Modelling of RF Exposure in Children: Differences of Energy Absorption Between the Heads of Adults and Children

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Background

Debate on RF Absorption in Children Heads

- Studies show contradictory results regarding the energy absorption from RF exposure by mobile phones in the heads of children compared to absorption rates in the heads of adults under similar external conditions, e.g.,
  - Gandhi et al., 1996: significant differences
  - Schönborn et al., 1998: no significant differences
- Current compliance tests for SAR values are based on phantoms representing a 90th percentile adult male head.

General Absorption Mechanisms

- Currents are predominantly induced in the tissues by inductive coupling, i.e., they are mainly proportional to the magnetic field distribution at the skin of the user*.
- Main parameters determining SAR levels in the near-field:

~ H^2	(H	=	magnetic field strength at the skin)
~ j^2	(j	=	current density on antenna/enclosure)
~ $1/d^2$	(d	=	distance between tissue and antenna/enclosure)
~ σ	(σ	=	conductivity of the tissue)
~ f	(f	=	frequency)

- Reactive magnetic field components couple as efficiently as the radiating components.

-> Strong dependence of SAR on device position with respect to head
-> Strong dependence of SAR values on handset design
-> Dependence of SAR on scatterer

*Kuster et.al., IEEE Trans. on VT, Vol. 41, No.1 February 1992, pp. 17-23

Methodology Used by the Group of Om Gandhi

Human Models

- Scaled adult phantom to simulate children
  -> inappropriate because of the different anatomies, especially of the head; in addition, incorrect scaling factors were applied

Source

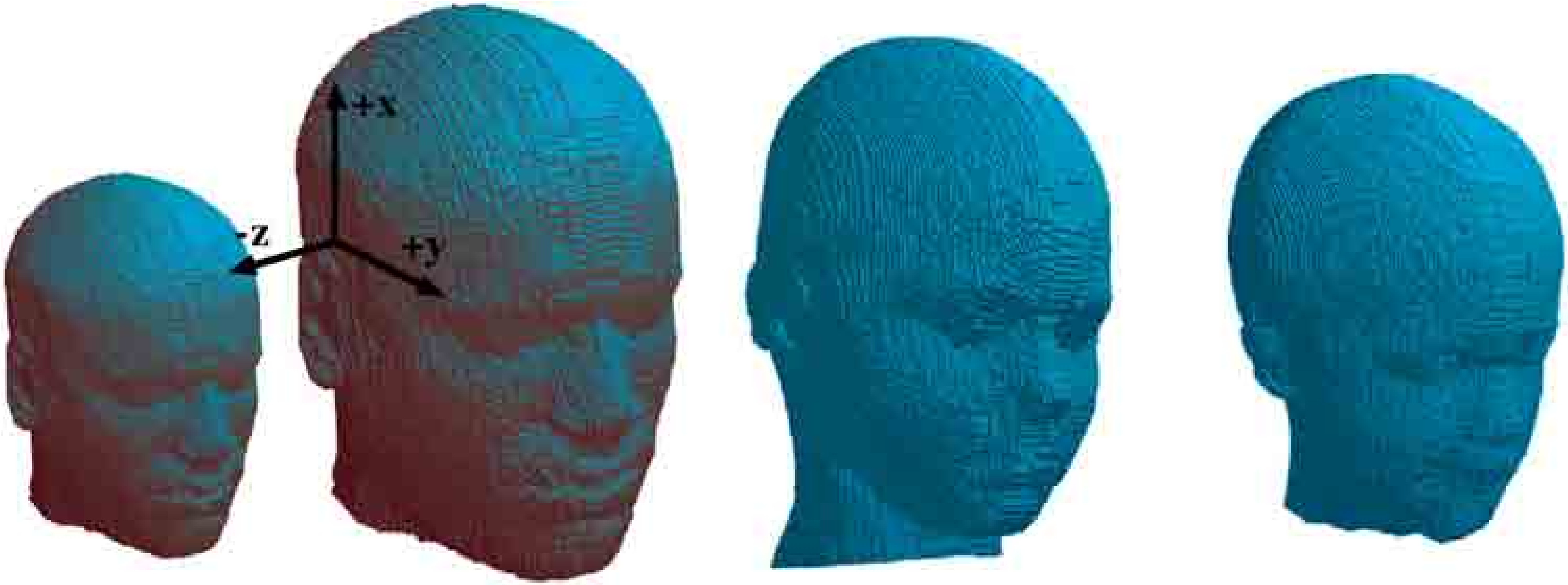
- Generic mobile phone with monopole antenna
  -> badly characterized source with respect to
    - impedance as a function of distance and dielectric loading in the near-field
    - position (small shifts parallel to the ear plane may result in strong variations for inhomogeneous human models)
    - distance between source and head tissue during scaling

Methodology

- The effects of various parameters on SAR are mixed together with the parameter of interest (head size).

-> The results demonstrating differences in the absorption can be explained due to different phone position, feedpoint impedance, voxel sizes and inappropriate scaling.

Applied Scaling Method



M5, scaled with 0.67

adult M5

7 year old child

3 year old child

Methodology Used by Schönborn et al.

Human Models

- Derived from MRI data of different adults and two children
- Scaled adult models

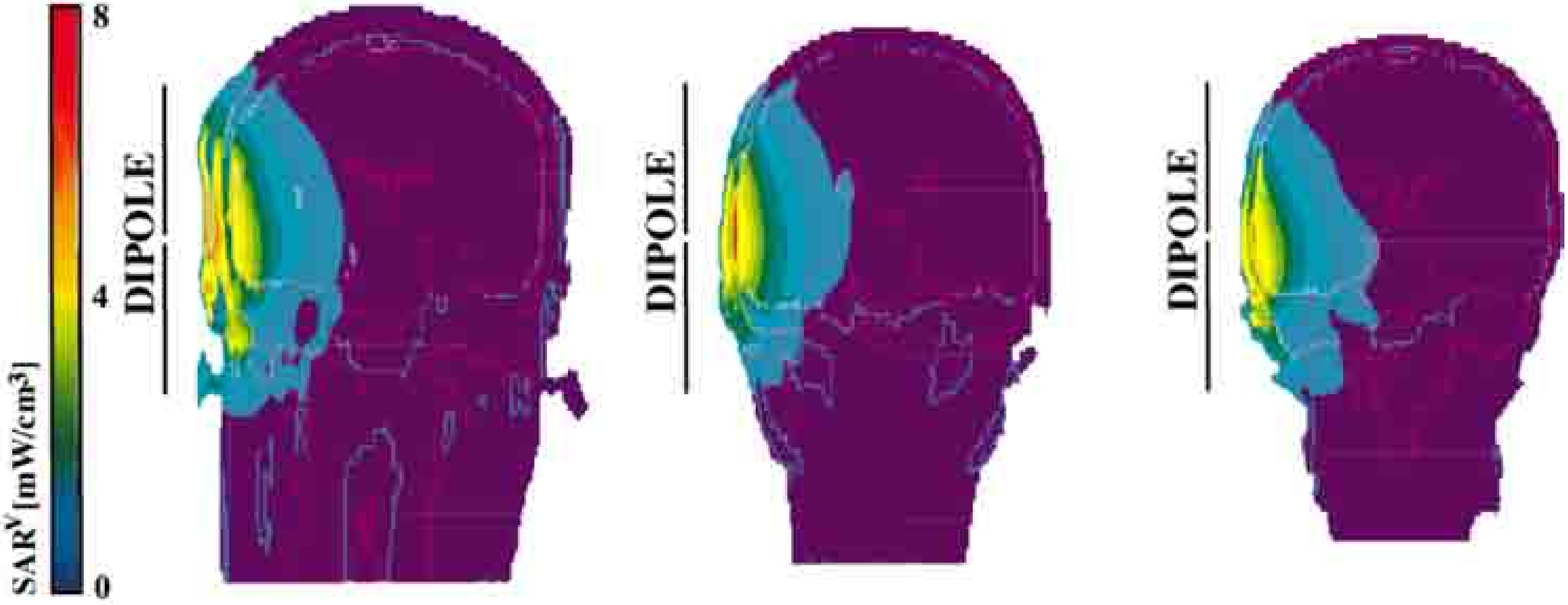
Source

- 0.45λ dipole source at a fixed position to the head (15 mm)
  - well defined current distribution
  - well defined impedance
  - well defined distance to the head

Results

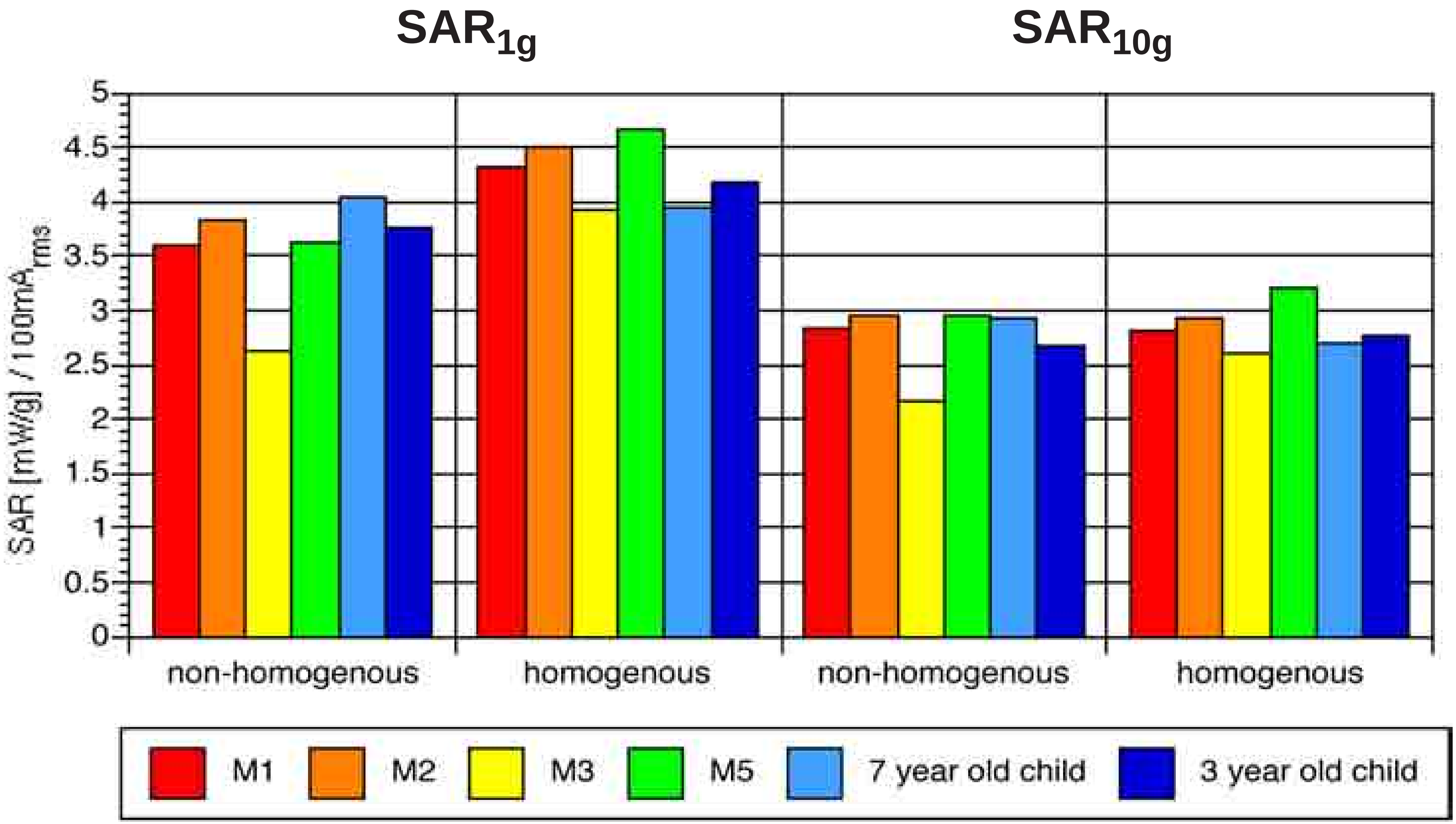
- No significant differences in the SAR distribution and penetration depth between the head phantoms of adults and children
- Spatial peak SAR values are within the variations found for different adult phantoms

SAR Distribution at 900 MHz



Adult M5 | 7 year old child | 3 year old child

Spatial Peak SAR Values (900 MHz)



Objectives

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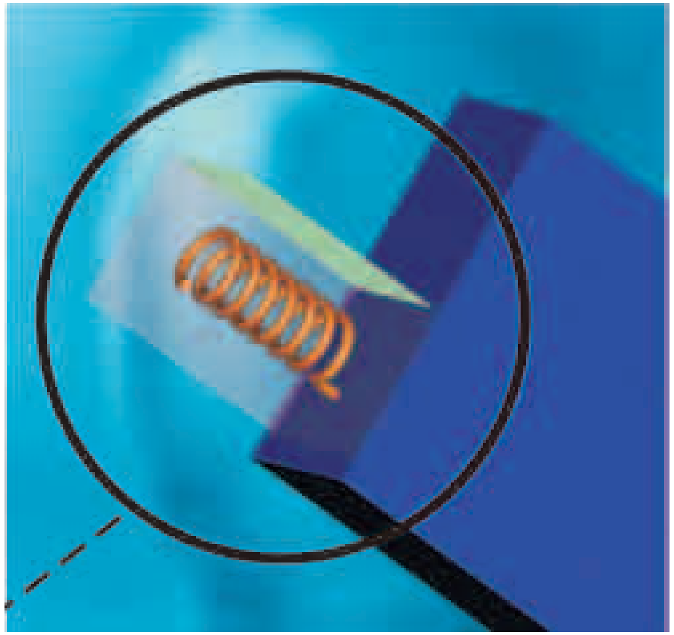
- Investigation of whether the generic finding from Schönborn et al. using dipoles also applies for generic and commercial mobile phones
- Verification that the SAM phantom (proposed by CENELEC/IEEE/IEC for compliance testing of mobile phones) constitutes a conservative approach, i.e., leads to higher SAR values when compared to the exposure of actual humans including children

Methods

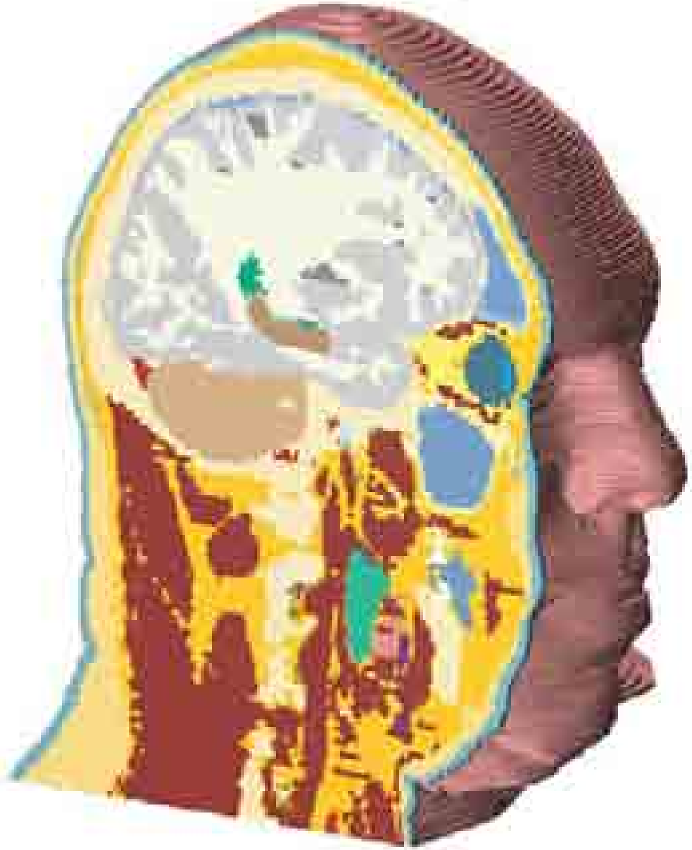
Numerical Simulation and Validation

- FDTD method (SEMCAD)
- CAD environment allowing free positioning, moving and tilting of head models
- High resolution head models discretized with a grid resolution < $\lambda/10$ and grid steps between 0.3 - 10mm (0.3 - 0.5mm in ear region)
- Grid step analysis: voxel size < 0.5mm results to less than 1% deviation of SAR from the reference (0.15mm voxel size)
- Simulation of helical antenna with subgrid algorithm (mesh step refinement of 1:2)
- Dielectric parameters according Gabriel
- SAR averaging for 1g and 10g masses according the IEEE standard
- SAR evaluation without ear pinna
- SAR normalization to feedpoint power
- Experimental SAR verification with the DASY4 near-field scanner



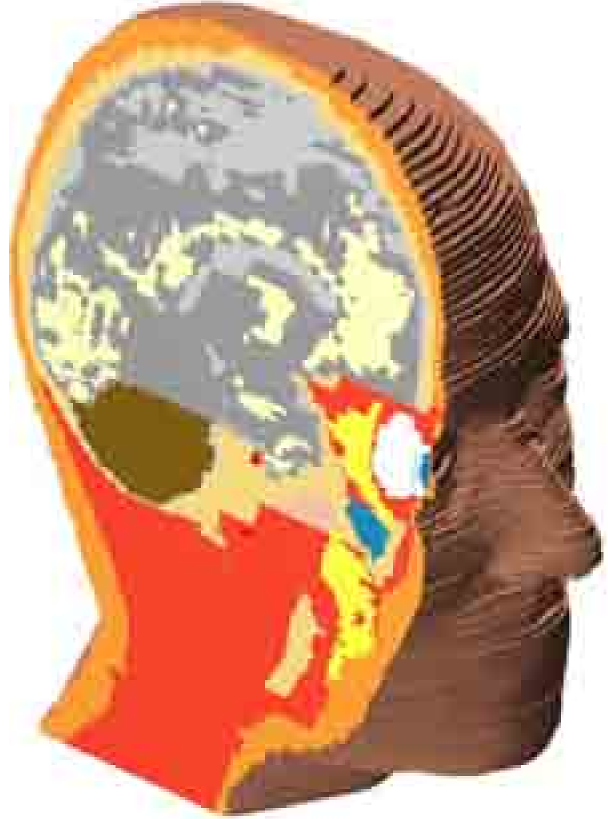
Adult Head Phantoms

Adult male



- based on Visible Human Project
- slice thickness: 2mm
- 23 different tissues

HR-EF-1

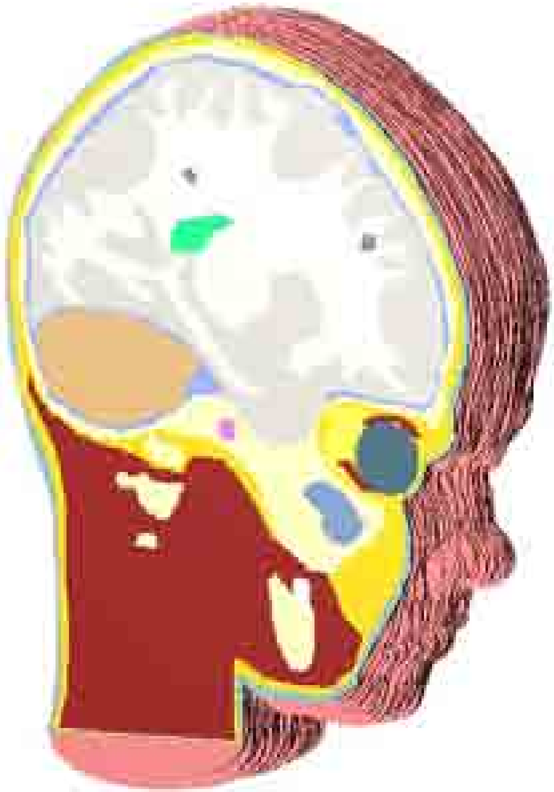


- based on MRI of female (40 years)
- slice thickness: 1mm in ear region
- compressed ear
- 15 different tissues

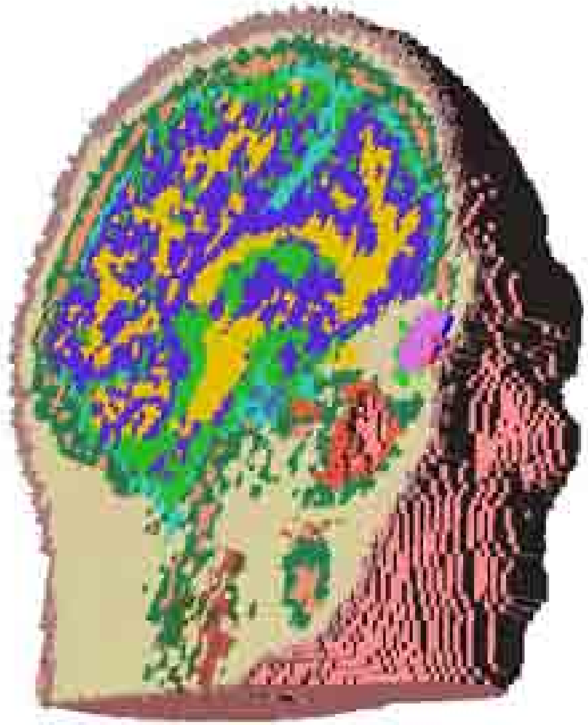
Child Head Phantoms□□□

3YC□□□□□□

7YC□□□□□□



J7YC



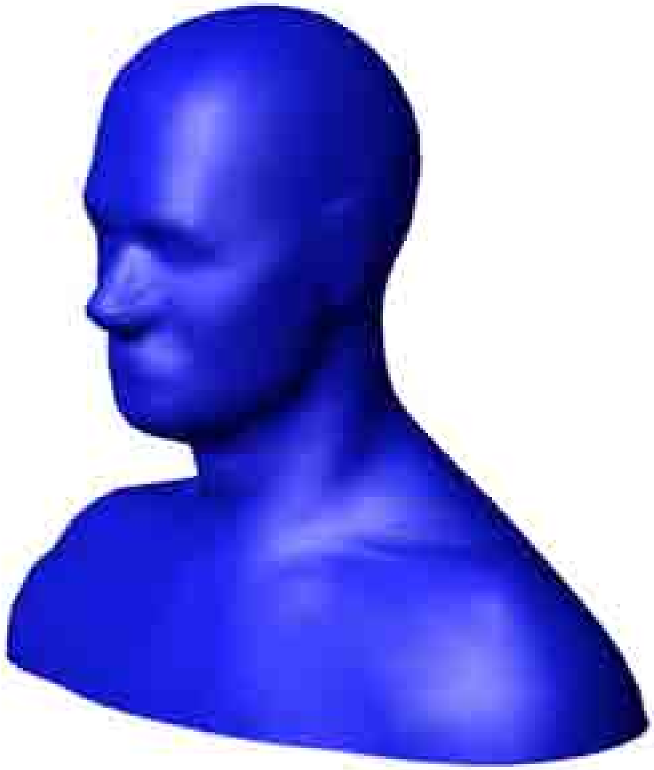
- 3 year old child
- phantom based on MRI
- slice thickness: 2mm
- 15 different tissues

- 7 year old child
- phantom based on MRI
- slice thickness: 2mm
- 15 different tissues

- Japanese adult scaled to 7 year child
- slice thickness: 2mm
- 20 different tissues

Phantoms Used for Compliance Testing

SAM



Specific Anthropomorphic Mannequin

- corresponds to 90th percentile male head
- shell thickness: 2mm, 6mm at ear

Generic Twin

- quasi-standard phantom in 1996 - 2000
- shell thickness: 2.7mm
- ear is represented by lossless spacer with thickness of 2 mm

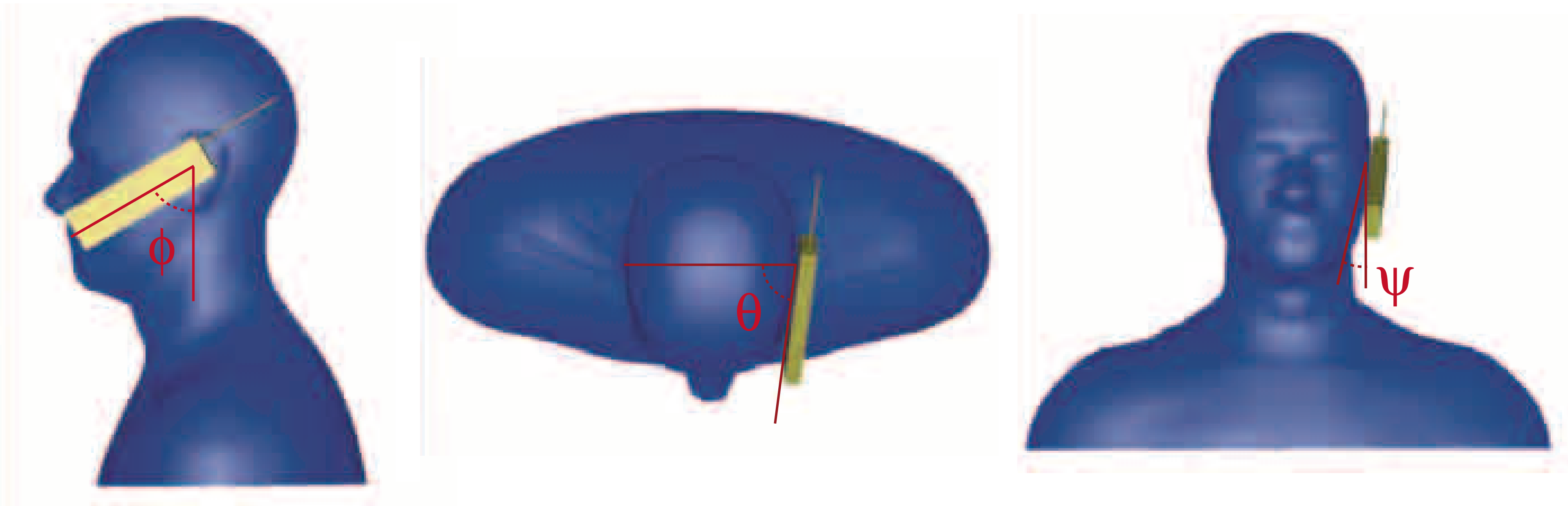
Mobile Phones

Hollow metallic generic phones with plexiglas coating and monopole and helical antennas

generic phones with with plastic body and center metallic sheet (proposed by SCC 34)

commercial tri-band phone (Motorola T250)

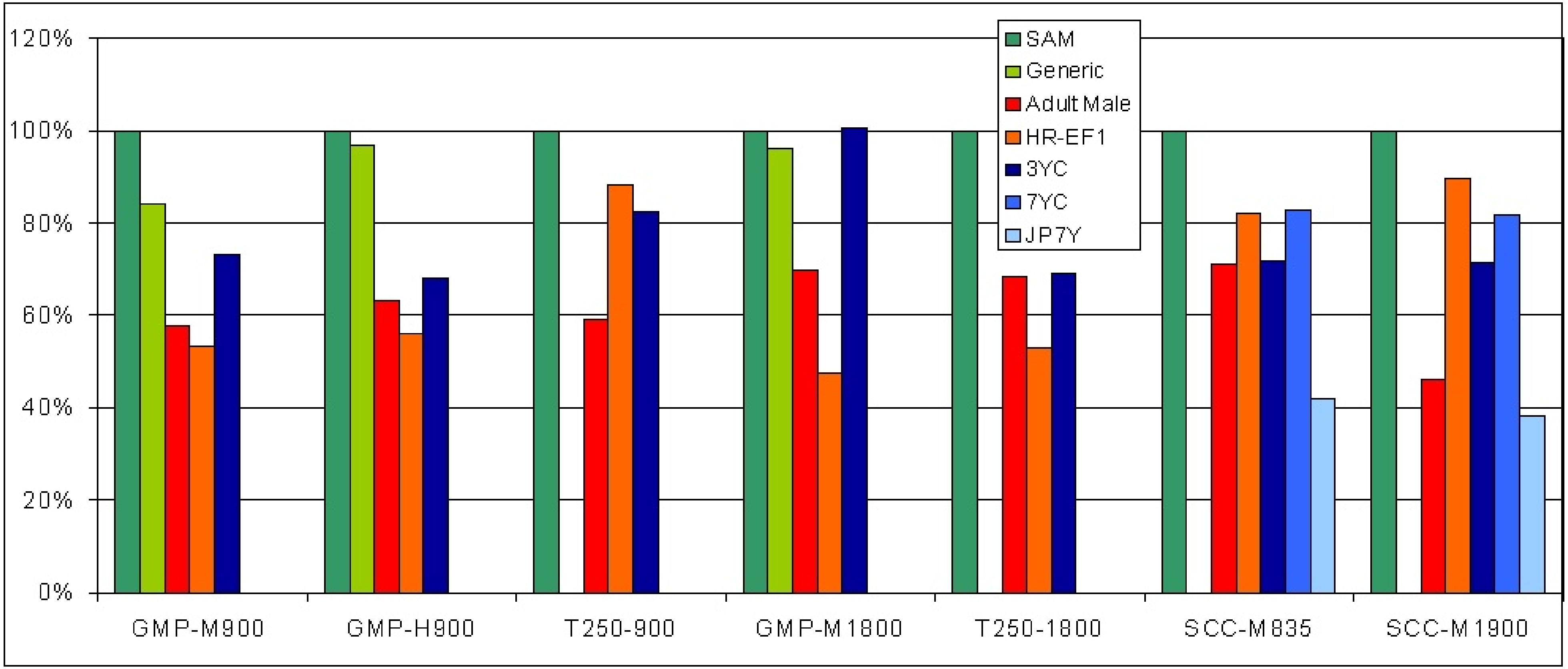
Holding Positions



	ϕ	θ	ψ
touch position	67°	10°	73°
tilted position	67°	10°	100°

Results

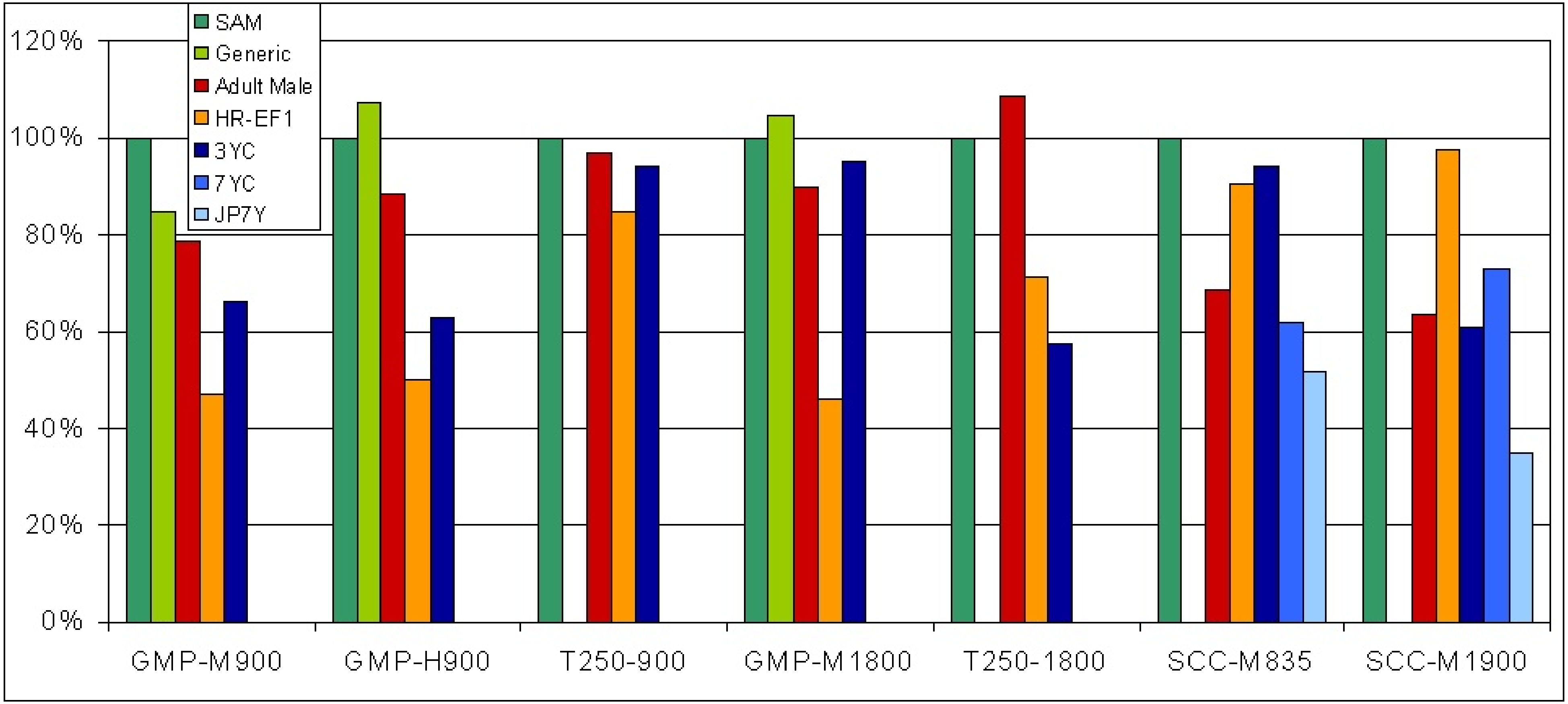
Worst Case Spatial Peak SAR Values 10g



-> No systematic difference between adult (red) and child (blue) heads.

-> SAM and Generic Twin are overestimating the SAR.

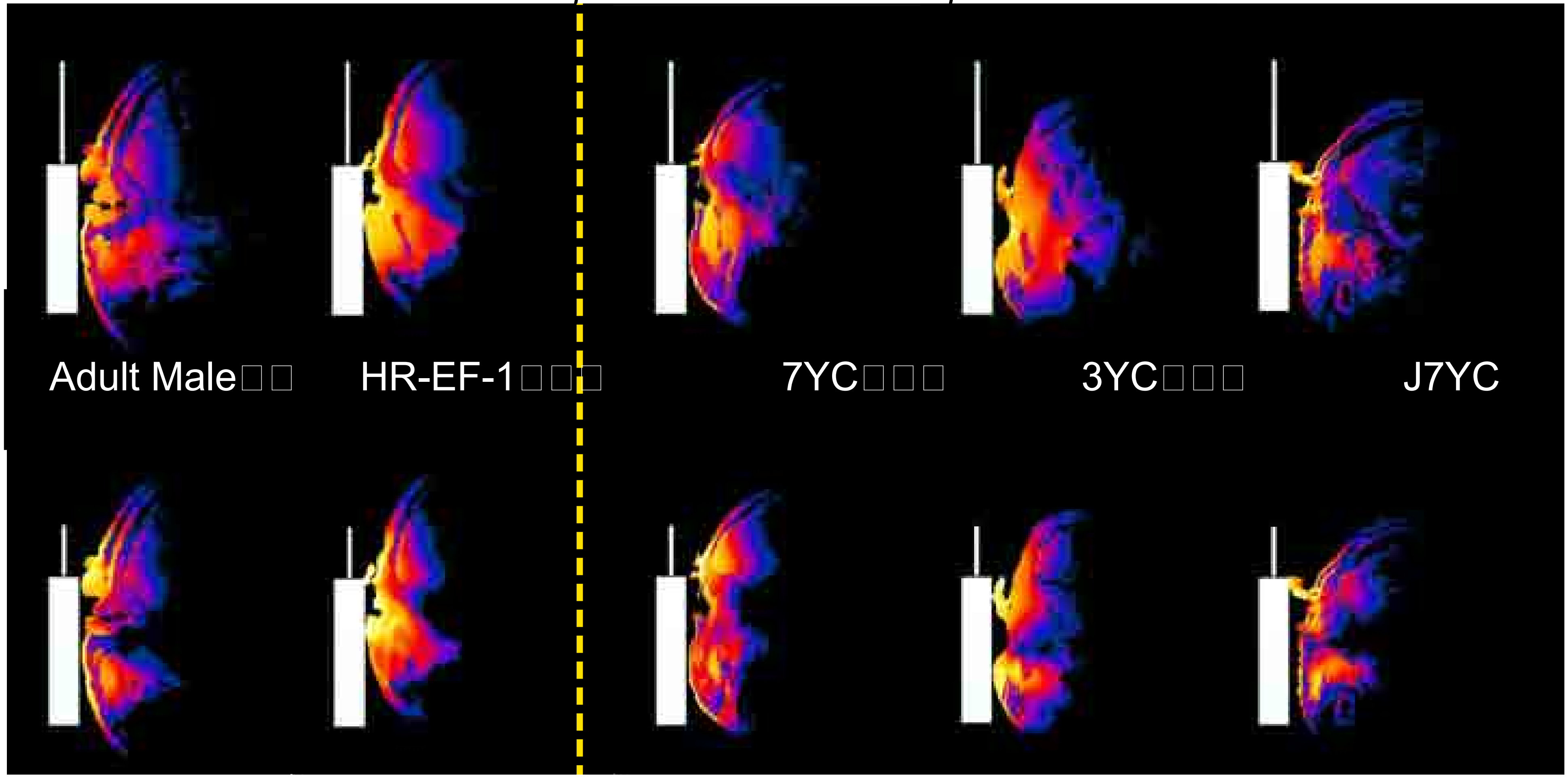
Worst Case Spatial Peak SAR Values 1g



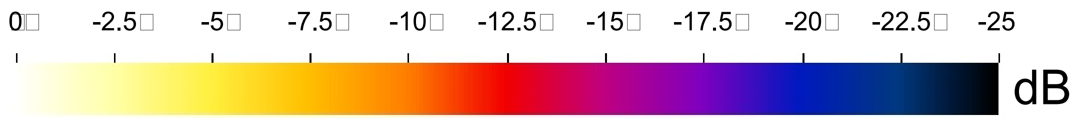
Selected SAR Distribution: SCC-M835 & 1900

835 MHz

SAR in plane of antenna feedpoint



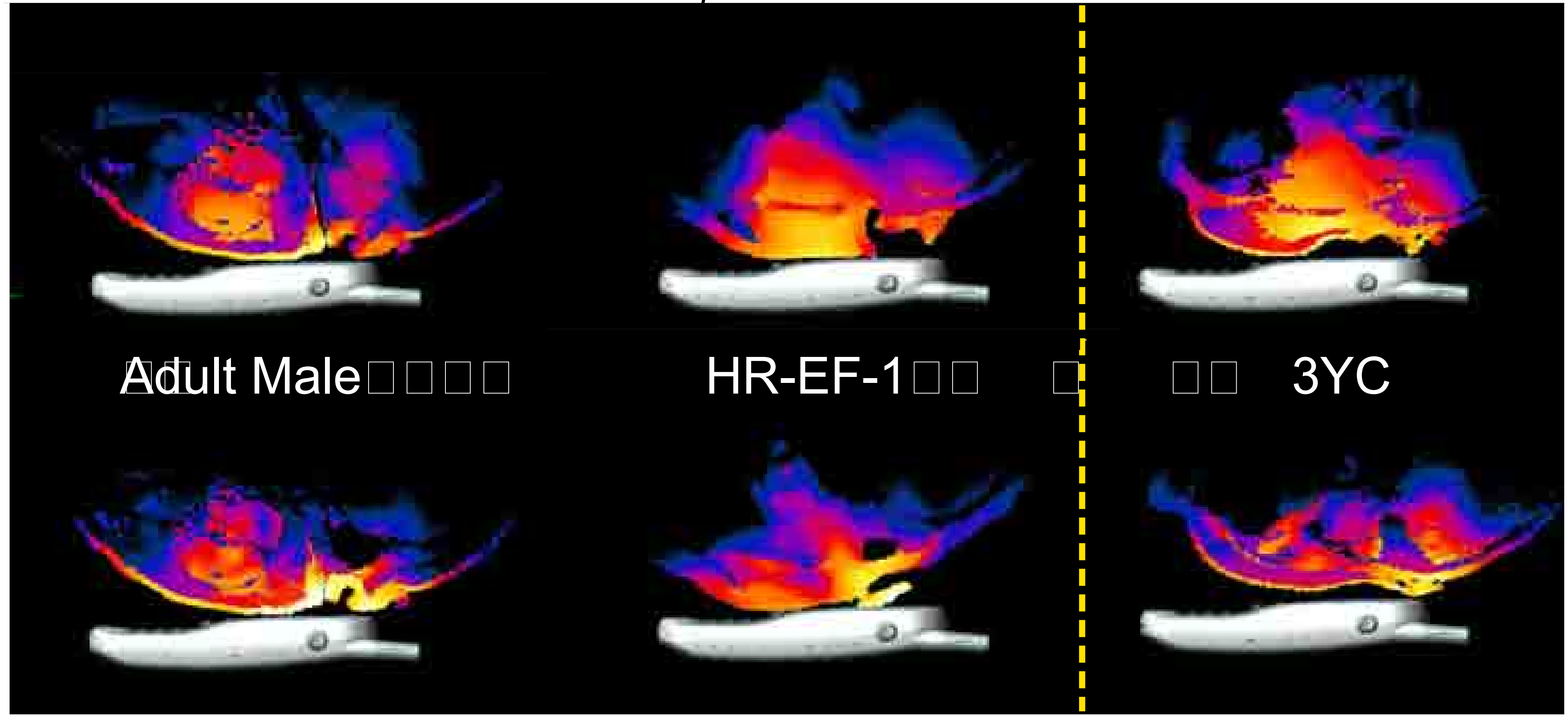
1900 MHz



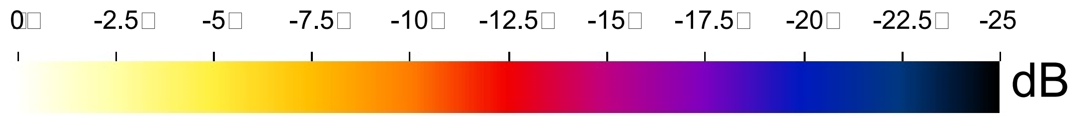
Selected SAR Distribution: T250

900 MHz

SAR in the plane of the SAR maximum



1800 MHz



Conclusions

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- Exposure values from mobile phones are sensitive to many parameters, e.g., distance of current source, individual tissue distribution, holding position, antenna feedpoint impedance, etc.
- The generic approach from Schönborn et al. as well as the physical coupling mechanisms show that the different head size of children is not a sensitive factor for the SAR. Differences of SAR for studies applying a mobile phone with an adult and child phantom are mainly caused by changing some of the parameters above and not due to the different head size.
- No significant differences between adults and children were found for the investigated head models (2 adult, 3 child), mobile phones (5 generic, 1 commercial) and holding positions (tilted, touch), i.e., child / adult variations are similar to those between different adults.
- For the tested cases, SAM provides a conservative exposure value.
- Open questions are the thickness of the compressed ear of children as well as the effect of different dielectric tissue parameters.

Acknowledgements

- Mobile Manufacturers Forum, Brussels