SPECIAL-j-resolved spectroscopy at 7T

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Introduction

In-vivo proton spectroscopy is a valuable tool that provides additional knowledge about basic metabolic processes for example in the human brain or important diagnostic in formation for various diseases. Unambiguous detection of coupled spin systems like Glutamate, Glutamine or GABA are quite challenging and hard to achieve with regular one dimensional single voxel spectroscopy. More sophisticated approaches include spectral editing or two dimensional spectroscopy. While difference editing methods for example utilize the intrinsic phase behavior of spin systems to detect one specific metabolite, two dimensional j-resolved spectroscopy exploits the phase evolution behavior of coupled spins to spread the overlapping and hardly accessible information into a second frequency dimension. The obvious advantage of the two dimensional approach is that j-resolved experiments are not tailored to detect only one metabolite but the whole range of available metabolite signals. Beside the strong correlations between the metabolites of interest their relatively fast relaxation times at 7T exhibit another significant problem. Previously proposed methods like jPRESS [1] for localized j-resolved spectroscopy turned out to be rather uneligible because pulse bandwidths, SAR or B1 restrictions limit the minimum achievable echo times. Therefore a lot of the signal that should actually be detected has already relaxed during the free evolution periods between excitation and acquisition. One remedy was found by Mlynárik [2] who proposed a 2 step ISIS localization scheme called SPECIAL to achieve very short echo times for three dimensional single voxel measurements. This localization principle is adapted in this work to implement a j-resolved two dimensional experiment that is also applicable under the strict constraints of a 7T MR system.

Materials & Methods

J-resolved SPECIAL was implemented on a Philips 7T Achieva system. A trapezoidal adiabatic pulse was used as inversion prepulse. The delays and flip angles of the VAPOR [3] water suppression were numerically optimized to account for the different delay time between the last water suppression pulse and the excitation compared to regular MRS sequences like STEAM or PRESS. To compensate for magnetization transfer artifacts from skull lipids the inversion pulse was not turned off and on but the frequency offset was varied from average to average in a way that the effect of magnetization transfer in lipids is canceled after subtraction but at the same time a spoiling of the localization scheme is prevented. The second frequency dimension was encoded with 64 echo time increments of 4ms leading to a bandwidth of 250Hz in t1 and a frequency resolution of about 5Hz in F1. A 16 channel Nova head receive array combined with a head transmit volume coil (B_1 = 18 uT) was used to acquire the data. A phantom with brain metabolites in physiological concentrations was used for initial measurements and in addition in-vivo J-resolved SPECIAL experiments in the human visual cortex were performed. The voxel size was set to usual values found in literature for jPRESS (25x30x20mm). The minimum achievable echo time was TE=16ms and the repetition time was constraint to TR=5000ms. Since the water suppression worked sufficiently well in-vivo, a maximum echo sampling scheme could be used like in jPRESS experiments. This leads to slightly higher SNR because of the additional signal that is sampled before the echo top and tilts residual water tails away from the metabolite signals after reconstruction. A delayed echo sampling scheme was used to encode the indirect frequency dimension of the phantom scan. This sampling approach allowed independent adjustment of frequency resolution in t1 and the tilt angle of the peaks. The acquisition delay for the delayed echo sampling was set to 1ms. The resulting time domain data were zero filled, filtered by a shifted exponential filter in the direct dimension and a regular exponential filter in the indirect dimension.

Results & Discussion

In-vitro (Figure 1) and in-vivo (Figure 2) J-resolved SPECIAL localized spectra acquired at 7T showed good spectral quality with a low artifact content and sufficient signal-to-noise ratio to detect multiplets from the coupled spin systems of interest. 2D prior-knowledge fitting (ProFit)-based quantification, which has been previously successfully applied to physiological studies based on 2D JPRESS at 3T [4], is currently adopted to 7T and will enable the precise evaluation of spectral information content and quantification precision in means of Cramer-Rao-lower bounds as well as covariance coefficients. J-resolved SPECIAL might also be combined with a transmit-receive surface coil at 7T to achieve even lower echo times and even higher SNR for future in-vivo studies.

[1] Schulte et. al., NMR in Biomedicine 19:264–270 (2006)
[2] Mlynárik et. al, Magnetic Resonance in Medicine 56:965–970 (2006)
[3] Tkác et. al., Magnetic Resonance in Medicine 41, 1999
[4] Walter et al; Archives of General Psychiatry 66(5), 478-486, 2009.

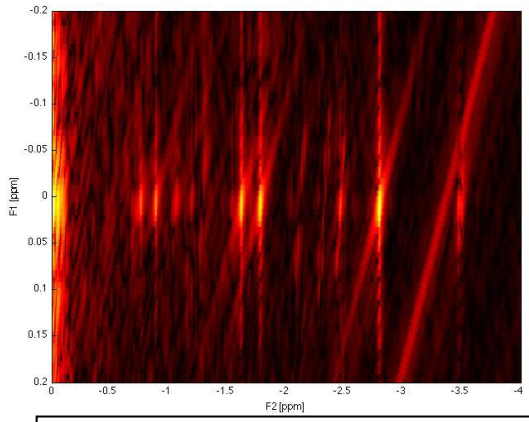

Figure 1 A J-resolved SPECIAL spectrum acquired from a brain metabolite phantom.

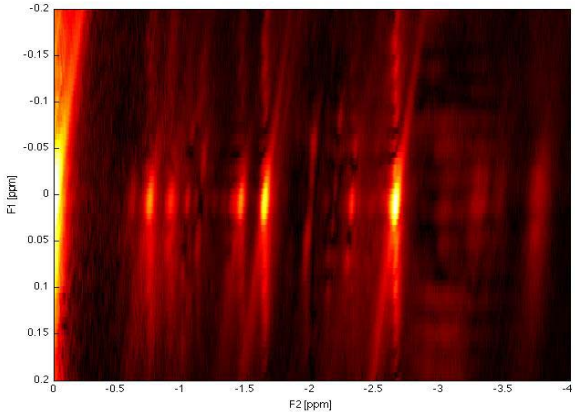

Figure 2 J-resolved SPECIAL spectrum acquired from the visual cortex of a volunteer. Maximum echo sampling was employed to maximize the SNR and to prevent residual water signal to interfere with the metabolites of interest.