

Combination of SPECIAL and 2D SSE Parallel Transmit Pulses for Volume Selection in MR Spectroscopy

Patrick Waxmann¹, Tomasz Dawid Lindel¹, Florian Schubert¹, Bernd Ittermann¹, and Ralf Mekte¹

¹Physikalisch-Technische Bundesanstalt, Braunschweig & Berlin, Germany

Introduction

Spatially selective excitation (SSE) using parallel transmission (pTx) to shorten the excitation pulses is a well known MR imaging technique today [1-3] and was recently also applied to MR spectroscopy (MRS) [4, 5]. Especially the excitation of anatomically shaped voxels is promising as this reduces contamination and eliminates the need for time and SAR consuming outer volume suppression. Since, in general, 3D SSE *k*-space trajectories are very long and the corresponding RF pulses computationally expensive, mainly 2D SSE is used. In this case the third dimension can be selected by a slice selective refocusing pulse but only at the cost of a longer echo time (TE). To obtain MRS acquisitions with short TE, we exploited the concept of the spin echo full intensity acquired localized (SPECIAL) sequence [6] and combined it with a 2D SSE scheme. Selection along the third direction was achieved by a double-shot scheme with a slice inversion pulse only before every second pTx excitation. This has the advantage over the conventional SPECIAL approach that due to the 2D selectivity of the pTx excitation no further refocusing pulse is necessary and readout can start directly after excitation. Thus, the echo time (TE) can be made as short as about half the excitation pulse length. The aim of this study is to prove the feasibility of this concept.

Methods

All experiments were performed on a 3 T Verio scanner (Siemens AG, Erlangen, Germany) equipped with 8 Tx channels and an 8-channel Tx/Rx head coil (Rapid Biomedical, Rimpf, Germany). The pTx pulses to excite the volume of interest (VOI) were calculated as in [3], using a 2D spiral trajectory designed for a 32x32 matrix with the small tip angle (STA) approach and an acceleration factor of 4, yielding a pulse duration of 2.5 ms.

To validate the spatial selectivity of the new sequence, the localization scheme was integrated into an imaging sequence and tested in a spherical water phantom (Fig.1). To reduce TR for the imaging scan a second inversion pulse after readout was used to restore the longitudinal magnetization.

A SPECIAL MRS sequence [7] was modified by replacing the excitation with the 2D pTx pulse and eliminating the refocusing pulse. The trajectory described above was used to calculate an amplitude encoding pulse to excite a 2 cm square with a flip angle (FA) of 10°. Voxel selection was validated in a cubical phantom (2 cm³) filled with citrate inside a cylinder filled with acetate. Spectra were acquired with the same pulse and the modified SPECIAL sequence from the inside and the outside of the cubical phantom with the following sequence parameters: Slice thickness = 2 cm, TR/TE = 4000/1.5 ms. Simulations for different off resonance frequencies were performed to estimate the bandwidth of the pTx pulse.

Results

The double-shot inversion scheme with a 2D SSE showed excellent slice selectivity along the third dimension (Fig.1e/2b) and the 2D SSE in Fig.2c shows only very little spurious excitation outside the target region of the cube. A bandwidth of about 200 Hz for the pTx pulse was estimated from simulations, sufficient to excite citrate and acetate simultaneously which differ by only about 50 Hz. Fig.3, showing the citrate resonance in the 'inside' and the acetate resonance in the 'outside' spectrum, both with very little contamination from the other component, is indicative of a good spatial selection, therefore. Low SNR is due to the small flip angle of 10° used for the pTx pulse and the small number of averages.

Discussion

The new excitation scheme provides spatial selectivity along all three dimensions. With a pulse duration of 2.5 ms, a TE of 1.5 ms was achieved, much shorter than any sequence employing a refocusing pulse can provide. This is especially an advantage at ultrahigh field strength where B_1^+ limitations and SAR constraints often require elongated refocusing pulses to achieve full inversion. For this proof-of-principle study a spiral trajectory was used, providing only limited spectral bandwidth. An extension of the concept to a segmented design [4], allowing pulse durations below 1 ms and hence much larger bandwidths combined with even shorter TE is currently under way.

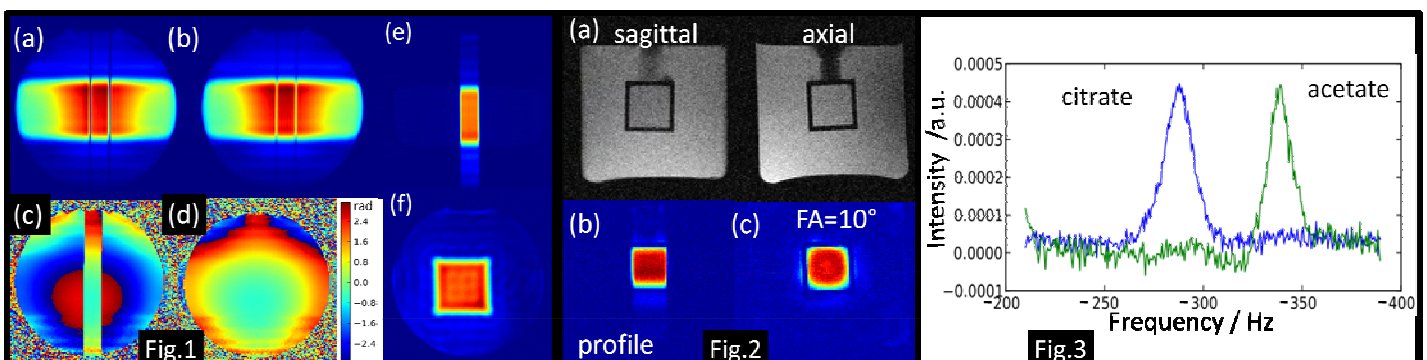


Fig.1: (a) to (e) show z-profiles & (f) x-y selection of the SSE. (a) and (b) show M_z with and without inversion pulse, (c) and (d) the corresponding phases. (e) is the complex sum of (a) & (b). The darker line at the slice borders in (b) is a saturation effect due to interleaved acquisition.
Fig.2: (a) cylindrical phantom with cube inside (b) profile and x-y view of 2D SSE with slice selection by inversion pulse.
Fig.3: Spectra with target region inside (blue) the cube and outside (green) the cube giving just the peak for citrate or acetate.

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