Tools and methods for low field MR imaging and elastography

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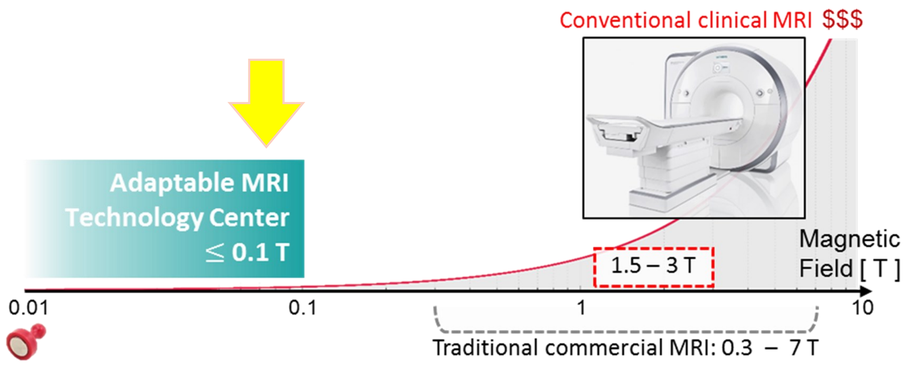
FNSNF Swiss National Science Foundation

What is low field MR?

MRI ≤ 0.1 T, much lower magnetic field than today's clinical scanners:

- ✓ accessibile & flexibile: siting, €, smaller size, maintenance, ...
- ✓ less ferromagnetic "bullet" risks
- ✓ less susceptibility artifacts from iron/implants/air
- ✓ less complicated coil optimization



But it does not mean "simple":

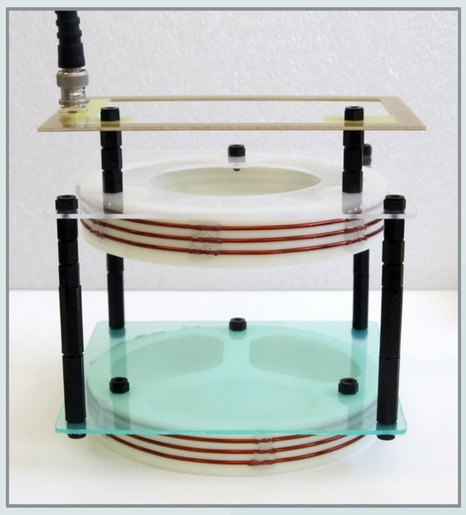
- x less signal = longer scan time
- x fine resolution is harder (but not impossible!)
- x smaller magnets are often more inhomogeneous
- x many tools must be custom-made

What have I worked on?

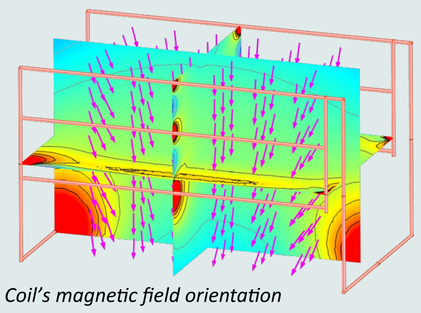
Optimized detectors: RF coils @ 4.2 MHz

If carefully designed and built, they may boost the MR signal or lower the noise, allowing faster scans. Innovative open-access coils enable adaptable, flexible applications (interventional MR, kinematic MRI, MRE, imaging with orthopedic implants).

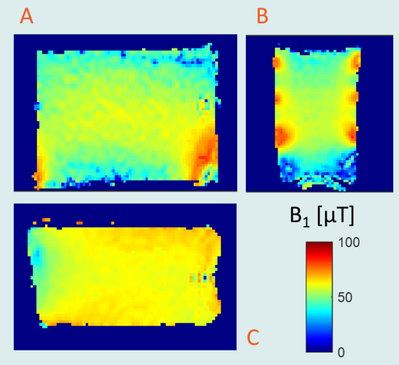
Open RF coil for MR Elastography



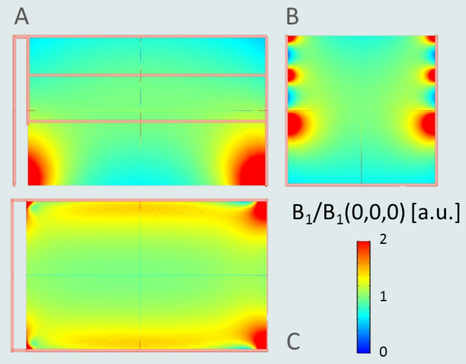
Left: open-access RF coil for flexible MRI and MR Elastography. Right: coil in a 0.1 T MRI for foot imaging.



Coil's magnetic field orientation



Acquired maps of a coil's magnetic field



Simulation of a coil's magnetic field

MR Elastography

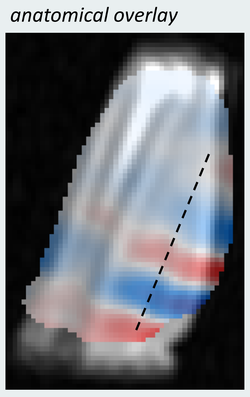
MRE quantifies the mechanical properties of organs, such as stiffness and viscosity.

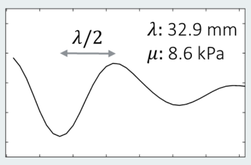
It requires 3 ingredients:

- wave propagation in the body,
- a motion-sensitive MR scan to capture the wave motion,
- mathematical inversion of raw data into diagnostic maps.

Often used for liver fibrosis, MRE becomes unreliable at clinical magnetic fields when iron accumulates in organs.

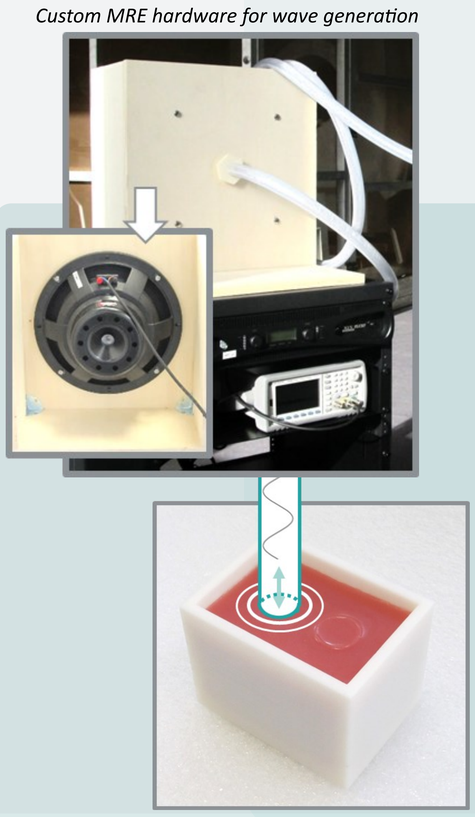
MRE wave example in the arm, 89 Hz vibration, with anatomical overlay



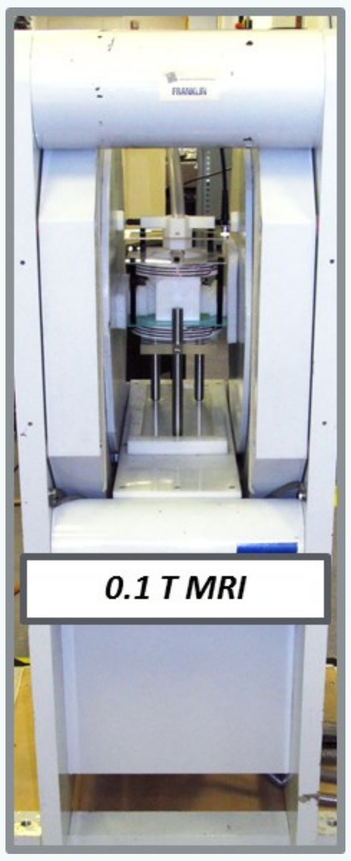


Example of wavelength and stiffness estimation from the wave profile

Custom MRE hardware for wave generation

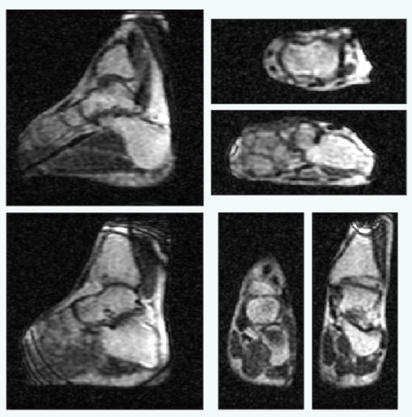


MRE vibration on a silicone phantom

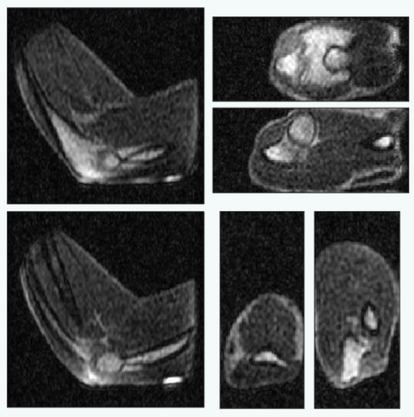


Dedicated MR sequences

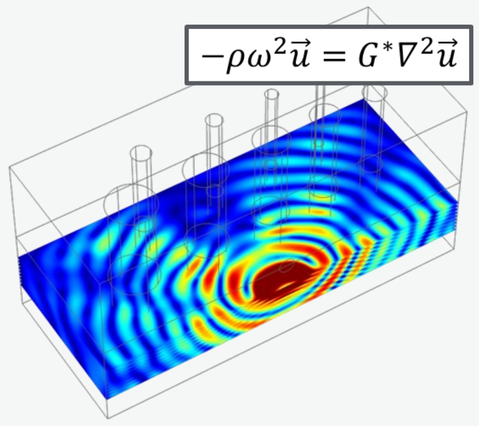
optimized for our hardware and magnetic field to speed up MR scans despite many challenges (e.g. low signal, unshielded scanner, B_0 inhomogeneity, no commercial sequences).



Ankle MRI views of a single 3D bSSFP scan, 7 min 54 s, voxel size: 0.8 x 0.8 x 1.1 mm³



Elbow MRI views of a single 3D DESS scan, 9 min 18 s, voxel size: 0.8 x 0.8 x 1.1 mm³



Wave simulation for synthetic MRE data

Simulations

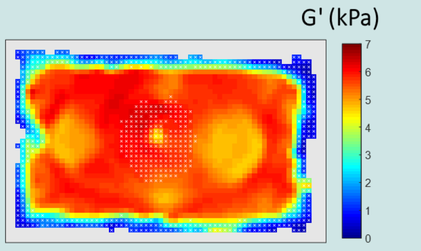
enable accurate optimization of a coil's magnetic field or provide synthetic MR data for validating Elastography reconstructions.

Phantoms

mimicking anatomical shapes or ideal objects with a controlled geometry for testing MR sequences, or different magnetic / mechanical properties for validating MRE methods at various magnetic fields.

Molded silicone foot phantom

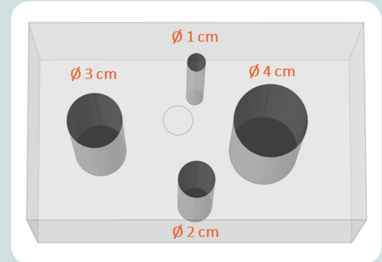
Silicone phantom for MRE

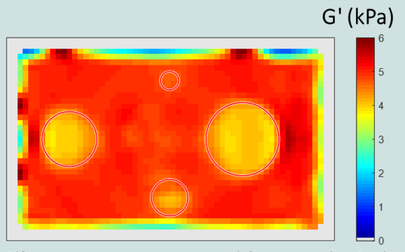


Stiffness maps from MRE on the phantom at 3 T

Yushchenko *et al.* Front Phys 2021

Simulated geometry of the real phantom





Stiffness maps reconstructed from synthetic data

Acknowledgements

Philippe Choquet, PhD (University of Strasbourg / AMT)
Jens Wuerfel, MD (University of Basel / MIAC AG)
Michael Amann, PhD (University of Basel / MIAC AG)
Ahmed Abdulazim, MD (Crossklinik Basel)
Olivier Braissant, PhD (University of Basel)
Marco Fiorito, PhD (AMT Center)
Reina Ayde, PhD (AMT Center)
Gabriel Zihlmann, MSc (AMT Center)
Tobias Senft, MSc (AMT Center)
Davide Cicolari, MSc (University of Pavia / AMT Center)
Thomas Quirin, MSc (University of Strasbourg / AMT)
Céline Worreth, BSc (University of Strasbourg / AMT)
Augustin Moreau, MSc (University of Strasbourg / AMT)

Supervision

Prof. Najat Salameh, PhD (AMT Center)
Prof. Mathieu Sarracanie, PhD (AMT Center)
Prof. Markus Heim, MD (Universitätsspital Basel)

Collaborations

Julien Rivoire, PhD (RS²D)
Lionel Broche, PhD (University of Aberdeen)
Xavier Maître, PhD (Université Paris-Saclay)
Arnaud Germaneau, PhD (University of Poitiers)
Laetitia Caillé, PhD (University of Poitiers)
Jean-Philippe Deneuville, MSc (University of Poitiers)
Prof. Ralph Sinkus, PhD (King's College London)
Prof. Helmut Harbrecht, PhD (University of Basel)

Funding

Swiss National Science Foundation
Grant No. PP00P2_170575

European Research Counsil
Horizon 2020 No. 668039

State Secretariat for Education, Research and Innovation
REF-1131-52107

September 2021