If J doesn't evolve, it won't J-resolve: J-PRESS with bandwidth-limited refocusing pulses

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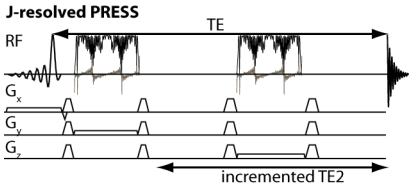
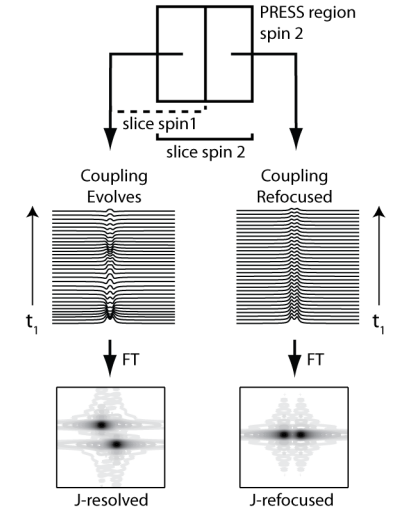


J-PRESS[1], or J-resolved PRESS, is a two-dimensional (2D) method that is becoming increasingly popular for *in vivo* proton brain spectroscopy, since it improves resolution of coupled metabolites compared to the conventional one-dimensional spectrum. J-PRESS involves acquiring PRESS data at a wide range of echo times (TE - also called t_1 in 2DNMR), followed by Fourier transformation with respect to TE, giving a 2D spectrum with the scalar (J) couplings present in the 2nd dimension.

In this abstract, we describe a new class of peaks which appear in J-PRESS spectra at high field and show that they arise from spatially dependent evolution of scalar couplings during TE. This leads to a reduction in signal intensity of the intended J-resolved peaks, and a subsequent decrease in resolution between metabolites. This spatially dependent coupling evolution leads to signal losses in PRESS and MEGA-PRESS[2]; here we investigate its impact on J-PRESS.



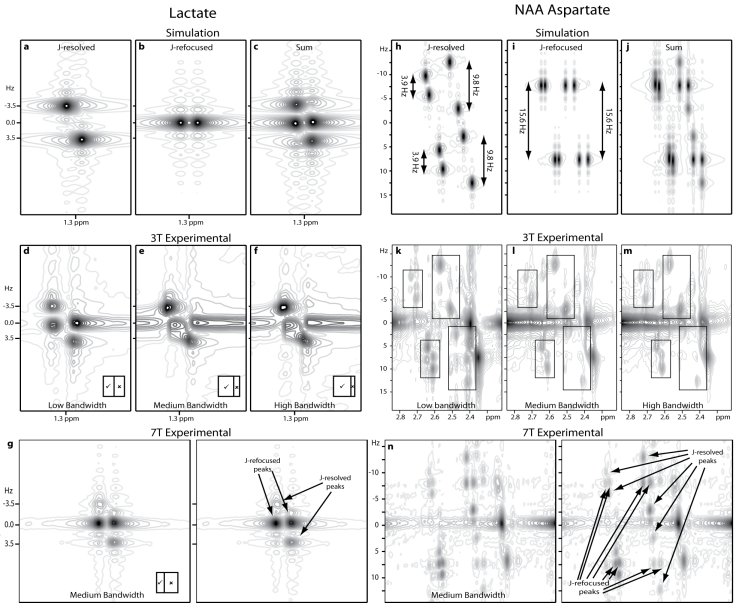
Theory

Instrumental limitations on peak transmit B_1 power place an upper limit on the bandwidth of slice-selective refocusing pulses (for a given pulse shape), leading to a chemical shift-dependent displacement (CSD) in the spatial profile of refocusing. In a PRESS-based experiment, if two coupled spins have significantly different chemical shifts, the behavior of coupling evolution during TE becomes spatially dependent when limited bandwidth 180˚ pulses are used (Fig 1). In those regions of the PRESS-excited volume in which both coupled spins undergo refocusing, coupling will evolve; conversely in those regions in which the passive spin (spin 1) does not experience the 180˚ pulse, couplings will be refocused on the observed spin (spin 2).

Evolution of coupling during TE is fundamental to the J-PRESS experiment - evolution leads to phase modulation of signals acquired at different TEs, encoding coupling information into the indirectly acquired dimension of the J-PRESS spectrum. When the passive spin does not experience the 180˚ pulse, refocusing of the coupling evolution occurs during TE, resulting in no phase modulation and giving 'J-refocused' peaks. The acquired spectrum will a weighted sum of these two cases, depending on the relative size of the two regions (which is determined by the chemical shift difference between coupled spins and the slice-selective refocusing bandwidth).

Methods

J-PRESS experiments were performed on Philips Achieva 3T and 7T scanners, using body coil for transmit (B_{1max}=13.5 μT) and an 8-channel phased array head coil for receive at 3T, and a dedicated head coil for transmit (B_{1max}=12 μT) and a 32-channel phased array head coil for receive at 7T. Spectra were acquired from a phantom containing metabolites at concentrations typical of healthy brain with the addition of lactate at 5 mmol/dm^3. 2048 datapoints across a 3 kHz spectral width were acquired in the directly acquired (t_2) dimension. At 3T, 32 increments of TE between 32 ms and 544 ms were acquired (δ_{TE}=16 ms). At 7T, 32 increments of TE between 40 ms and 660 ms were acquired (δ_{TE}=20 ms). At 3T, three different refocusing pulses were used): a standard sinc-gauss pulse, a numerically-optimized amplitude modulated pulse 'GTST1203', and a frequency modulated pulse 'FMREF07'[3] (bandwidth: 733 Hz; 1264 Hz; 2148 Hz). At 7T only the GTST1203 pulse was used. J-resolved experiments were also simulated in Matlab.



Results

Simulations of lactate (Fig 2a-e) and NAA aspartate (Fig 2h-j) spin systems clearly show the difference between J-resolved peaks and anomalous J-refocused peaks in the J-PRESS spectrum. J-resolved multiplets shown appear at an angle to the vertical, as different peaks of the multiplet appear at different frequencies in F_1 and F_2. In the lactate case, both peaks of the J-refocused doublet appear on the F_1=0 line. In the case of the NAA aspartate ABX spin system, J-refocused peaks are still modulated by coupling between the two spins with similar chemical shift (J_{AB}) whole both couplings to the X spin are refocused. Since refocusing only occurs during t_1, all peaks appear at the correct frequency in F_2.

Both J-resolved and J-refocused peaks can be observed in 3T and 7T experimental data (Fig 2d-n). The relative intensity of J-refocused peaks is greater at 7T than at 3T due to increased chemical shift displacement. Implementation of higher bandwidth refocusing pulses at 3T lead to reduction in the intensity of J-refocused peaks as expected.

Discussion

Additional peaks are observed in the J-PRESS spectrum at high fields when limited bandwidth refocusing pulses are used. Since these signals follow the same coherence transfer pathway as the J-resolved peaks, phase cycling and gradient selection cannot differentiate them. Since signal from the same volume is split between these two different sets of peaks, the intensity of the desired J-resolved peaks is reduced, and the resolution of the J-PRESS experiment is compromised by the increased footprint of multiplets. It is there important to use high-bandwidth refocusing pulses in J-PRESS experiments to minimize this problem.

References 1. Ryner et al. MRI 13:853-869 (1995). 2. Edden et al. MRM 58:1276-1282 (2007). 3. Murdoch. ISMRM 2001 Hawaii.