Czech Technical University in Prague
Faculty of Electrical Engineering
Department of Electromagnetic Field

Complex permittivity measurement of agar phantom at different temperatures

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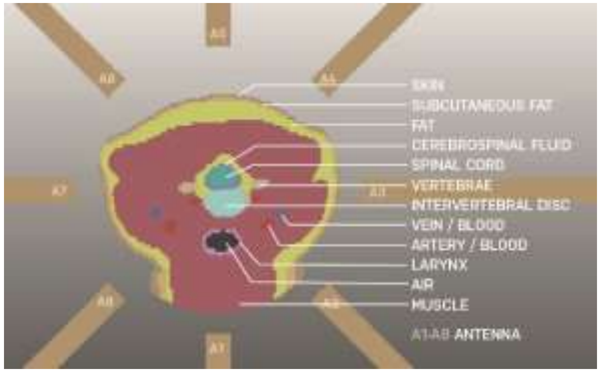
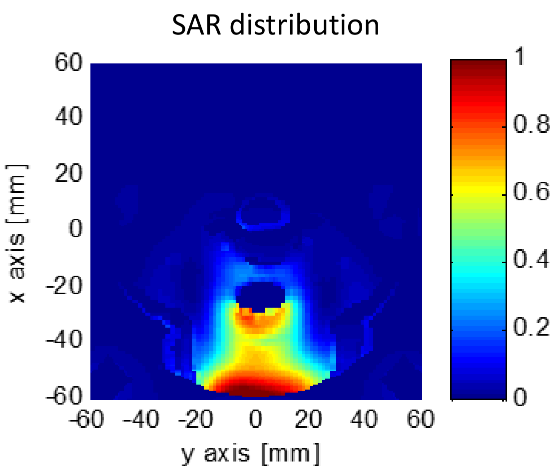
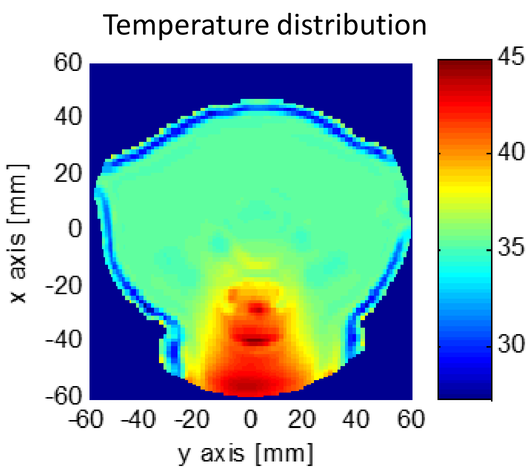
Introduction / Motivation / My Work

Microwave hyperthermia - Numerical simulations, power focusing

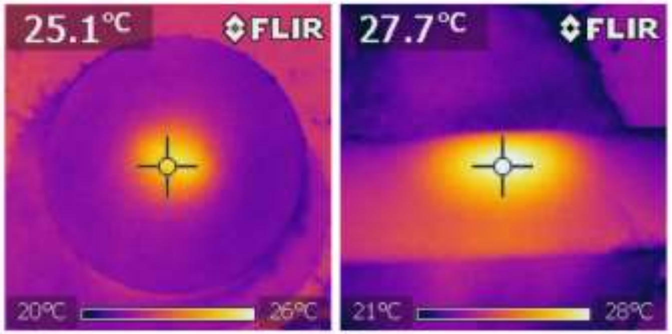


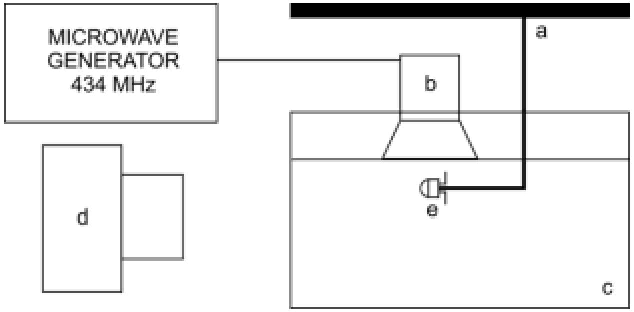


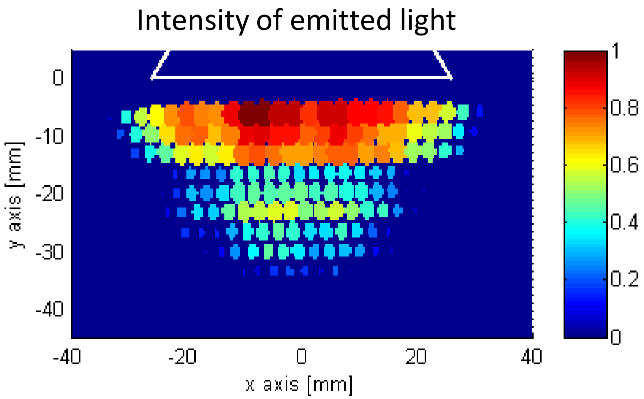


Introduction / Motivation / My Work

Microwave hyperthermia – Applicators design and its testing

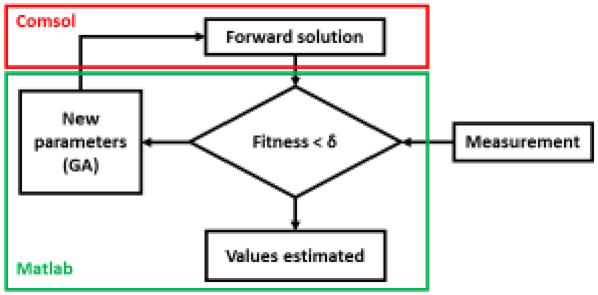


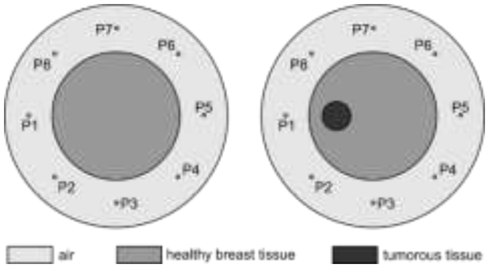




Introduction / Motivation / My Work

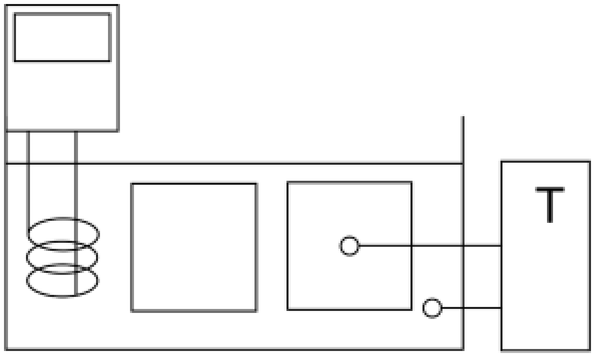
- **Microwave tomography –** reconstruction algorithms, hardware design



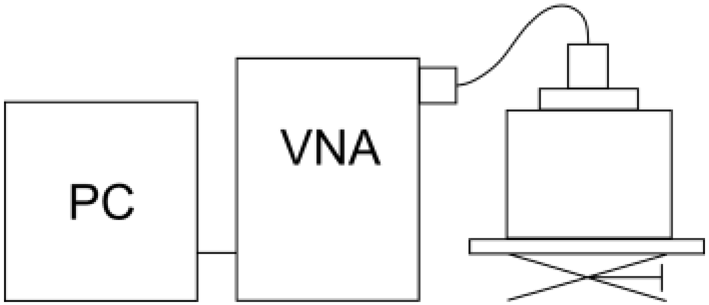


Measuring Setup

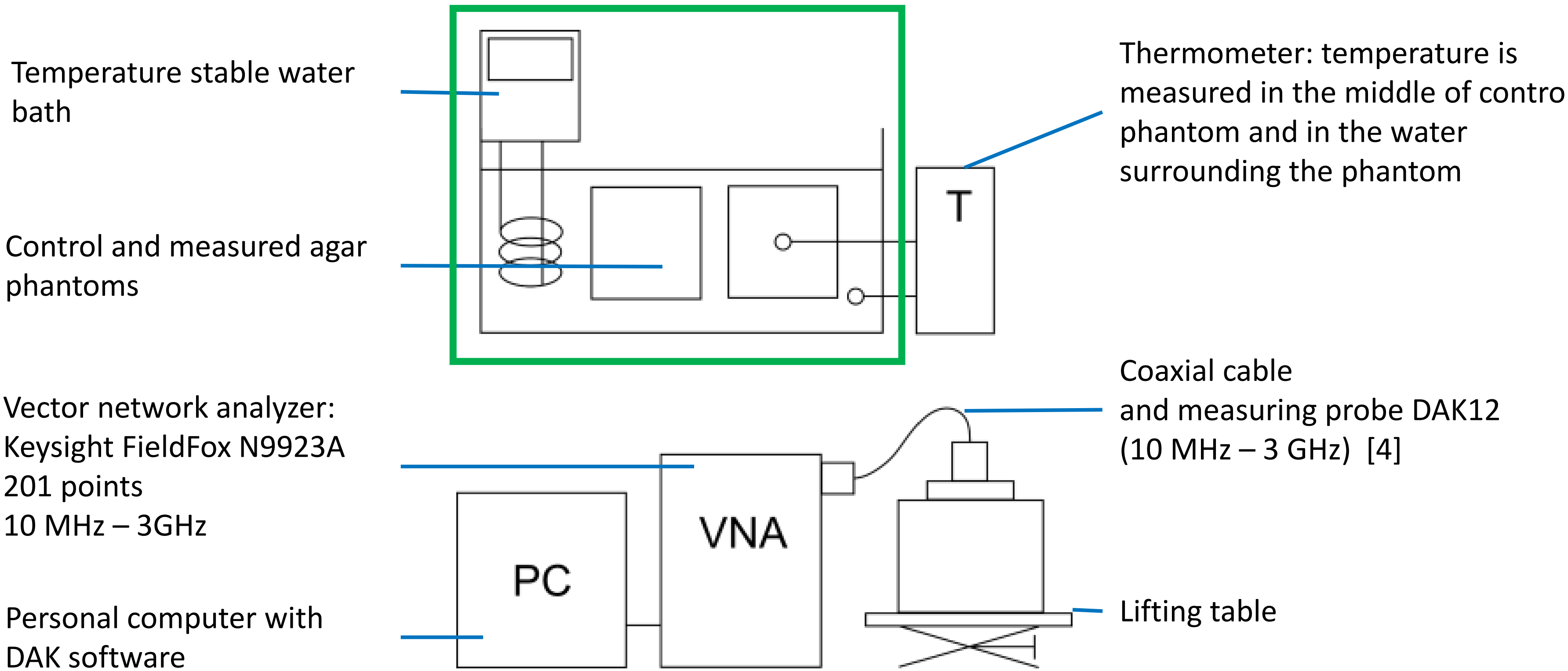
Heating part



Measuring part



Measuring Setup



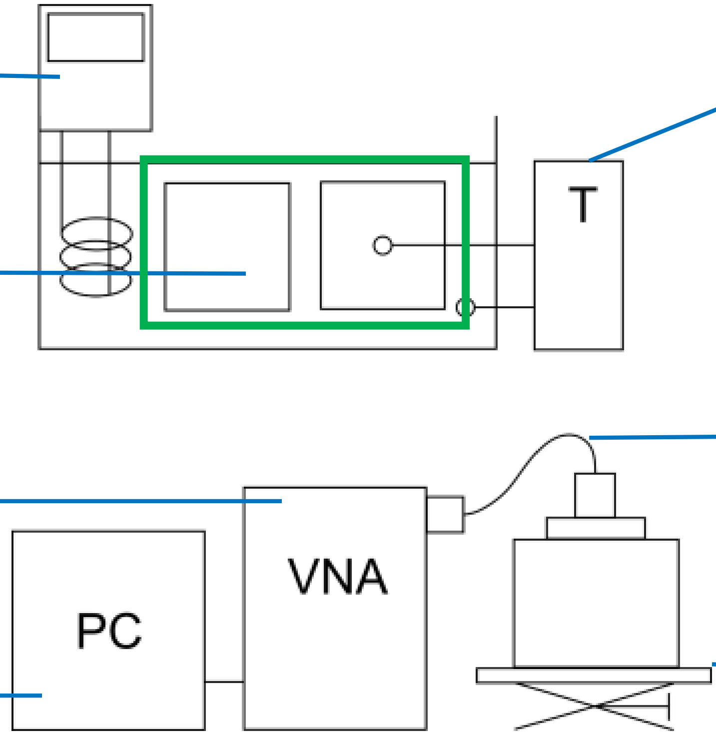
Measuring Setup

Temperature stable water bath

Control and measured agar phantoms

Vector network analyzer:
Keysight FieldFox N9923A
201 points
10 MHz – 3GHz

Personal computer with DAK software



Thermometer: temperature is measured in the middle of control phantom and in the water surrounding the phantom

Coaxial cable
and measuring probe DAK12
(10 MHz – 3 GHz) [4]

Lifting table

Measuring Setup

Temperature stable water bath

Control and measured agar phantoms

Vector network analyzer:
Keysight FieldFox N9923A
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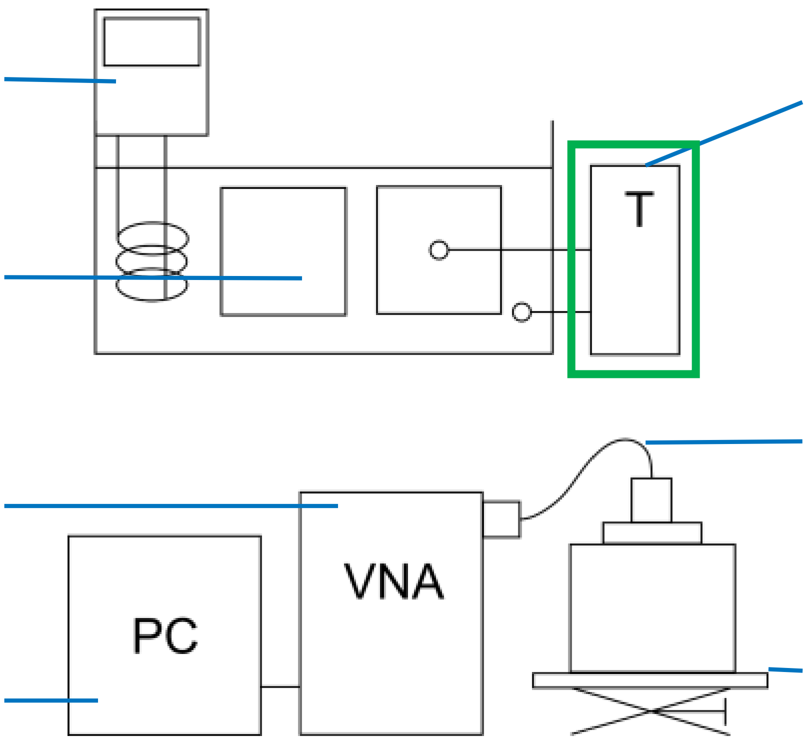

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Lifting table

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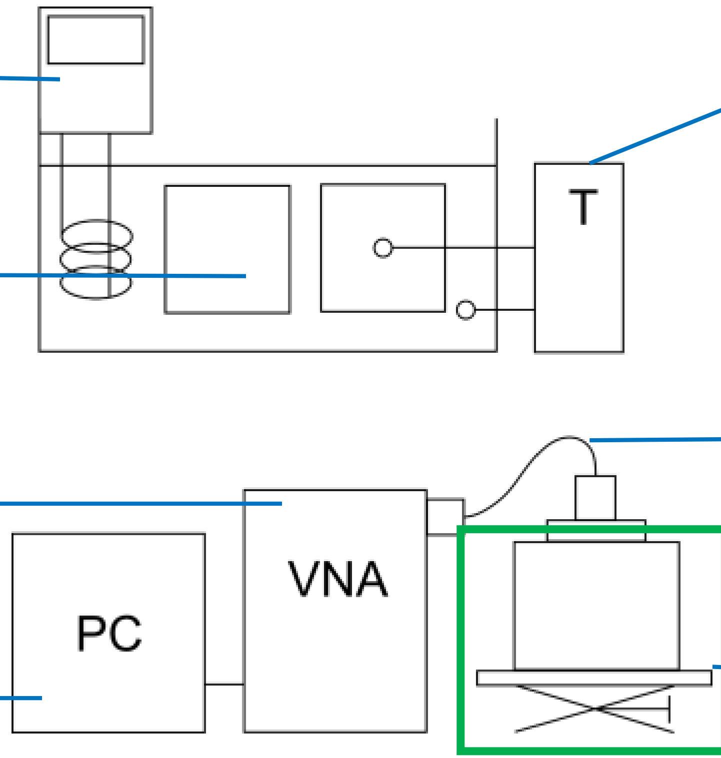

Thermometer: temperature is measured in the middle of control phantom and in the water surrounding the phantom

Coaxial cable
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(10 MHz – 3 GHz) [4]

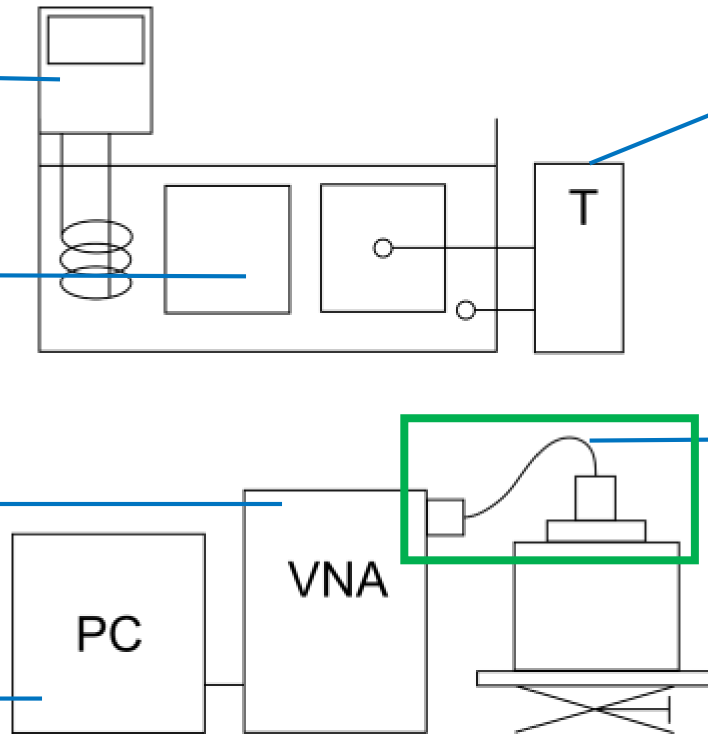
Lifting table + phantom

Measuring Setup

Temperature stable water bath

Thermometer: temperature is measured in the middle of control phantom and in the water surrounding the phantom

Control and measured agar phantoms



Coaxial cable
and measuring probe DAK12
(10 MHz – 3 GHz) [4]

Vector network analyzer:
Keysight FieldFox N9923A
201 points
10 MHz – 3GHz

Lifting table

Personal computer with
DAK software

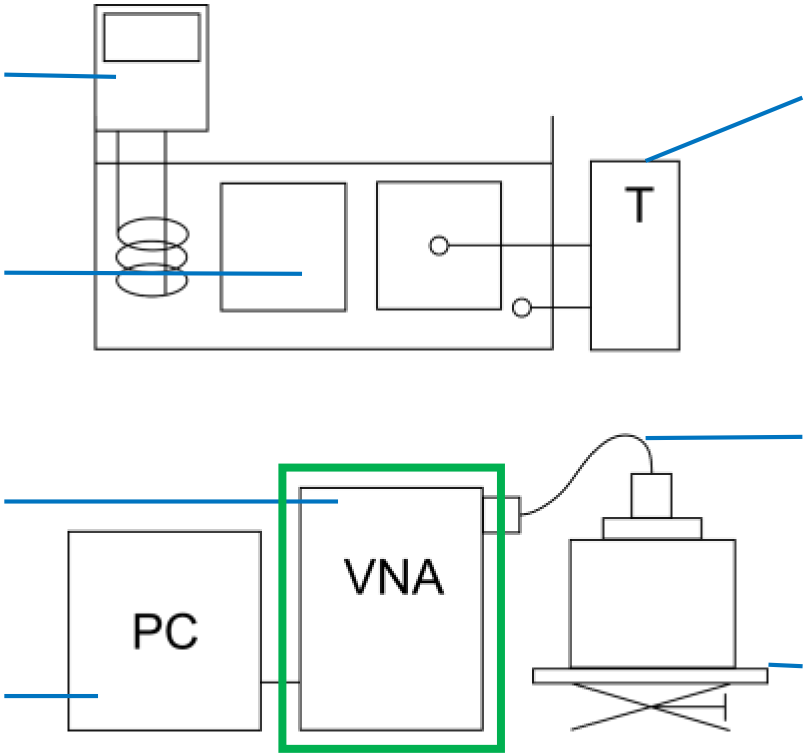
Measuring Setup

Temperature stable water bath

Control and measured agar phantoms

Vector network analyzer:
Keysight FieldFox N9923A
201 points, linear scale
10 MHz – 3GHz

Personal computer with DAK software



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Lifting table

Measuring Setup

Temperature stable water bath

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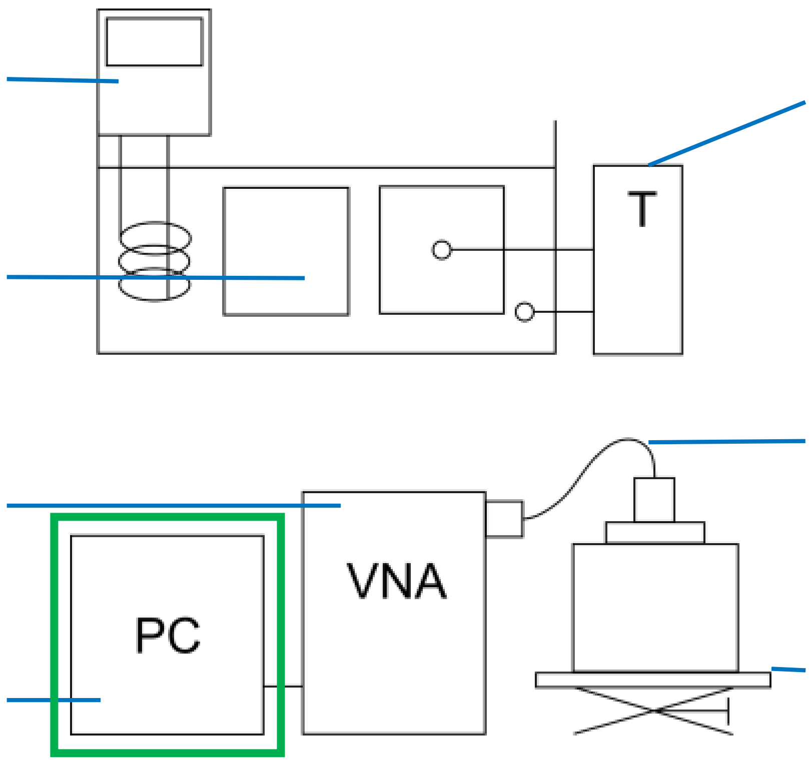

Thermometer: temperature is measured in the middle of control phantom and in the water surrounding the phantom

Coaxial cable
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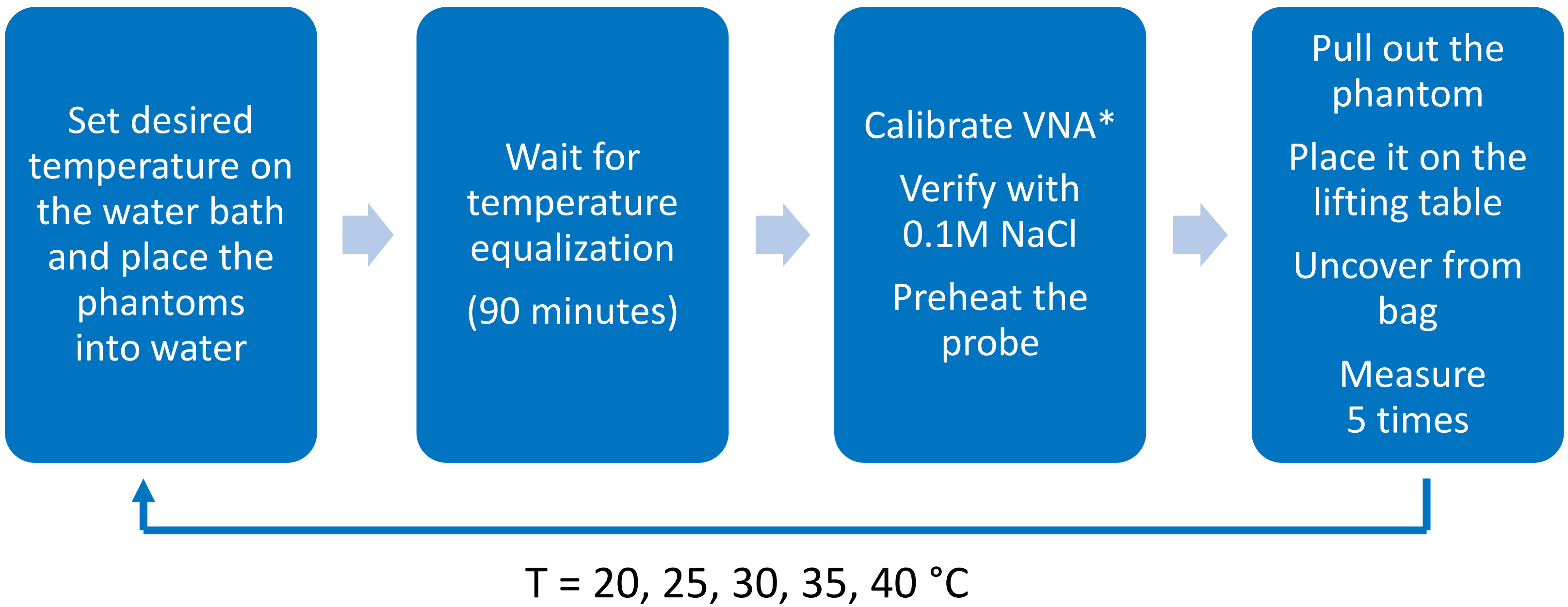
Lifting table

Measuring Setup

Measuring Procedure

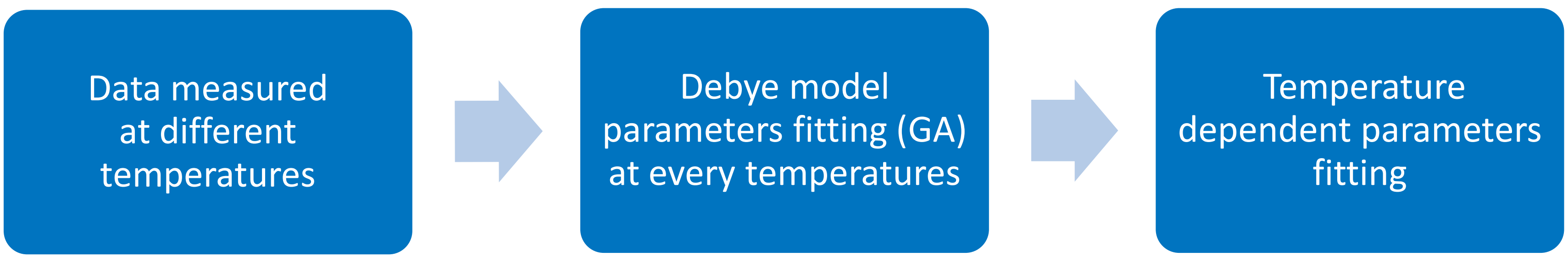


*calibration using deionized water – diameter 20 cm, height 11 cm

Model Parameters Fitting Procedure

- Temperature dependent model:

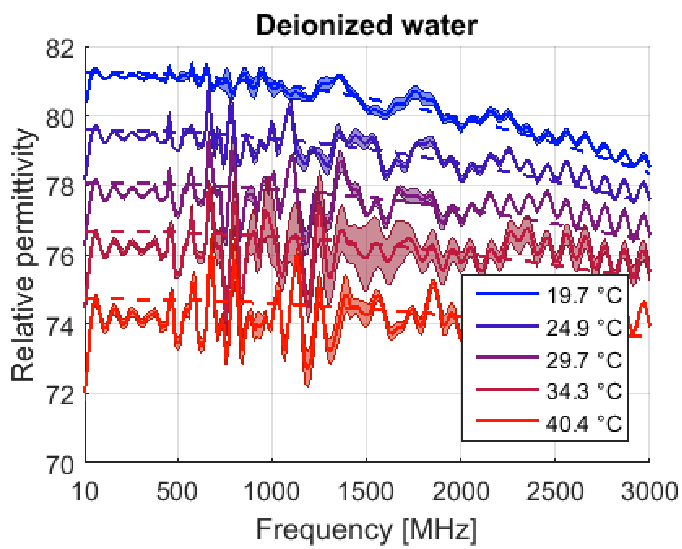
$$\hat{\varepsilon}(\omega, t) = \varepsilon_{\infty}(t) + \frac{\varepsilon_{\infty}(t) - \varepsilon_{s}(t)}{1 + j\omega\tau(t)} + \frac{\sigma_{i}(t)}{j\omega\varepsilon_{0}}$$

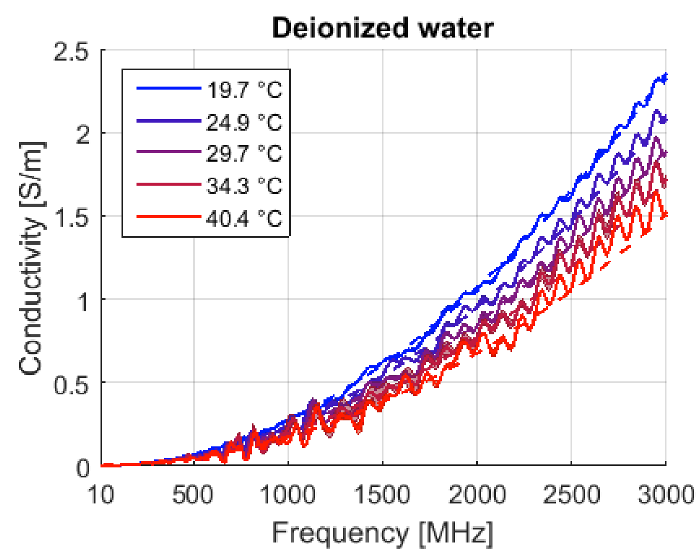


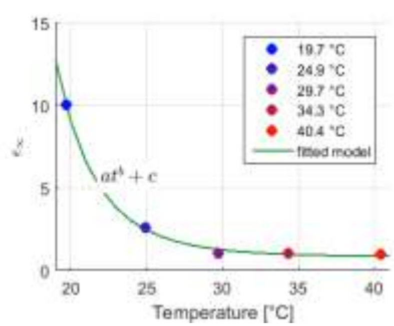
T = 20, 25, 30, 35, 40 °C

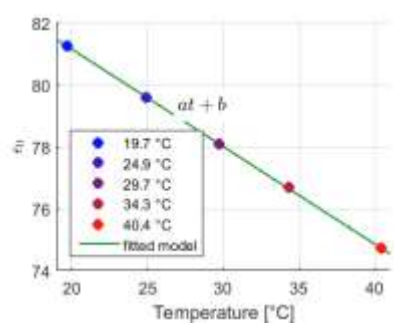
- M. Lazebnik, M. C. Converse, J. H. Booske, and S. C. Hagness, “Ultrawideband temperature-dependent dielectric properties of animal liver tissue in the microwave frequency range,” Phys Med Biol, vol. 51, no. 7, pp. 1941–1955, Apr. 2006.
- F. Krewer, F. Morgan, and M. O’Halloran, “DEVELOPMENT OF ACCURATE MULTI-POLE DEBYE FUNCTIONS FOR ELECTROMAGNETIC TISSUE MODELLING USING A GENETIC ALGORITHM,” Progress In Electromagnetics Research Letters, vol. 43, pp. 137–147, 2013.

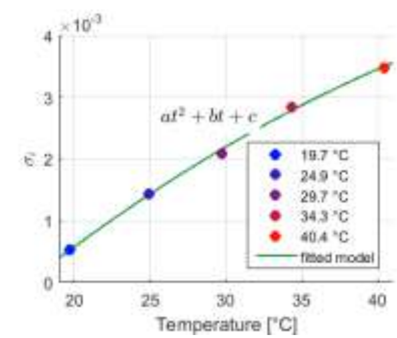
Measured Data And Fitting Procedure

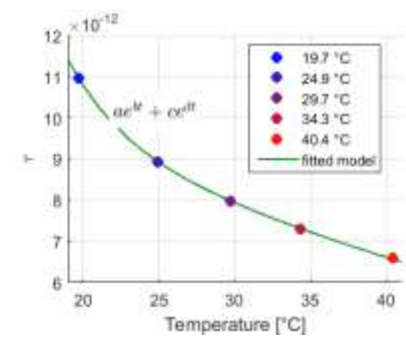






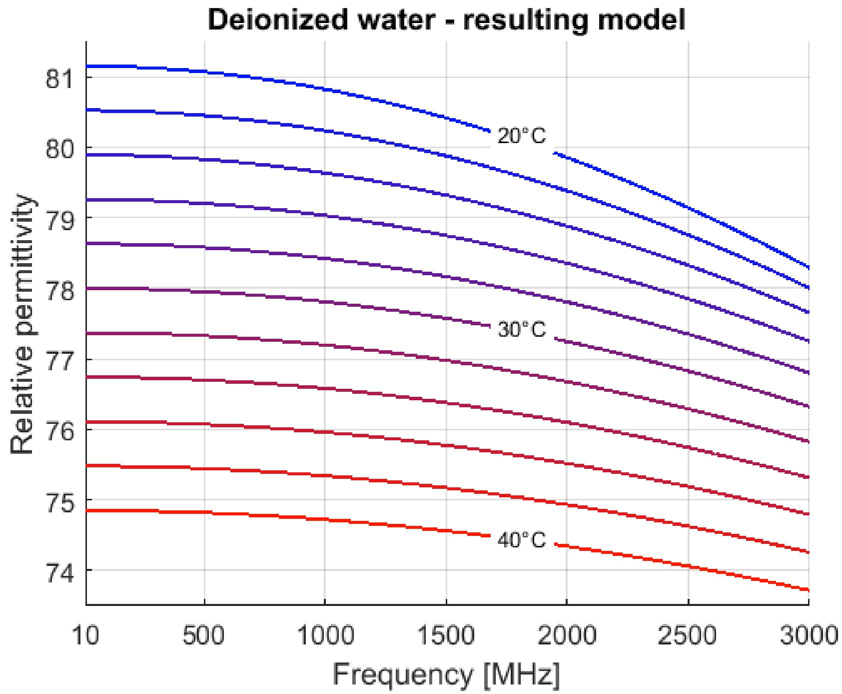


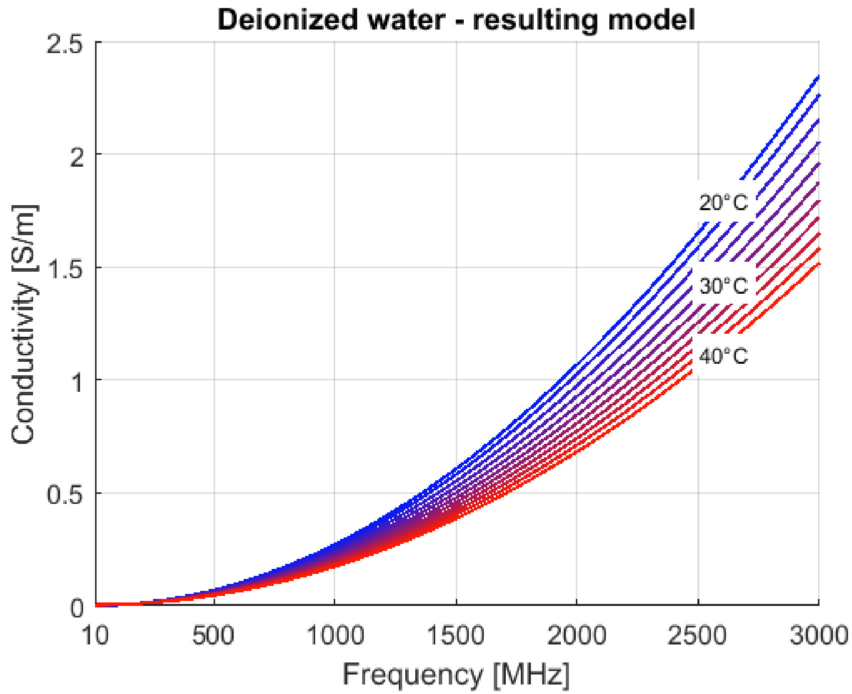




$$\hat{\varepsilon}(\omega,t) = \varepsilon_\infty(t) + \frac{\varepsilon_\infty(t)-\varepsilon_s(t)}{1+j\omega\tau(t)} + \frac{\sigma_i(t)}{j\omega\varepsilon_0}$$

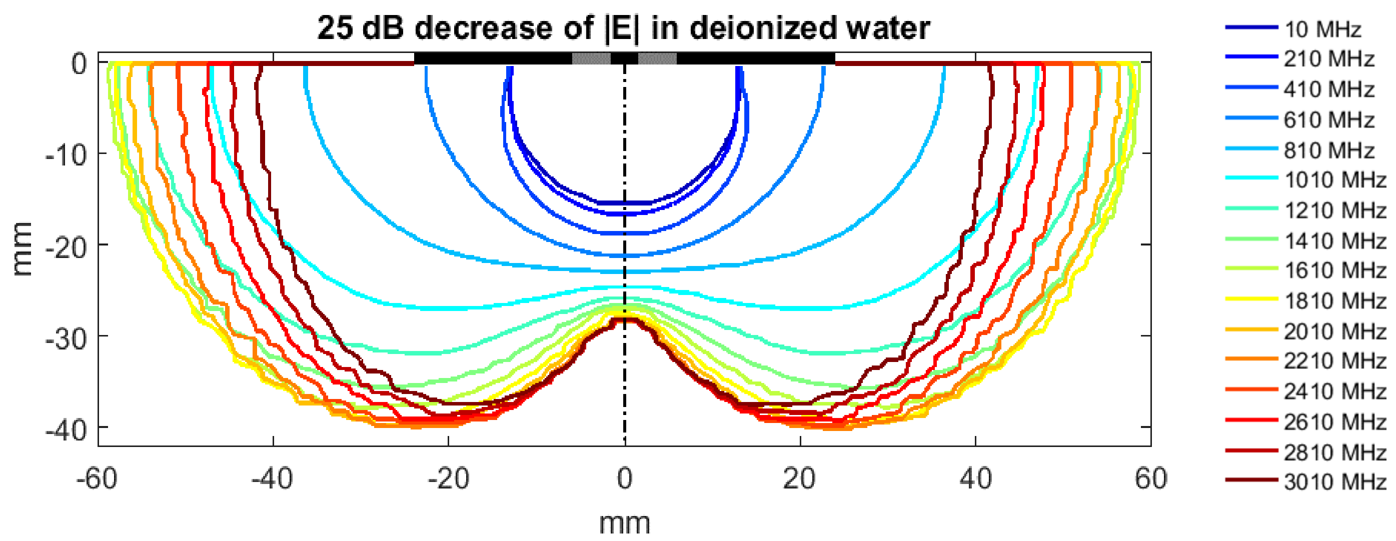
Deionized Water – Resulting Model





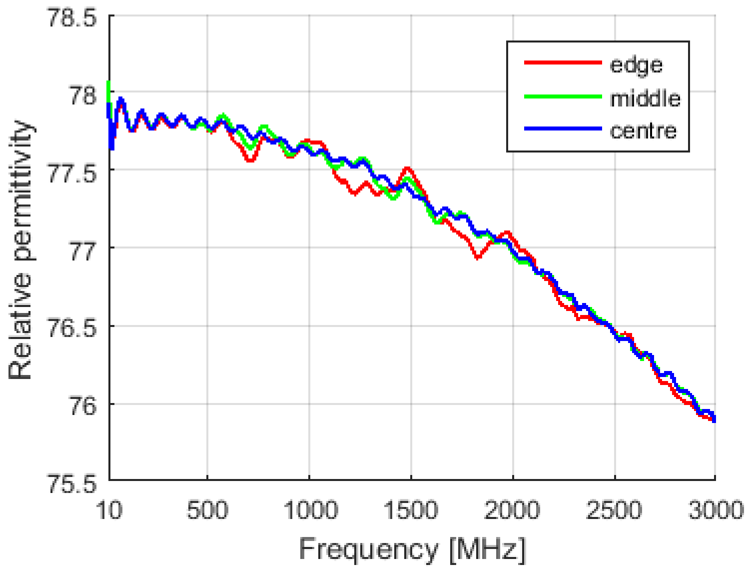
Sensing Volume of the Probe - Deionized Water

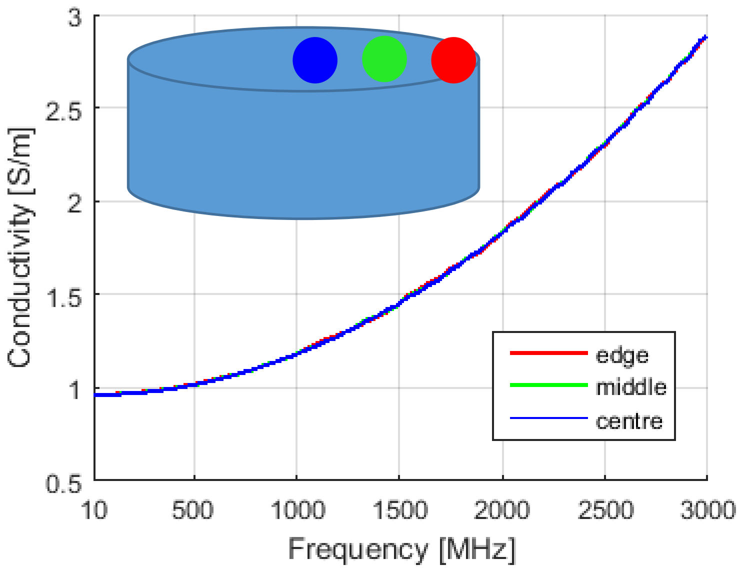
- Curves are noisy + position and size of peaks depend on the position of the probe
- Minimal size of the sample (measured with 11x20cm)?
- Probe facing into cylinder filled with deionized water
- Numerical simulations of EM field
- Frequency band 10-3000 MHz with 200 MHz steps



Calibration with 0.1M NaCl

- In order to avoid reflections from the boundaries of the sample
- Thanks to higher conductivity – smaller sample should be sufficient for calibration
- Model of 0.1 M NaCl solution has to be implemented and imported*
- Smaller spikes
- Boundaries are still visible for the probe

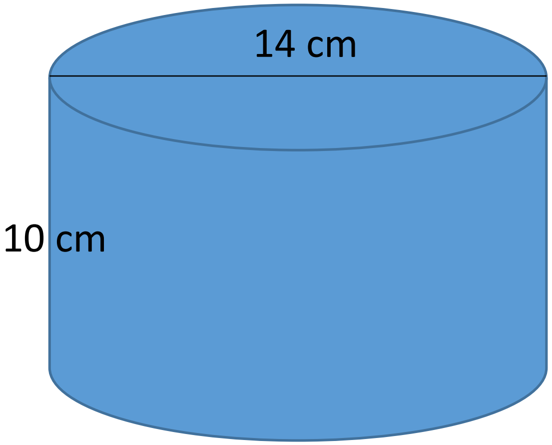




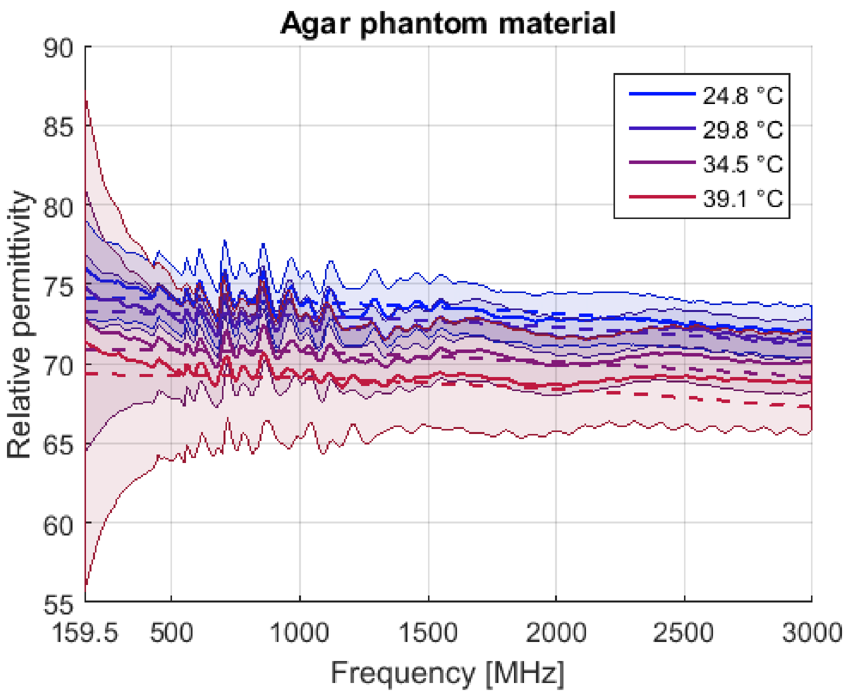
Peyman et al. 2007, Complex permittivity of sodium chloride solutions

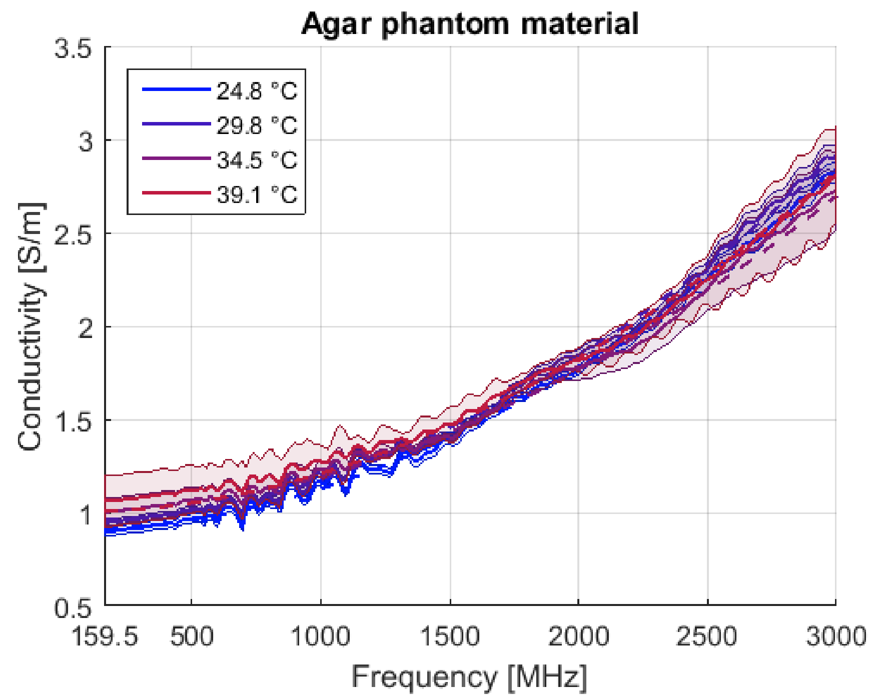
Agar phantom

- Used in MWH for testing of applicators
- Should simulate human muscle tissue
- Easy to prepare and use
- Mixture of deionized water, NaCl and agar powder
- Heat up to 90 °C + continuous mixing
- Cylindrical shape



Agar phantom - results





- Much higher uncertainty -> temperature dependent model was not developed
- The average change in dielectric constant (real part of relative complex permittivity) equals to **0.3 per 1°C and 0.013 S/m per 1 °C** in conductivity (depending on frequency)

Main Challenges – Sources of Uncertainty

- **Homogeneously heating up** the samples which must be of size given by sensing volume of the used probe
- Avoid **air bubbles** between the flange of the probe and the agar phantom
- Avoid **cooling of the sample** during the measurement cause by the probe and by the environment / continuous changes can be observed
- **Dimension changes of the probe** cause by temperature changes – calibrate at measured temperature?
- Keeping **the pressure between the probe** and the sample constant to avoid releasing of water from the agar phantom (probe dependent) / continuous increasing in CP can be observed. More stable phantom?
- What **size of the sample** should we use?
- What **model of material** and what **number of poles?**

Conclusion

- **Temperature dependent parameters** of one pole Debye model **were estimated** only for deionized water. Model correlates with well known model.

- **The sample** of deionized water with a shape of cylinder higher than 11 cm and with diameter longer than 20 cm **is not sufficient for calibration**.

- **Expanded uncertainty covers almost all the variations caused by temperatures changes in agar phantom**. However, we can say that the average change in dielectric constant (real part of relative complex permittivity) equals to **0.3 per 1°C and 0.013 S/m per 1 °C in conductivity** (depending on frequency).

Acknowledgment

COST Action BM1309: European network for innovative uses of EMFs in biomedical applications (EMF-MED)

COST Action TD1301: Accelerating the Technological, Clinical and Commercialization Progress in the Area of Medical Microwave Imaging

National University of Ireland in Galway

Czech Technical University in Prague

Thank You for Your Attention

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