Relaxation Enhancement by Longitudinal Multispin Orders

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Introduction: There is a great interest in increasing the longitudinal relaxation of nuclear spins for hyperpolarized imaging experiments. Longitudinal multispin orders (LOMO) correspond to the non-equilibrium population distribution and can be created in spin systems that exhibit J couplings, dipolar couplings or quadrupolar couplings (1). It can also be created via cross-correlated relaxation between different relaxation pathways present for the given spin system (2). Here we demonstrate the enhanced relaxation characteristics of 2-LOMO in weakly (AX) and strongly (AB) coupled spin systems.

Methods: The relaxation of longitudinal multispin orders was examined with Solomon's formalism (Fig.1) (3). All the experiments were performed at 298K on a Bruker 400 MHz DRX spectrometer using the inverse probe. Transition selective Gaussian pulse (200ms) was employed for selective inversion (Fig.2). 50mM Trans-cinnamic acid (AX system) in $CDCl_3$ and 50mM Sodium Citrate (AB system) in D_2O were used as the sample for all relaxation measurements. The frequency-cycling approach (4,5) was employed for creation of the two-spin orders. A 45° (optimized flip angle) reconversion pulse was applied to convert the 2-LOMO into observable magnetization. The inversion-recovery technique was implemented within the frequency cycling approach for relaxation analysis.

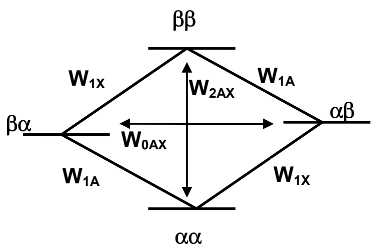

Fig.1. Energy level diagram for the AX spin system along with the transition probability for each relaxation connectivity.

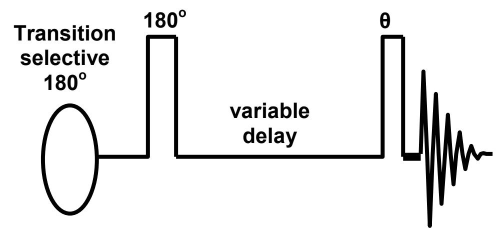

Fig. 2. Pulse sequence for measuring relaxation times of LOMO.

Results: Fig. 3)(a) and Fig. 4(a) show the conventional spectrum for different inversion delays, whereas Fig. 3(b) and Fig. 4(b) show the 2-LOMO spectrum for variable inversion delays. Our preliminary investigation clearly shows that the zero crossing of the 2-LOMO occurs at longer inversion delays compared to the conventional spectrum indicating longer T_1 values for the 2-LOMO. We observed a longitudinal relaxation enhancement factor of 2 in both, the AX and the AB spin systems.

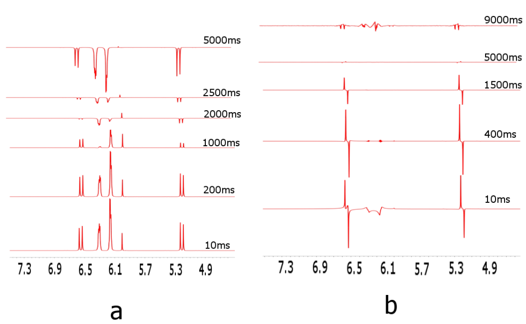

Fig.3. The AX spin system. (a) T_1 inversion recovery and (b) the 2-LOMO spectrum.

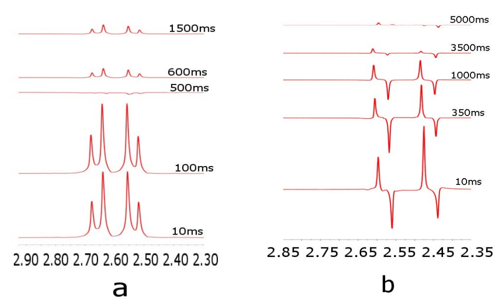

Fig. 4. The AB spin system. (a) T_1 inversion recovery and (b) the 2-LOMO spectrum.

Discussion: Our results indicate that the longitudinal two spin orders from both weakly and strongly coupled spin systems have longer T_1 compared to the conventional z-magnetization. Even though the T_1 of conventional z magnetization from strongly coupled AB spin system is reduced compared to AX spin system 2-LOMO from AB spin system exhibits longer T_1. Earlier studies (5) have shown that the 2-LOMO from the strongly coupled AB spin system is independent of the strong coupling parameter. This T_1 enhancement by spectral editing could be very useful in hyperpolarized experiments where an enhancement of T_1 by a factor of two is very significant. This frequency cycle based spectral editing approach can also be used for editing of several metabolites present in the brain or any other organ.

References:

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