Setup for the Controlled Plane Wave Exposure at GSM and UMTS Bands for In Vivo Experiments using a Parabolic Reflector

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Outline

- Introduction
- Description of the exposure setup
- Characterization of the exposure
- Summary

Introduction

- “In Vivo-Experimente unter Exposition mit hochfrequenten elektromagnetischen Feldern der Mobilkommunikation. A Langzeituntersuchungen”

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

Exposure setup requisites

- Standard, controlled and reproducible exposure conditions (e. g. linearly polarized plane wave) are of capital importance in RF exposure experiments.

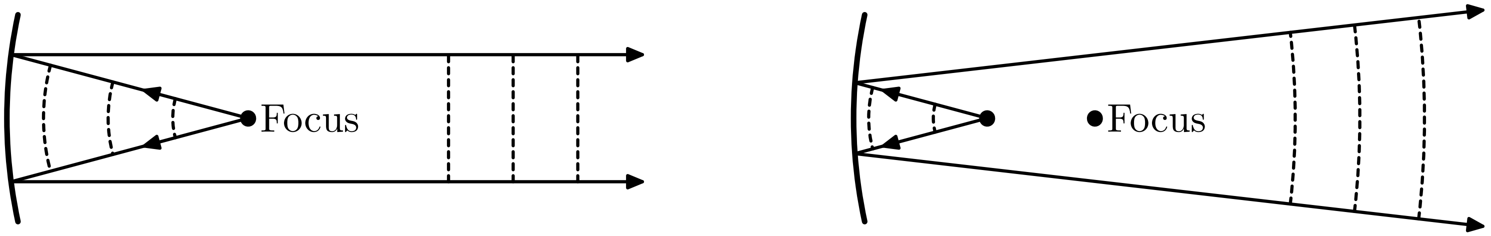
- Identical construction of three setups: GSM at 900 MHz, UMTS at 1966 MHz and sham (i. e. no exposure at all)

- Appropriate conditions for animal well-being and animal care must be assured to permit long-term and continuous exposition.

- Exposition of a high number of animals ($>$ 100) simultaneously must be possible to obtain statistic meaningful results.

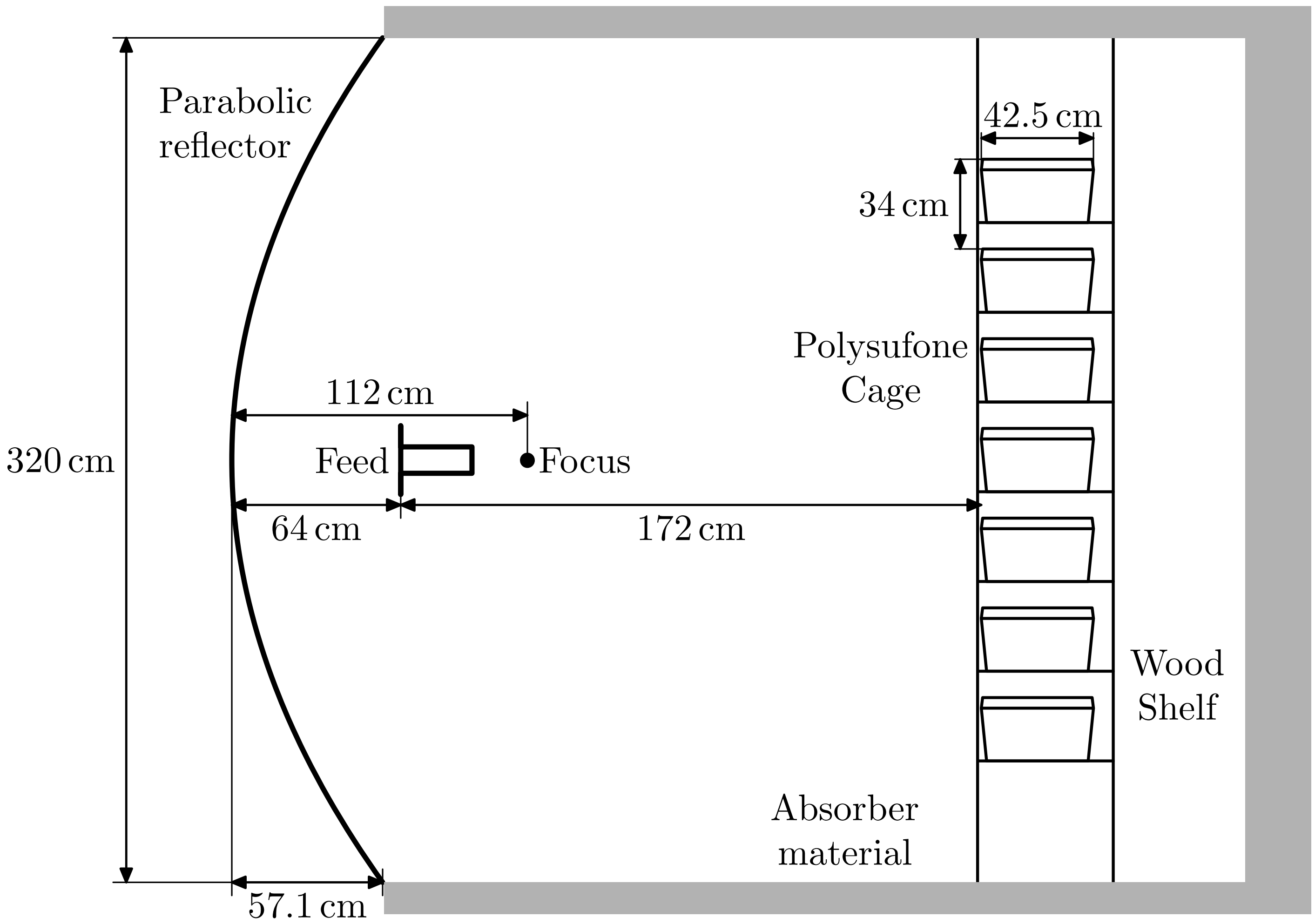
- Low-cost setup with standard components

Proposed solution for the exposure setup

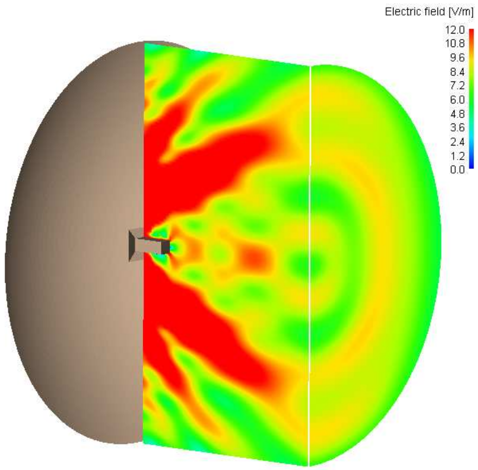


- Use of a parabolic reflector (in our case: diameter 3.20 m and focal distance 1.12 m) illuminated by an open waveguide to convert a spherical wavefront into a plane wave.
- Main problem of a focussed approach with this reflector: uniform illumination
- Proposed solution: feed defocussing together with the placement of the exposure zone away from the feed
- The exposure setup is placed in an electromagnetically shielded chamber to avoid external influences and to decouple the different exposed groups.

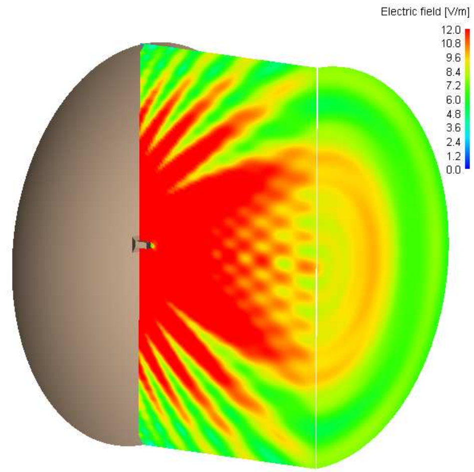
Exposure setup



Exposure setup simulation



$\vec{E}$ in the GSM setup (900 MHz) when $P_{feed} = 1\,W$



$\vec{E}$ in the UMTS setup (1966 MHz) when $P_{feed} = 1\,W$

- Setup simulated with the Method of Moments (MoM)
- Plane wave condition achieved with a maximum phase error of $\pm 12^\circ$ in a cage volume.
- 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 14.9 % (GSM) and 15.5 % (UMTS)

Exposure setup construction

- Construction of the three identical electromagnetic shielded chambers.
- Measured electromagnetic shielding of the chambers over 100 dB, i. e. attenuation of external signals, e. g. TV signal coming from the neighbor TV-tower, over 100 dB.

Exposure field measurement

- 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

Exposure field measurement without animals

0.51	0.97	1.21	1.46	1.53	1.29	1.05	0.55
0.89	1.20	1.18	0.95	0.98	1.27	1.47	1.05
0.85	1.00	0.79	1.31	1.35	0.84	0.99	0.81
0.75	0.70	1.09	1.18	1.14	1.13	0.73	0.87
0.94	0.92	0.61	0.93	0.92	0.64	0.91	0.97
0.92	1.18	1.07	1.03	1.01	1.11	1.14	0.94
0.49	0.96	1.07	1.24	1.25	1.04	0.89	0.47

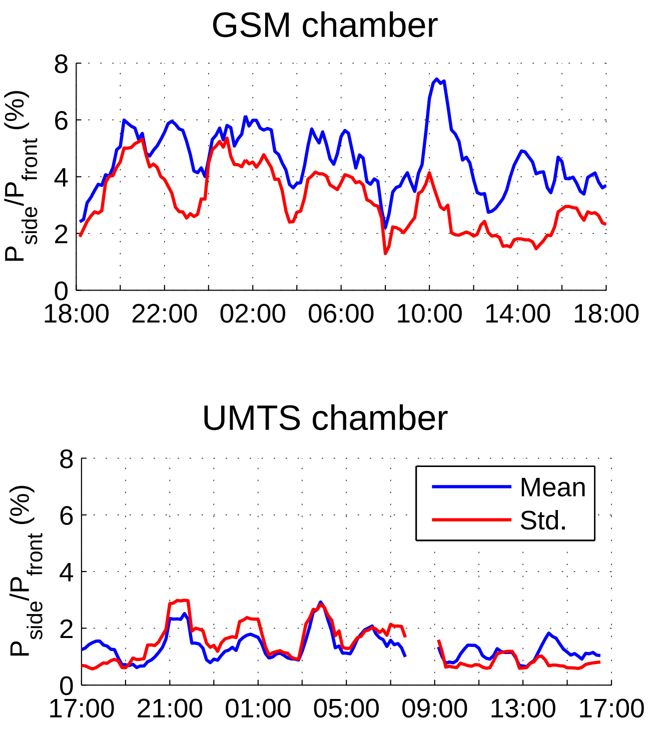
Normalized power density in the GSM chamber

0.50	0.27	0.57	0.94	0.93	0.47	0.30	0.46
0.70	0.98	1.63	1.83	1.68	1.48	1.06	0.66
0.75	1.15	1.03	0.80	0.74	0.88	1.13	0.62
0.62	1.38	1.10	1.51	1.34	1.01	1.35	0.58
0.65	1.57	1.25	0.99	1.03	1.27	1.48	0.58
0.49	1.16	1.47	1.21	1.30	1.56	1.23	0.51
0.49	0.49	1.00	1.85	1.88	1.01	0.36	0.46

Normalized power density in the UMTS chamber

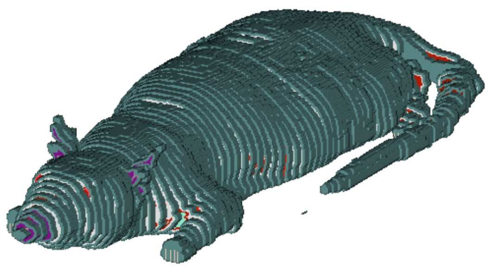
- Mean $|\vec{E}|$ for the best 40 cage positions: $|\vec{E}| = 7.8\,\mathrm{V/m}$ for the GSM setup and $|\vec{E}| = 8.2\,\mathrm{V/m}$ for the UMTS setup ($P_{\mathrm{feed}} = 1\,\mathrm{W}$)
- Standard deviation of the power density for the best 40 cage positions: 14 % for the GSM setup and 27 % for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

Exposure field measurement with animals

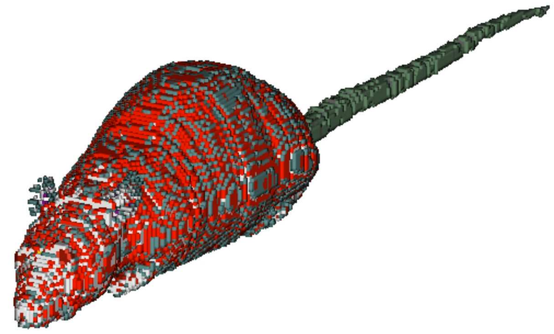


- Power density measurements for different orientations of the antenna
- Mean values for measurements with and without animals coincident
- The total standard deviation in the exposure dose due to the presence of animals $\left(\sqrt{\sigma^2_{\text{front}} + \sigma^2_{\text{left}} + \sigma^2_{\text{right}}}\right)$ is 7 % for GSM and 4 % for UMTS

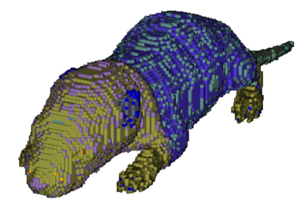
Numerical dosimetry (1)



Sprague-Dawley
male rat 370 g



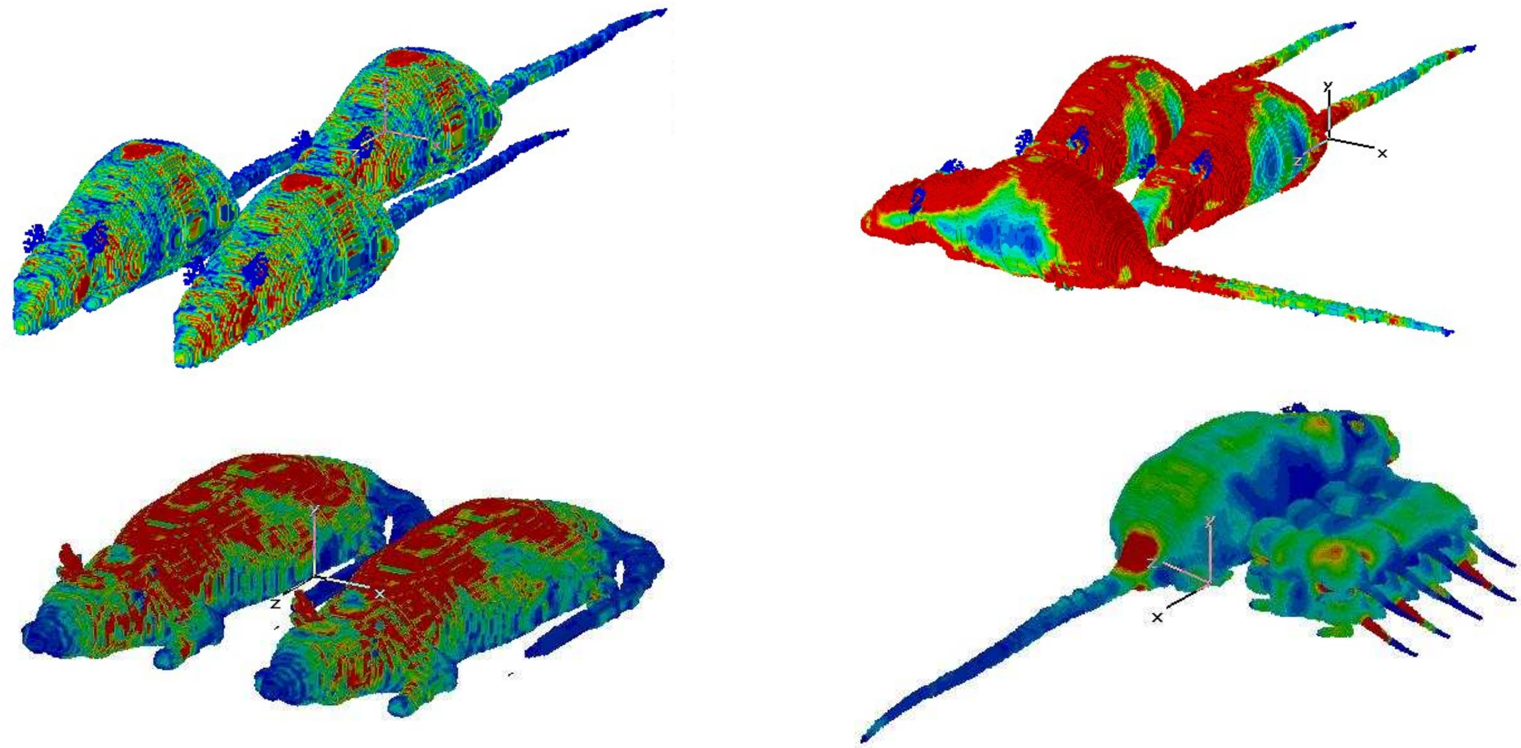
Sprague-Dawley
female rat 275 g



Sprague-Dawley
7-days-old rat 15 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).

Numerical dosimetry (2)



- 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.

Numerical dosimetry (3)

- A statistical analysis (48 cases per frequency) of the *Whole Body SAR* (WB SAR) in the rats 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 (i. e. a P_{feed} of 172 W and 161 W) for 900 MHz and 1966 MHz, respectively, is required.
- WB SAR standard deviation for the six different **multi-rat-scenarios**: 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.

Standard deviation for the Whole Body SAR

Origin	GSM Band	UMTS Band
Cage position in the chamber	14 %	27 %
Animals in the neighborhood	7 %	4 %
Size and change in attitude 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 rats 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.
- A high isolation from external fields is achieved.
- Conditions for the animal well-being and care 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.