Dielectric Properties of Biological Tissue: A Review on the Methods and Challenges

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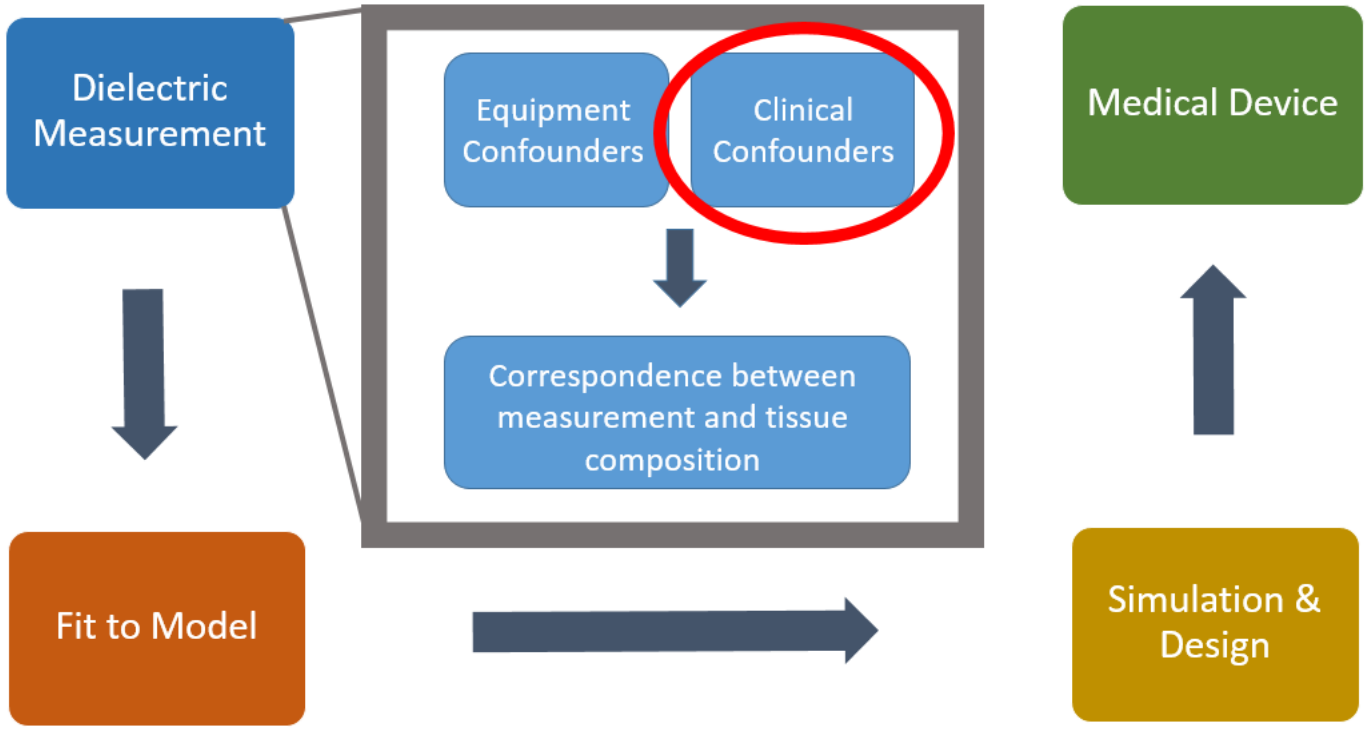
Technology Development Process



Outline

- Background
- Measurement techniques
- Potential sources of error
- Ex-vivo measurements and true dielectric properties: correlation?
- Challenges in In-Vivo Measurements
- Summary

Background

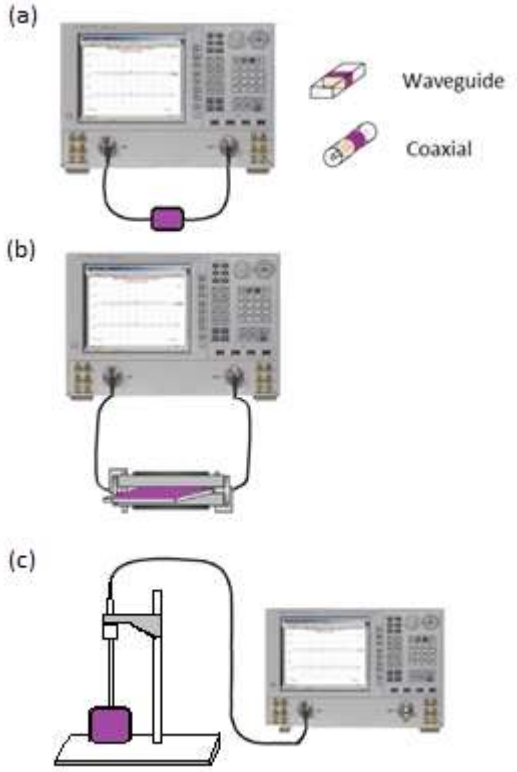
- Applications: dosimetry -> medical diagnostics and therapeutics
- True dielectric properties are essential
- Most of the measurements are performed on excised tissue
- Assumption: dielectric properties of excised tissue reflect actual properties of the tissue in body

Measurement Techniques

a) Transmission Line

b) Resonant Cavity

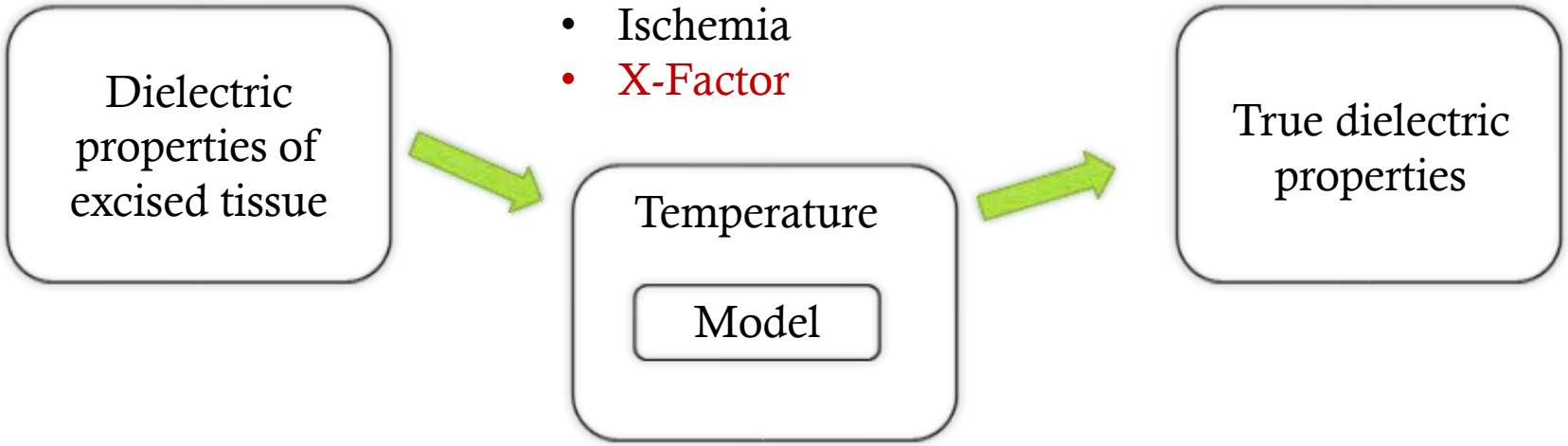
c) Open-ended Coaxial Probe
   - Simple Setup
   - Minimal Sample Handling
   - Non-destructive
   - Broadband



Agilent 2000 [1]

Potential Sources of Error

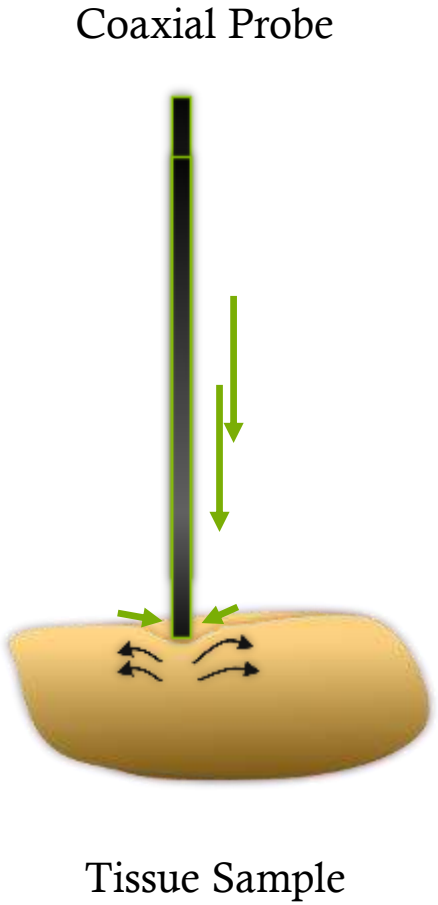
- Probe-tissue contact
- Probe pressure
- Tissue dehydration
- Surface fluids
- Ischemia
- X-Factor



Contact, Pressure, and Surface Fluids

1. Clean and dry surface
   - Fluids are squeezed away under probe tip
   - Abnormal decrease in the amount of fluid within sensing region

2. Wet surface (blood, body fluids)
   - Fluids gather around the probe tip
   - Abnormal increase in the amount of fluid within sensing region



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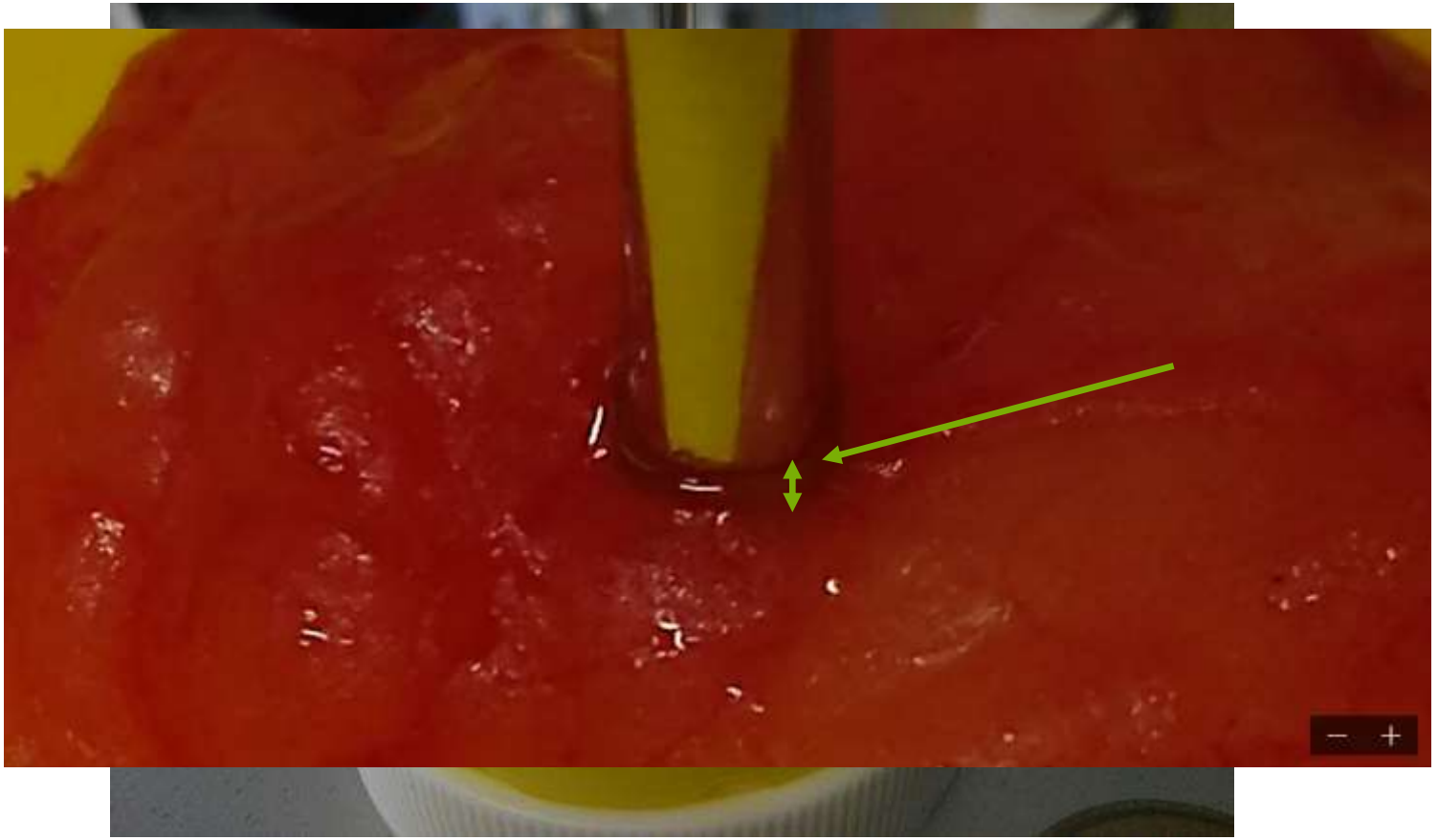
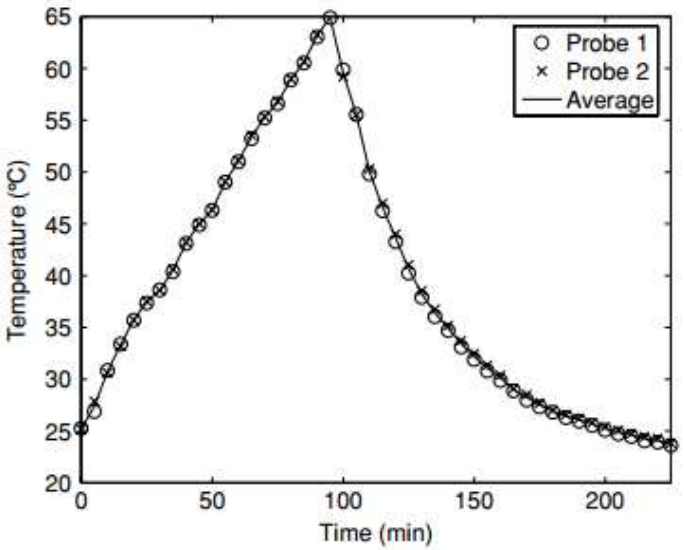


Modeling the Temperature Effects

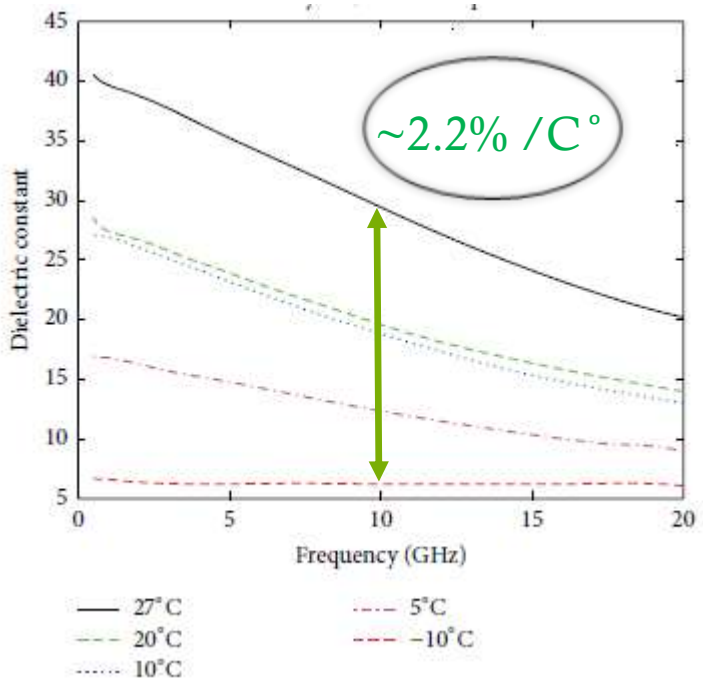
- Excised tissue is heated or cooled
- Artificial heating/cooling
  - Tissue structure can be damaged
  - May have different effect in contrast to natural convection through ambient temperature



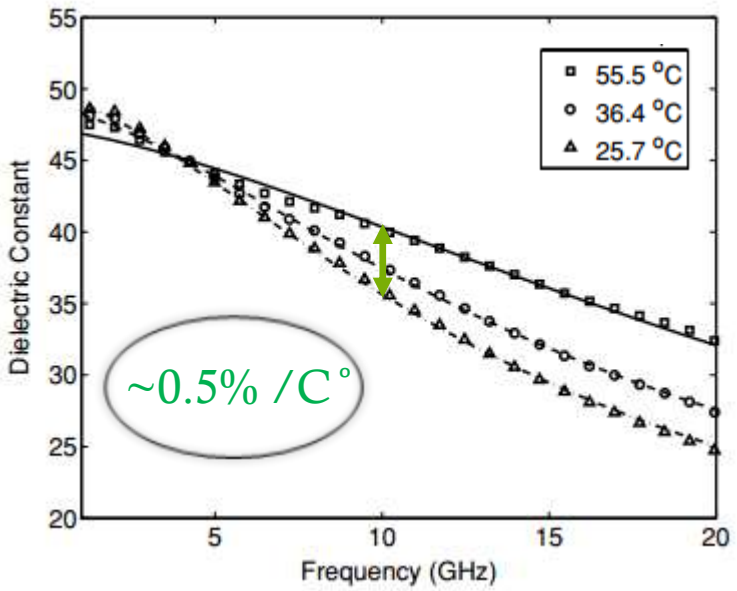
Lazebnik *et al.* 2006 [4]

Modeling the Temperature Effects

Cooling Cycle



Sabouni *et al.* 2013 [5]



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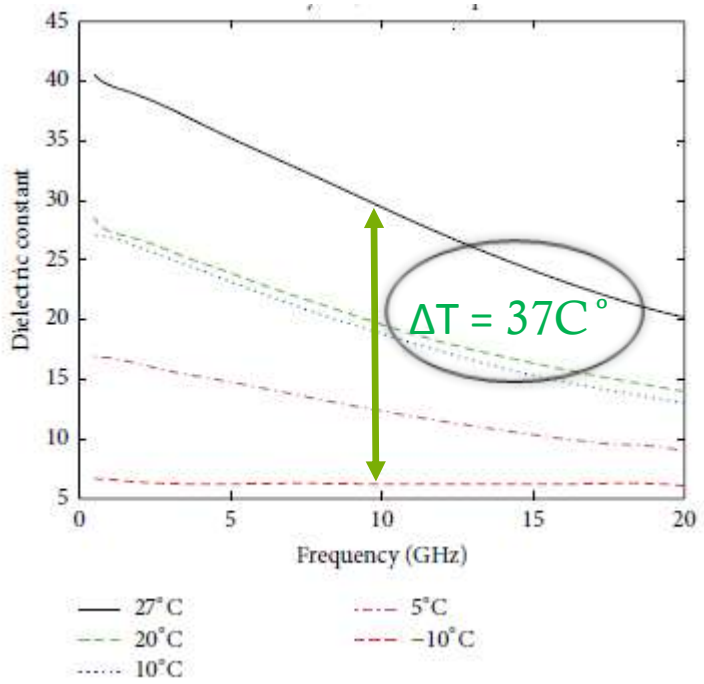
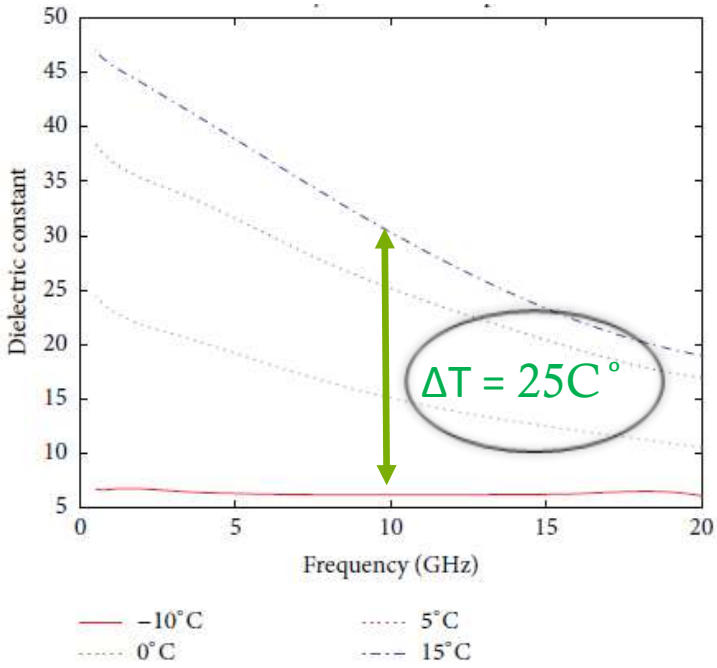
Modeling the Temperature Effects

Cooling Cycle

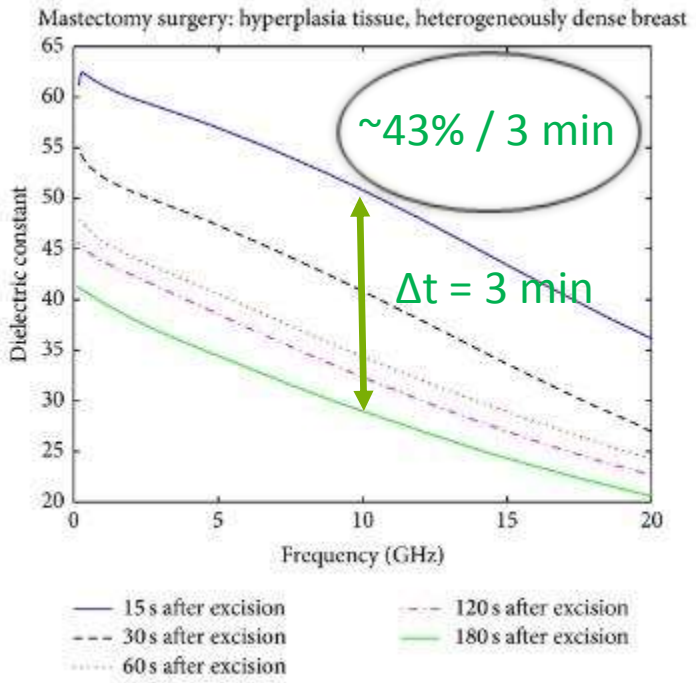


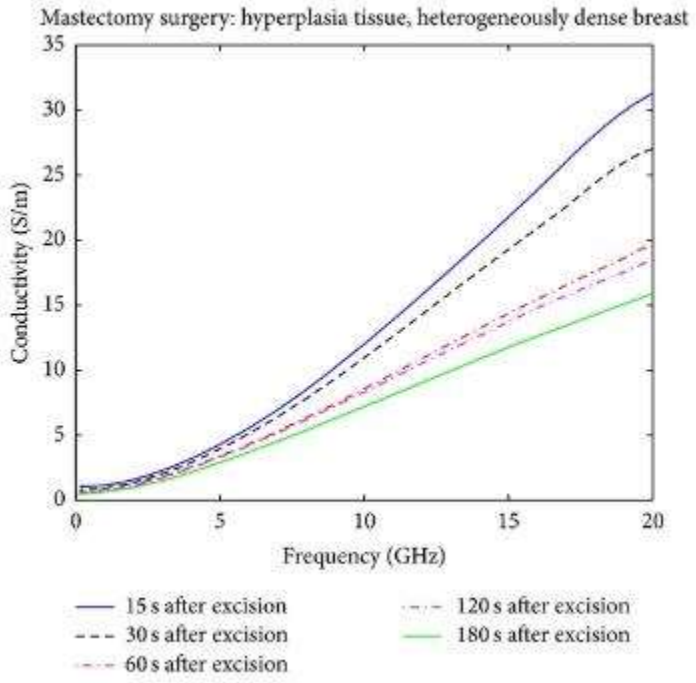
Heating Cycle



Sabouni *et al.* 2013 [5]

X-Factor





Sabouni *et al.* 2013 [5]

- Most of the dielectric measurements on excised tissue are performed over the period of 5min-5hrs

Correlation Between Ex-Vivo Measurements and True Dielectric Properties?

- Can we model the correlation between ex-vivo measurements and true dielectric properties?
  - In presence of multiple clinical confounders
  - Without accurate (and reliable) temperature model
  - In presence of X-Factor

Challenges in In-vivo Tissue Dielectric Measurements

- Health and safety requirements
- Probe contact
- Tissue surface fluids
- Cable movements
- Anisotropic tissue
- Influence of surrounding tissue
- Tissue marking and histopathology

Summary

- True dielectric properties are essential for wide range of application
- Most of the existing data is based on ex-vivo measurements
- In-vivo measurements on human is challenging – can we overcome these challenges?
- Can we find a correlation between ex-vivo and true dielectric properties?

Thank you!

References:

[1] Note, Application. "Basics of measuring the dielectric properties of materials." Agilent Technologies (2000).
[2] T. Sugitani, et al., "Complex permittivities of breast tumor tissues obtained from cancer surgeries," Applied Physics Letters, vol. 104, no. 253702, pp. 1-5, 2014.
[3] Halter, Ryan J., et al. "The correlation of in vivo and ex vivo tissue dielectric properties to validate electromagnetic breast imaging: initial clinical experience." Physiological Measurement 30.6 (2009): S121.
[4] Lazebnik, Mariya, et al. "Ultrawideband temperature-dependent dielectric properties of animal liver tissue in the microwave frequency range." Physics in medicine and biology 51.7 (2006): 1941.
[5] Sabouni, Abas, et al. "Study of the effects of changing physiological conditions on dielectric properties of breast tissues." ISRN Biomedical Imaging 2013 (2013).