AD/A-003 948

A PRIMATE RESTRAINT CHAIR FOR USE IN MICROWAVE RADIATION STUDIES

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Pensacola, Florida

11 September 1974

Unclassified
Security Classification

AD/A 003948

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Aerospace Medical Research Laboratory Pensacola, Florida 32512	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP N/A
3. REPORT TITLE A Primate Restraint Chair for use in Microwave Radiation Studies.	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) N/A	
5. AUTHOR(S) (First name, middle initial, last name) Vernon R. Reno, John O. de Lorge, George D. Prettyman, Clayton S. Ezell and Toby A. Griner	
6. REPORT DATE 11 September 1974	7a. TOTAL NO. OF PAGES 15 7b. NO. OF REFS 3
8a. CONTRACT OR GRANT NO. b. PROJECT NO. BuMed MF51.524.015-0012BE7X c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NAMRL-1211 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) .2
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.	
11. SUPPLEMENTARY NOTES N/A	12. SPONSORING MILITARY ACTIVITY N/A

13. ABSTRACT

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DD FORM 1 NOV 65 1473 (PAGE 1)
S/N 0102-014-6600

Unclassified
Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Biological effects						
Microwave fields						
Restraint chair						
Primates						

DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)

Unclassified
Security Classification

1a

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MF51.524.015-0012BE7X

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SUMMARY PAGE

THE PROBLEM

The need for better understanding of the biological effects of microwaves continues to increase as generators operate at higher output powers and at an increasing number of frequencies. As the research designed to provide this understanding becomes more sophisticated the requirements for accurate dosimetry become more stringent.

One factor common to most studies of microwave bioeffects is the necessity to limit the movements of the experimental animal to a specific location during exposure. Conventional restraint devices are often constructed of materials that are highly reflective at microwave frequencies. Indiscriminate use of such apparatus may cause serious errors in exposure estimations with consequent uncertainty in the evaluation of experimental results.

FINDINGS

A restraint chair has been developed for use with subhuman primates in microwave research. The chair is essentially non-reflective, causing minimal perturbation of the field incident on the restrained animal. The basic design of the chair is adaptable to many different configurations as required.

ACKNOWLEDGMENTS

This report is part of a study on the 'Effects of microwave radiation on man" with Dietrich E. Beischer, Ph.D., as principal investigator.

INTRODUCTION

Requirements for information concerning the interaction between living systems and microwave radiation continue to increase. As research activity in this area develops dosimetry considerations become more and more significant. The complex problems associated with microwave dosimetry in biological studies and the consequent uncertainties in evaluating the results of the studies are known and have been discussed in some detail (1).

One of the problems is related to the property of microwave radiation to reflect at the interface of media of different dielectric characteristics. This property is the basis for a current approach to the problem of estimating the energy absorbed by an intact, living organism from an incident microwave field (2), however, wide variations in power density can be caused by reflections and standing waves due to dielectric material such as Plexiglas from which animal cages and restraint devices are commonly constructed (3). Field variations of this type may be highly localized and if not recognized and properly accounted for may result in gross errors in exposure estimations (2).

The most straightforward approach is to avoid the problem by elimination or substantial reduction of the reflections. The need for a non-reflective device to restrict movement became apparent during reflection studies with man and the requirement prompted the development of a restraint device from one of the foam plastics (2). The concept of a non-reflective restraint device used successfully in the studies with man was subsequently extended to the development of restraint chairs for lower primates as described in the present report.

METHOD

MATERIALS

The property of some of the foam plastics to transmit microwave energy with minimal reflection is well known. The material is frequently used for this reason in radar investigations to construct target-support columns where the purpose is to limit reflections to those from the target itself.

The selection of Styrofoam (The Dow Chemical Company, Midland, Michigan) as the primary material to be used in the construction of the chairs was based on several properties in addition to that of low microwave reflectivity. This material is a closed-cell, polystyrene foam with reasonable mechanical strength. The closed cellular structure contributes several desirable properties for the construction of animal restraint devices. Since the cells are closed the material is resistant to moisture penetration from body fluids and drinking water and is therefore easy to clean. The fact that bacteria cannot penetrate below the surface layer of cells is a significant advantage in preventing cross-infections and the spread of disease. The mechanical properties of the Styrofoam plastics vary with density--in general, the higher the density, the greater the strength. Styrofoam HD-300 was selected on the basis of both acceptable mechanical and electrical properties as demonstrated in the preliminary tests. This material is available in boards, 1, 1 1/4, 2 and 3 inches thick by 16 inches wide by 9 feet long--the thickness used depends primarily upon the mechanical strength and configuration of a chair required to hold an animal of given size. Three inch material was used in the construction of the present chairs designed for rhesus monkeys. The thinner boards can probably be used for chairs for smaller animals.

FABRICATION

Fabrication techniques are dictated by a combination of factors related both to the type of material and to its intended use. The material is a thermoplastic with a rather low heat distortion point of approximately 77°C (170°F). Conventional woodworking methods can be used for cutting and shaping if care is taken that the operations do not generate sufficient heat to melt the surface. A wide set on saw blades is helpful in clearing the kerf of foam dust quickly thereby minimizing melting and glazing. Although not specifically tested, it is probable that such a glazed surface would increase microwave reflections. It is unlikely that "hot wire" cutting procedures can be used for similar reasons. The closed-cell nature of the material makes it feasible to use either wet or dry sanding for shaping and finishing. Wet sanding has the advantage that it simultaneously minimizes the risk of dust inhalation and reduces its accumulation in the surface cells of the material.

A significant factor in the chair design was the suitability of various types of joints for use between component parts. Conventional fasteners could not be used since they are highly reflective, therefore, joints that were interlocking proved most useful.

A prototype was constructed to demonstrate the feasibility of the concept (Chair I). Three inch thick Styrofoam HD-300 was used as the basic material and joints were of the interlocking, "egg crate" type. This type of joint can open in only one direction and movement in this direction was prevented by closures of very thin nylon tape. This chair is in daily experimental use and has successfully held rhesus monkeys weighing approximately 4 kilograms (kg) for continuous periods up to 120 hours.

A more compact version of the chair (Chair II) was developed from similar material, and strength and rigidity were improved by the use of dovetailed grooves at the joints.

Joint construction is clearly shown in Figures 1 and 2. Note the neck yoke and seat piece and their associated locking pieces. The animal is introduced into the chair from the back (the side facing the viewer in Fig. 1) in a standing attitude and the neck

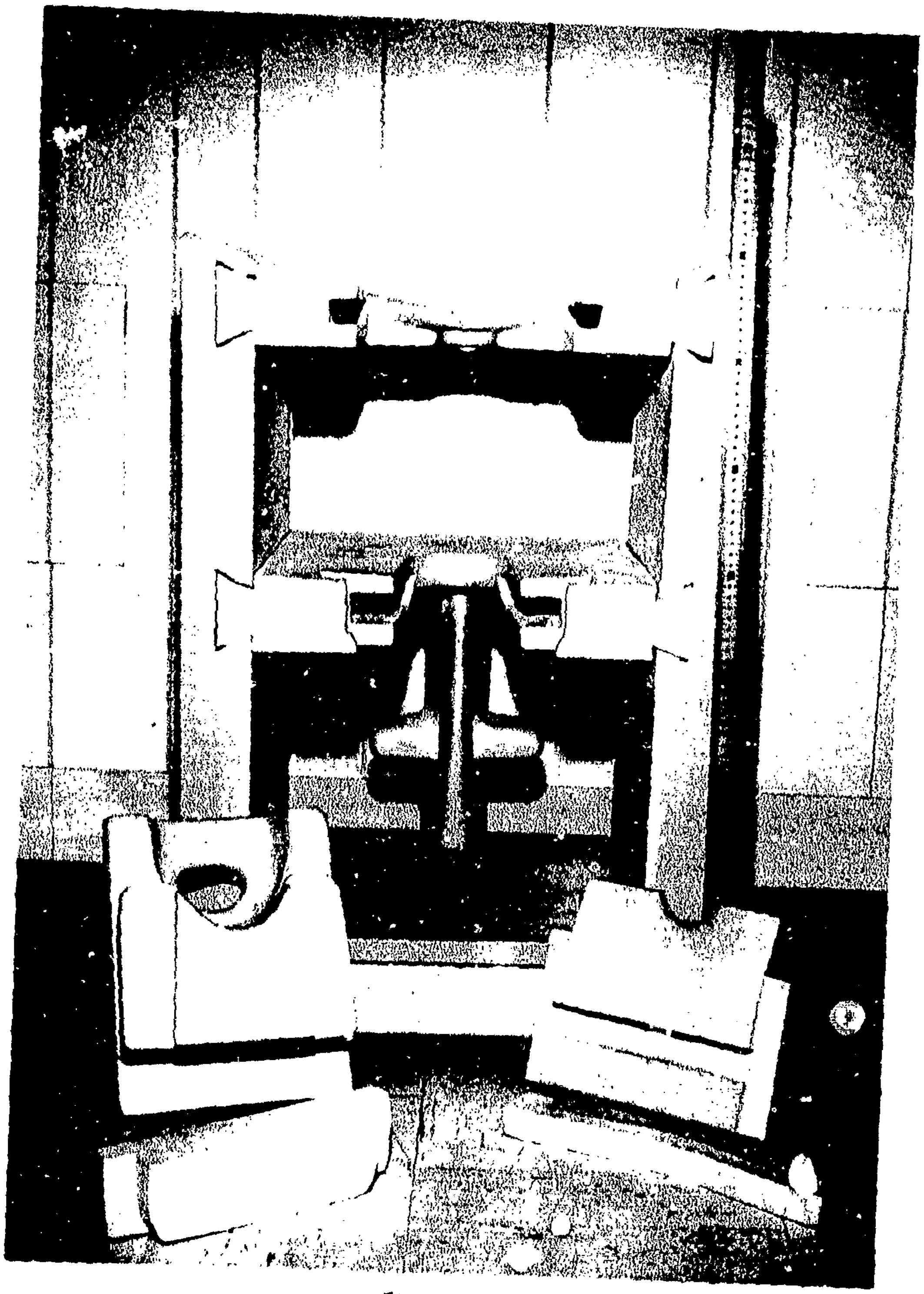

Figure 1

Back view of the restraint chair for rhesus monkeys. Chair in open position ready to receive the animal. Note neck yoke and seat and associated locking pieces.

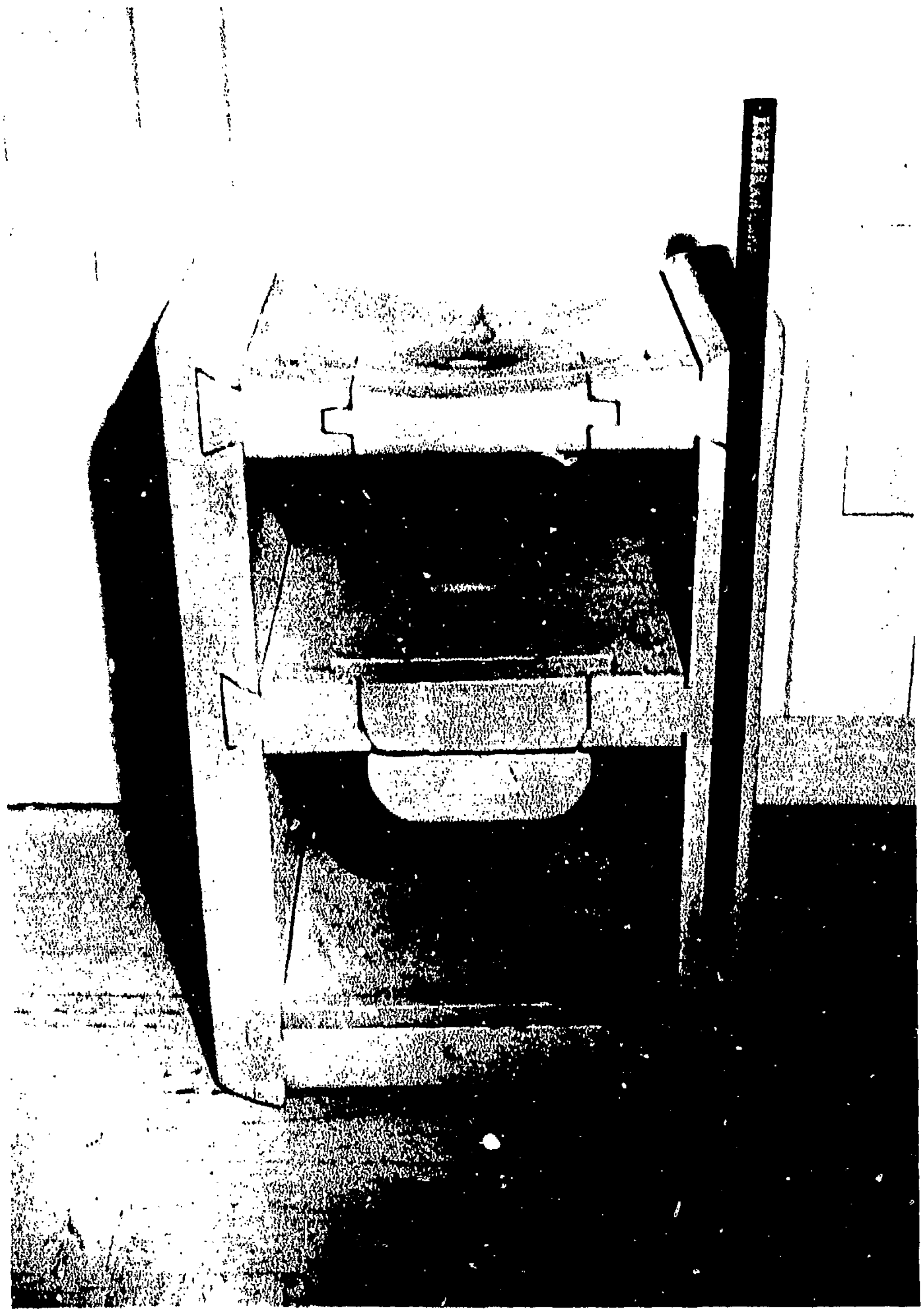

Figure 2

Back view of the chair in closed and locked position. The animal is normally in position in this configuration.

yoke inserted and locked. The seat is then inserted into the guide slots and the tail inserted through the seat opening. As the seat is advanced the animal assumes a sitting posture and the seat can be locked in position. The chair with the neck piece and seat in the closed and locked positions is shown in Figure 2.

Figure 3 shows the chair from the front with a rhesus monkey in position for experimentation. The chair can, of course, be oriented so that the animal is illuminated from any desired direction. The basic design of the chair is sufficiently versatile to permit different configurations as required for the intended use. For example, Chair I is arranged to facilitate instrumentation and I.V. catheterization while Chair II contains a 1-inch thick Styrofoam panel (not shown) in front of the animal on which various manipulanda can be mounted for behavioral research. All subsequent discussion will refer to Chair II although, in general, similar conclusions are applicable to its predecessor.

FIELD MEASUREMENTS

Extensive E-field measurements were taken to evaluate field perturbations caused by the chair. The measurements were conducted at a frequency of 2450 MHz since initial utilization of the chair will be in experimentation at that frequency. The chair was situated so that it was illuminated from the front by vertically polarized cw radiation.

One series of measurements was made by an isotropic field sensor mounted at the end of an arm supported from an overhead gantry. The sensor scanned the field on a line parallel to the incident wavefront at successive or selected locations on a horizontal plane extending in the direction of propagation. The voltage from the instrument was directed to an X-Y plotter to produce a curve indicating the field intensity. A detailed discussion of the sensor, the field-scanning apparatus and the illumination facility was previously reported (2).

RESULTS AND DISCUSSION

Field scans were made at the same spatial location with and without the chair. Six scans were made with, and six without the chair in each of three planes selected so that they would intersect the head, thorax and abdomen of a monkey contained in the chair. In one set of three measurements the sensor traveled in front of the chair (between the chair and the antenna); in the other set the sensor passed behind the chair on the same plane (with the chair between the sensor and the antenna). Comparison of each of the field plots with the chair in position with the appropriate control (without the chair) indicates the perturbations of the field due to the chair. Typical results of the measurements appear in Figures 4 and 5.

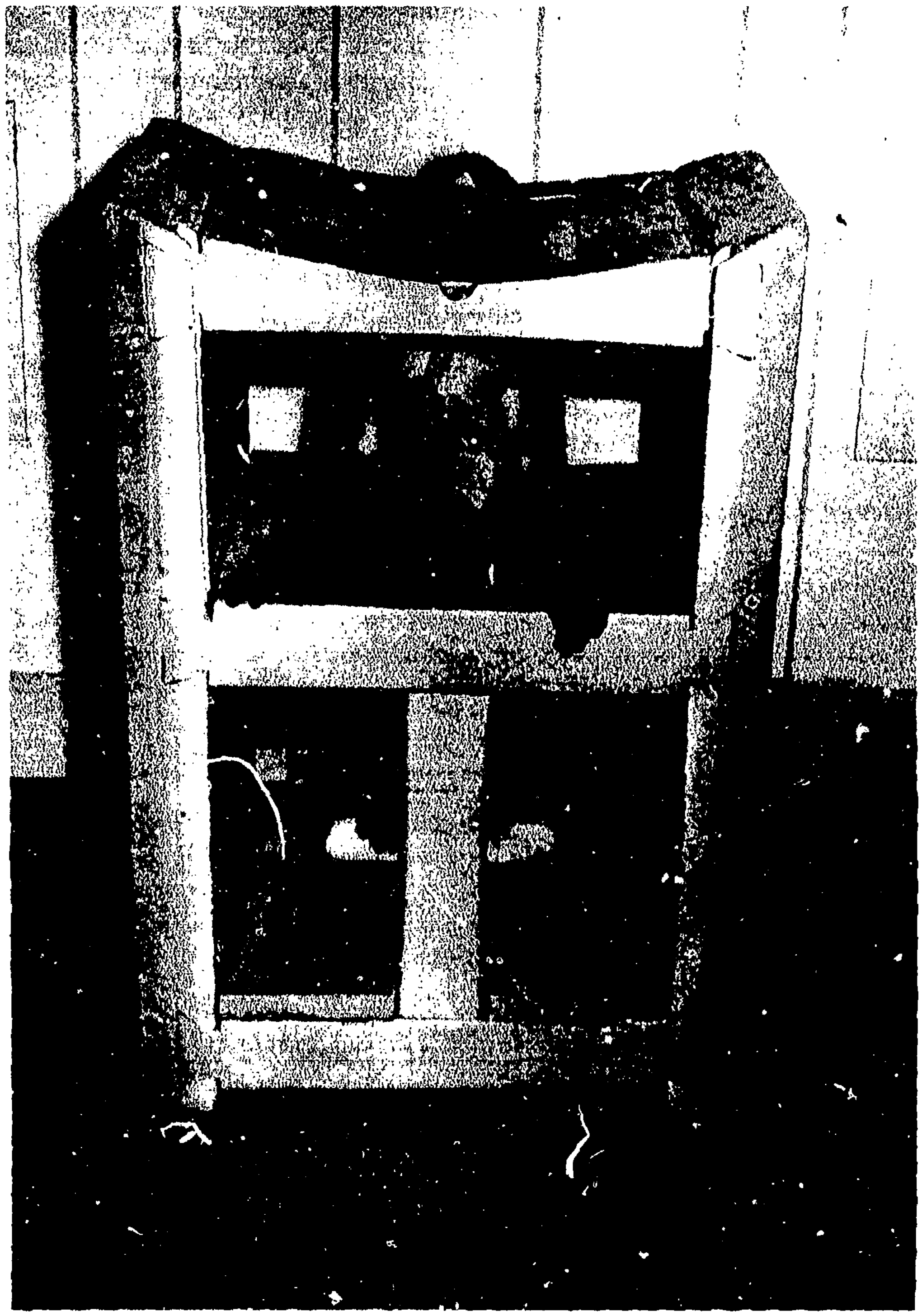

Figure 3

Front view of the chair with animal in position.

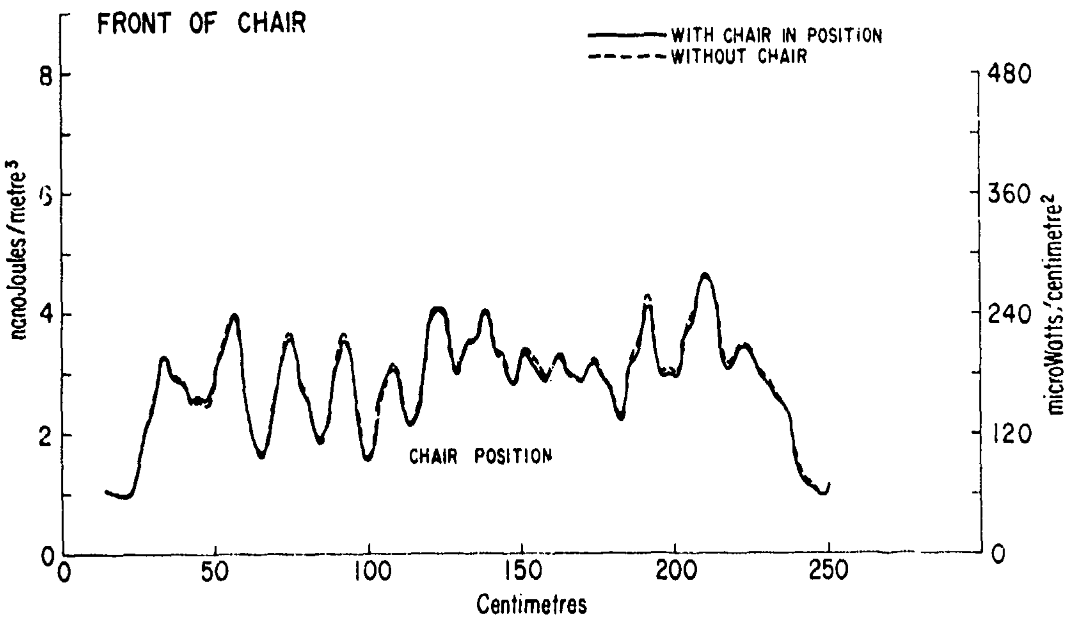

Figure 4

Microwave field on the thoracic plane. In front of the chair position.

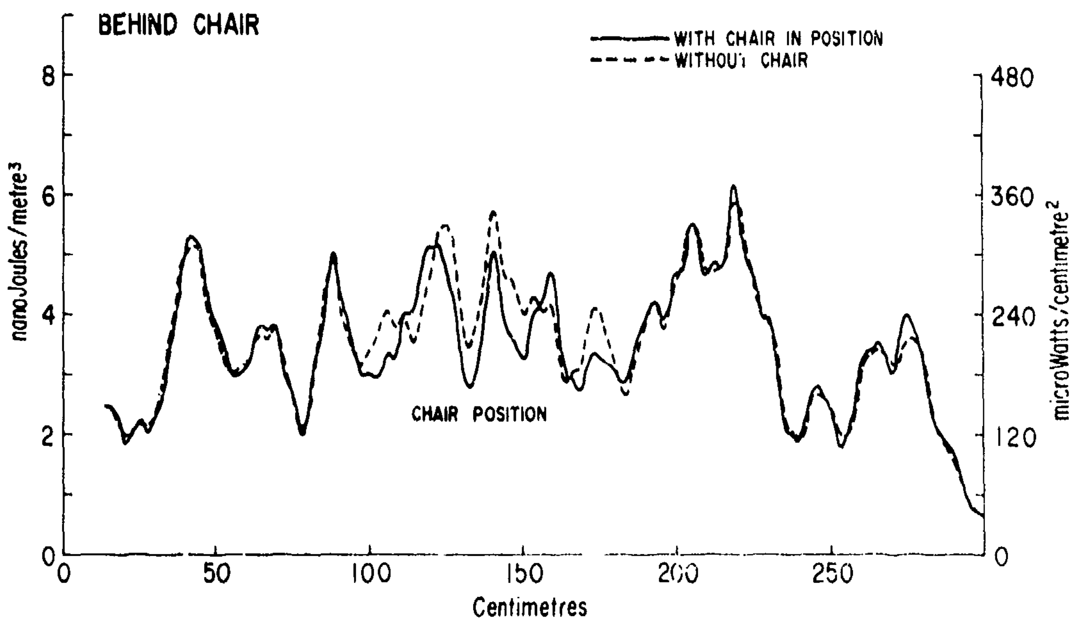

Figure 5

Microwave field on the thoracic plane. Behind the chair position.

Excellent agreement of the curves represented by Figure 4 indicate minimal reflection from the chair. It should be kept in mind that all field measurements were taken with a very sensitive, isotropic sensor, i.e., one that measures radiation incident on it from all directions simultaneously, therefore, if significant reflections were present the two curves would be dissimilar.

A dissimilarity is seen in the field scans behind the chair (Fig. 5). The difference in the curves is probably due primarily to absorption. It should be noted that the field perturbations are localized to the general area behind the chair while the remainder of the curves coincide. This is strong evidence that the effect is due to the chair rather than to some measurement artifact.

A second series of field measurements was taken on a point-by-point basis inside the chair cavity normally occupied by the animal. The cavity measurements were made on the same planes as the field scans exterior to the chair. Measurement points on the head and thoracic planes were located at the center of the cavity and two centimetres from the center at each of the cardinal points. A single measurement was taken at the center on the abdominal plane. In each case the sensor was positioned at the same point in space and a measurement taken without the chair. The results of this series of measurements are most important to the specification of the microwave field in biological studies, and are presented in Table I. There is very good agreement between the field intensities measured inside the chair cavity and those taken at the same spatial position without the chair, providing further evidence that the chair has minimal effect on the field.

Many of the current studies of the biological effects of microwave radiation are quite sophisticated in terms of the physiological or behavioral concepts involved. An attempt is usually made to demonstrate a correlation between an observed effect and some numerical value intended to be an index of the absorbed energy. It is at this point that considerable care must be taken to prevent the introduction of uncertainty into the interpretation of the studies.

The state of the art in microwave dosimetry is not sufficiently advanced to permit a direct and unequivocal measurement of the energy absorbed by an intact living animal from an incident microwave field. One of the more common indirect methods in use is the introduction of the animal into a previously measured field. The field incident on the animal is then assumed to be that measured in its absence. This assumption is valid only if certain criteria are met: (1) the animal must be the only object introduced into the field or (2) any restraint or holding device introduced with the animal must be essentially non-reflective and non-absorptive. Field measurements taken inside the holding device can minimize errors due to absorption. They cannot, however, completely account for reflections, particularly those from the animal itself. For example, measurements taken inside an empty Plexiglas cage may not be a true representation of the field incident on a contained animal since reflections from the animal to the cage wall will be re-reflected toward the animal.

Table I

E-Field Measurements With and Without the Chair

Plane of Measurement	Location of Measurement Point	Field Intensity nanoJoules/metre^3 (microWatts/centimetre^2*) With Chair		Without Chair	
Head	Center	4.8	(288)	4.3	(258)
	Front	4.6	(276)	4.6	(276)
	Back	3.9	(234)	3.9	(234)
	Right	3.7	(222)	3.7	(222)
	Left	5.1	(306)	5.2	(312)
Thorax	Center	1.8	(108)	1.7	(102)
	Front	2.1	(126)	2.1	(126)
	Back	1.8	(108)	1.9	(114)
	Right	2.2	(132)	2.1	(126)
	Left	2.5	(150)	2.5	(150)
Abdomen	Center	2.9	(174)	2.7	(162)

*Equivalent plane wave power density units.

The present report demonstrates that by careful consideration of the theoretical and practical factors involved it is possible to design animal restraint devices that eliminate many of the problems caused by microwave reflection and thereby reduce some of the uncertainties extant in the complex problems of microwave biodosimetry.

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