Anechoic Chamber Design for Microwave Research

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Abstract

An anechoic chamber was constructed for precise microwave exposure conditions. Construction and calibration procedures are described. Use of the chamber in several experiments demonstrated consistent operation of the generator and reproducible exposure conditions.

In recent years microwave technology has expanded rapidly and its use has become widespread in military and industrial applications and in commercial and home food preparation. The increasing potential for injury to personnel and the general public has stimulated research and discussions concerning the biological effects of microwave radiation. Much of the research reported in the literature was conducted under poor exposure conditions and lacked adequate dosimetry. This paper describes the construction and calibration of an anechoic chamber designed to give a uniform, reproducible microwave field for biological and dosimetric studies.

Microwave Generation System

The microwave power generation system is shown in Figure 1. The generator, Model HI 1200, and power control unit, Model HI-1001-X, were obtained from Holaday Industries, Hopkins, Minn. The generator produced 0.2 to 1.5 kilowatts of 2450 MHz continuous-wave micro-

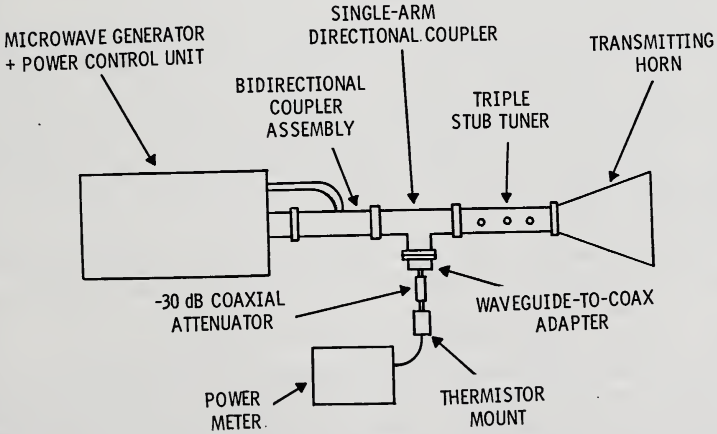

FIGURE 1. *Microwave power generation system.*

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wave radiation which was delivered to the anechoic chamber by WR-284 waveguide. A constant fraction of forward power was coupled out of the waveguide by a bidirectional coupler. This power was rectified and used by the power control unit to regulate the output of the generator.

A single arm directional coupler was used to extract a constant portion of the forward power. This power was attenuated (Model 771-30, Narda Microwave Corp., Plainview, N.Y.) before being measured by a thermistor mount (Model 478A, Hewlett, Packard, Palo Alto, Cal.) and power meter (Hewlett-Packard Model 432A). A triple stub tuner (Holaday Model HI-1004) was used to obtain maximum transfer of power from the generator to the anechoic chamber. The wave was transmitted into the chamber by a Narda Model 644 standard gain horn.

Anechoic Chamber Construction

The frame for the anechoic chamber was constructed from 2-inch x 4-inch pine stock and, except for the bottom, was lined with ¾-inch plywood. The outside of the plywood was lined with aluminum foil before it was attached to the frame to prevent leakage of microwave radiation from the interior of the anechoic chamber. The foil was lapped and then stapled with metallic staples to the plywood walls of the chamber. The inside dimensions were 10 feet x 8 feet x 7 feet. A door 6 feet x 2 feet was positioned in one of the plywood panels on a side wall immediately adjacent to the back wall of the chamber. A hole was cut for the insertion of the transmitting horn in the geometrical center of the front wall so the antenna boresight would coincide with the horizontal axis of the chamber. The horizontal axis passed through a point which was located 3.5 feet from the top and bottom and 4 feet from each side wall panel.

The frame of the chamber was designed to allow ambient air to circulate under the chamber. The bottom of the chamber was lined with ¼-inch pegboard to allow air to be drawn up into the chamber by an exhaust fan which was located outside the chamber above the back wall where most of the radiated power was dissipated as heat. Temperature analysis with thermistor beads showed that the exhaust fan maintained a range of 21°C to 25°C with the generator on nearly full power for 1 hour.

Anechoic material obtained from Eastern Microwave Corp., Winchester, Mass. was connected to the plywood panels with thermoplastic glue. The two sides, the ceiling and the floor were completely covered with -40 decibel (db) anechoic material except for a 1-foot wide border around their perimeters which was lined with -30 db anechoic material. The back wall was completely covered with -40 db anechoic material except for a 6-inch border around its perimeter which was lined with -30 db anechoic material. The front wall through which the transmitting antenna entered the chamber was completely covered with -30 db anechoic material. Three sections of 2-feet x 2-feet -40 db walk-on anechoic material were used in the floor to support polystyrene blocks which were utilized to support samples irradiated in the quiet zone. The floor blocks also supported the weight of a person.

A microswitch was connected to the door of the chamber in a manner to cause an open circuit when the door was opened. The microswitch was connected to the interlock jack in the power control unit. When the door was opened (causing an open circuit) the generator immediately ceased rf generation. The door and interlock could not be closed from inside the chamber. This system minimized the possibility that a person would be inside the chamber or be in the process of entering it while the generator was operating.

Calibration of Single-Arm Directional Coupler

To determine the directivity of the single-arm directional coupler a flap attenuator was placed in the waveguide assembly between the triple stub tuner and the transmitting horn. The single-arm directional coupler was first oriented so that it monitored the reflected power from the ideal load formed by the horn and the flap attenuator. The depth of insertion of the resistive card flap in the attenuator was adjusted to minimize the reflected power as monitored on the power meter. The three threaded stubs in the triple stub tuner were adjusted until the reflected power was at a minimum. The orientation of the coupler was then changed to monitor the forward power. Then the horn and the flap attenuator were tuned to the generator, and the condition of zero reflected power was closely approximated. The condition of zero reflected power was assumed in the determination of the directivity. The directivity was calculated to be -40.62 ± 1.45 db.

The coupling factor of the single-arm directional coupler was determined by removing the flap attenuator from the waveguide assembly and connecting the transmitting horn directly to the triple stub tuner. The positions of the three stubs in the triple stub tuner were varied until the power reflected from the transmitting horn was minimized. A Narda 8110 microwave survey meter was used to measure the power density 92 inches from the transmitting horn along its boresight. The power incident on the coupler from the generator was calculated from the measured power density, the gain of the horn, and the distance from the horn where the power density was measured. The power which was coupled out of the forward wave was calculated utilizing the known attenuation value of the -30 db coaxial attenuator and the power as indicated by the thermistor mount and power meter. The coupling factor was computed to be -31.72 ± 1.45 db.

Amplitude Modulation of Generator

A coaxial patch cord connecting the forward power diode and the forward power jack of the power control unit was separated approximately in the middle, and a BNC tee was inserted. The voltage from the BNC tee was connected to an oscilloscope by a length of coaxial cable. The waves were smooth and very slightly skewed to the right. There were no jagged deviations or other anomalies to indicate moding. The output waveform had 120 Hz modulation.

Fundamental Frequency of Generator

A pyramidal antenna identical to the irradiating antenna was connected to a section slotted WR-284 waveguide 16.25 inches long. A Hewlett-Packard 5082-2800 microwave mixer diode was positioned with a plexiglas carriage in the center of the slot and perpendicular to the long side of the waveguide. Approximately 0.5 inch of lead wire was attached to each end of the diode. The wire leads acted as a dipole antenna. The voltage developed by the diode during rectification was monitored by two small wires attached to the leads of the diode. The end of the receiving waveguide assembly was open circuited to cause the minima in the standing wave structure to be better defined. The rectified voltage from the diode was monitored on a volt-ohm meter. The plexiglas carriage containing the diode was slowly moved along the slot in the waveguide section and the positions of two adjacent minima were located. The guide wavelength was found to be 22.90 $\pm$ 0.1 cm. The free space wavelength and the frequency of the microwave power source were calculated to be 12.207 cm and 2457.67 MHz, respectively.

Anechoic Exposure Facility Calibration

A Narda survey probe with a 25-foot cord was used to determine power density and inverse square law behavior of the radiation pattern from 18 inches to 106 inches from the horn along boresight. The tips of the anechoic material on the back wall of the chamber started at 106.25 inches from the horn. The power density measurements made along boresight showed inverse square law dependence for distances of 56 to 100 inches. When the E-M survey probe came closer than a wavelength (about 5 inches) to the tips of the anechoic material on the back wall of the chamber, the radiation pattern departed from the inverse square law behavior and exhibited maxima and minima. Thus, no samples to be irradiated should be placed closer than one wavelength to the back wall.

Conclusion

Several studies were conducted using this anechoic chamber for exposure of various materials. Exposure conditions were easily reproduced and the system operated consistently. Temperature inside the chamber increased 4°C when the generator was operating at full power for extended time periods, but the microwave intensity was much higher than intensities normally used.