A MICROSTRIP MICROWAVE BIOLOGICAL EXPOSURE SYSTEM

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ABSTRACT

A compact microstrip system for exposing cells and subcellular particles to uniform precisely-measured fields at 2.45 GHz has been developed for use by experimenters performing medical research.

INTRODUCTION

The system is designed to provide a uniform precisely-measured exposure of biological cells and subcellular particles. The frequency chosen is 2.45 GHz.

Several systems have been developed for exposing suspensions of cells, and subcellular particles to microwaves.[1,2,3] Many of these systems are quite accurate in the hands of experimenters well versed in the use of microwave equipment, but they do require the use of tuners, VSWR meters, couplers, and other pieces of equipment not ordinarily found in biological laboratories. The system described here attempts to eliminate the need for complex equipment, and to include all elements in one self-contained assembly.

DESCRIPTION

Since the assembly is self-contained, the experimenter needs only a microwave power meter and a microwave power source in addition to the microstrip system itself. The biological sample is held in a cavity machined out of the microstrip dielectric material between the ground plane and the microstrip conductor. Directional couplers are built into the integrated circuit for observing the forward, reflected and transmitted power. The output of these couplers is connected by means of a three-way switch to a single Type-N output. Thus, all three directional couplers can be monitored with a single power meter and, by simple subtraction of the transmitted and reflected powers from the incident power, a determination of the power absorbed by the sample can be made. A complete system is shown in Figure 1, which is a front view, and in Figure 2, which is a rear view.

In addition to the microwave power inputs and outputs, fluid connections by way of channels in the dielectric material are provided for replacement or continuous flow of the fluid samples. Fiberoptic bundles allow light transmission and 90° scattering properties of the sample to be monitored. For this purpose, the internal surface of the cavity is lined with a black epoxy to prevent reflection and reduce possible adverse biological effects on the sample due to contamination. The corners of the cavity are rounded to facilitate flow and to prevent bubbles from attaching to the walls. An additional feature is a copper tube which has been brazed to the ground plane for the circulation of temperature-controlling fluids. An access hatch made of stainless steel coated with the fluorocarbon compound, KEL-F, and with O-ring seals for cleaning and access to the cavity completes the assembly.

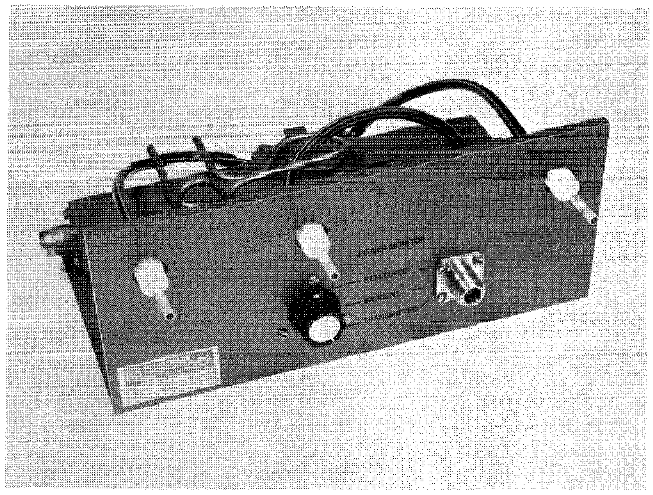

Figure 1
Front Panel

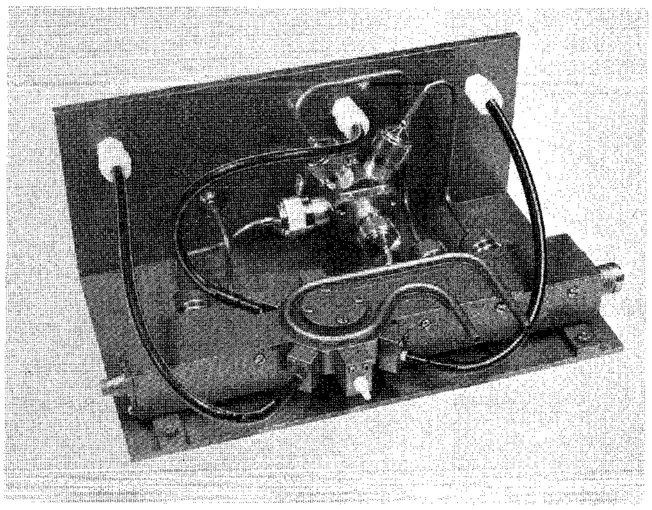

Figure 2
Assembly Details

The cavity is designed on the principle that the field in the sample will be relatively uniform if all dimensions of the sample are less than one-quarter wavelength. At 2.45 GHz, the wavelength in air is approximately 12.24cm. Since the dielectric constant of an aqueous solution is about 80, the wavelength in the sample chamber when filled with such a solution will be about 14mm. This means that in order to maintain a dimension less than one-quarter wavelength, a cavity with maximum dimensions of only 3.4mm must be used. A larger cavity is desirable. This problem can be solved by considering the boundary conditions of the interface between the microcircuit dielectric material and the aqueous sample in the cavity. Only certain solutions to the wave equation are allowed in the sample since the boundary conditions require that they fit the external fields of the microcircuit dielectric material. These allowed solutions will, in general, have space variations comparable to the longer wavelengths in the surrounding dielectric material. Therefore, the size restriction can be relaxed to one-fourth of the wavelength in the dielectric material which is about 3cm.

As a precaution, it was decided to make the cavity dimensions somewhat smaller than the maximum allowable size. They are 8mm on a side and 3mm thick. These dimensions were also about the maximum that could be accommodated using standard microstrip construction methods. The depth of 3mm provides adequate room to bring in the fiberoptics and fluid channels through the dielectric. The cavity volume is slightly less than 200 cubic millimeters which is adequate for many biochemical and biophysical test procedures. Larger volumes can be accommodated by flowing the samples through the cavity. It is estimated that the field is uniform over about ninety percent of the cavity volume.

The field lines are essentially parallel and pass through the sample perpendicular to the 8mm x 8mm faces. Figure 3 shows a cross-section of the microstrip line in the area of the test chamber. The electric field vectors from the line normally run in straight lines, except in the areas of the line close to the edge where some fringing occurs which causes field distortion. For this reason, the center conductor has been widened in the area of the transmission line and the ground plane spacing adjusted to maintain a constant impedance. This permits the sample to flow well within the straight line portion of the electrical field between the conductor and ground.

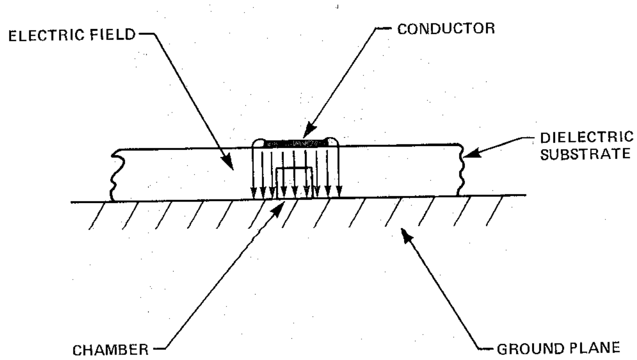

Figure 3
Microstrip Configuration

The fluid channels are brought in perpendicular to the microstrip line to avoid interference with the field pattern, as illustrated in Figure 4. The channels enter at opposite corners of the cavity to facilitate flow. The fiberoptics are brought into the flat sides of the cavity at an angle to the microstrip conductor. Since the fiberoptics have a dielectric constant similar to the microcircuit dielectric material, the field is not perturbed in this area.

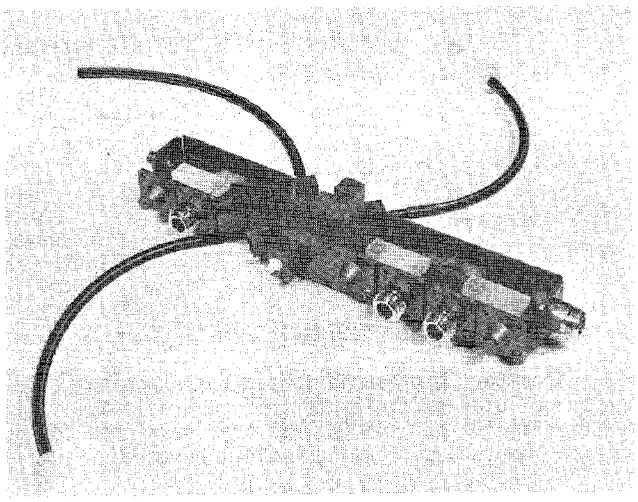

Figure 4
RF Assembly

The system is designed to be impedance matched at 50 ohms when the cavity is empty. The residual input VSWR is about 1.11 when empty. The couplers are calibrated with the cavity empty and using the assumption that little absorption occurs when this is the case. About fifteen percent of the incident power is absorbed when the cavity is filled with physiological saline solution. Although these measurements were made at a single frequency (2.45 GHz), it is clear that the system could operate over a band of frequencies approaching one octave, since the only limitation is the directional couplers which are used for monitoring purposes. Further, the system could be readily redesigned for use at any lower frequency. Use at higher frequencies is ultimately limited by the sample size required by the investigator. For very small samples, the method would work even up into the range of millimeter-waves.

We believe that this system is significantly simpler to use under ordinary conditions found in biological laboratories than many of the microwave exposure systems which have been described in the literature.

ACKNOWLEDGMENT

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