Letters

Comments on "EM Local Heating with HF Electric Fields"

MARK J. HAGMANN, MEMBER, IEEE

The above paper[1] recently described a synthesis procedure that is intended for use in designing multisection capacitor-plate applicators for treatment by hyperthermia. The distribution of potentials on the subelectrodes is determined in order to obtain a specified pattern of energy deposition. While the derivation in that paper appears to be sound, considerable care must be used if the procedure is to be applied for the design of a practical applicator for use in patient treatment.

The synthesis procedure is derived using the method of moments [1] with a pulse-function basis and point matching. It is necessary to consider the limitations inherent in this choice of basis and testing. For example, it is essential that all variables represented by pulse-functions have little variation between adjacent subvolumes. This requirement is severely violated by both the desired SAR distribution specified in their Fig. 7 and the calculated potential distribution shown in their Fig. 8. It is surprising that the authors did not realize the significance of the instability in their solution when the calculated potentials were as high as 480 MV with a phase difference of approximately 180 degrees between adjacent subelectrodes. This is reminiscent of the instability in the coefficients obtained when one attempts to force a polynomial of high degree through a set of points. The calculated values of potential are likely to be highly sensitive to approximations made in evaluating the matrix elements. There is an additional limitation due to point matching in that even when a solution is compatible with a pulse-function basis the local energy deposition may oscillate from the specified values at locations between the centers of the subvolumes. The experiments described do not support the synthesis procedure since they are only tests of forward solutions. The good agreement of theory with the data in the two experiments is undoubtedly dependent on the fact that the specified potential distributions and the calculated values of electric field are all slowly varying functions for which the pulse-function basis is appropriate.

In unpublished work done in 1977, I developed a similar synthesis procedure for use in two-dimensional problems. The required distribution of currents in a sheath of parallel wires was determined such that a specified pattern of deposition was obtained within a cylindrical target. Some problems encountered were similar to those described by Hessary and Chen. For example, the calculated currents had unrealistically high magnitudes and tended to be approximately opposite in sense for adjacent wires. The magnitudes of the currents were found to increase sharply as the number of wires in the sheath was increased. Subsequently, a synthesis procedure was developed for optimization of the regional deposition in a block model of man by varying only the currents and locations for a small number of dipoles. The latter procedure was found to have stable solutions with practical values for all parameters and may be considered for use in hyperthermia [2].

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[1] M. Hessary and K-M. Chen, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-32, pp. 569–576, June 1984.

Reply[2] *by Kun-Mu Chen*[3]

Some explanations are in order to answer Dr. Hagmann's comments on our paper.

The major portion of our paper was devoted to the development of a theoretical method for analyzing the induced EM field in a biological body placed between a pair of capacitor-plate electrodes. Only a section of the paper dealt with the synthesis of the capacitor-plate array applicator. The purpose of this section was to demonstrate, theoretically, a possibility of synthesizing a potential distribution on the array to produce a desired heating pattern inside the biological body. Our result showed an unstable potential distribution (very high amplitudes and phase reversal between array elements) for the array. This instability was clearly pointed out in our paper and this phenomenon was compared with that of the super gain antenna array. We have performed a numerical test by calculating the distribution of an induced EM field within a single cell with a synthesized array potential distribution. This numerical test indicated a fair accuracy of the theoretical results. Nevertheless, we cautioned that if more accurate results are needed the body needs to be subdivided into a larger number of cells and a larger computer is needed for calculation. We also commented in the conclusion that the required potential distribution for a highly localized heating pattern may become quite unrealistic and unstable for the practical implementation. Besides those explanations, perhaps, we should not rule out a remote possibility that the unstable potential distribution was entirely due to numerical instability.

Our experiment was designed to check the accuracy of the analytical method developed for the capacitor-plate applicator. This is obvious from the geometry of our experimental model. There was no attempt made to experimentally check the accuracy of theoretical results on the capacitor-plate array applicator. We would like to add that the problems concerning the numerical solution of an EFIF using the method of moments, as pointed out by Dr. Hagmann, are well known among EM researchers, including the authors.

REFERENCES

[1] R. F. Harrington, *Field Computation by Moment Methods*. New York: Macmillan, 1968.

[2] P. F. Wahid, M. J. Hagmann, and O. P. Gandhi, "Multidipole applicators for regional and whole-body hyperthermia," *Proc. IEEE*, vol. 70, pp. 311–313, Mar. 1982.

[2] Manuscript received August 20, 1984.

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