Using Dedicated Fieldprobes for Trajectory Measurements in Parallel Excitation Experiments

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Introduction: Parallel spatially selective Excitation (PEX) relies on an exact matching of RF pulses and a simultaneously traversed k-space trajectory. However, e.g. eddy currents or gradient amplifier bandwidth limitations may lead to deviations of the traversed trajectory resulting in reduced excitation accuracy due to the susceptibility of PEX pulses to trajectory errors [1]. Therefore, different methods for measuring actually traversed k-space trajectories and for calculating PEX pulses based on such calibration data have been presented and have proven to be advantageous [1,2]. However, most of the applied trajectory measurement techniques are based on phase evolutions in situ within the object and suffer therefore, especially at high field strengths and for long trajectories, from object-dependent limitations like fast T1* decays, off-resonances, intra-volume effects or motion artifacts. To overcome these limitations, this work exploits the field monitoring approach [3,4] using newly developed field probes on D2O basis in order to achieve object-independent trajectory measurements. This allows a robust acquisition of calibration data for the calculation of PEX pulses and results in parallel excitation with high accuracy.

Material and Methods: PEX experiments were carried out in a T2*-doped water phantom and a rat (post mortem) using a 9.4 T Bruker BioSpec animal system with an 8-channel parallel transmit extension [5] and an 8-element Tx/Rx coil array. The k-space trajectories were measured with a newly developed D2O field probe (Fig. 1) consisting of a 5 µl droplet of pure D2O within a micro Tx/Rx coil encapsulated in an epoxy ellipsoid. The use of 2D, whose gyromagnetic ratio is 6.5144 times the one of 1H, eliminates the need for decoupling or shielding of the field probe against the coil array used for proton imaging and offers therefore an convenient way for field measurements in parallel to proton experiments. Disadvantages of reduced signal intensity could be compensated for by an adequate probe size (see Fig. 1) resulting in sufficient SNR.

One single field probe was attached to the measurement object with a certain offset to the gradient center in all three spatial directions and it was interfaced to an independent X-nuclei spectrometer channel operating at the 2D frequency of 61.4 MHz. The probe position p was determined by a simple projection scan in three directions. For trajectory measurements prior to the PEX experiments the D2O was excited by the microcoil and the phase evolution φi(t) of the transverse magnetization was acquired while the gradient waveform to be measured was applied simultaneously. This measurement was repeated for each gradient channel i=x,y,z consecutively. For elimination of unwanted phase contributions due to eddy currents or gradient amplifier bandwidth limitations may lead to deviations of the traversed trajectory resulting in reduced excitation accuracy due to the

Results: The signal of the D2O field probe exhibits a very slow decay with a time constant T2* of approximately 200 ms at 9.4 T which is one order of magnitude longer compared to most in-situ measure-ments. Furthermore, given the gamma-ratio of 6.5144 between 1H and D2O, the field probes used allow monitoring trajectories for 1H image- / excitation-resolution of down to 160 µm. Beyond this value the gradient fields measured would cause intravolume dephasing leading to signal cancelation.

The traversed trajectory was calculated afterwards for the 1H PEX experiments according to \( k(t) = 6.5144 \cdot \left[ \phi_i(t) - \phi_{ref}(t) \right] / p \). For comparison the trajectories were also measured using the commonly in-situ multislice method according to Duyn [6] consisting in measuring the phase evolution within thin slices inside the objects.

For the PEX experiments in our study, 2-fold accelerated spiral k-space trajectories were used for encoding a field of excitation of (64 mm)2 / (40 mm)2 with a resolution of (1.0 mm)2 / (0.6 mm)2 in the phantom / rat; pulses for the excitation of a checkerboard-like target pattern in the phantom and of a ROI covering the brain of the rat were calculated according to [2] based on the trajectory data measured with the field probe.

Conclusion: This study demonstrates that the previously presented [1] potential of a trajectory measurement for high accuracy in parallel excitation can effectively be exploited by an object independent, robust calibration procedure using a dedicated field probe. The use of different nuclei for the field probe (e.g. D2O) and for imaging (1H) allows a comfortable setup and handling of the field probe since coupling between the field probe and imaging coils is avoided. The benefits over the common in-situ methods are significant especially in case of long trajectories or complex and structured objects. Minimal effort of attaching one single field probe onto an object and connecting it to an existing spectrometer channel allows a very robust, convenient and object-independent measurement of an actually traversed k-space trajectory within seconds prior to the excitation experiment. The calculation of PEX pulses based on such measured data results in very precise excitation within an object. Applications like inner volume imaging in realistic and complex objects may greatly benefit from this technique. For detection of non-linear components of the gradient fields, which can be integrated into the pulse calculation process similarly [1], the approach of this study can be extended by the use of multiple field probes at different positions according to the field monitoring approach presented in [4].

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