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

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Introduction: ^{13}C spectroscopy offers several advantages compared to ^{1}H MRS, including increased spectral dispersion, and eliminates the need for water suppression, though it suffers from inherently low sensitivity. In addition, ^{13}C 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 ^{13}C detection and an outer saddle for ^{1}H detection. To increase ^{13}C 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 ^{13}C and ^{1}H, respectively, were synthesized on a Bruker Avance console. The intra and inter-pulse delays were set according to the ^{13}C-^{1}H scalar coupling of acetate (130 Hz). Both BINEPT with direct ^{13}C detection and double BINEPT for indirect ^{13}C detection via 1H were designed and tested. ^{1}H 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 ^{13}C, when compared with direct excitation following a 90° pulse (Figures 2 and 3a). Similar results were obtained *in vivo* on a mouse (natural-abundance ^{13}C spectra shown in Figure 3b). The optimized BINEPT sequence showed significant signal increase over INEPT and direct excitation (^{1}H 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).

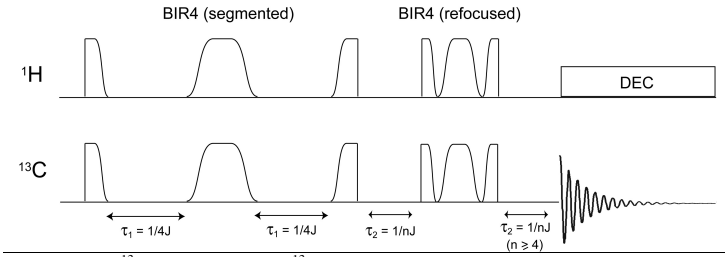


Figure 1. Adiabatic INEPT using segmented adiabatic BIR4 pulses. ^{13}C signal is increased through polarization transfer via scalar coupling from ^{1}H.

Figure 2a. ^{13}C spectra of [1,2-^{13}C] labeled acetic acid: in red adiabatic INEPT, and in black direct excitation. An increase by a factor of 2.8 is obtained. Note that adiabatic INEPT acts also as a spectral editing sequence suppressing the carbons that do not have a direct proton attached, such as COOH.

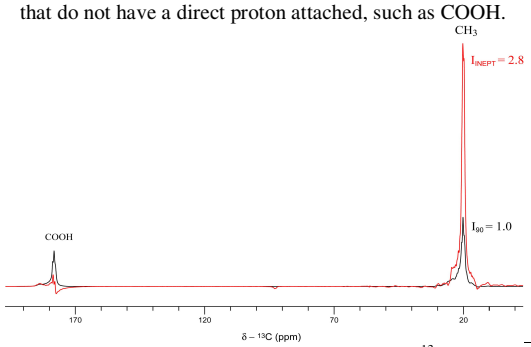


Figure 2b. ^{1}H spectra of [1,2-^{13}C] labeled acetic acid: in red double adiabatic INEPT, and in black direct excitation. An efficiency of 30% is obtained compared to direct excitation. However, proton detection has superior sensitivity over the ^{13}C from Figure 2a.

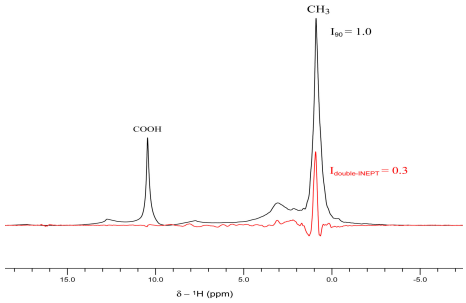


Figure 3a. Comparison of direct excitation ^{13}C 90° pulse (^{1}H-decoupled), ^{13}C INEPT and ^{13}C BINEPT on a phantom containing [2-^{13}C] labeled acetate. The BINEPT peak is 170% of the INEPT peak (the acetate peak has been set at 0 ppm).

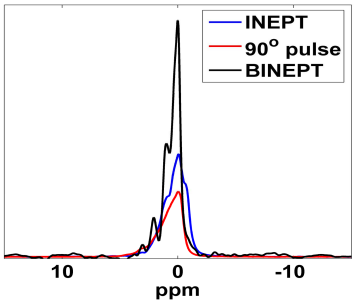
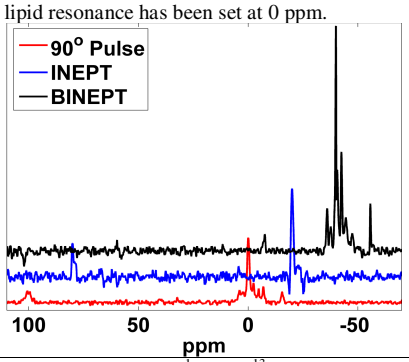


Figure 3b. *In vivo* ^{13}C spectra of a mouse, collected with direct excitation ^{13}C 90° pulse (^{1}H-decoupled), ^{13}C INEPT and ^{13}C BINEPT. The main BINEPT peak is 320% of the direct excitation peak (NEX=256, 10min total acquisition time). The lipid resonance has been set at 0 ppm.



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

References:

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