

Biological effects of radar type 3 GHz microwave exposure on Wistar rats

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Abstract

The aim of this work was to simulate human exposure to high power pulsed microwave (HPM) emitted by radars. The exposure of navy staff can be occasional, prolonged or repeated. A special emitting experimental device was developed in order to reproduce these exposure conditions with an experimental model of adult rat. Results obtained for 29 days after a single 3 GHz exposure (mean SAR 15 W/kg) will be presented. At day 30, the animals were sacrificed. Parameters related to the central nervous system, hematological and endocrine system were studied. The condition of rats was followed up by regular body weighing and clinical check-up. The data obtained did not show significant biological and behavioral effects after an acute exposure to radar's HPM at 3 GHz.

Introduction

Navy staff exposure to radars may be occasional, prolonged or repeated depending on activities aboard (Charles De Gaulle aircraft carrier, all electric frigates). Only few studies have been performed on the effects of high power microwaves emitted by the radars. Thus, it was necessary to investigate their potential health effects in order to contribute to the risk assessment and anticipate potential litigation. A special emitting experimental device was developed in our laboratory in order to reproduce these exposure conditions with an experimental model of adult rat.

We present here the results obtained for 29 days (i.e. short-term effects) after a single S-band (3 GHz) exposure under non thermal conditions. The effects on the central nervous system were assessed by two types of behavioral tests. In parallel, the condition of the rats was followed up by regular body weighing and clinical check-up. At the end of the experiment, hematological parameters were examined with complete blood count. The endocrine pathway involved in stress management have been studied through adrenocorticotrope hormone (ACTH) and corticosterone assays. 30 days after exposure, the animals were sacrificed by decapitation.

Materials and methods

Animals

Four-month old male Wistar rats (Charles River, France) were randomly housed four per cage under standard conditions of temperature ($21 \pm 1^\circ\text{C}$) and humidity (50-60 %), with a 12h:12h day/night cycle and free access to food and water.

Exposure setup

The emitting system consisted of a microwave signal generator (Anritsu, France) and a S-band 3 GHz pulse amplifier (TOP IFI EuroMC), connected to a coaxial antenna (Sairem, France) through a waveguide (Sairem France) both located in an anechoic chamber (Emerson & Cuming, France).

During exposure, animals (Wistar rats, male, 16 weeks old at the time of exposure) were placed symmetrically around the antenna in individual specially designed Plexiglas® boxes.

The freely moving rats were laterally exposed. A metallic grid was placed above the cages to confine the field and optimize exposure uniformity in the cages (Fig. 1). Two identical anechoic chambers were used: one for microwave exposure, the other one for sham exposure in order to reproduce all manipulations except HPM exposure.

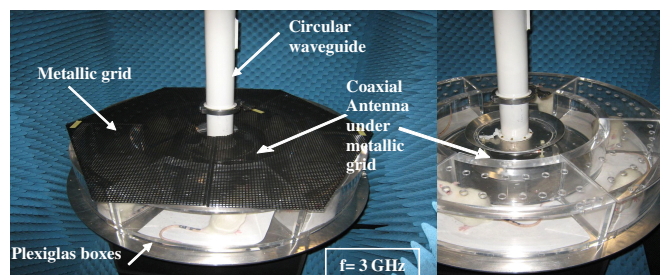


Figure 1: 3 GHz exposure system for *in vivo* experiment in an anechoic chamber

The temperature was controlled. The room temperature was maintained by air-conditioning ($20 \pm 1^\circ\text{C}$) and an electric fan ensured air renewal in the anechoic chamber. The temperature in the chamber was measured with an electronic thermometer all along the exposure.

A camera linked to a video recorder was placed at the top of the chambers in order to observe the spontaneous activity of the animals.

Exposure condition and dosimetry

Rats were exposed for 2 x 8 minutes separated by 4 minutes break phase, with a 20 μs pulse duration and a 600 Hz repetition time. During exposure, light was set up in order to be in accordance with day/night cycle of the animals. The experiment was repeated twice with 2 series of 24 animals for each experiment (12 exposed rats and 12 shams).

The dosimetry was obtained by numerical simulation (FDTD) and completed with experimental measurements. Temperature measurements were realized with a microprocessor-controlled thermometer equipped with four fluoro-optic fiber probes (Luxtron, Optilas, France).

The mean SAR value (whole body) was 15 W/kg and peak SAR value was 1300 W/kg.

Parameters	Values
Frequency	3 GHz
Repetition time	600 Hz
Pulse duration	20 μs
Duty cycle	1.2%
Exposure duration	8 min exposure - 4 min break phase – 8 min exposure
Mean SAR	15 W/kg
Peak SAR	1300 W/kg

Table 1: parameters used for the acute exposure condition.

Behavioral tests

Memory and learning were regularly assessed for 29 days following acute exposure using passive avoidance test, water maze test (1).

Body Weight

All the rats were weighed regularly, at least once a week.

Follow-up

Clinical examination of the animals was performed in parallel including palpation, aspect of faeces, aggressiveness, tearing, bleeding, etc.

Hematological parameters

At day 30, blood was collected to perform complete blood count immediately and for hormonal assays (ACTH and corticosterone). Complete blood count was performed on ABX Pentra 120 (ABX Horiba; Montpellier, France), and in parallel, with May Grunwald Giemsa slides (MGG, kit RAL 555, réactif RAL, Elvetec Services).

Aliquots of whole blood samples were centrifuged immediately. Plasma was stored frozen ($-80\text{ }^{\circ}\text{C}$) until corticosterone (Coat-a-Count, Rat Corticosterone, Siemens, France) and ACTH assays (^{125}I RIA Kit, ImmChem™ Double Antibody, MP Biomédical, USA). Hormonal assays were realized according to the manufacturer's instructions.

Statistical analysis

Statistical analysis was performed using the Statistica® 9.1 software (Statsoft Inc., Tulsa, OK, USA). Statistical analysis of the data was based on ANOVA for cognitive studies. Mann-Whitney test was used for body weight and hematological parameters. p values lower than 0.05 were regarded as statistically significant.

Results

Cognitive studies

Behavioral tests showed no significant effect of microwave exposure on memory, learning, motor skills and overall neurological evaluation during the month following the exposure. The results obtained for the 2 series of rats were processed together for cognitive studies. The results are illustrated by the Water-Maze experiment (Fig.2) and data are not shown in this paper for the other tests.

In the Water-Maze, the rats were allowed 3 min to escape from the water by climbing a plastic ladder. In case of failure they were removed by the experimenter. The number of orientation errors (if the rat goes in a blind way) and the time to escape from the maze were recorded [1].

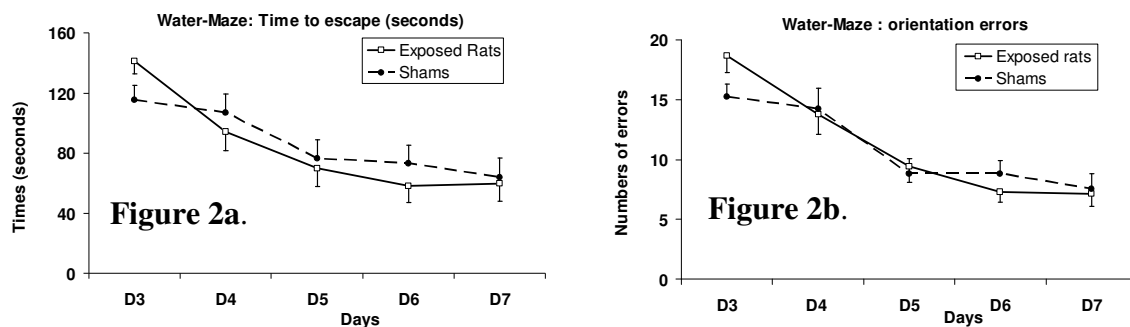


Figure 2: the time to escape (in seconds) and the number of orientation errors recorded for exposed and sham rats are illustrated in Figure 2a and 2b respectively

The results didn't indicate a significant effect for the time to escape from the maze (ANOVA, $F(4,184) = 1.5057$; $p = 0.20229$) and for the number of orientation errors in the maze (ANOVA, $F(4,184) = 1.0959$; $p = 0.36001$), for exposed compared to sham rats.

Body weight and check-up

Rats were observed clinically throughout the experiment for death and signs of illness. Body weight was measured weekly for 30 days. No rat died during this period. The clinical check-up did not reveal any signs of disease associated with microwave exposure in both series. No statistically significant difference in weight gain was observed between exposed and sham rats.

Hematological parameters

Complete blood count

17 hematological parameters were measured (white blood cells, red blood cells, lymphocytes, monocytes, blood platelets, granulocytes neutrophils, granulocytes eosinophils, granulocytes basophils...). No significant variation was found on the 17 hematological parameters tested between sham and exposed rats.

Hormonal assays

For the first series (2 x 12 rats), at day 30, a decrease in plasma ACTH (-35%, $p = 0.02$, Mann-Whitney test) and corticosterone (-38%, $p = 0.08$, Mann-Whitney test) was observed in the exposed group. For the second

series (2 x 12 rats), the results were confirmed for corticosterone level ($p = 0.71$, Mann-Whitney test). No significant effect of exposure was observed on ACTH ($p = 0.51$, Mann-Whitney test). The results obtained for the ACTH of the series 2 didn't confirm the variation of ACTH rate observed between exposed and sham rats of series 1. For the series 1, detailed analyses of the data showed that the difference was not due to a decrease in the exposed rats but to an increase of ACTH level of the sham rats. Complementary analyses of the data indicated that an experimental bias due to the manipulation of the animals was certainly responsible for the effect observed in the first experiment as the ACTH level was related to the order of sacrifice.

Conclusion

In our experimental conditions and in both series, no significant behavioral effect either on memory or on learning occurred for 29 days after acute exposure of the rats to HPM at 3 GHz. No sign of disease and no effect on tumor development were detected in the exposed rats, 30 days after an acute exposure. Surprising effects were observed in the first experiment concerning stress hormones levels and weight gain. There was an important individual variability in ACTH level between the rats, and the ACTH assay was less reproducible in the duplicates than corticosterone assay. Furthermore, an experimental bias was discovered and gave a plausible explanation to the difference between sham and exposed rats in group 1. Although many problems were encountered with ACTH assay, we concluded that there was no significant effect of microwave exposure on ACTH and corticosterone levels at 30 days.

Acknowledgments

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References

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