A MICROWAVE DOSIMETRY SYSTEM FOR MEASURING SAMPLED INTEGRAL DOSE RATE

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Abstract

An interface has been developed to allow the measurement of sampled integral dose rate, defined as the change in integral dose during a particular time interval divided by that interval, absorbed by test animals as they are exposed in a waveguide to 2450 MHz CW microwave energy.

Glossary

Integral dose $\mathcal{E}$ -- total electromagnetic energy absorbed by the test animal.

Integral dose rate $\dot{\mathcal{E}}$ -- the time rate of absorption of electromagnetic energy.

Sampled integral dose rate $\dot{\mathcal{E}}_i^*$ -- the change in electromagnetic energy absorbed during the ith time interval divided by the value of that interval.

Distributed dose D -- the electromagnetic energy absorbed by a macroscopic element of mass within the test animal divided by the value of that mass.

Introduction

A previously reported environmentally-controlled microwave waveguide irradiation facility operating at 2450 MHz allows for the measurement of integral dose absorbed by a test animal during a given irradiation period. During typical exposures with this facility, test animals are not anesthetized or restrained, but are restricted to a 10.9 cm x 11.4 cm x 5.5 cm volume in the waveguide. As a result of their freedom of movement, the integral dose rate absorbed by the animals varies with time. The purpose of this investigation is to quantify the variations in integral dose rate as a function of time.

Integral dose absorbed by the animal is given by the following equation:

$$\mathcal{E} = \int_o^T P_f dt - \left[\int_o^T P_r dt + \int_o^T P_t dt\right] \quad \text{joules} \qquad (1)$$

where $\mathcal{E}$ is the integral dose, T is the exposure time in seconds and P_f, P_r and P_t are the forward, reflected and transmitted power, respectively. An analog signal for each of these power terms is applied to a separate channel of a voltage integrator. A digital count proportional to the integral of power with respect to time is produced for each channel. Equation (1) can be converted to:

$$\mathcal{E} = S_f C_f - \left[S_r C_r + S_t C_t\right] \quad \text{joules} \qquad (2)$$

where $\mathcal{E}$ is the integral dose; S_f, S_r and S_t are scale factors for the forward, reflected and transmitted channel, respectively; and C_f, C_r and C_t are the counts in the forward, reflected, and transmitted channel, respectively.

Measurement of Sampled Integral Dose Rate

An interface has been developed which transfers the accumulated counts from the voltage integrator to a tape cassette at pre-determined intervals. One digital word consisting of two digits each for the forward channel, the reflected channel and the transmitted channel, is transferred during each sampling interval. The system allows adjustment of the sample period from 1 to 1000 seconds. After the experiment has been terminated, data stored on tape is read into CALL/OS, a time-shared computer operating system which runs on an IBM 370/155 computer. A software package was developed which calculates the sampled integral dose rate in watts as well as the integral dose in joules. The software package also allows these two quantities to be plotted as a function of time on a Tektronix Graphics Display Terminal. Experience has shown that it is practical to collect between one hundred and five hundred digital words per experiment for later analysis with the computer.

The first step in this analysis is to reconstruct the cumulative counts for each channel. The integral dose can then be calculated for each sample point collected, using equation (2). The sampled integral dose rate is given by

$$\dot{\mathcal{E}}_i^* = \frac{\mathcal{E}_i - \mathcal{E}_{i-1}}{\Delta t} \quad \text{watts} \qquad (3)$$

where $\dot{\mathcal{E}}_i^*$ is the sampled integral dose rate for the ith sampling interval; $\mathcal{E}_i$ and $\mathcal{E}_{i-1}$ are the integral doses during the ith and (i-1)th sampling interval, respectively; and Δt is the value of the sampling interval in seconds.

The interface is only capable of transferring an integer number of counts to the tape cassette. There is an uncertainty between the measured sampled integral dose rate and the actual sampled integral dose rate which can be attributed to neglecting the fractional portion of the counts when calculating the measured value. This difference can be accounted for by assuming that the actual sampled integral dose rate is within a range of values which can be represented by $\Delta\dot{\mathcal{E}}_i^*$, the percent deviation from the measured sampled integral dose rate during the ith sample interval. A worst case analysis, in which the fractional portion of the count for each channel was allowed to assume the value zero or one, was performed which supplied a technique for calculating the upper and lower values for $\Delta\dot{\mathcal{E}}_i^*$. This technique involves calculating the minimum and the maximum value for the integral dose during a particular sample interval. The computer program calculates $\Delta\dot{\mathcal{E}}_i^*$ for each sample interval and allows selection of different sample intervals for analyzing the data. As the sample interval increases, $\Delta\dot{\mathcal{E}}_i^*$ decreases. The criteria used to select the optimum sample interval, was to choose the solution using the shortest sample interval which reduces $\Delta\varepsilon_i$* to less than ±4.0%.

Results

The results obtained by exposing twelve CF1 mice to 2450 MHz CW microwave energy are presented in Table I. The sampled integral dose rate was measured for each exposure and its mean is reported in the table. An arbitrary upper threshold, T_H, was established and the percentage of values of the sampled integral dose rate which are greater than T_H are reported. Similarly, a lower threshold, T_L, was established which was used to calculate the percentage of sampled integral dose rate values which are less than T_L. Representative plots of the sampled integral dose rate as a function of time are presented in figures 1 through 3. The integral doses and the means of the sampled integral dose rate are approximately equal for these three exposures, although their sampled integral dose rates are different.

The measurement system was tested for fluctuations in sampled integral dose rate which are caused by parameters other than animal movement by exposing a dead animal. The results of this exposure are summarized in Table I for animal #12, the dead animal. The sampled integral dose rate was constant within the normal variation inherent with the measuring technique. This exposure used as a control demonstrates that the variation in sampled integral dose rate shown in figures 1 through 3, is due to animal movement.

Discussion

If the integral dose absorbed by the animal is the only factor which determines the biological effect produced by microwaves, animal movement will not affect the results of experiments in which integral dose is measured. On the other hand, if the biological effect is dependent upon integral dose rate and distributed dose, animal movement may affect the results of animal experiments. A system for measuring the sampled integral dose rate has been built and tested. Data have been collected for the irradiation of several CF1 mice and show that the sampled integral dose rate varies as a function of time due to movements of the animals. Additional work is planned to investigate the effect of animal movement on distributed dose. Both the effects of variations in integral dose rate and variations in distributed dose can be minimized by anesthetizing the animals and orienting them consistently in the waveguide.

References

(1) Ho, H.S., Ginns, E.I., and Christman, C.L., Environmentally-Controlled Waveguide Irradiation Facility, IEEE G-MTT Transaction, Symposium Issue, December 1973.

Table 1

MEASUREMENT OF SAMPLED INTEGRAL DOSE RATE

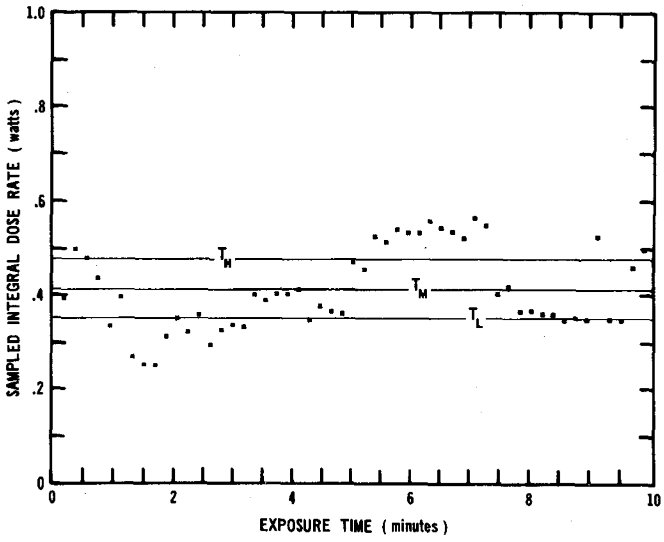
Animal Number	Weight (grams)	Integral Dose (Joules)	Mean of Sampled Integral Dose Rate (Watts)	Percentage of Observations greater than T_H* (%)	Percentage of Observations less than T_L* (%)
1	32.4	299.4	0.499	12.7	1.3
2	36.8	177.4	0.296	25.0	29.5
3	30.8	254.0	0.424	19.4	22.4
4	28.3	246.1	0.408	28.3	26.4
5	24.7	254.2	0.424	1.5	6.0
6	24.4	265.1	0.442	24.5	22.6
7	16.6	189.7	0.316	13.2	11.3
8	29.7	234.6	0.392	24.5	26.4
9	30.3	246.7	0.411	17.8	20.0
10	14.0	147.8	0.246	13.3	13.3
11	36.3	298.7	0.498	17.9	14.9
12	27.7	151.6	0.253	0.0	0.0

Exposure Conditions

Frequency	2450 MHz
Exposure Time	10 mins.
Temperature	24°C
Relative Humidity	50%
Air Flow	38 liters/min.

*T_H equals 1.15 times the mean of the sampled integral dose rate

*T_L equals 0.85 times the mean of the sampled integral dose rate

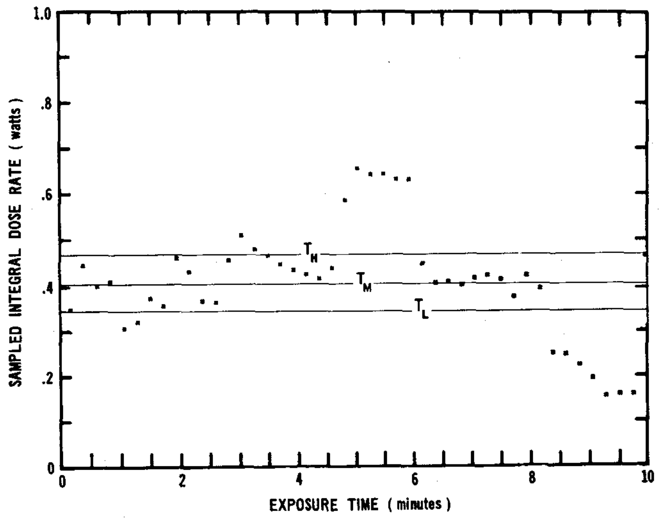


FREQUENCY 2450 MHz
INTEGRAL DOSE 246.1 Joules
TEMPERATURE 24°C
ANIMAL WEIGHT 28.3 g

T_m - MEAN OF SAMPLED INTEGRAL DOSE
T_H - 1.15 TIMES MEAN OF SAMPLED INTEGRAL DOSE RATE
T_L - 0.85 TIMES MEAN OF SAMPLED INTEGRAL DOSE RATE

Figure 1

Variation of Sampled Integral Dose Rate with Time for Animal #4

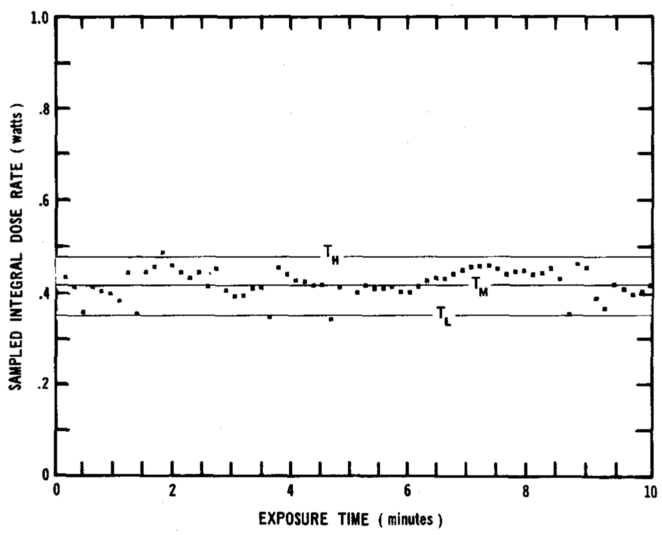


FREQUENCY 2450 MHz
INTEGRAL DOSE 246.7 Joules
TEMPERATURE 24°C
ANIMAL WEIGHT 30.3g

T_m - MEAN OF SAMPLED INTEGRAL DOSE RATE
T_H - 1.15 TIMES MEAN OF SAMPLED INTEGRAL DOSE RATE
T_L - 0.85 TIMES MEAN OF SAMPLED INTEGRAL DOSE RATE

Figure 3

Variation of Sampled Integral Dose Rate with Time for Animal #9



FREQUENCY 2450 MHz
INTEGRAL DOSE 254.2 Joules
TEMPERATURE 24°C
ANIMAL WEIGHT 24.7 g

T_m - MEAN OF SAMPLED INTEGRAL DOSE RATE
T_H - 1.15 TIMES MEAN OF SAMPLED INTEGRAL DOSE RATE
T_L - 0.85 TIMES MEAN OF SAMPLED INTEGRAL DOSE RATE

Figure 2

Variation of Sampled Integral Dose Rate with Time for Animal #5