Inclusion of Thermal Dependent Material Relations for Modeling Microwave Ablation Antennas

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Outline

1. What is Microwave Ablation?
2. Motivation
3. Antenna and model in QW
4. Results
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Microwave Ablation (MWA)

- Cancer treatment that uses microwave energy to generate heat
- Typically 900 MHz or 2.45 GHz
- Heating caused by friction of oscillating water molecules
- Cancer tissues are more likely to heat (more water molecules, higher conductivity)
- Modified coaxial cable is the simplest example of the MWA antenna
- Ablation Zone ≥ 60°C [4]

References

[1] QWED, *QuickWave Basic Heating Module*. [Online] Available: https://www.qwed.com.pl/qw_bhm.html

[2] M. Cavagnaro, C. Amabile, P. Bernardi, S. Pisa, and N. Tosoratti, “A Minimally Invasive Antenna for Microwave Ablation Therapies: Design, Performances, and Experimental Assessment,” IEEE Transactions on Biomedical Engineering, vol. 58, no. 4. Institute of Electrical and Electronics Engineers (IEEE), pp. 949–959, Apr. 2011. doi: 10.1109/tbme.2010.2099657

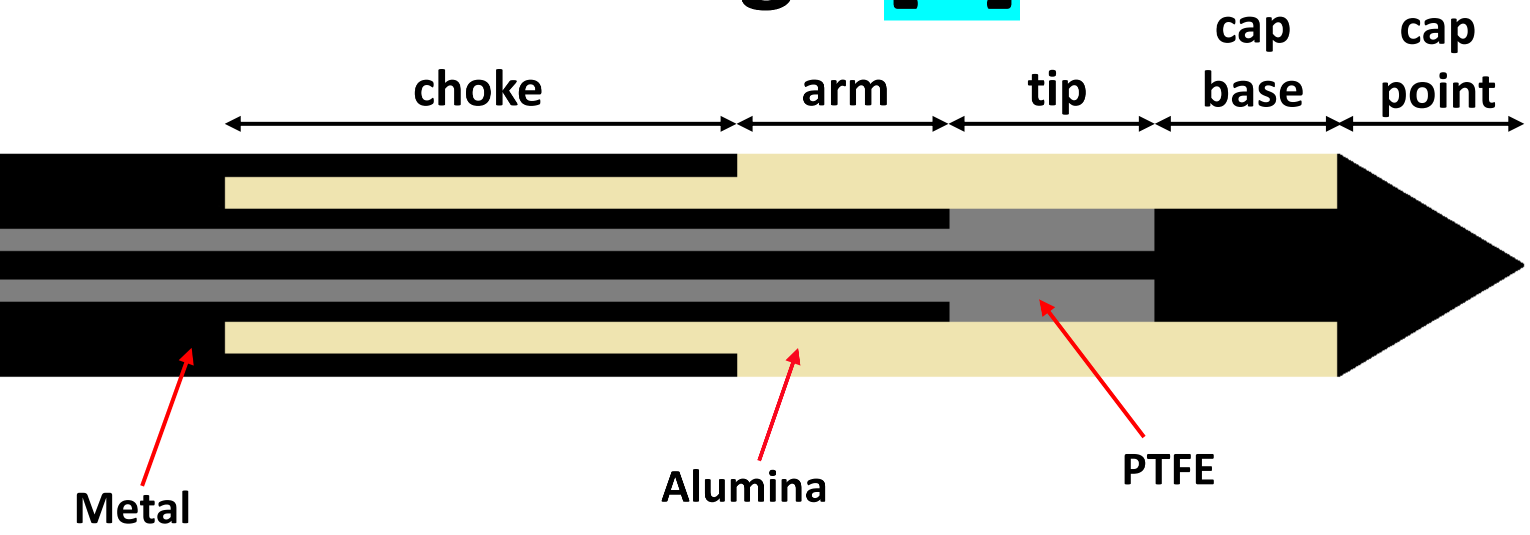
[3] QWED (2023), *NanoBat – Coupled GHz Thermal workflow for a battery model.* [Online] Available: https://www.qwed.com.pl/nanobat_coupled_ghz_thermal_woorkflow.html

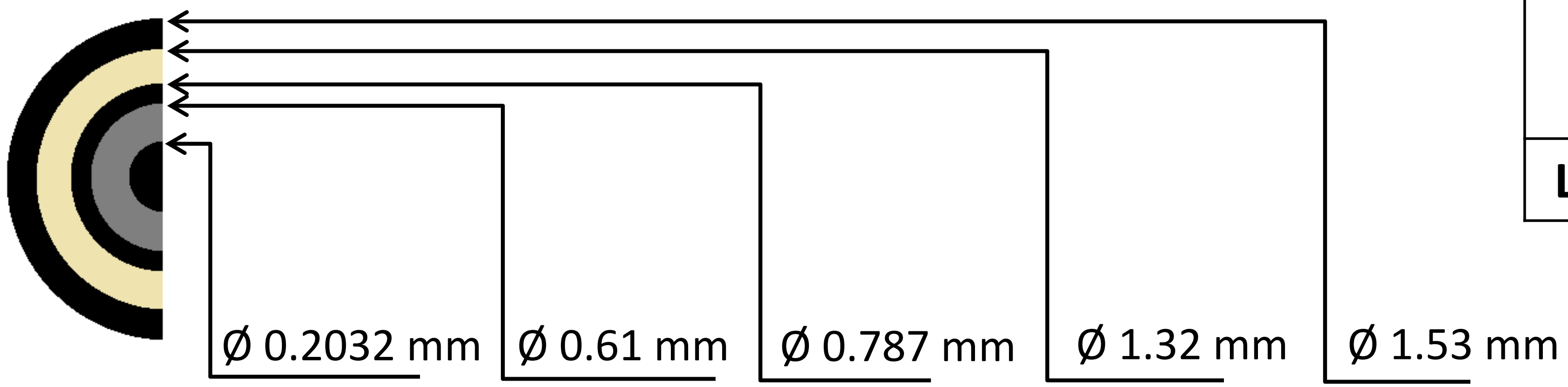
[4] V. Lopresto, R. Pinto, L. Farina, and M. Cavagnaro, “Microwave thermal ablation: Effects of tissue properties variations on predictive models for treatment planning,” Medical Engineering & Physics, vol. 46. Elsevier BV, pp. 63–70, Aug. 2017. doi: 10.1016/j.medengphy.2017.06.008.

Motivation and Background

- Accurate simulations of microwave ablation antennas are essential for optimizing their design, predicting thermal distribution and improving clinical outcomes.
- We want to test and show capabilities of QuickWave FDTD simulator in simulating the MWA and further improve it.
- As a benchmark, we shall use designs and additional material parameters from paper [2].

Antenna Design [2]



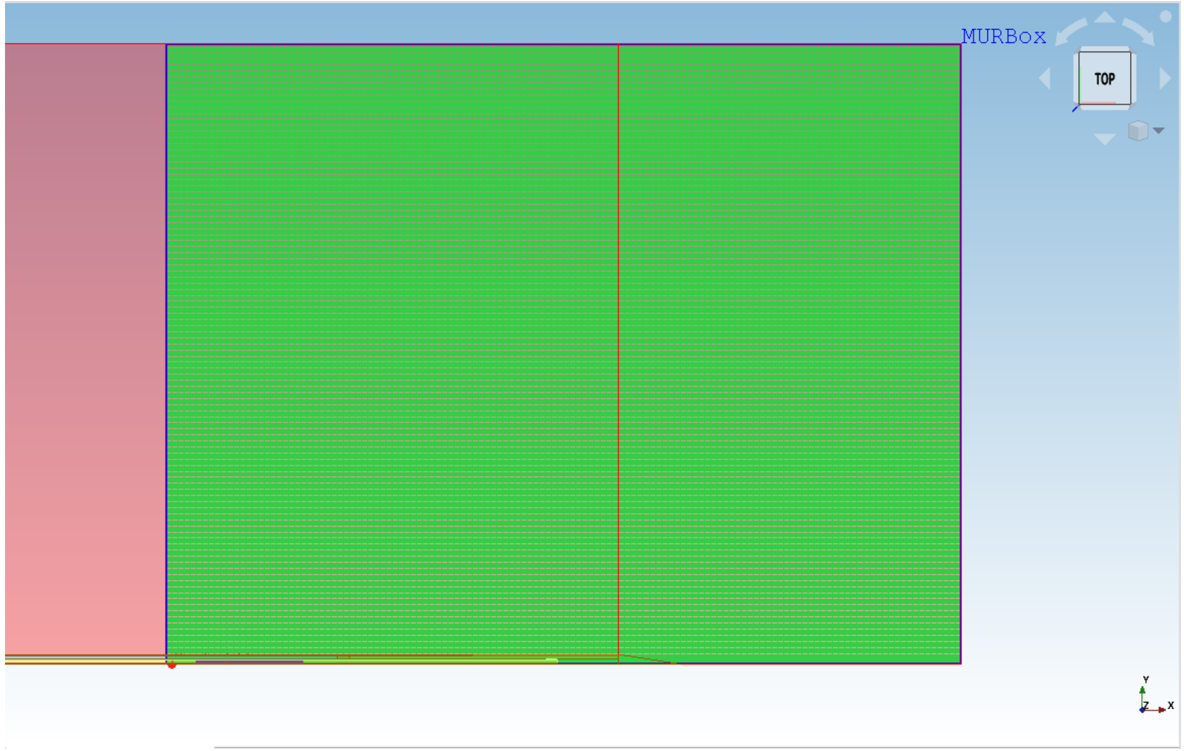


Medium	PTFE	Alumina
Permittivity	2.2	10

Choke	**Arm**	**Tip**	**Cap Base**	**Cap Point**
10 mm	6 mm	1 mm	5 mm	5 mm

	ε_r	σ (S/m)	ρ (kg/m³)	C (J/kg·°C)	K (J/s·m·°C)
Liver	43.03	1.69	1041	3600	0.51

Antenna Model in QW



BOR V2D

Cell size: dx = 0.5 mm
dy = 0.1 mm

Number of cells with boundaries:136144
Project size (RAM): ~13 MB
Whole model size: 80 mm x 50 mm
Length of the antenna: 57 mm

TEM field at 2.45 GHz
Heating: 15 min – 20 W

Antenna Model in QW

The QW-BHM is a heating module that was used in several projects before [1, 3].

The three different setups were applied:

- Neumann Boundary Condition without heatflow
- Neumann Boundary Condition with heatflow
- Neumann Boundary Condition with heatflow and temperature-dependent liver parameters

Antenna Model in QW

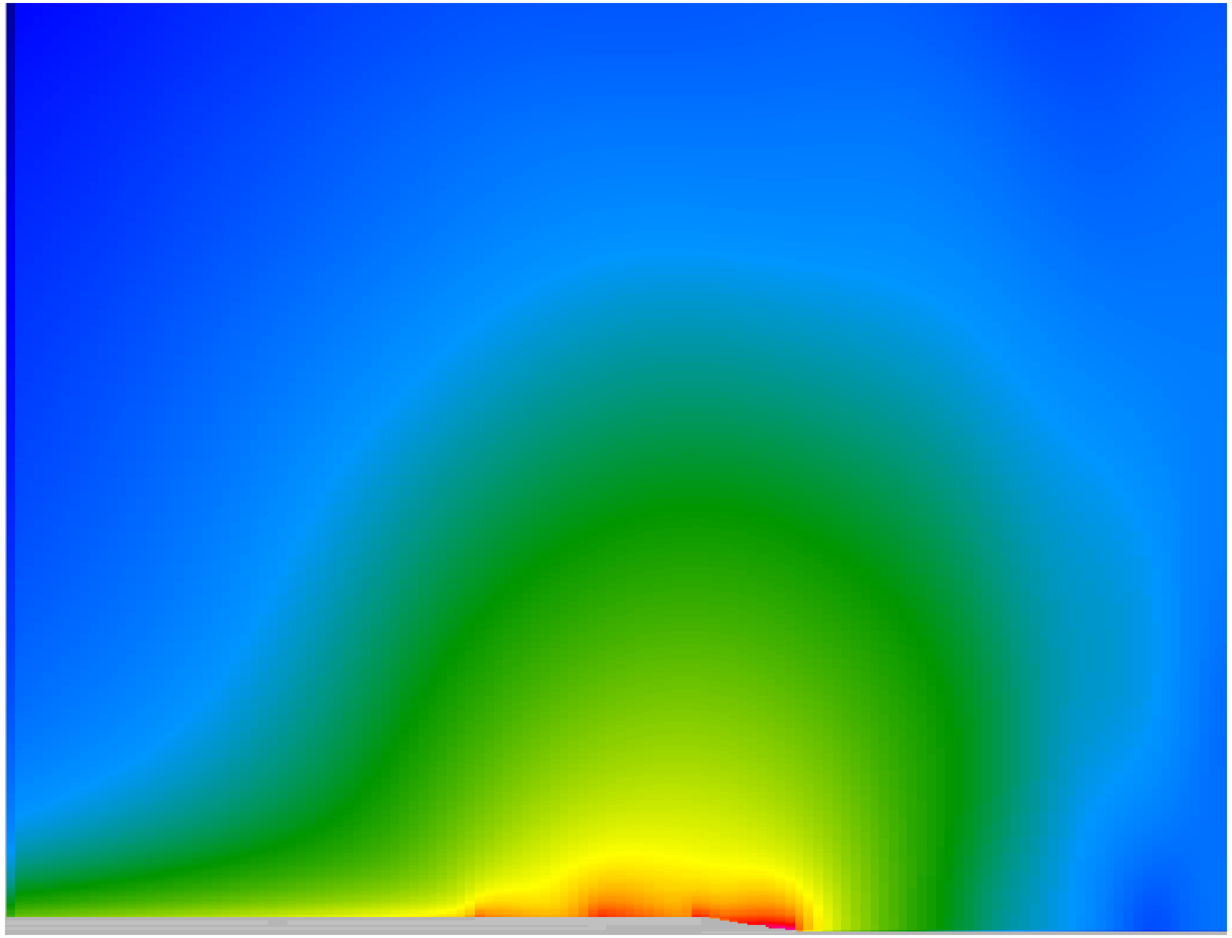
Temperature-Dependent parameters of the liver

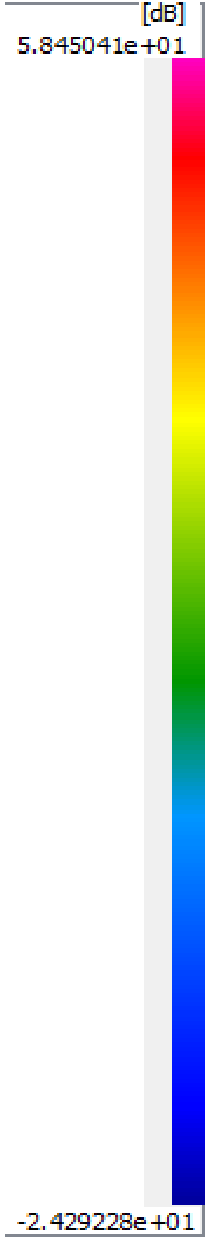
```
# DATA FROM -20 C to +80 C, dH/dV in J/cm3 reversedEnth/Temp column
!Temperature     Enthalpy        EPa              SIGa     SpecHeat Density   Ka
# Data deg C     J/cm3                            S/m
-20              0               4.9              0.064    2.21     1.041    0.0051
-15              14.0            5.5              0.093    2.21     1.041    0.0051
-10              34.4            6.1              0.153    2.21     1.041    0.0051
-5               71.4            12.3             0.573    2.21     1.041    0.0051
-3               110.4           22.0             1.118    2.21     1.041    0.0051
-2.2             144.4           30               1.636    2.21     1.041    0.0051
-1.6             192.4           42               2.113    2.21     1.041    0.0051
-1.3             240.4           46               2.385    2.21     1.041    0.0051
-1.1             274.4           48.9             2.426    2.21     1.041    0.0051
-1.0             288.4           49.2             2.440    2.21     1.041    0.0051
10               327.9           48.9             2.317    2.21     1.041    0.0051
20               382.9           48.2             2.194    2.21     1.041    0.0051
35               450.4           46.9             2.072    2.21     1.041    0.0051
50               517.9           45.5             1.949    2.21     1.041    0.0051
65               585.4           43.6             1.922    2.21     1.041    0.0051
80               652.9           41.7             1.908    2.21     1.041    0.0051
```

Each values of the parameters are defined for each value of the temperature

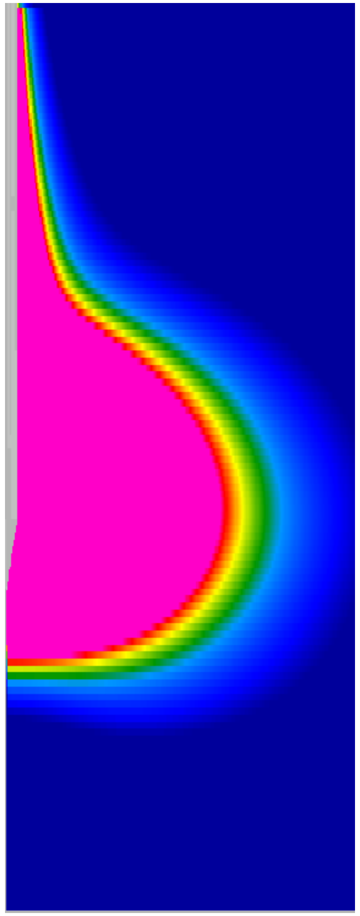
Measurements & refinements by Per O Risman, Microtrans AB, Sweden

Results -Average SAR Distrubutions

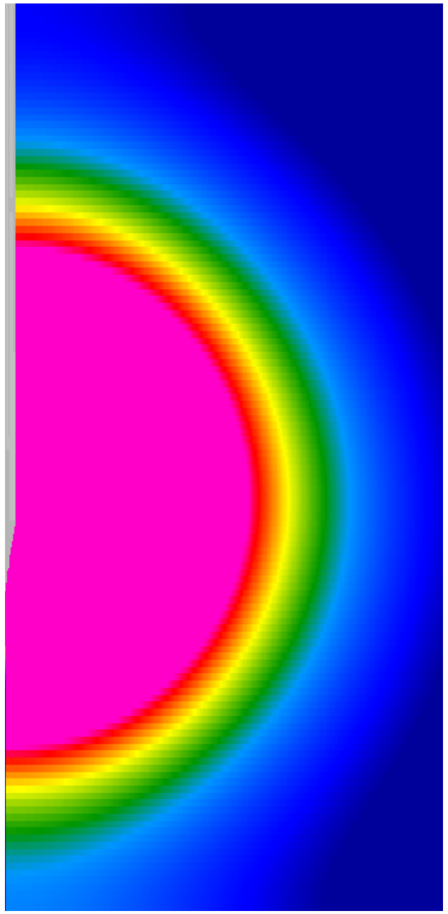




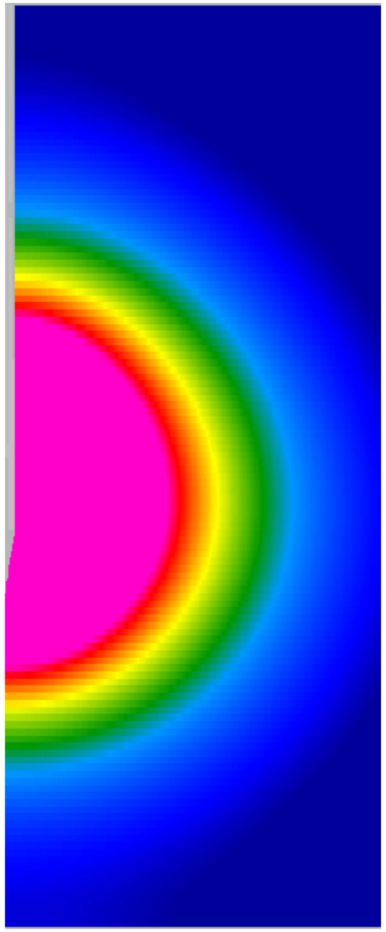
Results - Ablation Zones



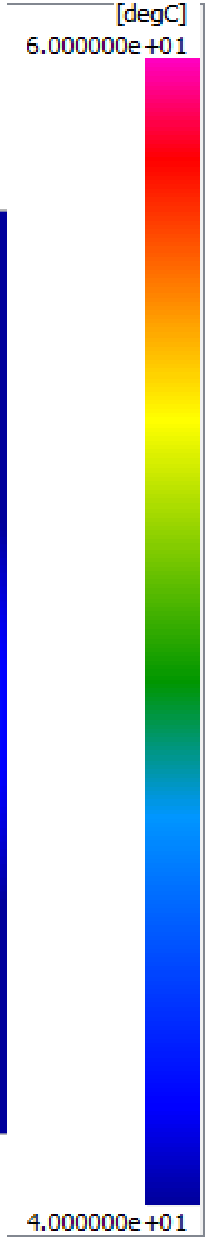
NBC w/o HF



NBC with HF



NBC with HF and TD parameters



The maximum is set to 60°C so the ablation zones can be clearly visible

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Results - Ablation Zones

Ablation Zones Dimensions.

	Length x Diameter (mm)
Experiment	38 x 31
NBC+HF	36 x 35.48
NBC	— x 31.28
NBC+HF+TD material parameters	25 x 23.08

Using the heat distribution, ablation zones (≥ 60˚C) were determined.

In that case it is impossible to determine the length of the AZ cause to its irregular shape.

Conclusions

- The difference between the results may have several reasons like innacurate experimental methods and due to differences in the parameters of the real liver and those assumed in the model
- Adding the bio-heat equation to BHM should make the results more precise
- Further works requires an experimental method that will allow for more precise determination of the ablation zone and parameters of the liver or other samples

We are open to new collaborations!

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