BASIC STUDY ON COAXIAL-SLOT ANTENNA FOR INTERSTITIAL MICROWAVE HYPERTHERMIA

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1. Introduction

Hyperthermia is one of the promising treatments of cancer[1]. If tumors are heated more than 43 ℃ while normal tissues are kept less than 45 ℃, the tumors may be selectively killed. This technique is especially powerful when it is performed in combination with radiation therapy. We have been studying an applicator for interstitial microwave hyperthermia that is effective for large-volumed and deep-seated tumors[2],[3].

As an ideal applicator for interstitial microwave hyperthermia, the antenna should (a)be thin enough, (b)have wide and flat heating region along the antenna, (c)have sufficient tip heating, and (d)have high efficiency. We considered that the condition (a) was already achieved[2].

Heating measurements using agar phantoms and experiments with animals[3] have estimated that the applicator antenna developed in our laboratory is of practical use. In the present paper, we will report the availability of evaluating heating regions around the antenna by means of the SAR distributions measurement. We will describe how to put it into practice.

2. Method and results of the SAR distribution measurement

Fig.1 illustrates the configuration of a coaxial-slot antenna applicator[2]. Several ring slots are placed with equal spacing of 5mm along the outside conductor of a thin coaxial semirigid cable. So, the number of the ring slots is multiplied by 5mm, and the product is the antenna length, L_A. The antenna is inserted into a catheter in use.

An SAR(Specific Absorption Rate) is the absorbed power per unit mass of a medium radiated by electromagnetic fields, and given by

$$SAR=\frac{\sigma}{2\zeta}\{|Ez|^2+|E\rho|^2\} \quad [W/kg]$$

where ζ is the density(kg/m^3) and σ is the conductivity(S/m) of the medium. The SAR distributions are equivalent to those of heat generation. They are important to evaluate such an applicator for hyperthermia.

Electric fields produced by the antenna are composed of ρ (perpendicular to the antenna) and z(parallel)-components. Each component was measured by the following method. In fig.2, a water tank was filled with 0.4% saline solution regarded as a liquid phantom of equivalent muscle. SAR distributions around the antenna inserted in the solution were measured. The operating frequency was 430MHz.

In the experiments, we adopted a small monopole and dipole antennas(Fig.3) as probes to measure perpendicular($E\rho$) and parallel(Ez) components of electric fields, respectively. Compensation coefficient that is shown in Table 1 was obtained by measuring sensitivities of the two probes using a standard antenna in advance.

Figs.4 ~ 6 show measured results of the SAR distributions for the antenna length, L_A of 40mm, the depth from the surface, D_s of 30mm. Fig.4 and Fig.5 show squared magnitude of each electric field components. Fig.6 is the SAR distribution composed of the two distributions taking into account the above-mentioned coefficient. Here, 'iso' means normalization that the maximum value of measured data is 100%. This normalization was done in Figs.4 and 5, too. (Hence '100%' on each figures of iso-SAR distributions do not express the same SAR value. For reference, the ratio of the maximum value on Fig.5 to it on Fig.4, $|E\rho|_{max}^2/|Ez|_{max}^2 = 2.3$.)

Fig.7 is a photo of heat generation taken with an infrared camera at an agar phantom experiment under the same condition as Fig.6. A practical heat generation at Fig.7 agreed roughly with the SAR distribution at Fig.6. We have confirmed that for evaluation of a hyperthermia applicator, SAR distribution measurement is useful instead of heating experiments using an agar phantom. The former is easier to carry out than the latter.

Figs.8 and 9 show the measured SAR distributions when L_A was kept 40mm, and D_S was changed to 10 and 50mm. Figs.10 and 11 show when D_S was kept 30mm, L_A was changed to 20 and 60mm. Generally, to lengthen L_A caused proportionally enlargement of heating extent, and to lengthen D_S made smaller a hot spot(unnecessary heating region) generated close to the boundary surface[4]. In addition, heating regions around the tip of the antenna expanded beyond the tip in every case.

3.Improvement of heating region

For a large-volumed tumor, only a single antenna can not heat sufficiently. An array composed of multiple antennas can cope with it. Besides, the heating pattern can be controlled by adjusting its array arrangement, excitation amplitudes and phases[5]. This technique is expected to be able to adjust heating pattern to various form of tumors, and has been studied by use of computer simulation in our laboratory. In Fig.12, four antennas as an array were inserted into an agar phantom.

An absorbent cotton block placed on the point of insertion was containing physiological salt solution(0.4%), and considered as an extension to a human body. In a hospital, the cotton block is quite available. This cotton block got good results to restraint hot and cold spots and to enlarge effective heating region. Fig.13 shows the heating pattern of Fig.12 without the cotton block. With the cotton block, Fig.14 shows obvious improvement. This method that we have been studied experimentally is to make it possible to treat large-volumed tumors at shallower depth with conventional interstitial heating.

In addition, we have investigated frequency dependence of SAR distributions and measured return loss of the antenna ,and so forth.

4.Conclusion

We can get perspective of evaluating the applicator antenna by means of the SAR distribution measurement mainly from now. We will continue the measurements to grasp the relation between construction parameters L_A, D_S, and D_T(the depth of tip from the surface) and SAR distributions.

In order to pursue the most suitable heating region for all of irregular forms and locations of tumors, we will continue further research of a theoretical analysis and design technique for a coaxial-slot antenna.

5.Reference

[1]J. W. Hand and J. R. James (Ed):"Physical techniques in clinical hyperthermia", Research Studies Press, UK (1986).

[2]Ito, K., Ueno, K.,et al.:Interstitial applicator composed of coaxial ring slots for microwave hyperthermia, Proc. ISAP'89 :pp.253-256, 1989.

[3]Masunaga, S., M. Hiraoka, and others(1990). Proceedings of the 7th Annual Meeting, Japanese Soc. of Hyperthermic Oncology, Okayama,61.

[4]Sasaki, H., Oikawa, M.,et al.:Characteristics of SAR distributions around coaxial-slot antenna for microwave hyperthermia, Proceedings of the 8th Annual Meeting, Japanese Soc. of Hyperthermic Oncology, Tokyo, to be published in 1992.

[5]Shimura, M., and others(1990). Proceedings of the 7th Annual Meeting, Japanese Soc. of Hyperthermic Oncology, Okayama,69.

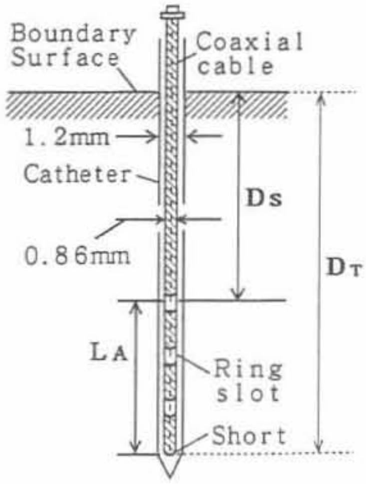

Fig.1 Coaxial-slot applicator

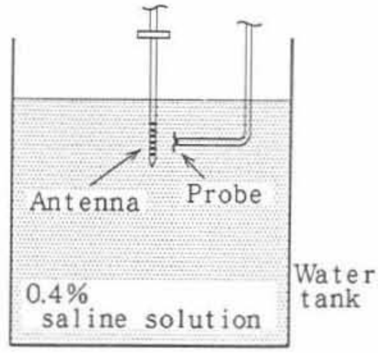

Fig.2 Experimental setup for SAR measurement

Table.1 Sensitivity of dipole (monopole = 1)

Freq.	ratio of sensitivity
300MHz	4.91
430MHz	5.61
500MHz	5.26
600MHz	5.35

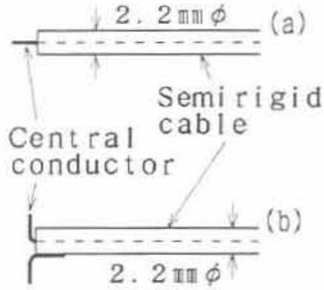

Fig.3 Probes
(a) small monopole
(b) small dipole

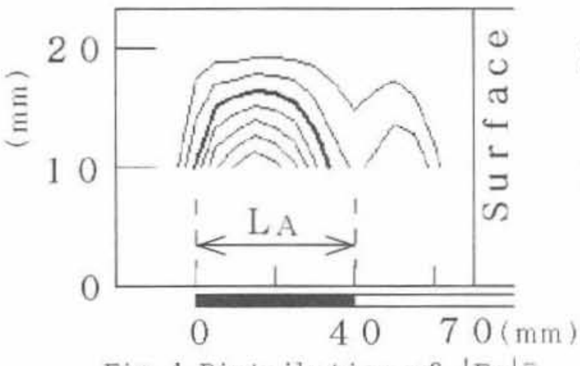

Fig.4 Distribution of $|Ez|^2$ (D_S=30mm, L_A=40mm)

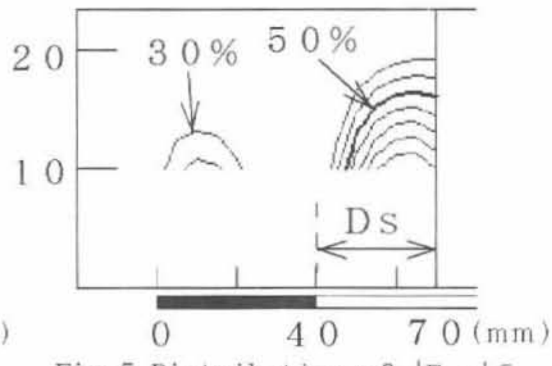

Fig.5 Distribution of $|E\rho|^2$ (D_S=30mm, L_A=40mm)

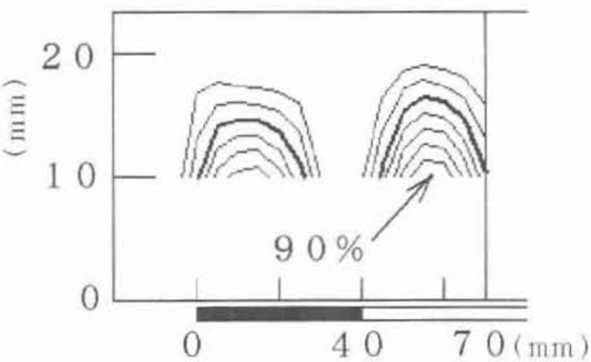

Fig.6 Iso-SAR distribution (D_S=30mm, L_A=40mm)

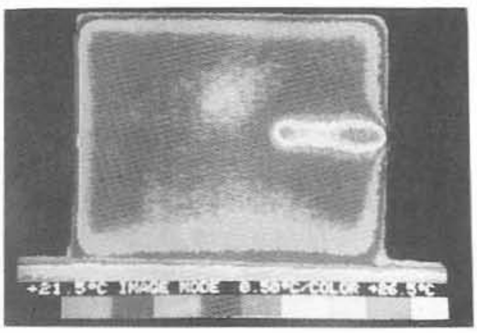

Fig.7 Photo of heat generation (D_S=30mm, L_A=40mm)

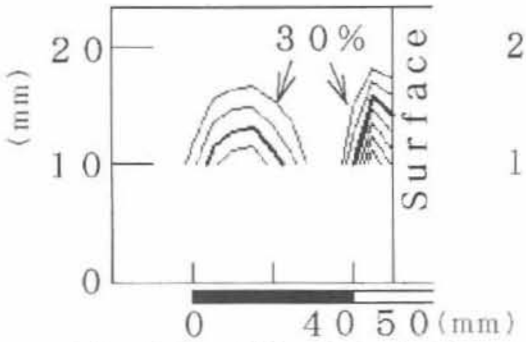

Fig.8 Iso-SAR distribution
(D_S=10mm, L_A=40mm)

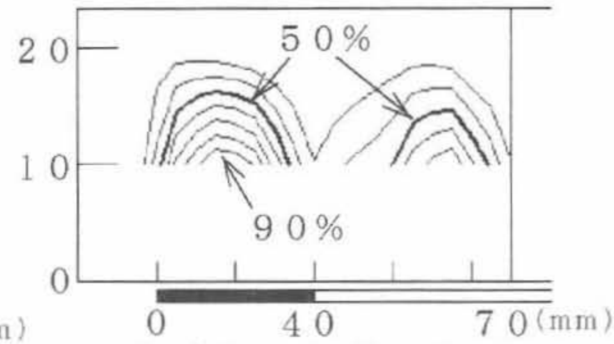

Fig.9 Iso-SAR distribution
(D_S=50mm, L_A=40mm)

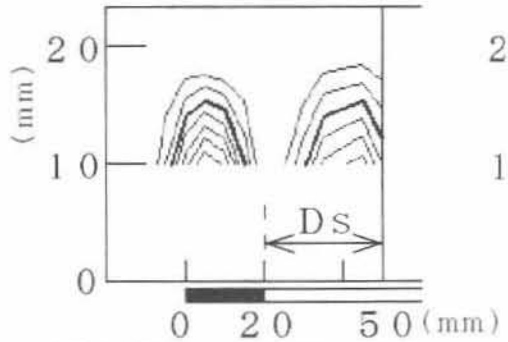

Fig.10 Iso-SAR distribution
(D_S=30mm, L_A=20mm)

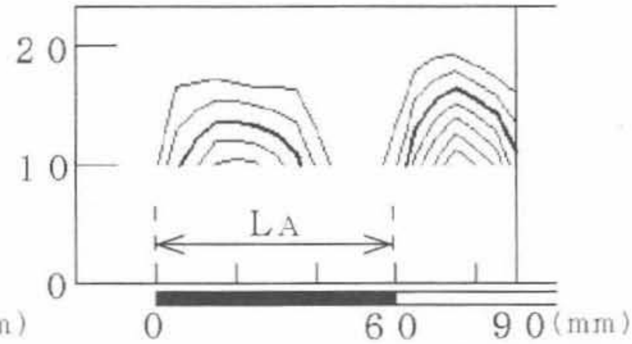

Fig.11 Iso-SAR distribution
(D_S=30mm, L_A=60mm)

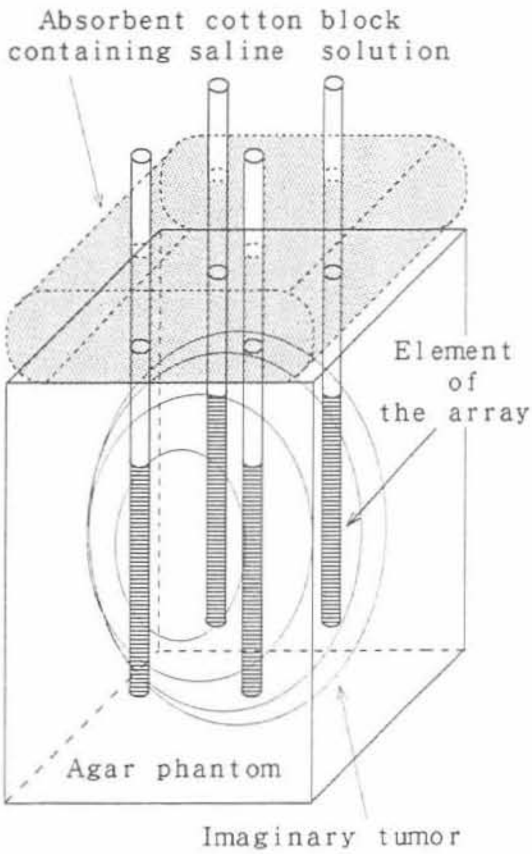

Fig.12 Four antennas
forming array

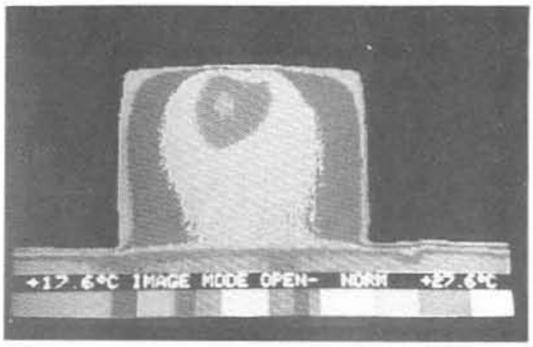

Fig.13 Heat generation of array
without cotton block

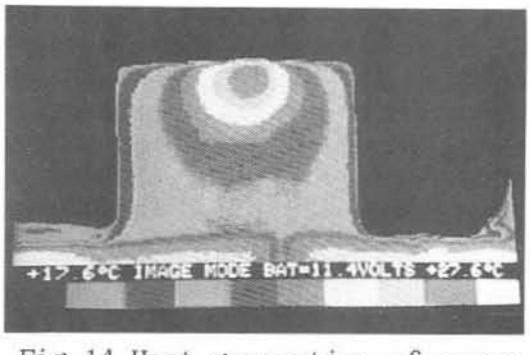

Fig.14 Heat generation of array
with cotton block