Electromagnetic field (EMF) dosimetry

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Agenda

What is EMF dosimetry?
Why is it done?

Numerical methods and models
Validation of a numerical simulation

Exposure setups for mobile phone studies

- Animal study (CEMFEC)
- Cell study (LaVita)
- Human study (Wirecom)

Conclusions

What is EMF dosimetry?

- Assessment of the EMF exposure level inside the body
  - SAR (specific absorption rate)
  - Electric field
  - Current density
- Measurement of internal exposure is practically impossible
- Analytical methods can give a rough estimate
  - Simple situation (uniform field, homogeneous model)
- Numerical simulations are needed in most cases
  - Complex situation (non-uniform field, anatomically realistic heterogeneous model)
  - Local exposure

Why is it done?

- Dosimetry is an essential part of studies on health effects of EMF
- Exposure level is known
  → Comparable results, possibility to replicate the study
- Distribution of the exposure is important in some studies
  (e.g. mobile phone exposure vs. activation of brain regions)

- **Inadequate dosimetry → Wasted study**

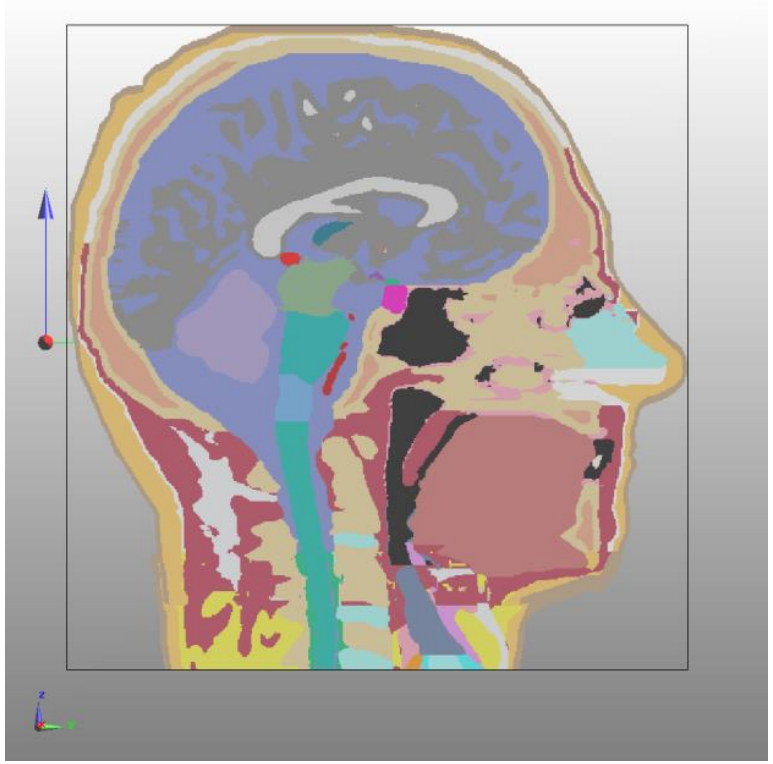
Numerical methods

- Maxwell's equations
  - Fundamental equations in electromagnetics
- FDTD (Finite-Difference Time-Domain)
  - Most common method for RF
- Other methods (e.g. FEM, FIT, SPFD)
- Computational domain is divided into voxels (usually cubical)
  - Boundary conditions
- Electric and magnetic fields are calculated in each voxel

Numerical models

- Correct dielectric properties of the tissues
- Human models
  - Several anatomically realistic human models available (adult, child, obese model, pregnant woman)
  - Usually tissues segmented from MRI or CT images
  - Resolution < 2 mm
- Animal models (e.g. rat, mouse, swine)
- Source model
  - Accurate replica of the real model (e.g. CAD model of a mobile phone)
  - A simplified model with similar radiation characteristics

Virtual Family – Duke model



Validation of a numerical simulation

- Validation of the numerical source model is essential
  - Exposure from the numerical model corresponds to the real source

- How to validate a simulation?
  - Measurement (SAR, electric field)
  - Numerical simulation
  - Comparison of the measured and calculated values

Exposure setups for mobile phone studies

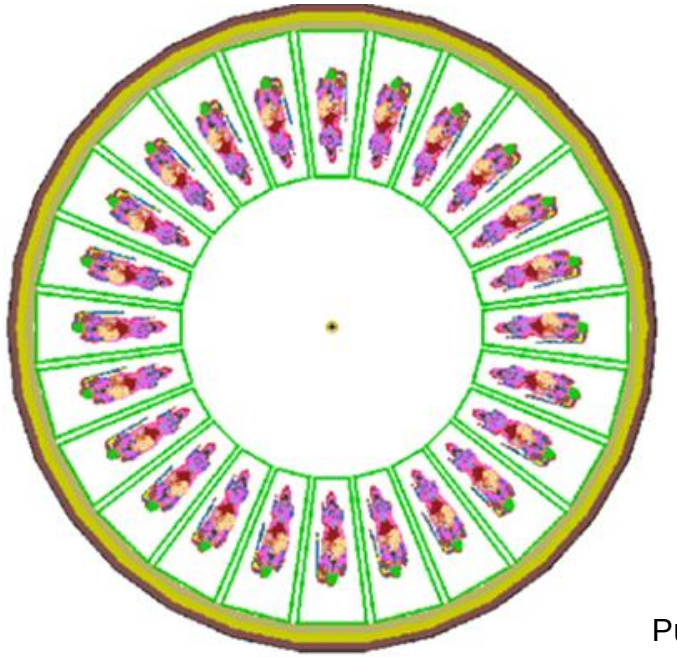
- Animal study (CEMFEC)
- Cell study (LaVita)
- Human study (Wirecom)

Animal study (CEMFEC)

- Radial transmission line for the exposure of rats at 900 MHz
- 9 chambers, 24 rats / chamber
  - Rats can move freely in their cages
- Exposure level
  - Sham
  - Low (SAR_{wba} = 0,4 W/kg)
  - High (SAR_{wba} = 1,3 W/kg)
- Signal source: modified GSM900 phone
  - RF amplifier + variable attenuator
- Exposure setup used at UEF
  - Combined effects
    (EMF + environmental carcinogen)

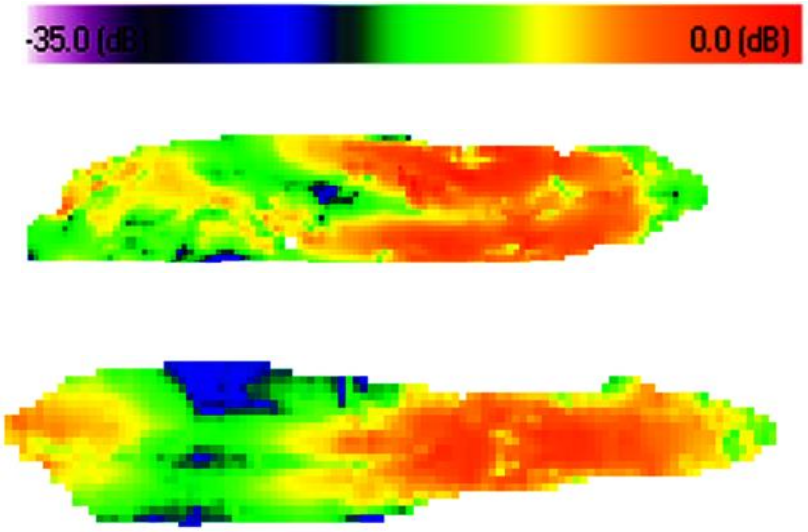
Animal study (CEMFEC)
Numerical simulation

- SAR in rats calculated with FDTD (by VTT)
- Validation
  - Calorimetrical measurements (temperature rise in homogeneous rat phantoms)
  - Good agreement (difference < 20 %)



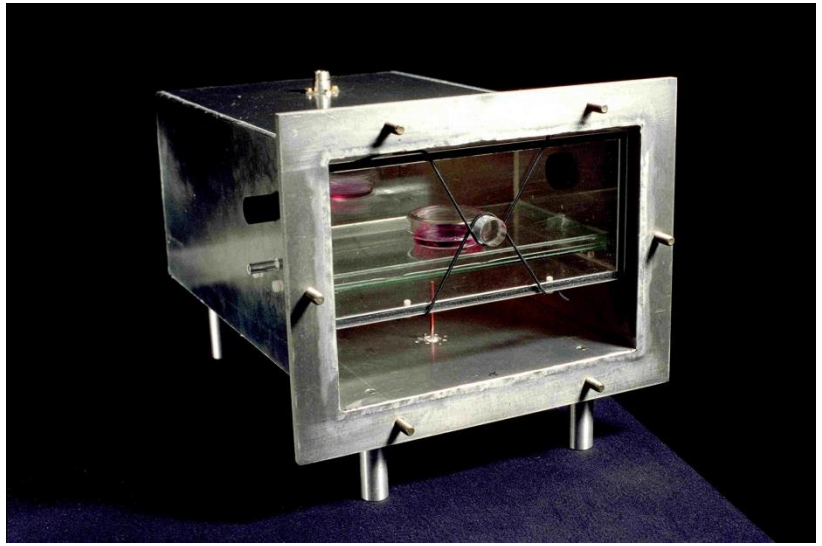
Puranen et al. 2009

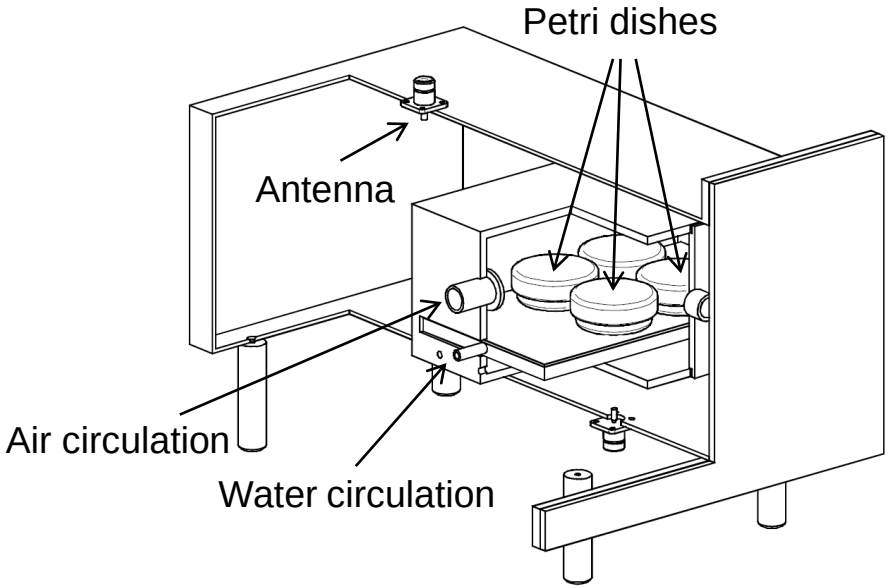
Normalized to 1 W input power
0 dB = 0,744 W/kg



Cell study (LaVita)

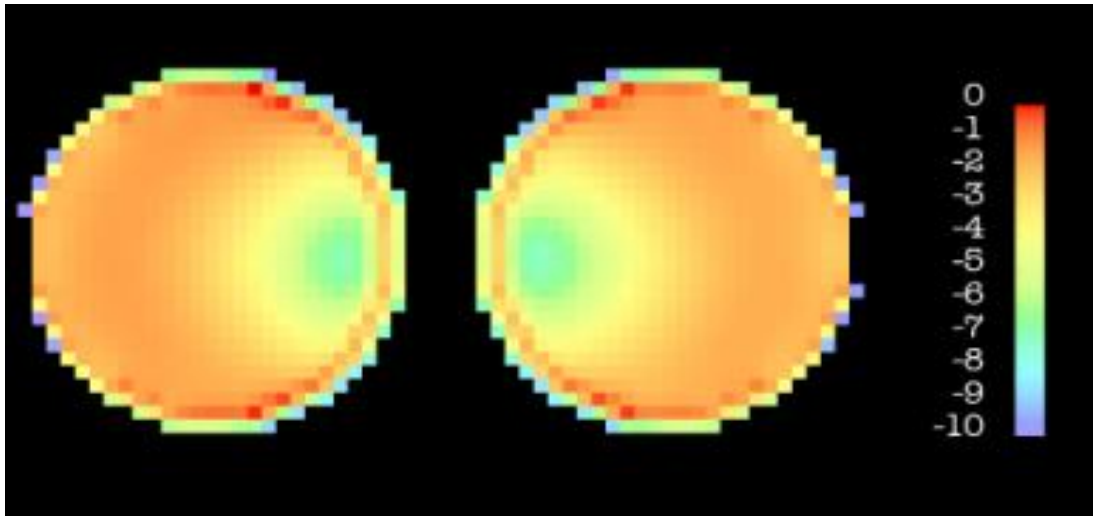
- Waveguide chamber for the exposure of cells at 900 MHz
- Adjustable SAR level (0 - 10 W/kg)
- Signal source: GSM simulator + signal generator
  - RF amplifier
- Water cooling to control the temperature of the cells
  - Non-thermal effects of RF exposure
- Air from an incubator directed to the chamber
  - Suitable environment for the cells
- Exposure setup used at UEF





Cell study (LaVita)
Numerical simulation

- SAR in cells calculated with FDTD
- Validation
  - Calculated and measured electric field values inside the chamber were compared (< 5 %)

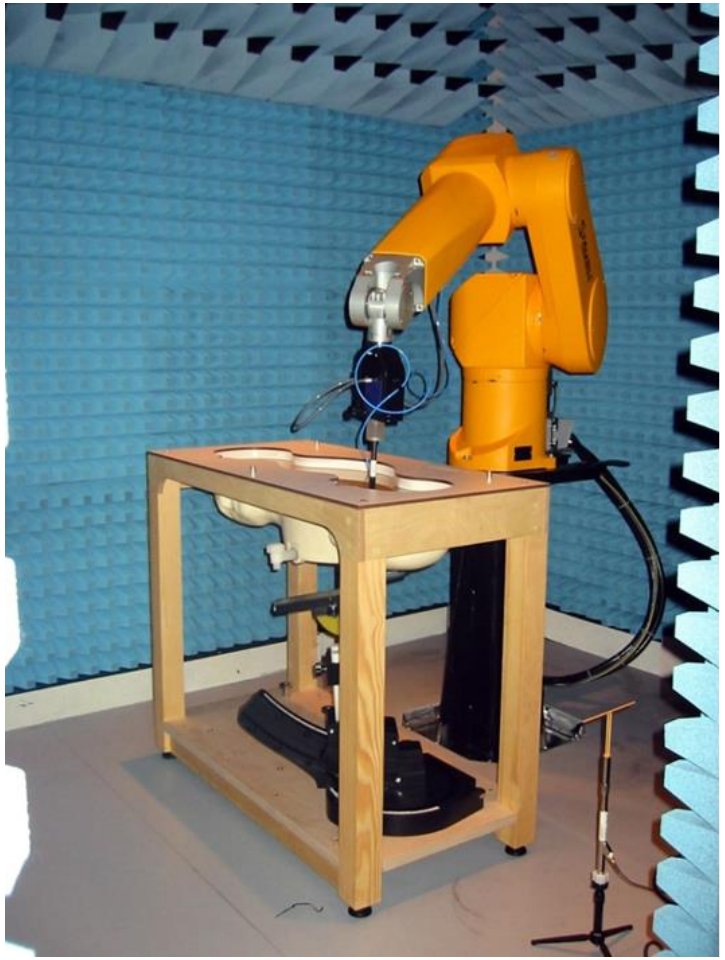


SAR_{avg} 4,2 W/kg
(dB scale)

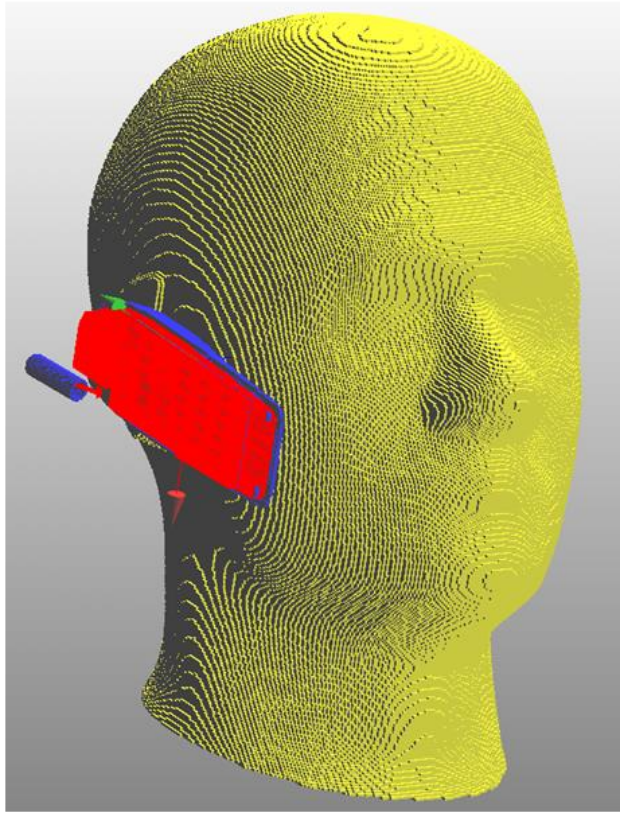
Human study (Wirecom)

- Setup for the exposure of volunteers to GSM type signal at 900 MHz
- Two exposing phones (real + sham)
  - Signal source: modified GSM900 phone
  - RF amplifier + variable attenuator
- SAR in the head calculated with FDTD
  - CAD model of the phone
  - Heterogeneous head model (res. ≤ 1 mm)
  - Temperature probes
  - About 100 million voxels
- Exposure setup used at UTU
  - Glucose metabolism in the brain after EMF exposure (PET, positron emission tomography)

Human study (Wirecom)
Validation



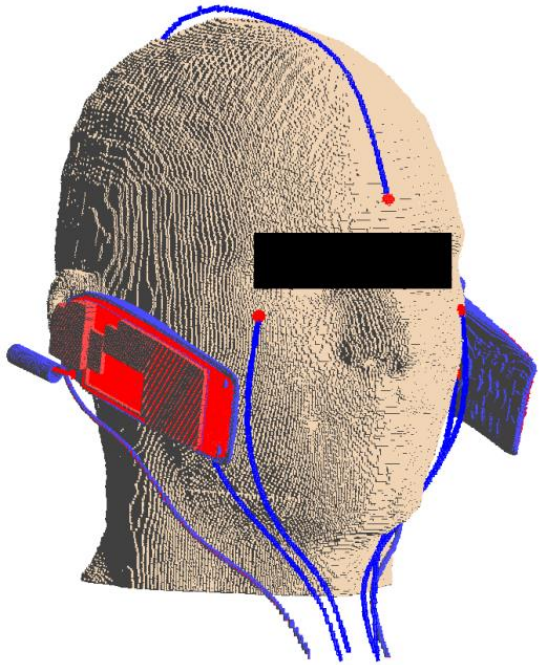
vs.

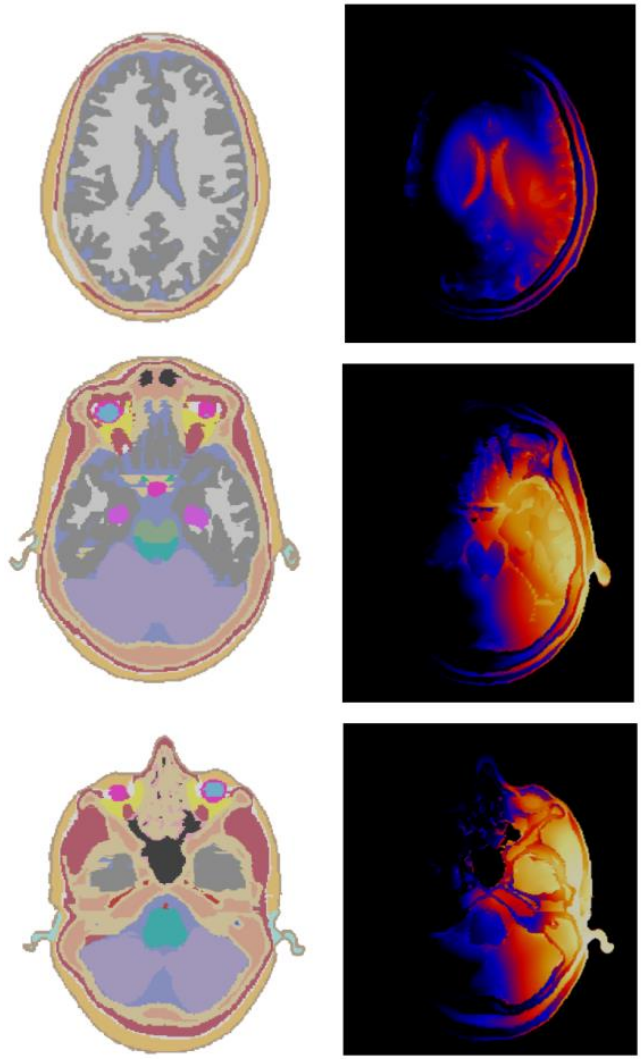


Chosen exposure level
SAR_{10g} = 1 W/kg

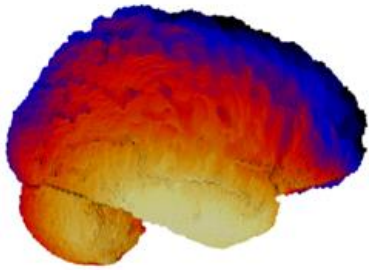
Difference < 5 %

Human study (Wirecom)
Numerical simulation





SAR_{10g} 0,74 W/kg
(heterogeneous head model)



Kwon et al. 2011

Conclusions on EMF dosimetry

- Assessment of the EMF exposure level inside the body (SAR, electric field, current density)
- Essential part of studies on health effects of EMF
- Numerical simulations are needed in most cases
- Validation of the numerical simulation is necessary

- **Inadequate dosimetry → Wasted study**