HYPERTHERMIA APPLICATOR COMPATIBLE WITH "MR"

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ABSTRACT

Microwave thermotherapy is being used in medicine for the cancer treatment and treatment of some other diseases since early eighties [1,2,3,4]. Until now in temperature monitoring and control there is a lack of non-invasive 3D thermometry system, e.g. either Nuclear Magnetic Resonance (NMR) or ultrasound (US). The goal of this paper is to describe design and experimental evaluation of a new type applicator for microwave thermotherapy, which will be compatible with NMR. The first applicator of this type is just being used for a hyperthermia treatment of the experimentally induced pedicle tumours of the rat.

INTRODUCTION

Our work is focused on the design, optimisation and experimental evaluation of the microwave applicators compatible with non-invasive 3D temperature measurements systems via US and/or NMR. This means to design a microwave structure capable above all:

- to transfer efficiently the electromagnetic energy into the biological tissue,
- to create the required 3D temperature distribution in the area to be treated,
- to guarantee the compatibility with US and NMR.

The main goal of the planned biological experiment is a hyperthermia treatment of the experimentally induced pedicle tumours of the rat to verify the feasibility of ultrasound diagnostics and magnetic resonance imaging respectively to map the temperature distribution in the target area of the treatment. That means to heat effective volume of approximately cylindrical shape (diameter approx. 2 cm, height approx. 3 cm). Temperature to be reached is 41 ^{o}C or more (i.e. temperature increase of at least 4^{o}C from starting point 37 ^{o}C), time period of heating is 45 minutes.

DESCRIPTION OF THE DISCUSSED APPLICATOR

Considering the necessary effective heating depth for the planned experiments, we have found 915 MHz to be suitable frequency.

As an excellent compatibility of the applicator with non-invasive temperature measurement system (ultrasound or NMR) is a fundamental condition for our project, we should have to use non-magnetic metallic sheets of minimised dimensions to create the conductive elements of the applicator. Therefore the applicator itself (see Fig.1) is created by two inductive loops tuned to resonance by capacitive elements [5,6]. Dimensions of these resonant loops were designed by our software, developed for this purpose. Coupling between coaxial feeder and resonant loops (not shown in Fig.1) as well as a mutual coupling between resonating loops could be adjusted to optimum by microwave network analyser.

The position of the loops is fixed by perspex holder. There is a special cylindrical space for experimental animal in lower part of this perspex holder. As the heated tissue has a high dielectric losses, both loops are very well separated and so no significant resonance in heated area can occur. From this follows, that either the position of the loops with respect to heated area or the distance between the loops is not very critical.

EVALUATION OF THE DISCUSSED APPLICATOR

First measurements to evaluate the basic properties of the discussed applicator were done on agar phantom of muscle tissue:

- evaluation of basic microwave properties (transfer of EM energy to the tissue, reflections),
- evaluation of compatibility with US and NMR,
- calculation and measurement of SAR and temperature distribution and its homogeneity.

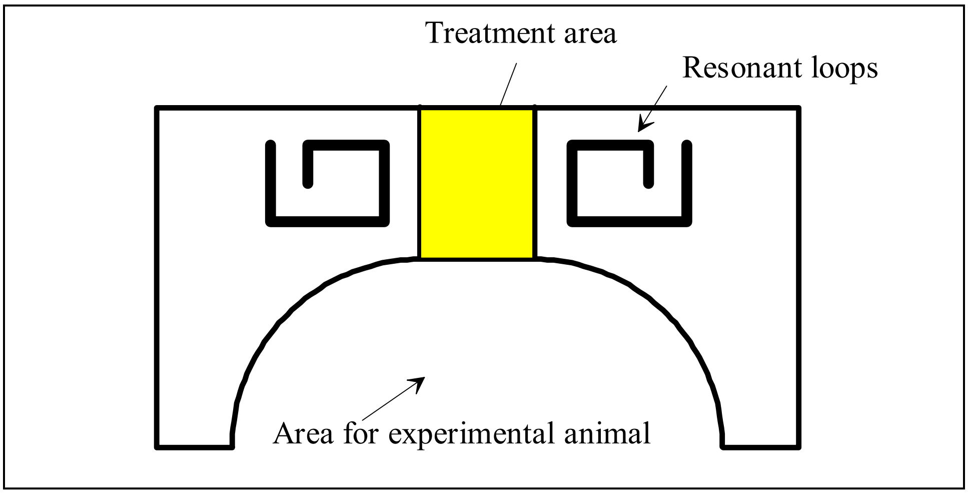
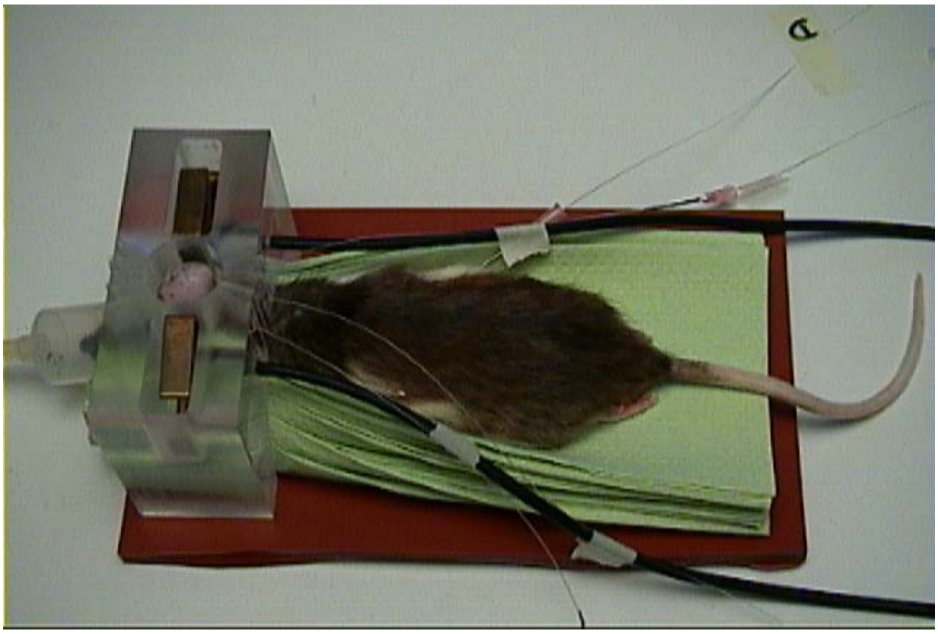


Figure 1. Arrangement of discussed microwave hyperthermia applicator.



Photograph of the discussed applicator.

EVALUATION OF MICROWAVE PROPERTIES

Exact tuning of the resonant loops to frequency 915 MHz has been easy and we could optimise the coupling between the coaxial feeder and resonant loops as well, reflection coefficient less than 0.1. We have tested the power to be delivered to the applicator to obtain sufficient temperature increase (approximately 4 ^{o}C in less than 5 minutes is required). With power 10 W delivered to each loop for period of 2 minutes we succeeded to obtain the temperature increase of approximately 7 ^{o}C. To keep the increased temperature for a long time, 2 W in each loops were sufficient. Similar values were obtained during first experiments on rats also. Even with higher level of delivered microwave power we did not observe the change of resonant frequency (caused by increased temperature of the loops).

EVALUATION OF COMPATIBILITY WITH “US” AND ”MR”

We have tested the influence of the applicators on US diagnostics and NMR imaging and the result of this evaluation shows very good compatibility. Only a negligible deterioration of the US images have been observed when the incident power was kept under 100 W.
Details about influence of microwave power on NMR imaging are given in Fig. 2. We can see here a sequency of images of the discussed applicator made by NMR unit for four different cases. First case (upper left) is image for the case without power excitation of the applicator. Second case (left down) a power of 10 W has been delivered to each loop. We can see quite clear configuration of the applicator set-up. Third case (upper right) gives situation when 20 W has been delivered to each loop. Slight noise but still quite a clear configuration of the applicator set-up can be observed. Fourth case (right down) gives situation when 40 W has been delivered to each loop. In this case noise disturbed the possibility to observe the configuration of the applicator.

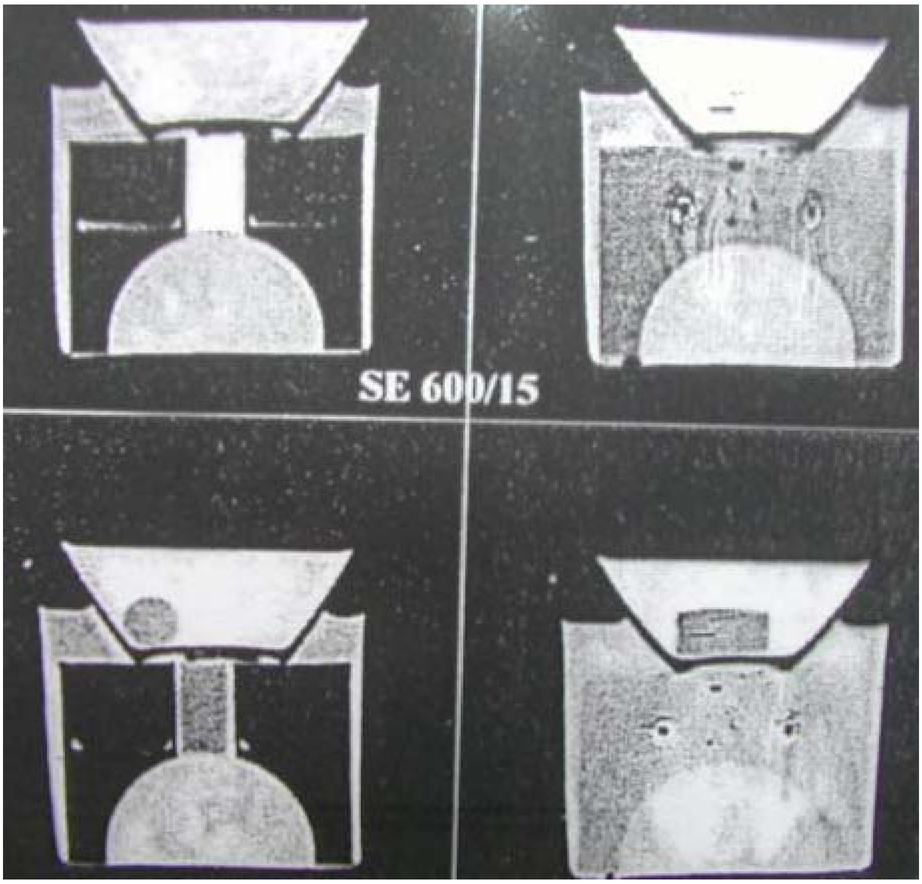


Fig. 2. NMR images of the discussed applicator for different levels of excited power.

CALCULATION AND MEASUREMENT OF THE TEMPERATURE DISTRIBUTION

In theoretical and experimental evaluation, the grade of homogeneity of the temperature distribution in the target area has been tested, see the Fig. 3. Our mathematical approach is based on idea of waveguide TM_{01} mode excited in the agar phantom under the given conditions (see the dashed lines). Measurement of SAR (full lines) has been done on agar phantom of the muscle tissue. Very good agreement have been obtained when verifying these results numerically by software product FEMLAB (Fig. 4).

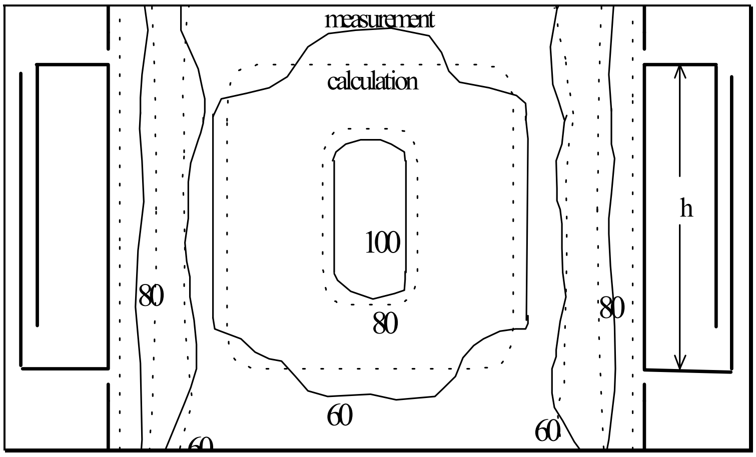


Fig. 3. Normalised SAR distribution (both calculated and measured) in the heated agar phantom.

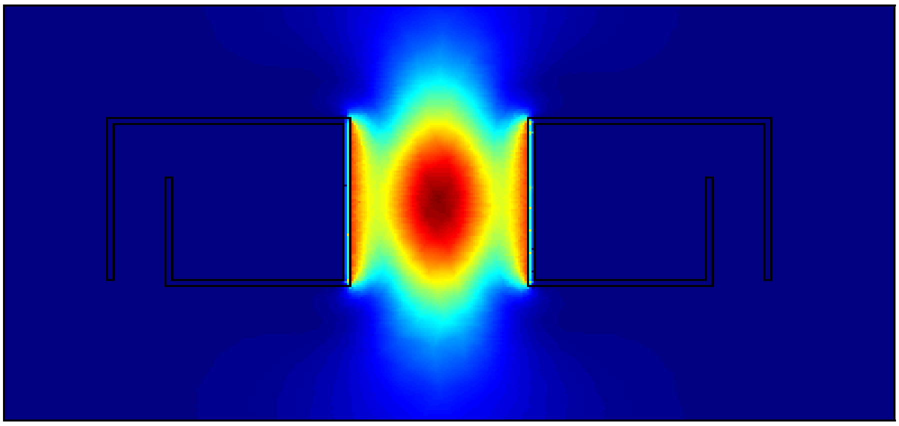


Fig. 4. Numerical SAR analysis made by software product FEMLAB.

CONCLUSIONS

As a novel results of our work we could mention that the new type of microwave applicator for cancer treatment has been developed and evaluated. Evaluation procedures have shown, that this applicator is a very effective heating structure and excellent compatibility with US and NMR has been approved as well. Having approved this applicator in animal experiment, we are now working on development of it's big version to be used in clinical praxis.

ACKNOWLEDGEMENT:
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