Specific Absorption Rate (SAR) in the head of Google glasses and Bluetooth user's

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Abstract— **Two popular wireless communication devices are considered in this paper. Firstly, the Bluetooth which is one of the most popular mobile accessories and the Google glasses which are a representation of the new futuristic vision. 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, brain cancer. The Specific Absorption Rate (SAR) is simulated for three different head models and compared with the available international recommendations. The first model used is the Specific Anthropomorphic Mannequin (SAM phantom), as well as two realistic models of human head (i.e., a 34 years old adult and a 10 years old child). The simulations were performed using the finite difference time domain (FDTD) method and the frequency used to feed the antennas was 2.45 GHz.**

Keywords—Bluetooth, Google glasses, SAR, SAM phantom, FDTD.

I. INTRODUCTION

There has been a rapid growth in wireless communication appliances in the past two decades. These devices include notebook computers, smart phones (using handset Bluetooth) and the new Google glasses. A substantial concern has risen regarding the possible adverse effects on human health due to the user's electromagnetic (EM) energy absorption for long periods of time. As a result, several safety standards have been defined recently [1]–[3] in order to prevent harmful effects in human beings exposed to non-ionizing radiation (NIR). The Specific Absorption Rate (SAR) indicates the amount of power absorbed per unit mass of human biological tissue when exposed to electromagnetic radiation. The limits can be established in international exposure recommendations for the peak spatial SAR (psSAR) averaged over 1 g or 10 g of body tissue. EM exposures from cell phones and notebooks have been examined in previous papers [4]-[10].

This paper will focus on the impact of the radiation on the SAR values produced by Google glasses and Bluetooth devices in realistic adults and children head models based on the Finite Difference Time Domain (FDTD) method. The commercial software SEMCAD-X was used for the SAR simulations [11].

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

II. MODELING

A. Devices

The Bluetooth antenna was positioned in the ear and we assumed surrounded by a plastic material. The device is shown in Fig 1.

The Google glass is a type of wearable technology. The device communicates with the internet via natural language voice commands. The glasses were characterized in the AUTOCAD 3D software and then imported into the SEMCAD X software. The measurements (Fig 2) were taken from the FCC - Federal Communications Commission report which issues the ID label ("FCCID"). This corresponds to a certification issued to electronic products manufactured or sold in the United States. Among others, it certifies that the electromagnetic interference from the device is under limits approved by the FCC [12].

B. Antennas

Two types of antennas were used in this approach. First, a monopole antenna as it is shown on Fig 3. The antenna was made with a mini coaxial cable and is designed to operate in the 2.45 GHz Wi-Fi communication band. The other antenna is a Planar Inverted F (PIFA) which consists of a patch placed at a certain height above and in parallel with the ground plane. This antenna is shown in the Fig 4. The antennas relevant parameters are included in Table I.

C. SAM phantom

The Specific Anthropomorphic Mannequin (SAM phantom) which is an adult human head model made of lossless 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 realistic head tissue dielectric parameters. Table II contains the dielectric properties of the SAM phantom [13]. The SAM phantom with the Google glasses and the Bluetooth are shown in Fig 5.

D. Adult and children head models

Two 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). The first one is a 34 years old adult and the second is a 10 years old child. The different tissue dielectric parameters used in these simulations were obtained from [14]. These models are shown on the Fig 6. The head shape of a child differs greatly from that of an adult, as do the dimensions of the device to put on him. Depending on the head size, the antenna will be located in different positions above the ear (Fig 7). The reference values between the head and the antenna using the devices for the models are presented in Table III, Table IV and Table V respectively.

Fig. 1. Bluetooth headsets used in the simulations.

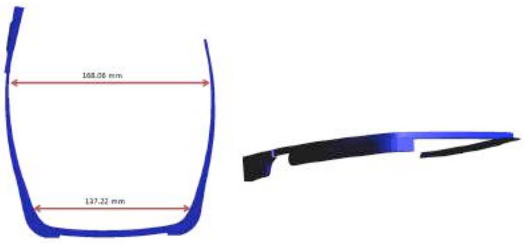
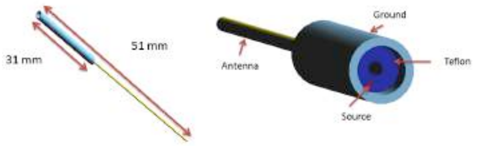
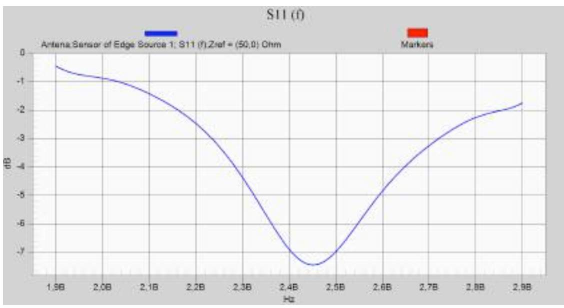


Fig. 2. Google glass characterized for thesimulations.



(a) Specifications

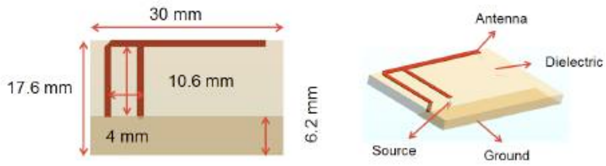


(b) S11 Parameters

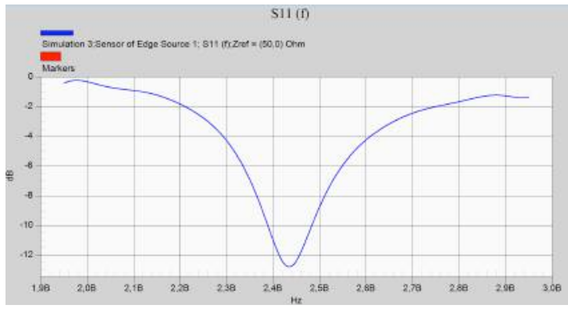
Fig. 3. The monopole antenna

TABLE I.
ANTENNA PARAMETERS

Antenna	σ [S/m]	Er	S11 for 2.45 GHz [dB]	Z0 [Ω]
PIFA	0.0001	2.08	-10.77	38
MONOPOLE	0.0001	2	-8	45



(a) Specifications



(b) S11 parameters

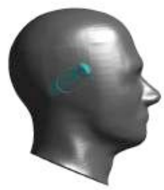
Fig 4. Planar Inverted F antenna (PIFA)

TABLE II
DIELECTRIC PROPERTIES OF SAM PHANTHOM AT 2,45 GHZ

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

(a) Google glass with PIFA

(b) Google glass with monopole



(c) Handset Bluetooth with PIFA

Fig 5. SAM phantom

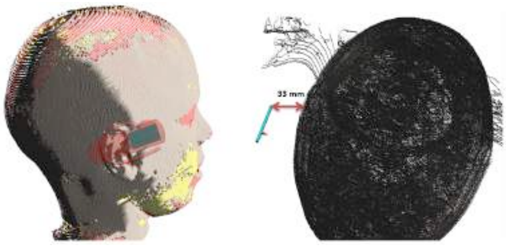
(a) 34 years old adult with Google glass

(b) 10 years old child with Google glass

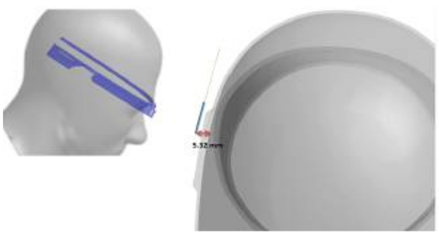
(c) 34 years old adult with Bluetooth

(d) 10 years old child with Bluetooth

Fig. 6 Heterogeneous models



(a) Child using a Handset Bluetooth p. ex., d1= 33mm



(b) SAM using the Google glass p. ex., d2= 5.32mm

Fig. 7 Minimun distance between the antenna and the head.

TABLE III
MINIMUM DISTANCE BETWEEN THE ANTENNA AND THE SAM PHANTOM HEAD

	SAM phantom		
	Google PIFA	**Google Monopole**	**Bluetooth PIFA**
Distance [mm]	7	5.32	39.87

TABLE IV
MINIMUM DISTANCE BETWEEN THE ANTENNA AND THE ADULT HEAD

	34 years old adult		
	Google PIFA	**Google Monopole**	**Bluetooth PIFA**
Distance [mm]	5	3.32	19.38

TABLE V
MINIMUM DISTANCE BETWEEN THE ANTENNA AND THE CHILD HEAD

	10 years old child		
	Google PIFA	**Google Monopole**	**Bluetooth PIFA**
Distance [mm]	9.51	6.95	33

III. INTERNACIONAL RECOMMENDATIONS

International organizations recommend the evaluations and exposure limits to electromagnetic fields generated by wireless devices near the human body.

The IEEE 1528.2003 standard [15] uses a simplified human head model to estimate the average peak SAR value generated by communication devices in the range from 300 MHz to 300 GHz. It provides 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. IEC 62209-1 and IEC 62209-2 standards [16] deal with the assessment of exposure to electromagnetic fields generated by wireless devices near the human body in the frequency range 30 MHz to 300 GHz. These are applicable to any device operating at distances up to 200 mm away from the body, e.g., when it is near the face or any other body region. The exposure limit recommended by ICNIRP (International Commission for Non-Ionizing Radiation Protection) for the SAR inside the head and trunk of the human body is 2 W/kg for any 10 g of tissue.

IV. COMPUTATIONAL RESOURCES

All the simulations in this work were performed using a computer Intel Core i5 3470 @ 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 together with SEMCAD X software was used to simulate different scenarios for the models and to estimate the SAR.

In addition, some simulations were performed using the Sun Fire Cluster (Newton) of CESUP [17], with a theoretical peak performance of 12.94 tflops, 8 nvidia Tesla GPUs in 2 units S1070, 16 GB of RAM per server and a total of 188TB of storage capacity.

V. RESULTS AND DISCUSSION

Both devices were simulated @ 2.45 GHz assuming 100mW normalized radiated power. The SAR in the head models is estimated in each situation of exposure. In Table VI the radiated and absorbed power percentages are shown in each case. For the Google glass more than 55% of the energy was absorbed by the head models. For the Bluetooth the results were better in the heterogeneous models: less than 30% of the energy was absorbed by the head. The estimation with the SAM phantom shows that more than 80% of the energy was absorbed by this model.

The 10 g and 1 g psSAR were estimated and are shown in Table VII for the Google glass and in Table VIII for the Bluetooth. All the results simulated with the Google glass using the two antennas are above both the FCC psSAR limit [18] of 1,6 W/Kg in each 1g of tissue and the ICNIRP psSAR limit of 2 W/Kg in each 10 g of tissue. In the simulations with Bluetooth with any head model, psSAR below the FCC and ICNIRP limits are estimated.

For each case of exposure, the SAR is calculated at every 1 g of tissue. The tissues showing the highest 1 g psSAR values are the muscles, the skin and the bones and are represented in the Fig 8-13. The skin (1 g psSAR: 10.50 [W/Kg]) for the adult head and the muscle (1 g psSAR: 6.64 [W/Kg]) for the children head were the most affected tissues when using the Google glass with the PIFA (Fig. 8). In the simulations for 10g of tissue, all results were below the 2 [W/Kg] ICNIRP limit (Fig. 9). The simulations with the monopole antenna show that the most affected tissues are the muscles (1 g psSAR: 8.01 [W/Kg]) and the skin (1 g psSAR: 7.26 [W/Kg]) at the adult head and the muscles (1 g psSAR: 7.66 [W/Kg]) at the children head (Fig. 10). For 10g of tissue, all results are below the 2 [W/Kg] ICNIRP limit (Fig. 11). The simulated results with the Bluetooth using the PIFA show 1 g psSAR close to the ICNIRP 2 [W/Kg] limit (Fig. 12). However, the simulations of 10g of tissue do not result more than 0.4 [W/Kg] for the child (Fig 13).

TABLE VI.
RADIATED AND ABSORBED POWER PERCENTAGE

	SAM PHANTOM		Adult head		Children head	
Google glass	Radiated Power	Absorbed Power	Radiated Power	Absorbed Power	Radiated Power	Absorbed Power
PIFA	30.8%	69.2%	31.7%	68.3%	39%	61%
MONOPOLE	30.2%	69.8%	31%	69%	43%	57%
Handset Bluetooth	Radiated Power	Absorbed Power	Radiated Power	Absorbed Power	Radiated Power	Absorbed Power
PIFA	17.45%	82.55%	67%	33%	74.2%	25.8%

TABLE VII
GOOGLE GLASS: psSAR OVER 10 g AND 1 g [W/Kg]

Google glass	**SAM PHANTOM**		**Adult head**		**Children head**	
	SAR 10g	SAR 1g	SAR 10g	SAR 1g	SAR 10g	SAR 1g
PIFA	3.56	7.72	2.38	4.44	1.96	4.01
MONOPOLE	3.86	8.34	2.57	5.41	1.98	5.02

TABLE VIII.
BLUETOOTH: psSAR OVER 10 g AND 1 g [W/Kg]

Handset Bluetooth	**SAM PHANTOM**		**Adult head**		**Children head**	
	SAR 10g	SAR 1g	SAR 10g	SAR 1g	SAR 10g	SAR 1g
PIFA	0.23	0.42	0.39	0.64	0.49	0.96

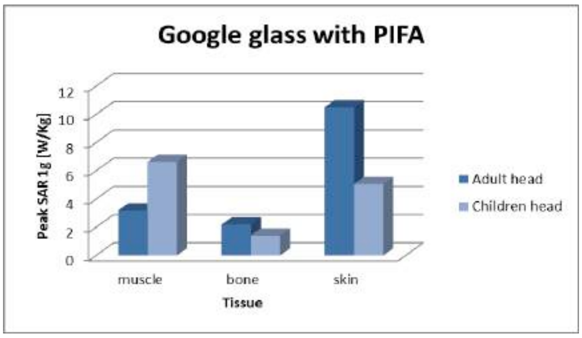


Fig 8. psSAR over 1 g @ 2.45 GHz.

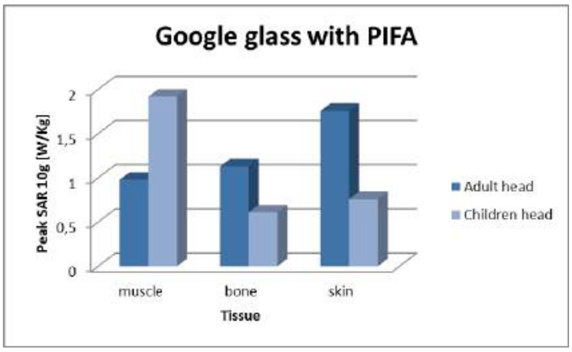


Fig 9. psSAR over 10 g @ 2.45 GHz.

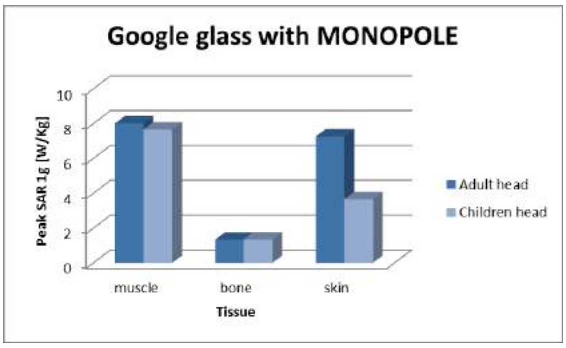


Fig 10. psSAR over 1 g @ 2.45 GHz.

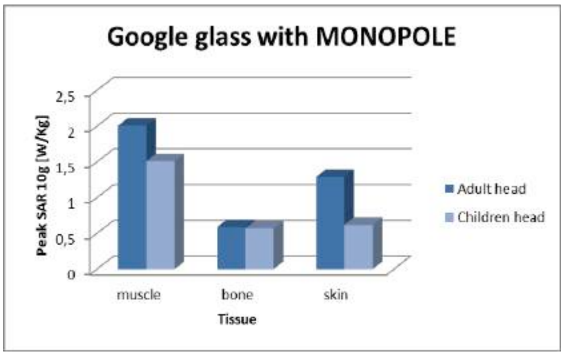


Fig 11. psSAR over 10 g @ 2.45 GHz.

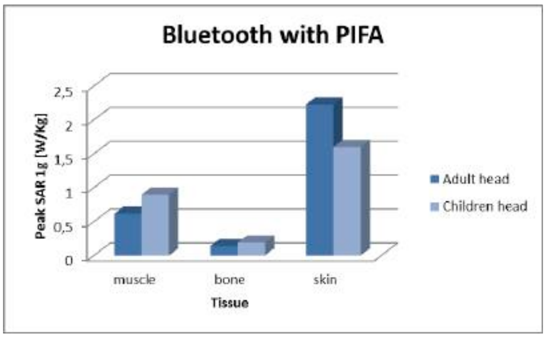


Fig 12. psSAR over 1 g @ 2.45 GHz.

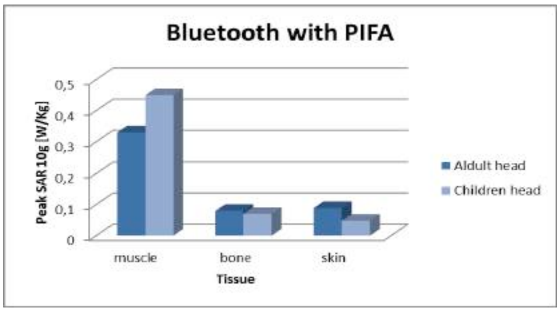


Fig 13. psSAR over 10 g @ 2.45 GHz.

VI. CONCLUSION

The 1 g and 10 g of tissue psSAR produced in the head of Google glass and Bluetooth user's was simulated when a PIFA and a monopole antenna were employed in three different head models. The distance between the device antenna and the user's head is extremely important, since SAR increases substantially with the reduction of this distance.

The homogeneous SAM phantom head model presented the highest levels of psSAR in the simulations compared to the two heterogeneous adult and child head models. The dielectric parameters of the SAM Phantom were developed to obtain a higher exposition compared to human head tissues. Besides, the SAM Phantom dimensions are higher so the liquid can be closer to the device, then the SAR in the SAM Phantom is expected to be generally higher. The tissues showing the highest simulated absorbed power values were the muscles, the bones and the skin. Some simulated psSAR values were around 8 [W/Kg], well above the FCC and the ICNIRP limits (e.g., in the SAM phantom using the Google glass with the monopole antenna). On the other hand psSAR simulations using the Bluetooth presented values lower than the ICNIRP 2 [W/Kg] limit.

As these portable devices may be used for long time very close to the user's head, even low level exposure can be dangerous for the user's health, especially for children and adolescents.

Finally, 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.

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