AN RF DECOUPLED ELECTRODE FOR MEASUREMENT OF BRAIN TEMPERATURE DURING MICROWAVE EXPOSURE *

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Abstract

The thermistor probe mount involving the use of micro-circuitry, current limiting, series resistance and thermal isolation makes possible temperature measurements in the presence of continuous RF radiation to a resolution of 0.1° C.

Summary

Conventional temperature transducing probes are found to be subject to great (several degrees C) error when used in microwave environments (S-Band, 30 mw/cm^2) where cross polarization is not possible. In the past, these difficulties forced RF interruption prior to temperature measurements. This makes continuous measurements impossible, severely limits interpretation and makes many investigative objectives difficult, if not useless.[1,2]

The problem of making continuous temperature measurements during RF exposure is four fold:[3] (1) Sudden artifactual temperature rise (fast artifact) simultaneous with RF on-set, (2) Gradual excessive temperature rise with continuous exposure, (3) Conduction of heat to surrounding tissue and (4) Distortion of RF power absorption in surrounding tissue. Measurement of brain temperature in the anterior hypothalamic/pre-optic (AH/PO) area requires solution of these problems because the temperature of the central thermodectors critically determines thermoregulatory effector responses, state of arousal and pathophysiology of microwave induced injury or death. Any measurement procedure, which itself changes brain temperature, not only invalidates the temperature measurement, but also produces wide spread physiological aberration due to the internal misinformation. The techniques being reported today enable measurement of temperature to a resolution of 0.1°C in AH/PO of the brain of subject animals, chiefly rabbits, but with later extension to subhuman primates.

These problems led to the development of a microwave integrated circuit (MIC) with the following characteristics: (1) The thermistor lead "wires" consist of balanced line 5 μ wide, 2000 Å thick, and 5 μ apart. This design minimizes loop area and thereby power extraction. The effect on the fast artifact is shown in Figure 1 which compares the new microcircuit (5 and 15 μ dimensional cases) and conventional designs. The new microcircuit design showed fast artifact comparable to shielded leads in the conventional design. Residual artifact due to incident radiation on the thermistor was accountable for less than 0.1° C. The 15 μ circuitry displays a fast artifact intermediate between these cases which confirms the importance of minimizing loop coupling.

Long term RF heating of the mount, due to microwave frequency dipole current is suppressed through the action of current limiting flip chip resistors and series resistance of the MIC. The MIC is connected to an external full bridge and detector by means of high impedance, conductive monofilament. The substrate mount for the current limiting resistors and junction with the conductive monofilament are thermally isolated from the substrate supporting the thermistor and balanced microline.

Long term heating due to power absorption by whatever route was studied by IR thermography.[4,5] It was found that the mount and all its connections did not alter absorption in a 3 cm (radius) hemisphere filled with a dielectric approximating brain at 918 and 2450 MHz. Figure 2 shows the effects of thermal isolation as well as loop and dipole current suppression. Figure 2A shows the conventional (glass) mount heated in a 10.5 mw/cm^2 field for 5 seconds. The altered pattern of power absorption is evident. Figure 2B shows the effect of thermal conduction from a metallic connector heated in a 270 mw/cm^2 field for 30 seconds. Figure 2C demonstrates the same configuration with thermal isolation in 139 mw/cm^2 for 60 seconds. Figure 2C also contrasts the MIC with the conventional design. Figure 2D is a one line scan at the position of probe tip (i.e. sensor) where the empty, 3 cm, dielectric filled hemisphere was heated by 139 mw/cm^2 for 30 seconds. Figure 2E shows the same phantom with the MIC present. There are no detectable changes in power absorption at the thermistor. (Calibration: 2-1/2°C/div V, 2 cm/div H.)

In the paper detailed performance of the thermistor mount relating to each of the sources of heat will be given. The combination of microcircuitry, current limiting series resistance and thermal isolation now make possible continuous temperature measurements in subject animals in the presence of RF radiation.

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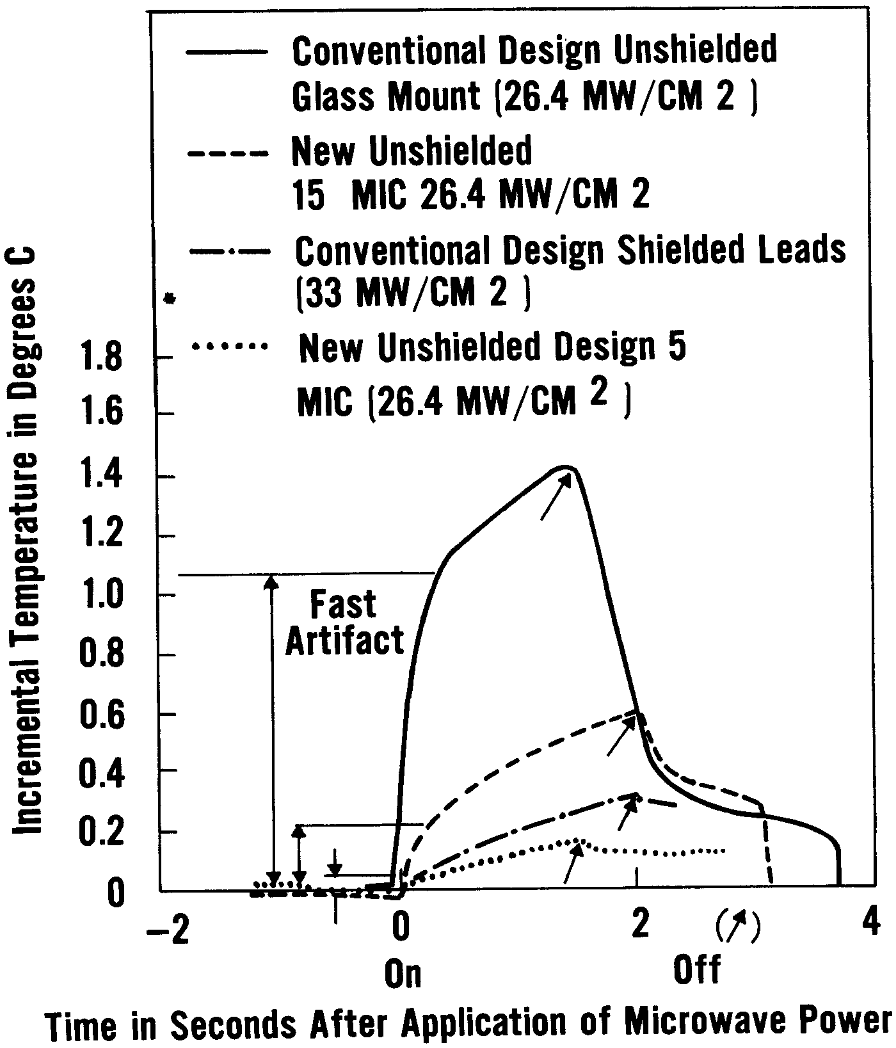

FIG. 1 TEST OF FAST ARTIFACT FOR CONVENTIONAL AND MIC TEMPERATURE PROBES IN SALINE FILLED TEST CHAMBER IN WAVEGUIDE.

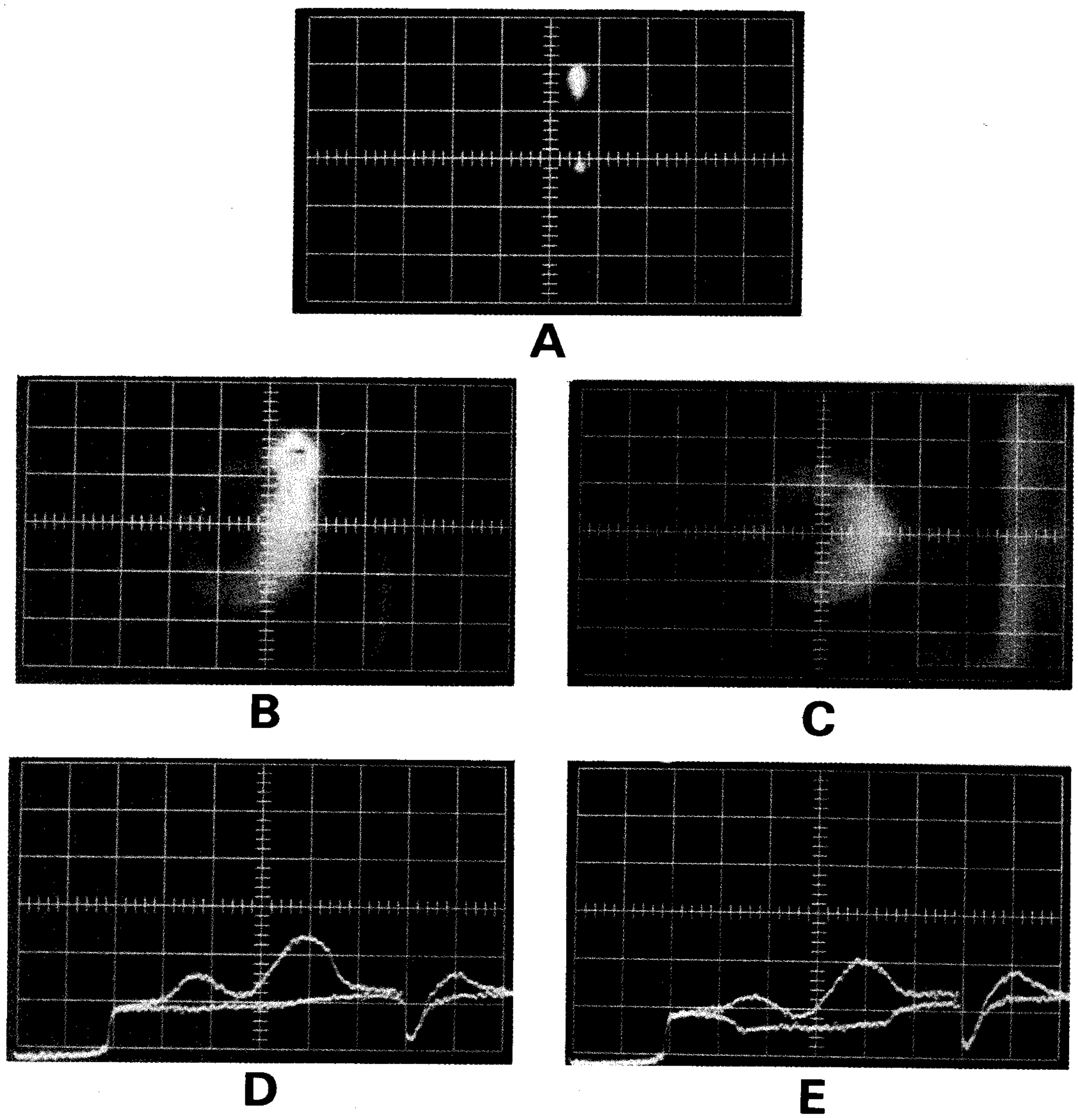

FIG. 2 THERMOGRAMS OF TEMPERATURE PROBES IN DIELECTRIC FILLED THREE CENTIMETER PLOYSTYRENE HEMISPHERE (PHANTOM). C-SCANS ARE GIVEN IN (A) CONVENTIONAL PROBE, (B) MIC WITH METALLIC CONNECTOR WITHOUT THERMAL ISOLATION AND (C) WITH THERMAL ISOLATION. B-SCANS ARE GIVEN IN (D) FOR THE EMPTY PHANTOM AT THE POSITION OF THE ELECTRODE TIP AND (E) THE PHANTOM WITH THE MIC IN PLACE.