Rapporteur's Report - Dosimetry

International Workshop
Held at BfS, Munich
25-26 July 2006

Simon Mann

Workshop Objectives

To discuss the results of the dosimetry projects conducted within the research programme and to answer the following questions

1) What has been achieved by the projects?
2) Where do we still have gaps in knowledge?
3) Can minimum standards be defined for future work?
4) Do any of the findings impact on setting standards and guidelines?

Sessions

1) Numerical Models and Computations
2) Dosimetry in Biological Studies
3) Exposure of the General Public

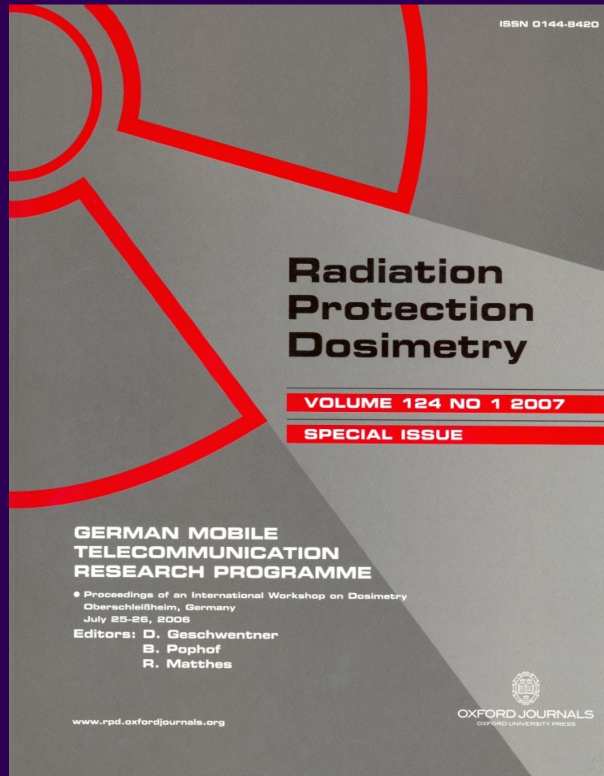
Written Reports

Long report includes

- Summaries of individual presentations
- Discussions following each presentation
- End of session discussions
- Final discussions

Short report includes

- Summaries of discussions organised to give answers in the context of the four questions asked by BfS



http://www.emf-forschungsprogramm.de/abschlussphase/KP_intFG_Dosi.html
http://rpd.oxfordjournals.org/content/vol124/issue1/index.dtl

Session 1 – Numerical Models and Computations

SAR-distribution in human beings when using body worn RF Transmitters

Andreas Christ
IT'IS Foundation

SAR-distribution in human beings exposed to RF radiation with regard to small structures and thermo-physiological parameters

Gernot Schmid
ARC Seibersdorf Research GmbH

SAR-distribution in test animals exposed to RF radiation

Niels Kuster
IT'IS Foundation

Session 2 – Dosimetry in Biological Studies

Exposure setups for in vivo RF experiments using waveguides — *Tina Reinhardt, University of Wuppertal*

Exposure setup for animal experiments using a parabolic reflector — *Simon Schelkshorn, University of Munich*

Exposure setups for laboratory animals and volunteer studies using body mounted antennas — *Andre Rennings, IMST GmbH*

Exposure setups for in vitro RF experiments — *Niels Kuster, IT'IS Foundation*

Session 3 – Exposure of the General Public

Health Protection Agency

Individual exposure assessment in epidemiological studies	*H.-Peter Neitzke Ecolog Institute GmbH*
Exposure of the general public due to GSM and UMTS base station transmitters	*Christian Bornkessel IMST GmbH*
Exposure of the general public due to wireless LAN-applications in urban environments	*Gernot Schmid ARC Seibersdorf Research GmbH*
Exposure of the general public due to digital broadcast transmitters compared to analogue ones	*Markus Schubert IMST GmbH*
Exposure from using mobile phones in typical day-to-day situations and in partly shielded rooms	*Reinhard Georg, Telekom-Consult & Gernot Schmid*
Exposure caused by wireless technologies used for short range indoor communication in homes and offices	*Gernot Schmid ARC Seibersdorf Research GmbH*

Recently Completed Projects

Almost all projects that had not been finalised by June 2006 have been completed since

Final reports contain an English summary and/or abstract:
http://www.emf-forschungsprogramm.de/forschung/dosimetrie/dosimetrie_abges

The final reports on three projects are currently available as draft versions:

1) Development of a practicable computational procedure for the determination of the actual exposure in complex exposure scenarios with several different RF-sources
http://www.emf-forschungsprogramm.de/forschung/dosimetrie/dosimetrie_verg/dosi_090.html

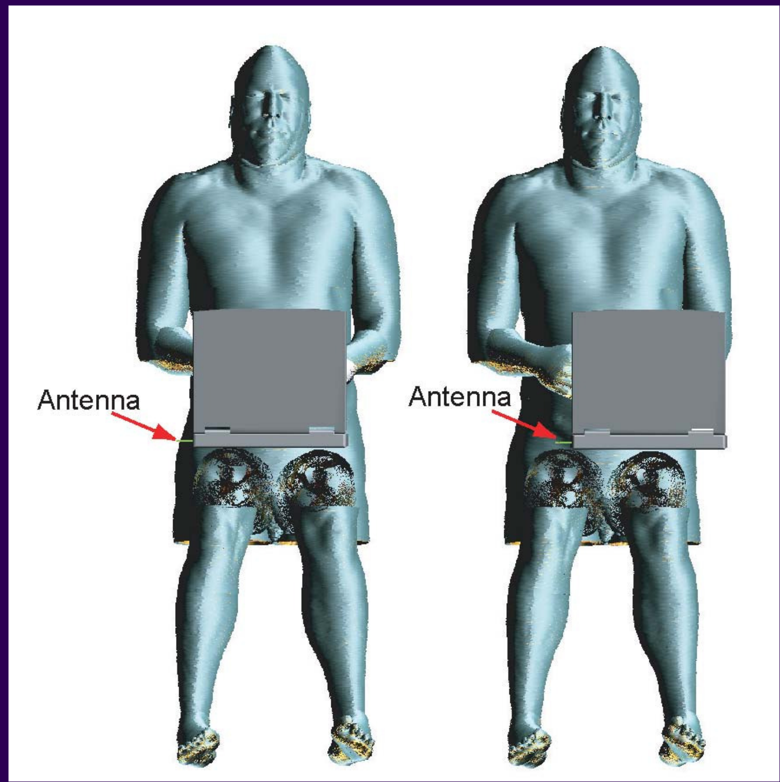
2) Study on the influence of antenna topologies and topologies of entire devices of wireless communication terminals operated near the body on the resulting SAR values
http://www.emf-forschungsprogramm.de/forschung/dosimetrie/dosimetrie_verg/dosi_091.html

3) Determination of exposure due to ultra-wideband technologies
http://www.emf-forschungsprogramm.de/forschung/dosimetrie/dosimetrie_verg/dosi_092.html

1) What has been achieved by the projects?

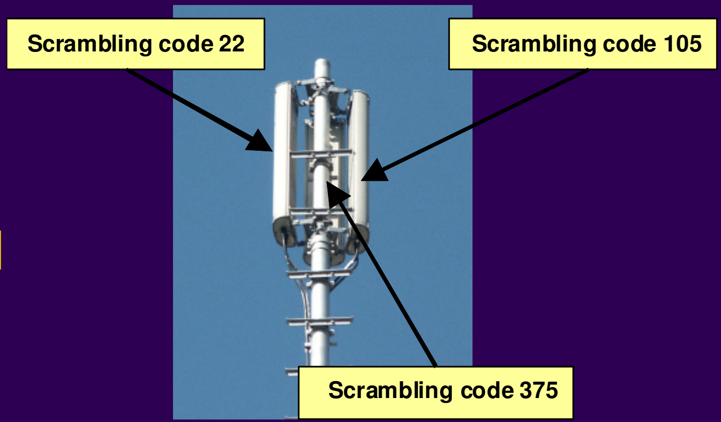
Achievements – Thermal Aspects

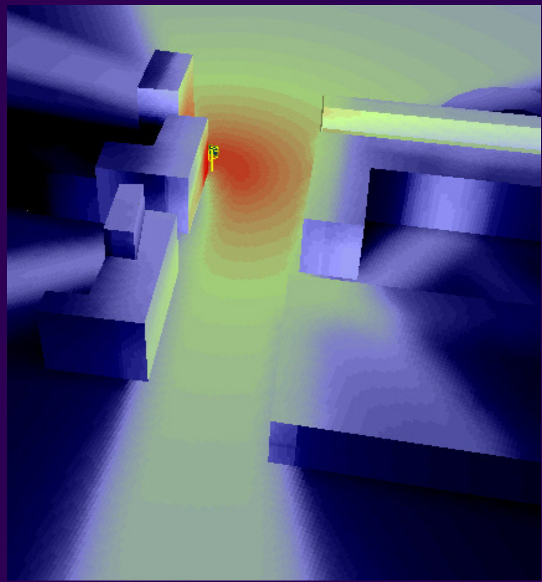
- Typical radio devices were modelled next to the body
  - Mobile phones (900, 1800 & 1950 MHz)
  - Walkie talkie (450 MHz)
  - Laptop (2450 MHz)
- SAR and temperature rises were calculated for different device positions
- Convection is reduced where device is held next to the skin
  - Temperature rises of 3 – 5 ℃ are possible at the body surface
  - Maximum rise in the brain is around 0.1 ℃
  - Temperature rises in the inner organs of the trunk are ~ 0.2 – 0.3 ℃



Achievements – Exposure Quantification

- Understanding of exposures in environmentally relevant situations has been improved
- Environmental transmitters considered
  - GSM & UMTS base stations
  - Wireless LAN access points
  - Digital TV broadcast sites
- Techniques have been developed for assessing exposures
  - Scenarios defined and modelling done
  - Measurements made
- Exposure levels compared with guidelines

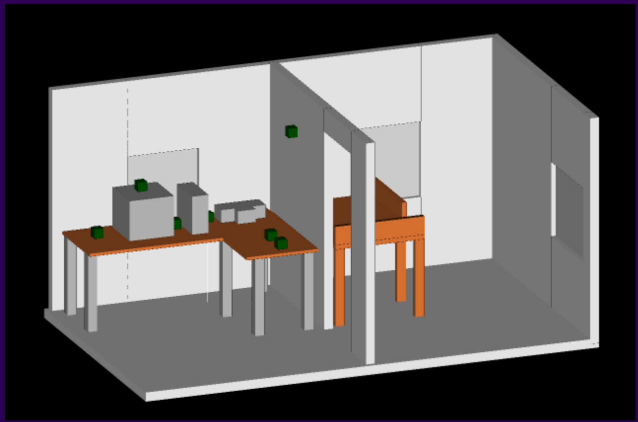




Achievements – Exposure Quantification

Short range devices in the home:

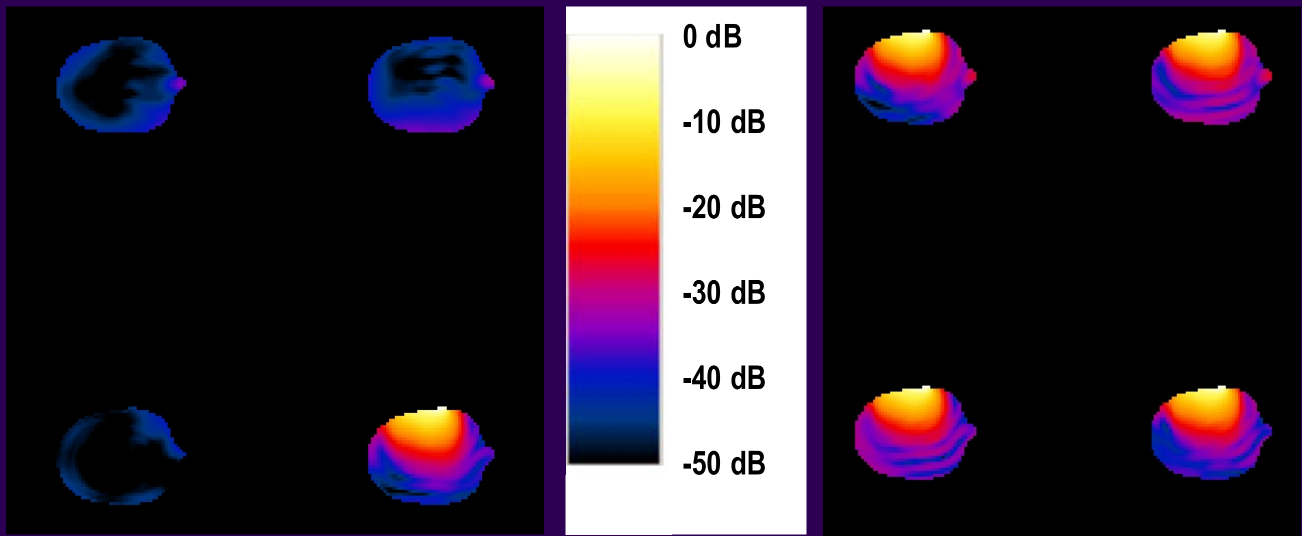
- Wireless local area networks – IEEE 802.11 b, g
- DECT – cordless phones
- Bluetooth – headsets, computer peripherals
- Wireless mouse/keyboard (not Bluetooth)
- Baby alarms / monitors
- Wireless audio transmission systems - headphones
- Wireless video transmission systems - webcams
- Remote controls for toys



- Far-field exposures < 0.1% of reference level
- Some near field situations give local SARs ~ basic restrictions
  - Close vicinity of Class 1 Bluetooth and WLAN with continuous transmissions
- Near field exposures are usually 1-2 orders of magnitude lower

Achievements – Exposure Quantification

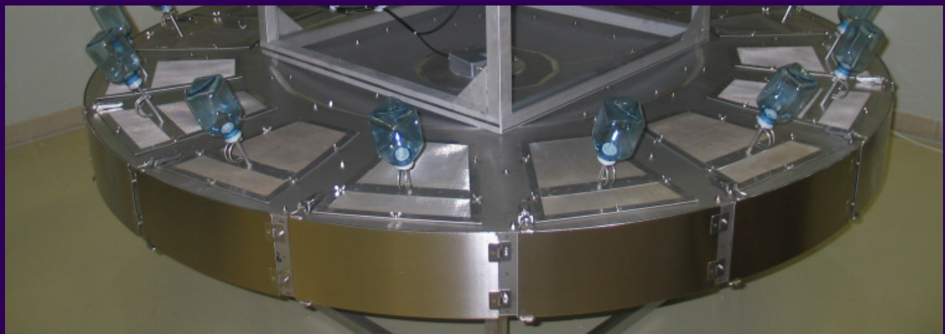
- Reflection of radio waves occurs when devices are used in enclosed metal environments, e.g. cars, trains, elevators
  - Can this increase exposure of the device user and others in their vicinity?
- This was examined experimentally and computationally
  - Preliminary results shown in workshop

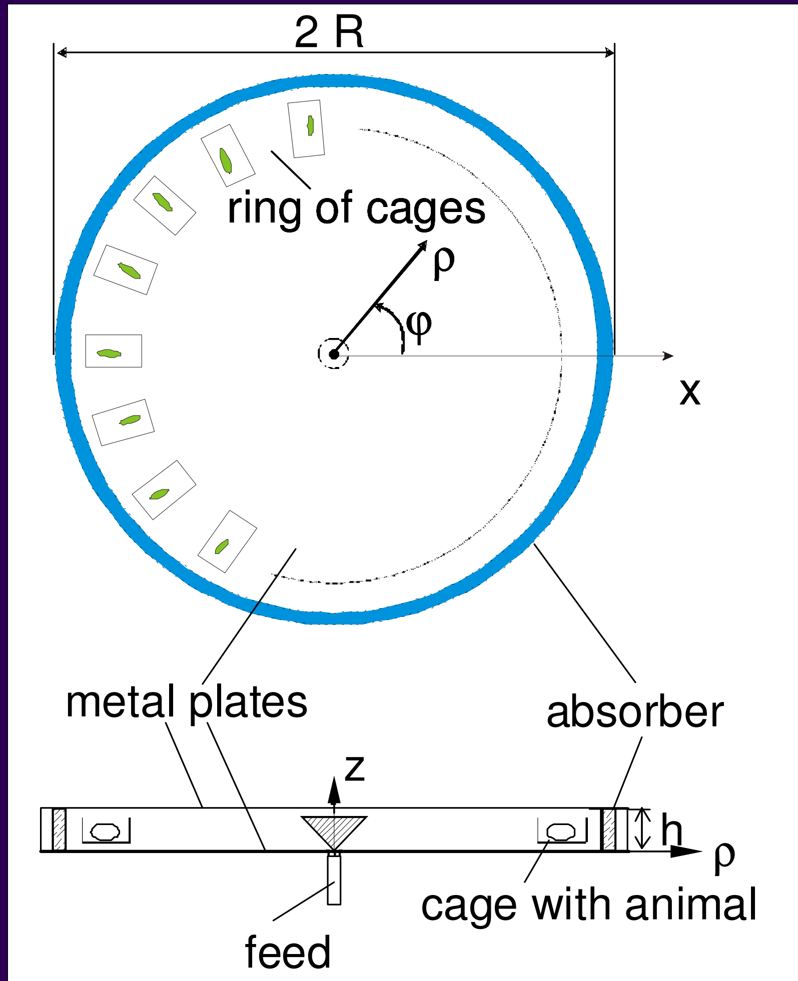


Elevator:
Max 10 g SAR was 3% higher with 3 extra phones in use

Achievements – Exposure Systems

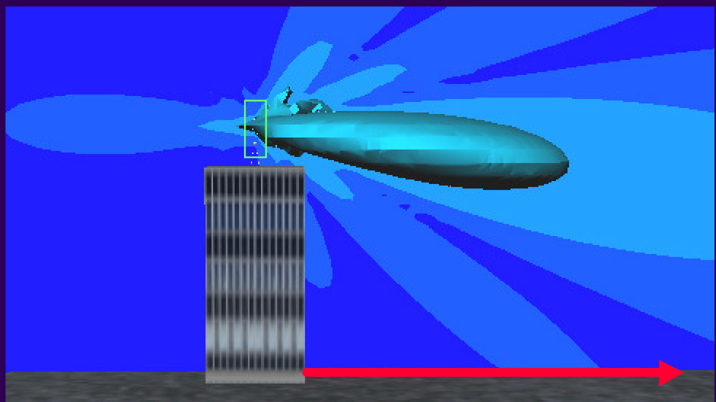
- Multidisciplinary teams worked well together
  - Improved designs and understanding of exposure systems
- Improved measurement techniques and standardisation
  - Data more useful for comparison with future studies

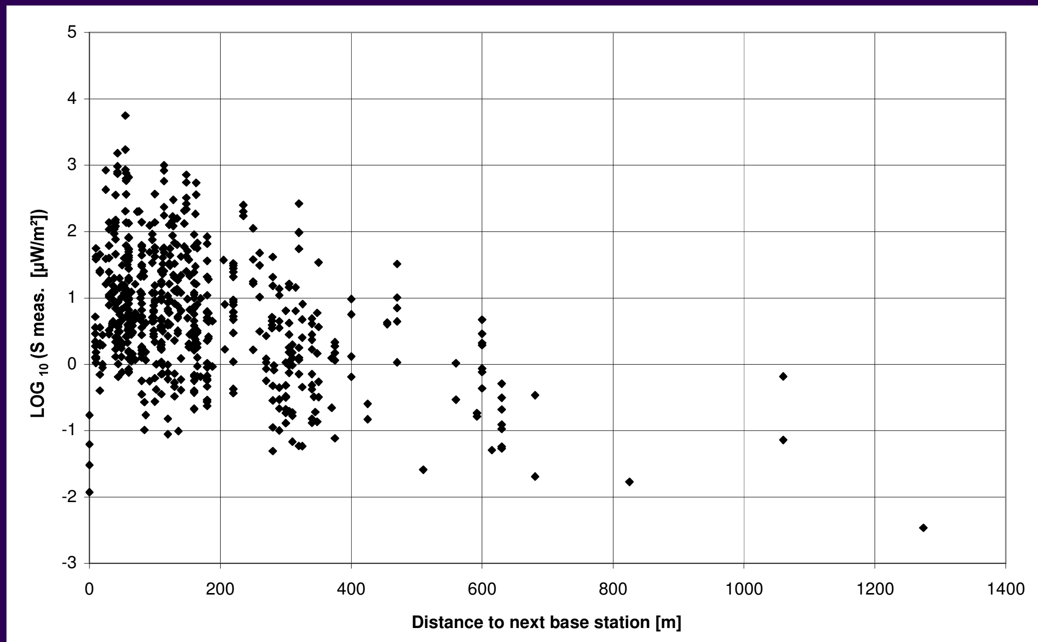




Achievements – Base Stations and health

- Exposure was measured in 1100 rooms and 120 outdoor locations near 60 base station sites
  - Determinants of exposure were examined
- Distance (alone) was a poor predictor of exposure
  - Angle to antenna was a factor for distances less than 200 m
  - Exposure was greatest in rooms with windows facing the BS
  - Vegetation and walls caused attenuation





Achievements – Base Stations and Health

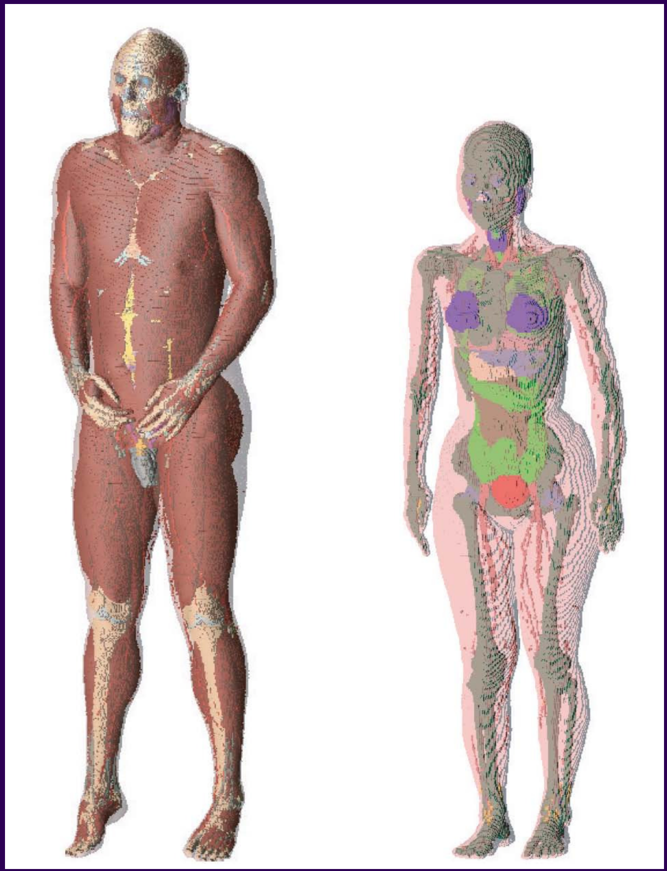
- A model was developed for predicting exposure at the locations
- Good agreement with measurements for
  - low density areas with houses up to three floors
- Acceptable agreement with measurements for
  - low-density areas with houses with more than three floors
  - high-density areas with courtyards and/or small greens
  - closed high-density areas
- Overall, the model gave acceptable to good correlation with the measured values and did not produce a systematic error

2) Where do we still have gaps in knowledge?

It is the nature of research for there to be gaps
Should not over-emphasise these gaps
We have a lot of knowledge already

Remaining Gaps – Numerical Body Models

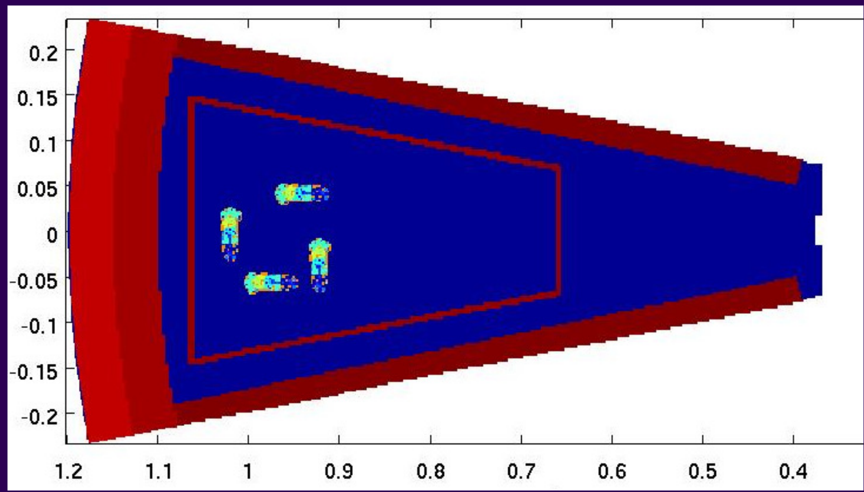
- Models of children, babies and obese people
- Tools to change postures easily, e.g. for work scenarios
- Include vascularisation, metabolism and other biological processes in thermal modelling
- Need to better-understand the relation between temperature rise and SAR in the context of biological effects



Remaining Gaps – SAR in Moving Animals

- Can only simulate static scenarios to derive SAR
  - How many to account for motion?
- For each scenario
  - How many animals to include,
  - What size should they be,
  - Where to place them, and
  - In what posture
- How to combine the results for the static scenarios to get
  - The time-averaged SAR
  - The uncertainty in SAR

  for freely moving animals



Statistical motion studies of animals in cages may help

Remaining Gaps – Occupational Exposures

- Fields are close to and exceed reference levels in certain situations, hence complex assessments have to be used
  - RF heater sealers
  - Induction heaters
  - Live line working
- There is a need for simple to use tools, especially in support of the coming EMF Physical Agents Directive
  - Need to allow postures of body models to be altered easily, while preserving the internal anatomical integrity
  - Need to allow sources to be easily incorporated

Remaining Gaps – Personal Exposures

- The exposures presented were for specific places and scenarios
- There is a need to gain information about the exposure of people as they move about over time
- Recently developed personal exposure meters should be used to gather information during people's everyday lives at home and work

Remaining Gaps – Base Stations and Health

- Need to demonstrate reliable exposure classifications suitable for epidemiology
- But, only 9% of bedroom exposures were found to be above 100 μW m^{-2}
  - 0.1 second phone call gives same brain exposure as 8 hours in bed, given a cumulative exposure model
- Also must decide how to account for
  - Other environmental sources
  - Personal use of mobile/cordless phones
  - Other RF sources in the home
  - Historical exposures

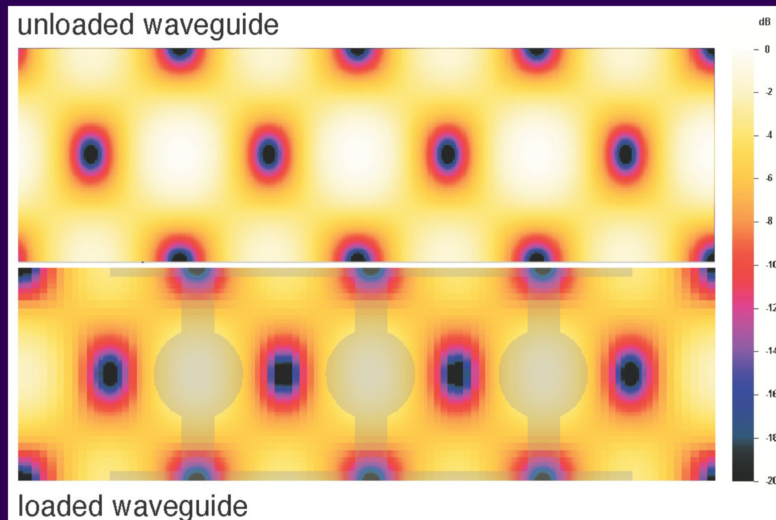
3) Can minimum standards be defined for future work?

Future Minimum Standards – Exposure Systems

- Necessary but difficult
  - Must be designed with regard to the aims of individual projects
  - Must not hold back innovation
  - Multidisciplinary involvement is essential
- Engineering possibilities may be compromised by practical aspects
  - Animals must be free to move for other than very short exposures
  - Cells may have to be exposed in particular containers
- No point in striving for extremely uniform fields when the fact that animals are moving (*in vivo* systems) will degrade exposure uniformity
- Engineers may not be needed after the system has been delivered and the protocol has been confirmed
  - Controls should prevent parameters not in the protocol from being changed

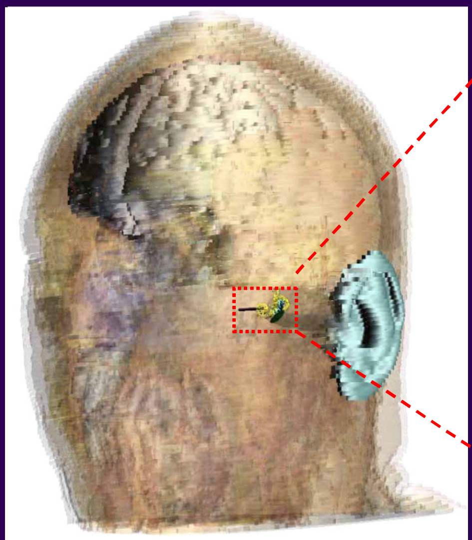
Future Minimum Standards – In Vitro Systems

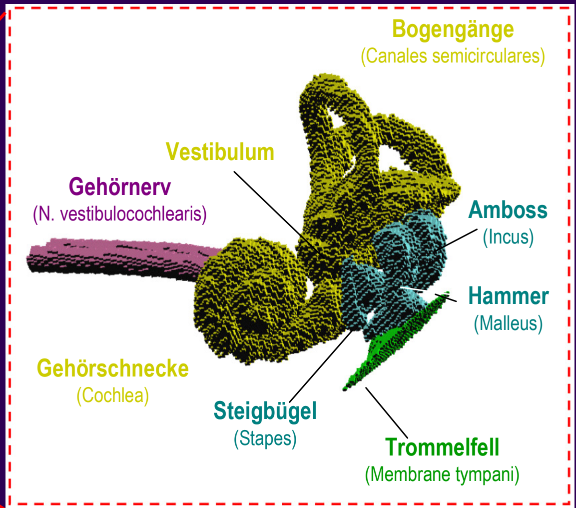
- Field homogeneity is required to achieve exposure homogeneity
  - Should define minimum exposure homogeneity
  - 300–400 % not acceptable
- Where cells are exposed in short-circuited waveguides
  - Monolayers are exposed at H-field maxima
  - Suspensions are exposed at E-field maxima
- For a given SAR level, the H-field in the cells will be different in these two cases
  - H-field must be recorded in case it is implicated in any (non-thermal) effects



Future Minimum Standards – Anatomical Models

- Small anatomical structures have to be resolved in order to examine for changes in them
  - 0.5-1 mm resolution is fine for most human situations
  - 0.2 mm may be needed for animals, e.g. to model thin skulls
- Electric field strength varies at these resolutions, but temperature does not
  - Coarser resolutions are adequate for assessing compliance with exposure guidelines





4) Do any of the findings impact on setting standards and guidelines?

Impact on Standards – Exposure Metric

Would temperature rise be a better quantity to restrict than SAR?

SAR

- Theoretical construct
- Good knowledge of tissue electrical parameters
  - Low uncertainty in calculated values

Temperature rise

- Physically relevant
- Blood circulation and metabolism not rigorously modelled
  - High uncertainty in calculated values

- Better rationale needed than is available today would be needed in order to justify a change to temperature rise as the restricted quantity

Impact on Standards – Averaging Mass

What mass should SAR be averaged over?

- Modelling small anatomical structures at 0.1 mm resolution revealed SAR variations at this resolution
- Temperature rise did not reflect these SAR variations because of efficient thermal diffusion in tissue
- Averaging over a 1 g mass is more conservative than 10 g
- Averaging over a 10 g mass was considered sufficiently small to protect against RF-induced temperature variations in tissue

Impact on Standards – Averaging Shape

Should SAR be averaged over a cubical or contiguous volume?

- Difference in result more marked with 10 g than with 1 g mass

Cubical mass

- No physical or biological meaning
- Convenient for measurement-based standards with homogeneous phantoms

Contiguous mass

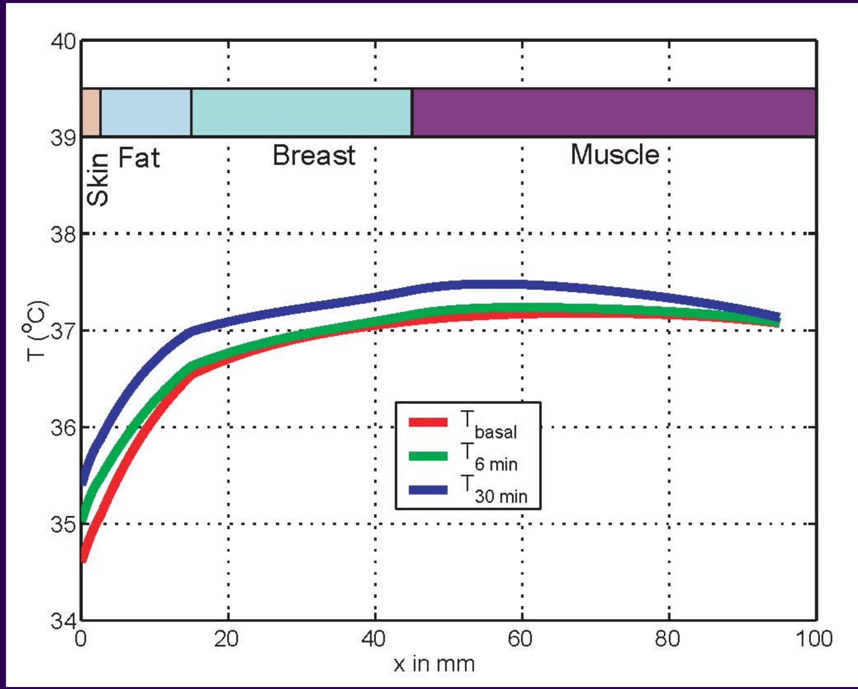
- Follows anatomical boundaries
- No more difficult to average over than a cube in computational (voxel) phantoms

- Temperature rise in a cube would be greater than in a thin heated layer at frequencies where penetration is appreciable (below 5 GHz)
  - Cube is more conservative
- Situation may be different above 5 GHz where heating is at the surface

Impact on Standards – Averaging Times

Health Protection Agency

- Calculations showed time to achieve a steady temperature state is around 30 minutes
- Model has limitations
  - Metablism, blood flow etc are not well-accounted for
- Exposure guidelines average over 6 minutes
  - Conservative



Outcomes Summary

Health Protection Agency

- Successful co-operation between researchers from different disciplines
- Improvements in exposure assessment methods and the design of exposure systems
  - Assessment basis for base station epidemiology still not satisfactory
- Advances in knowledge in several areas
  - Exposures from real devices in real situations
  - Reduced uncertainties regarding temperature rises in relation to SAR
- DMF results should be useful to international organisations responsible for developing future standards

Bundesamt für Strahlenschutz

Deutsches Mobilfunk Forschungsprogramm (DMF)