Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

Design and Construction of Resonant Cavity Applicator for Brain Tumor Hyperthermia Treatment without Contact

Y.Takahashi[1], K.Kato[1], K.Tsuchiya[1], T.Yabuhara[1], T.Uzuka[2] and H.Takahashi[2]
[1]Dept. of Mechanical Engineering Informatics, Meiji University, Kawasaki, Japan
[2]Dept. of Neurosurgery, Brain Research Institute, Niigata University, Niigata, Japan

Abstract – A re-entrant type resonant cavity applicator for brain tumor hyperthermia treatment is presented. In this method, a human brain is placed between the gap of the inner re-entrant cylinders without contact. This cavity has a window for insertion of the human head. Here, first, to design and construct a resonant cavity applicator, the results of the temperature distribution inside an agar phantom and electromagnetic field leaked from the attached window to the environment by the computer simulation were presented. Second, the developed resonant cavity and inner electrode, which were made of an aluminum alloy, were presented. Third, the experimental heating result of the agar phantom was presented. In the experiment, the center region of the agar phantom is heated to 42 ℃. The leaked electric field strength at the position of 10 cm away from the center of the window was less than that of 10 % of the center of the agar phantom. It was found that the developed resonant cavity applicator was applicable to both deep and regional brain hyperthermia treatment.

Ⅰ. INTRODUCTION

It is important to concentrate heating energy deep into a human body for successful hyperthermia treatments. Various types of applicators to heat the deep tumors were proposed [1]-[3], and some of them have been in practical use, but they have advantages and disadvantages. Successful heating has not yet been realized. We proposed the re-entrant type resonant cavity applicator to heat a human abdomen, and tested them experimentally using the developed heating system with an agar phantom [4], [5].

We have proposed a new method to heat the brain tumor non-invasively. First, to design and construct a resonant cavity applicator for brain tumor, the temperature distribution inside the agar phantom and the leaked electromagnetic field distribution from the attached window to the environment were calculated by the finite element method (FEM). Second, the resonant cavity applicator was made of an aluminum plate which provides visibility into the cavity. Third, we heated the agar phantom using the developed applicator.

From these results, it is shown that the resonant cavity applicator is efficient for brain tumor hyperthermia.

Ⅱ. METHOD

Fig. 1 shows an illustration of our heating system. In Fig. 1, a human head is placed in the gap of inner electrodes, and is heated by

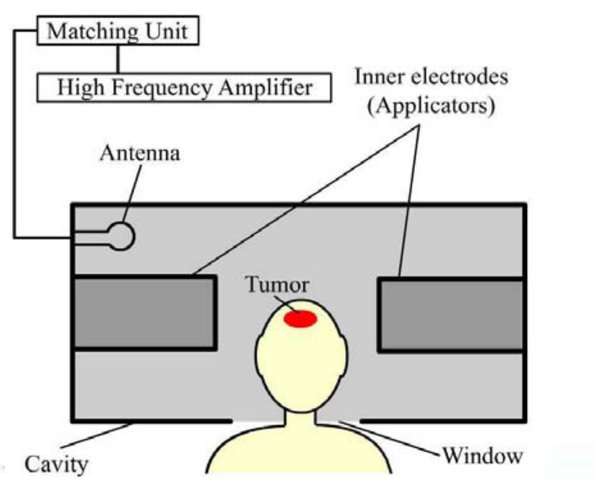


Fig. 1 Illustration of heating system.

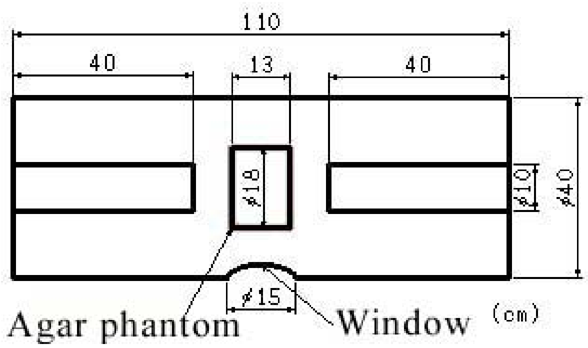
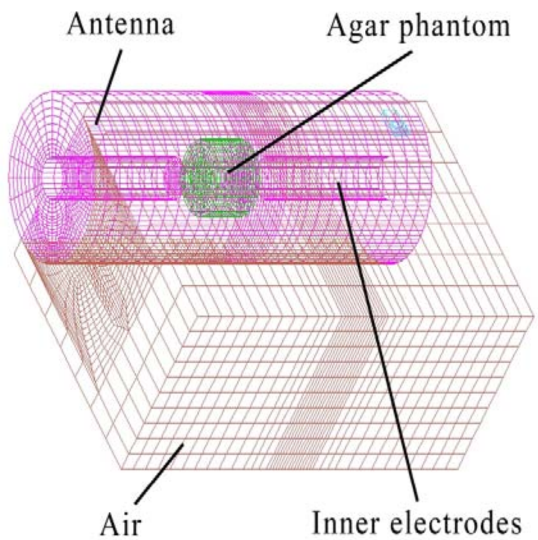


Fig. 2 Re-entrant resonant cavity.



Number of elements 45,647

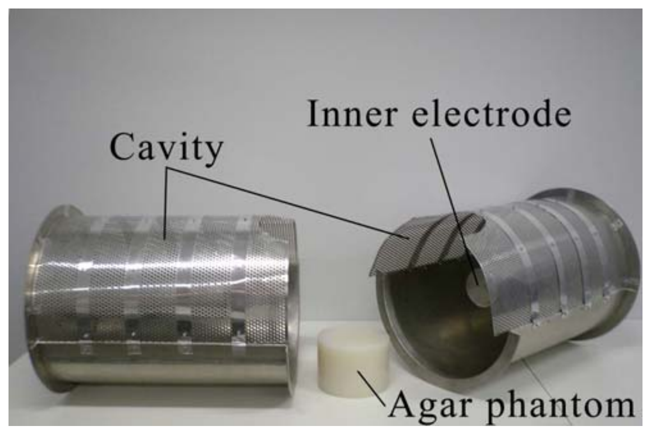
Fig. 3 Finite element mesh for calculating electromagnetic field and temperature distributions.

electromagnetic energy non-invasively. The window is in the lower part of the cavity for human head insertion. To design and construct a resonant cavity applicator, we calculated the temperature distribution inside an agar phantom and electromagnetic field leaked from the attached window to the environment by computer simulation. Fig. 2 shows the diagram of the cavity of which dimensions were determined by a computer simulation. Here, we used the FEM program which was JMAG-studio in computer simulation. Fig. 3 shows a finite element mesh for calculating

TABLE I Typical values of phantom parameters.

	ϵ_r	σ (S/m)	κ (W/m°C)	ρ (kg/m^3)	c (J/kg°C)
Phantom	75	0.6	0.6	1000	4200
Air	1	0.0	0.025	1.165	1010

(a)



(b)

Fig. 4 Constructed re-entrant type resonant cavity applicator, (a) inner electrode, (b) cavity.

electromagnetic field and temperature distributions. The physical parameters used in the calculation are listed in Table I. Fig. 4 shows the designed and constructed re-entrant type resonant cavity applicator based on the computer simulations. The cavity is made of

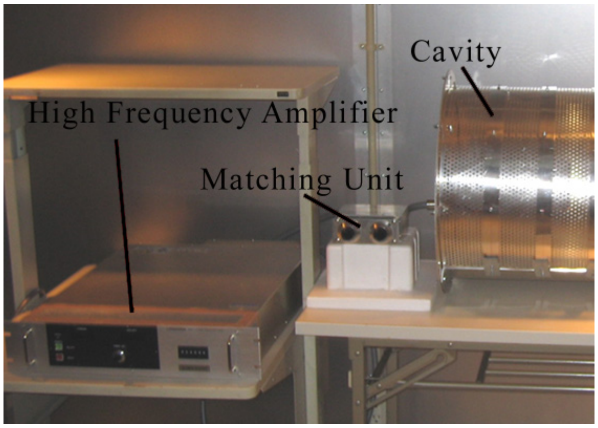


Fig. 5 Developed heating system.

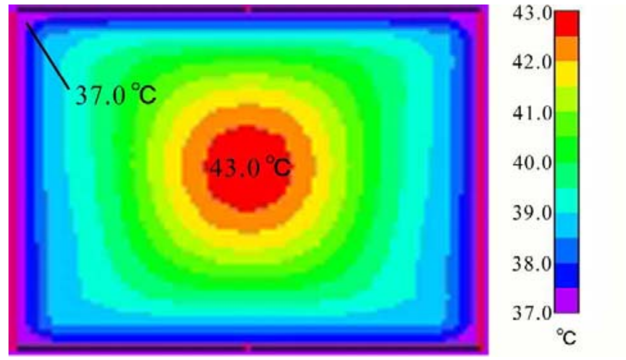


Fig. 6 Estimated temperature distribution.

an aluminum plate which is 0.3 mm in thickness. Fig. 5 shows the developed heating system. It consists of the re-entrant type resonant cavity, a high frequency amplifier, and an impedance matching unit. The operating frequency is between 50 MHz and 200 MHz, and the maximum input power is 150 W. In the heating experiments, the heating power was 30 W with the heating time of 30 minutes.

III. Results and Discussions

Fig. 6 shows the computer simulation result of the temperature distribution of the sagittal slice of the agar phantom estimated by the resonant frequency of 156.6 MHz. In Fig. 6, an initial temperature is 37.0 ℃, and the center of the agar phantom is heated to 43.0 ℃. For comparison, the same agar phantom was heated using the developed system. Fig. 7 is a sagittal sectional thermal image of the agar phantom taken with an infrared thermal camera just after heating. The resonant frequency was 156.2 MHz. In Fig. 7, the initial temperature is 22.5 ℃, and the center of the agar phantom is heated to maximum temperature (29.0 ℃). From Figs. 6 and 7, it is found that the estimated temperature pattern agrees with the measured one, and the center region of the agar phantom was selectively heated concentrically.

Fig. 8 is the normalized electric field distribution estimated by the computer simulation. Fig. 8 shows that the maximum electric field strength appears at the center of the agar phantom, and the electric field hardly leaked near the attached window. Fig. 9 is the normalized electric field profile along the z-axis shown in Fig. 8.

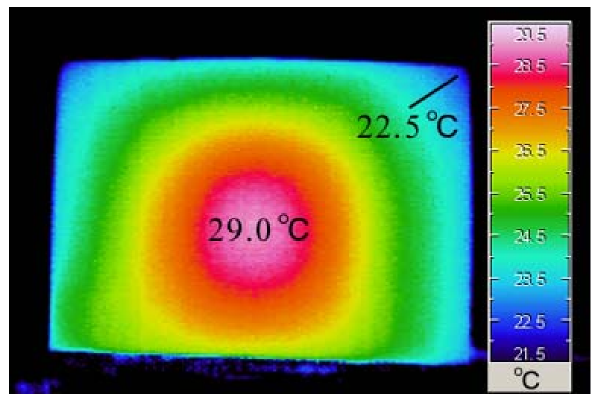


Fig. 7 Thermal image.

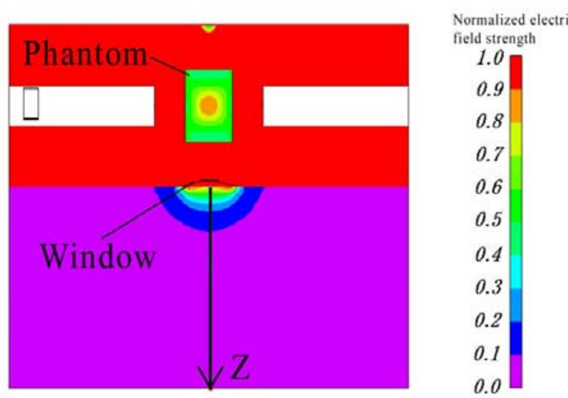


Fig. 8 Estimated electric field distribution.

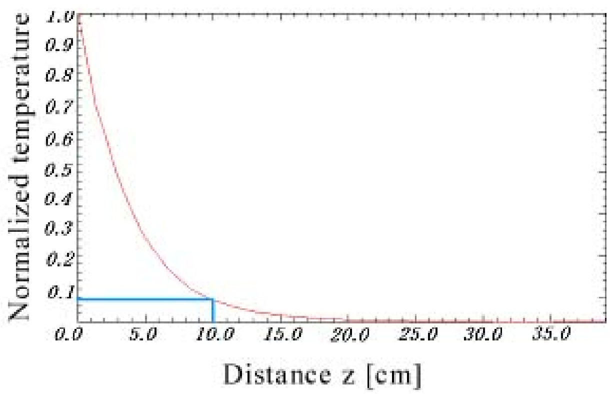


Fig. 9 Profile of electric field strength.

Fig. 9 shows that, at the position of 10 cm away from the center of the window, the normalized field strength is 10 % of the center of the agar.

IV. Conclusion

For the design and construction of the re-entrant resonant type cavity applicator, the computer simulation results showed that the temperature distribution inside the agar phantom and electromagnetic field leaking from the attached window to the environment. Based on the computer simulation results, the heating system for the brain tumor hyperthermia treatment was developed. From the computer simulation and experimental heating results, it is found that the developed heating system is efficient for brain tumor hyperthermia treatment non-invasively.

References

[1] G. H. Nussbaum, J. Sidi, N. Rouhanizadeh, P. Morei, C. Jasmin, G. Convert, J. P. Mabire, and G. Azam, "Manipulation of central axis heating patterns with a prototype, three-electrode capacitive device for deep-tumor hyperthermia", IEEE Trans. Microwave Theory Tech., vol.34, no.5, pp. 620-625, 1986

[2] P.F. Turner, "Regional hyperthermia with an annular phased array" IEEE Trans. Biomed. Eng., vol. 31, no. 1, pp. 106-114, 1984.

[3] J.J.W.Langendijk, "A new coxial TEM radiofrequency/ microwave applicator for non-invasive deep-body hyperthermia", J. microwave Power., vol. 18, pp. 367-375, 1983.

[4] K. Kato, J. Matsuda, and Y. Saitoh, "A re-entrant type resonant cavity applicator for deep-seated hyperthermia treatment", Proc. of IEEE EMBS, vol. 11, pp. 1712-1713, 1989.

[5] K. Kato, E. Kasai and J. Matsuda,"A study of re-entrant type resonant cavity applicator for deep tumor hyperthermia", Proc. Of 7th International Congress on Hyperthermic Oncology, pp. 473-475, 1996.