Exposure setup for animal experiments using a parabolic reflector

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Overview

Introduction

Exposure Setup

Numerical Dosimetry

Conclusion

Motivation

- Public concern about possible negative health effects
- Biological *in-vivo* experiments are indispensable to create a strong body of evidence
- To verify the results, all experiments have to be carried out under well defined and reproducible conditions

Project Description

- Investigation on cognitive faculties of electromagnetically exposed Wistar rats
- Long-term, continuous exposition (20 Months, 24 h/day) with GSM and UMTS signals at 900 MHz and 1966 MHz, respectively

Prerequisites

- Standard, controlled and reproducible exposure conditions: e. g. linearly polarized plane wave
- Identical construction of the setup for three different exposure groups: GSM (@900 MHz), UMTS (@1966 MHz) and sham (no exposure)
- Shielding between the three groups and from external fields
- Possibility to expose a large number (> 100) of animals over a long period of time
- Appropriate conditions for the animal well-being: e. g. air-conditioning, easy access to the cages
- Low-cost setup

Basic Principle

- Usage of a parabolic reflector to convert a spherical wavefront to a plane wave

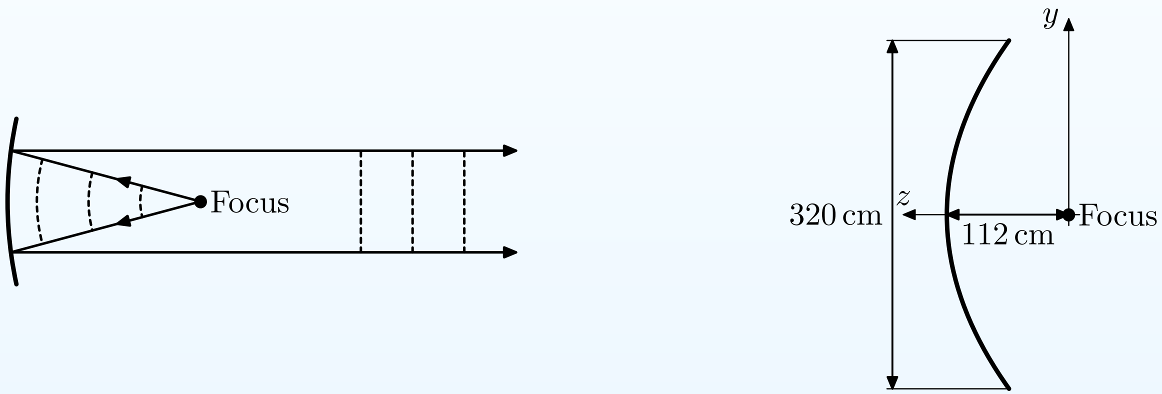


Fig. 1: Parabolic reflector

- Mass-production reflector for the reception of satellite TV, diameter: 320 cm, focal distance: 112 cm
- Exposure setup is placed in an electromagnetically shielded chamber to decouple the three exposure groups and to prevent influences from external fields

Basic Principle – First Simulations

- UTD assuming an ideal point source at the focus with uniform illumination

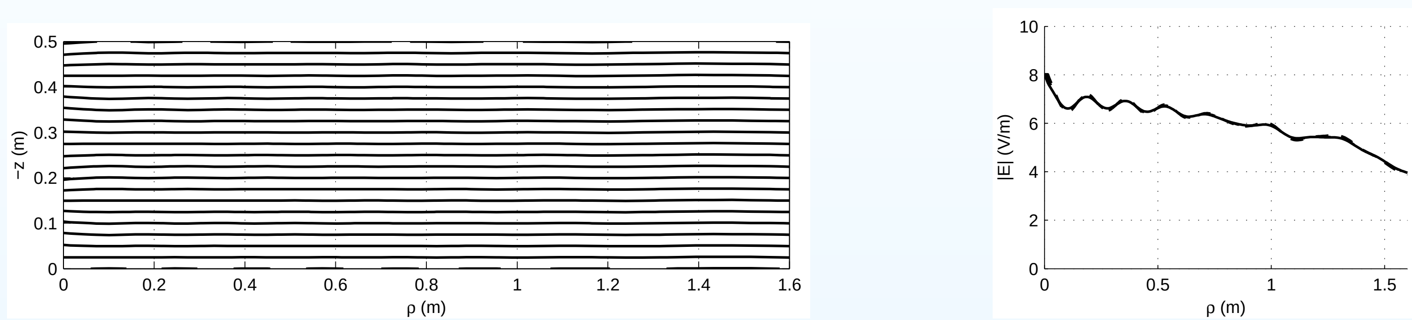


Fig. 2: Phase fronts and absolute value (1966 MHz)

- Main problems of the prime focus configuration when using a real feed
  - Feed spillover
  - Uniform illumination

Basic Principle – Feed Defocussing

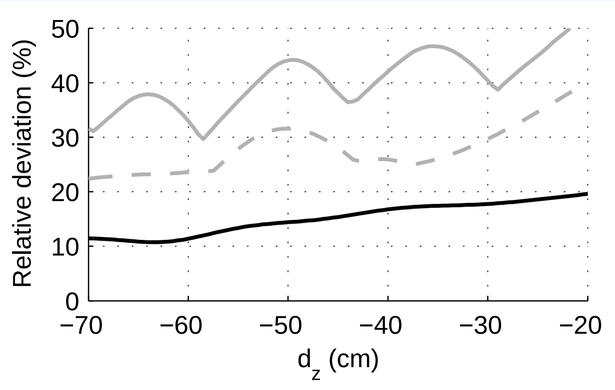
- Proposed solution: feed defocussing together with the placement of the exposure zone away from the feed

Fig. 3: Focused vs. defocused setup

- The exposure zone is placed where the feed's spillover effect can be neglected
- With the same feed beamwidth a greater illuminated area is obtained
- The defocussing originates a smooth tapering of the field at the focal plane, preventing ripples along the wave trajectory caused by abrupt changes in the illumination

Basic Principle – Feed Defocussing (2)

- The exposure zone is set to $-250\,\mathrm{cm} < z < -200\,\mathrm{cm}$ and $15\,\mathrm{cm} < \rho < 125\,\mathrm{cm}$
- The feed is chosen to be an open waveguide
- The maximum and the standard deviations are analyzed as a function of the defocussing distance d_z



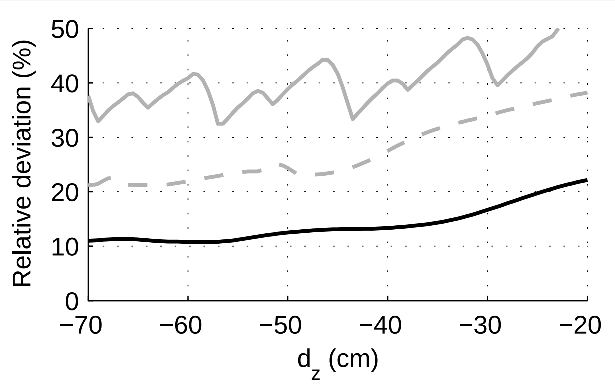
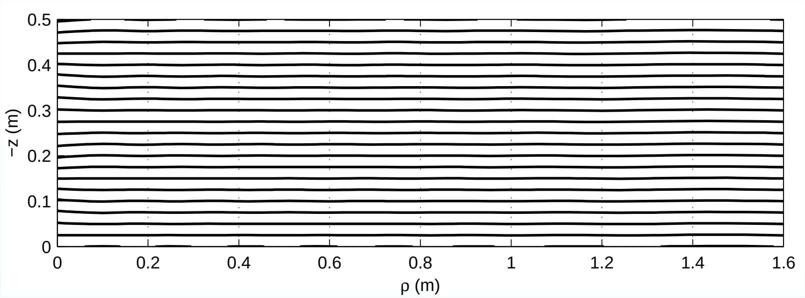


Fig. 4: GSM-band setup (Optimum $\mathrm{d}_z = -59\,\mathrm{cm}$)

Fig. 5: UMTS-band setup (Optimum $\mathrm{d}_z = -56\,\mathrm{cm}$)

Basic Principle – Comparison



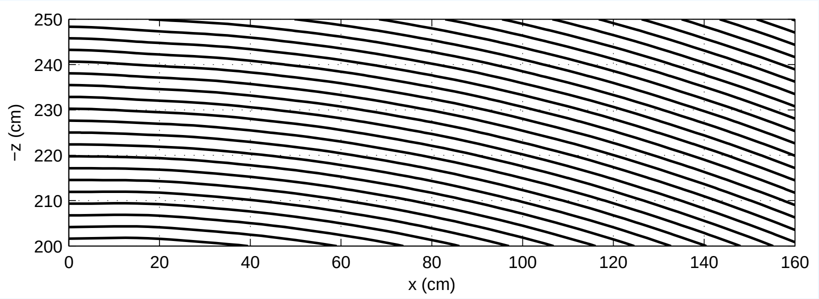


Fig. 6: Phase fronts for focused setup

Fig. 7: Phase fronts for defocused setup

Exposure Setup

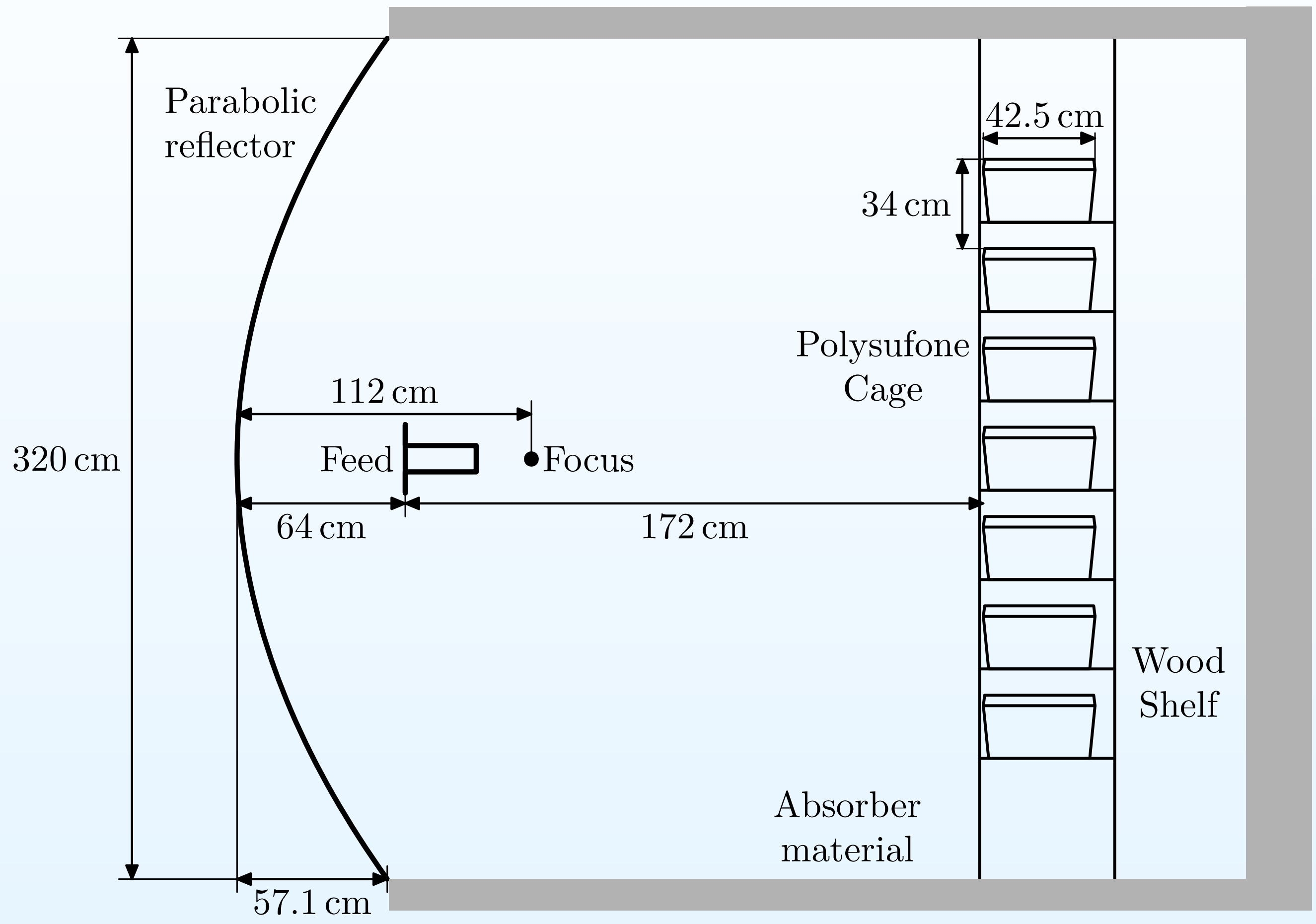


Fig. 8: Final exposure setup

Simulation Results (Method of Moments)

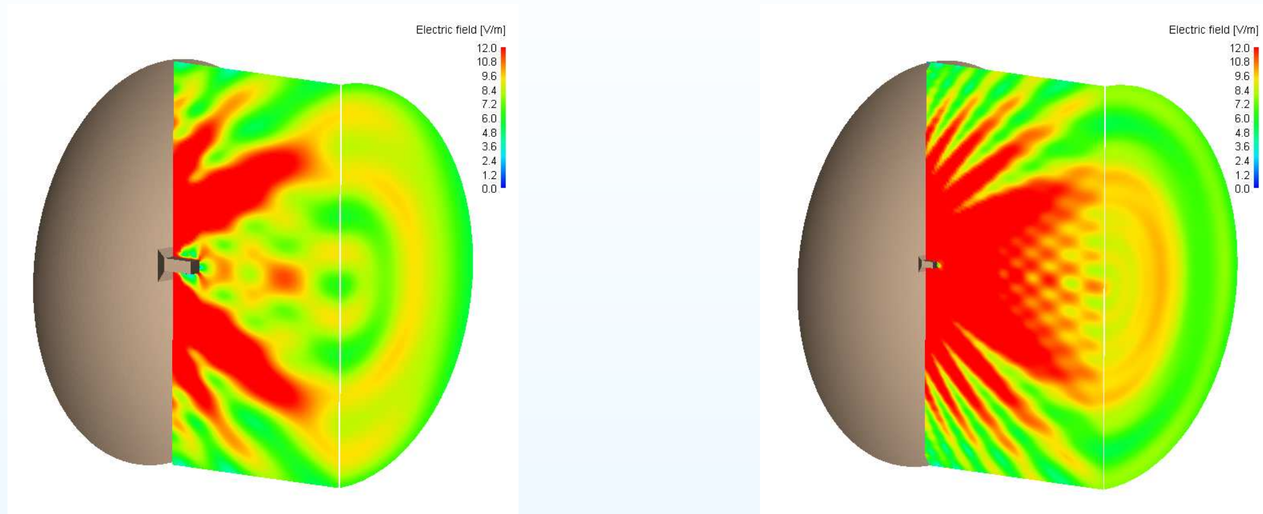


Fig. 9: E in the GSM / UMTS setup when the feed radiates 1 W

- Plane wave condition achieved with a maximum phase error of $\pm 12^\circ$ in a cage volume
- Electric field and power density standard deviation in a cylindrical exposure volume (2.4 m diameter and 0.5 m height, i. e. space for 40 cages) of 7.6 % and 15 % respectively

Real Setup

Fig. 10: Photos of the real setup

- Construction of the three identical electromagnetic shielded chambers
- Measured electromagnetic shielding of the chambers over 100 dB

Measurement Results

Fig. 11: Measurement setup without and with animals

- Power density measured with aperture antennas
- Measurements without animals in the chamber and with animals surrounding the measuring position
- Characterization of the mean power density incident at each cage and its perturbation due to the surrounding animals

Measurement Results (2)

Fig. 12: Normalized power density in the GSM / UMTS chamber

- Mean $|\mathbf{E}|$ for the best 40 cage positions: $|\mathbf{E}| = 7.8\,\mathrm{V/m}$ for the GSM setup and $|\mathbf{E}| = 8.2\,\mathrm{V/m}$ for the UMTS setup ($P_{\text{feed}} = 1\,\mathrm{W}$)
- Standard deviation of the power density for the best 40 cage positions: $14\,\%$ for the GSM setup and $27\,\%$ for the UMTS setup

Rat Models

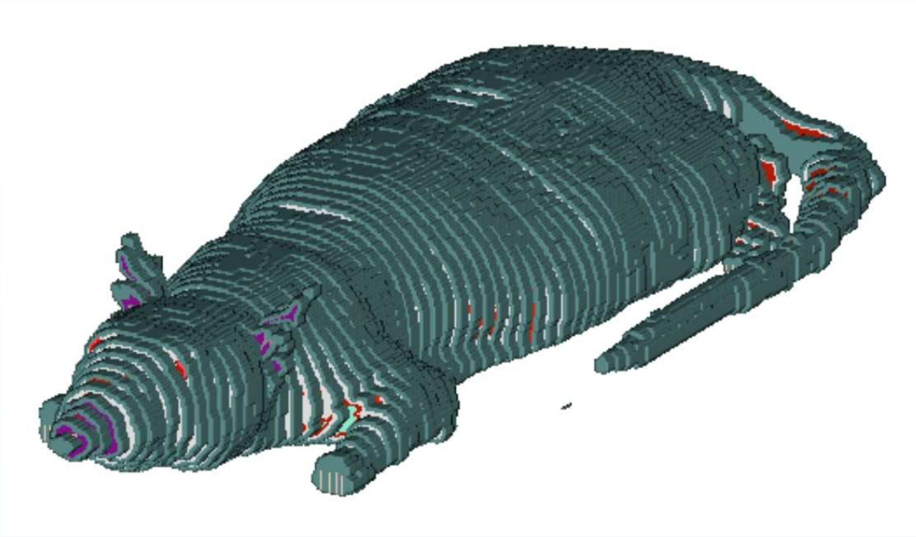


Fig. 13: Example rat model: Sprague-Dawley male rat 370 g

- Voxel data sets are used to model the animals. The animal is divided into cuboids of different biological tissues
- The Specific Absorption Rate (SAR) is obtained by using the Finite Integration Technique (FIT)

Rat Configurations

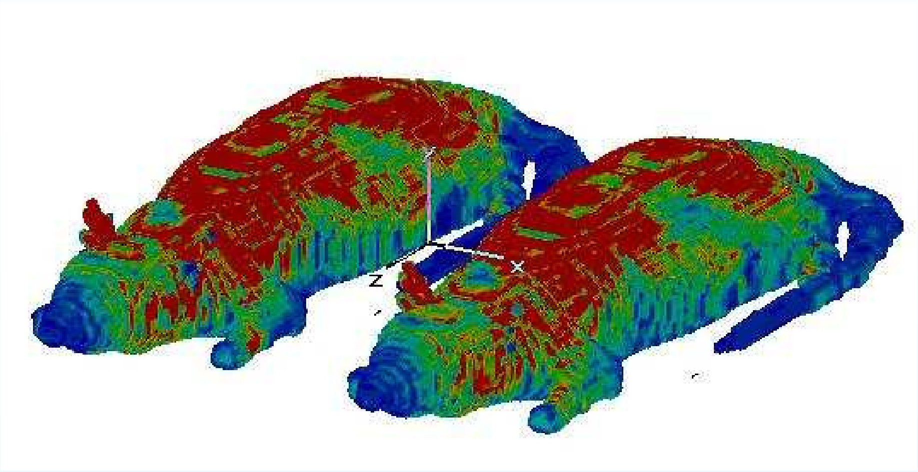


Fig. 14: Example multi rat scenario

- Different scenarios with male, female and baby rats have been created. For each scenario, several simulations with one incident plane wave coming from different directions were carried out

SAR Simulation

- A statistical analysis of the *Whole Body SAR* (WB SAR) is realized for six different multi-rat-scenarios
- To achieve a mean WB SAR of 0.4 W/Kg a plane wave with 102 V/m and 104 V/m for 900 MHz and 1966 MHz, respectively, is required
- WB SAR standard deviation: 42 % and 45 % for 900 MHz and 1966 MHz respectively
- The WB SAR standard deviation of six single-animal scenarios results in 50 % and 26 % for 900 MHz and 1966 MHz, respectively

SAR Simulation – Variations

Origin	GSM Band	UMTS Band
Cage position in the chamber	14 %	27 %
Animals in the neighborhood	7 %	4 %
Size and movement of the animals in the cage	$> 42\,\%$	$> 45\,\%$

- The standard deviation of the WB SAR in the rats is mainly due to the changes in size and attitude of the rat and the effects of the cohabitant animals in the same cage, i. e. by the long-term, *in vivo* characteristic of the experiment.

Summary

- The exposure concept based on a defocussed parabolic reflector results in a low-cost and energy efficient exposure setup
- A high number of rats (40 cages) can be exposed simultaneously
- High decoupling between the exposed groups
- Conditions for the animal well-being are assured
- SAR efficiency of $0.0024\,{}^{\mathrm{W \cdot Kg^{-1}}}\!/\mathrm{W}$
- The standard deviation of the WB SAR in the rats is mainly due to the changes in size and attitude of the rat and the effects of the cohabitant animals in the same cage, i. e. by the long-term, *in vivo* characteristic of the experiment