ENVIRONMENTALLY CONTROLLED WAVEGUIDE IRRADIATION FACILITY

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Abstract

An environmentally-controlled waveguide irradiation facility has been built for the exposure of small animals to 2450 MHz, CW microwave energy. Integral dose rate is determined without significantly perturbing the microwave field interacting with the irradiated animal.

Introduction

In the past, the significance to radiation protection of experiments on biological effects of microwaves has been severely limited by the lack of quantification of the total and the distributed microwave energy absorbed by test animals. It was also found that the amount of heat stress experienced by animals depends, in part, on the environmental conditions as well as on the amount of microwave energy absorbed.

Studies using tissue equivalent models, or phantoms, have shown that for both far field[1,2,3] and near field[4,5] exposures, the amount of microwave energy absorbed by a biological body depends on the geometry, size, and complex dielectric constant. Hence for a given exposure condition, different animals could receive different doses of microwaves.

The extent of heat stress imposed upon animal systems during microwave irradiation has been evaluated by several workers.[6,7,8] Belding and Hatch,[6] and Hannes and Hatch,[7] proposed that heat loss or gain due to convection, heat gain due to infrared and visible radiation, and the subject's metabolic rate, all contribute to the actual heat load upon the subject in a microwave field. They developed a Heat Stress Index (HSI) to reflect the physiological strain resulting from exposure to microwave radiation. In an effort to quantitatively describe the physiologically stressed state of a standard man in a microwave field, Mumford[8,9] derived values for the Heat Stress Index (HSI) as a function of the Temperature-Humidity Index (THI).

The Waveguide Irradiation Facility

An environmentally-controlled waveguide irradiation facility has been built for the exposure of small animals (mice, hamsters, small rats and biological samples) to 2450 MHz microwave energy. A chamber surrounding the waveguide permits the control of temperature (between 20° and 40° ± 0.5°C), and relative humidity (between 25% and 65% ± 1.5%). This conditioned air is drawn through the waveguide at controlled flow rates up to 38 liters per minute. The total amount of microwave energy absorbed by the animal specimen (integral dose) is determined without significantly perturbing the microwave field interacting with the irradiated animal. The rate of absorption of microwave energy by the animal (integral dose rate) can also be continuously recorded throughout the experiment.

The schematic diagram of the waveguide assembly is shown in Figure 1. The generator provides up to 100 watts of CW power at 2450 MHz. The output power is fed through a four-port variable attenuator which controls the amount of power to be fed into the animal chamber. An isolator absorbs the power reflected from the animal chamber and hence isolates the generator. The waveguide unit is a WR 430 waveguide with 4.3 inches by 2.15 inches cross section. It is designed to operate at TE_{10} mode within the frequency ranges of 1.7 to 2.6 GHz. The powers fed into (P_f) and reflected from (P_r) the specimen are measured through coaxial directional coupler No. 1 by two calorimetric power meters. The power transmitted (P_t) is measured through waveguide directional coupler No. 2 by another calorimetric power meter. The apparatus terminates in a resistive load which absorbs the transmitted power. Within the test unit, the animal is contained in a thin holder made of low loss dielectric material (.02 inch thick low density polyethylene with $\epsilon_r = 2.25$ and $\tan\delta = 0.00031$). In order to facilitate experimentation with animals, the waveguide assembly is mounted on casters and the test unit is equipped with quick-release clamps.

Calorimetric testings and theoretical considerations indicate that the power loss due to the waveguide walls and the dielectric holder are negligible. The integral dose rate (time rate of microwave energy absorption) is therefore

$$\dot{\mathcal{E}} = P_f - (P_r + P_t) \qquad \text{Watts} \qquad (1)$$

where P_f is the forward power, P_r is the reflected power and P_t is the transmitted power. $\dot{\mathcal{E}}$ denotes integral dose rate.

The integral dose rate is found to vary with the movement of the test animal. This variation is caused by the changes in the reflected and transmitted power. This characteristic of the irradiation system is useful, in that the various stages of stress of the animal result in different modes of movement of the animal. By monitoring the transmitted or reflected power, the stages of stress can be qualitatively determined.

In order to determine the integral dose, analog voltage outputs from the three power meters are fed into an integrator of our design and construction which integrates each of the power readings with time.

The integral dose absorbed by the animal is

$$\mathcal{E} = \int_0^T P_f dt - \left[\int_0^T P_r dt + \int_0^T P_t dt\right] \qquad \text{joules} \qquad (2)$$

where $\mathcal{E}$ is the integral dose, T is the exposure time, and P_f, P_r, and P_t are respectively the forward, reflected and transmitted power.

The analog integrator provides analog output signals so that the forward, reflected and transmitted power can be monitored continuously on a chart recorder. Currently we are testing computer means by which the integral dose rate can be averaged over small time intervals and the informations for each time interval stored. In this way, one can get an idea of the amount of dose the animal receives during any given small interval of time within the whole irradiation period.

Conclusion

A microwave waveguide irradiation facility has been developed to irradiate small animals in such a manner that the integral dose and its time rate can be determined. However, microwave heating in tissues is often non-uniform. The spatial distribution of absorbed microwave energy in a test animal is also of importance, since hot spots could occur in vital organs under certain exposure conditions.[10,3] Several techniques such as thermographic camera and miniaturized microwave diode probes are being explored as means to determine the distributed dose in test animals exposed to microwave sources.

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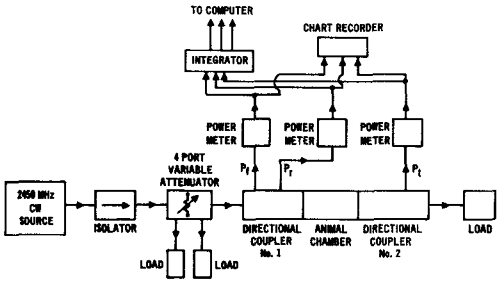

Figure 1. Schematic Diagram of Waveguide Irradiation Facility.