

MICROWAVE EXPOSURE SETUP FOR A LONG-TERM *IN VIVO* STUDY

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1 Introduction

The health effects of exposure to microwaves (MWs) from cellular telephones have become a great concern of the general public. Although responsible organizations have found no evidence in previous biological studies to support restricting the use of cellular telephones, they recommend further biological studies of good quality [1]. A large-scale and long-term bioassay is especially given the highest priority.

For such studies, several hundred laboratory animals and a period at least two years are needed. To simulate the biological effects of using cellular telephones, the MW energy absorption should be focused within the head region of the test animals. The most commonly used laboratory animals are rats and mice, but they are much smaller than the human body. Their body size is comparable to the wavelength of the electromagnetic waves used for cellular telephones. It is therefore difficult to achieve partial-body exposure in small laboratory animals.

Some exposure setups have been developed using the near field [2, 3] because the field strength of the near field decreases rapidly with the distance from the radiation source. Under near-field exposure conditions, however, the radiation source interacts strongly with the test animal. It is thus difficult to accurately estimate the SAR in small animals in the near-field.

We developed a new exposure setup for large-scale and long-term *in vivo* studies. It uses Sprague-Dawley rats to simulate the health effect in humans of localized exposure to MWs from cellular telephones. We also developed realistic rat models to accurately estimate the SAR distribution in the rats.

2 Exposure Setup

As shown in Fig. 1, our exposure setup has 1/4-wavelength monopole antenna that is fed at the center of the top. Ten rats fixed in a plastic tube are located like a carousel. Similar exposure setups have been developed [2, 4, 5], but in those setup, the antenna feed point was located on the bottom plane, so that the highest SAR occurred around the lower part of the head, i.e., the chin, not around the upper part of the head including the target tissue, i.e., the brain. Feeding the antenna at the top plane should improve the localized exposure condition.

The reflection coefficient (S11) at the input connector of the monopole antenna with the ten rats was measured and less than -10 dB even if the rats were moved in the tube. The variation of the radiation power of the antenna due to the movement of the rats was thus negligible.

3 Numerical Rat Models

A rat model based on anatomical charts was developed for studies of liver cancer in rats [3, 6, 7]. This model is not appropriate for SAR dosimetry under rat-head localized exposure conditions because the tissue types defined (skin, bone, liver, and muscle) did not include the brain.

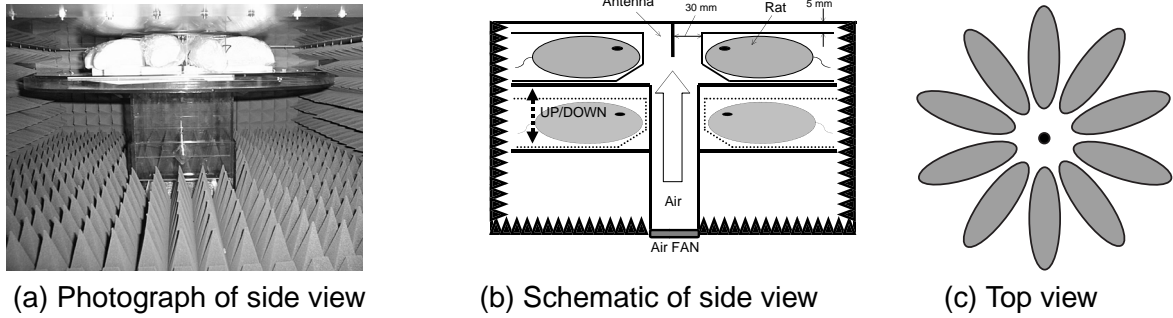


Figure 1: Exposure setup for large-scale and long-term *in vivo* studies.

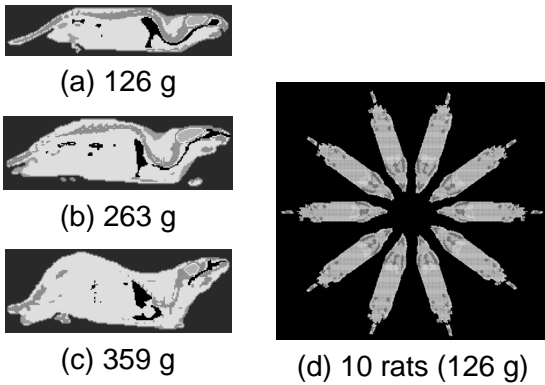


Figure 2: Numerical rat models developed from the section data of the x-ray CT.

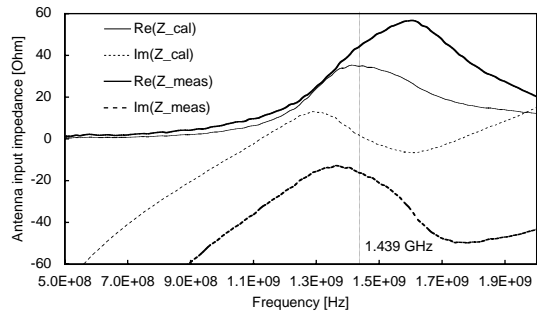


Figure 3: Calculated and measured antenna input impedance.

A more realistic rat model based on MRI section data was developed by a research group at USAF Brooks Laboratory (<http://www.brooks.af.mil/AFRL/HED/hedr/hedr.html>). It has many defined tissues (over 40 types), but the shape of the rat data of an anesthetized rat was made from the MRI. It is thus not a good model for a rat in a plastic tube. The difference in the shape of the rat can cause a large error in the estimated SAR. Burkhardt et al. developed a rat model with a realistic shape from the MRI data of a rat in the plastic tube used in their exposure setup [2]. The rat models we developed were also based on the section data of rats in plastic tubes.

In a long-term exposure experiment, the size of the test animals changes greatly. The weight of a rat will increase from under 100 g to over 400 g. Scaled models have been used for SAR evaluation of different-sized rats [5, 8], but the results are not necessarily valid because the degree of growth of the different body parts (head, legs, body, etc.) can vary. We therefore used the section data of three different-weight rats (126, 263, and 359 g) and developed three numerical rat models.

The section data were obtained using the x-ray CT and MRI. The CT gives more clearer pictures than the MRI, making it easier to distinguish between air, bone, and soft tissues. The rat models were therefore developed based on the CT pictures. Their spatial resolution was 1 mm. Ten tissues were labeled at each voxel (Fig. 2 (a)–(c)).

4 Numerical Dosimetry (Preliminary)

The finite-difference time-domain (FDTD) method was used for calculating the SAR distribution in the rat models. The calculation region was $520 \times 520 \times 95$ meshes. The resolution of each mesh was 1

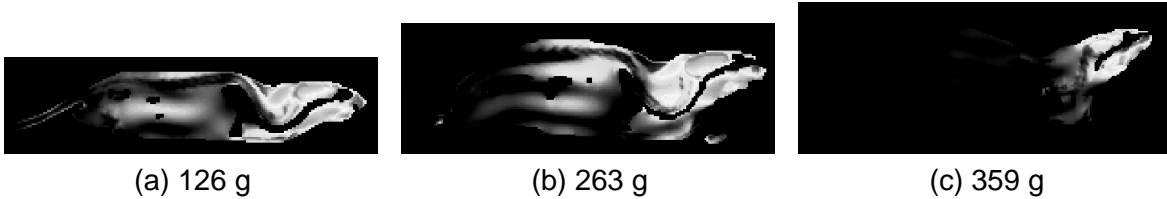


Figure 4: Calculated SAR distributions in the mid-sagittal section of the numerical rat models.

Table 1: Calculated SAR values of the numerical rat models. The antenna input power is 1 W.

Weight of rat	Whole-body SAR [W/kg]	Brain-averaged SAR [W/kg]
126 g	0.45	2.02
263 g	0.25	1.77
359 g	0.20	1.25

mm. The ten rat models were located at the same position as the actual setup (Fig. 2 (d)).

The 1/4-wavelength monopole antenna was modeled using the thin-wire algorithm [9]. The radius of the wire was 0.25 mm, not the actual antenna radius (1.5 mm). Although this antenna model for our preliminary investigation was relatively coarse, the calculated antenna input impedance was fairly equal to the measured data (Fig. 3).

The SAR distributions in the sagittal sections of the rats are shown in Fig. 4. The whole-body averaged SAR and the brain-tissue-averaged SAR are listed in Table 1. These results show that this exposure setup can simulate localized exposure conditions.

5 Experimental dosimetry

We used solid rat phantoms and a thermographic camera to evaluate the SAR distribution of the rats in the exposure setup. Rat phantoms with the same shape as the numerical rat model were manufactured. The recipe for the phantom material and the measurement methods are discussed elsewhere [10].

The SAR distributions in the mid-sagittal section of the rat phantoms are shown in Fig. 5. The calculated SAR distributions of homogeneous rat models having the same electrical properties are also shown. Localized exposure within the head region was displayed in both the experimental and calculated results.

The SAR distributions along the axis through the nose and the center of the brain are shown in Fig. 6. Good agreement was found between the experimental and calculated distributions.

6 Conclusion

We have developed a new exposure setup for large-scale and long-term *in vivo* studies. Three different-size-rat models with an actual shape were developed to improve the accuracy of the SAR estimation. The numerical and experimental results agreed well, showing that this exposure setup can achieve localized MW absorption within the head region of rats in our exposure setup.

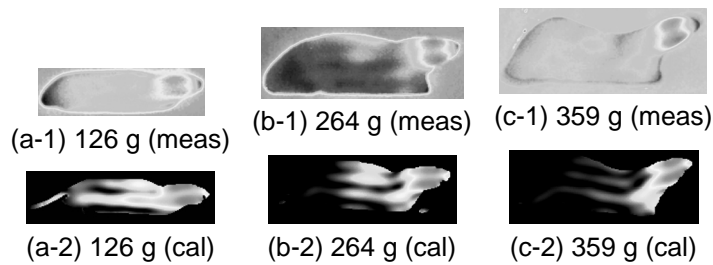


Figure 5: Measured temperature distributions in the mid-sagittal section of the rat phantom after a 30W-60s exposure and calculated SAR distributions of the homogeneous rat models.

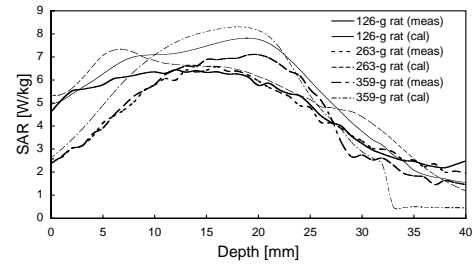


Figure 6: Experimental and calculated SAR distributions along the axis through the nose and the center of the brain. The antenna input power is 1 W.

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