MICROSTRIP SPIRAL ANTENNA FOR LOCAL HYPERTHERMIA*

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ABSTRACT

Several microstrip spiral antenna applicators suitable for local hyperthermia treatment operating at 433 and 915 MHz have been developed. Design and experimental results are compared with other types of applicators. A summary of current clinical experience with these applicators is presented.

INTRODUCTION

Microstrip antennas have been increasingly popular for communication and radar systems since early 1970. They are small, light-weight, low-cost, flexible and easy to fabricate. Also, conformal arrays of antennas can be built on one substrate and combined with the remainder of the MIC (Microwave Integrated Circuit). Yet very few microstrip antennas are used for medical applications. The advantages of microstrip antennas are directly applicable to the building of applicators for local hyperthermia, which requires uniform heating over large areas (larger than 5 cm in diameter), especially those areas with appreciable curvature.

In this paper, we describe the performance of direct-contact microstrip antenna applicators designed for production of local hyperthermia. Also, comparative test results with a typical waveguide applicator are presented.

DESIGN AND EXPERIMENT

In order to obtain the optimum microstrip antenna structure, we investigated many different types of microstrip antennas such as the patch antenna, the slot antenna, the multiple radial arm antenna, the ring antenna, and the spiral antenna. All antennas were fabricated on hexagonally shaped substrates of .062 inch RT Duroid (dielectric constant 2.35), with .0014-inch thick copper conductor. This construction permits assembling many elements into a single applicator, if necessary. The low-power and high-power heating experiments were carried out with a 1-cm water pad over a Guy muscle phantom model with or without a 1-cm surface fat layer.

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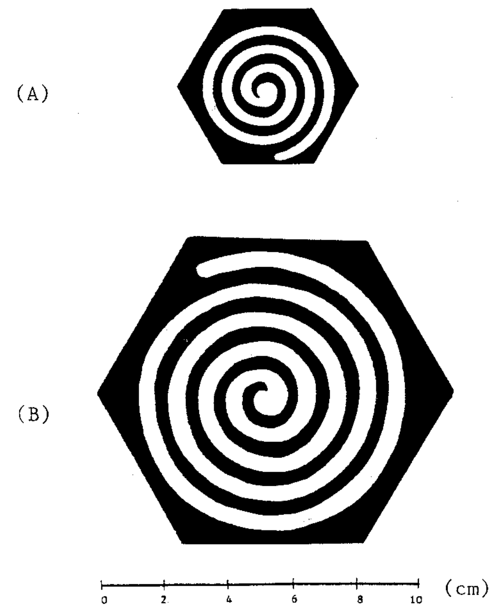

Fig. 1 Microstrip spiral antennas designed to operate at (A) 915 MHz and (B) 433 MHz.

Of the types of antennas we tried, the spiral design best demonstrated a combination of broad bandwidth in the desired frequency range, and good coupling to tissue through the cooling water. Moreover, the spiral microstrip antenna exhibits a circularly polarized radiation pattern. These features are particularly important for uniform power deposition in tissues over large areas, using multi-element microstrip antenna arrays.

Fig. 1 shows two spiral microstrip antenna designs, with spiral conductor outer diameters of 3.5 cm and 8.5 cm. They are designed to operate at frequencies of about 915 MHz and 433 MHz, respectively. The antennas are fed at the center of the spiral with coaxial cables. Fig. 2 shows the variation of return loss with frequency for (A) the 433 MHz spiral antenna and (B) a commercially available ridged waveguide antenna. Bandwidth with return loss greater than 10 dB (VSWR less than 1.9) for the spiral antenna is 200 MHz.

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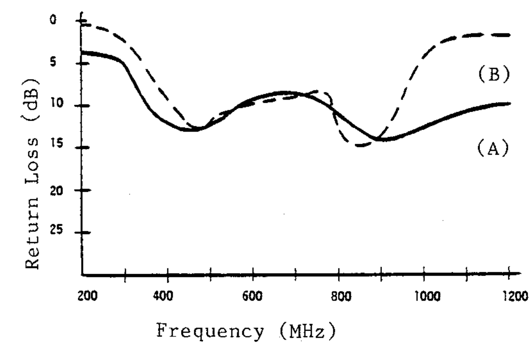

Fig. 2 Variation of return loss with frequency for (A) the 433 MHz spiral antenna and (B) a commercially available ridged waveguide antenna.

A split-phantom technique, using a thermographic camera to record the temperature distribution, was employed to measure the heating patterns.

Fig. 3 shows a comparison of relative SAR at 2 cm depth in muscle phantom tissue with a 1 cm fat layer, for the 433 MHz spiral microstrip antenna and for a commercially available ridged waveguide applicator.

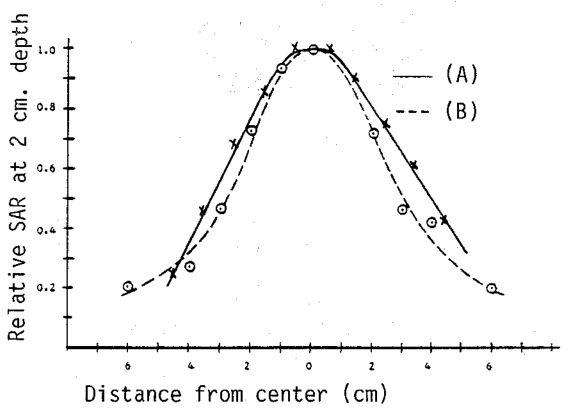

Fig. 3 Comparison of SAR for (A) the 433 MHz spiral antenna and (B) a commercially available ridged waveguide antenna.

CLINICAL TRIAL

To date, 14 patients having superficial tumor nodules have been treated with spiral microstrip applicators (a total of 100 treatment sessions). The majority of cases have been single nodules treated with the 8.5 cm diameter spiral operating in the 433 MHz frequency range, as shown in Fig. 4. Smaller nodules have been treated with the 3.5 cm diameter 915 MHz spiral antenna. These smaller radiators have also been used in arrays containing 3 or more elements to heat larger tissue regions. In the treatment setup, these applicators are efficiently coupled to tissue (VSWR 1.4 - 1.8) through a deionized water interface in the form of a flexible membrane enclosure. The water is thermostatically regulated and circulated to control skin temperature. Temperature profiles have been measured in tissue during treatments using non-perturbing high-resistivity thermistor probes (Bowman probes). These profiles compare favorably with those obtained using the more conventional waveguide applicators. The spiral microstrip applicators also have better coupling efficiency and, because of their physical size, are much easier to handle in clinical practice.

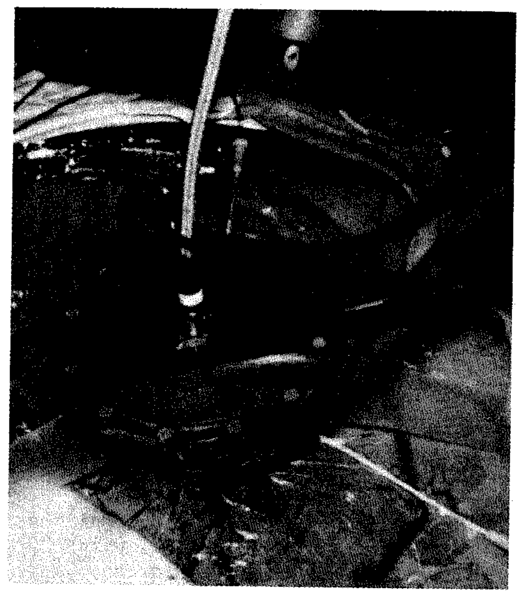

Fig. 4 Clinical trial of 433 MHz spiral antenna.

CONCLUSION

The experimental results of microstrip spiral applicators operating at 433 and 915 MHz are presented. They exhibit the following advantages over conventional microwave applicators such as the waveguide or horn antenna types:

1. Small, light-weight, low-cost, flexible and easy to fabricate.

2. Can be assembled in arrays of multiple elements.

3. Good RF power coupling over a wide frequency bandwidth.

4. Less RF leakage, which reduces undesired exposure to the patient and the operator.

5. Minimum edge effect (less pain for patient).

6. Better for clinical implementation, e.g. consistent positioning, easier placement at curved anatomical sites (i.e. neck, head and arm), no requirement for bulky applicator support.