S-PRESS: a Novel Approach to Difference Spectroscopy Editing

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Introduction

In the past few years, various proton MR methods have been proposed for detecting resonances of strongly coupled spin systems, with a particular attention to resonances which lie underneath singlets [1]. These methods are based either on difference spectroscopy editing or on multiple quantum coherence editing. Many of them work at field strengths higher than the one of clinical MR scanners and/or they involve complex pulse sequences which have not become standard on clinical systems. Here, we present a novel approach for spectral editing which employs a single PRESS (S-PRESS method) sequence. The novel concept for editing of strongly coupled resonances is the following: the spectral shape of a strongly coupled spin system under PRESS excitation ($90°_x$ – [τ_1] – $180°_y$ – [TE/2] – $180°_y$ – [TE/2 - τ_1] – Acq) depends not only on the echo time (TE) but also on the relative position of the 90° and 180° pulses, i.e., on the interpulse delay τ_1. By knowing the exact behavior of the strongly coupled spin system as a function of τ_1 and TE, it is possible to identify an echo time such that two different interpulse delays will result in two completely different spectra, because of the J-modulation. Thus, by subtracting the spectra, coupled resonances which lies underneath singlets can be resolved, since the shape and intensity of singlets is dependent exclusively on TE. In the present study, this effect, that is, the τ_1 dependent J-modulation, is demonstrated theoretically by means of density matrix simulations [2,3]. It is then verified experimentally on citrate (which is chosen as a model of an AB system) and GABA ($I_2S_2W_2$ system) [4], at 3 T and 1.5 T, respectively.

Materials and Methods

Quantum mechanics simulations, based on the density matrix formalism, were developed to investigate the exact behavior of the signal shape for citrate (AB system, J = 16 Hz, δ = 0.146 ppm), and GABA ($I_2S_2W_2$ system, J_{IS} = 7.1 Hz, J_{SW} = 7.7 Hz; [δ_I, δ_S, δ_W] = [3.01, 1.88, 2.28] ppm) under PRESS excitation. In the simulations, ideal pulses were considered and T_2 relaxation effects between pulses were assumed negligible. In order to identify the optimal echo time and interpulse delays for difference editing, 3D plots of the spectral peak area as a function of τ_1 and TE were generated. MRS experiments were performed at 3 Tesla (Siemens Trio) on a phantom containing citrate, choline and creatine and at 1.5 Tesla (Siemens Sonata) on a GABA phantom. A standard PRESS sequence, with the values of TE and τ_1 found from the simulations, was employed.

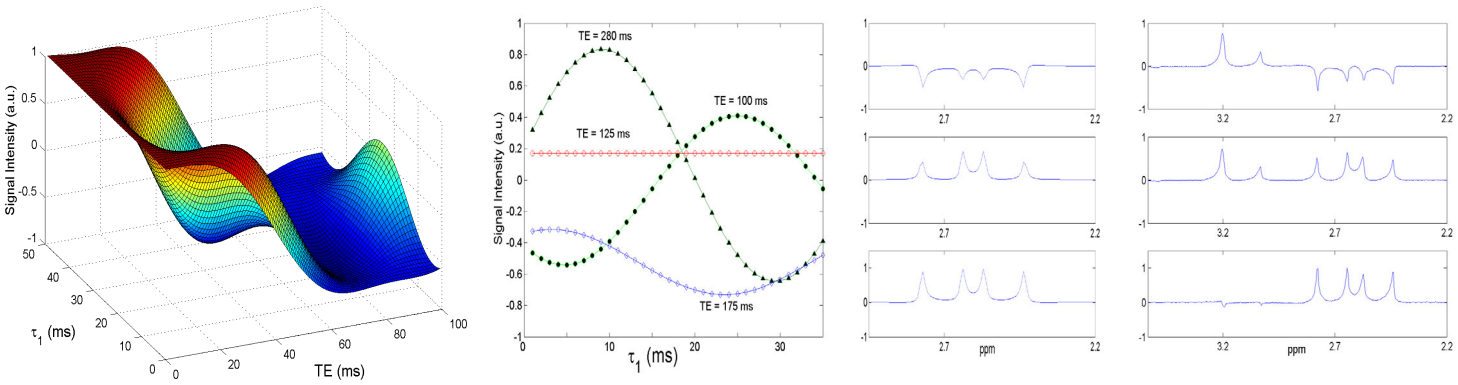
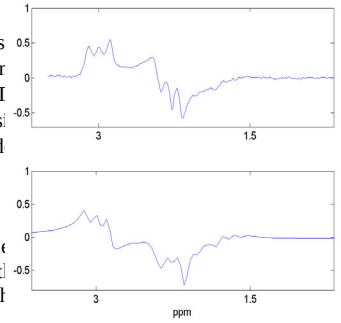


Figure 1. **Left panel**. *Simulated* citrate signal intensity (spectral peak area) from PRESS at 3 T as a function of τ_1 and TE (plotted, for clarity, only for to TE up to 100 ms). Note at TE =100 ms the τ_1 dependent J-modulation. **Middle-left panel**. S*imulated* citrate signal intensity plotted as a function of τ_1, at four TE values. At TE = 280 ms the τ_1 dependent J modulation is maximum, with positive values of the signal at τ_1 ~10 ms and negative values at τ_1 ~30 ms. **Middle-right panel**. *Simulated* citrate spectra (TE = 280 ms) at 33 ms (top), 10 ms (middle) and difference spectrum (bottom). **Right panel**. *Experimental* citrate spectra (TE = 280 ms) at 33 ms (top), 10 ms (middle) and difference spectrum (bottom). Here note also the singlets of creatine and choline.

Results

Density matrix simulations provided the complete behavior of the AB spin system as a function of τ_1 and TE (Left panel). These s
= 280 ms), small (TE = 175 ms), or negligible change (TE = 125 ms) in the AB spectral shape as a function of τ_1 (Middle-left par
TE = 280 ms was such to generate a quasi-inverted spectrum when the τ_1 was changed from 10 to 30 ms (Middle-right panel). T
280 ms) at τ_1 = 33 ms (top), τ_1 =10 ms (middle) and the difference spectrum (bottom) is shown in the right panel. The same densi
the $I_2S_2W_2$ system of GABA. It was found that the echo time of 40 ms, together with the two τ_1 values of 4 ms and 10 ms, provid
resonance at 3 ppm (Figure 2).



Discussion and Conclusions

The τ_1 dependent J-modulation in strongly coupled spin systems, predicted by quantum mechanics simulations, was verified e
spectra agree well with the simulations. The results of this study show that difference spectroscopy editing could be achieved wit
This effect could be exploited for editing of strongly coupled system or for removal of singlets in spectra. This novel approacl
simple, and directly applicable on standard clinical MR scanners, provided that the exact behaviour of the resonance is known.

Figure 2. **Top**: *Simulated* GABA difference spectrum (TE = 40 ms, τ_1 = 4 and 10 ms). **Bottom**: *Experimental* gaba difference spectrum at 1.5 T.

References

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