Evaluation of 2DRF echo-planar pulse designs for parallel transmission

Rainer Schneider[1,2], Dieter Ritter[1], Jens Haueisen[2], and Josef Pfeuffer[1]
[1]*Siemens Healthcare, Erlangen, Germany,* [2]*Institute of Biomedical Engineering and Informatics, TU Ilmenau, Ilmenau, Germany*

Introduction: Parallel transmission (pTx) has been shown to enable the design of spatially selective pulses with mitigated excitation inhomogeneity and off-resonance effects. Further the redundancy due to additional rf channels increase the degree of freedom (DoF) within the optimization scheme, which offers amongst others the opportunity to accelerate time intensive spatially selective pulses (1, 2). However, the majority of pTx studies used spatially selective pulses based on a 2D spiral k-space trajectory design analyzing the excitation quality in dependence of the Tx acceleration factor.

The aim of this work firstly pursues the introduction of slice selective pulses based on a rectilinear blipped EPI trajectory (2DRF) to the parallel transmission regime. Second, an analysis regarding the ability to compensate B0 and B1 inhomogeneities is done showing the benefits of additional rf transmit channels in comparison to a single channel CP mode. For this purpose the proposed methods are evaluated with simulations and in phantom experiments.

Methods: The 2DRF pulse optimization is a multi-channel extension of the framework proposed elsewhere (3). In brief, within a spatial domain design approach the sub-pulses along the fast direction (SS) are optimized by taking the B0 and B1 information into account. In addition, a novel k-space trajectory design driven by the off-resonance information is used, which variably adjusts the k-line density along the phase encoding direction and further is able to correct the geometric deformation due to the accrued phase error. For comparison to the optimized 2DRF pulses analytically pulses were calculated according to ref. (4). Phantom experiments were performed on a 2-ch pTx system, based on a 3T MAGNETOM Skyra (Siemens, Erlangen, Germany). B1 and B0 information were obtained with presaturation TurboFLASH (5) and a dual echo time gradient-echo approach, respectively. All 2DRF pulses were designed with a flyback EPI trajectory and proper excitation side-lobes according to the field of excitation. Acquisition was done with gradient-echo EPI with FA=15°, resolution 3x3x5 mm^3, FOV 192x38 mm^2, TR 1000 ms, TE 48 ms.

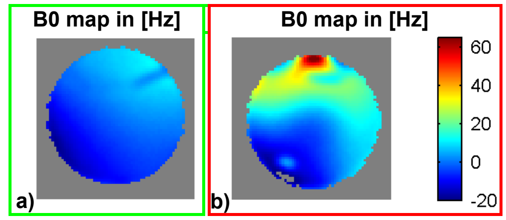

Figure 1: B0 maps of phantom experiments with ***a)*** **weak** and ***b)*** **strong** off-resonance.

Within the same setup the performance of the independent dual-ch pTx excitation was compared to a 1-ch circular-polarized (CP) mode. Bloch-simulations and experiments were evaluated via the root mean square error (RMSE) to the ideal excitation pattern. In order to highlight the ability of the 2-ch pTx excitation vs. 1-ch CP mode to compensate B1 and B0 inhomogeneities, i.e. a stepwise incorporation of B1 and B0 map information into the optimization, experiments with low (**Fig. 1a**) and strong (**Fig. 1b**) off-resonance were conducted. The latter was achieved by introducing susceptibility differences via an air bubble in the phantom. For comparison, experimental data were normalized to the simulated data to the same mean value within the excited region.

Results: Experimental results of optimized 2DRF pulses for 1-ch and 2-ch pTx are depicted in **Fig. 2** and **Fig. 3** using different levels of optimization methods. Note that according RMSE values from the *simulation* are given in brackets. The optimized pulses generally reveal superior RMSE values compared to the respective analytical ones. In terms of B1 mitigation (**Fig. 2**) and compensating the geometric deformation due to strong off-resonance (**Fig. 3**), RMSE is decreased for 1-ch pulses by 15% and 16%, respectively. For the 2-ch pTx case an additional gain of 14%, in simulations even up to 18% less RMSE can be observed due to the increased DoF. Higher errors in the experimental setting are likely due to additional noise and system imperfections compared to the simulation.

Conclusion: Within this study we have firstly successfully implemented spatially selective 2DRF pulses based on a blipped, rectilinear EPI trajectory on a 2-ch parallel transmission system. Secondly, optimized 2DRF pulses incorporating B1, B0 and variable-density TX trajectories outperform analytical designed pulses. More precisely, B1 and B0 inhomogeneity mitigation improve up to 16%, with 2-ch pTx even up to 29% lower RMSE. Finally, 2-ch pTx offers additional improvements of 14% (in simulations 18%) due to higher DoF compared to single channel mode.

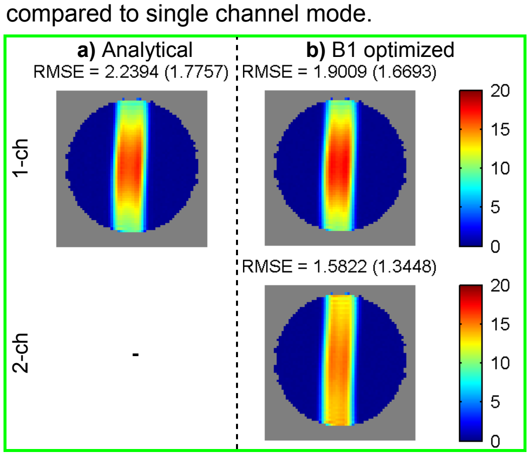

Figure 2: 1-ch and 2-ch comparisons in the phantom with **low** off-resonance ***a)*** analytical 2DRF pulse ***b)*** B1 optimized pulse for inhomogeneity mitigation

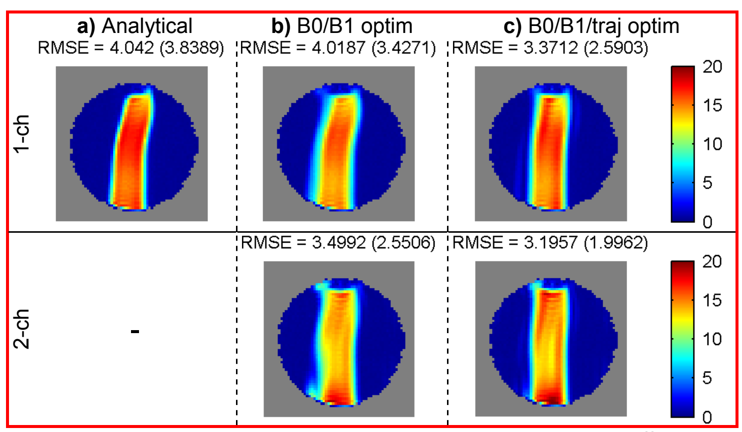

Figure 3: 1-ch and 2-ch comparisons in the phantom with **strong** off-resonance: ***a)*** analytical, ***b)*** B1/B0 optimized pulse and ***c)*** B1/B0/k-space trajectory optimized design.

References: 1. Grissom MRM 2006,620. **2.** Setsompop. MRM 2008,908. **3.** Schneider this meeting. **4.** Rieseberg. MRM2002,1186, **5.** Fautz, ISMRM 2008,1247.