shown on Fig. 4. The first one is a 34 years old adult man (DUKE) and the second is a 6 years old boy (THELONIOUS). The different tissue dielectric parameters used in these simulations were obtained from [11] and are included in Table IV.

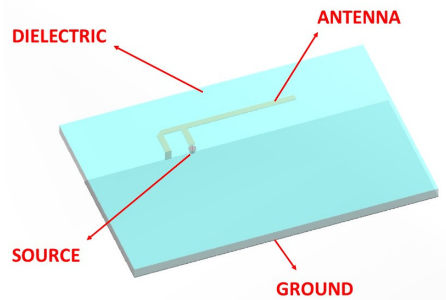
(a)

(b)

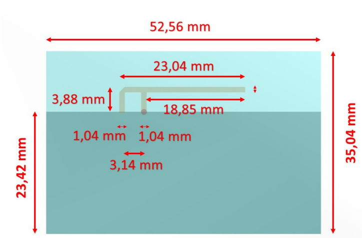
Fig. 1. Tablet configurations: (a) Tablet (front view); (b) Tablet (side view).

TABLE I. Dielectric Properties of the Tablet @ 2.45GHz.

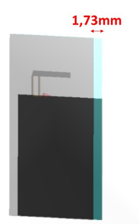
	σ [S/m]	ε_r
Screen	0.0001	2.3
Case	0.0001	2.3



(a)



(b)



(c)

Fig 2. Antenna (PIFA) configurations: (a) Antenna PIFA (structure); (b) Antenna PIFA (front view); (c) Antenna PIFA (side view).

TABLE II. Dielectric Properties and Measured Characteristics of the Antenna PIFA @ 2.45GHz.

Dielectric Properties		***Measured Characteristics***	
σ [S/m]	ε_r	*S11 [dB] for 2.45 GHz*	*Zo [Ω]*
0.0001	2	-36.8	50

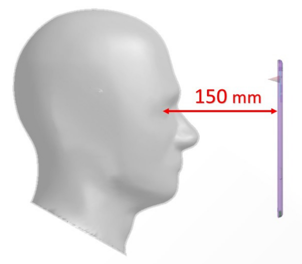
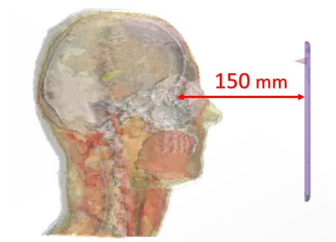


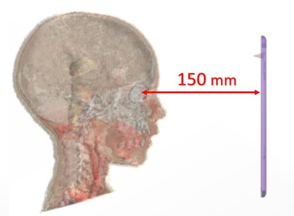
Fig 3. SAM phantom (homogeneous model) with Tablet.

TABLE III. Dielectric Properties of the SAM Phantom following the IEEE 1528 Recommended Practice @ 2.45 GHz

Material	*σ [S/m]*	ε_r
SAM shell	0.0016	5
SAM liquid	1.8	39.2



(a) 34 years old adult man (DUKE)



(b) 6 years old child (THELONIOUS)

Fig. 4. Heterogeneous models with Tablet.

TABLE IV. Dielectric Properties of the Heterogeneous Models Tissues @ 2.45 GHz.

Tissue	ε_r	*σ [S/m]*
Fat	0.104	5.280
Bone	0.394	11.381
Grey matter	1.807	48.911
White matter	1.215	36.167
Liquid Brain	66.243	3.457
Muscle	52.729	1.738
Aqueous Humor	68.208	2.478
Skin	38.007	1.464
Crystalline	44.625	1.504
Sclera	52.628	2.033
Vitreous Humor	68.208	2.478
Cerebellum	30.145	1.088
Nerve	30.145	1.088

III. International Recommendations

Some international organizations recommend the evaluations and exposure limits to electromagnetic fields generated by wireless devices near the human body (e.g., [3-5]). Table V shows some recommended exposure limits.

The IEEE 1528.2003 standard [9] uses a simplified human head model to estimate the average peak spatial SAR value generated by communication devices in the range from 300 MHz to 3 GHz. It is designed to provide a conservative estimate of the maximum average values of SAR during normal use of these devices. A model for the human anatomy (SAM phantom) was developed to evaluate the exposure in the near field produced by wireless devices.

The IEC 62209-1 and IEC 62209-2 standards [12] deal with the assessment of exposure to electromagnetic fields generated by wireless devices near the human body in the frequency range 30 MHz to 6 GHz. These are applicable to any devices operating at distances up to 200 mm away from the body, e.g., when it is near the face or any other body region.

TABLE V. Standard and Recommendations. Limits for General Population/Uncontrolled Exposure

	ICNIRP [5]	**IEEE [3]**	**IEEE [14]**	**FCC [4]**
Last Revision	1998	2005	2004	2001
Head and Trunk SAR (W/kg)	2	2	1.6	1.6
Tissue mass (g)	10	10	1	1
Exposure time (min)	6	6	30	30

IV. Computational Resources

All the simulations in this work were performed using a computer Intel Core i5 3470 at 3.4 GHz equipped with 32 GB of RAM, NVidia Tesla C1060 GPU card, and Windows 7 Professional x64 operating system, available in the communications laboratory (LACOM) of the Federal University of Rio Grande do Sul. The finite difference time domain-FDTD method was used to simulate different scenarios for the models and to estimate the SAR.

V. Results and Discussion

A tablet, including the antenna and the box, was simulated at 2.45 GHz assuming 30 mW normalized radiated power and the distance between the eye lens of the head models and the tablet was 150 mm. The SAR in the head models is estimated in each situation of exposure.

In Table VI the absorbed power percentages are shown in each case. The estimation with the SAM phantom shows that 5,5 % of the energy was absorbed by this model. For the Adult Head model 4,71 % of the energy was absorbed and for the Children Head model 3,97 %. In the Fig. 7 the radiation pattern as well as the SAR in a sagittal slice are shown.

The 10 g and 1 g psSAR were estimated and are shown in Table VII and Fig. 5-6. All the results simulated are below the FCC psSAR limit [13] of 1.6 W/Kg in each 1 g of tissue and the ICNIRP psSAR limit of 2 W/Kg in each 10 g of tissue.

In the simulations for 1 g of tissue, the highest psSAR value is in the children head model (Fig. 5).

In the simulations for 10 g of tissue, the highest psSAR value is in the SAM Phantom, and in the heterogeneous models, the highest psSAR value is in the children head model (Fig. 6).

TABLE VI. Absorbed Power Percentage

SAM Phantom	**Adult Head (DUKE)**	**Children Head (THELONIOUS)**
5.50 %	4.71%	3.97%

TABLE VII. psSAR OVER 1 g AND 10 g [W/kg]

SAM Phantom		**Adult Head (DUKE)**		**Children Head (THELONIOUS)**	
SAR 10 g	***SAR 1 g***	***SAR 10 g***	***SAR 1 g***	***SAR 10 g***	***SAR 1 g***
0.0062	0.0122	0.0047	0.0114	0.0056	0.0132

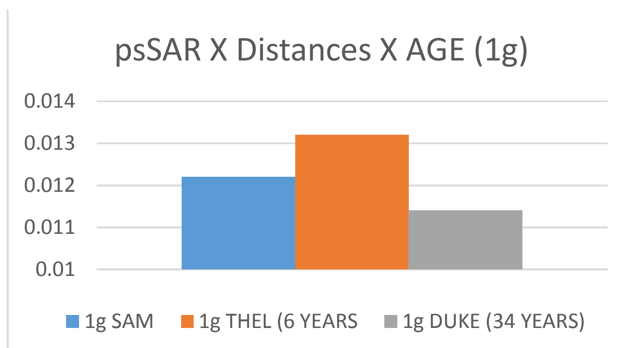


Fig. 5. psSAR 1 g

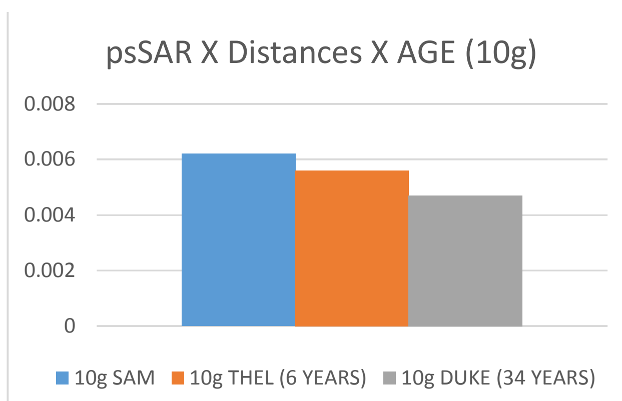


Fig. 6. psSAR 10 g

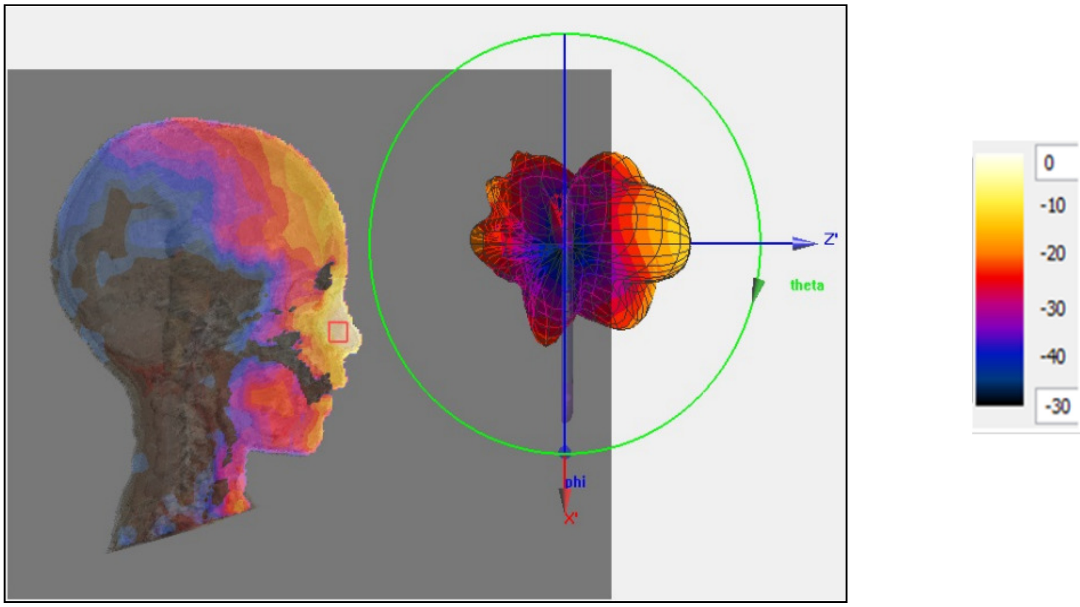


Fig. 7. Radiation pattern normalized to 0.0132 W/g = 0 dB, with a 30 dB color scale, and SAR averaged over 1g cube of tissue.

VI. *Conclusion*

The 1 g and 10 g of tissue psSAR produced in the head of Tablet user's was simulated when a PIFA antenna was employed in three different head models.

The homogeneous SAM phantom head model did not present the higher levels of the 1g psSAR. Therefore, according to these simulations, in 1g volume the SAM is not conservative. It is recommended that the existing mobile devices certification process should be complemented:

- … with an FDTD computer simulation process,
- … using anatomically based models, including those representatives of the children,
- … measuring the SAR, averaged over smaller volumes,
- …and in different tissues.

Then certification should be approved only if all tests result in psSAR below the recommended limits.

The psSAR simulations in heterogeneous models (adult and child) show higher levels in the children model. The possible reasons for the higher SAR estimated in the child head model compared with adult model can be due to different reasons (e.g. thinner skull, higher dielectric parameters, smaller dimensions, etc.).

It is very important to remark that the recommendations and the standards usually adopted in different countries only consider the health effects of short time of exposure. Adults, adolescents and children may use these devices for many hours a day, many days a week and many weeks each year. Then these exposures should be reduced in order to reduce the health risks and the standards should be revised again since the last review was many years ago.

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