Single- and Multi-Voxel MR-Spectroscopy Using Parallel Excitation

P. Ullmann[1], J. T. Schneider[1,2], M. Haas[2], R. Wissmann[1], and W. Ruhm[1]

[1]Bruker BioSpin MRI GmbH, Ettlingen, Germany, [2]Dept. of Diagnostic Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Germany

Introduction

The use of multi-dimensional spatially-selective excitation (SSE) pulses for MR-spectroscopy (MRS) offers great potential for solving several problems generally occuring in classical volume-selective MRS with single rectangular voxels. On the one hand, the possibility of exciting arbitrarily shaped voxels, adapted to anatomical structures, can help maximizing the target-volume while avoiding so-called "partial-volume effects". On the other hand simultaneous acquisition of multiple non-contiguous voxels can be advantageous in terms of SNR. However, the use of SSE for MRS is frequently hampered by the long durations and the limited bandwidth of the excitation pulses making them susceptible to off-resonances and leading to a bad definition of the excited volume for different spectral components. The recently introduced technique of Parallel Excitation (PEX) / Transmit SENSE [1,2] offers the possibility to overcome these difficulties by taking advantage of the additional degrees of freedom for shortening the excitation pulses or improving their spectral characteristics. The present study gives an example for localized single and multi-voxel spectroscopy in a simple model-system using PEX-accelerated spatially selective excitation.

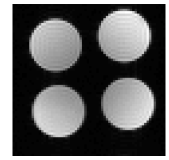

Fig. 1: Pilot scan

Materials and Methods

The experiments in this study were performed on a 30-cm bore BioSpec 9.4 T animal scanner (Bruker BioSpin MRI, Ettlingen, Germany) with 8 transmit- and receive-channels in combination with a transceive volume-array with 8 elements in classical loop design. The used spectroscopy phantom was composed of four tubes containing water / dimethyl sulfoxide (DMSO) mixtures with different concentrations (see transversal image in Figure 1). The spectrum of this two-component system consists of only two lines with chemical shifts of about 4.7 ppm (water) and 2.5 ppm (DMSO). When acquiring a spectrum using PEX, it is important that the excitation pulse has the same spatial selectivity for all relevant spectral components. For a complex spectrum it is therefore necessary to use a PEX pulse based on a specially designed *k*-space trajectory, e.g. with a large number of interleaves ensuring a broad bandwidth as proposed in the ASSESS technique [3]. In the present case of a simple two-line spectrum it is also possible to use a standard e.g. spiral-type *k*-space trajectory while applying a so-called dual-band SSE-pulse for the two relevant resonance frequencies as already described in [4,5] for optimal simultaneous fat-water excitation. In the present study it is shown that spectra can be acquired from a single or simultaneously from multiple arbitrarily-shaped non-overlapping voxels using accelerated PEX. For imaging and spectroscopic acquisition a simple spin-echo sequence was used with a 2D-PEX pulse for excitation and a slice-selective refocusing pulse. Signal reception was performed with the 8 array-elements in parallel.

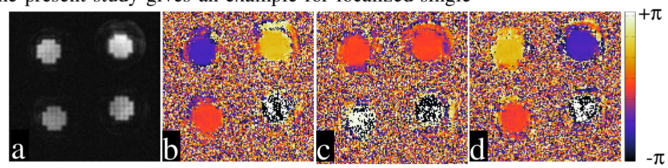

Fig. 2: (a): Sum-of-squares image of the simultaneous 4-voxel excitation. (b-d): Excited phase patterns during experiments 2-4 relative to the phase pattern excited in experiment 1.

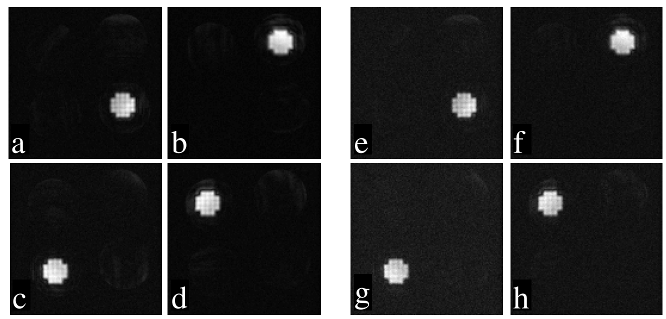

Fig. 3: Sum-of-squares images of the different voxels obtained from simultaneous 4-voxel excitation with subsequent Fourier decoding (a-d) and from single voxel excitation (e-h).

Results

Figure 2a shows the simultaneous excitation of cross-shaped ROIs, one within each of the four tubes, using a 2-fold accelerated dual-band 2D PEX-pulse centered at 0 and 838 Hz. The pulse was based on a spiral k-space trajectory with 16 turns corresponding to a excitation matrix of 64x64 points in the field of excitation of (4.2 cm)². The selection in the orthogonal direction was performed by the selective refocusing of a 2 mm slice. In order to obtain MR-spectra from each of the voxels individually two approaches were pursued. In a first series of 4 experiments the voxels from figure 2a were excited always simultaneously with identical amplitudes, but with voxel-specific phases of the generated transverse magnetization according to the following Fourier-like scheme: (0°,0°,0°,0°) – (0°,90°,180°,270°) – (0°,180°,0°,180°) – (0°,270°,180°,90°). Images as well as spectra were acquired from these multi-voxel excitations. Figure 2b-d displays phase images of the magnetization generated in the different experiments relative to the magnetization generated in the first experiment. The different phase patterns assigned to the individual voxels are clearly visible. By a proper Fourier-like linear combination of the acquired images and spectra, an image and a spectrum of each of the individual voxels can be obtained (see Figures 3a-d and 4). During a second series of experiments each of the 4 voxels was excited individually and an image as well as a single-voxel spectrum were acquired (see Figures 3e-h and 4).

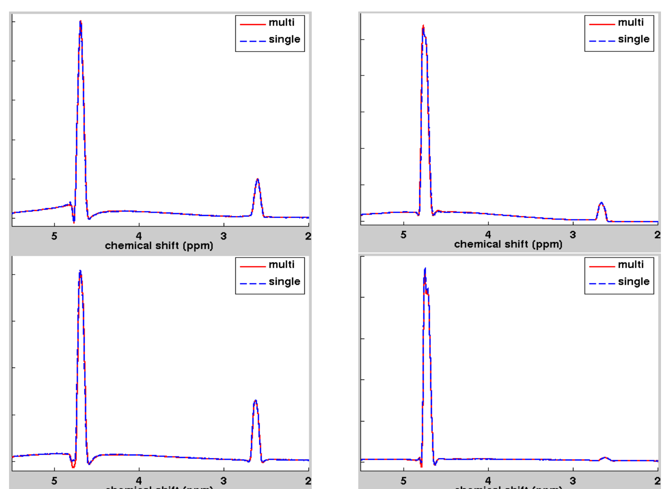

Fig. 4: Spectra from the different voxels using decoded multi-voxel acquisition (red) and single-voxel acquisition (blue).

Discussion and Conclusions

It can be nicely seen from Figures 3 and 4 that the images and spectra obtained by simultaneous multi-voxel excitation in combination with Fourier-decoding correspond excellently to the images and spectra obtained by single voxel excitation while the multi-voxel approach results in a higher SNR. The dual-band PEX-pulse excites the two spectral components with a good common spatial definition. However, at some locations small amounts of transverse magnetization are excited outside the desired voxels which leads to slight distortions of the spectra. This is partly due to imperfections of the excitation process, but also due to the trade-off between spatial accuracy and spectral behaviour in multi-band PEX pulses (see [6]). An improvement could be obtained by going back to unaccelerated PEX-pulses and spending acceleration for better spectral definition of the pulses.

The present study gives a first experimental proof-of-principle of PEX-based volume-selective MR-spectroscopy. It is shown in a simple model system that MR-spectra can be acquired from a single or simultaneously from multiple arbitrarily-shaped voxels using accelerated dual-band PEX-pulses. Next steps will include the acquisition of more complex spectra using PEX-pulses with more specific *k*-space trajectories as proposed e.g. in [3]. The results from this study support the expectations that Parallel Excitation will be a suitable technique to reduce the shortcomings related to SSE-based spectroscopy and to better exploit the great potential inherent in this technique for spatially resolved MR-spectroscopy.

References: [1] Katscher et al., MRM 2003, 49:144-150 [2] Zhu, MRM 2004, 51:775-764 [3] Qin et al., MRM 2007, 58:19-26 [4] Setsompop et al., Proc. ISMRM 2008:616 [5] Kerr et al., Proc. ISMRM 2008:617 [6] Brunner et al., Proc. ISMRM 2008:615

Acknowledgement: This work is part of the INUMAC project supported by the German Federal Ministry of Education and Research. Grant #13N9207.