Modélisation électromagnétique des interactions ondes personnes

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(Unrestricted)

Context

- Tremendous development of mobile communications
- Public concerns about health impact
- Authorities have established guidelines and recommendations
  - Guidelines exist (ICNIRP, IEEE)
  - In 1999 EU council has output recommendations
  - State of the art dosimetry basis for the standards
- No evidence of health effects below the limits
- Worldwide Research goes on
  - High quality dosimetry needed

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Outline

- The objectives of Dosimetry
- Methodology
- Samples of dosimetry applied to
  - **Mobile phones**
  - **Base station antennas**
- Challenges of future radio systems

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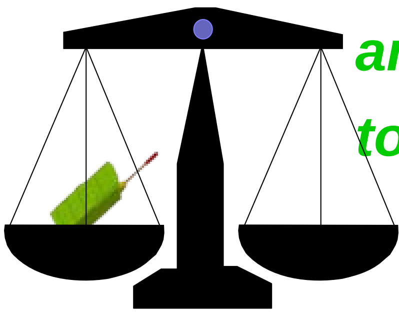
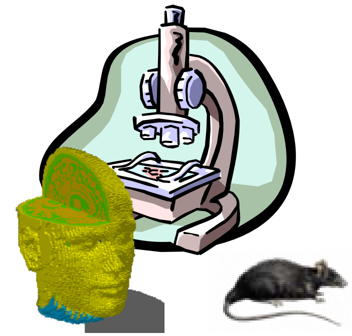
The objectives of Dosimetry



➔ ***Estimate the fields or the absorbed power to analyse the compliance to standards***

SAR < 2 Watts/kg ?



➔ ***Know the field levels in the tissues to allow biologists to conclude***

➔ ***Estimate the field levels induced by a mobile phone and a base station in operational mode***

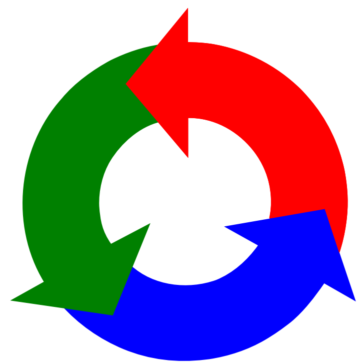
Methodology

- *E field, H field, Power density, SAR*
- *Distribution, Absolute Value*

Physical Quantities

- *Simulation tools : what if scenarios, extrapolation, cost effective*
- *Measurement tools : real, asked for by the public*
- *Complementary*

Methods

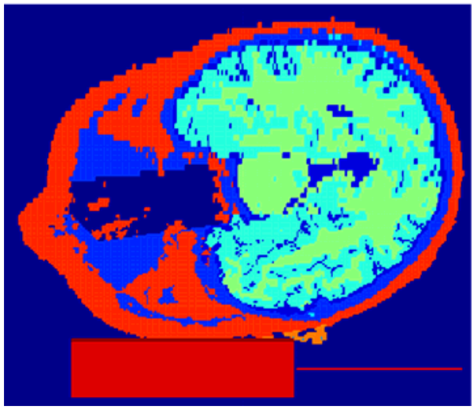


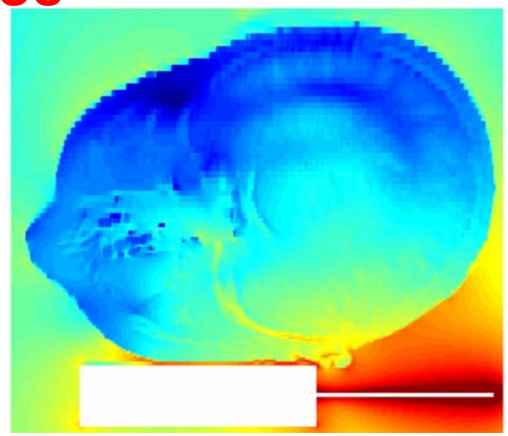
- *Frequency, Modulation, time-varying characteristics*
- *Near field/Far field*
- *Huygens principle*

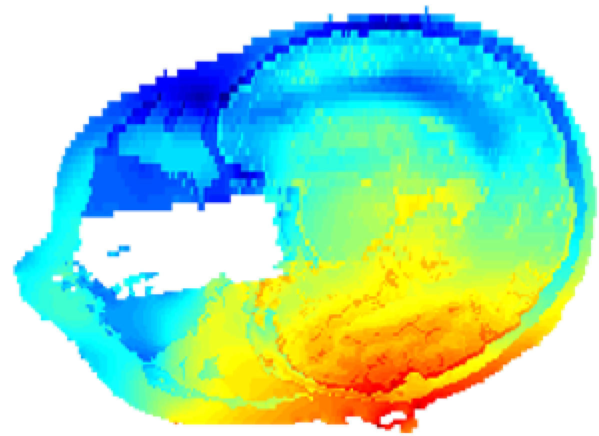
Characterisation of the sources

Mobile numerical dosimetry

➔ *FDTD (Finite Difference Time Domain, Yee 1966),* ***method of choice***







➔ ***MRI segmentation for head tissue modelling***

➔ ***Phone modelling***

➔ ***E field***

➔ ***SAR averaged over 10g of tissue***

$$SAR = \frac{\sigma E^2}{2\rho}$$

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Dosimetry
and Children exposure

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SAR in children head

The questions

Is child exposure comparable to adult exposure?

Is SAM conservative for children?

To answer we need children head models to compare to adult and SAM

- heads derived from adult?
- heads coming from MRI?

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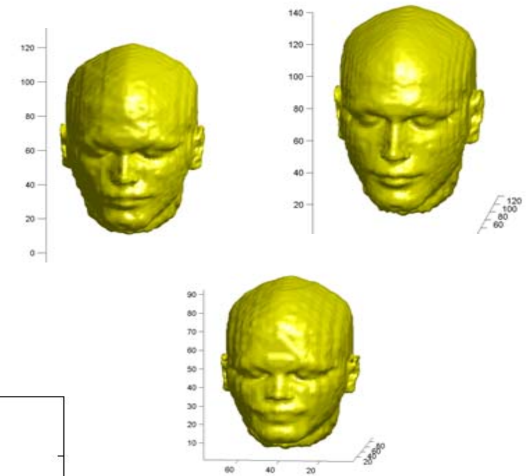
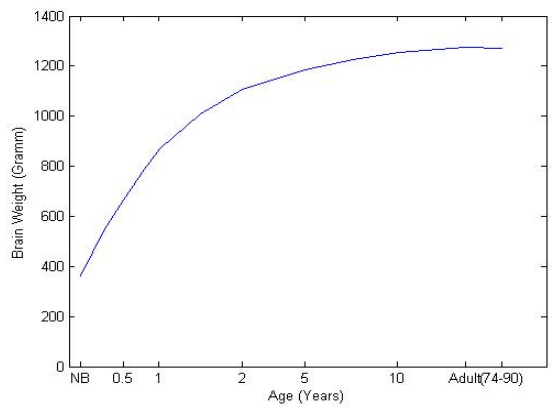
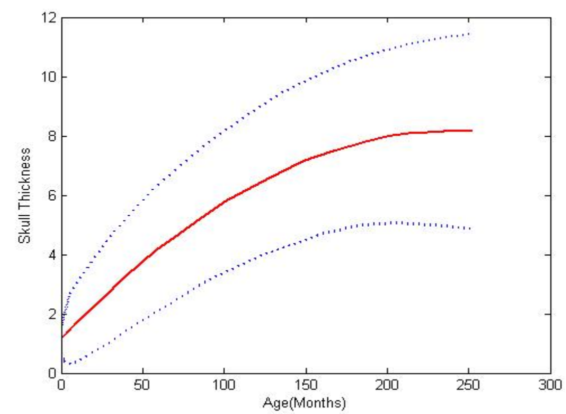
Child Head model based on adult

Morphing based on external shape is possible

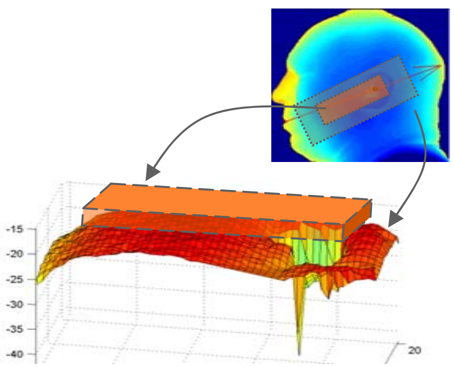
Nevertheless organs have specific growth and analysis using morphing approach has to be handled carefully.



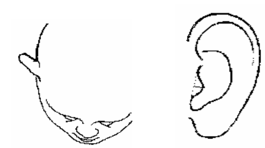




Phone positioning and ear shape influence



The positioning of the phone induces uncertainties

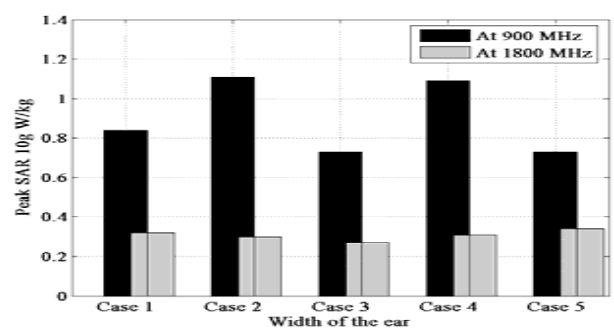


The ear shape induces uncertainties

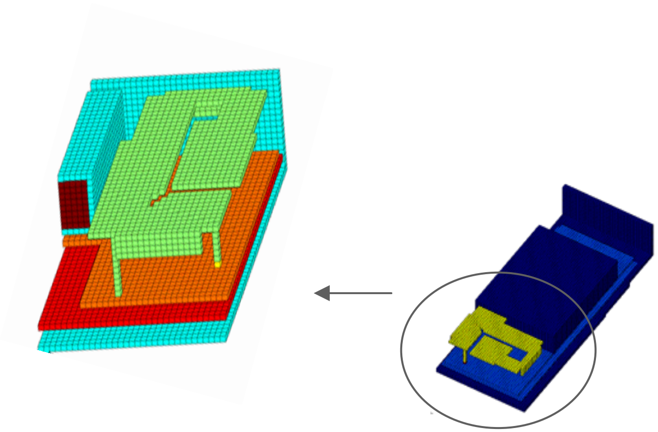
Ear dimensions	Length auricle (mm)	Width auricle (mm)	Depth ear (mm)
Case 1	56	33	2
Case 2	58	35	4
Case 3	60	37	6
Case 4	63	38	8
Case 5	59	33	10

Ear	Length of the auricle	Width of the auricle	Depth of the ear
12 y. old Child head	59 mm	33 mm	10 mm
12 years age class	59,6 ± 3,6 (mm)	35,3 ± 2,3 (mm)	6 ± 4 (mm)

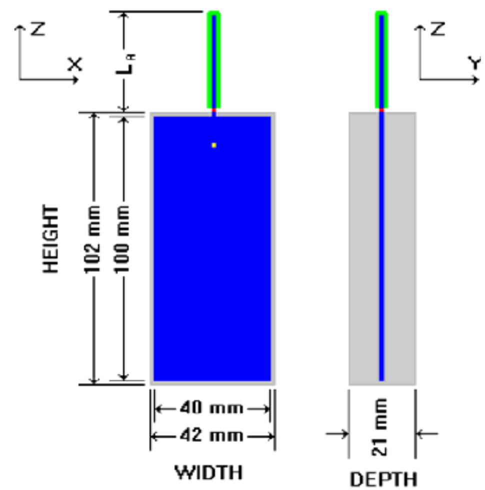
TABLE I: EAR DIMENSIONS OF CHILD HEAD OF 12 YEARS OLD



Handset model

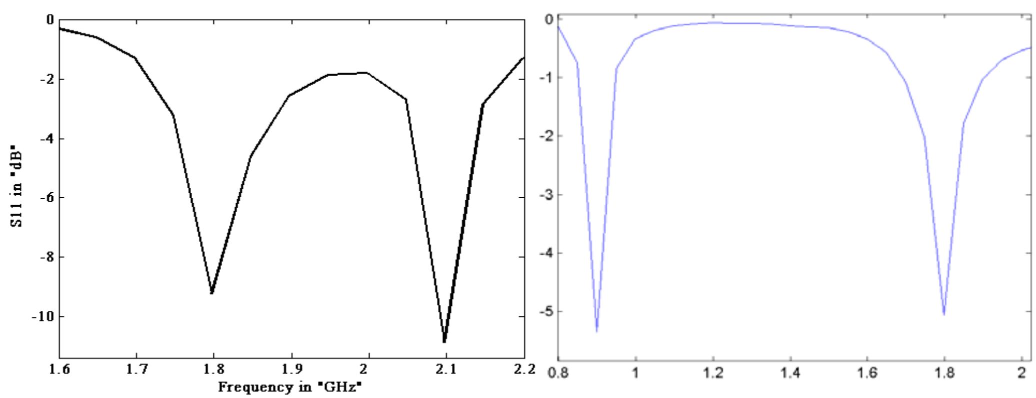


PATCH



IEEE

Monopole + box



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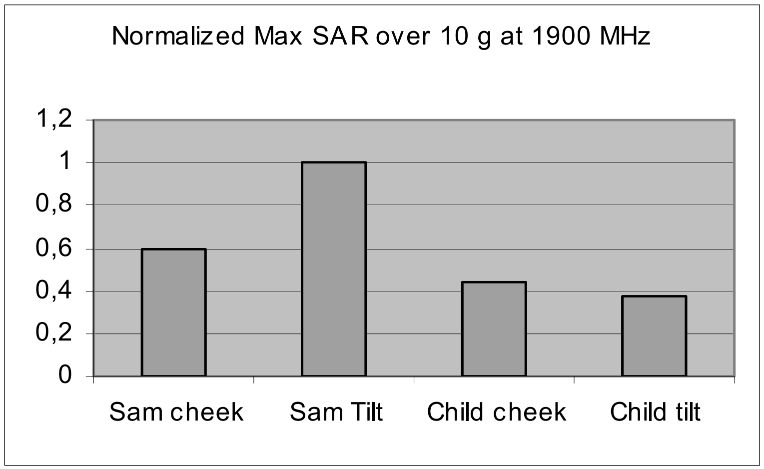
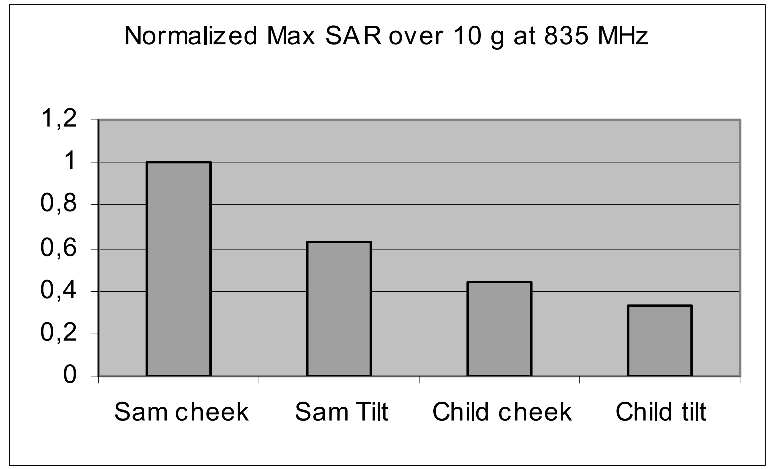
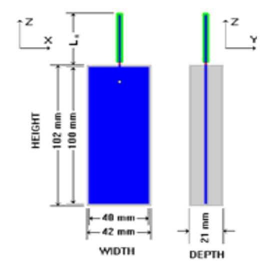
Child like versus SAM







Study carried out with the international intercomparison

SAM can be considered as conservative

The IEEE Child like head is coming from Japan (Nagoya Institute of Technology)

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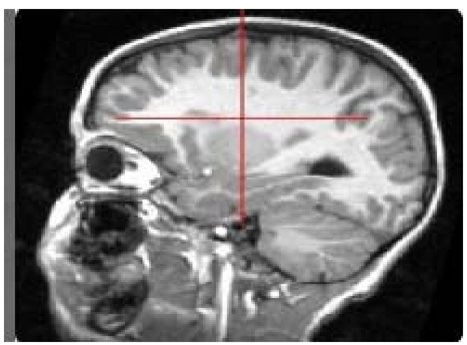
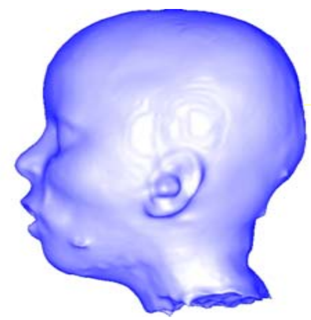
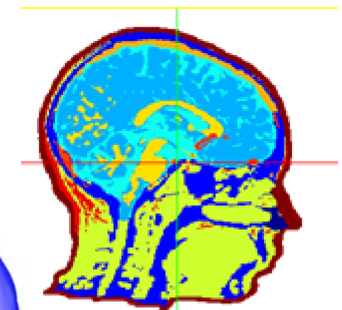
Children Head models based on MRI

December 2004 model developped
- 4 years old
- 5 years old
- 9 years old
- 12 years old



12 years old





5 years old

4 years old

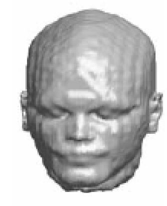
Comparisons

adulte

12 ans

4 ans

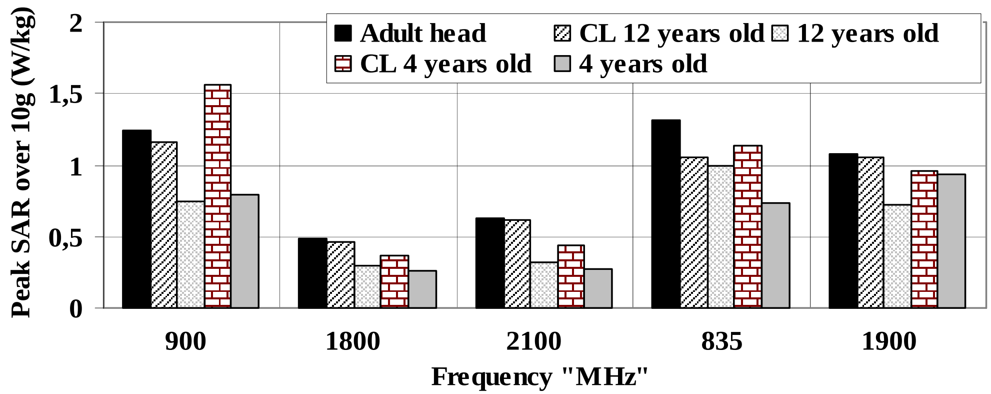
CL 12 ans

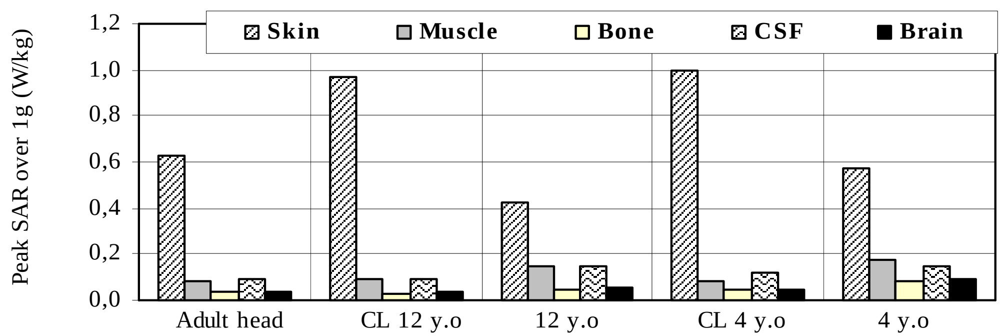


CL 4 ans

Modèle tête / Freq. (MHz)	Tête Adulte	CL 12 ans	Child 12 ans	CL 4 ans	Child 4 ans
900	58 %	59 %	53 %	55 %	58 %
1800	32 %	34 %	32 %	28 %	36 %
2100	42 %	45 %	40 %	42 %	46 %
835	55 %	51 %	60 %	53 %	60 %
1900	35 %	37 %	44 %	30 %	50 %

Comparisons





900 MHz

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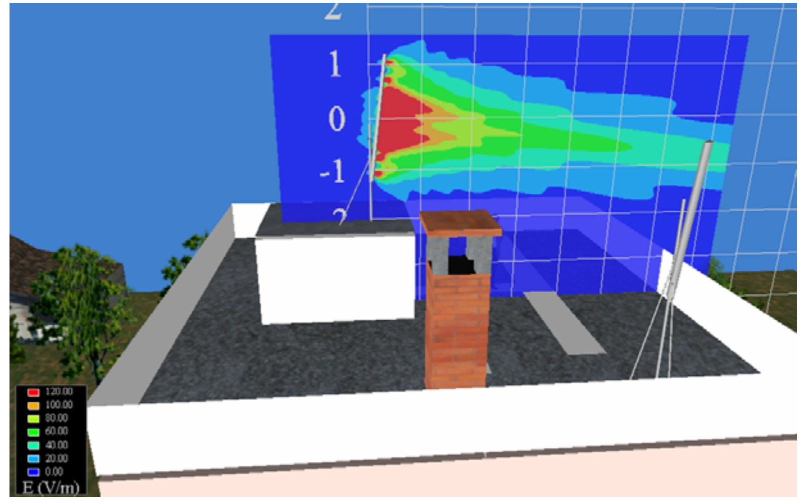
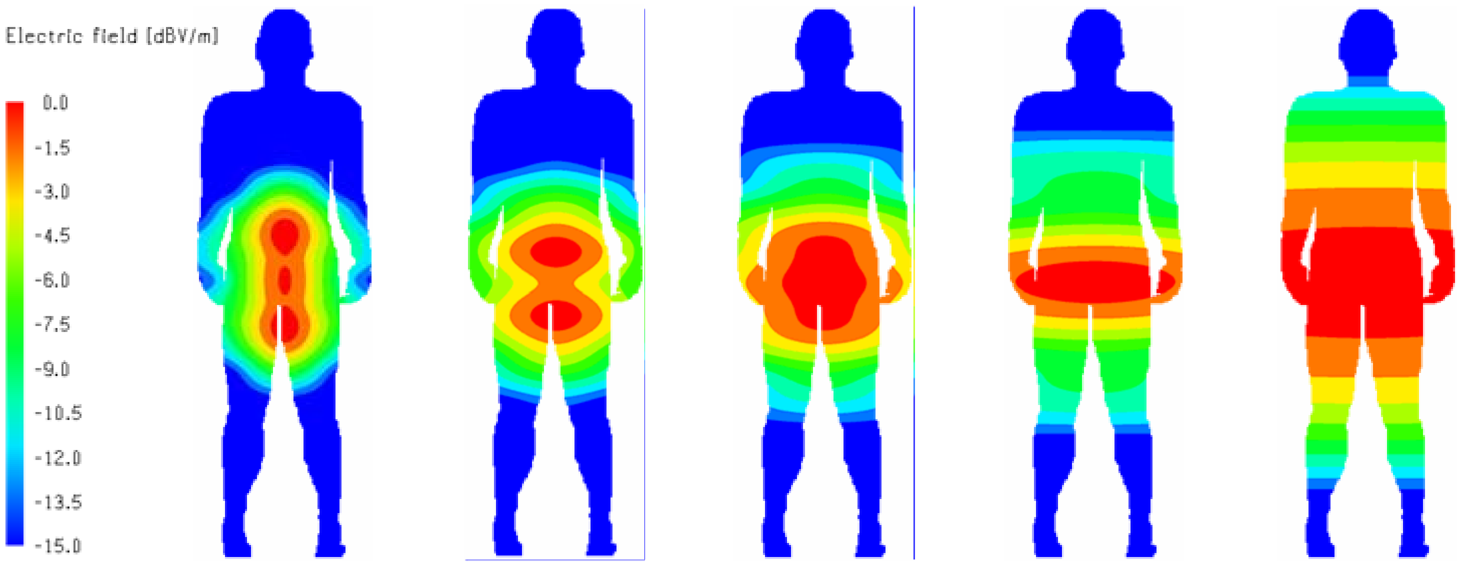
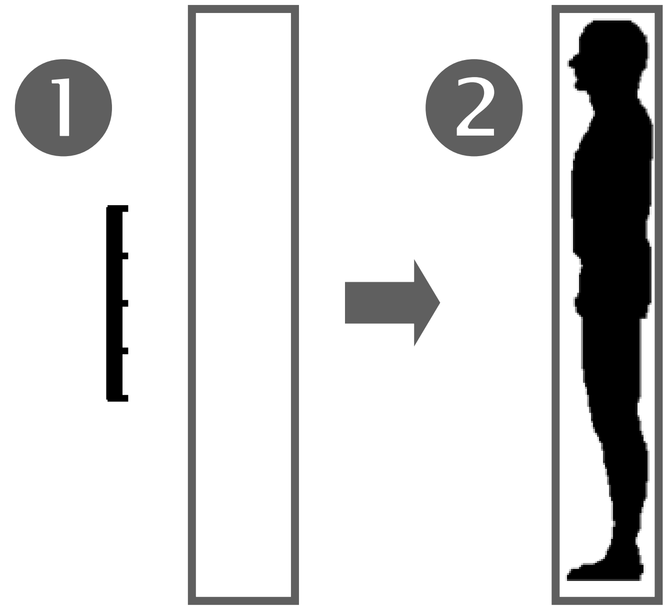
Whole body exposure of workers



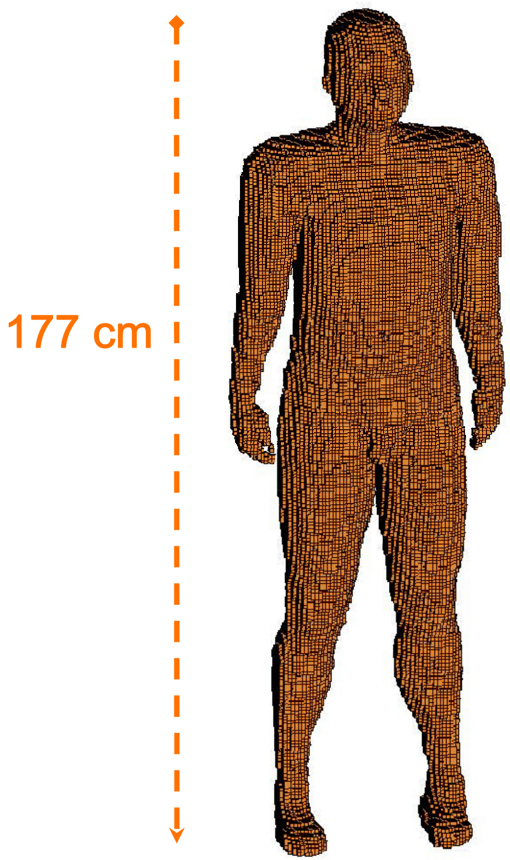


Hybrid MoM/FDTD

- Two steps
  - Source modeling with MoM or other technique or measurement
  - FDTD calculation of SAR with incident field on Huygens box
  - One-way coupling

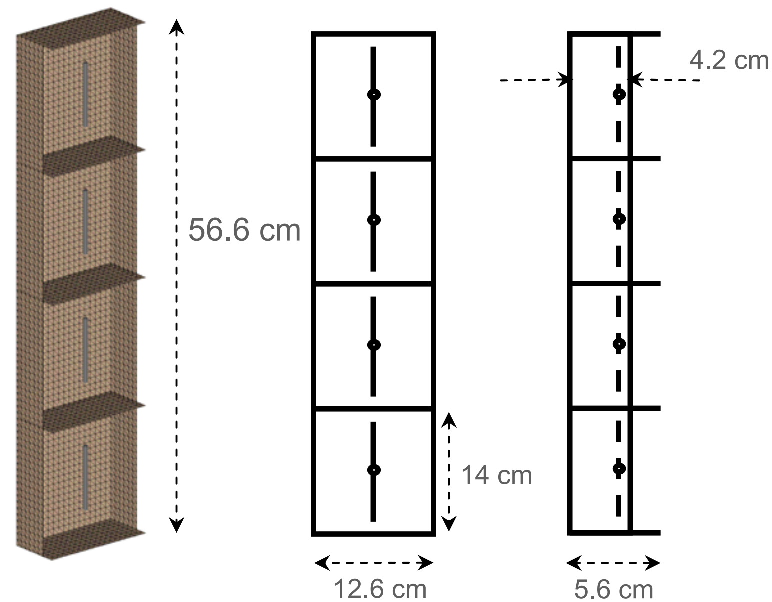


Exposure to UMTS antenna



"Zubal"

- 3.6 mm x 3.6 mm x 3.6 mm
- 78 kg
- 31 tissues



UMTS (2140 MHz)

- FEKO
- 7 cm dipoles (4)
- Quarter wavelength from reflector

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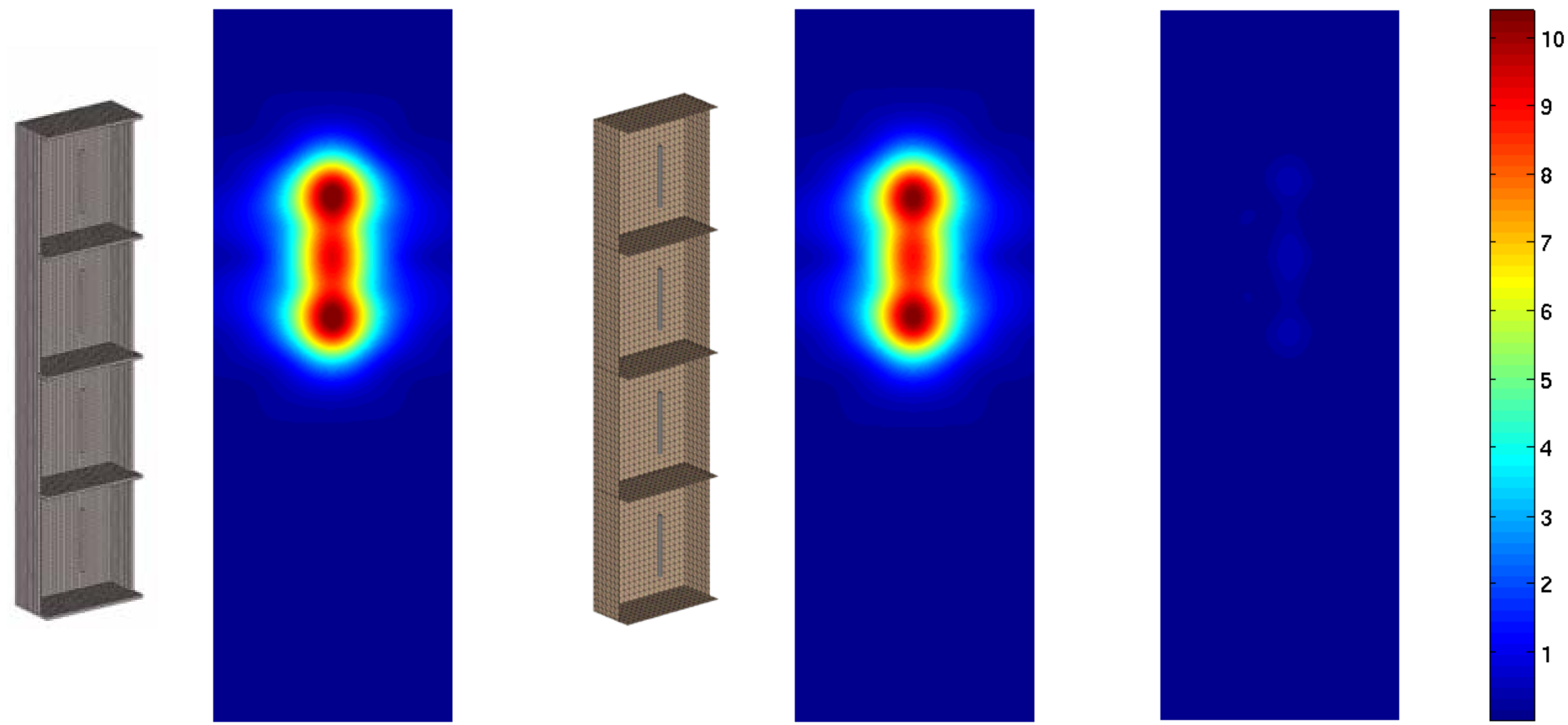
Antenna modeling comparison



FDTD FEKO + FDTD Différence S (W/m²)

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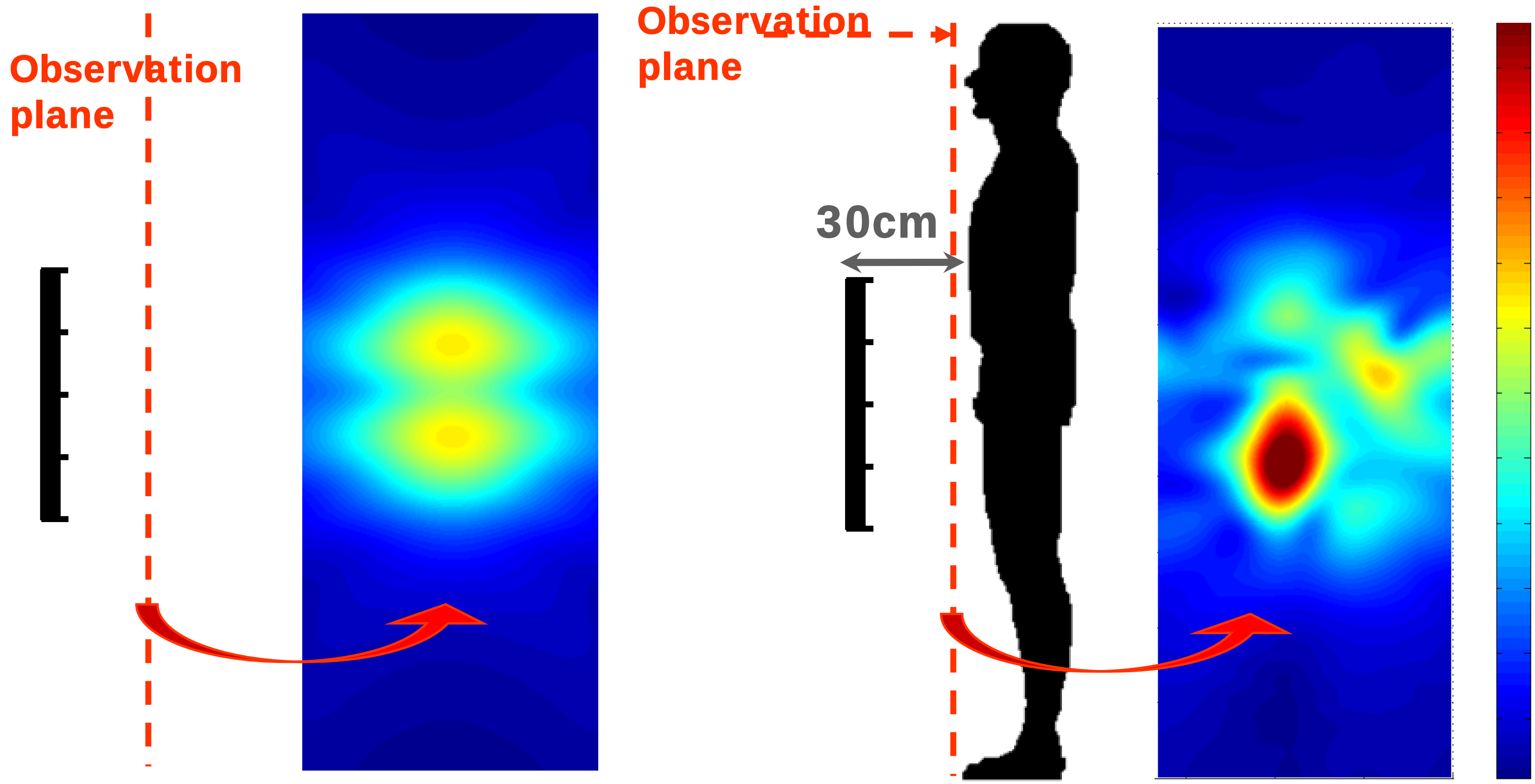
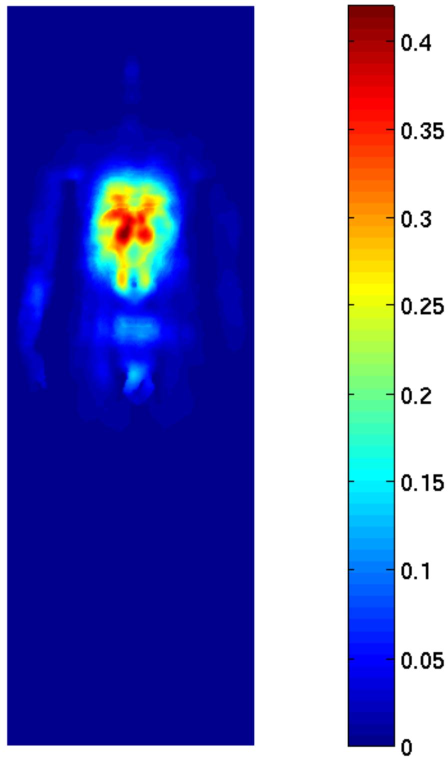
Electric field strength distribution comparison



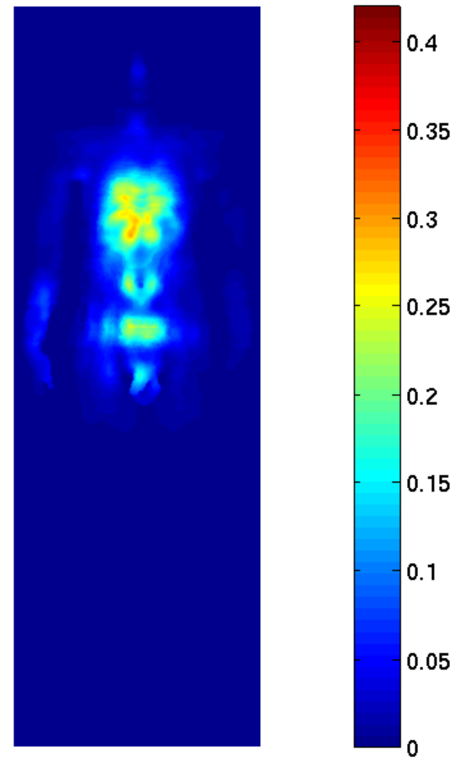
Antenna in free space

Antenna with the body

SAR distribution comparison

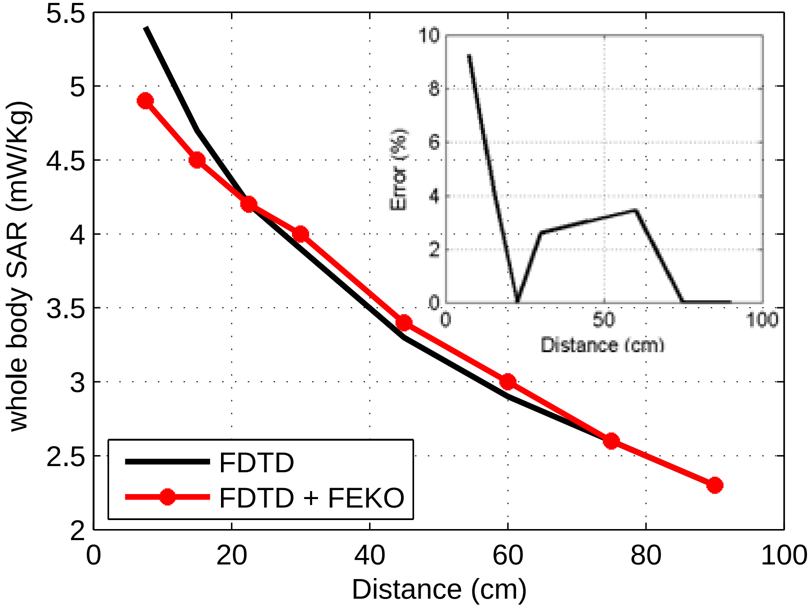


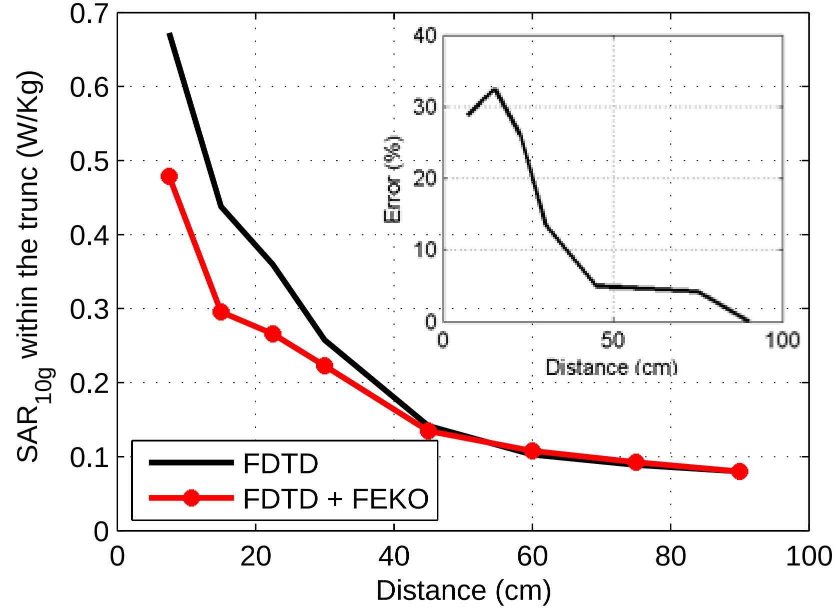
FDTD



FEKO + FDTD

Comparisons FDTD vs FEKO+FDTD





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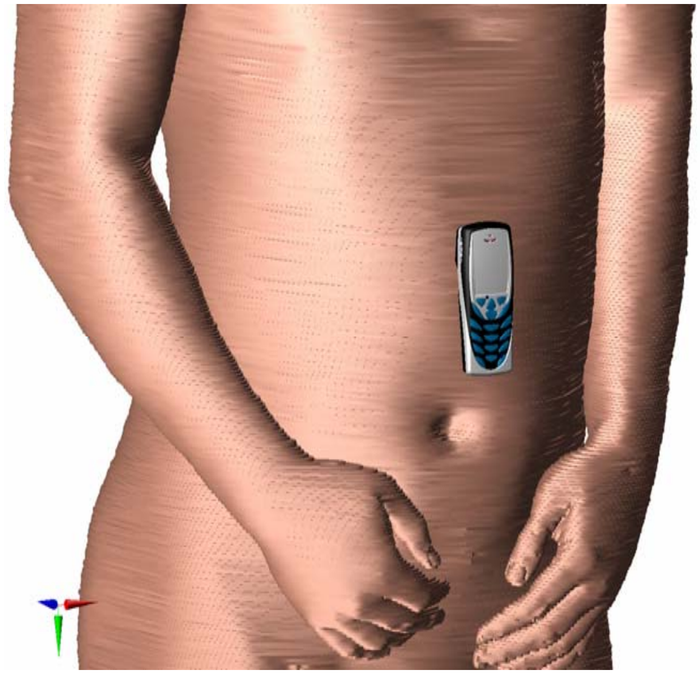
Dosimetry and new usage



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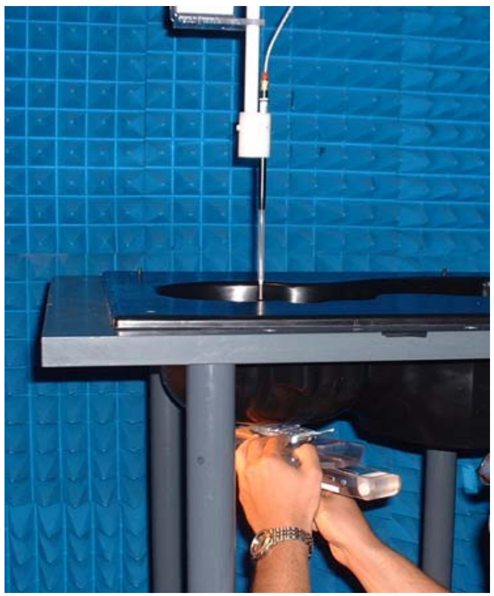
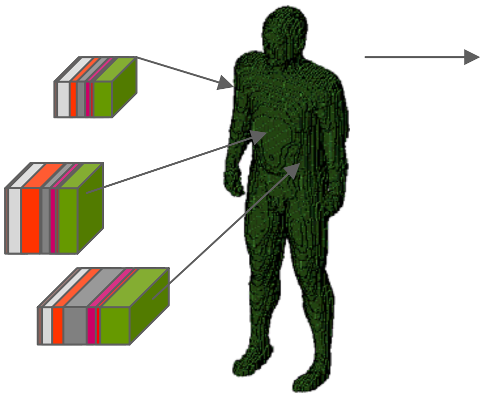
March 2006

Dosimetry and body worn

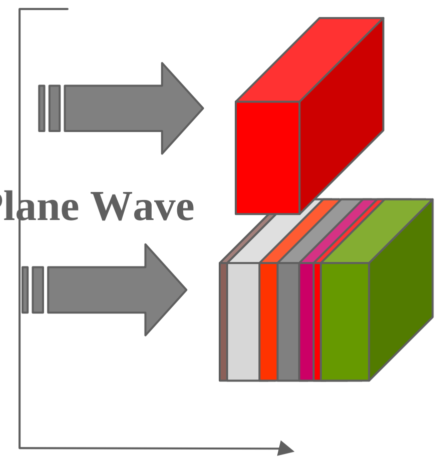
Body Worn: Is the "head" liquid applicable to body worn estimation?



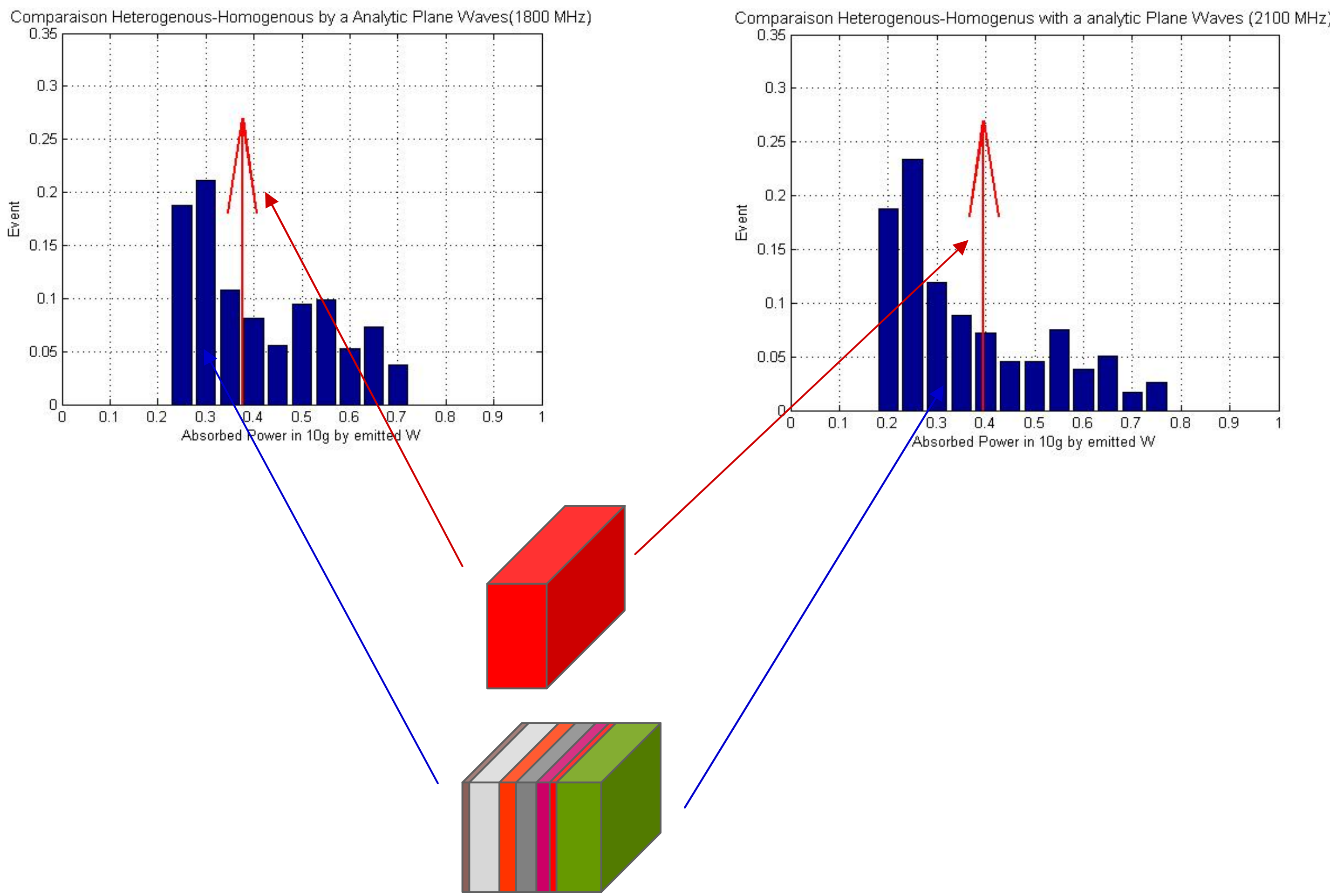
Multilayer model : plane waves



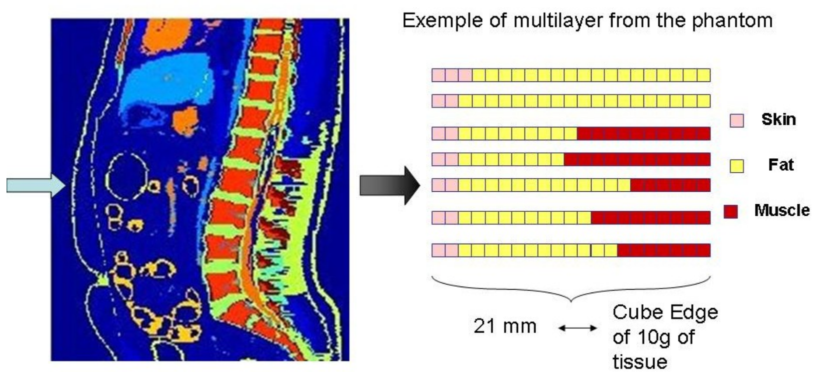
Layers thickness and occurrence coming from VH
Multi-layers approach
Comparison to homogeneous structure



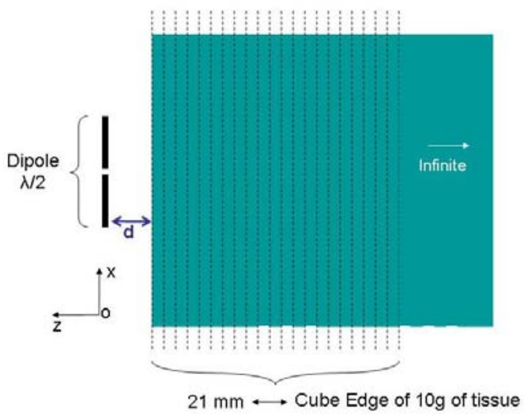
Plane waves results

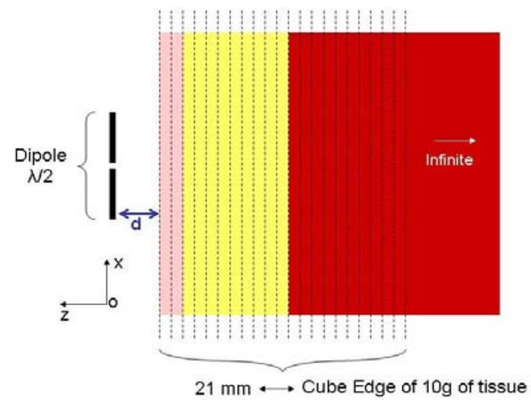


Multlayer model: dipole



ML#	Thickness Skin (mm)	Thickness Hypoderm (mm)	Thickness Muscle (mm)	Number of structure	%
1	3	17		30335	17.16
2	2	18		28972	16.39
3	2	9	10	5735	3.24
4	2	8	11	4662	2.64
5	2	10	9	4472	2.53
6	2	13	6	4440	2.51
7	2	12	7	4357	2.47
8	2	14	5	4282	2.42
9	1	20		4236	2.40
10	3	14	4	4001	2.26
Number Total structure for the 45 ML#			176749		





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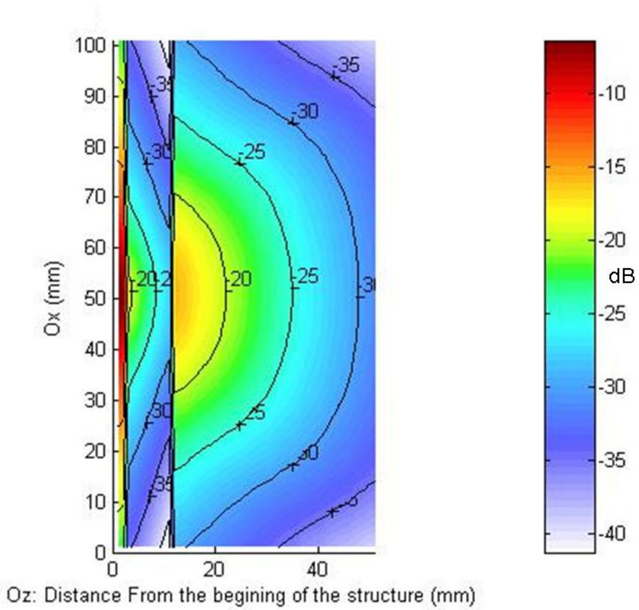
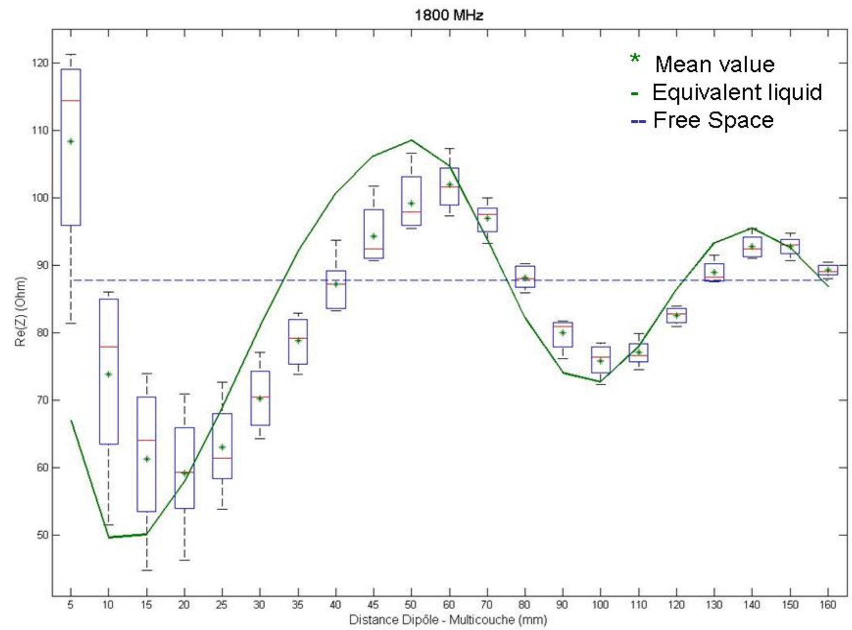
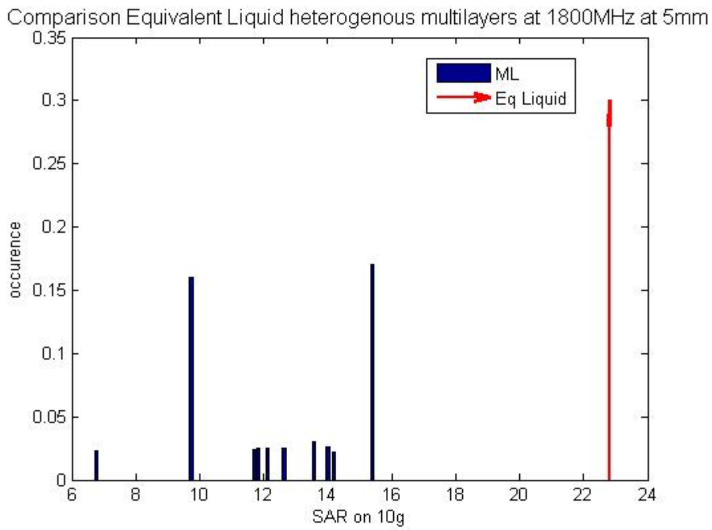
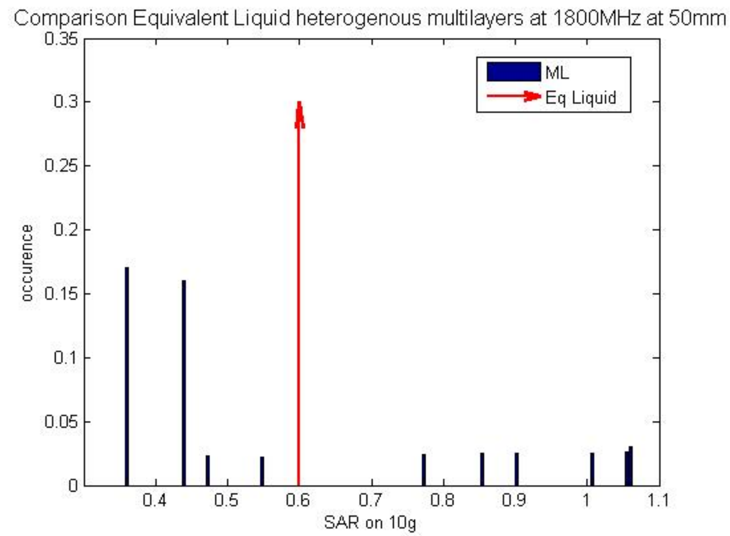
Dipole results (1/3)

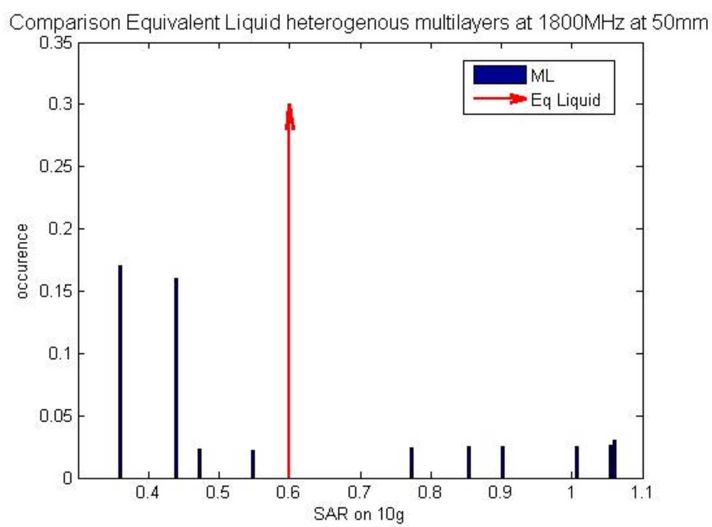




Dipole results (2/3)







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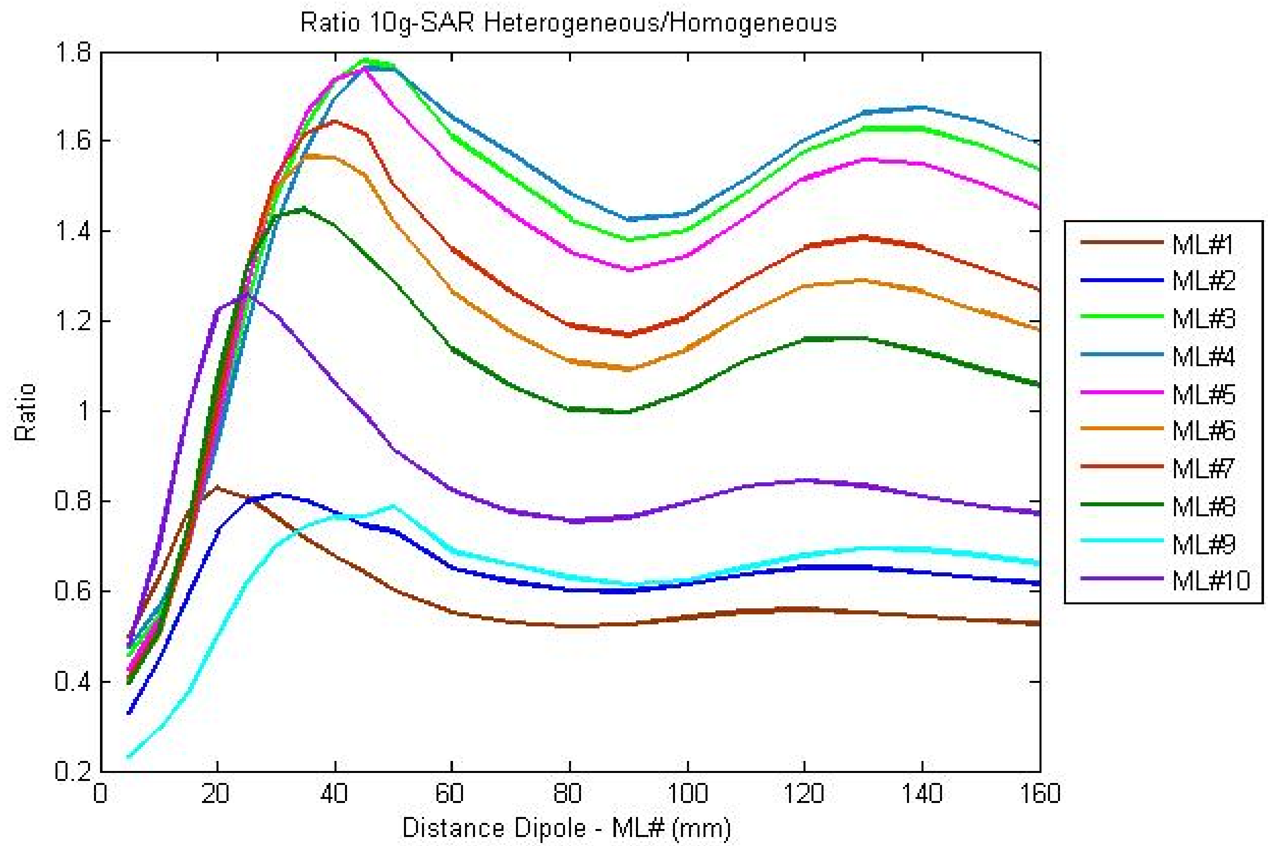
Dipole results (3/3)



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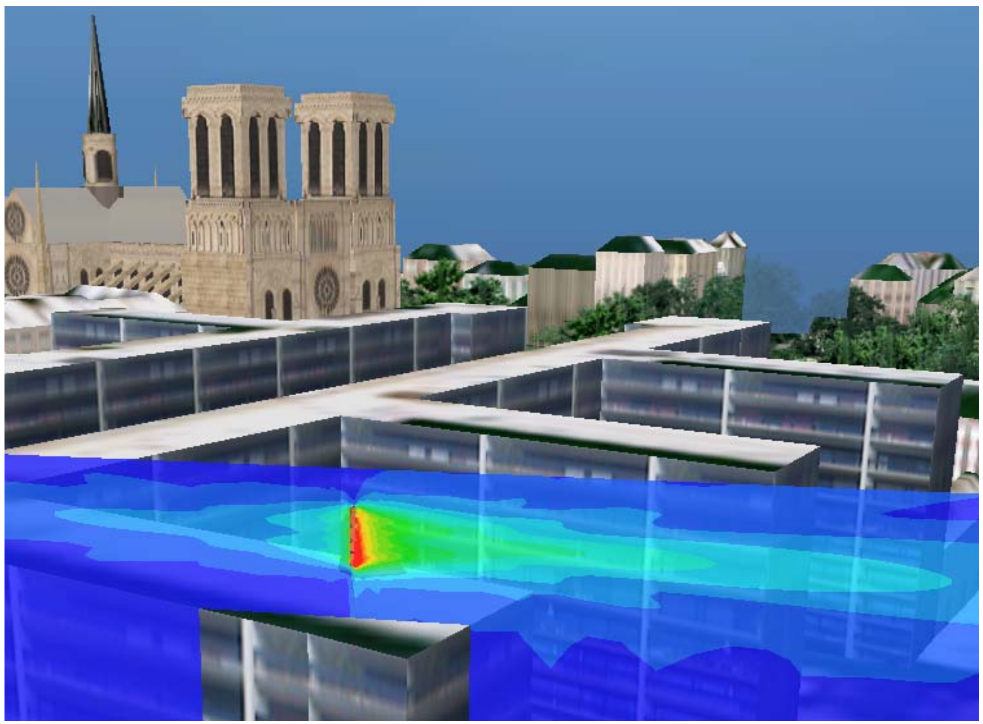
Dosimetry
and base station antennas



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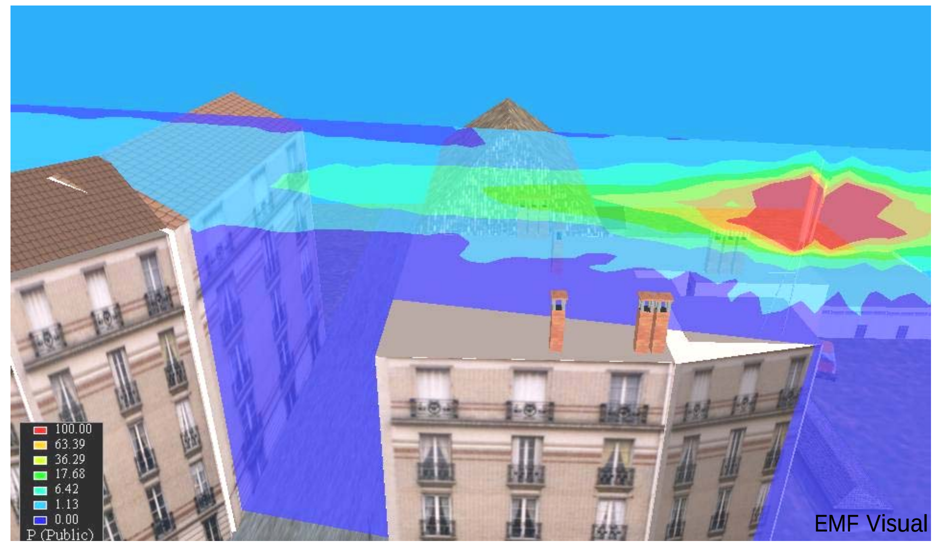
Human exposure from Base station

- Public concerns on fields emitted by BSA close to living areas
- Expert groups recommend information

Public Compliance Boundary



Field levels

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Specific antenna model is needed

- Near field is able to be described using full wave analysis
  - These approaches (MoM, FDTD, FEM…)
    - Are accurate
    - Quite heavy compared to the objective
    - Should be waste of time if the environment is not perfectly known
- Far field gain is easy to use but inaccurate in the near field
- New and specific approach is needed in the vicinity of the base station

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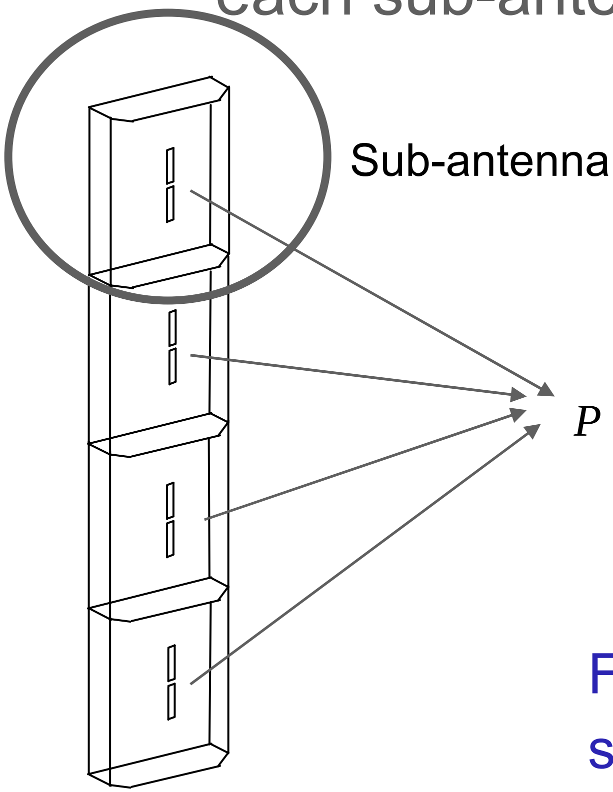
Specificity of radio base station

➔the field is the superposition of the field emitted by each sub-antenna



$$E_{cell}^{i}(P) \cong \frac{\sqrt{30\,P_{cell}^{i}\,G_{cell}^{i}(\theta_i,\phi_i)}}{R_i}\,e^{-jkR_i}\,\hat{\rho}(\theta_i,\phi_i)$$

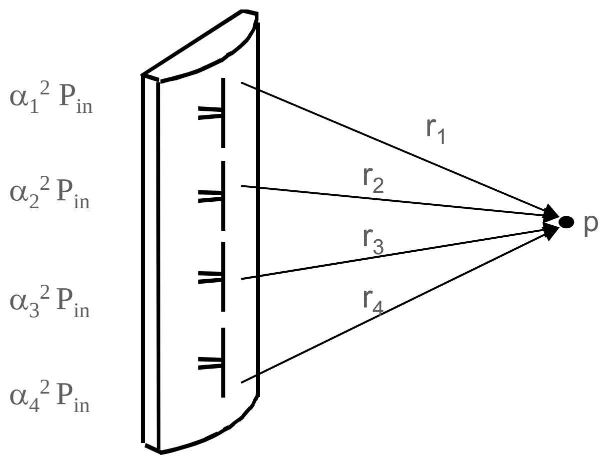
$$E(P) \cong \sum_{i=1}^{N_{cells}} E_{cell}^{i}(P)$$

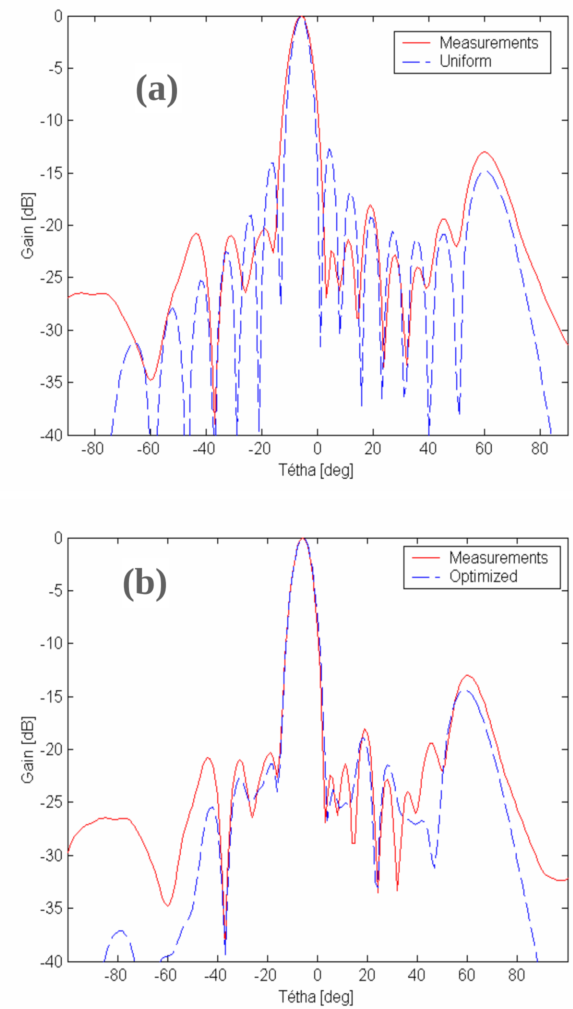
Far field zone of sub-antenna :

$$D \approx \lambda; R \geq \frac{2D^2}{\lambda} = 2\lambda$$

Synthesis problem

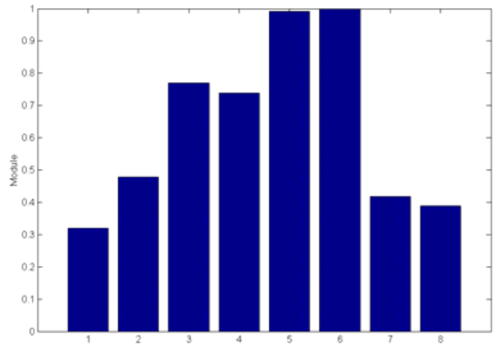
- ➔ Given the antenna characteristics (sub-antennas are known), find the power distribution
- ➔ Genetic Algorithm can be used



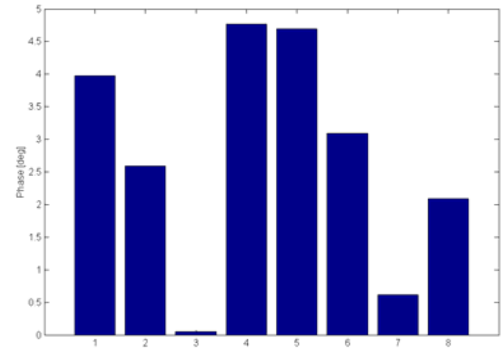


- ➔ The cost function based on the maxima of the far field gain

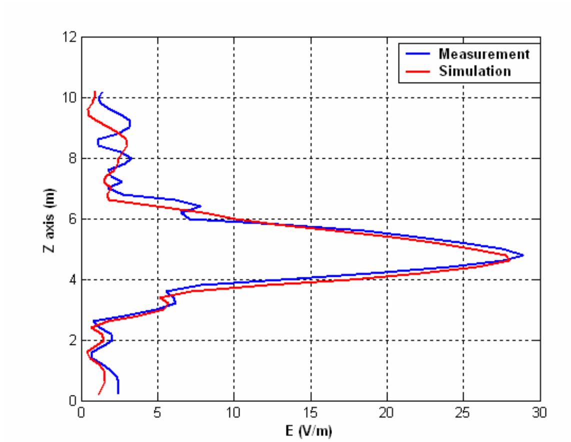
Real antenna model K739636



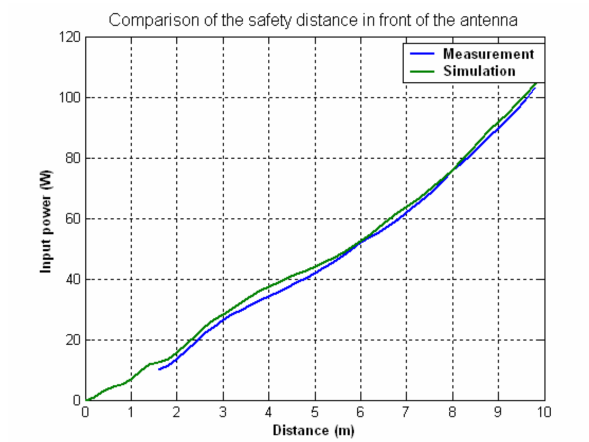
➔ **Optimized power feed pattern (amplitude)**



➔ Optimized power feed pattern (phase)



➔ E field 5m in front of the antenna on a vertical line

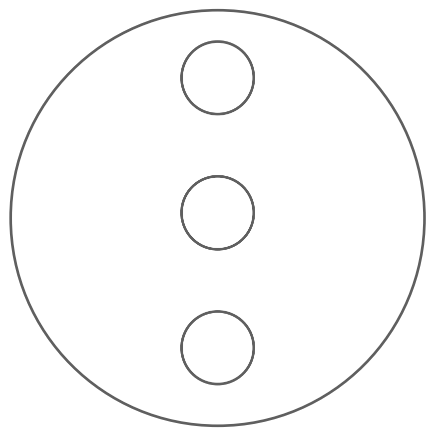


➔ Compliance distance vs Input Power

(Unrestricted)

Perfectly matched model

- Synthesis problem : “Given the antenna characteristics, find the sub-antennas (sub-antenna gain patterns and the power distribution)”
- Spherical harmonics decomposition of the sub-antennas and of the whole antenna

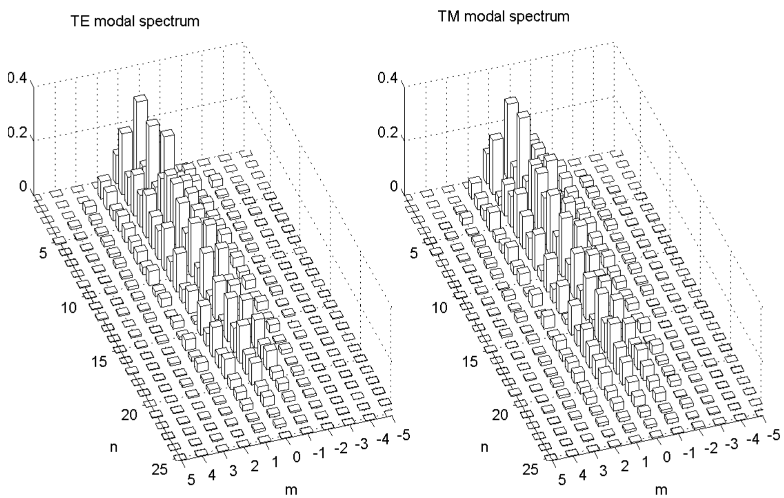


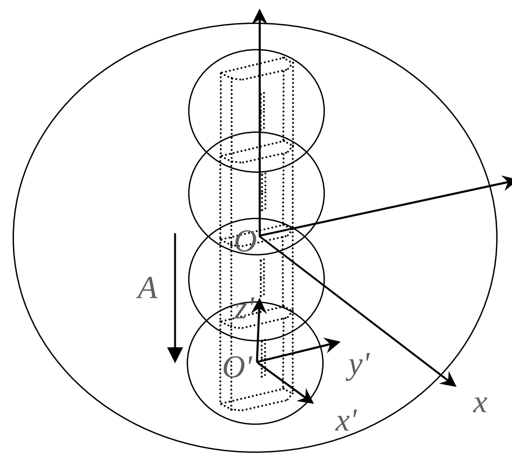
(Unrestricted)

Spherical waves expansion

$$E = \sum_{s=1}^{2} \sum_{n=1}^{N} \sum_{m=-n}^{n} \zeta_{smn} \vec{F}_{smn}(r,\theta,\phi)$$

- Spherical modes spectrum
  : optimal representation of





$$\left[M_1\; M_2\; M_3 \cdots M_{N_{sub}}\right] \times \begin{pmatrix} \chi_1 \\ \chi_2 \\ \vdots \\ \chi_{N_{sub}} \end{pmatrix} = \begin{pmatrix} \zeta_{1-11} \\ \zeta_{101} \\ \vdots \\ \zeta_{2NN} \end{pmatrix}$$

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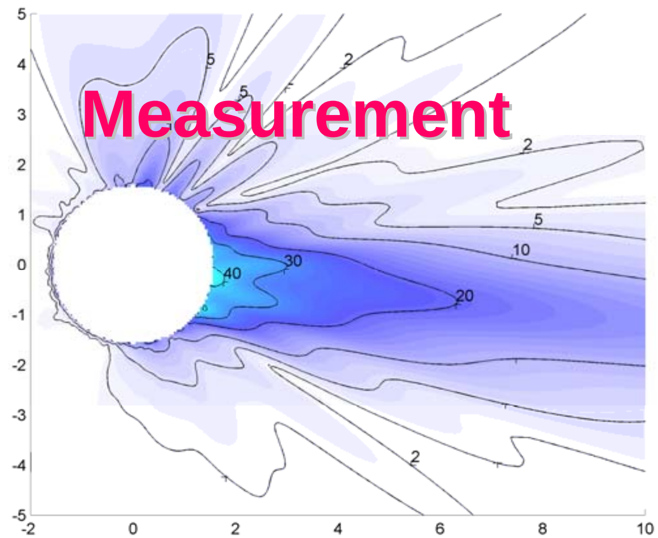

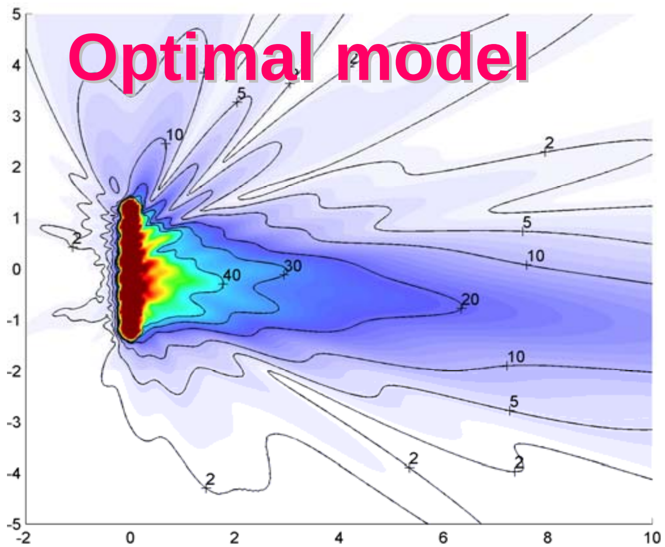

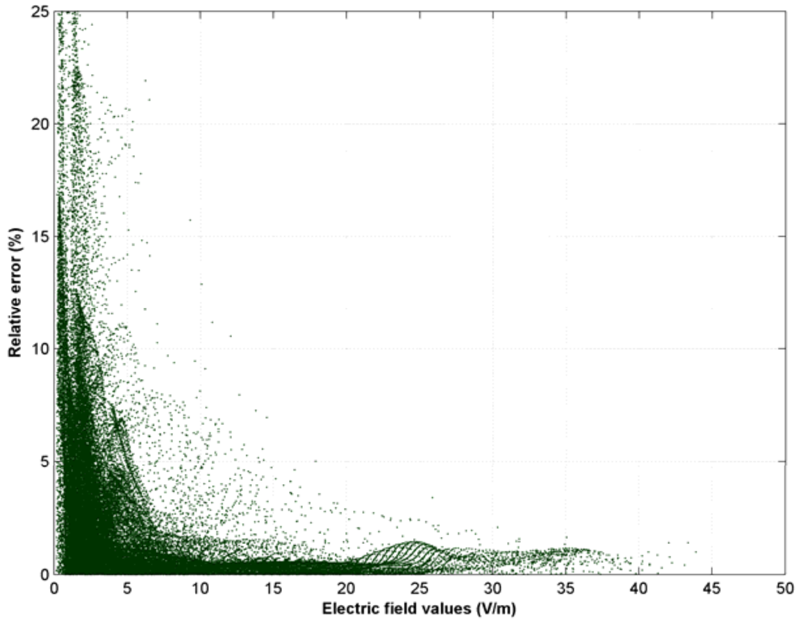

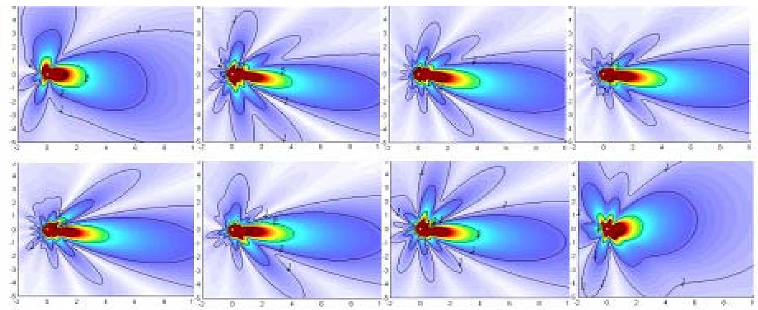

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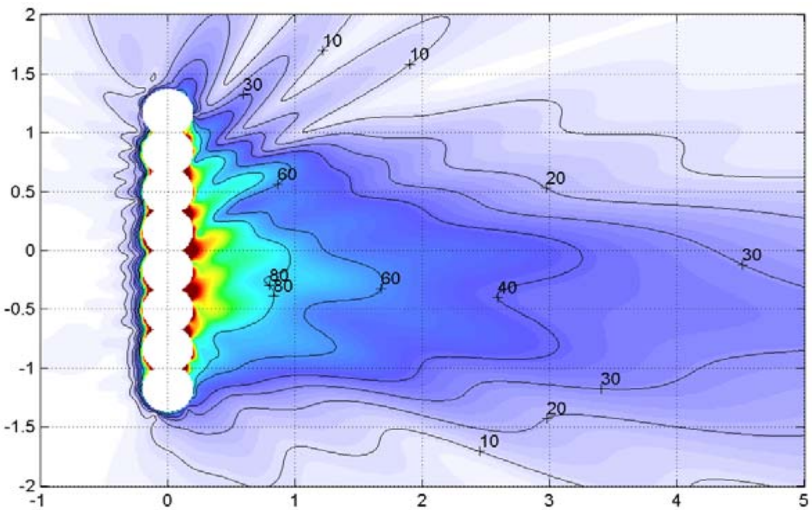
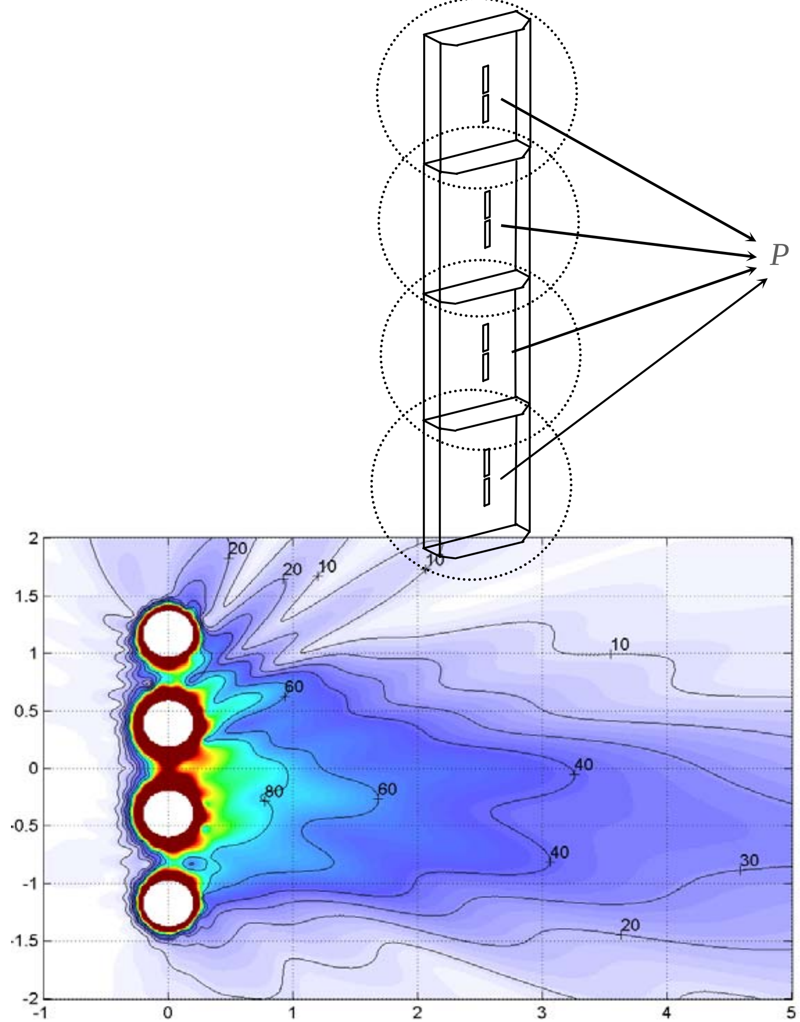
Reduced model
Base station antenna



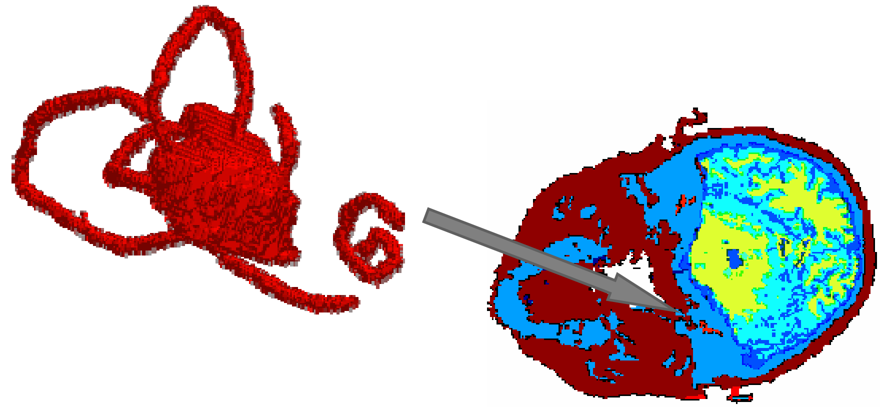
8 cells
96 modes / cell
1 λ spaced



4 cells
160 modes / cell
2 λ spaced

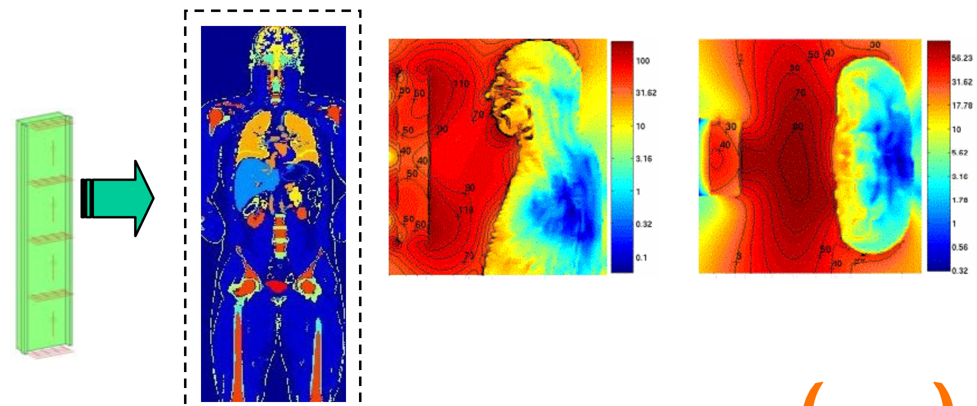
Challenges in Electromagnetic Modelling

- Fine details of the field (distribution and absolute levels)
  - from the source (close to tissues)
  - in the tissues



- Need of fine tissue modelling
  - Segmentation <1mm
  - Head models for children

- Staircasing of FDTD issue, modelling of the source
  - Subgridding
  - Advanced numerical algorithms
  - Hybridization of techniques
  - Coupling to other physics (thermal, cellular, …)



(Unrestricted)