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Letter to the Editors

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The invited paper 'Noninvasive microwave phased arrays for local hyperthermia: a review', by R. L. Magin and A. F. Peterson, which recently appeared in your journal (Magin and Peterson 1989), was in many respects an excellent treatment of the state of the art of surface microwave hyperthermia. Unfortunately the article gave the impression that microstrip microwave surface applicators are significantly inferior to more conventional microwave waveguide applicators, and the reader comes away with a point of view that would discourage the investigation and use of microstrip antenna applicators for surface hyperthermia. For the past 5 years at Stanford we have been using microstrip applicators routinely in the clinic for the hyperthermia treatment of superficial tumours. As early as 1984 (Tanabe *et al.* 1984), we documented that such applicators were used clinically and had a number of clear advantages. With proper choice of the particular microstrip antenna (Tanabe *et al.* 1983), a variety of applicators tailored to the particular clinical need can and have been developed. These include small single-element stationary devices as well as scanned single- and dual-element applicators and stationary arrays containing a large number of individual antennas. These developments are made possible because of the lightweight compact nature of the antennas, which have power deposition properties very similar to much larger and much more bulky waveguide antennas. Two publications dealing with these applicators (Fessenden *et al.* 1988, Kapp *et al.* 1988) appeared in the literature before the Magin and Peterson review was accepted in October 1988.

The review article implies that the near-field problem with microstrip antennas is significantly more severe than that with waveguide (including horn) applicators and, therefore, microstrip applicators should be discouraged for use in the clinic. As discussed by Tanabe *et al.* (1983), the type, design and fabrication of the particular microstrip antenna is very important. The Archimedian spiral antenna was determined to be particularly suitable for development of clinical applicators because of its efficiency and large band width. Use of it with a bolus at least 1–1·5 cm thick eliminates the near-field problem. If distilled water is used in the bolus the energy lost in this intervening bolus is not a problem.

Much attention is paid, in the review article, to the ability for groups of antennas to be operated coherently such that there is a focusing effect increasing the relative power deposition at depth. This is certainly true, but care must be exercised so that this feature is not overstated. Some gain in penetration is realized, but the gain is not as great as that achieved with focused ultrasound, where there is a greater energy deposition at depth than near the surface. As shown by the authors' own work (figure 9B) the result of focusing to 6 cm depth still causes a 6 dB loss. In other words, only 25% of the power deposition that is realized near the surface is achieved at a depth of 6 cm. It should also be pointed out that when scanning of the focus is utilized to spread out the pattern at depth, you do not gain something for nothing. The effect of focusing is diminished directly in proportion to the increase in the area scanned at depth. As the scanning takes place to spread out the area of coverage at depth, the surface power deposition rate remains constant, but each point at depth has the focused spot depositing power for a shorter time increment, thereby decreasing the effective gain factor.

There was little discussion in the review of using arrays of antennas that are operated incoherently. This approach, in fact, in many situations could be the method of choice

because of the difficulty with coherent operation of controlling to advantage the phase relations in all lateral directions simultaneously. In the controlled situation on the laboratory bench, phase and amplitude relations may be such that relative uniformity of power deposition at certain depths can be achieved. In the clinic, differences among different antenna couplings, tissue inhomogeneities, etc., can disturb these phase and amplitude relations, resulting in unacceptable hot and cold spots. At 915 MHz, in muscle tissue, a 1 cm antenna–tissue displacement error, such as might be caused by breathing or muscle flexing, translates to a relative phase error of about 75 degrees. The alternative of using incoherent operation with the proper geometry with respect to spacing and antenna to tissue distance, can be much more forgiving and, in fact, results overall in more uniformity of power deposition where it is desired.

In summary, we remind the authors of some of the advantages associated with microstrip microwave antennas that give them much promise for incorporating into versatile applicators for use in the clinic. Well over 1000 clinical treatments have been delivered at Stanford with applicators based on spiral microstrip technology. Much of this information had been presented in the literature and at national meetings prior to the time when the review article by Magin and Peterson was accepted for publication.

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