2D J-resolved spectroscopy at 7T

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Introduction

Taking advantage of increased SNR as well as improved spectral resolution, MR spectroscopy is one of the most promising applications on 7T human MR systems. Two-dimensional (2D) spectroscopy methods can particularly enhance the spectral information content and reduce the spectral overlap for coupled resonances such as GABA, GSH and Glu. Therefore 2D spectroscopy at ultra high field strengths is an obvious approach aiming simultaneous detection and quantification of an increasing number of metabolites, therewith providing a deeper insight into the human metabolism and the patho-physiology of neurological and psychiatric disorders. In this work, *J*PRESS was implemented on a 7T human MR system, addressing specific high field problems such as localisation and shimming.

Materials and Methods

To minimize chemical shift displacement, a *J*PRESS sequence, based on broad-band frequency-modulated excitation (fremex05) and refocusing (fmref07) pulses was implemented on a 7T Philips Achieva human MR system [1,2]. Localisation was further improved with OVS based on RF pulses with polynomial phase response, according to the principle of over-prescribed PRESS [3,4]. A maximum-echo acquisition scheme was used to prevent the impairment of the spectral region of interest by tilting the truncation-induced water side bands [5]. All measurements were performed using a birdcage transmit-receive head coil with a maximum B_1 of 10 µT. Two distinct shimming routines – fast map and shimming based on B_0-mapping - were available to perform B_0 inhomogeneity corrections up to the third order. For validation, in vitro experiments were performed on a phantom containing 50 mM citrate (strongly coupled) , 30 mM lactate (weakly coupled) and 30 mM creatine (uncoupled), as well as on a brain phantom with physiological metabolite concentrations. In addition, first in vivo spectra were acquired in the human brain.

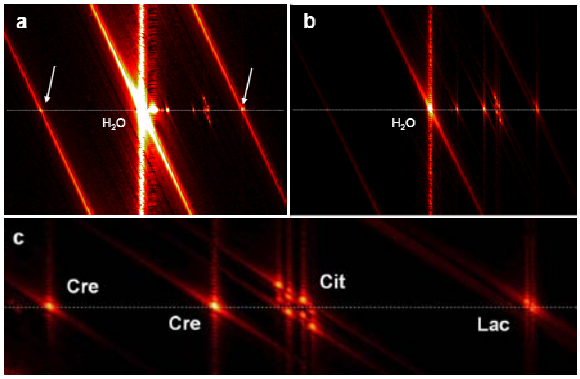

Figure 1 *2D JPRESS in vitro; 50 mM citrate, 30mM lactate and 30 mM creatine; T_R = 4000 ms, f_1 encoding range T_E = 73 – 273 ms; step size = 2ms; maximum B_1 = 10 µT a) using conventional amplitude modulated RF pulses – poor shim and water suppression and water side bands (indicated by white arrows) due to strong chemical shift displacement; b) using broadband frequency modulated RF pulses – artifact free spectra; c) enlarged view of b: typical occurrence of Creatine singlet, Lactate doublet and Citrate multiplet including strong coupling peaks;*

Results and Discussion

The comparison of *J*PRESS spectra measured with conventional amplitude-modulated pulses (Figure 1a) and broad-band frequency-modulated pulses (Figure 1b) demonstrates that a precise localisation technique is a prerequisite for successful 2D spectroscopy at 7T. It is shown that chemical shift displacement can be greatly alleviated by the use of broad-band RF pulses for excitation, refocusing and OVS. Hence the proposed method helps to avoid or at least mitigate bad shimming and poor water suppression leading to water side bands and ghosting artefacts, and signal cancellation due to anonymous *J*-modulation. Figure 1c shows typical spectral patterns for all three metabolites at 7T. While the weakly coupled lactate resonance appears as a doublet separated by 7 Hz along both domains, as observed at lower field strengths, the strongly coupled two-spin system of citrate gives rise to a multiplet, which is spread over a larger frequency range in f_1 compared to 3T. This effect is due to the increased chemical shift difference of the coupled spins at 7T and can be observed for all strongly coupled metabolites. This resolution enhancement in the indirect spectral dimension compensates for increased line widths in f_1 due to shorter T2 values. In vitro measurements in a brain phantom containing physiological metabolite concentrations demonstrate sufficient SNR to detect coupled resonances and the decrease of spectral overlap in *J*PRESS spectra compared to a SV spectrum (Figure 3a, b). However, the corresponding in vivo data, from a voxel in the occipital white matter, shows significantly reduced SNR for metabolites such as Glu or mI due to fast T_2 relaxation. Other sources of SNR loss are physiological noise and line broadening due to B_0 inhomogeneity.

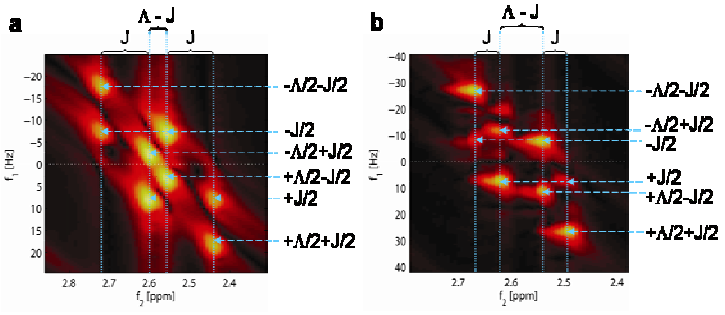

Figure 2 *Citrate multiplet at 7T (a) as compared to 3T (b): Peak assignment demonstrates the different coupling behavior of the AB spin system: J = strength of scalar coupling, $\Lambda = \sqrt{\delta^2 + J^2}$, where $\delta$is the difference in Larmor frequencies between the two coupled protons.*

Two-dimensional prior-knowledge fitting (ProFit) might be applied in future to access the full information content of the in vivo *J*PRESS data. At 3T it has already been shown that the number of quantifiable metabolites could be significantly increased using this method [6]. Refocusing pulses are 24ms long at a B_1 of 10 µT leading to a minimum echo time of 73 ms. Hence, to enhance the SNR for fast relaxing metabolites, ISIS localization based on the proposed frequency-modulated refocusing pulses in two dimensions and the excitation pulse might be implemented. For encoding of the f1-domain short spatially non-selective refocusing pulses could be used for a significant reduction of the minimum T_E.

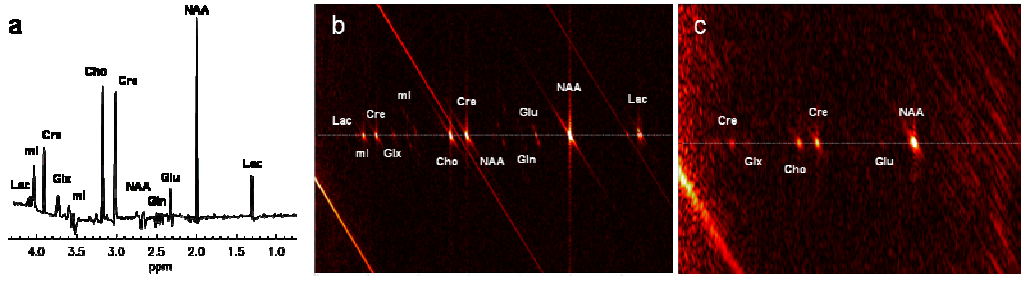

Figure 3 *a) SV spectrum and b) JPRESS spectrum in a phantom containing physiological concentrations of Brain metabolites; c) in vivo JPRESS spectrum from a voxel inside the occipital white matter; minimum TE = 73 ms;*

References
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