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Project Summary

Behavior, Physiology, and Energy Deposition in Rats Chronically Exposed to 2450 MHz Radiation

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This research program was designed to determine both the specific absorption rate (SAR) and the behavioral and physiological consequences of chronic CW microwave radiation exposure at 2450 MHz in the laboratory rat. Whole-body average and local SARs at discrete sites within the body of rats and mice were determined both by modelling techniques and experimentally using several different exposure systems. The whole-body average SAR and the distribution of SAR within the body depends on a variety of factors: type of exposure system, polarization of the field, size of the animal, and angle of radiation incident on the body. Three experiments were conducted to determine the effects of chronic exposure to 2450 MHz microwave radiation on several measures of rat behiavor and physiology. Groups of rats were exposed daily for 90 days to 2450 MHz radiation at power densities of 0.5 mW/cm^2 or 2.5 mW/cm^2. Reliable effects were only observed at a power density of 2.5 mW/cm^2.

This Project Summary was developed by EPA's Health Effects Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

There has been an ever-growing increase in the electromagnetic radiation emanating from communications sytems, television, radar, food-processing, industrial and medical devices. Since 1940, the growth of sources for such radiation has increased markedly and is continuing at an ever-accelerating rate. Concurrent with this growth in number of sources has been an increase in the power outputs of such devices. This situation has resulted in much concern over possible harmful biological effects from such radiation in the radio-frequency and microwave portions of the electromagnetic spectrum. It is well known that microwaves at very high power densities can cause adverse biological effects due to the generation of heat in body tissues. Unknown, however, are the subtle physiological, morphological, and behavioral changes due to long-term exposure at low power densities. This has led to a controversy in this country over the significance or even presence of effects produced by chronic low-level exposures. Several earlier studies have reported behavioral and physiolgical changes with repeated daily exposures to low levels of microwave radiation. In these studies, albino rats were given many weeks of exposure to microwave fields at intensities of 0.5 mW/cm^2 or below. Microwave-exposed rats showed a variety of effects including (1) lowered threshold for footshock detection, (2) altered cholinesterase and sulfhydryl groups in blood, (3) increased 17-ketosteroid levels in urine, and (4) retarded learning in an avoidance task.

In each study the exposure occurred in an anechoic chamber with the irradiating antenna placed above rats that were singly or multiply caged during irradiation.

This research program was initiated for two purposes. First, to determine what factors control the formation of locations with high levels of energy deposition (called hotspots) in the rat exposed to 2450 MHz radiation. Both computer modelling and laboratory measurement techniques were used to address this question. Second, to determine the behavioral and physiological consequence of chronically exposing rats to CW microwave radiation at 2450 MHz. The chronic exposure studies were carried out in a monopole-above-ground irradiation system that provides for a more uniform exposure of rats than do other irradiation systems.

Methods and Material

Both the whole-body averaged SAR, and the SAR at discrete sites within the rat body were determined by both analytical and experimental techniques.

Analytic Procedures

In the analytic approach, a 160-cubical-cell model of the rat was developed and a method of moments procedure, employing a pulse function, was used to obtain a number of solutions for whole-body averaged SAR and SAR within each cubical cell for 2450 MHz microwave exposure. The calculations were made with the model under several conditions of exposure and by orienting the length of the model parallel to: (1) the electric field vector; (2) the magnetic field vector; or (3) the direction of wave propagation. Additional details can be found in the full report and the computer programs used are listed in an appendix.

Measurement Procedures

SARs for both the whole-body averages and values at several discrete anatomical locations were measured in rat cadavers exposed to 2450 MHz microwave radiation in an anaechoic chamber. Additional experimental dosimetry experiments were conducted with both rat and mouse cadavers exposed in other open and closed exposure systems. SAR distribution was determined in the cadavers during exposure to 915 MHz and 2450 MHz radiation by sampling the temperature rise at discrete body lcoations with a microwave compatible temperature probe. Additional details can be found in appendices of the full report.

Chronic Microwave Exposures

Three long-term exposures were conducted to determine the effects of 2450 MHz microwave radiation on several measures of rat behavior and physiology. In a repeated measures experimental design, groups of rats were exposed to 2450 MHz radiation at power densities of 0.5 or 2.5 mW/cm^2. Microwave and sham exposures were given seven hours per day for 90 days over which time both behavioral and physiological measures were repeatedly sampled. Additional details can be found in appendices of the full report.

Results and Discussion

Both the specific absorption rate (SAR) and behavioral and physiological consequences of chronic CW microwave exposure of 2450 MHz were determined in the laboratory rat.

Whole-body averaged SAR and SARs at discrete sites within the body determined by both analytical and experimental techniques revealed differences due to differing exposure conditions. Generally, the analytical and experimental determinations of whole-body average SAR were quantitatively very similar for exposures in the E-polarization. There was, however, little agreement between the analytically and experimentally determined SAR distributions inside the rat body. The type of exposure system and the radiation frequency are important determiners for the distribution of SARs within rat and mouse cadavers. Distinct SAR patterns were observed in mice for anechoic chamber exposures and exposures in rectangular and circular waveguide systems. Differences of SAR distributions attributable to method of exposure were also observed in rats, but not to the extent found in mice.

Three experiments were conducted to determine the effects of chronic exposure to 2450 MHz microwave radiation on several measures of rat behiavor. During one exposure at 0.5 mW/cm^2 decrements in performance in active avoidance and schedule-controlled lever pressing for food were observed. Another experiment was conducted at 0.5 mW/cm^2 to reevaluate the behavioral effects. In this experiment the active avoidance decrement was not observed. Effects were observed in schedule-controlled lever pressing for food but were qualitatively different from those observed in the first experiment. It was concluded that microwave radiation at a field power density of 0.5 mW/cm^2 is below threshold for reliable and reproducible effects on a wide range of dependent variables. At a power density of 2.5 mW/cm^2, however, exposed and sham-exposed rats differed significantly in both the active avoidance and schedule-controlled lever pressing tasks. Reliable differences were also observed for sensitivity to an electric foot shock. It was concluded that microwave radiation at a power density of 2.5 mW/cm^2 is above threshold for reliable and reproducible effects.

Conclusions and Recommendations

The whole-body average SAR and the distribution of SAR within rat and mouse cadavers depends on a variety of factors: orientation of the body within the microwave field, the characteristics of the exposure system, size of the animal, and angle of radiation incident to the cadaver. Points of increased energy absorption, SAR hotspots, four times larger than the whole-body average, were observed in the esophagus of rat cadavers exposed to 2450 MHz microwave radiation in the E- and k-polarizations.

The analytical procedures used to predict whole-body average SAR were accurate for a rat model exposed to 2450 MHz radiation in the E-polarization. In contrast, the analytically predicted SAR distribution within the rat model was not in agreement with the experimentally determined values. Several factors were thought to account for this discrepancy.

Three chronic exposure experiments were conducted with rats irradiated daily for up to 90 days. At a power density of 0.5 mW/cm^2 two minor behavioral effects were observed: increased variability among rats performing the active avoidance task and a decrement on schedule-controlled lever pressing for food. During a second experiment conducted at 0.5 mW/cm^2, the active avoidance effect was not observed. In this experiment, effects were observed in schedule-controlled lever pressing for food which were qualitatively different from those observed in the first experiment. It was concluded that microwave

radiation at a field power density of 0.5 mW/cm^2 is below threshold for reliable, reproducible effects on rat behavior. At a power density of 2.5 mW/cm^2, exposed rats differed from sham-irradiated rats on both active avoidance and schedule-controlled lever-pressing tasks. Significant differences were also observed for sensitivity to an electric foot shock. All of the observed differences between microwave- and sham-exposed rats returned to normal values within 60 days following cessation of treatment. It was concluded that microwave radiation at a power density of 2.5 mW/cm^2 clearly results in behavioral effects.

In contrast to previous research in which reliable behavioral and physiological alterations were found for exposures at 0.5 mW/cm^2, reproducible changes were not observed in this study. However, the method of exposure in the earlier studies and in this study were different. Based on the findings in this study, the distribution of SARs within experimental subjects depends to a large extent on the method of exposure. To determine whether the SAR distribution may influence biological measures during chronic microwave exposure of rats, additional experiments comparing several methods of exposure are needed.

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***Michael I. Gage** is the EPA Project Officer (see below).*
The complete report, entitled "Behavior, Physiology, and Energy Deposition in Rats Chronically Exposed to 2450 MHz Radiation," (Order No. PB 88-171 418/AS; Cost: $19.95, subject to change) will be available only from:
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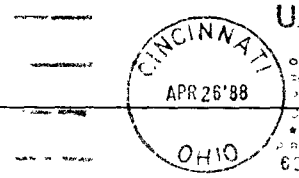

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