Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

MIMAS

“Smart” implants and parallel transmission MRI

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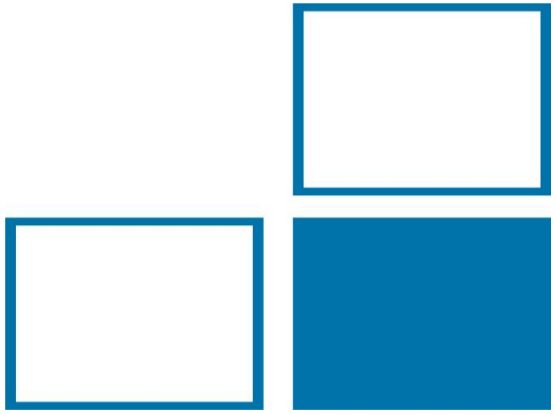
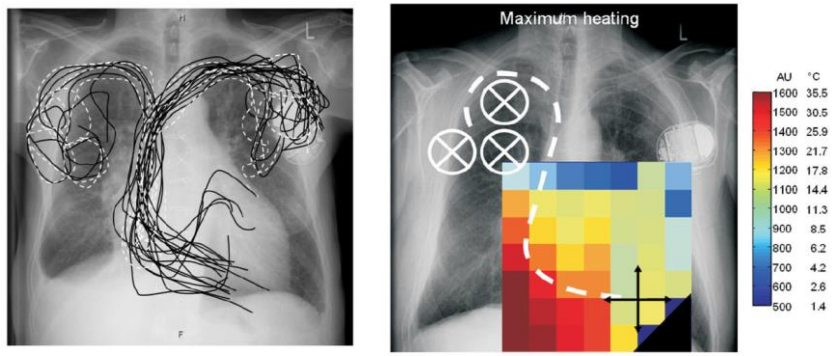
[1]*Physikalisch-Technische Bundesanstalt (PTB), Braunschweig and Berlin, Germany*



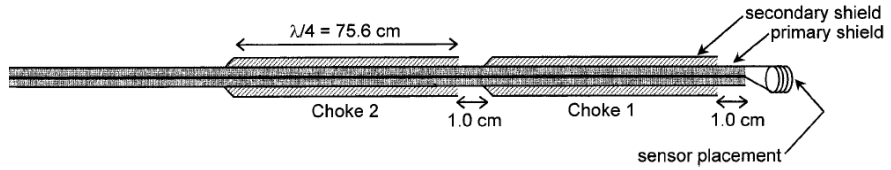
MRI and Implants

- RF safety risk for patients

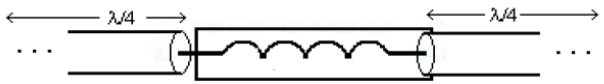


Nordbeck P, et al., MRM, 61:570-578, 2009

- Device protection needed

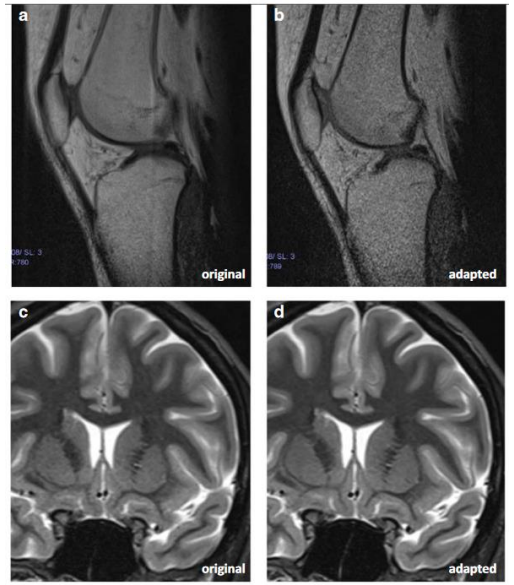


Ladd M & Quick H, MRM, 43:615-619, 2000



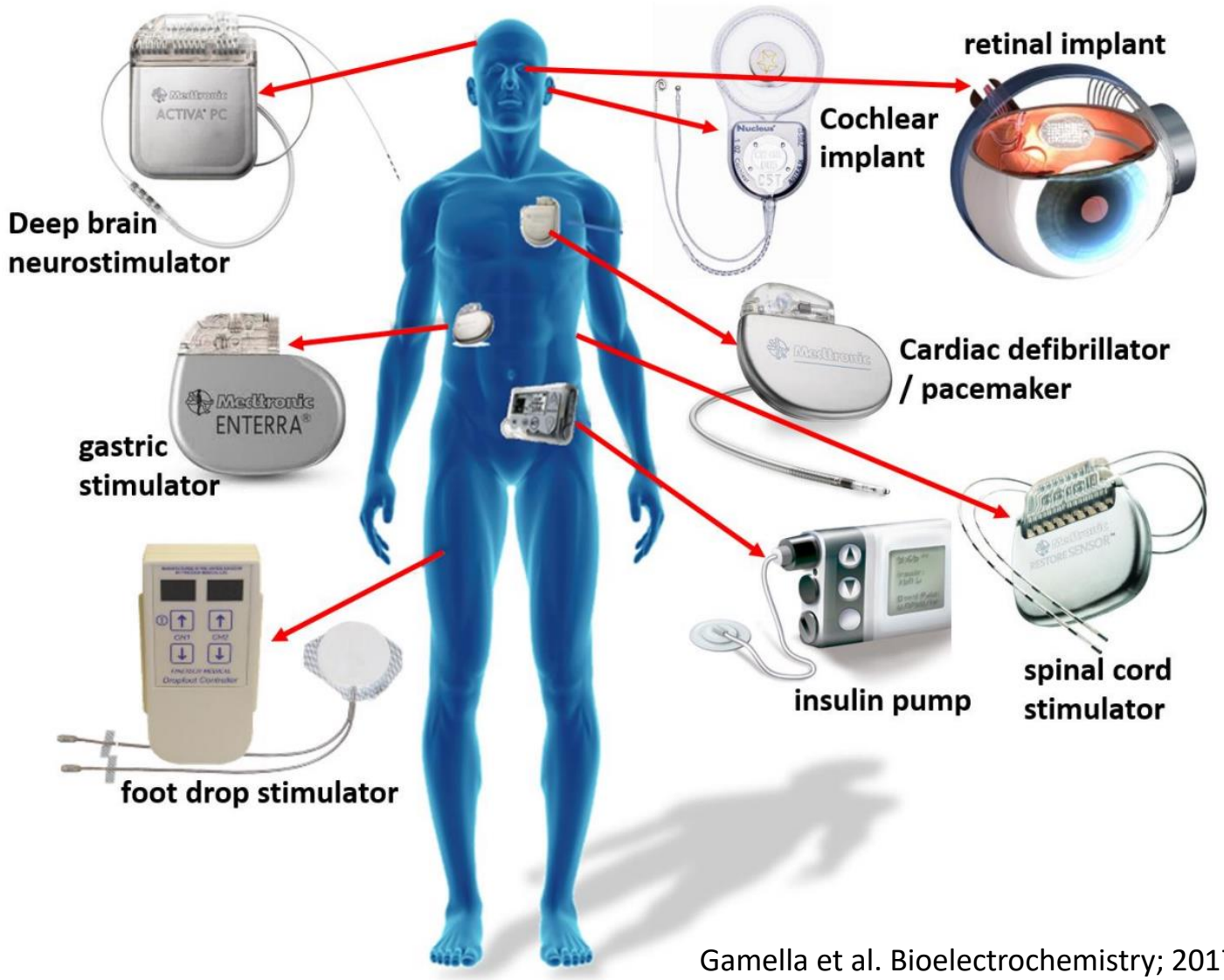
Ferhanoglu O, et al., ISMRM, 2005

- MR Imaging limitations



Lunden L, et al., Eur Radiol, 30:2571-2582, 2020

Age of the cyborg



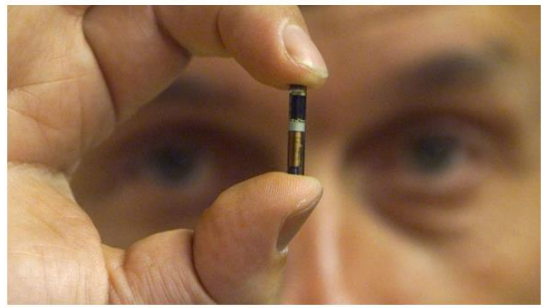
Gamella et al. Bioelectrochemistry; 2017

HEALTH

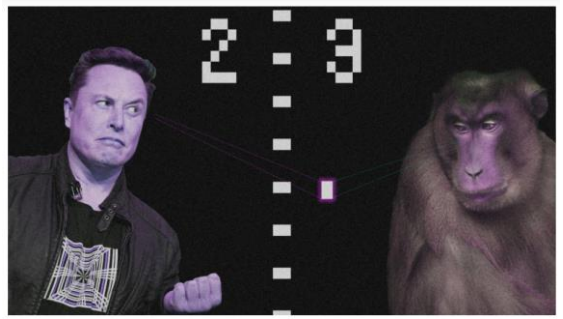
Why You're Probably Getting a Microchip Implant Someday

Microchip implants are going from tech-geek novelty to genuine health tool—and you might be running out of good reasons to say no.

HALEY WEISS SEP 21, 2018



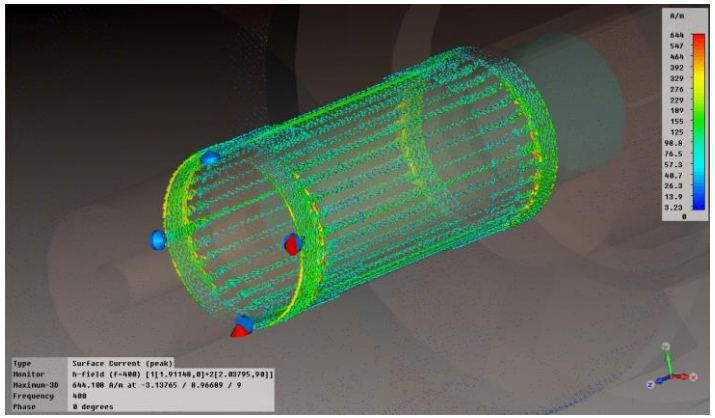
MIT Technology Review Sign in Subscribe



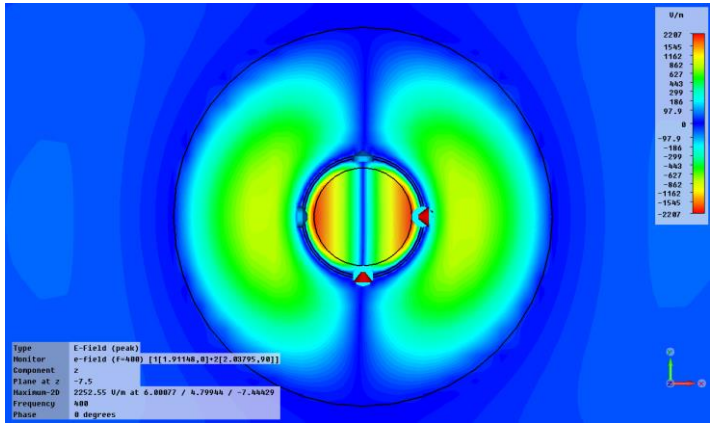
Single channel transmission

Birdcage RF coil (bodycoil type excitation)

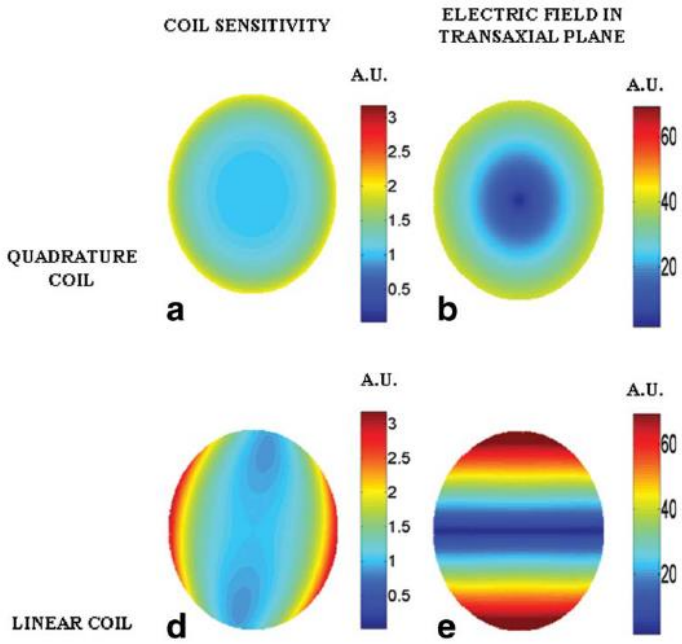
Surface current



E-Field



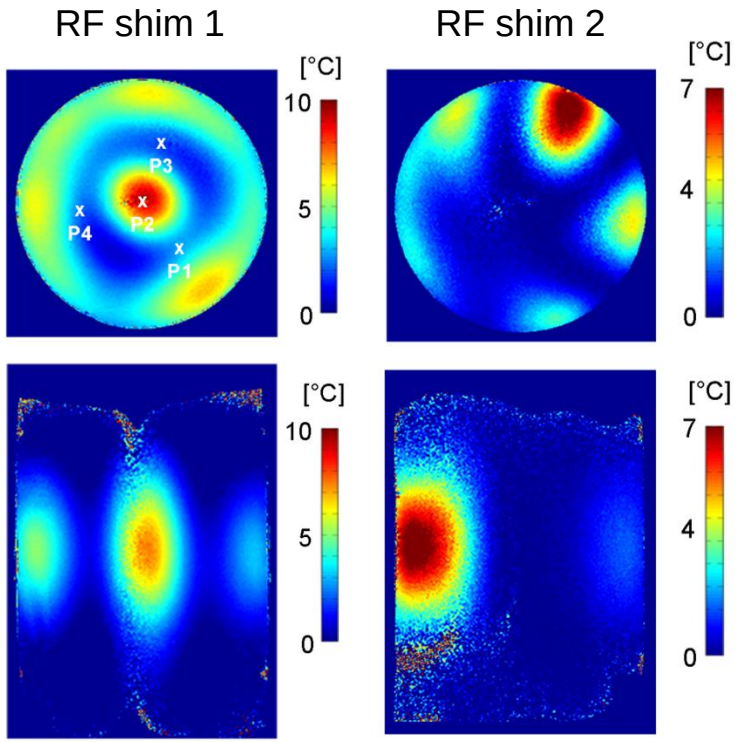
*courtesy H. Waiczies



Eryaman Y, et al., *MRM,* 65:1305-1313, 2011

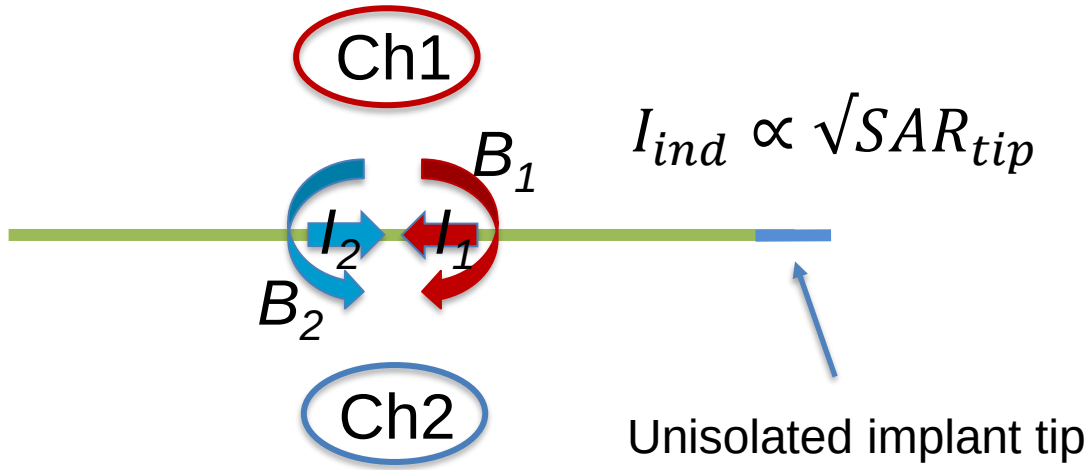
Multichannel transmission or pTx and implant heating

Background E-field

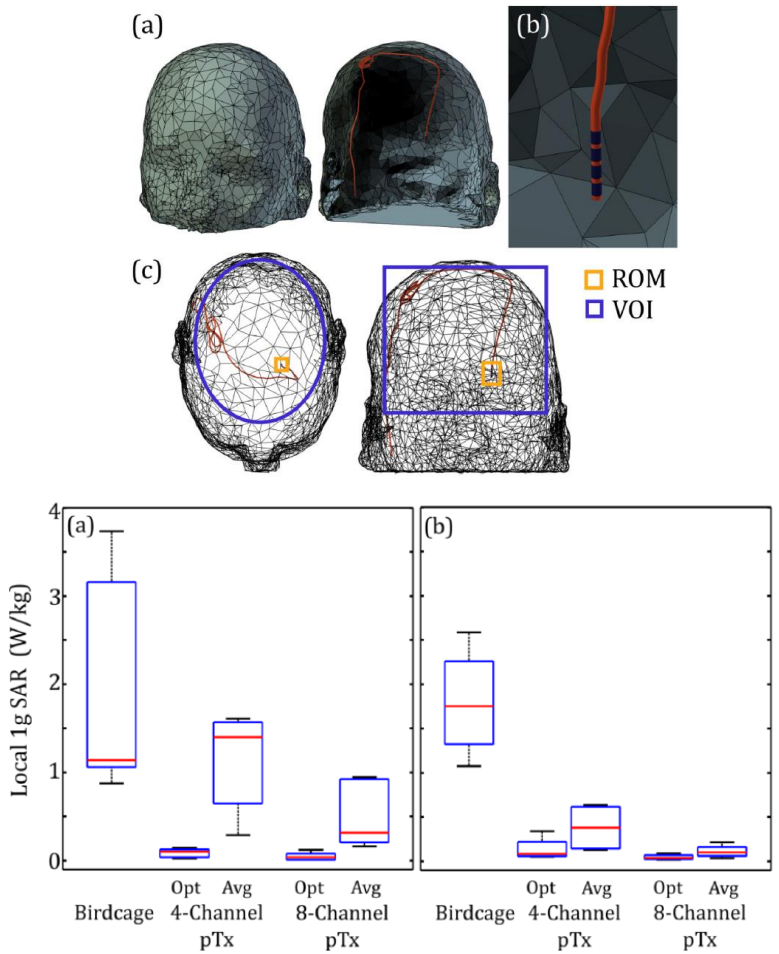


Winter L, et al., PlosOne, 8(4):e61661, 2013

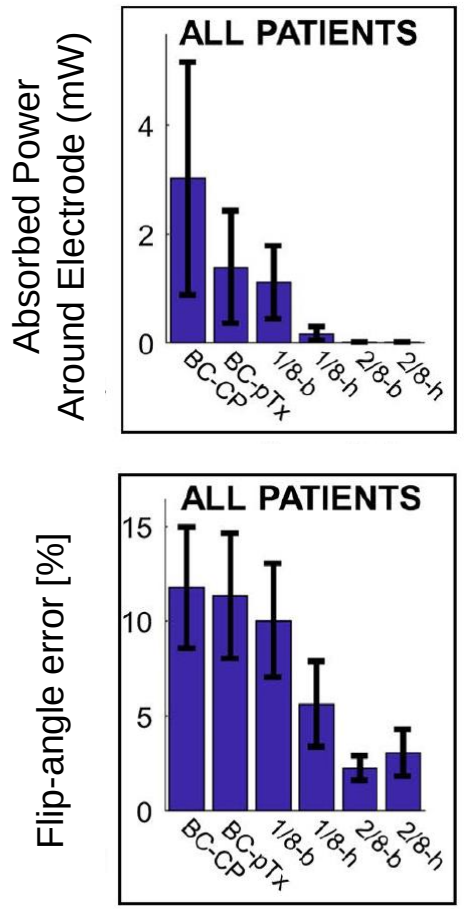
RF induced implant currents



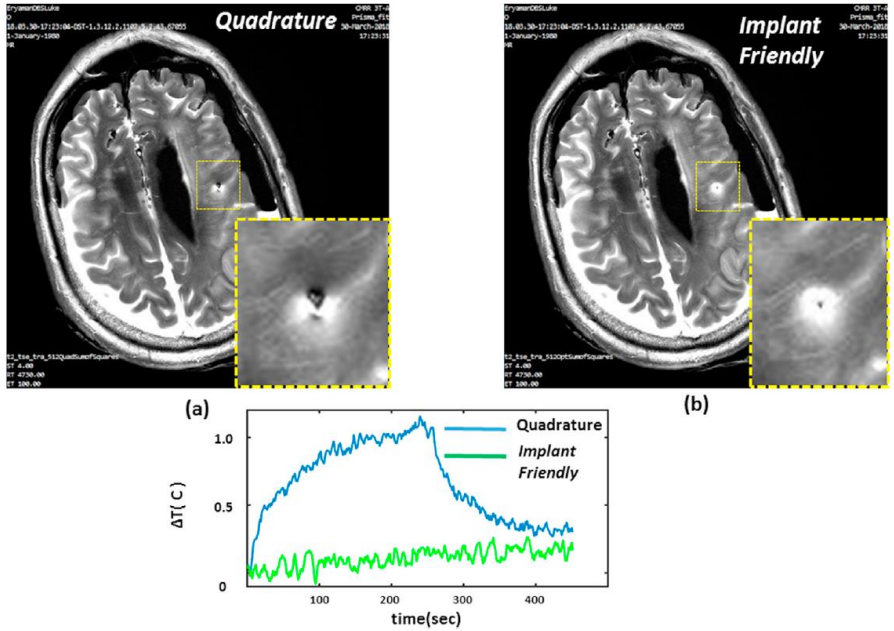
pTx benefits implant safety and imaging



McElcheran CE, et al., MRM, 78(6):2406-2415, 2017
McElcheran CE, et al., Sci Rep, 9(1):2124, 2019

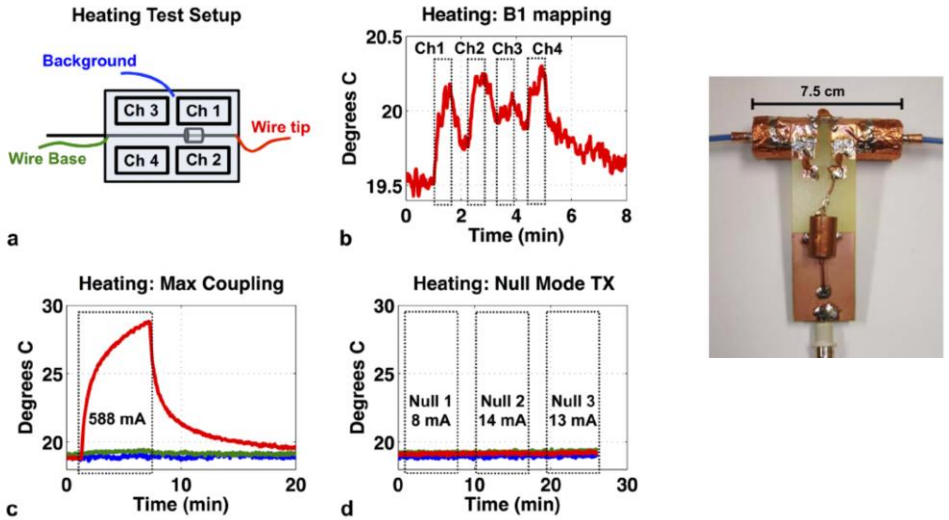


Guerin et al. MRM, 83(1):299-311, 2020

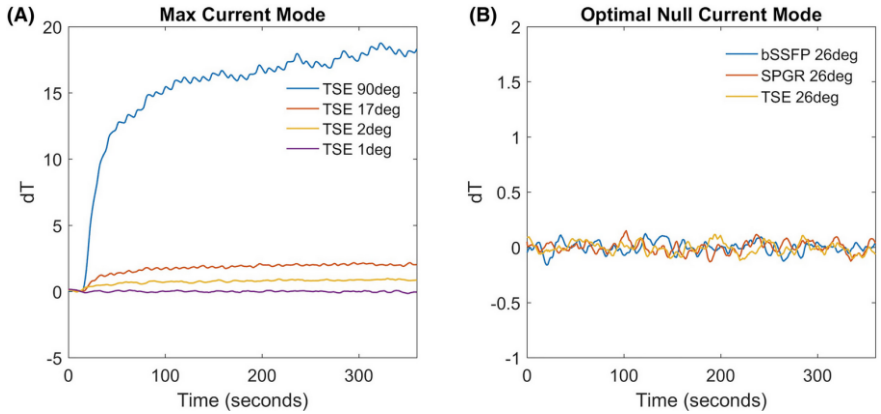


Eryaman Y, et al., *NeuroImage,* 184: 658-668, 2019

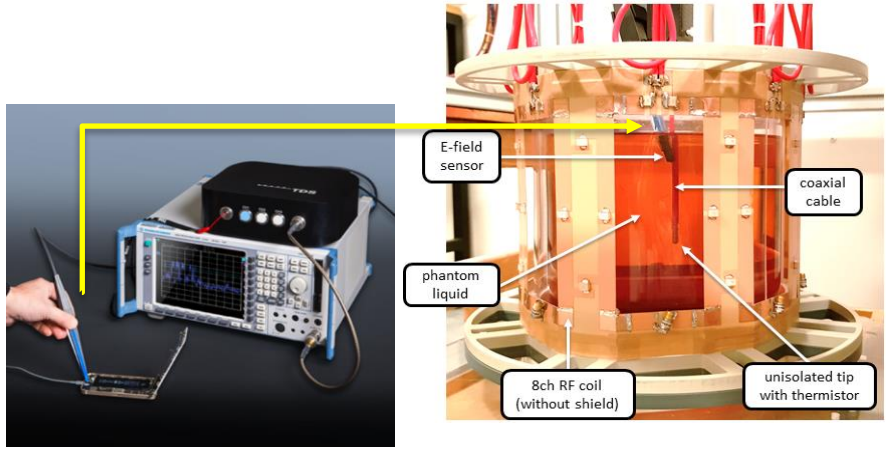
Sensor based pTx mitigation – time-domain probes

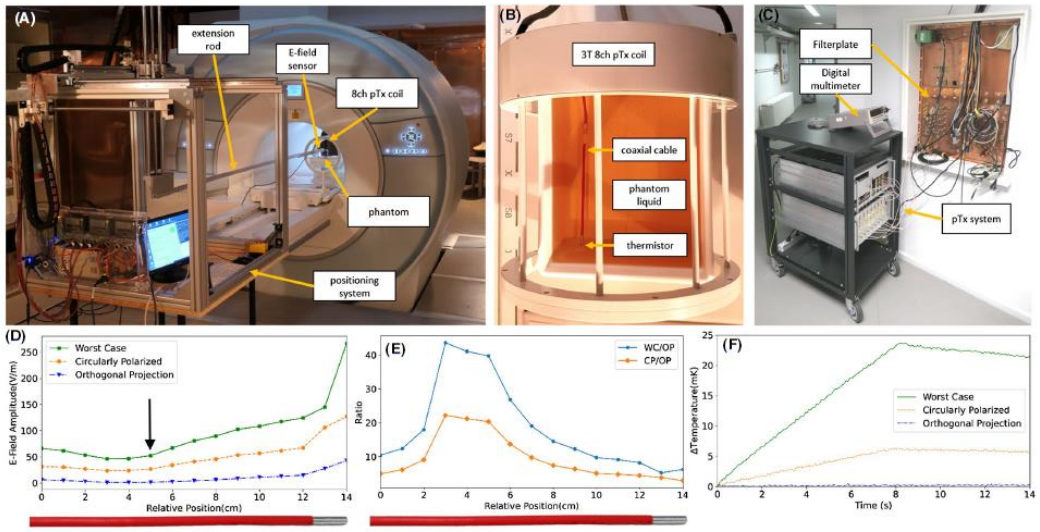


Etezadi-Amoli et al., MRM, 74(6):1790-1802, 2015



Godinez F, et al., MRM, 83(6):2343-2355, 2020





Winter L, et al., MRM, 84(6):3468-3484, 2020

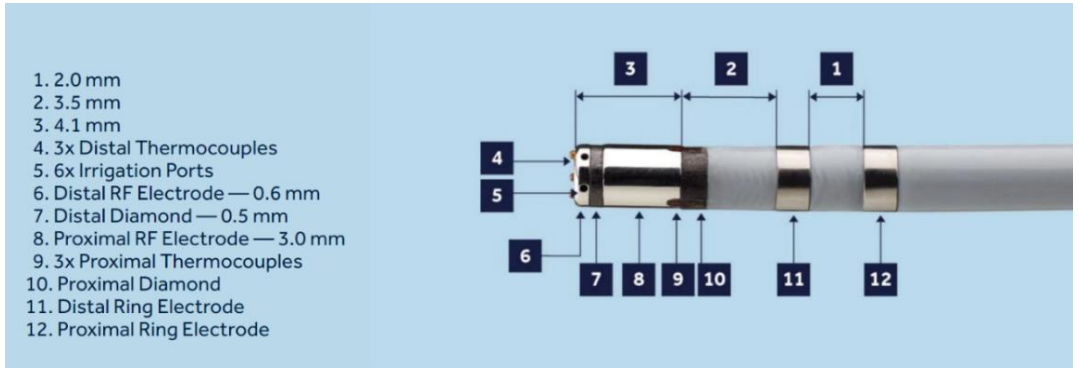
Root mean square (RMS) sensors

Pro:

- small (<2mm)
- cheap (<1€)
- fast readout (µs/ms)

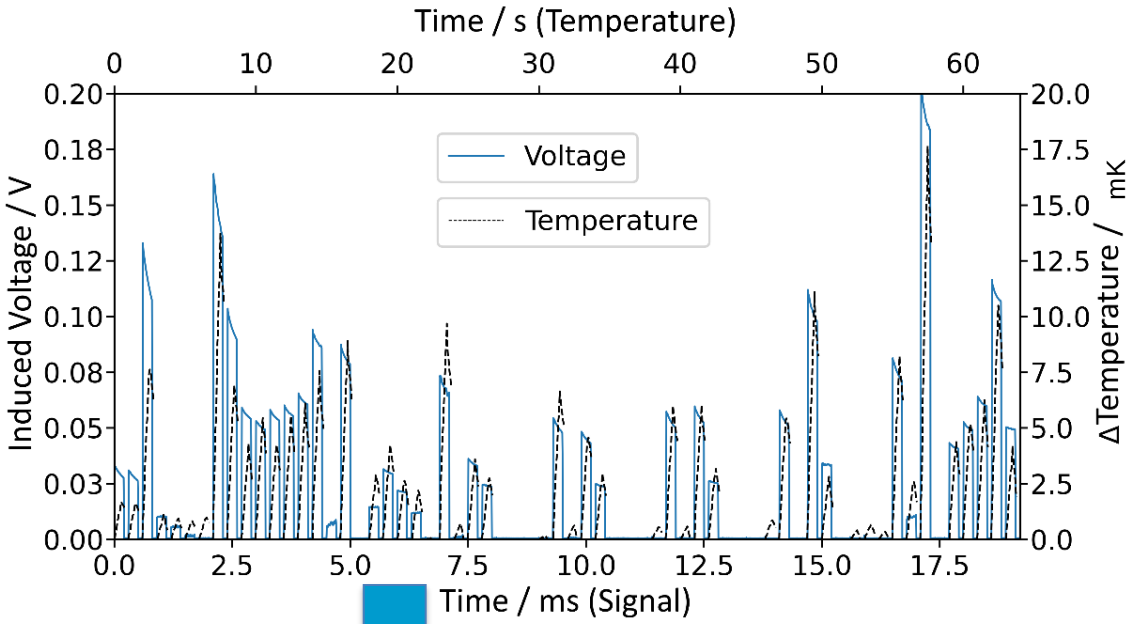
Con:

- No phase information



Medtronic – DiamondTemp Ablation Catheter
https://europe.medtronic.com/xd-en/healthcare-professionals/products/cardiac-rhythm/ablation-atrial-fibrillation/diamondtemp-ablation-catheters.html

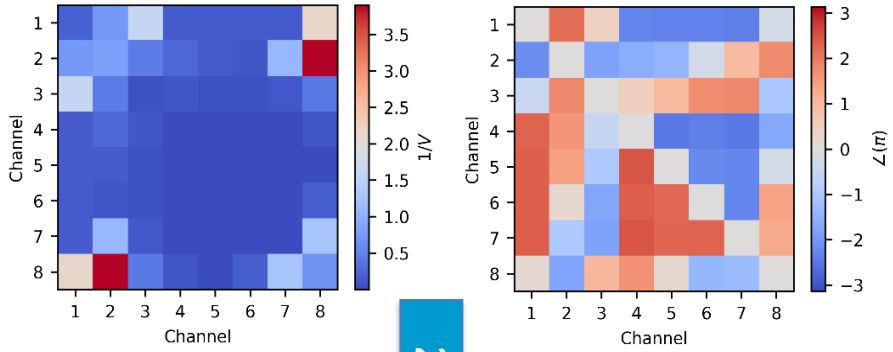
Sensor Q-matrix (Q_S) using RMS sensors



1

if E-field information is used i.e. Schottky diode

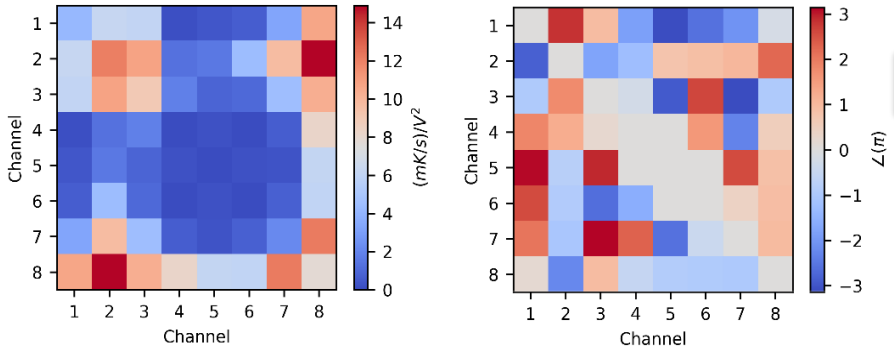
Q_S^E



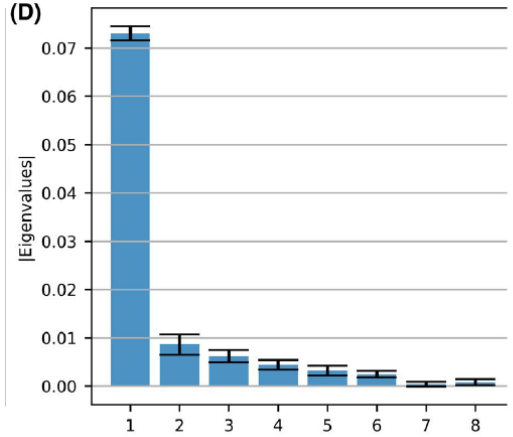
2

if temperature information is used i.e. thermistor

Q_S^T



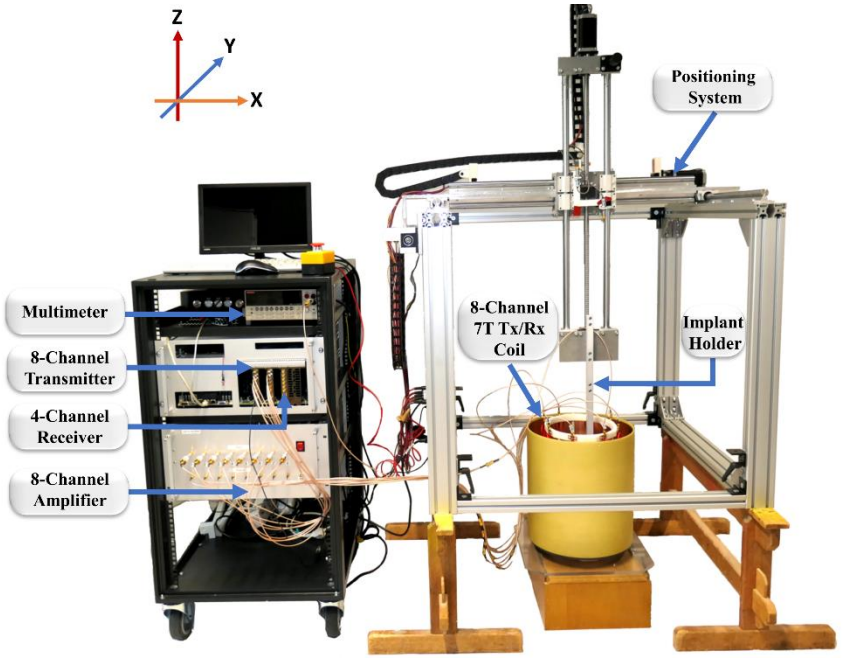
2



Silemek B, et al., MRM, doi:10.1002/mrm.28968, 2021

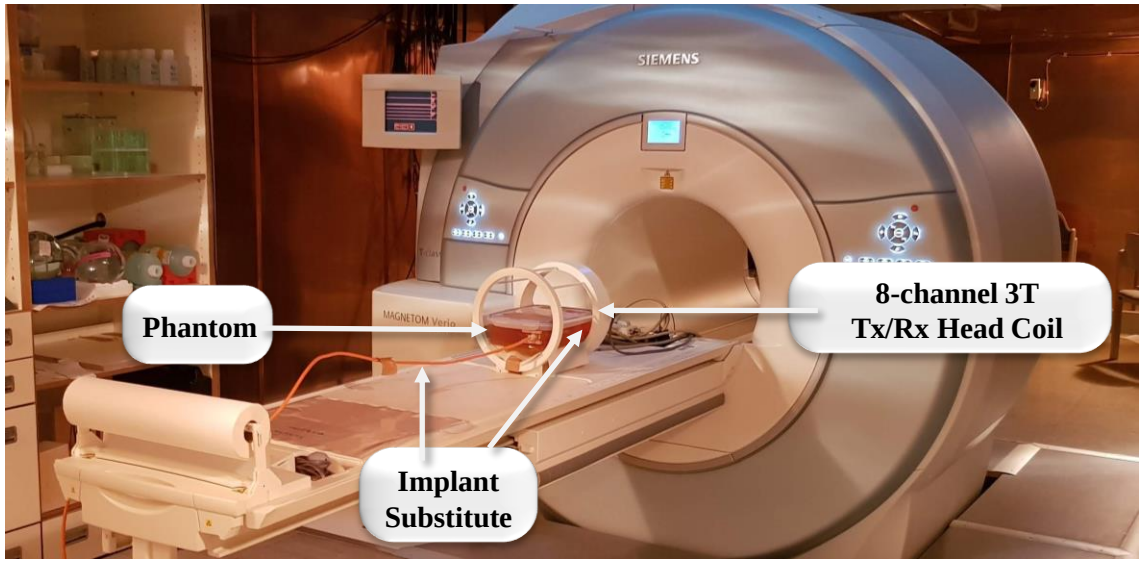
Experimental Setup

Implant Safety testbed[1]



- 8-channel 7T head RF coil[2]
- Positioning system COSI Measure[3]
- 154 implant locations
- Q_S^E and Q_S^T acquisition and pTx mitigation

3T MRI

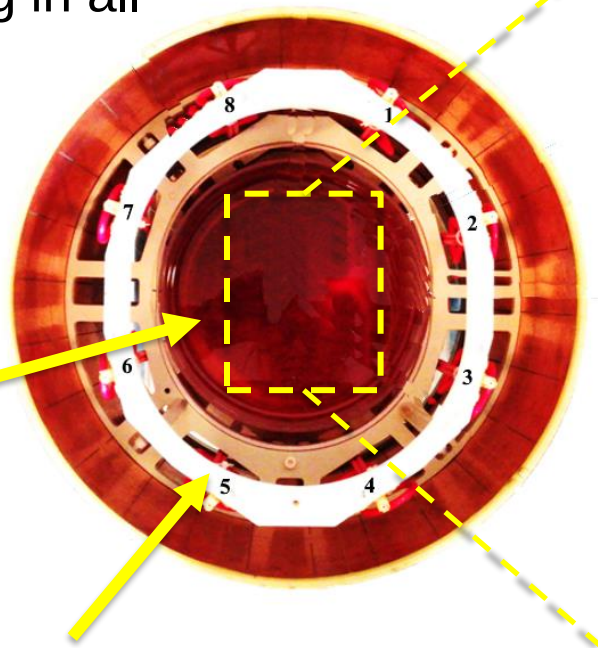


- 3T Verio (Siemens Healthineers)
- 8-Ch 3T head RF coil (Rapid Biomed.)
- Q_S^E acquisition and pTx mitigation
- GRE (TE=4ms, TR=11ms, spatial resolution=0.6 x 0.6 mm^2)

[1]Winter et al. MRM, 2020; [2]Seifert et al., ISMRM, 2016; [3]Han et al. Sci.Rep, 2017

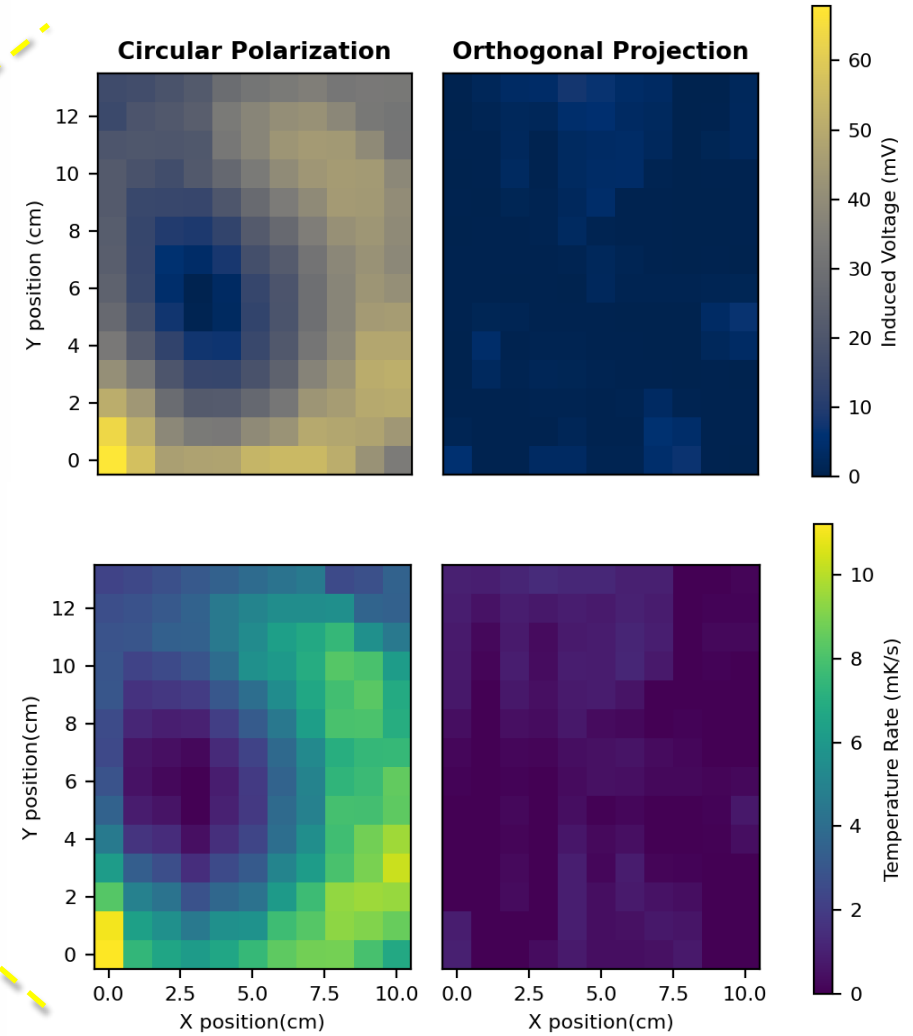
Q_S based pTx mitigation of RF induced heating

- Q_S^E acquisition and mitigation in real-time
- → 20 ms for a single location
- → Mitigation of RF induced heating in all investigated locations



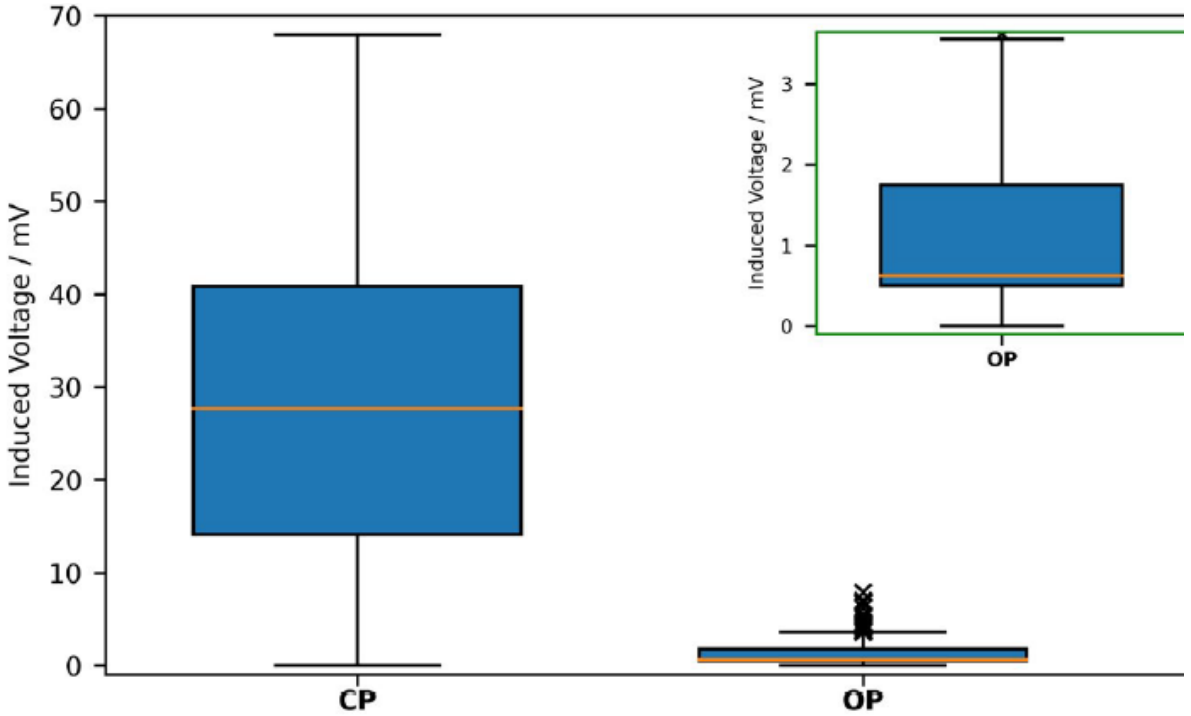
Phantom with embedded Implant

8-channel pTx RF coil



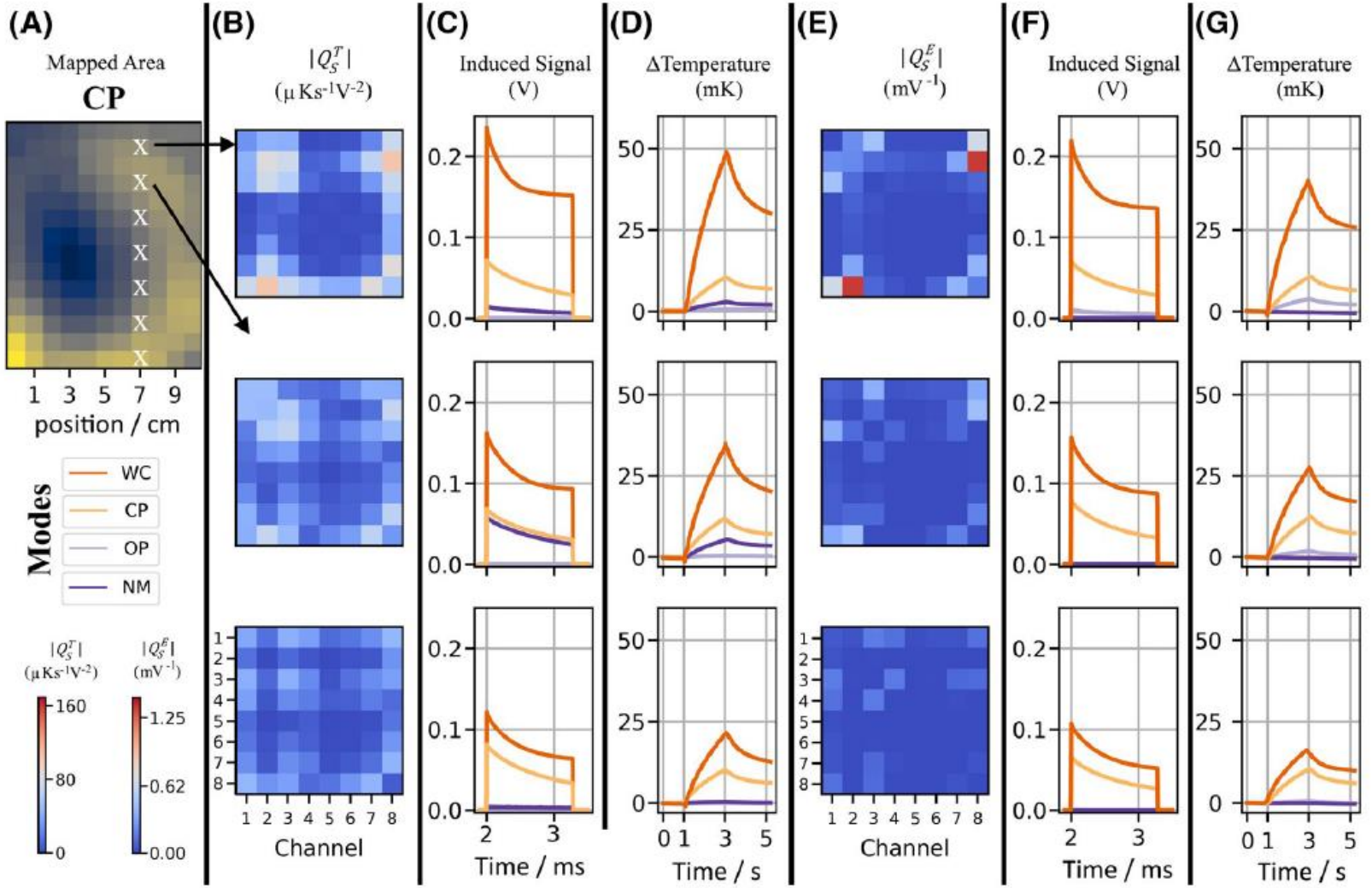
Silemek B, et al., MRM, doi:10.1002/mrm.28968, 2021

Q_S based pTx mitigation of RF induced heating



Silemek B, et al., MRM, doi:10.1002/mrm.28968, 2021

Field and temperature based pTx mitigation



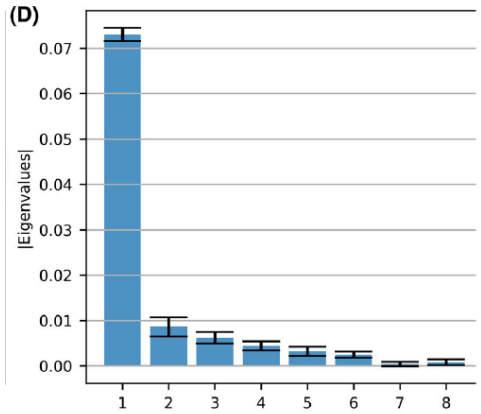
Silemek B, et al., MRM, doi:10.1002/mrm.28968, 2021

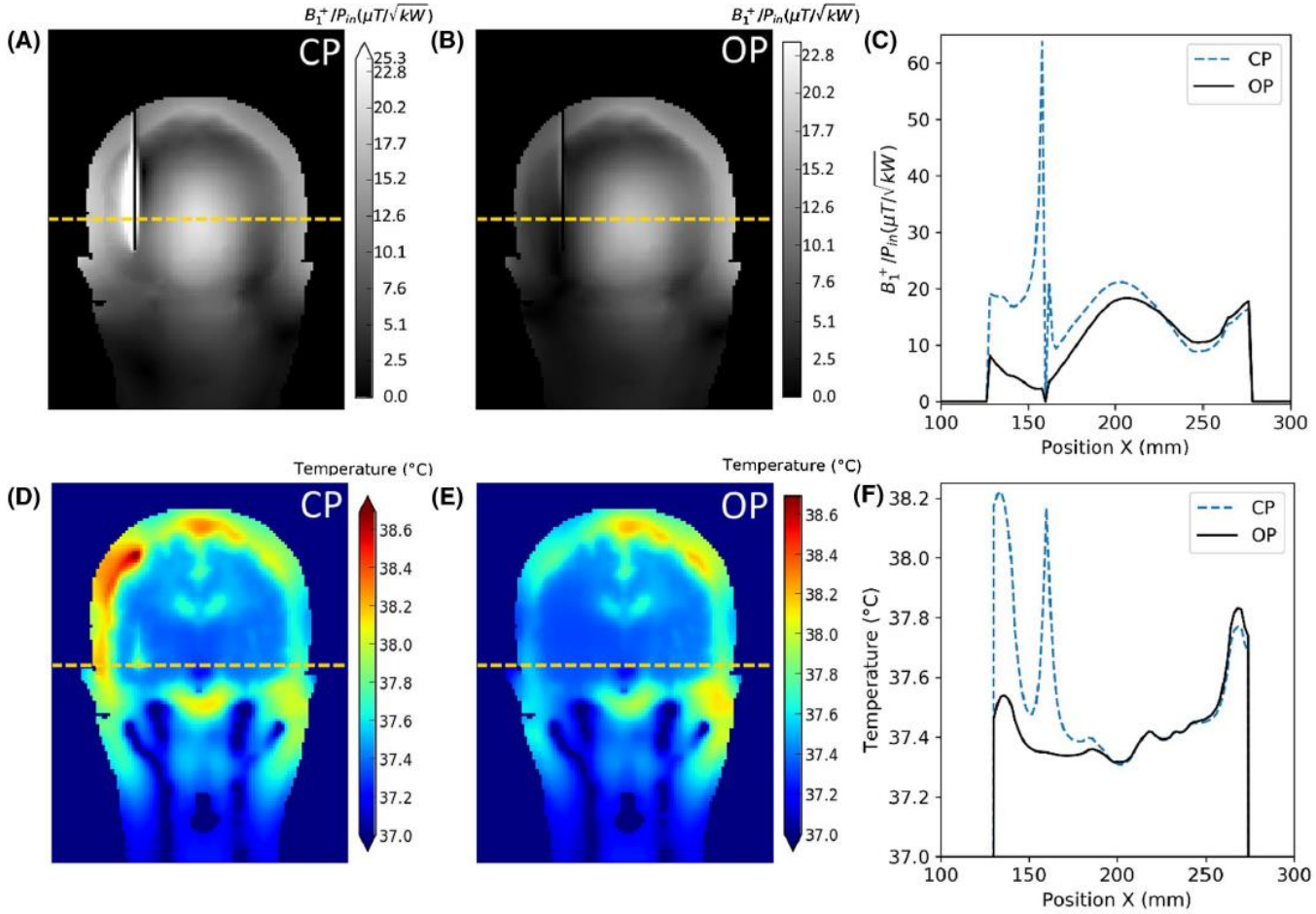
More than implant safety: Retained B_1^+

Orthogonal projection method:

1. Imaging transmission vector
2. „Worst case“ transmission vector based on measured Q_s matrix
3. Orthogonal projection using 1) and 2)

→ Substantially lower tip heating without sacrificing B_1^+ using only the RMS sensor information

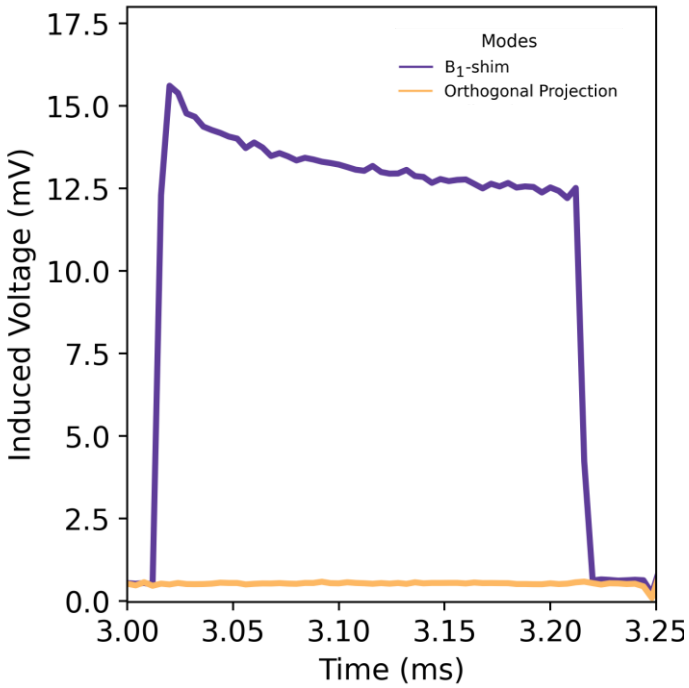


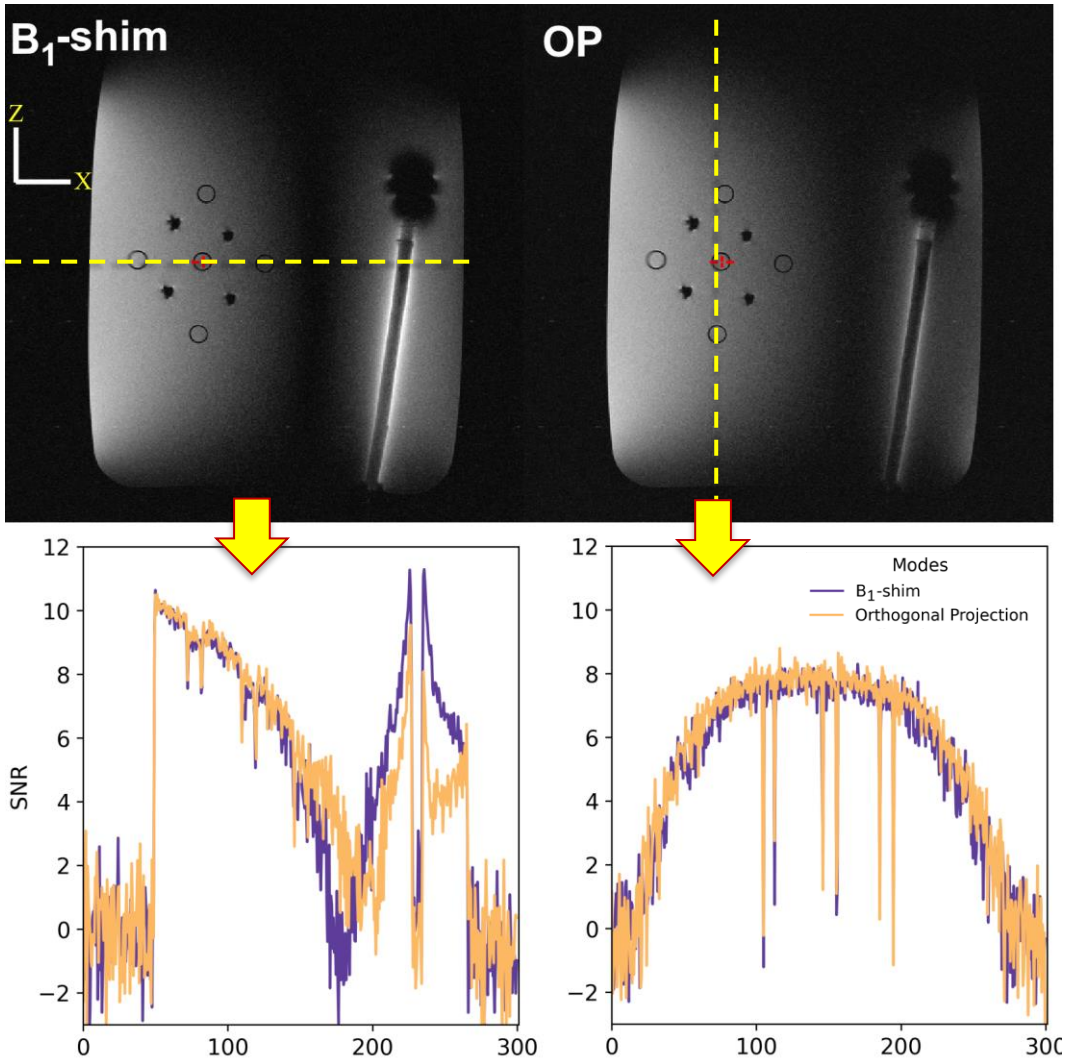


Winter L, et al., MRM, 84(6):3468-3484, 2020

MR Experiments at 3T

RF induced signals

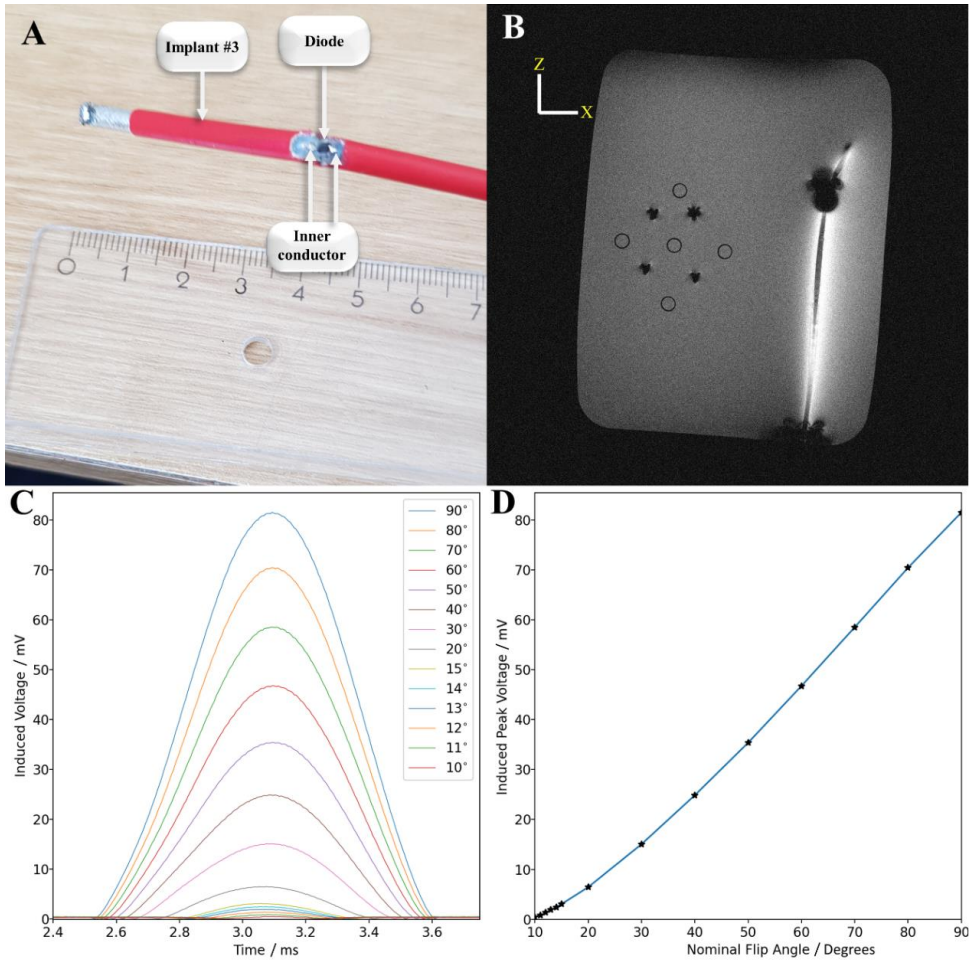




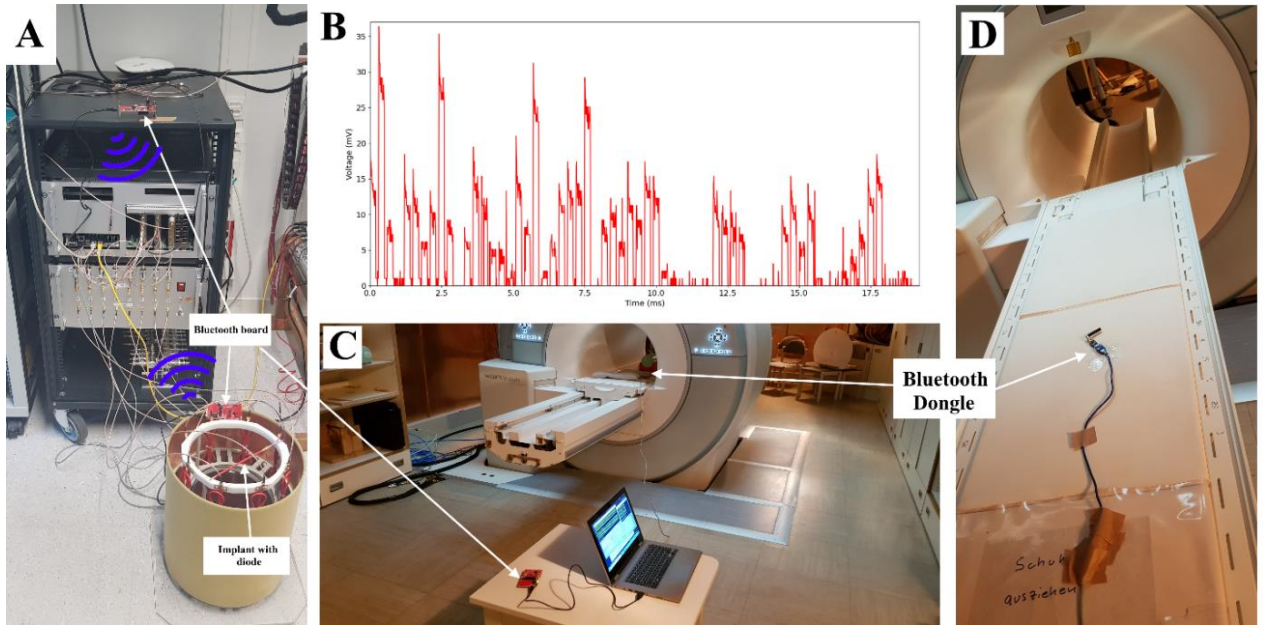
Silemek B, et al., MRM, doi:10.1002/mrm.28968, 2021

Towards more realistic implant scenarios

Flexible RMS sensor location

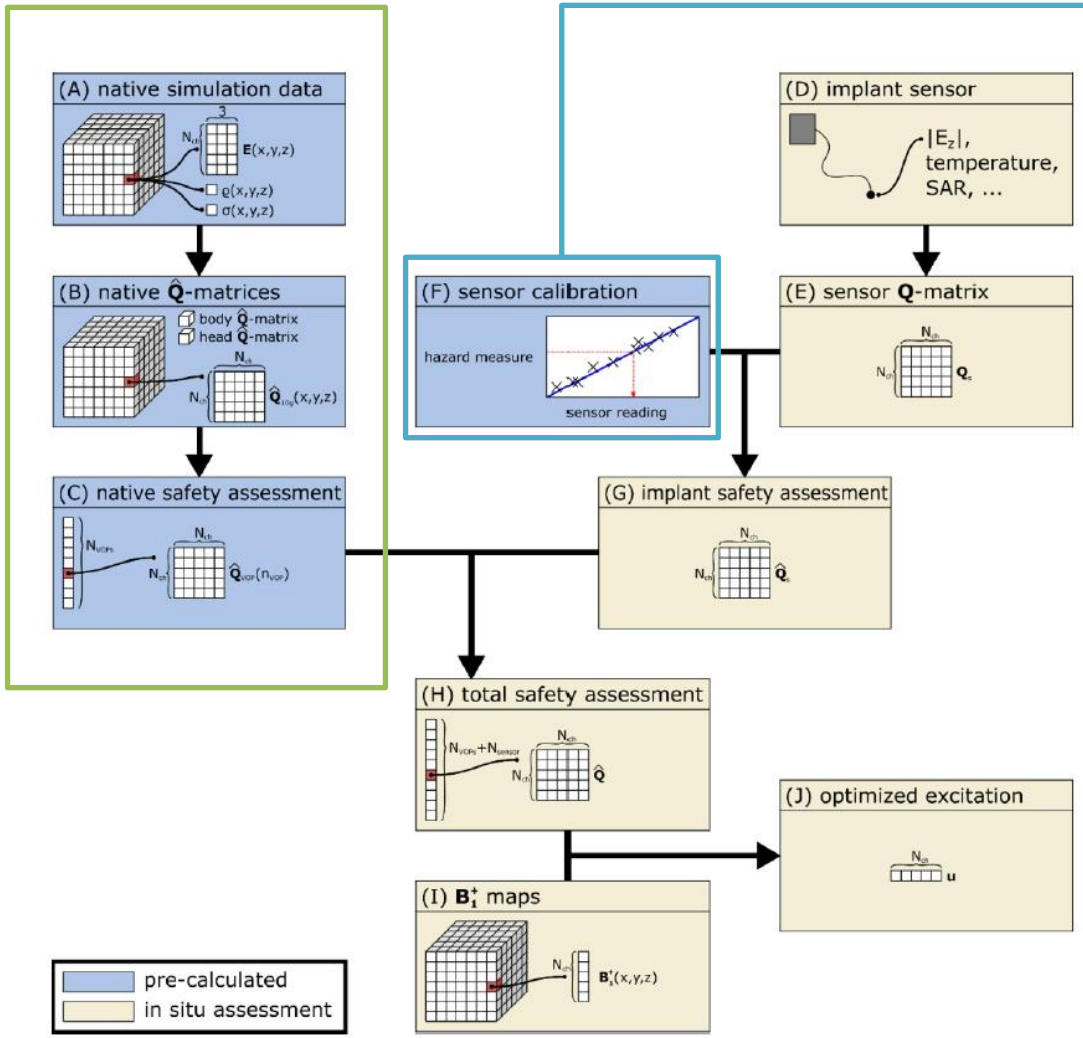


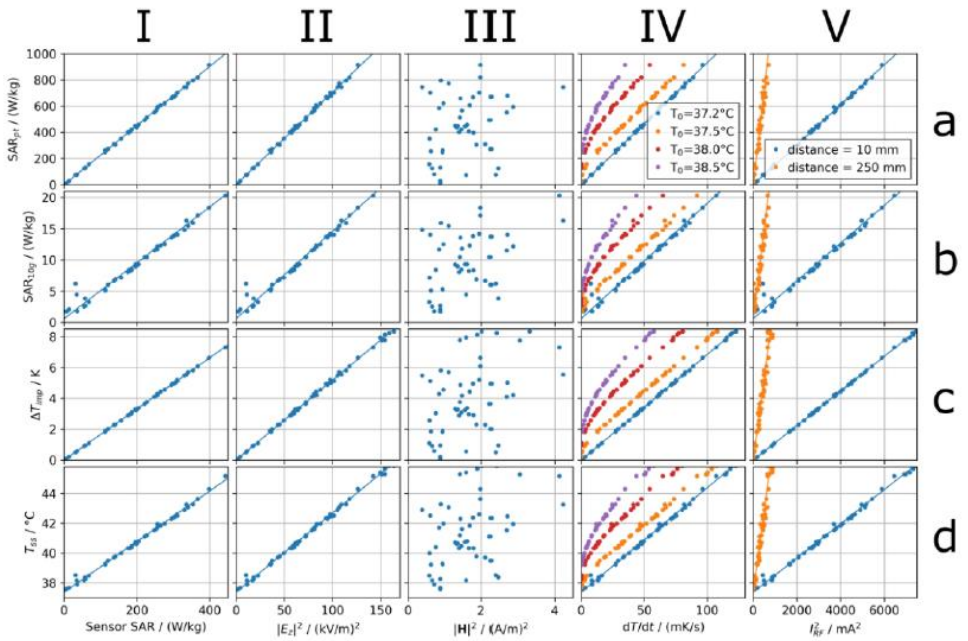
Wireless transmission of the sensor Q-matrix



Silemek B, et al., MRM, doi:10.1002/mrm.28968, 2021

Safety concept of smart implants





Petzold J, et al., MRM, [under review]

Summary

- pTx is capable to mitigate RF induced currents in implants
- Sensor Q-matrix approach enables RMS sensors to be used for pTx mitigation
- Methods exist that retain B_1^+ information based on the sensor signals alone
- Proof of concept demonstrated of applying the sensor Q-matrix approach using RMS sensors under MRI conditions
- Such novel safety concept of „smart“ implants could extend current approaches to implant safety with several advantages for implant manufacturers, MR vendors and patients

Discussion

„Smart“ sensor embedded medical implants communicating with a pTx capable MRI

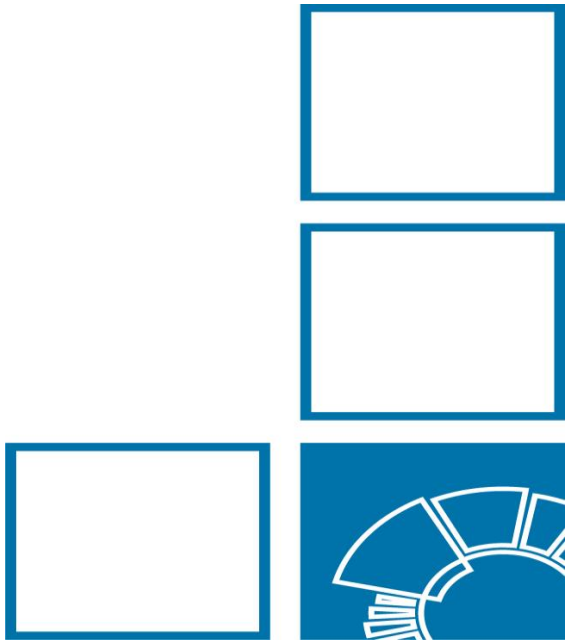
RF Safety
- No assumptions/approximations, but in-situ monitoring
- Severely reduced RF induced heating
- Less conservative due to smaller uncertainties
- Potential extension to multiple implants (also from different vendors)
- Independent of transmission frequency (0.55, 1.5, 3.0, 7.0T)

Imaging
- Improved diagnostics with implants present
- pTx available at 7T
- 2-channel RF coils at 3T

Implant design
- Relaxed measures for device protection
- Less testing
- Improves innovation potential

This project (17IND01 MIMAS) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

Thank You!



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