Enhancement of In Vivo iZQC Signal by Spin Locking Pulse

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INTRODUCTION:

In MRI, intermolecular Zero Quantum Coherences (iZQCs) have been applied to generate a new type of contrast shown to improve soft tissue characterization [1,2,3]. However, the primary limiting factor for *in vivo* iZQC signal intensity is T_2 relaxation. Two of the most significant contributions to T_2 relaxation are spin exchange and motional inhomogeneity [4,5,6]. Both of these effects can be alleviated through the spin locking technique, but the locking is different for iZQC sequences than for conventional sequences. We present our computer simulations of the related spin dynamics in order to optimize an iZQC spin locked sequence, and experimental verifications.

METHODS:

The iZQC signal is generated by the Distant Dipolar Field, (DDF), which transforms the antiphase magnetization into observable signal [3]. Including the DDF in the Bloch Equation, the computer simulation is set to model the spin evolution of two different proton species -- spin I with offset $\Delta\upsilon$ and spin S with offset $-\Delta\upsilon$ to model the water-fat peaks encountered in vivo. The spin exchange effect is modeled with first order chemical kinetics while motional inhomogeneity is imposed through temporal and spatial perturbation to the offsets. The iZQC lock sequence is:

$$90°(\phi_I,\phi_S) - t_1 - \{\text{Gradient}\} - \theta(x) - \tau - \text{Lock Module}[\text{continuous pulse (y, time}=t_{SL}/2) - 180(y) - \text{continuous pulse (-y, time}=t_{SL}/2)] \quad (1),$$

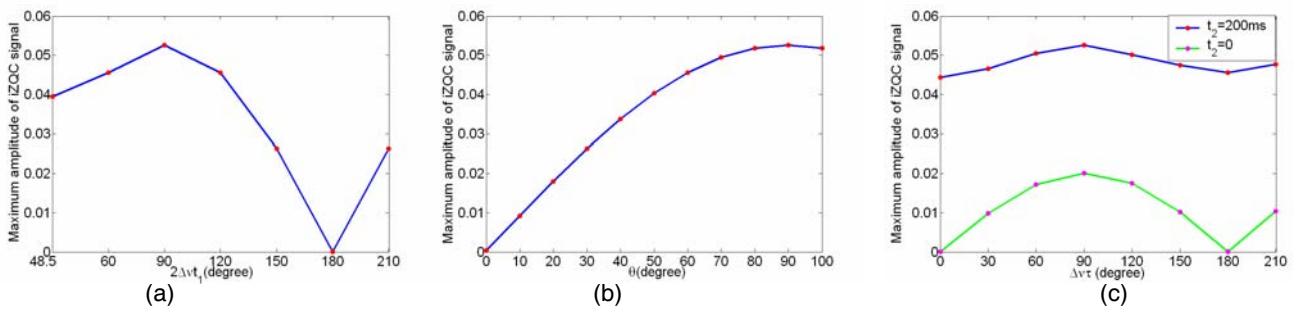
The "Lock Module" is designed to eliminate signal dependence on the net rotation angle and make the sequence robust to RF inhomogeneity. The iZQC signal from the heteronuclear spins is excluded through phase cycling:

$$\text{iZQC signal} = \text{Signal}(\phi_I=x,\phi_S=x)+\text{Signal}(\phi_I=-x,\phi_S=-x)-\text{Signal}(\phi_I=x,\phi_S=-x)-\text{Signal}(\phi_I=-x,\phi_S=x) \quad (2).$$

For experimental verification of the properties in an exchanging system, the optimized iZQC sequence is applied to a 0.5 M solution of 4-methoxy-N, N-dimethyl-Benzenecarbothioamide in chloroform. The solute has spin exchange between the two proton groups of the dimethylamide with a spin exchange rate estimated to be 7.3 s^{-1} [7].

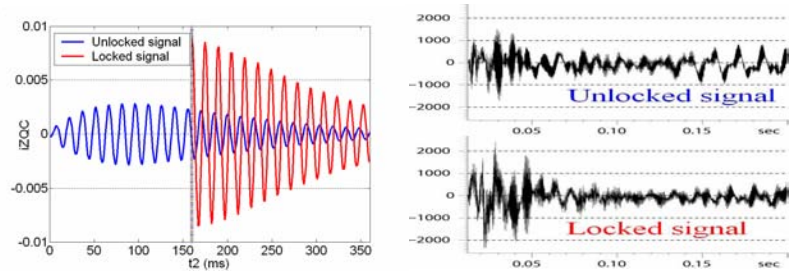
RESULTS:

Optimization for a resonance frequency centered between fat and water (Fig.1) gives $t_1=0.25/(2\Delta\upsilon)$, $\theta=90°$ and $\tau=0.25/(\Delta\upsilon)$. Thus the locking takes place in *quadrature* with a conventional lock; the conventional lock phase does not work. . Signal enhancement is also observed in both simulation and experiment in the presence of relaxation (Fig.2).



(a) (b) (c)

Fig.1: The iZQC Signal intensity as a function of parameter t_1 (a), θ (b) and τ (c). These parameters are specified in Eq. (1).



(a) (b)

Fig.2: Locked and unlocked iZQC signal: (a) simulated and (b) experimental results; t_{SL} = 160 ms.

CONCLUSION AND DISCUSSION:

As verified by experiment, the optimal sequence maximizes the antiphase term, which is readily locked and evolved into observable signal during the lock pulse. The proposed Lock Module effectively enhances the iZQC signal intensity and could be used for signal enhancement for iZQC applications in vivo.

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