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Magnetic Resonance Elastography simulation with an Object Oriented Development Interface for NMR

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Introduction

Magnetic Resonance Elastography[1] (MRE): non-invasive MR method quantifying mechanical properties of tissues by imaging the propagation of a shear wave inside the investigated tissue, using a **specific MRI sequence**. Tissue motion is encoded in **phase images** thanks to a **Motion-Encoding Gradient** (MEG) synchronized to an external mechanical excitation.

Context: some studies[2] implemented innovative sequences for MRE, but, to our knowledge, none have so far simulated these sequences before experiments.
Aim of the study: simulation of a MRE experiment, with a gradient-echo sequence and a dynamical phantom, using the software ODIN[3].

Method

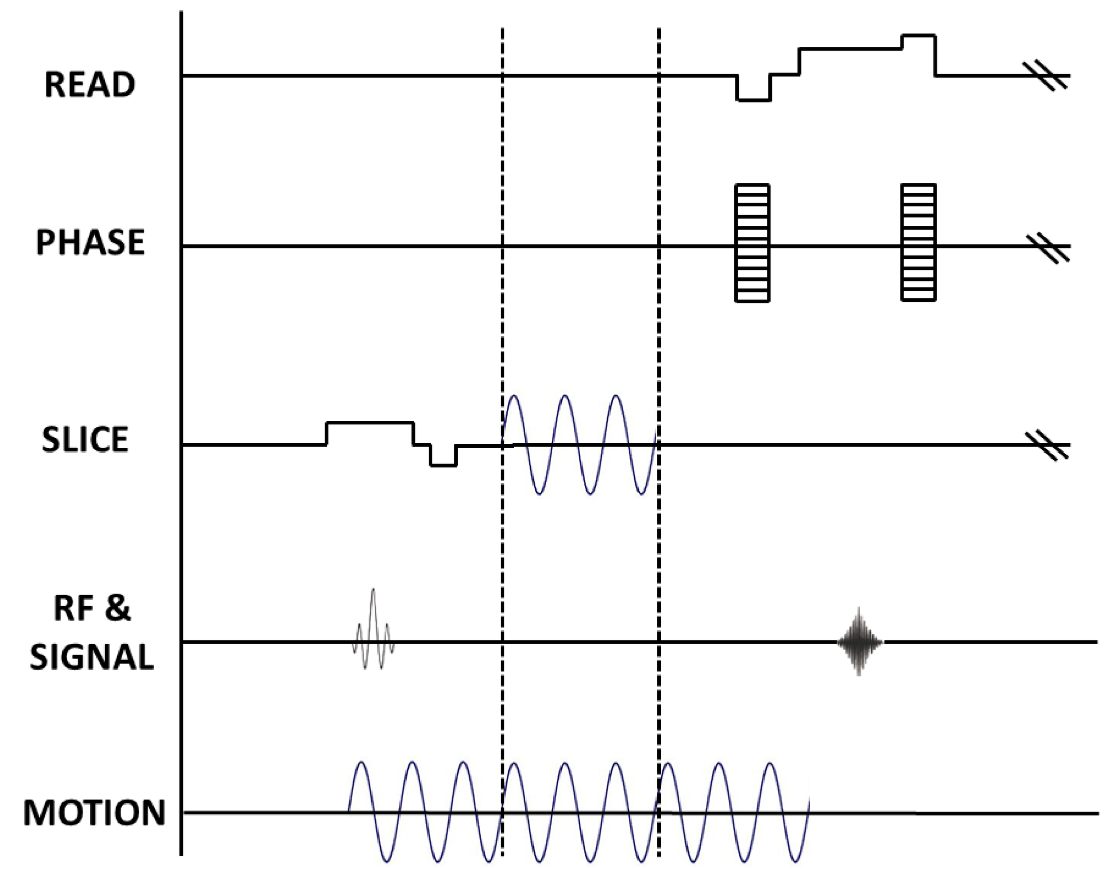
ODIN

- C++ software framework[3] designed to develop and simulate MR sequences
- Simulates the spin-physics of the sequence, with Bloch-Torrey equations
- Allows the design of customized MRI sequences and phantoms

MRE sequence		Phantoms properties		Motion properties	
Tr/Te	1000/10 ms	T1	300 ms	Frequency f	400 Hz
MEG amplitude G	0.150 T/m	T2	75 ms	Amplitude A_0	50 µm
Scan Resolution FOV	64x64 pix 4x4cm	Size	3.8x3.8 cm	Wavelength λ	10, 15 and 20 mm

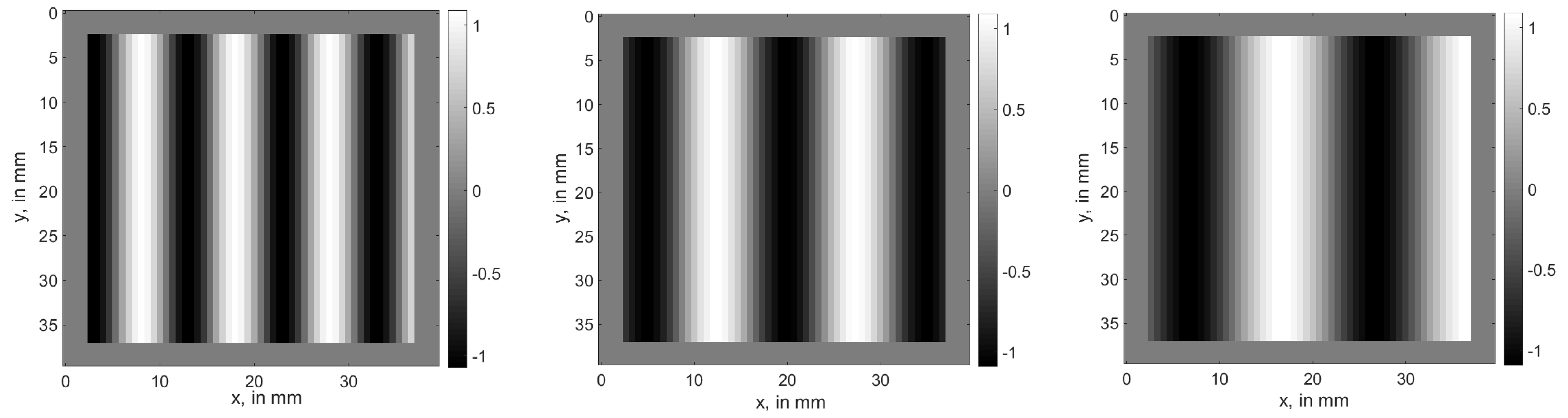
MRE sequence

Customized MRI Gradient-Echo sequence



Phantom generation

Effect of the motion encoded as a B0 field oscillation (in ppm), at an arbitraty time



a) λ = 10 mm b) λ = 15 mm c) λ = 20 mm

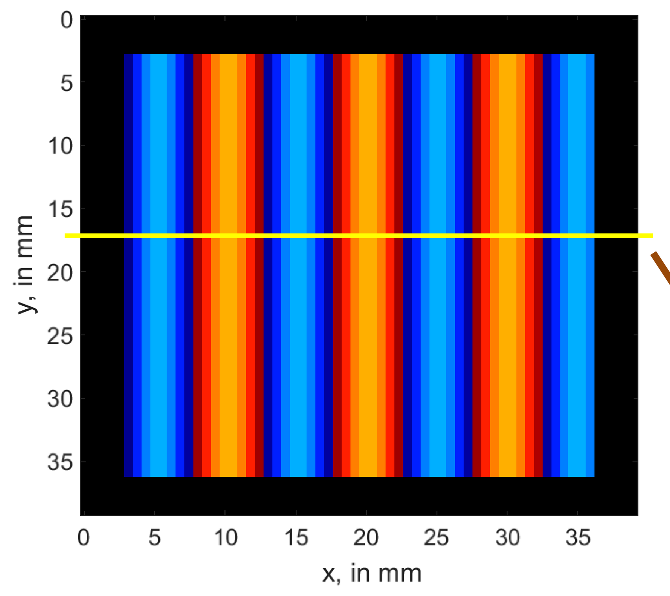
$$\Delta B_0(x,t) = \frac{10^6}{B_0} * \left(G * \sin(2\pi f t) * A_0 * \sin\left(2\pi f t - 2\pi \frac{x}{\lambda}\right)\right)$$

with *G* gradient amplitude, *f* excitation frequency, *λ* wavelength, A_0 motion amplitude and B_0 static MRI field (4.7 T).

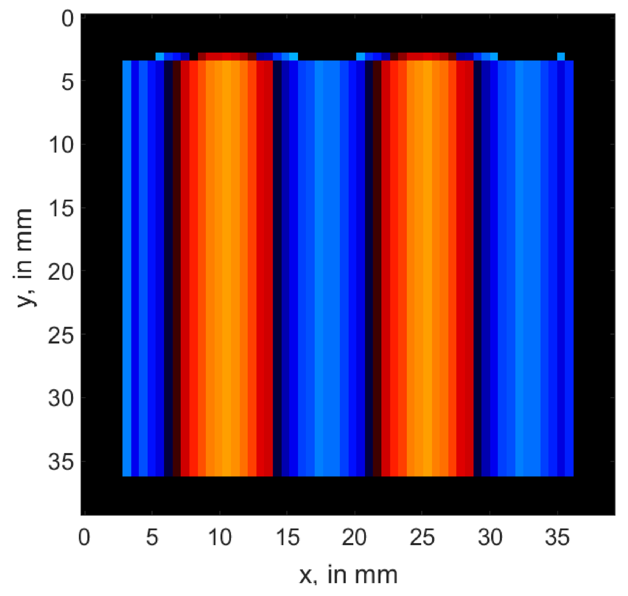
Results

Phase images (a-c) obtained from MRE simulations (with 3 different wavelengths)

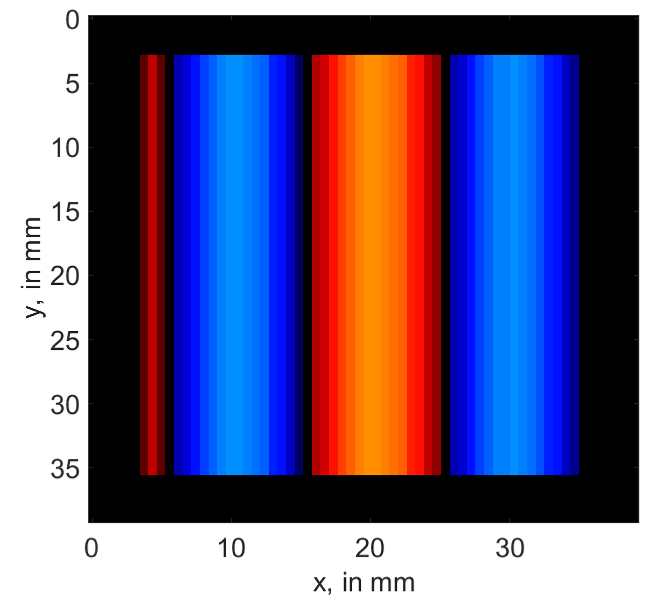
a) λ = 10 mm



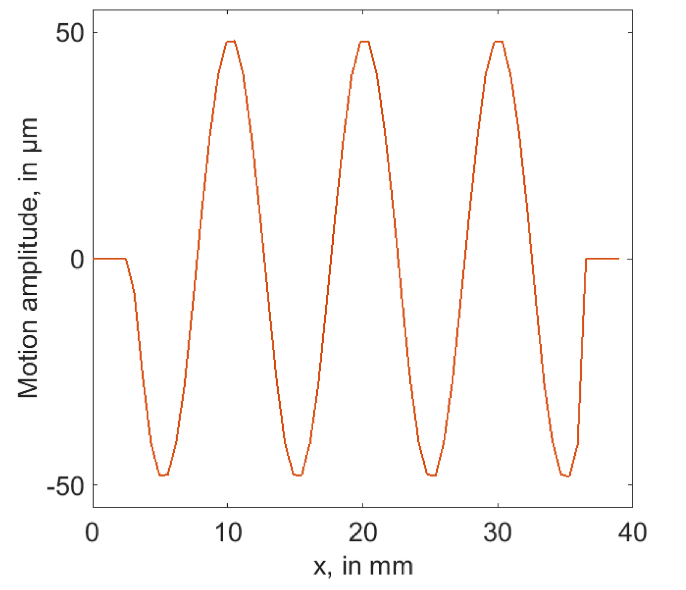
b) λ = 15 mm



c) λ = 20 mm



d) Projection of motion amplitude after conversion



- Phase images transformed into motion amplitude images, using the conversion factor *C=2*f / (γ*N*G)* (*γ* being the gyromagnetic ratio and *N* the number of MEG cycles):
  - ✓ **Wave pattern** consistent with the wavelength of the motion
  - ✓ **Wave amplitude** consistent with the motion generated inside the phantom.(d)

Conclusion and future work

- ✓ Results obtained from the simulations consistent with the expected values
- ✓ Great interest of using a reliable, open-source and flexible simulation tool to validate new MRE sequences
- ✓ Future work will include the investigation of the impact of experimental variations (coils types, field inhomogeneities, noise…) on new MRE sequences

References:
(1)Muthupillai et al – Science 269:1854-57 (1995)
(2)Garteiser et al – NMR in Biomedicine 26(10): 1326-35 (2013)
(3)Jochimsen et al – JMR 180(1): 29-38 (2006)

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