DIELECTRIC MEASUREMENTS FOR THE DESIGN OF A PHANTOM EYE

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Abstract

Measurements at microwave frequencies of the complex permittivity of four partitions of the rabbit eye are reported. The small quantity of some of these tissues required the design of a special sample holder and appropriate techniques for its use.

Summary

Measurements at 300 to 9000 MHz of the dielectric constant and loss tangent of four partitions of the rabbit eye were made for the selection of simulation materials for a phantom eye and are reported. The "phantom eye" is a dielectrically matched model of the rabbit eye which has been conceived as an aid in studying the dosimetry of microwave exposures leading to cataractogenesis in vivo. The limited quantity of tissue available from an eye, particularly the cornea, presented a problem in measurement. Therefore, a special coaxial sample holder was constructed with provision for measurement over this wide frequency range of physiological temperatures.

The outer conductor of the coaxial sample holder was constructed from copper tubing with an inside diameter of 0.55", to approximate the diameter of the cornea (0.5"). The first higher order mode (TE_{11}) for this line with the inner conductor dimension of 0.190" would be at 10.4 GHz; thus measurements at 9000 MHz are single mode. The sample was always at a position of one-quarter wavelength from a terminating short as various airline and dielectric filled terminating sections were made to be used at each frequency. A rexolite plug filled the space between the inner and outer conductors, supported the inner conductor and formed the upper constraint for the sample. A disc with another rexolite plug, which represented a quarter wavelength at the highest frequency, was then added, forming the floor of the sample chamber and attaching by a threaded screw which inserted into the center conductor of the main line. The sample was about 150 µm in length; its thickness was fixed by this extension of the upper center conductor which contacted the center conductor of the sample holder floor. The exact thickness of the sample space was determined by filling with distilled water to calibrate the thickness against the known dielectric constant of water. At the highest frequency, a shorting plate was attached to terminate the test section; at lower frequencies, the terminating sections replaced the shorting plate with appropriate lengths of airline or dielectric filled line to form a quarter wavelength. Fig. 1 shows the 2450 MHz configuration. A collar enclosed the entire test section and was wrapped with heating tape for elevating temperatures to 37°C, a physiologic value and 45°C, a possible value during microwave exposure.

Numerical calculations of the dielectric constant and loss tangent from measurements of the node shift and half power width were performed with a program which is a modification of one previously described.(1) Three dielectric layers are assumed but the empty sample holder impedence was used to correct for the exact position of the "thin" sample, nominally at a quarter wavelength, and with a dielectric "cover".

The rabbit eye was dissected and parts were each placed in the sample holder according to the following procedures. Aqueous and vitreous humors were extracted with syringes and the lens was scooped out with a spatula. The lens was placed on a glass slide and the outer part, the cortex, was scraped away and placed in the sample holder. Next, the firmer core, the nucleus, was placed in the holder. Sections of the cornea were cut on a freezing microtome and a hole punch was used to pierce the center of the section to allow for the center conductor to pass through the tissue. Measurements were performed at room temperature, 37°C and 45°C. Temperatures were measured with a thermocouple (iron-constantan) which was inserted into a hole drilled into the outer conductor.

Reference

(1) Westphal, W. B. and J. Iglesias. "Dielectric Spectroscopy of High Temperature Materials," AFML-TR-71-66, p. 11, April 1971.