THE DESIGN AND PERFORMANCE OF A CIRCULARLY POLARIZED DIRECT CONTACT APPLICATOR FOR MICROWAVE DIATHERMY

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Abstract

A direct contact applicator, specifically designed for microwave diathermy, is described. Its performance characteristics are a circularly polarized field pattern, a relatively uniform heating pattern and low leakage radiation.

Introduction

Since high power direct contact applicators for microwave diathermy are not presently commercially available, Transco, in accordance with Bureau of Radiological Health specifications, designed such an applicator. Three important considerations guided the design of the applicator: The structure should be as simple and as small as possible; the near field pattern should be uniform and circularly polarized; and leakage radiation during patient contact should be held at a minimum. The special design features consist of a microwave choke around the output aperture to suppress leakage and a resistive card at the back (input end) of the horn (placed 90 degrees to the input probe) to minimize mismatch while applied to human tissue.

Design

The commercially available design (figure 1) is a circularly polarized conical horn operating at the ISM band of 2.45 GHz with an outside diameter of 15.2 cm, a far field beamwidth of 55.5 degrees with a maximum input power carrying capability of 300 Watts. The final design consists of a circular waveguide fed with a coaxial probe, two sets of posts placed in the guide at 45 degrees to the input probe to generate a circularly polarized field and the previously mentioned card for matching. The output end of the guide contains a conical-flare horn section surrounded by an annular choke. By adjusting the polarizing posts and the annular choke, good circular polarization over the beamwidth with a sharp drop-off of power at $\pm$ 90 degrees from beam maximum was obtained in the far field.

Test

To evaluate the performance characteristics of the applicator, the near field at 5 mm from the aperture was mapped. Heating patterns in planar phantoms of simulated fat and muscle tissue were investigated and the impedance match and leakage radiation were measured.

The data shown in figures 2 and 3 was obtained using the near field power density mapping facility at the Bureau of Radiological Health.[1] (The power density values are actually E^2 values or "equivalent far field power density.") Figure 2 shows "isopower density contours" of the sum of the near field horizontal (x-axis) and vertical (y-axis) components which lie in a transverse plane 5 mm from the applicator aperture and parallel to the aperture. (The circular contour with the crosses indicates the position of the outside diameter of the housing.) The pattern is symmetrical with a maximum value of 15.7 mW/cm^2 per Watt of forward power in the center and a minimum of about 0.2 mW/cm^2 per Watt of forward power at its periphery. Figure 3 shows a three-dimensional plot of the total E^2 near field in the same transverse plane. Since the longitudinal component (This field component, normal to the aperture, is ineffective in terms of energy deposition in tissue.) is negligible in front of the aperture, the maximum and minimum values are essentially the values given for the transverse field. Notice in figure 3 a low-level ridge near the edge of the plot. This is due to a small longitudinal field in the vicinity of the annular choke.

Figure 4 shows data for the impedance matching characteristics of the applicator. At four locations on the back of a person and for free space radiation, the VSWR is shown to be less than 2.1 for all cases. (For a spacing of two inches between a Type B applicator and the back of a person, the VSWR is about 2.8.)

The experimental set-up for measuring heating patterns was described previously in detail.[2] Figure 5 shows the microwave heating of a planar phantom with a direct contact applicator (top sketch) and the subsequent viewing of the phantom separation midplane with a thermographic camera (bottom sketch). A typical heating pattern with the center of the aperture moved 3.8 cm from the separation midplane along the z-axis is shown in figure 6. The upper figure gives a spatial configuration of the heating pattern in the phantom midplane with a white scan line positioned parallel to the fat muscle interface in the region of maximum temperature (about 1.2 cm below the phantom surface). The corresponding "parallel" temperature profile is shown in the lower photograph of figure 6. From this profile, the width w of the heating pattern can be determined (w is defined[2] as the width of the trace for which the temperature rise is half the maximum temperature rise.). The "normal" profile is obtained by rotating a planar phantom 90 degrees counterclockwise from its horizontal position and setting the white scan line in the maximum region of heating. From this profile, the depth of penetration d can be determined (d is defined[2] as the distance between the fat-muscle interface and the depth at which the temperature decreases by 50 percent with respect to the maximum.). For the symmetrical case (the center of the applicator directly above the phantom midplane), w is equal to 7.5 cm and d is equal to 2.2 cm.[2] For the 3.81 cm case of figure 6, w is equal to 7.0 cm and d is equal to 2.0 cm. This decrease is in agreement with the shape of the near field plot of figure 3. The relatively large values of w suggest uniform heating in the center of the heating pattern.

Leakage measurements were also obtained by positioning the applicator on top of the planar phantom.[2] With a probe-applicator spacing of 5 cm and with a $\pm$ 2 dB uncertainty in the measurements, the maximum leakage with direct contact loading is 0.8 mW/cm^2 per 100 Watts of forward power. A maximum leakage of 4 mW/cm^2 per 100 Watts of forward power was measured with a dielectric shim of 1 cm between the applicator and the phantom.

Conclusion

In summary, the Transco circularly polarized direct contact applicator, designed specifically for microwave diathermy -- and a viable candidate for hyperthermia application -- provides for a relatively uniform heating pattern with low leakage radiation. The design can be modified to operate at a lower frequency, such as 915 MHz, in approximately the same size package.

References

1. G. Kantor, H.I. Bassen, and M.L. Swicord, "Mapping of Free Space and Scattered Fields in Microwave Diathermy," Biological Effects of Electromagnetic Waves -- Selected Papers of the USNC/URSI Annual Meeting, Boulder, Colorado, October 20-23, 1975, vol. II, December 1976, DHEW Publication (FDA) 77-8011.

2. G. Kantor and T.C. Cetas, "A Comparative Heating Pattern Study of Direct Contact Applicators in Microwave Diathermy," URSI meeting, Fall 1976.

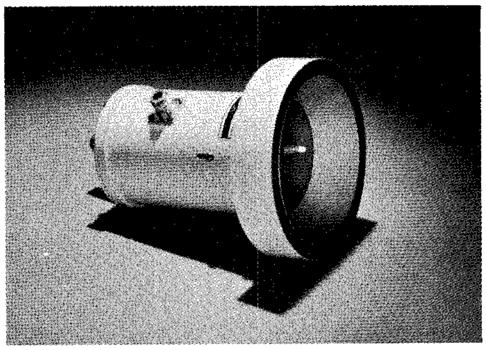

Fig. 1-Direct contact microwave diathermy applicator

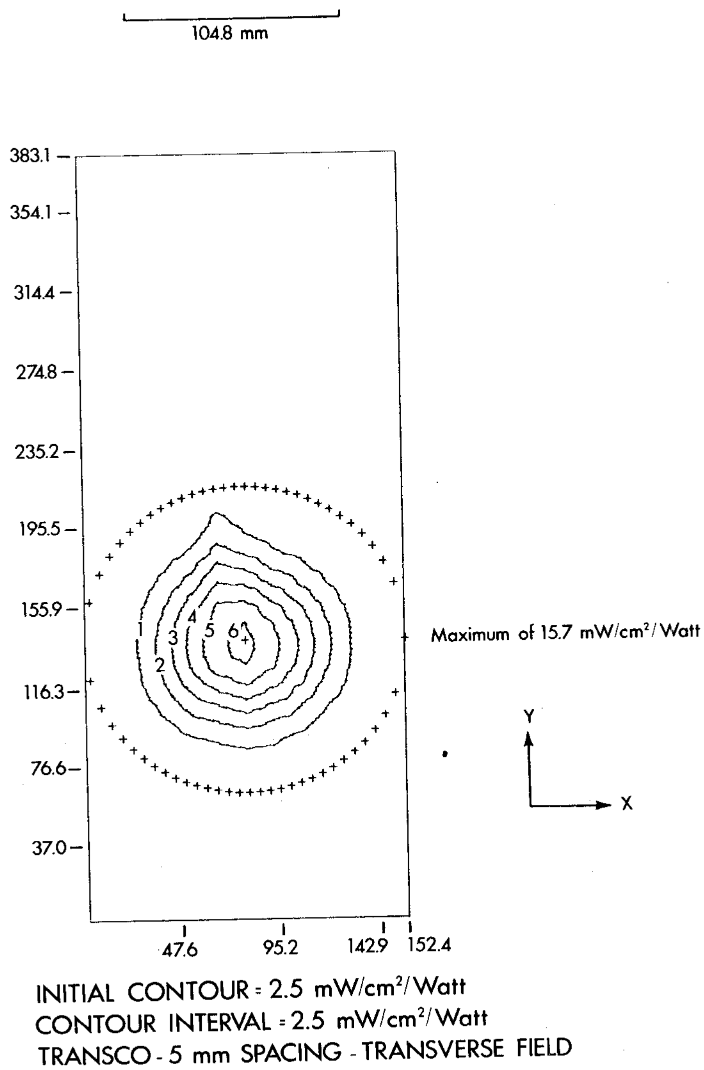

Fig. 2-Isopower density contours in transverse plane

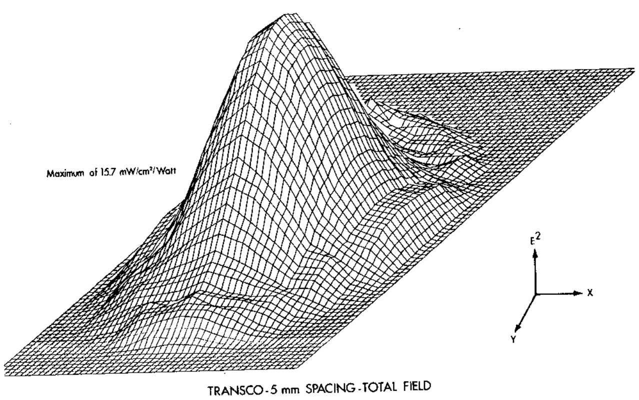

Fig. 3-Three-dimensional plot of total field

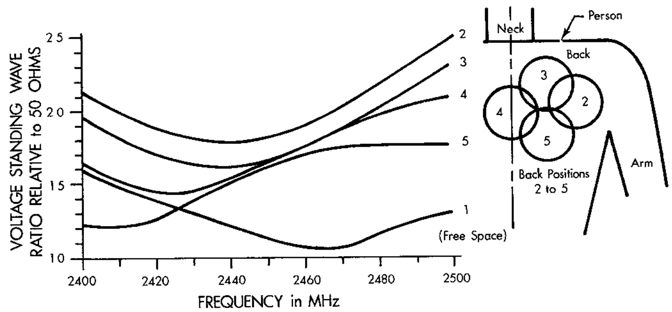

Fig.4-Free space and loaded matching characteristics

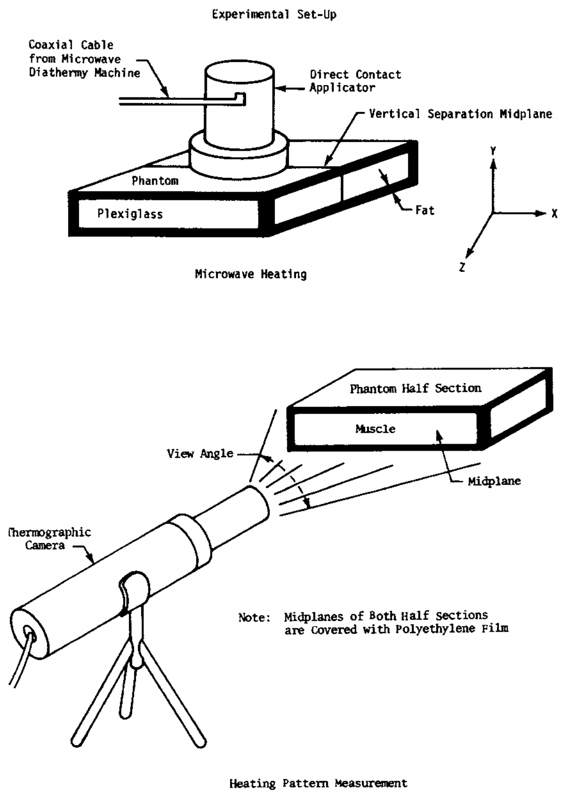

Fig. 5-Microwave-thermographic experimental set-up

TRANSCO DIRECT CONTACT APPLICATOR
(Heating Pattern 3.81 cm from Center of Aperture)

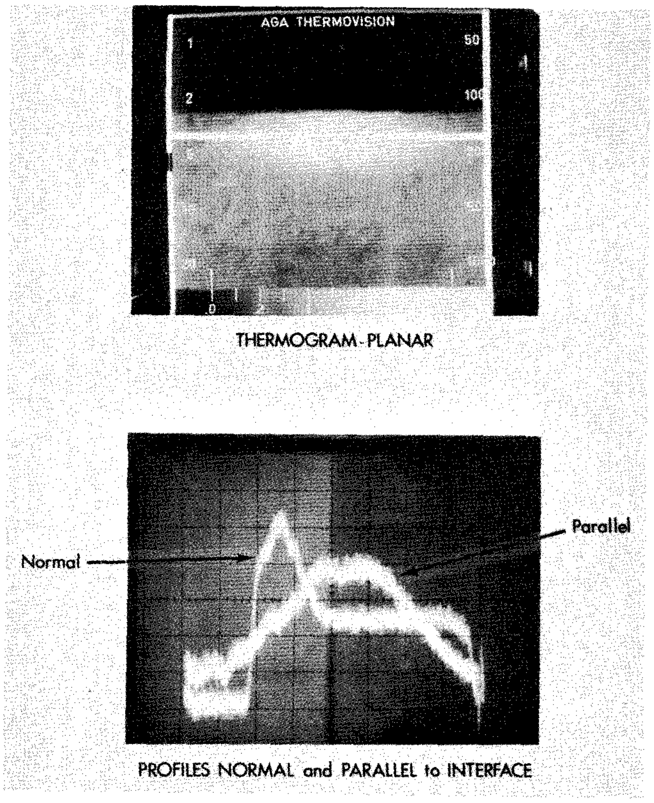

Fig. 6-Heating pattern with temperature profiles normal and parallel to fat-muscle interface