Ultrafast 2D spectroscopy for in vivo applications on a 7T whole body scanner

R. Panek[1], and W. Kockenberger[1]
[1]SPMMRC, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

Introduction: *In vivo* ^{1}H NMR spectroscopy (MRS) is made difficult owing to complex and overcrowded spectra and signal overlap of broadened resonance lines. A powerful strategy to facilitate the assignment of crowded spectra is the use of 2-dimensional spectroscopy. In such schemes indirect detected dimensions are encoded by incrementing the duration of evolution periods [1]. However, these methods suffer from long data acquisition times that makes their use for *in vivo* applications difficult, although there are routinely used for *in vitro* measurements [2]. Ultrafast gradient assisted single-scan 2D MRS schemes proposed recently [3, 4] have the potential to overcome these limitations but their implementation on whole body scanners is technically challenging due to the requirement of fast and accurate gradient switching times. This work demonstrates the first implementation of an ultrafast single-scan approach on a 7T whole body scanner. It is based on a number of phantom experiments that were carried out to investigate the benefits and limitations of this strategy.

Methods: The gradient assisted single-scan schemes were implemented in conjunction with water suppression and outer volume suppression using a pre-saturation sequence. An optimised CHESS method was used for water suppression. In the single-scan 2D spectroscopy experiment the volume of interest is progressively excited using frequency swept 'chirp' pulses in the presence of gradients. Using this strategy the signal evolution in the indirect detected spectroscopic dimension is encoded into a spatially depending phase modulation. This phase modulation can be refocused with a suitable gradient and individual echoes generated which represent the various frequencies of the spectrum. The direct detected spectroscopic dimension is obtained from the signal modulation of a set of echoes acquired using an oscillating EPI-like gradient train.

The gradient strengths and durations were optimized to cover spectral widths relevant for *in vivo* brain spectroscopy. The spectral width in the direct dimension depends on the duration T_a during which an acquisition gradient G_a is applied:

$$SW_2 = (2T_a)^{-1}$$

In the indirect dimension the spectral width is given by:

$$SW_1 = \frac{\Delta OT_a G_a}{t_{1\max} G_e} \quad ,$$

where G_a and G_e are the acquisition and excitation gradient strengths respectively and $t_{1\max}$ is the total chirp sweep-time.

Both phase-modulated and amplitude-modulated 2D acquisition schemes for ^{1}H correlation spectroscopy (COSY) were implemented and tested on a 7T Philips whole body scanner. Furthermore, the spectral width of the 2D spectra was increased significantly using an echo interleaving strategy [3] with two consecutive scans. Initial tests involved the calibration of the chirp pulses, the minimisation of the rf power deposition and the optimisation of the gradient amplitudes and durations using an ethanol phantom. To demonstrate the potential of the method for *in vivo* applications further experiments were performed with 30mM L-Glutamine dissolved in water.

Results: Fig.1 shows a L-Glutamine ^{1}H COSY spectrum acquired on a 7T Philips scanner with a total acquisition time of 2x330ms (Fig. 1B). This is a significant reduction in comparison to the conventional ^{1}H COSY spectroscopy which required 25min. Despite the concomitant decrease in the SNR ratio the single-scan technique delivers spectra in which the correlation peaks $\alpha-\beta$ (3.76, 2.1 ppm) and $\gamma-\beta$ (2.44, 2.1 ppm) can be clearly distinguished.

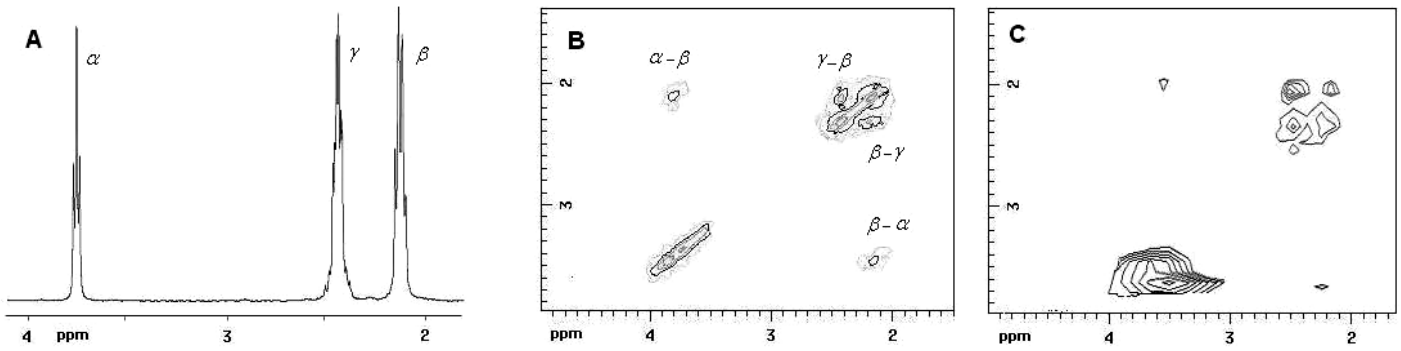

Fig. 1. 1D NMR spectrum of L-Glutamine (A) and conventional COSY spectrum (B) acquired at a 400MHz high resolution spectrometer. (C) Ultrafast single-scan COSY spectrum of glutamine; For the single-scan experiments, 90° and 180° chirps with 8 kHz offset increments were used in the presence of G_e=3mT/m. The duration of the chirps was 10ms and 5ms respectively followed by an additional 10ms evolution delay. 128 gradient echoes with T_a=0.8ms were recorded. The conventional 2D NMR spectra: 128 x 1024 (t1,t2) points were acquired.

Conclusion: Ultrafast single-scan techniques can be implemented using the hardware of whole-body scanners. A significant reduction in the acquisition time may be useful for *in vivo* applications

Acknowledgement
This work was supported by a Marie Curie Early Stage Fellowship (MEST-CT-2004-8041, MagRes Training) and by an EPSRC grant. We would like to thank Professor Lucio Frydman for fruitful discussions and suggestions.

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