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Efficiency Analysis of Magnetic Field Measurements for MR Electrical Impedance Tomography (MREIT)

Cihan Göksu[1-2], Lars G. Hanson[1-2], Philipp Ehses[3-4], Klaus Scheffler[3-4], and Axel Thielscher[1-2-3]

[1] Danish Research Centre for Magnetic Resonance, Centre for Functional and Diagnostic Imaging and Research, Copenhagen University Hospital Hvidovre, Denmark, [2] Center for Magnetic Resonance Group, DTU Elektro, Technical University of Denmark, Kgs. Lyngby, Denmark, [3] High-Field Magnetic Resonance Center, Max-Planck-Institute for Biological Cybernetics, Tübingen, Germany, [4] Department of Biomedical Magnetic Resonance, University of Tübingen, Tübingen, Germany

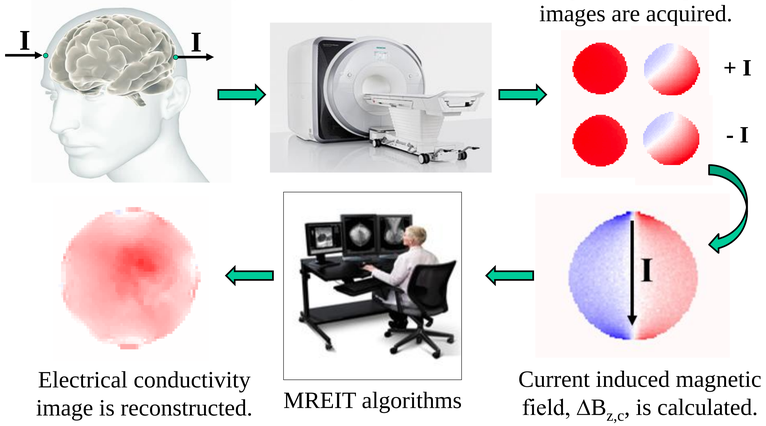
Introduction

MREIT is an emerging method to measure the ohmic tissue conductivities, with several potential biomedical applications. Its sensitivity depends on the magnitude of the applied current, which is limited to 1-2 mA in the human brain. This renders in-vivo applications challenging. Here, we aim to analyze and optimize the efficiency of two MREIT pulse sequences for in-vivo brain imaging.

MREIT

External current, I, is injected during the MRI scan.

Magnitude and phase images are acquired.



Electrical conductivity image is reconstructed.

MREIT algorithms

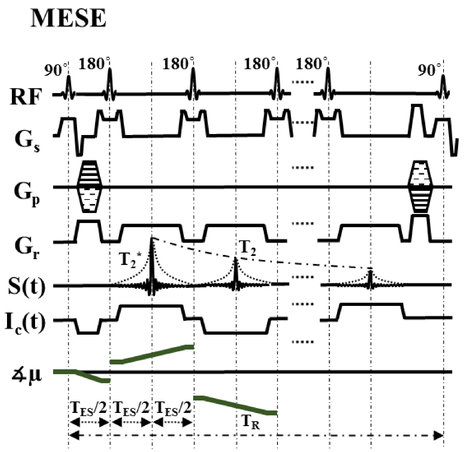
Current induced magnetic field, $\Delta B_{z,c}$, is calculated.

Efficiency of MREIT

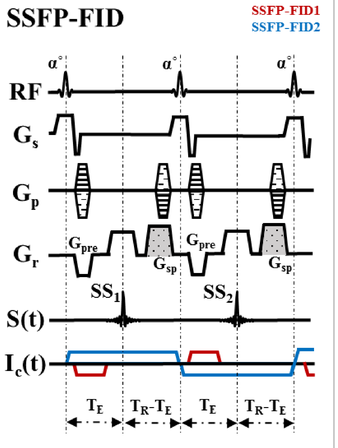
The quality of the reconstructed MREIT images depends on the sensitivity of the $\Delta B_{z,c}$ measurements. The efficiency η can be defined as signal to noise ratios (SNRs) of $\Delta B_{z,c}$ per square root measurement time. Here, we analyze the two sensitive MREIT pulse sequences, multi-echo spin echo (MESE) and steady-state free-precession free induction decay (SSFP-FID).

$$\eta^{MESE}_{\Delta B_{z,c}} = \frac{\Delta B_{z,c}\sqrt{\sum_{n=1}^{N_{echo}} 2\left\{\gamma SNR_n\left[(T_{ES}-\tau_\pi)n-\frac{\tau_{\pi/2}}{2}\right]\right\}^2}}{\sqrt{T_{tot}}} \qquad \eta^{SSFPFID}_{\Delta B_{z,c}} = \frac{\Delta B_{z,c} SNR \left.\frac{\partial \angle \mu}{\partial \Delta B_{z,c}}\right|_{\Delta B_{z,c}=0}}{\sqrt{T_{tot}}}$$

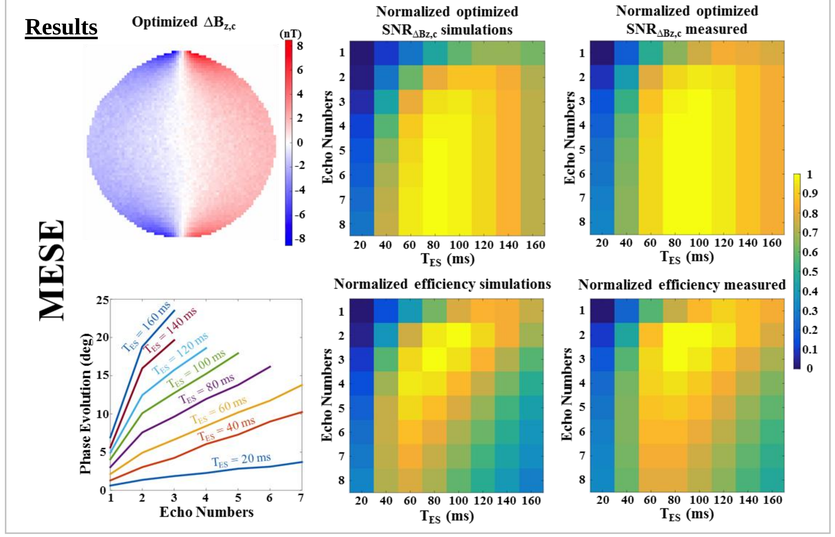
MESE

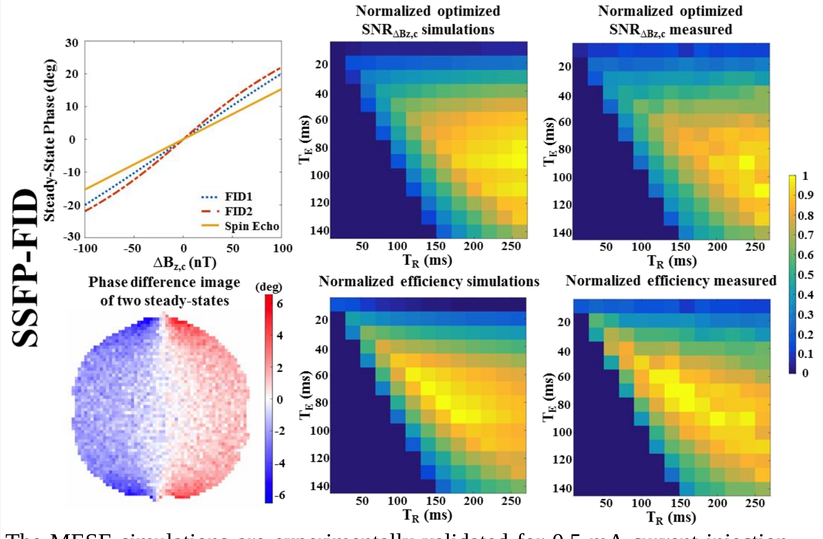


SSFP-FID



Results





The MESE simulations are experimentally validated for 0.5 mA current injection in a saline filled spherical homogenous phantom, 10 cm in diameter (T_1 = 1 s, T_2 = 100 ms). The phase evolution of two SSFP-FID variants are simulated and compared with spin echo. The most sensitive variants simulations are experimentally validated for 1 mA current injection in the same phantom.

Discussion and Conclusion

The measured and simulated efficiency maps for the MESE and SSFP-FID experiments are in good agreement. The most efficient regions for the MESE and SSFP-FID2 are Necho = [2, 3], T_{ES} = [60 - 100] ms, and T_E = [60 - 90] ms, T_R = [120 - 180] ms for $\alpha = 20^\circ$, respectively. Both sequences are promising for testing in in-vivo applications.

References

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