UNIFORM HEATING OF MULTI-STRUCTURAL BIOLOGICAL OBJECTS BY MEANS OF ELECTRIC AND MAGNETIC FIELDS' PHASED EMITTERS

Shamaev N. V., Pulver A. Yu, Buslov D. S.

Institute of Biology of Aging, Voronezh, 394018, Russia. E-mail: pulver.ibs@gmail.com

ABSTRACT

We describe an approach to achieving uniform heating of bulky multi-structural biological objects by coherent electromagnetic radiation, guided by the data from the MRI thermometry. The explanation of how we plan to "focus" electromagnetic fields which in principle cannot be focused, is also given. We hope that this technique (patent pending) will allow to reach previously unattainable speeds of rewarming from cryogenic to near-zero temperatures, including non-vascular areas and cavities. This will allow achievement of rapid and uniform warming rates that are necessary to avoid devitrification even with reduced cryoprotectants concentrations, thus eliminating the main problems in applying vitrifying techniques to bulky tissues and organs

The main problems in applying vitrifying techniques to bulky tissues and organs are related to the difficulty in achieving sufficiently rapid and uniform warming rates that are necessary to avoid devitrification. Non-uniformity of temperature increases the risk of mechanical stresses and fractures developing in the glass during rapid warming.

Heating by conduction becomes increasingly inadequate as the size of the tissue increases and, once the tissue exceeds a few millimeters in thickness, can lead to excessively high temperatures on the periphery when the core remains vitrified. Such large temperature gradients also lead to mechanical stresses, fracture and tissue damage.

Electromagnetic absorption (dielectric heating) as an alternative method for warming of bulky tissues has been the subject of study for over 25 years. Early studies on whole tissue using conventional microwave ovens operating at frequency of 2450MHz were not successful. It was later established that a lower frequency would give a greater penetration depth and better uniformity of heating, and that the optimum frequency range for dielectric heating of tissues was 300–1000MHz. Uniformity of warming in a dielectric field is heavily dependent on the dielectric properties of the aqueous phase and, in particular, its cryoprotectant component.

Still, the best result was a purpose built power source and resonant applicator operating at 434MHz was that produced relatively uniform heating across 36mm gelatin spheres containing various concentrations of dimethylsulphoxide, with the final maximum temperature difference not exceeding 9°C [Wusterman, Robinson et al., 2004].

We describe an approach to achieving uniform heating of bulky multi-structural biological objects by coherent electromagnetic radiation with zero field intensity region, guided by the data from the MRI thermometry.

Our method consists in the use of high-frequency heating in order to uniformly heat of heterogeneous tissues. For that we suggest to use a proposed focusing of coherent electromagnetic emission to obtain regions with zero electric and magnetic field component.

Creating a point of zero field strength will be obtained by placing a minimum of four emitters in the corners of a tetrahedron. The power of emission and the phase of emitters is defined on the basis of the provisions of the "zero point" within it.

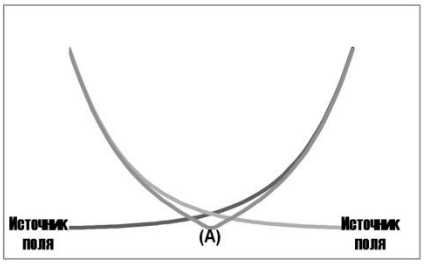

Figure 1 Two-dimensional interference pattern of emission from two emitters.

The figure 1 shows the field strength of the two emitters which are functioning with a shift of 180 °. The total field strength is shown in black. At the point A, the field intensity is zero.

We're changing the emission power of the emitter. So the "point" (A) moves on the X-axis between the emitters. We solved the system of linear equations in which the initial data are:

• size of the object;

• the heat capacity of each virtual object point (VOP);

• absorptive capacity in each of the VOP;

• the initial value of the temperature in each of the VOP;

The solution is represented by the matrix with the following set of elements:

№	Coordinates	Power of emitters 1	Power of emitters 2	Phase of emitters 1	Phase of emitters 2	Time of heating
1						
2						
3						
4…						

The matrix will determine the work of the magnetic and electric fields of the emitters. The application of electric field is more complicated due to nature of its distribution.

There is a reason why we suggest using two types of fields. Objects at low temperatures are more effectively heat by the capacitive method. A functioning of magnetic field depends from an electrical conductivity of the heated material. At the same time, objects with higher temperatures are more effectively heat by magnetic field.

Application of this method requires a solving of the matrix for at least four emitters. More sources of emission such as inductors for the magnetic field and the capacitors for electrical is associated with difficulties of solving the matrix. So it would be helpful to state that the emitters are located on the surface of the conceptual sphere in order to reducing of the dimensionality of the system. More precisely – the set of nested spheres. So we could avoid excessive tension on the borders of the field heated object.

Basically, we calculate phases, capacities and time of concentrate of the point (A) in each VOP ("concentrate non-heat"). It could be done by using a matrix obtained by a three-dimensional MRI thermometer [Basgal, 2008]. Raw date is getting through information processing of variations, as result we have "three-dimensional matrix of specific heats".

Most basic application of the method could be represent as move of virtual point of non-heat with high speed in volume of the heated sample. It's like deflected beam in a television picture tube. More accurate likeness could be represented as accelerated in the hundreds of thousands times repetitive work of 3D-printers.

We could use more effective patterns of "movement" depending on the structure of the heated object. But they have to be discovered first.

Mathematical tools are extremely difficult in any case. We have to use either supercomputers, or create a hardware implementation of the math module using a large number of FPGAs in order to monitor the temperature of the object in real-time.

We hope that this technique (patent pending) will allow to reach previously unattainable speeds of rewarming from cryogenic to near-zero temperatures, including non-vascular areas and cavities. This will allow achievement of rapid and uniform warming rates that are necessary to avoid devitrification even with reduced cryoprotectants concentrations, thus eliminating the main problems in applying vitrifying techniques to bulky tissues and organs.

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