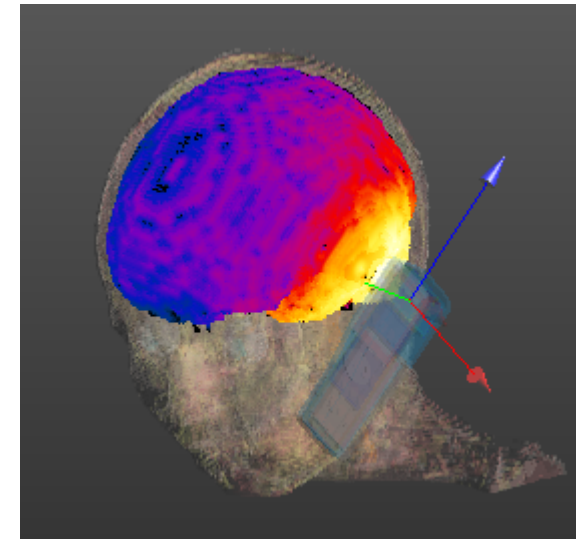


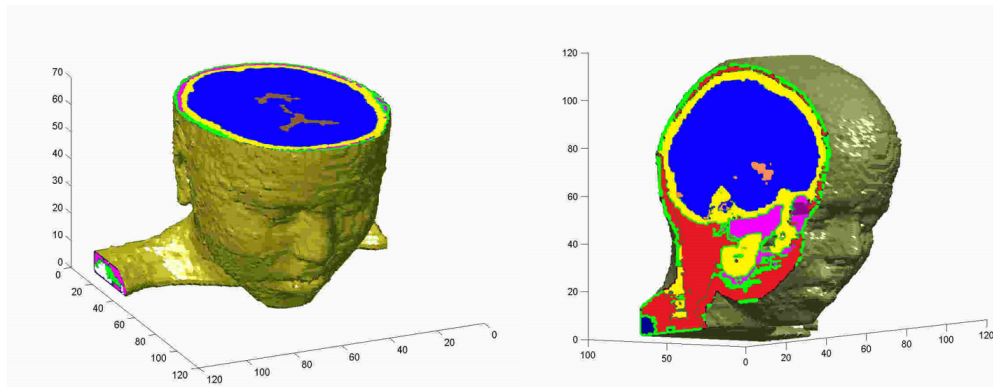
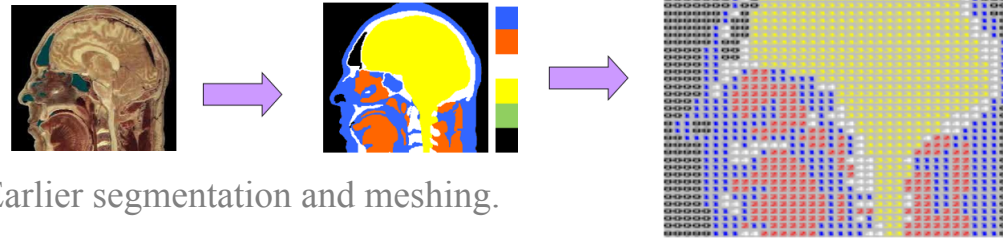
Simulations of Peak Spatial Exposures to Children and Adults from Multiple Devices

Claudio Enrique Fernández-Rodríguez

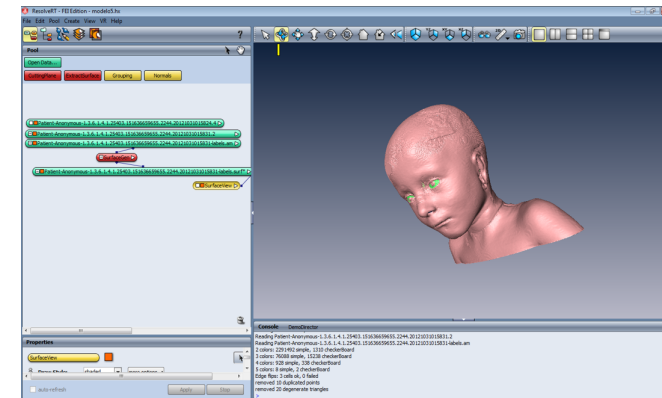


Previous works

Development of “home made” models and FDTD codes since 1998;



Model of DIEGO (10) developed from CTI in 2004.



DAVID (8) segmentation using AMIRA.

Dosimetric Parameters and Exposure Standards

Dosimetry is in “Specific Absorption Rate” – SAR (W/kg) and it’s higher (“peak spatial”) value (psSAR).

Two exposure standards: ICNIRP and FCC.

ICNIRP: 2.0 W/kg for any 10 gram of tissue (10g-psSAR) averaged for 6 min

FCC (IEEE 1995): 1.6 W/kg for any 1 gram of tissue (1g-psSAR) averaged for 30 min.

Compliance tests (1)

Compliance tests for cell phones (FCC, ICNIRP) consider 10g or 1g SAR averages on a homogeneous head model (the IEEE-1528-2003 SAM) with a large adult man dimensions.

However designed to be conservative, this may disregard a significant part of the exposure possibilities and population, such as the children.



<http://www.ets-lindgren.com/pdf/AMS-8900.pdf>

Compliance tests (2)

Limits are designed to avoid heating (1°C increase) after 30 minute call.

This does not consider growing evidence of non-thermal impacts from chronic long term exposures.



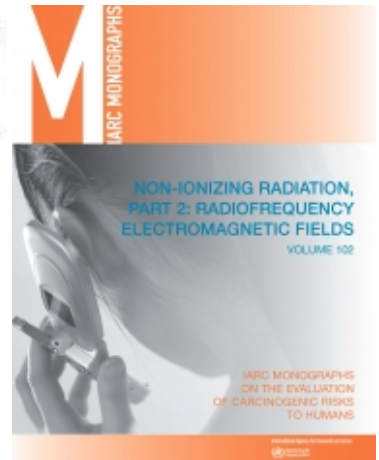
NTP Cell Phone Radiofrequency Radiation Studies

The National Toxicology Program (NTP) has been conducting experiments in rats and mice on potential health hazards from cell phone radiofrequency radiation. The NTP released a report on some important findings.

International Agency
Research on Cancer



World Health
Organization



anses



Anses - Agence nationale de sécurité sanitaire
de l'alimentation, de l'environnement et du
travail

Exposition des enfants aux radiofréquences : pour
un usage modéré et encadré des technologies
sans-fil



Compliance test (3): The pinna

- The uncompressed external ear of an adult man has 19 to 28 mm, typically.
- IEEE 1528 SAM modeled the (compressed) external ear with a 6 mm shell enlargement.
- The standards consider the external ear as an extremity, such as the hands and feet, allowing higher SAR values and the certification tests procedures do not perform measures of the external ear.
- This 6 mm spacing may overestimate the actual distance in many situations.



Measurements x Simulations

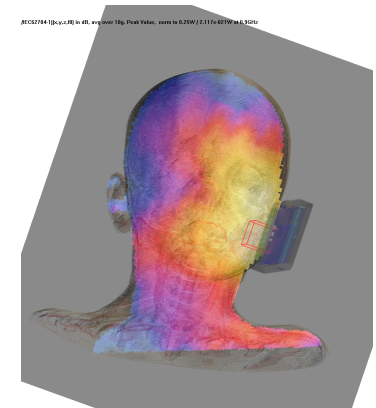
Two processes are used to determine the magnitude of absorbed radiation:



<https://www.speag.com/products/dasy6/dasy6-intro/>

1. Use a robotic arm with an electric field probe on a plastic bowl (the Specific Anthropomorphic Mannequin – SAM) filled with an absorbent liquid (average of 40 head tissues)

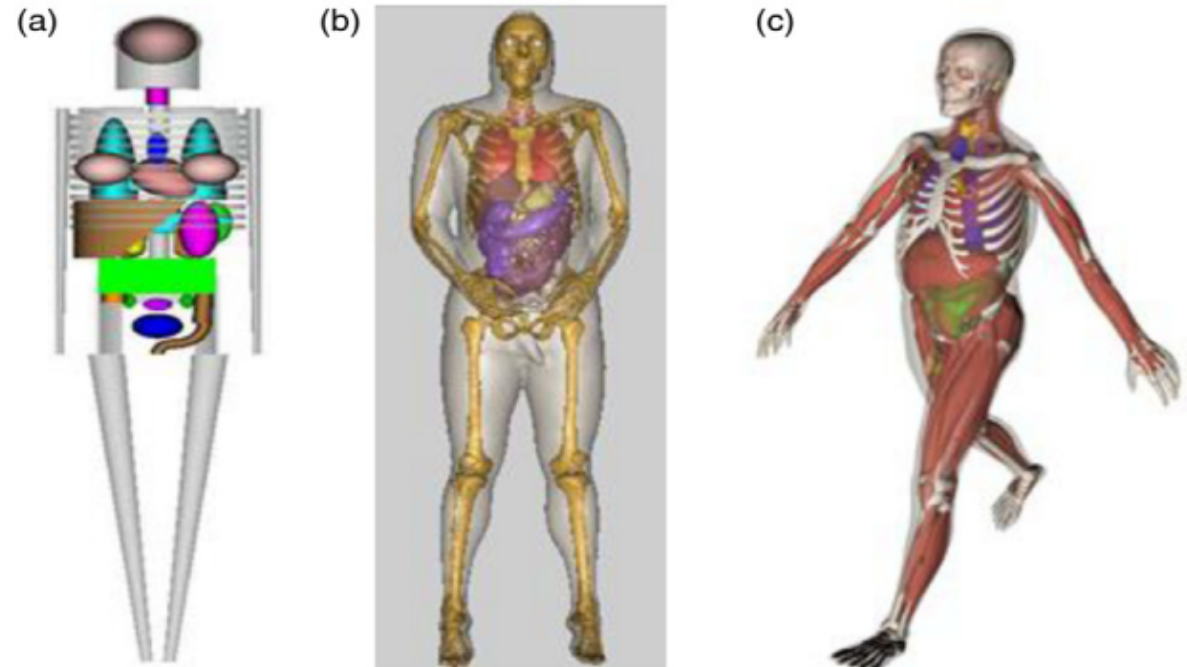
2. Use computer simulation (e.g. based on Finite Difference Time Domain – FDTD)



Models used in Simulations

The precise representation of the calculation domain is relevant for the accuracy of the simulated results.

The increase in computers processing capability allowed more refined models



(a) Stylized Model (1960 to 2000);
(b) Based on Human Anatomy (VHP), since the 1980's;
(c) Posable Model (since the 2000's).

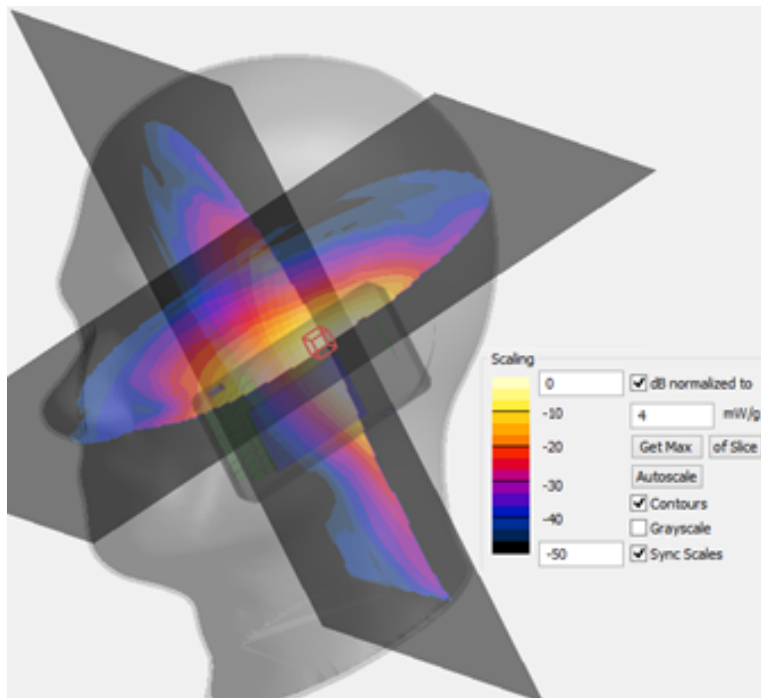
Comparing Measurements x Simulations

Measurements are in a homogeneous medium while simulations may be on “anatomically correct models of the human anatomy”

Attribute	SAM Process	FDTD Process	Comments
Children’s exposures	No	Yes	Male & female, multiple ages 1, 3 & 9 months
Pregnant women’s exposure	No	Yes	
Female exposure	No	Yes	
Small male exposure	No	Yes	
Large male exposure	Yes	Yes	
Electrical tissue parameters	Average of all tissues	Specific for each tissue	
3-D Resolution	1 cm ³	1 mm ³	
Relative cost	High	Low	
Medical implant modeling	No	Yes	
Testes exposure	No	Possible	
Eye exposure	No	Possible	
Thyroid gland exposure	No	Possible	

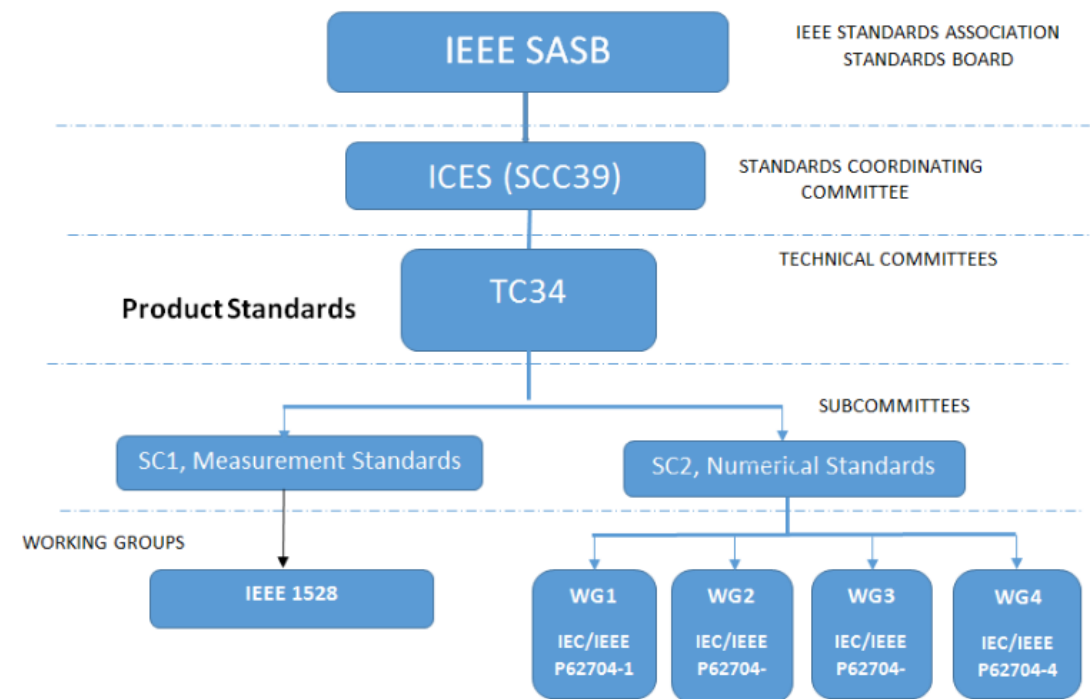
Use of Simulations for Compliance

What are the advantages of simulating on a numeric model of the plastic bowl?



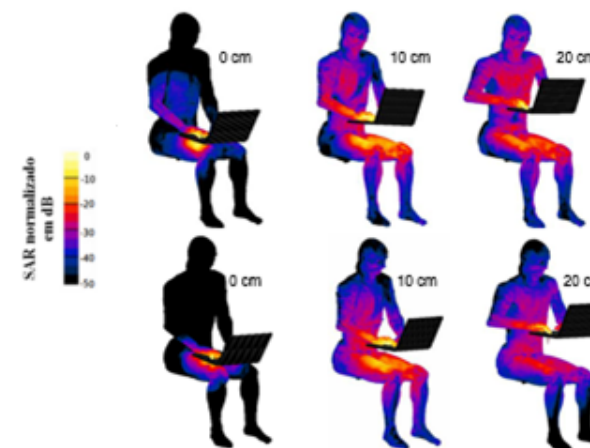
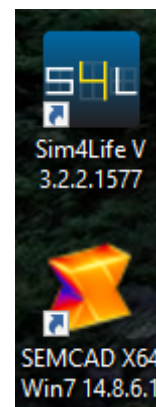
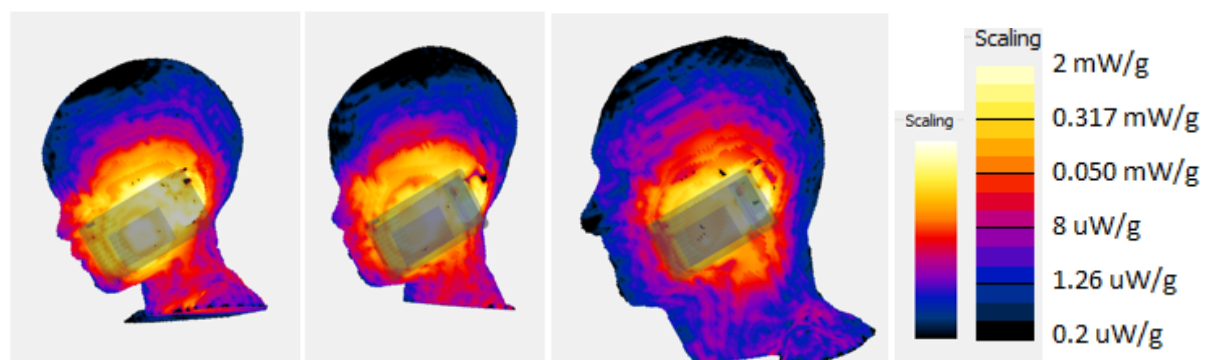
ICES

International Committee on Electromagnetic Safety (Brochure)
Technical Committee 34: Wireless Handset SAR Certification

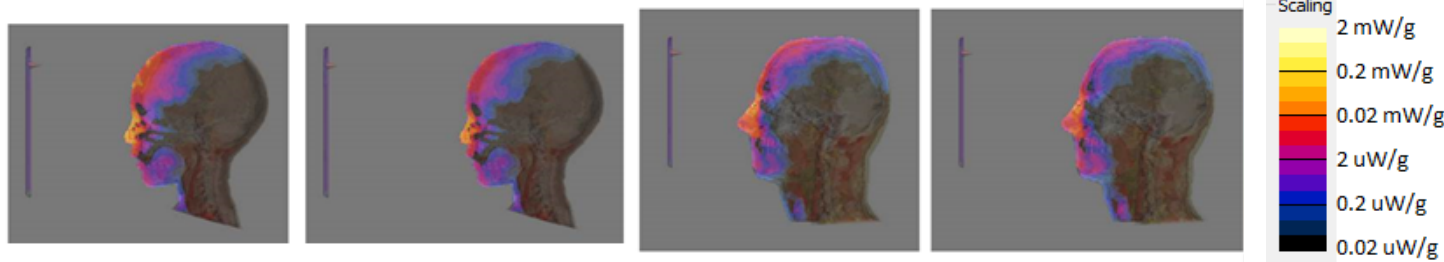


Some possible Dosimetric Simulations (1)

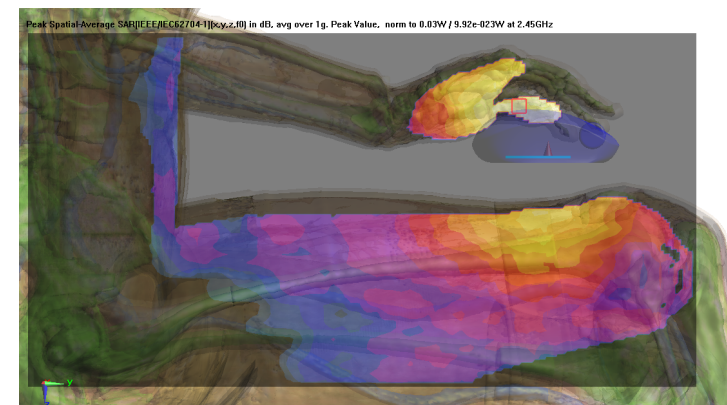
Superficial absorption (from cell phones)



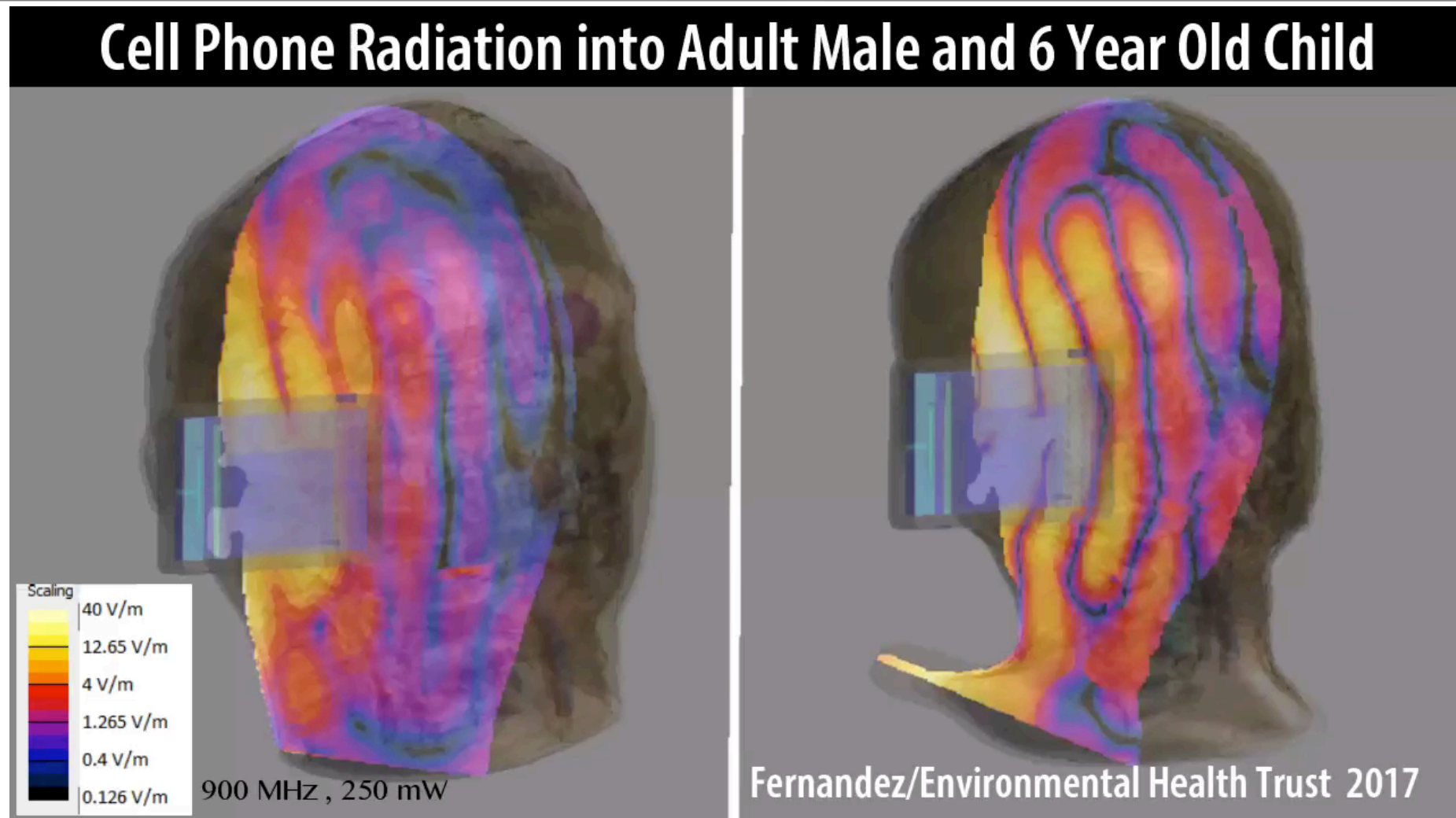
Sagittal plane absorption (from tablets)



WiFi devices

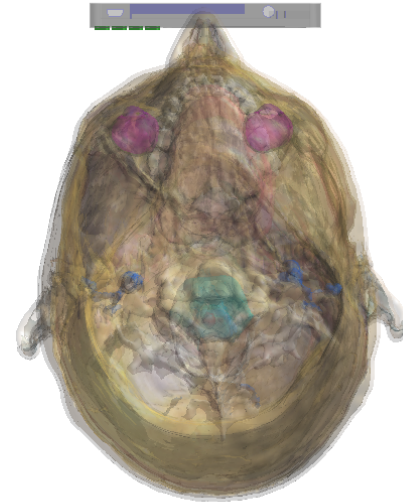
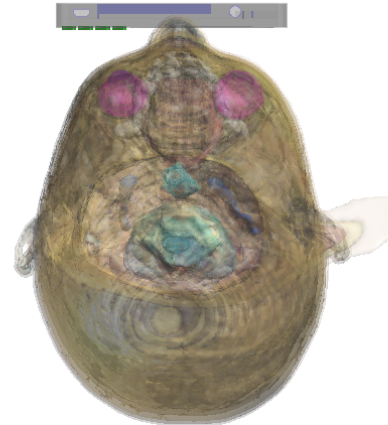


Instantaneous Value of the Electric Field Intensity (V/m) of a Propagating Sinusoidal Wave (900 MHz)

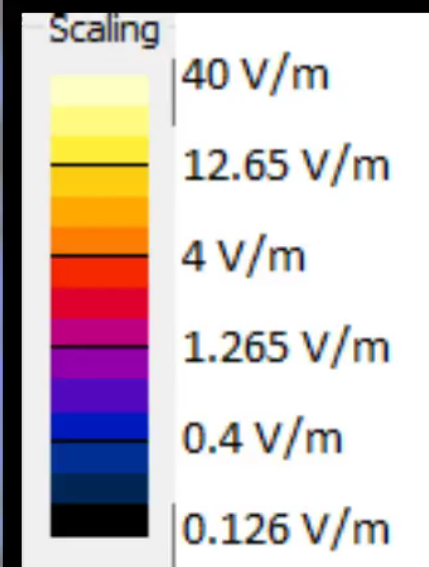
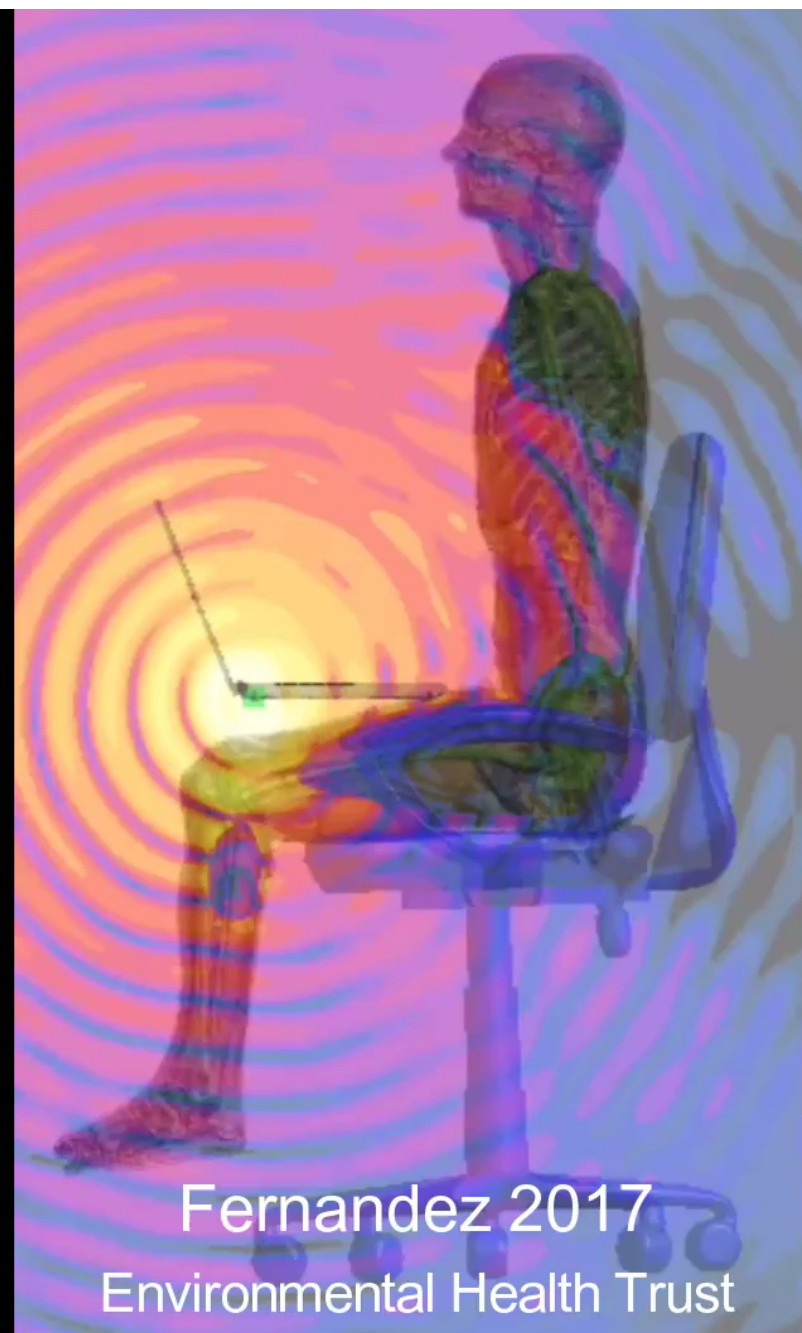


Some possible Dosimetric Simulations (3a)

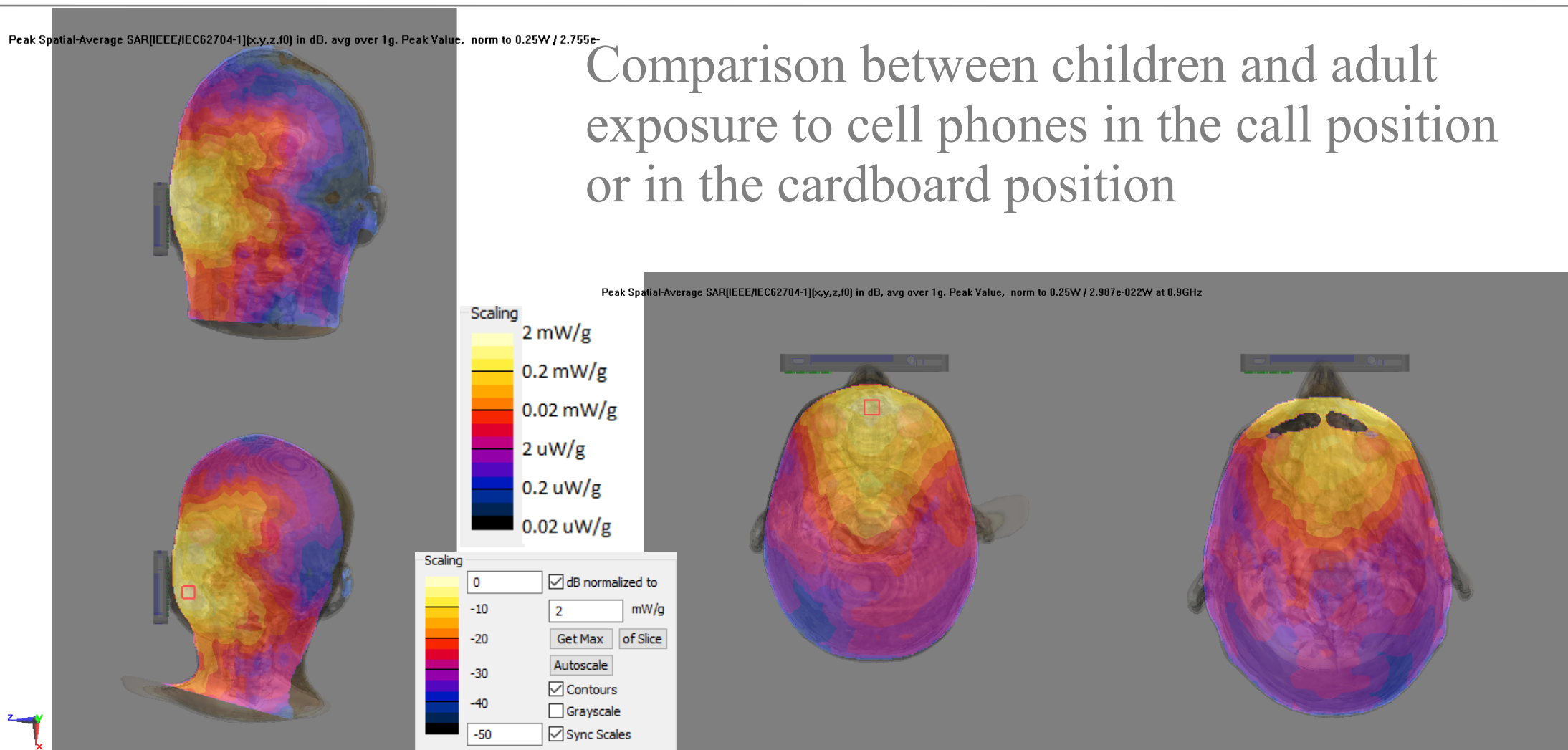
Examples of the models used for the comparison between children and adult exposure to cell phones in the call position or in the cardboard position



lateral 100mW 40V 50dB



Some possible Dosimetric Simulations (3b)



Simulated results: psSAR in the brain (1)

The younger the age
the higher the psSAR
in the brain

The lower the
averaging mass, the
higher the psSAR

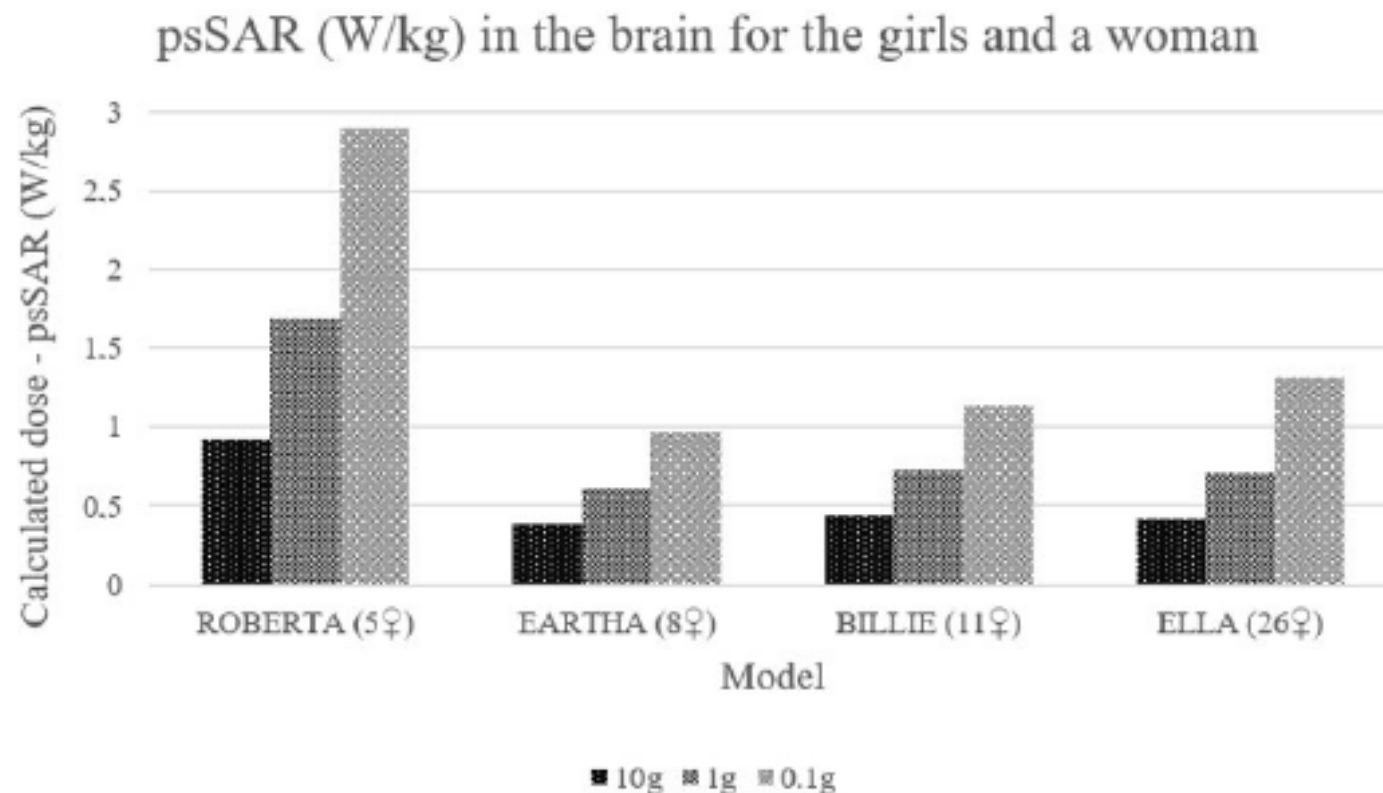


FIGURE 4. psSAR (W/kg) in the brains of four Virtual Family girls and a woman models.

Simulated results: psSAR in the brain (2)

The younger the age
the higher the psSAR
in the brain

The lower the
averaging mass, the
higher the psSAR

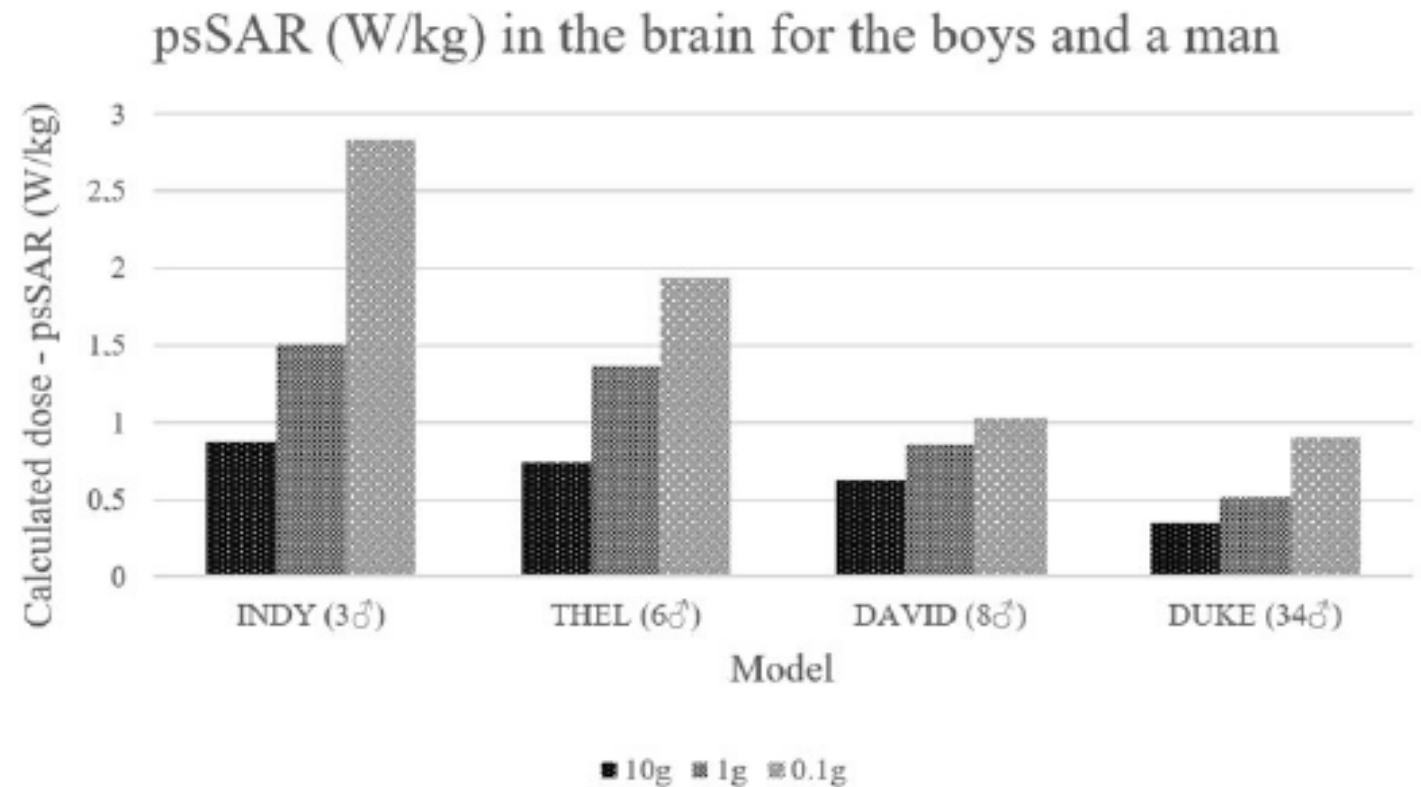


FIGURE 5. psSAR (W/kg) in the brains of one PAEHT boy model, two Virtual Family boys and a Virtual Family man models.

Simulated results: skull thickness

Uncertainty in the segmentation (modeling) process.

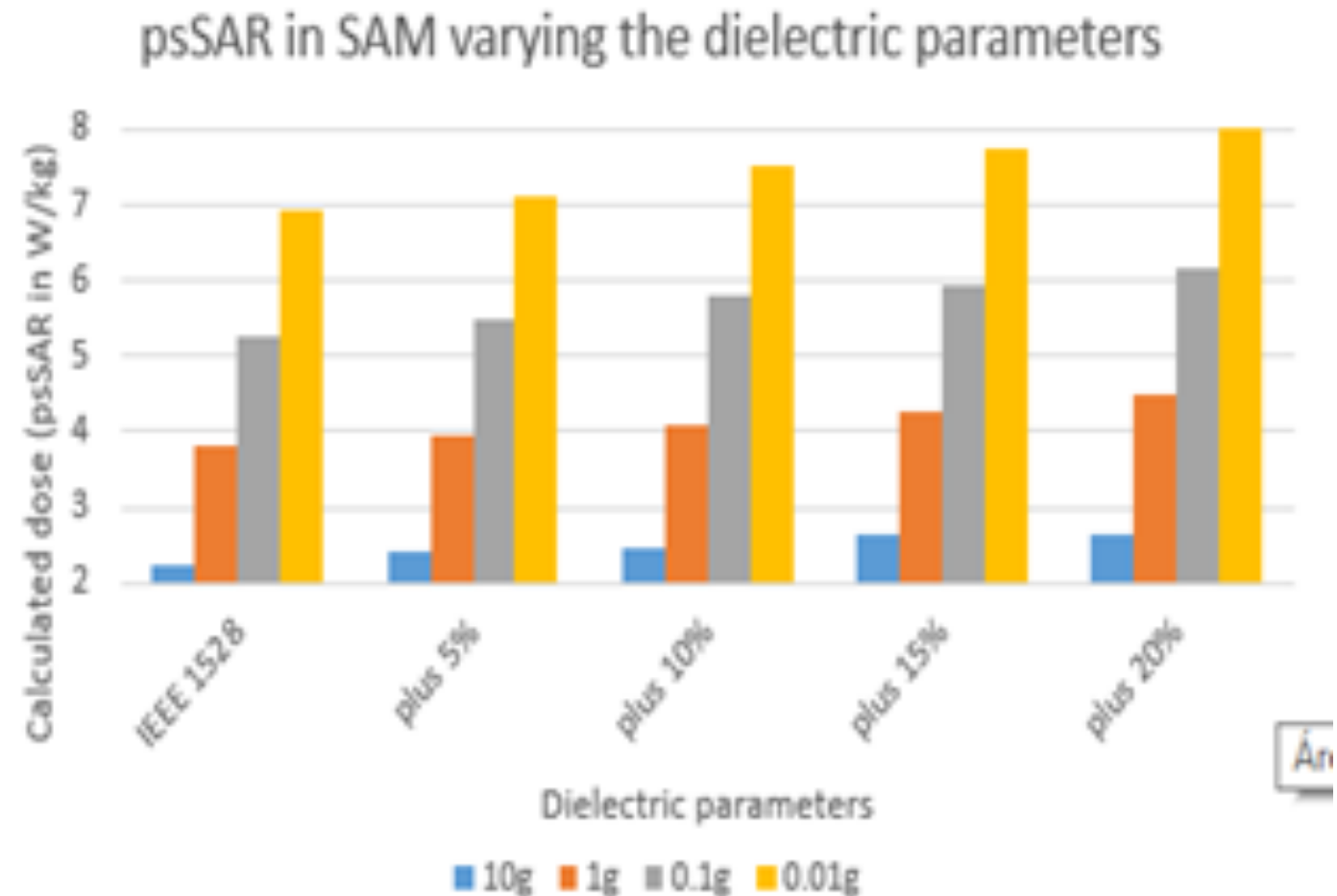
5%-10% higher psSAR in the brain in the thin skull



psSAR varying the dielectric parameters

Not surprisingly, psSAR is greater for smaller volumes.

In addition to be more selective, these smaller volumes are closest to the surface, where the field attenuation is lower.

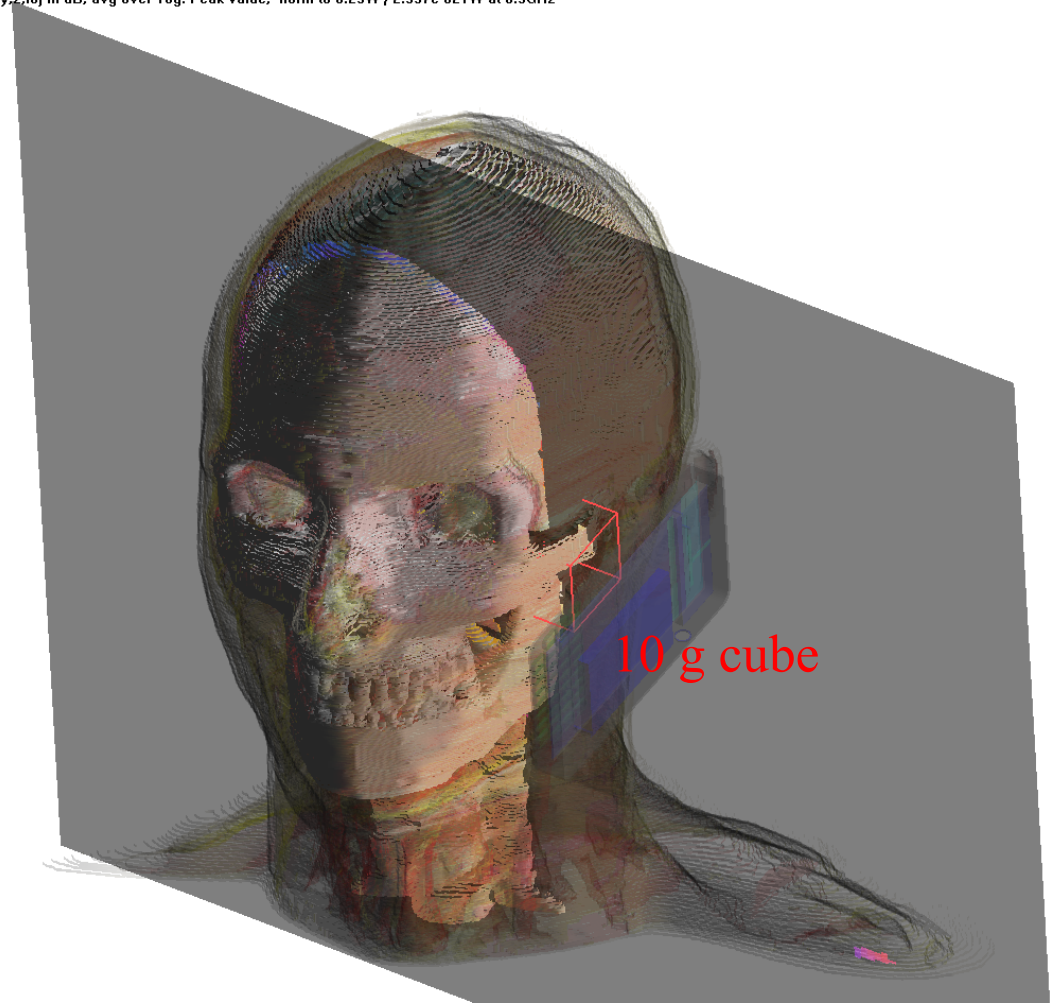


psSAR varying the averaging mass

Larger averaging volumes or masses may be inadequate to specific tissues dosimetry.

10 mg of brain tissue may contain around a billion neurons (of 4 microns diameter).

]](x,y,z,f0) in dB, avg over 10g, Peak Value, norm to 0.25W / 2.357e-021W at 0.9GHz



Dielectric parameters dependence with age

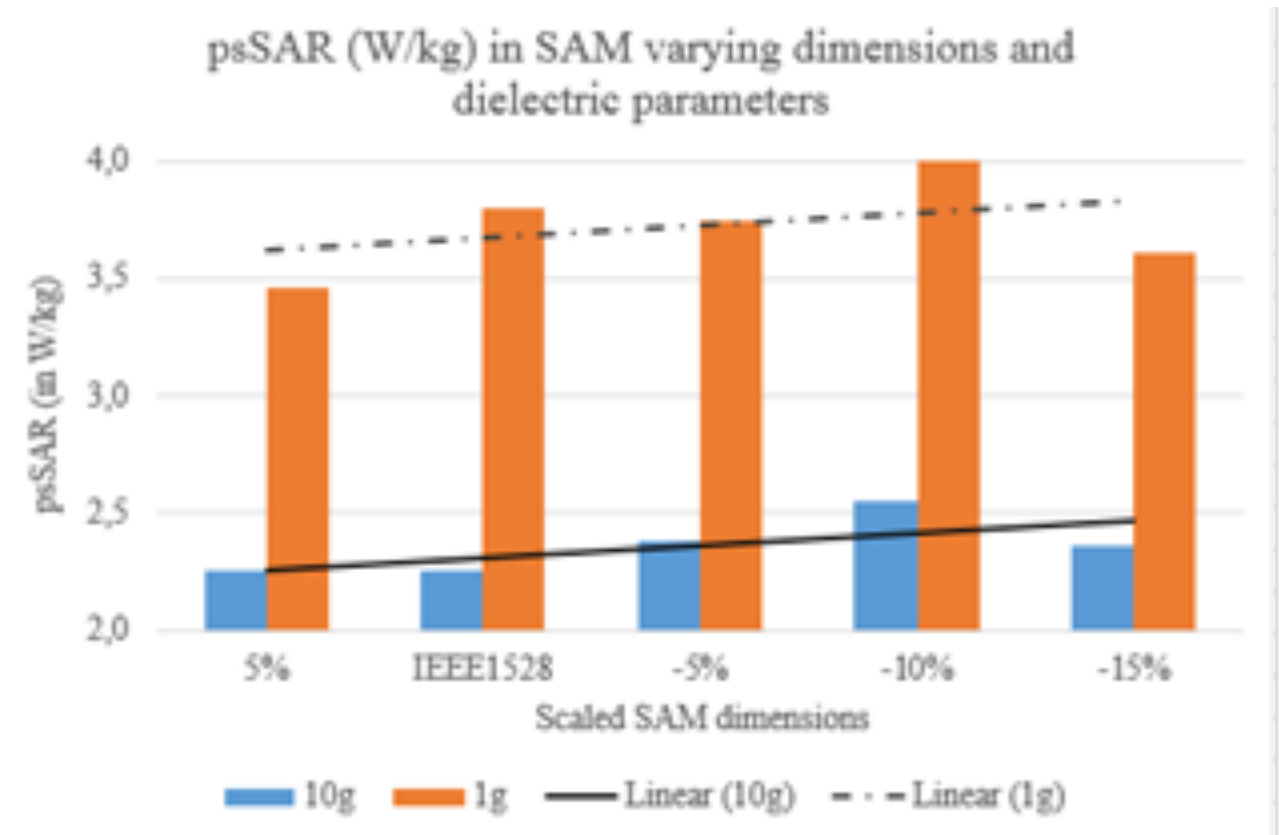
It is well established that most younger tissues have higher equivalent conductivity and permittivity. The following table is from A.Peyman works.

Dielectric parameters	250 kg White matter	50 kg White matter	10 kg White matter	250 kg Bones	50 kg Bones	10 kg Bones	Grey matter
Conductivity	0.48 S/m	0.59 S/m	0.67 S/m	0.26 S/m	0.65 S/m	0.75 S/m	1 S/m
Relative Permittivity	28.6	34	39.8	18.8	34.3	41.1	50

These parametric values come from animals. So the lower the weight the younger the animal. In addition the higher the conductivity and permittivity the larger the absorption of radiation.

Results for different dielectric parameters

psSAR is higher for the smaller head with higher dielectric parameters.



Results for higher frequencies and 5G

As the SAR is a mass (or volume) related parameter it would have no relevance for assessment at frequencies above 10 GHz since at these very high frequencies the absorption depth is only a few millimeters

Are the skin and eyes protected by the actual standards?

Are the used dosimetric parameters always the most relevant ?

Total absorption

Because the antenna and the wavelength of the radiation in the tissues are much smaller than the head all the radiation in the direction of the head is absorbed.

Since the dielectric constants (k) of the head tissues are higher than the air's, more than 50% of the cellphone radiation is absorbed by the both a child's and an adult's head (the “half space” of higher k).

Typically more than 70% of the delivered power is absorbed in the head.

A tricky question

“Do children absorb more RF than adults ?”

Total head absorption and psSAR over the total head (which is a superficial measure) may be similar for adults and children.

However, there are significant differences in the absorption distribution. The power is absorbed in proportionally deeper regions and tissues in the children.

psSAR in children's brain is twice than in adult's brain.

psSAR in some specific tissues (hippocampus, bone marrow,...) may be up to **10 fold in the children.**

SAR simulation limitations

SAR simulations does not consider the long-term, low level exposure effects.

The modulation is not (usually) considered in SAR simulations.

Blood-brain barrier, cell membrane or chemistry modifications related to the RF are not (usually) considered in SAR simulations.

Tissues are (usually) modeled as homogeneous materials.

Summary, comments and conclusions (1)

- The SAR and the recommended limits only consider heating effects.
- The existing SAM certification process relies only in a large homogeneous head model filled with a liquid that has the average dielectric parameters of the 40 tissues within an adult's head.
- We found situations in which the IEEE 1528 SAM process underestimates the psSAR (e.g. for the children).
 - IEEE 1528 is conservative for a “significant majority of persons”... but not for children.
- Higher dielectric parameter values, such as those in younger tissues, result in significantly increased psSAR (up to 15%).

Summary, comments and conclusions (2)

- ICNIRP standards indicates averages over 10 g.
- Averaging over smaller volumes or masses, such as 1 g (like in FCC/FDA standard) and 100 mg, which are consistent with the probe size, the human anatomy and the simulation models, doubles and triples the measured SAR.
- Additional uncertainties in the certification process can arise because the compliance test considers the total head psSAR and not specific tissues exposure, such as the white matter, the grey matter, the bone marrow, the hippocampus, etc.
- The IEEE 1528 defines a $\pm 30\%$ uncertainty factor (page 55)
 - This means it is uncertain, whether or not, any psSAR that is $\geq 70\%$ of the limit, violates the limit.

Summary, comments and conclusions (3)

e.g. ICRP consider the precautionary principle.

Since ICNIRP consider only proved thermal effects,

Should we propose the creation of the ICNIRNTEP ?

Summary (4): Dosimetry in the brain

“Do children absorb more RF than adults ?”

psSAR in children’s brain is twice than in adult’s brain.

psSAR in some specific tissues (hippocampus, bone marrow,...) may be up to **10 fold in the children.**



Summary, comments and conclusions (5)

- It is recommended that the existing SAM certification process should be
 - *Complemented or replaced* with an FDTD computer simulation process ...
 - ... using anatomically based models, including those representatives of the children, ...
 - ... and measuring the SAR, averaged over smaller volumes, ...
 - ... in different tissues.

Acknowledgments

Alvaro Augusto Almeida de Salles



An Invitation to www.imoc2017.com



Submission deadline
April 17th 2017

August 27–30

Venue
Hotel Majestic, Águas de Lindoia,
SP, Brazil

The SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC) is a biennial event organized by the Brazilian Microwave and Optoelectronics Society (SBMO) and IEEE Microwave Theory and Techniques Society (MTT-S) since 1985.

One of the suggested topics is “Biological Effects of Electromagnetic radiation, EMC and EMI”