SIEMENS Healthineers

PhD Student (f/m/diverse)

Versatile and robust dynamic parallel transmission-enabled 2D Turbo Spin Echo MR imaging at 7 Tesla

CEA NeuroSpin, Saclay, France
Siemens Healthineers, Erlangen, Germany

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Our culture: We are part of an incredible community of scientists, clinicians, developers, researchers, professionals, and skilled specialists pushing the boundaries of what's possible, to improve people's lives around the world. We embrace a culture of inclusivity in which the power and potential of every individual can be unleashed. We spark ideas that lead to positive impact and continued success.

Location: As a Siemens Healthineers employee, the CIFRE PhD candidate will be enrolled at the University Paris-Saclay in the Physics & Engineering doctoral school (EOBE) and will be located at CEA NeuroSpin, one of the largest Magnetic Resonance Imaging (MRI) platforms in the world. In particular, it holds the first 7 T MR system in France as well as the most powerful MRI in the world, to image humans at 11.7 Tesla.

Profile sought: The PhD candidate is a student with a MSc degree with a specialization in Medical Imaging, or a background in Engineering Sciences, with a strong taste for MR Physics and programming. Knowledge of *C/C++*, *Python* and/or *Matlab* is strongly recommended. A strong ability to work in a multi-disciplinary team is also required, along with high capabilities in the English language.

Key words: Ultra-high field MRI. Turbo-Spin-Echo. Anatomical imaging. Parallel Transmission. MR sequence programming. Refocusing. Multi-slice imaging. SAR. Machine learning.

Skills:	Medical Imaging. MR Physics. Programming. Optimization.
Supervision:	Dr. Vincent Gras (CEA NeuroSpin) Dr. Aurélien Massire (Siemens Healthineers France) Dr. Jürgen Herrler (Siemens Healthineers Germany)
Application deadline:	June 30th, 2024
Duration:	36 months
Desired start date:	October 2024
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Background:

In MRI, ultra-high-field (UHF) strengths ($\geq$7T) provide a higher signal-to-noise ratio, enabling increased spatial resolution and/or reduced acquisition time as compared to lower-field MR systems. Since the Siemens Healthineers Magnetom Terra 7T MR system received the CE & FDA clearance for clinical use, thousands of patients have been scanned, allowing the 7T to markedly demonstrate its added value for the diagnosis of several brain diseases [1]. However, destructive field interferences can lead to spatial inhomogeneity in the radiofrequency (RF) excitation profile at 7T. In the head, the cerebellum and the temporal lobes can be affected by such inhomogeneities, which result in signal voids in the images.

The use of parallel transmission (pTx) technology with an array of transmit coil elements has proven to be very efficient in addressing these challenges [2]. With pTx, the amplitudes and phases of the RF pulses transmitted by the channels of the coil array are independently modulated in time to homogenize the excitation profile over the volume of interest, provided that the actual transmit RF field (B_1^+) and static field offset (ΔB_0) distributions are known. For nonselective excitations used in 3D anatomical MR sequences, various parametrization approaches, such as k_T-points [3] or GRAPE [4], have been proposed to design optimized RF and magnetic field gradient waveforms. The design of such subject-tailored RF pulses results in very homogeneous RF excitation profiles, but at the cost of the extra scan time required to map the patient field distributions and to design the RF pulses. Alternate methods to a subject-tailored approach can avoid systematic measurement of the RF and static field distributions for each subject and subsequent RF pulse computation. An original approach that uses “Universal Pulses” (UP) for calibration-free pTx neuroimaging was recently developed [5] and extended to slab-selective excitations of any thickness/orientation/rotation while preserving a plug-and-play philosophy [6]. Another hybrid method, called FOCUS, that combines both UP and a fast subject-specific online calibration requiring <1 min additional sequence preparation time also showed high potential for clinical workflow compatibility [7]. Finally, machine learning [8] might drastically reduce RF pulse design computational load and enable subject-tailored efficient solutions in a challenging clinical workflow.

In 2D multi-slice MRI acquisitions, the RF inhomogeneity is generally solved using slice-by-slice RF shimming or multi-spoke pulses [9]. Unfortunately, these solutions are usually attached to a given set of slice positions and orientations [10] and thus must be recomputed for every new slice positioning. A new concept, called "meta-pulses", which expresses the RF pulse complex coefficients and gradient blip moments as smooth functions of the slice position and orientation, was very recently proposed to offer full latitude to the user in a real-life setting [11]. This solution, combined with multi-spoke RF pulses, was successfully deployed for 2D gradient echo-based *in vivo* brain MR imaging at 7T (see Figure below), but remains to be investigated for 2D Turbo Spin Echo (TSE) imaging, a cornerstone of modern MRI portfolio.

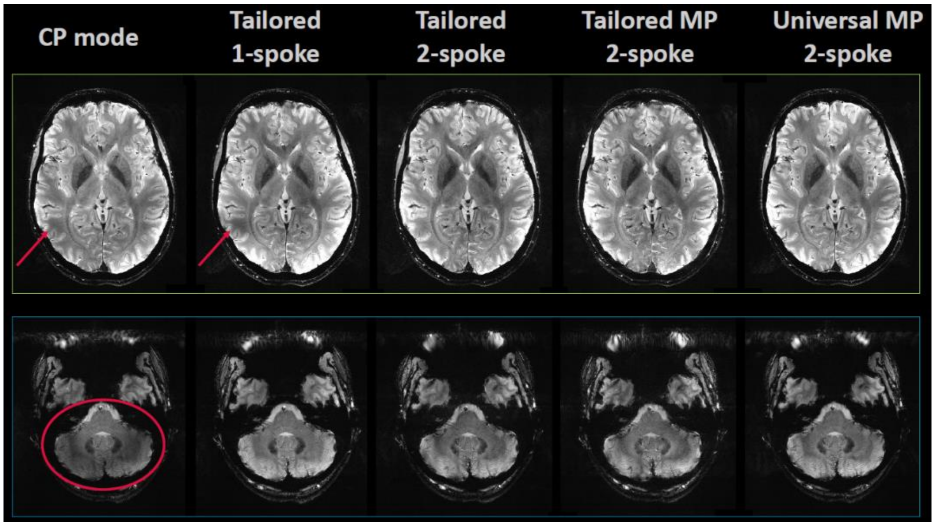

Figure: 2D gradient echo-based *in vivo* brain MR imaging at 7T using tailored or universal RF pulse design, incl. Meta pulses.

Objectives:

This PhD project aims at enabling performant 2D TSE brain imaging using 7 Tesla MR system, with reliable image quality for any orientation or position, in a time-constrained setting (i.e. within a clinical workflow). To do so, the parallel transmission technology has been identified as the most elegant solution. Comprehensive pTx capabilities should be therefore successfully implemented in a dedicated MR sequence programmed in *IDEA*, the proprietary programming environment of Siemens Healthineers. MR experiments will be carried out on the 7T MR system of CEA NeuroSpin, with opportunities to also experiment on the Erlangen 7T MR system.

Efficient and robust RF refocusing appears as a major challenge for successful UHF TSE imaging, due to the required high energy demand of slice-selective large-flip-angle pulses. The meta-pulse solution promotes signal smoothness and energy deposition continuity along the protocol slices when compared to the slice-by-slice solutions, which also appears instrumental in successful TSE imaging. The resulting pulse design computational burden is significant and should nonetheless be executed in a very short time. To address all these challenges, the following strategies will be investigated and benchmarked, using Bloch simulations and MR experiments:

- RF pulse design under strict Specific Absorption Rate (SAR) constraints using state-of-the-art second order optimization (*Matlab*, *Python*) to achieve scalable and SAR-efficient (VERSE) RF solutions.
- Machine learning-based methods (e.g. Deep Learning) to quickly and reliably extrapolate the adequate RF shapes for any orientation and position (Meta-pulse).
- TSE sequence refinements based either on hyper-echoes, variable flip angle echo train, or direct signal control [12].

To evaluate the various contributions of RF pulse design and sequence implementation, several qualitative and quantitative success criteria will be investigated: image quality assessment by an experienced neuroradiologist, presence of image artifacts, required calibration measurements, required computational burden for online scanning, obtained SAR and signal-to-noise ratio (SNR) levels. The methods developed in this PhD project might be adapted for patent filling. A long term perspective could be the certification of such methods for clinical use on a patient cohort scanned using the latest 7T Terra.X platform.

References:

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