EMERALD
ElectroMagnetic imaging for a novel genERation of medicAL Devices

Changes in the Dielectric Properties of ex-vivo Ovine Kidney Before and After Microwave Thermal Ablation

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Microwave Thermal Ablation (MTA)

Microwave Thermal Ablation (MTA):

- Minimally invasive
- EM energy applied by MW antenna
- High localized temperature increase (> 50-60 °C)

Applications:

- Widely used in interventional oncology
- Clinical treatment of solid tumours in different organs
- Cardiac diseases
- Endometrium disorders
- Prostate hypertrophy

Relative permittivity and effective conductivity are important for MTA [1, 2]
→ They primarily determine the interaction between the deployed electromagnetic energy and the tissue

[1] V. Lopresto, R. Pinto, G. A. Lovisolo, and M. Cavagnaro, "Changes in the dielectric properties of ex vivo bovine liver during microwave thermal ablation at 2.45 GHz," Phys. Med. Biol., vol. 57, no. 8, pp. 2309–2327, Apr. 2012, doi: 10.1088/0031-9155/57/8/2309.
[2] C. L. Brace, "Radiofrequency and Microwave Ablation of the Liver, Lung, Kidney, and Bone: What Are the Differences?," Current Problems in Diagnostic Radiology, May 2009, doi: 10.1067/j.cpradiol.2007.10.001.

Dielectric Properties and MTA

- Dielectric properties affect EM propagation into the tissue

$$\nabla^2 \vec{E} = \mu \boldsymbol{\varepsilon} \frac{\partial^2 \vec{E}}{\partial^2 t}, \quad \nabla^2 \vec{B} = \mu \boldsymbol{\varepsilon} \frac{\partial^2 \vec{B}}{\partial^2 t}$$

and the antenna behaviour: changes in dielectric properties can induce antenna mismatch!

- Conductivity σ affects the specific absorption rate (SAR) deposition into the tissue

$$\boldsymbol{SAR} = \frac{\boldsymbol{\sigma}}{2\rho} \left| \vec{E} \right|^2$$

and in turn the temperature increase into the tissue

$$\rho c \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) - W \rho_{\mathrm{bl}} c_{\mathrm{bl}} (T - T_{\mathrm{bl}}) + Q + \rho \boldsymbol{SAR}$$

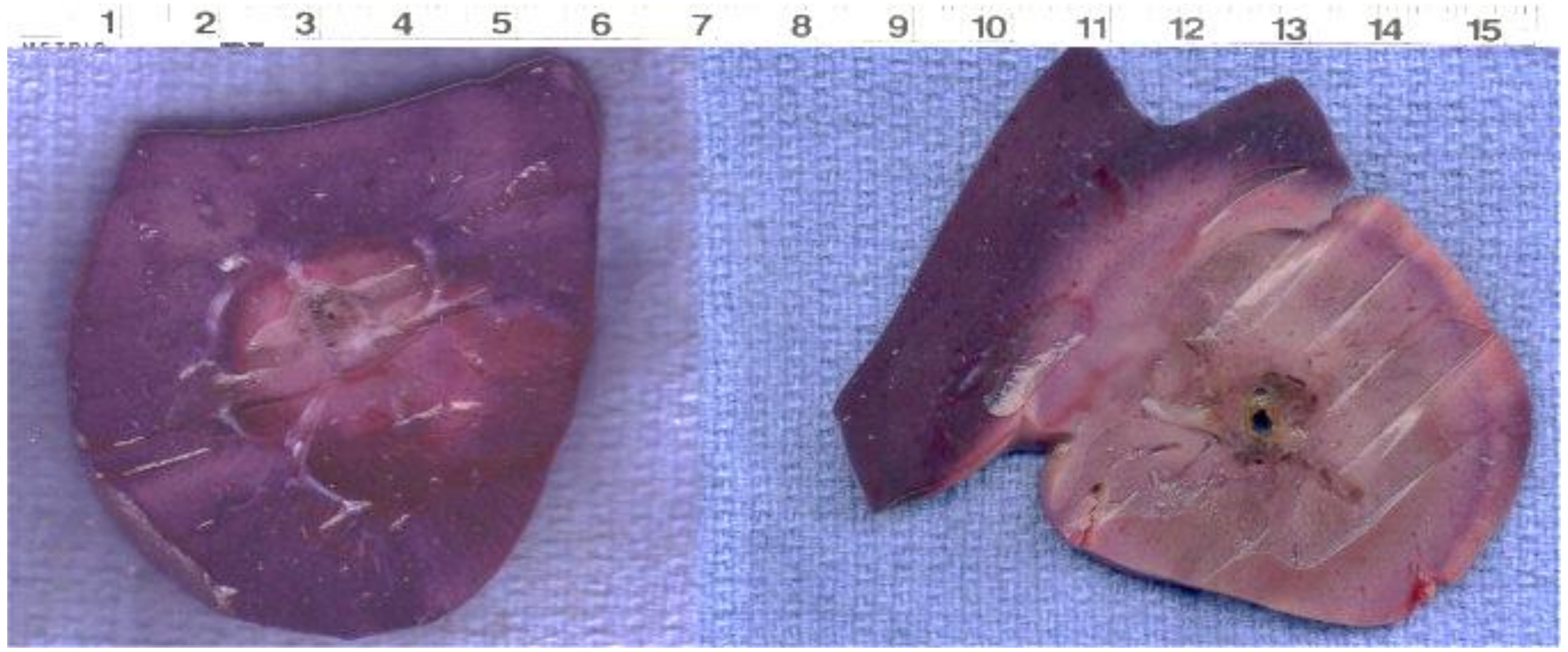
→ Multiphysics EM/thermal simulation can be used to model the MTA and predict the temperature increase. Simulation can be used to optimise the ablation treatment only if we know the dielectric and thermal properties.

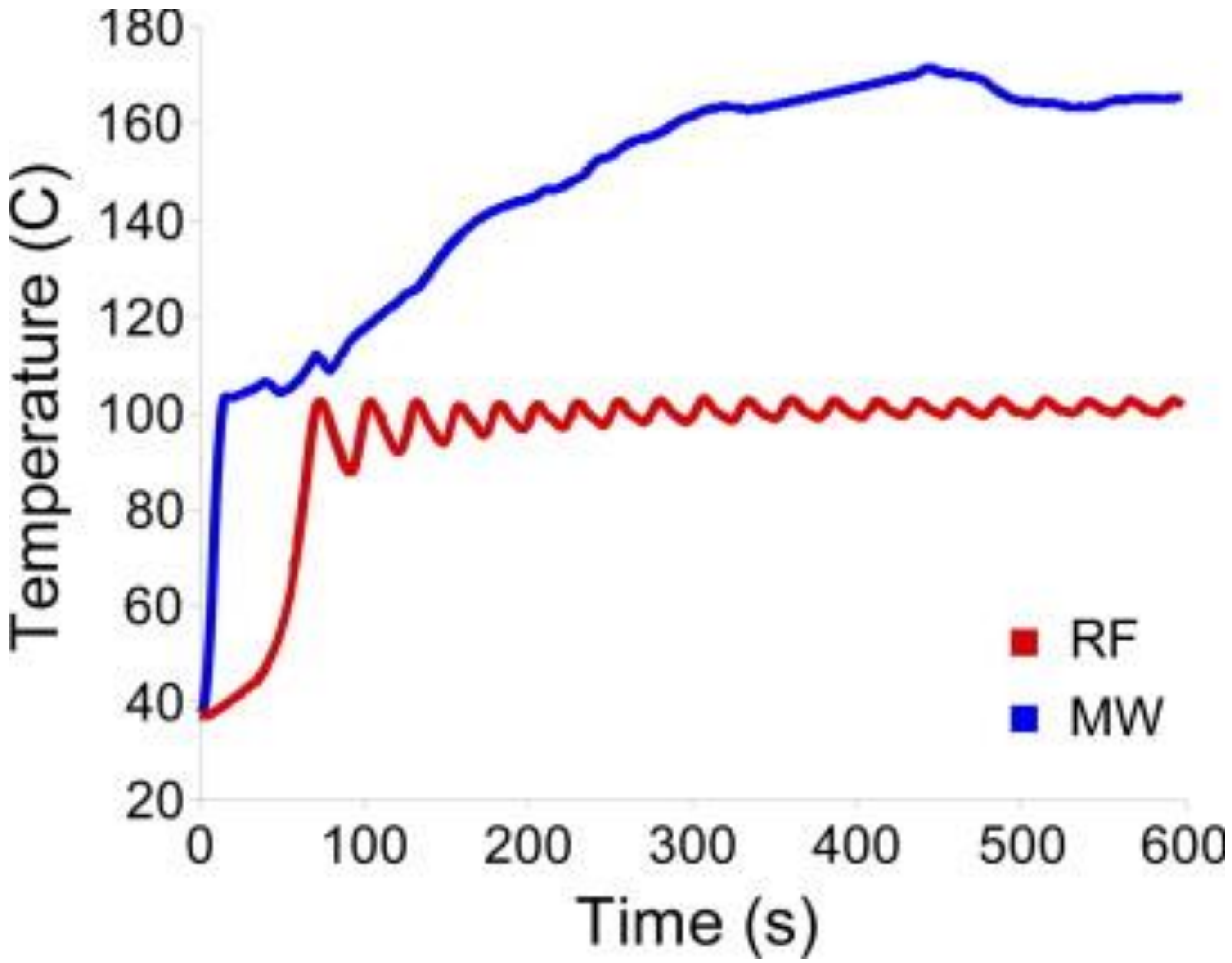
Kidney Ablation

Kidney is characterised by high perfusion rate and high electrolyte content

RFA limited by high perfusion rate and conductivity changes in the tissue due to heating

MTA may overcome this issue in kidney ablation



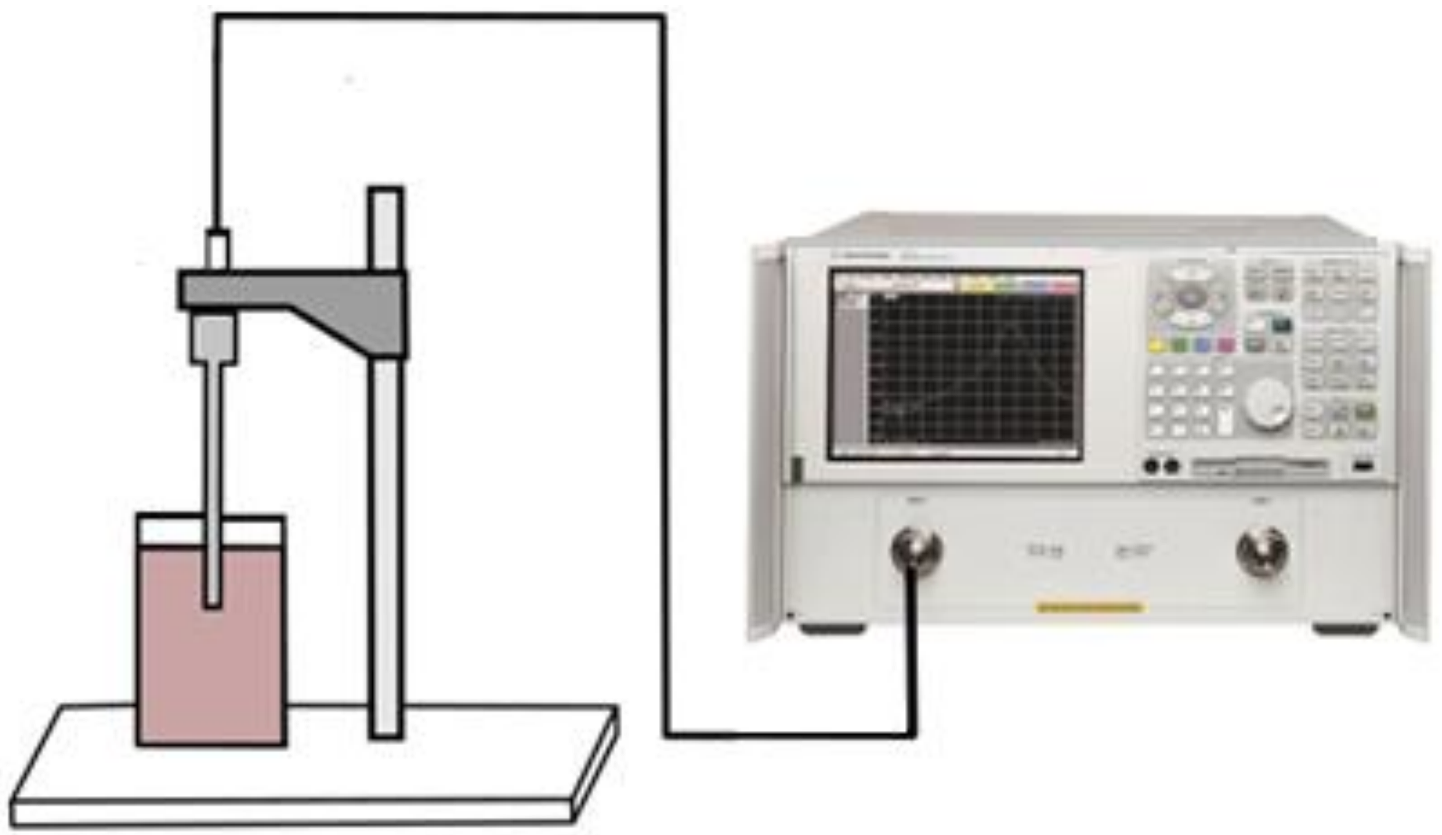


[1] C. L. Brace, "Radiofrequency and Microwave Ablation of the Liver, Lung, Kidney, and Bone: What Are the Differences?," Current Problems in Diagnostic Radiology, May 2009, doi: 10.1067/j.cpradiol.2007.10.001.

Protocol I: Measurement Method

Open-ended coaxial probe method

- Simple
- Broadband
- Non-destructive
- Minimal sample handling
- *Ex-vivo*
- *In-vivo*



Protocol:

- Open-ended coaxial probe: Keysight 85070E
- VNA: Keysight 5063A @ 500 MHz – 8.5 GHz
- Calibration: Open-Short-Load
- Validation: 0.1 mol/L sodium chloride solution

Table 1. The mean and the maximum value of the validation error in percentage

	Mean error [%]	Max error [%]
Relative permittivity	1.96	3.52
Conductivity	2.41	10.19

[1]
A. La Gioia *et al.*, "Open-Ended Coaxial Probe Technique for Dielectric Measurement of Biological Tissues: Challenges and Common Practices," *Diagnostics*, vol. 8, no. 2, p. 40, Jun. 2018, doi: 10.3390/diagnostics8020040.

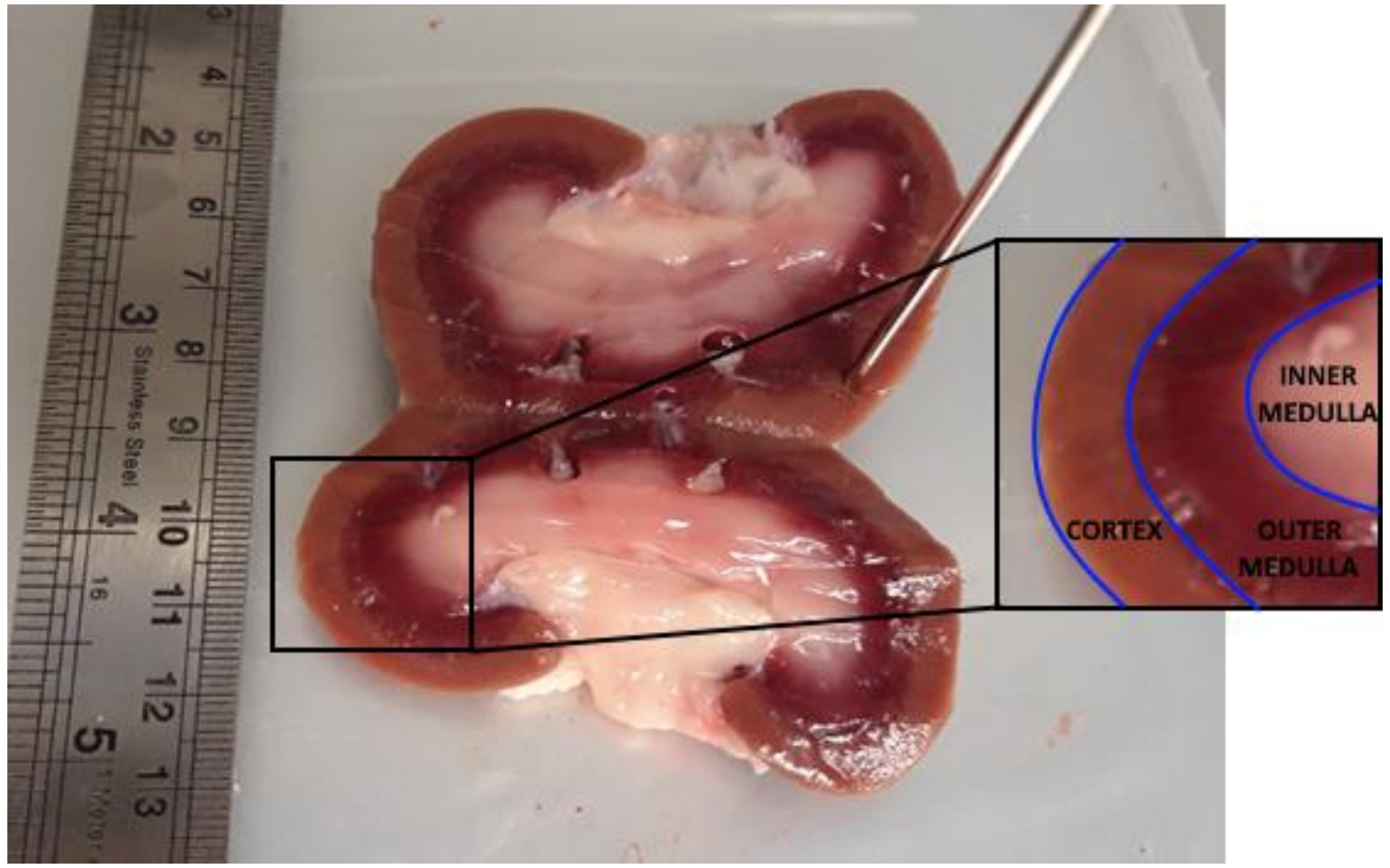
Protocol II: Sample Treatment

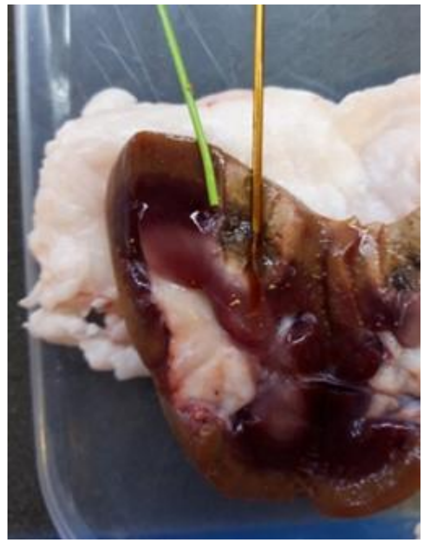
N=3 ovine kidney samples

- Before MTA
- After MTA
- Fully cooled triaxial-based monopole antenna
- 30 W for 1 min @2.45 GHz

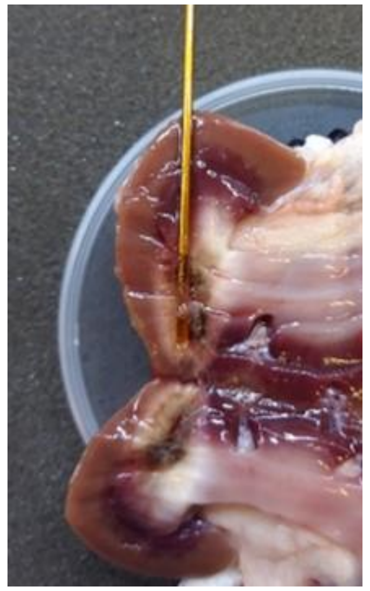
Three distinct tissues inside the kidney:

- Cortex
- Outer Medulla
- Inner Medulla





Sample 1



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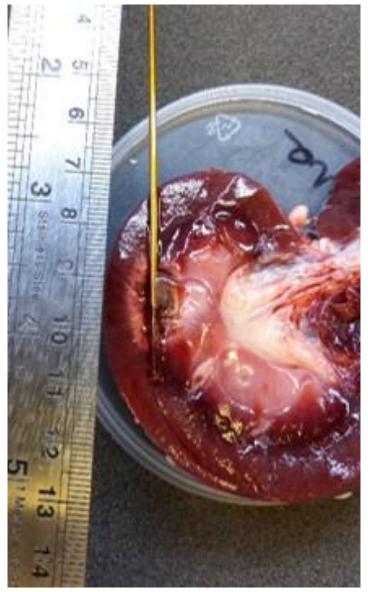
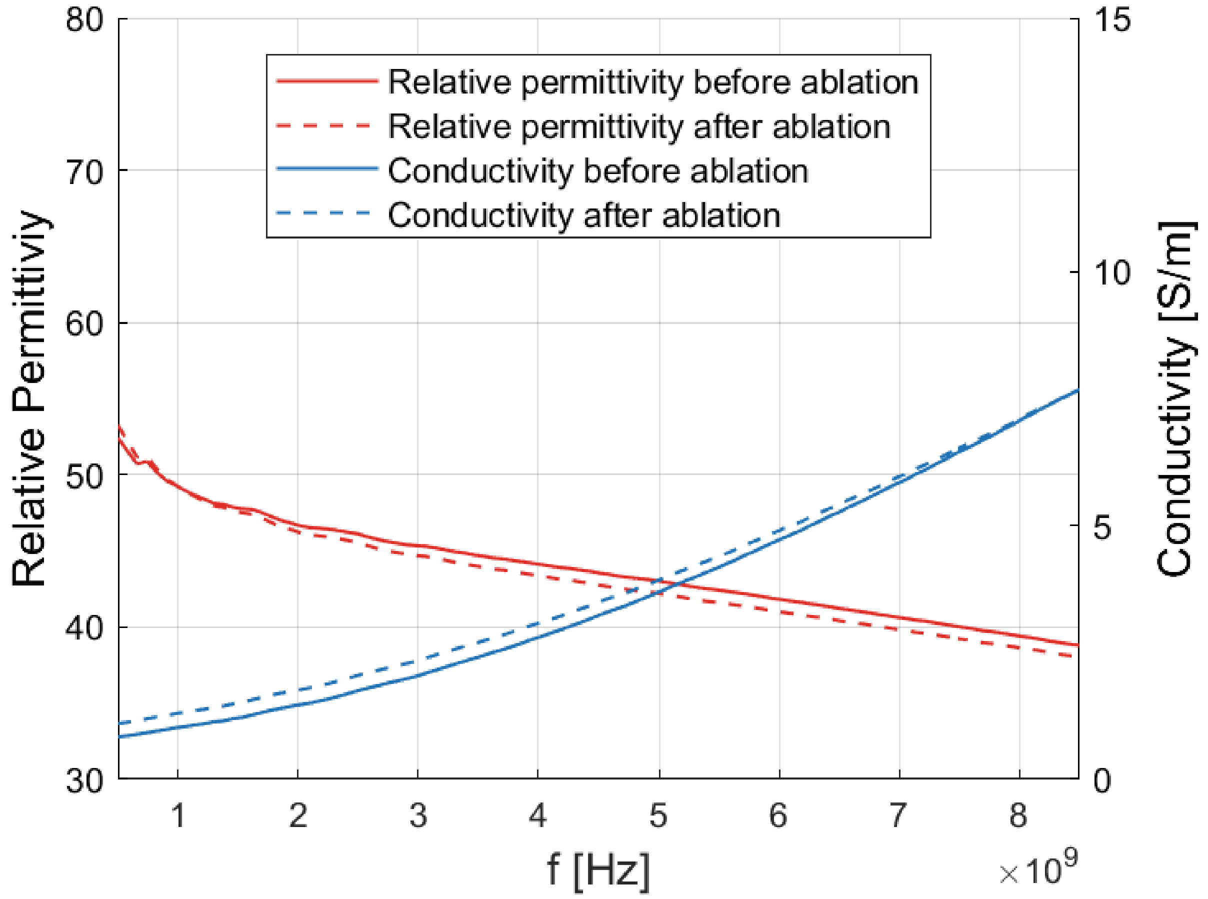
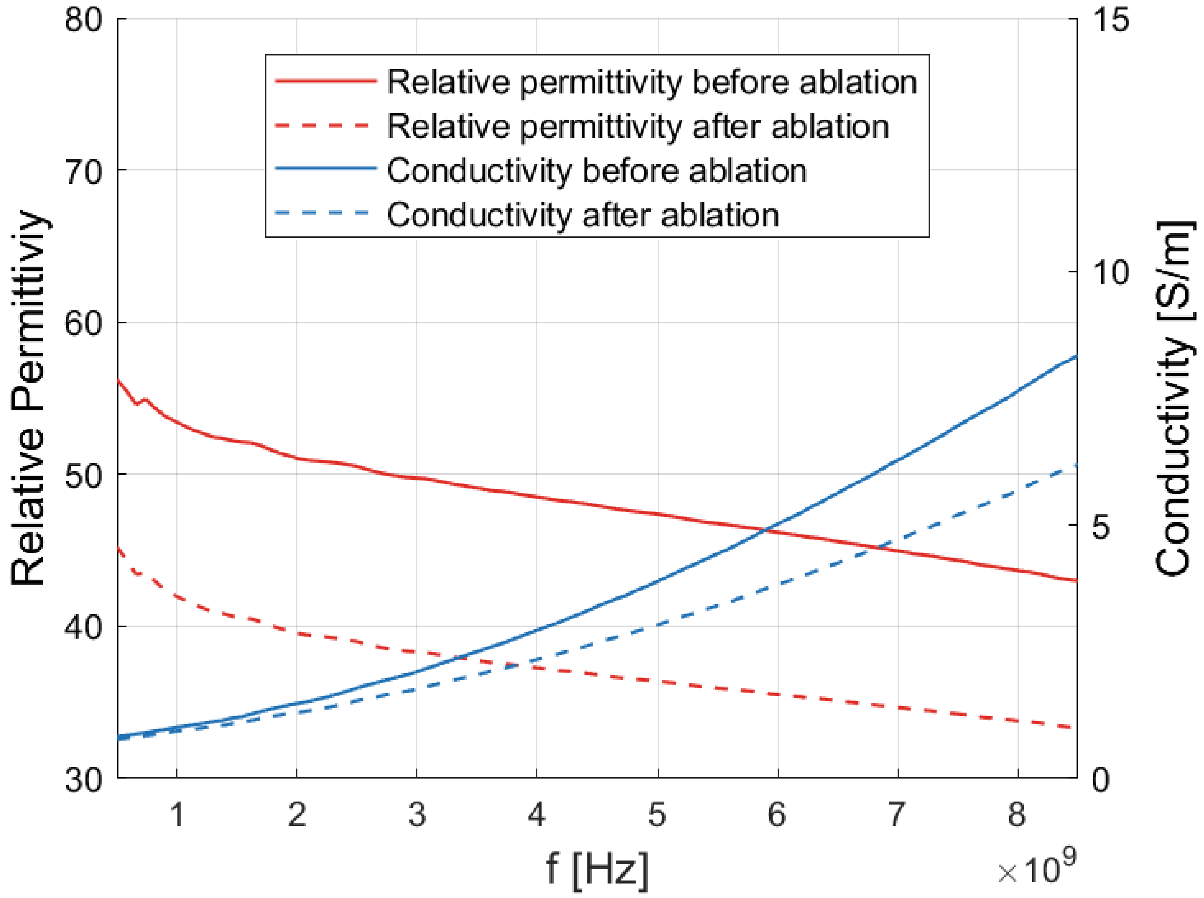


Sample 3

Results I: Cortex



Sample 1



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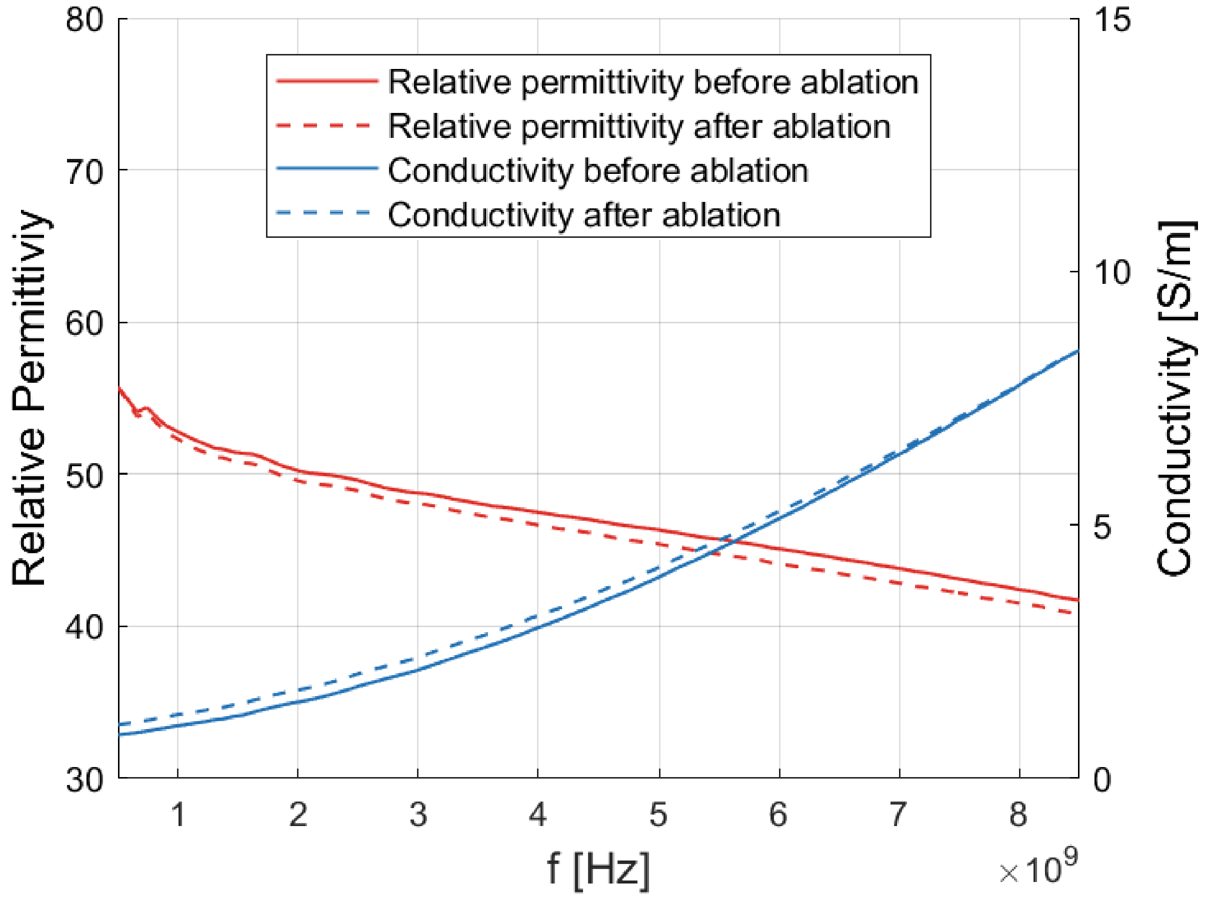
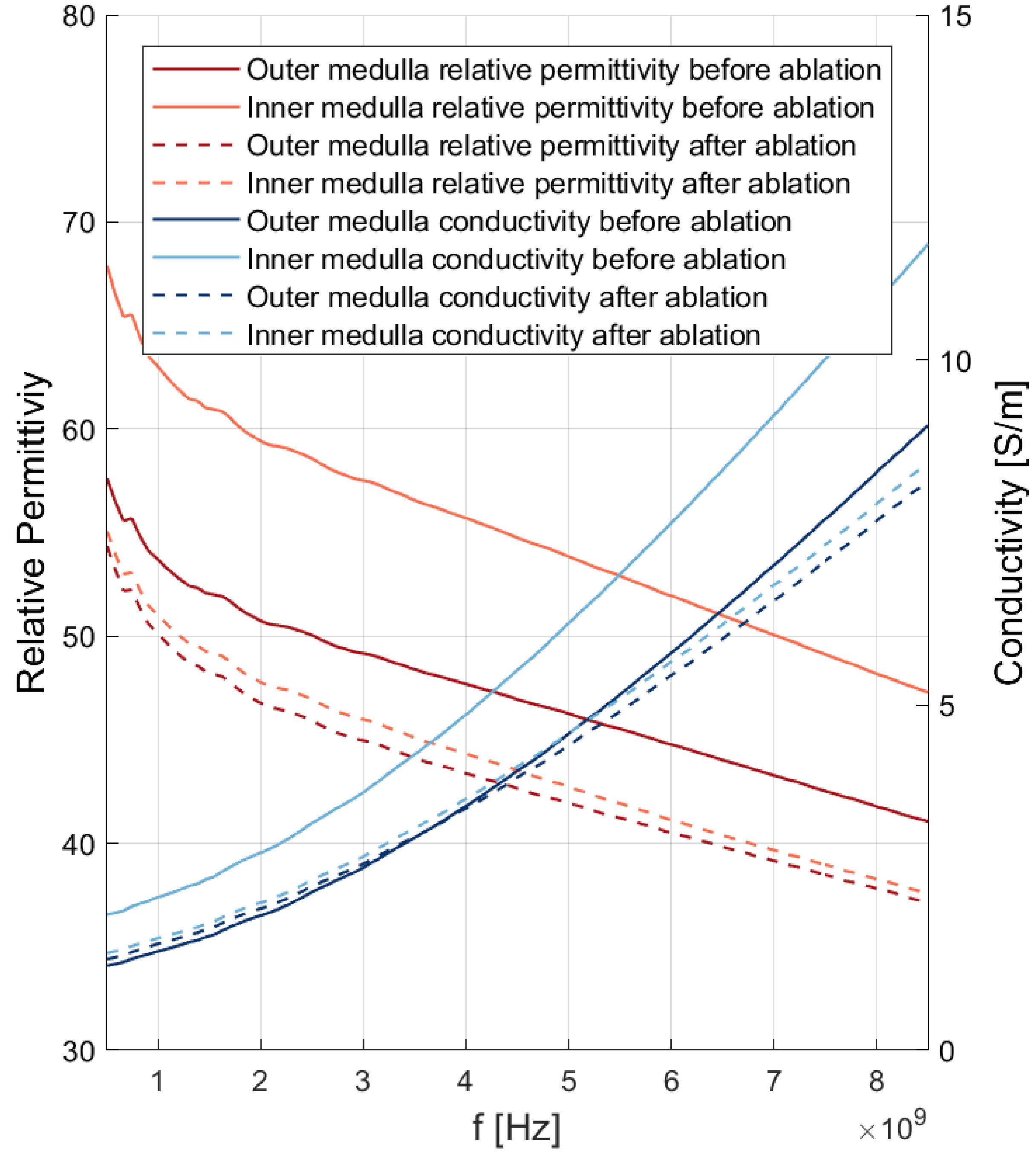
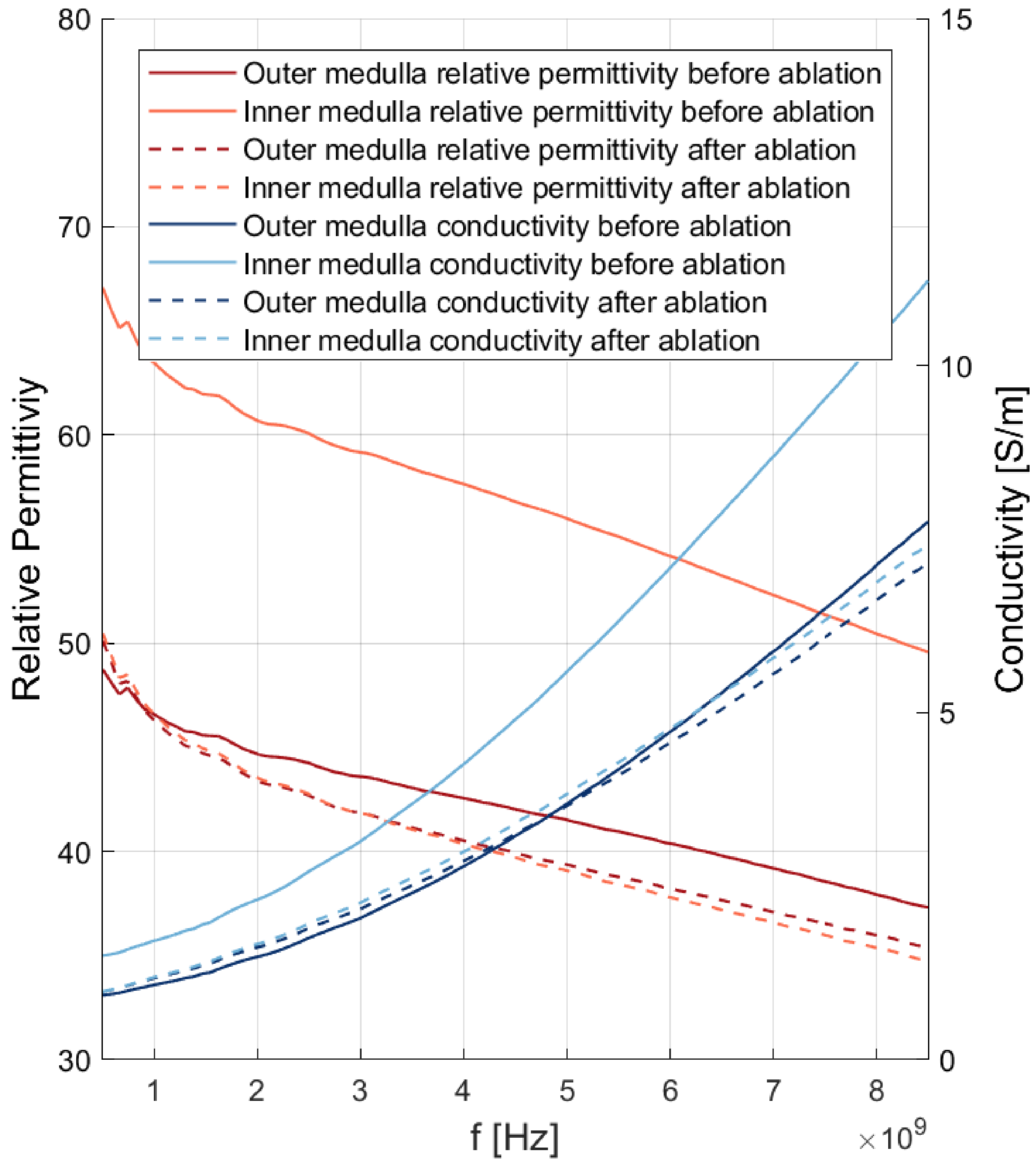


Sample 3

Results II: Inner and Outer Medulla



Sample 1



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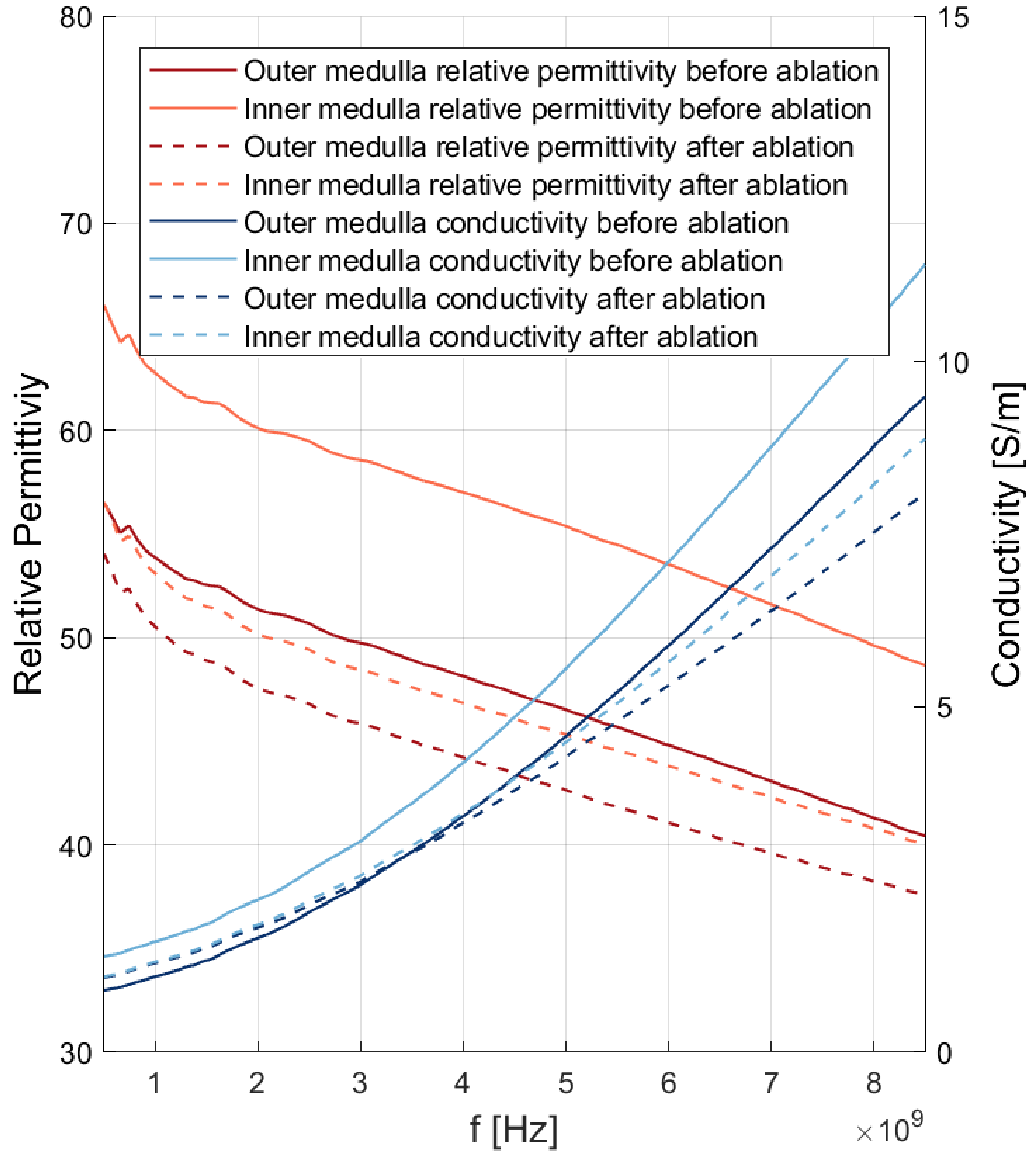

Sample 3

Conclusion

Relative permittivity and conductivity decrease after MTA

- Decrease in water content
- Higher the original water content – higher the drop in the dielectric properties

After MTA, the differences in relative permittivity and conductivity among the different tissues composing the kindey are minimised

- Their difference in water content is minimised
- Denaturation of proteins