ELECTROMAGNETIC DEVICE FOR HYPERTHERMIA TREATMENT MONITORING

A. Prokhorova[1], O. Fiser[2], J. Vrba[2], M. Helbig[1]

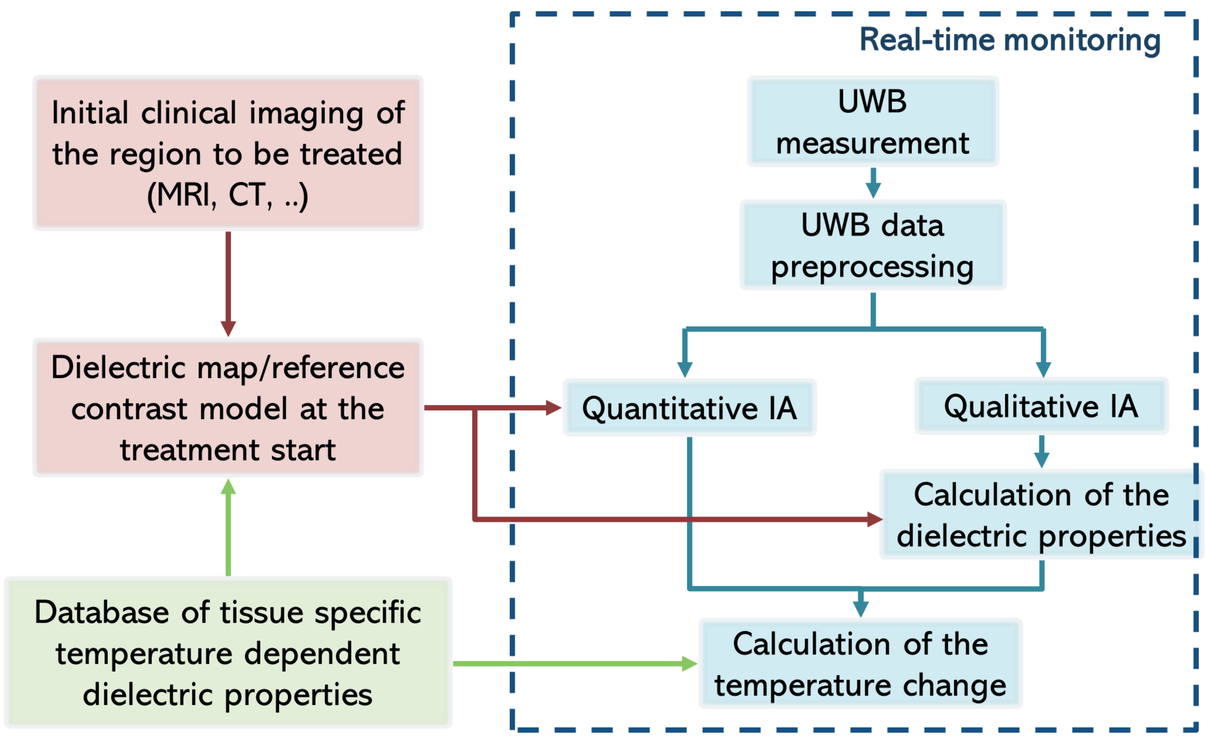
[1]Technische Universität Ilmenau, Ilmenau, Germany

[2]Czech Technical University in Prague, Prague, Czech Republic

Abstract

This work focuses on the development of a prototype for non-invasive tissue temperature monitoring inside the human body during thermal treatment based on microwave medical imaging, specifically, ultra-wideband M-sequence radar technology developed at the Technische Universität Ilmenau. The methodology of tissue temperature estimation is based on the temperature dependency of the tissue dielectric properties in the microwave frequency range. Numerical studies of the heating antennas in co-existence with the sensing ones, modelling of the optimal antenna array configuration as well as preliminary experiments are performed to desigh the prototype of the microwave hybrid system.

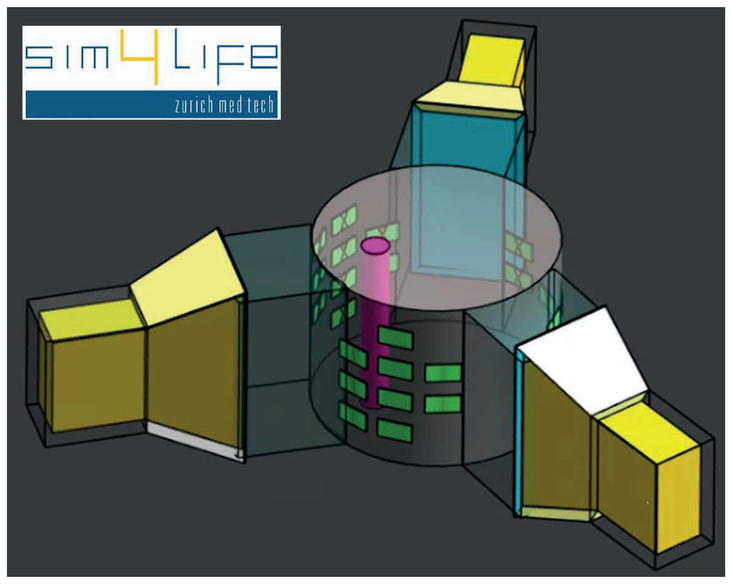
Methodology of temperature estimation



$$\hat{\underline{\varepsilon}}_t(\mathbf{r}_0,\omega,T)=\underline{\varepsilon}_{bg}(\omega)\left(\frac{I_{ref}(\mathbf{r}_0)-\underline{\Gamma}_{ref}(\mathbf{r}_0,\omega)I(\mathbf{r}_0,T)}{I_{ref}(\mathbf{r}_0)+\underline{\Gamma}_{ref}(\mathbf{r}_0,\omega)I(\mathbf{r}_0,T)}\right)^2$$

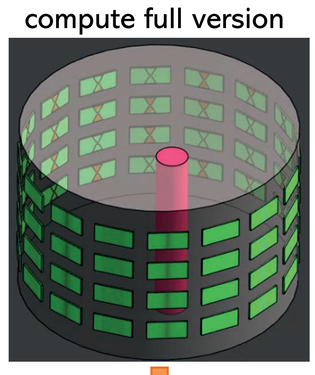
Estimated relative permittivity

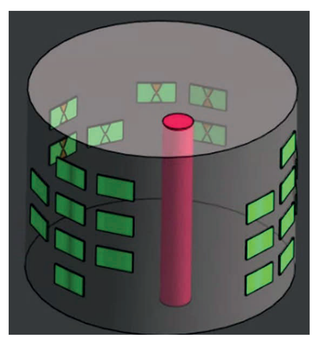
Numerical simulations

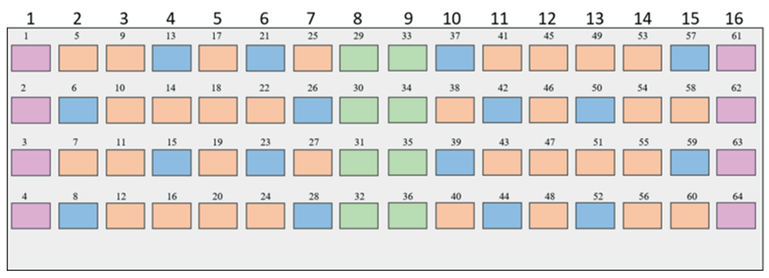


- simulation software Sim4Life®
- computation method FDTD
- adaptive mesh and voxelization

compute full version



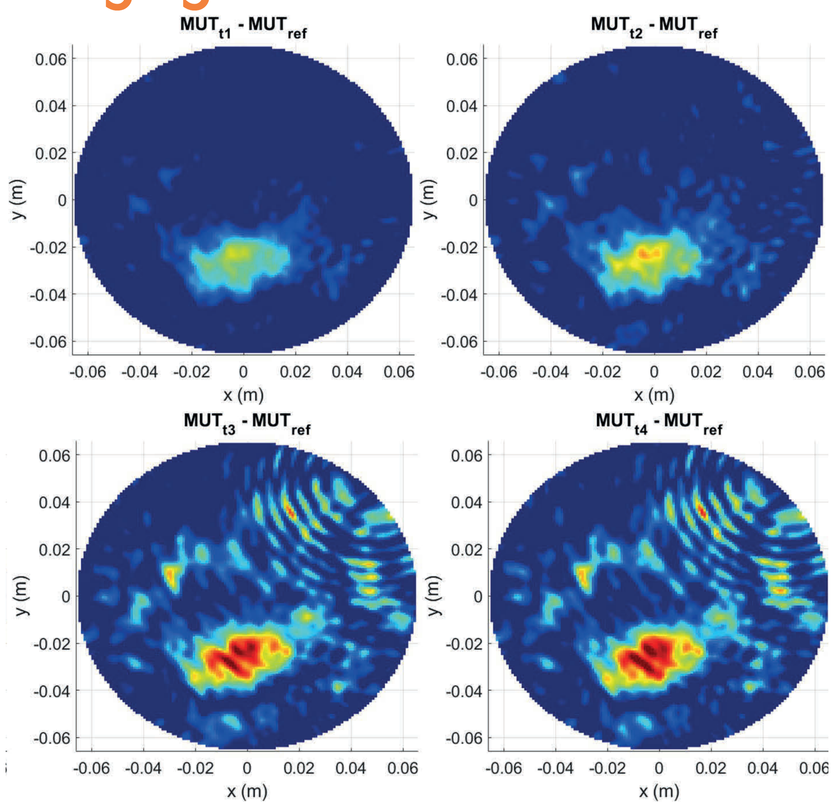




Antenna placement map

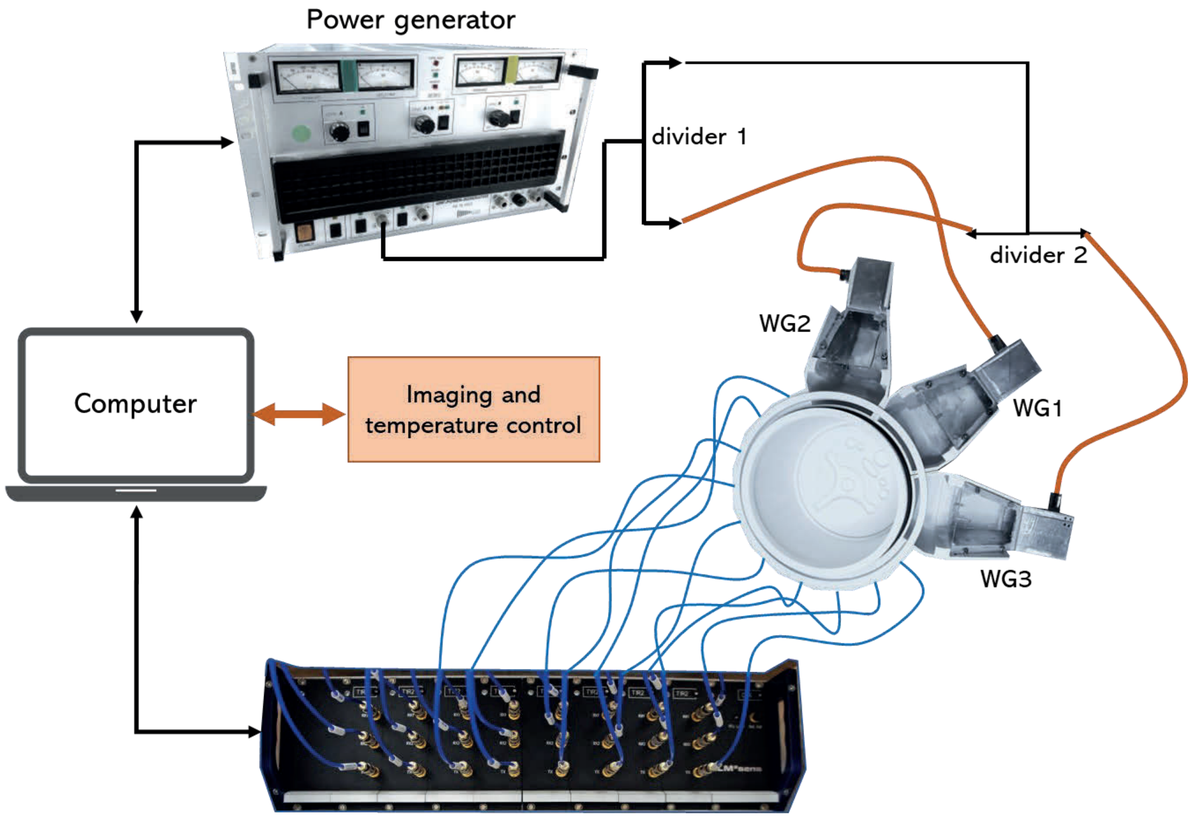
analyze specified version

Imaging results



Differential UWB images of phantom demonstrating correlation between image intensity and tumor permittivity

Hybrid system prototype



M-sequence MIMO UWB radars

- baseband MIMO radar device
- 48 dipole antennas
- 512 measurement channels
- 3D-printed corpus
- matching layer
- cylindrical phantom
- simulation of tumor heating
- differential imaging
- time domain beamforming
- tumor $\varepsilon\downarrow 0.1 = \uparrow 1°C$

Conclusion:

Based on numerical and experimental investigations a laboratory prototype of the hybrid system for neck HT with non-invasive UWB MWI of the temperature changes was designed and assembled. The results revealed that temperature induced changes in the hyperthermia range can be detected and quantitatively interpreted, suggesting a promising improvement of the oncological treatment by thermal therapies.

Illustrations and photographs: A. Prokhorova 2022

98693 Ilmenau, Germany
Phone: + 49 3677 692860
Fax: + 49 3677 691311
E-Mail: alexandra.prokhorova@tu-ilmenau.de

EMERALD ElectroMagnetic imaging for a novel genERation of medicAL Devices

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