Computer simulation and temperature measurement for MR hyperthermia therapy using coaxial-slot antenna

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Introduction

Hyperthermia therapy is commonly used for tumor treatment that already has been widely investigated. The principle of hyperthermia therapy employs the clear difference in heat sensitivity of normal cells and tumor cells at 42℃ to 43℃ and above.(1) This difference is used for selective killing of only the tumor cells. Recently, hyperthermia therapy combined with magnetic resonance imaging has been suggested and implemented. This new method has several advantages for the treatment of small tumors. In general, High Frequency Ultrasound (HIFU) is commonly used as heating source in this method. HIFU, however, has some drawbacks.(2) First, HIFU cannot apply to some regions because ultrasound cannot pass through bone and lung. In addition, ultrasound may cause a damage of the tissue on a permeation pathway. Nevertheless, microwave heating could be applied for the treatment of various sizes of tumor by varying the length of the slot and antenna. Microwave heating is expected to fill a gap of HIFU. In this study we propose a coaxial-slot antenna as a useful local heating source for MR combined hyperthermia therapy.

Methods

A. Computer simulation:

The Finite Element Method (FEM) was conducted to optimize coaxial-slot antenna using HFSS (Ansoft, LLC) software and to obtain the electromagnetic structure. The antenna slot was formed by removing the annular portion of the outer conductor of the coaxial cable. The heating pattern was determined by the position and number of the slots of the antenna axis.(3) The frequency characteristic of coaxial-slot antenna was calculated based on the slot length (L_s), length from the tip to the slot center (L_{ts}) and antenna length (L). To measure the heating pattern, SAR distribution was calculated according to the relative permittivity, conductivity and density because SAR is widely used as performance evaluation tool for hyperthermia heating source. The SAR value represents the amount of electromagnetic energy per unit mass absorbed by a biological tissue.

B. Custom-made coaxial-slot antenna & temperature measurement:

Coaxial-slot antenna was made of semi-rigid type (SF085) coaxial cable in laboratory based on the computer simulation results. Maximum power of the microwave generator is 910W and the center frequency is in the range of 2.45㎓±50㎒. The microwave generator was connected to the wave guide that was composed of launcher, taper, coaxial transducer. A 2% agarose gel phantom was used to examine the heating pattern according to the SAR distribution from simulation results. A multi channel digital thermometer was used to measure temperature change induced from the coaxial-slot antenna. Seven channels were employed with the gap of 1㎝ to each other and 1㎝ away from the antenna.

C. MR temperature map:

MR temperature image is obtained using T2* GRES with parameters: TR/TE=150/20msec, FOV=100mm, slice thickness=10mm, matrix=256x128, NEX=4, and flip angle=60°.

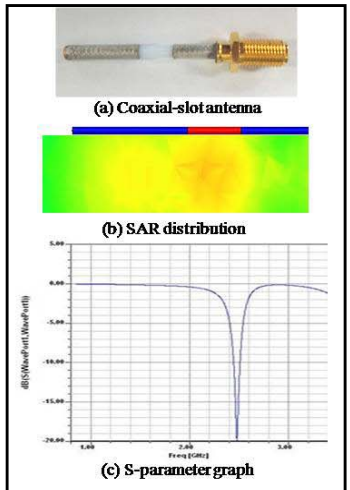

Fig.1. coaxial-slot antenna & results of computer simulation : (a) Coaxial-slot antenna (b) SAR distribution of coaxial-slot antenna simulation (c) frequency characteristic of coaxial-slot antenna

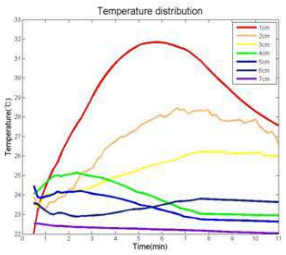

Fig.2. Temperature change from coaxial-slot antenna center

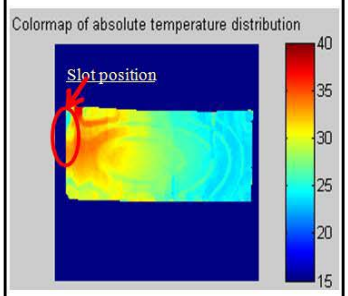

Fig.3. MR temperature image

Results

Fig.1. shows (a) home-made coaxial-slot antenna and computer simulation results. The length of coaxial-slot antenna (L), length from the tip to the slot center (L_{ts}) and slot length (L_s) is 35㎜, 21㎜ and 8㎜, respectively. The SAR distribution shows that area close to the slot has higher SAR values. The S parameter shows that at the center frequency of 2.45㎓ the gain drops off to -20dB. Temperature variations of each channel for the agarose gel phantom experiment during the process of heating up and cooling down were shown in Fig. 2. Maximum temperature of the channel 1㎝ away from the slot antenna is 32℃ after 5minutes heating. Fig.3. shows the MR temperature map acquired using the PRF technique with the center array-sequencing phase unwrapping algorithm(4) after heating the upper leftmost part of the phantom with proposed slot antenna.

Conclusion

Coaxial-slot antenna can be possibly used as a local heating source for MR combined hyperthermia.

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