Enhanced in-vivo C13 spectroscopy using adiabatic INEPT sequences and custom-made RF coils

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Introduction: 13C spectroscopy offers several advantages compared to 1H MRS, including increased spectral dispersion, and eliminates the need for water suppression, though it suffers from inherently low sensitivity. In addition, 13C spectroscopy is important from a physiological point of view because it offers the ability to measure metabolic fluxes such as those of the TCA cycle [1]. In this abstract, we report results obtained with a high-quality custom-made RF coil and optimized sequences including INEPT [2] (with square pulses) and adiabatic INEPT with BIR-4 pulses (BINEPT) [3, 4].

Materials and Methods: All experiments were performed on a 9.4 T horizontal bore (20 cm) animal scanner. We employed a high-quality custom-made RF probe, custom made by the third author, with an inner solenoid for 13C detection and an outer saddle for 1H detection. To increase 13C signal we employed INEPT [2] and adiabatic INEPT with BIR-4 pulses [3, 4]. BIR-4 pulses of 400 μs having maximum amplitude of 16 kHz and 4 kHz for 13C and 1H, respectively, were synthesized on a Bruker Avance console. The intra- and interpulse delays were set according to the 13C-1H scalar coupling of acetate (130 Hz). Both BINEPT with direct 13C detection and double BINEPT for indirect 13C detection via 1H were designed and tested. 1H decoupling with adiabatic WALTZ-16 sequence was employed during acquisition.

Results: In phantoms our BINEPT sequence (Figure 1) resulted in increased sensitivity by a factor of 2.8 for 13C, when compared with direct excitation following a 90° pulse (Figures 2 and 3a). Similar results were obtained in vivo on a mouse (natural-abundance 13C spectra shown in Figure 3b). The optimized BINEPT sequence showed significant signal increase over INEPT and direct excitation (1H decoupled). The BINEPT sequence also acted as a spectral editing sequence suppressing the carbons that do not have a direct proton attached, such as COOH (Figures 2b and 3b).

Discussion: INEPT results in increased 13C signal through manipulation of the scalar coupling between 1H and 13C to transfer polarization from 1H to 13C. BINEPT (INEPT with adiabatic BIR-4 pulses) results in significant further 13C signal enhancement due to improvement of RF inhomogeneity, resulting in highly uniform spin excitation. Further improvements are possible, involving inverse detection of 13C through 1H and/or extension to multidimensional heteronuclear experiments, useful for unambiguous assignment and quantification of in vivo spectra.

References: