

Synthetic signal injection using a single RF channel

K. I. Marro¹, D. Lee¹, E. G. Shankland¹, C. M. Mathis¹, and C. E. Hayes¹

¹Radiology, University of Washington, Seattle, WA, United States

Introduction

Conversion of MR signals to units of concentration can be simplified by injection of a precalibrated, electronic reference signal, or pseudo-signal [1,2]. The primary advantage of this approach is that it automatically compensates for sample-dependent variations in coil loading conditions. In previous implementations, the pseudo-signal was acquired simultaneously with the real signals arising from the sample. This requires a second RF channel, which can complicate implementation since many clinical MR systems have only one fully synchronized RF channel able to transmit shaped waveforms with the correct timing and phase. Here we present an alternative approach, which is to acquire the pseudo-signal in a separate measurement, while the sample of interest is still properly positioned in the probe to maintain loading conditions. With this innovation it is feasible to implement the pseudo-signal injection method using only one RF channel. It also increases flexibility in terms of the amplitude, number and location of pseudo-signals. This flexibility can be exploited to increase the signal to noise ratio (SNR) of the pseudo-signals and provide a more robust conversion of the real signals to units of concentration.

Methods

Measurements were conducted on a 4.7 T Bruker magnet with a Varian Inova spectrometer and VNMR version 6.1. ³¹P-MRS data were obtained from tibialis anterior muscles in 5 normal male subjects. The data were acquired using a specially built probe that consisted of a 20 mm diameter surface coil and a second RF coil, the injector coil, that was only used to inject a pseudo-FID (pFID) during the data acquisition window. Inductive coupling between the injector coil and the surface coil caused pseudo-peaks to appear in the spectra. A single calibration session, conducted on a phantom containing 75 mM sodium phosphate (NaH₂PO₄), was required to establish the ratio of the pseudo-peak to a known concentration. The integrals of the raw in vivo PCr signals were converted to units of concentration using pFID signals that were acquired simultaneously with the real signals arising from the sample and in separate acquisitions, with the subjects still properly positioned in the acquisition coil so that coil loading conditions were maintained.

Results

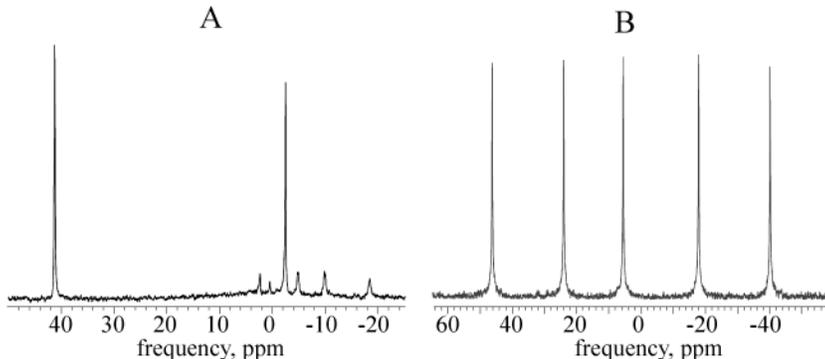


Figure 1. (A) Sample spectrum acquired from tibialis anterior muscles with the real and pseudo-peaks acquired simultaneously. The pseudo-peak appears at about 42 ppm. (B) Five pseudo-peaks acquired separately from the real peaks. Separate acquisition allows multiple peaks to be injected without overlap. It also allows the option of increasing the amplitude of the pseudo-signals. Both options can be used to increase the SNR of the pseudo-signals.

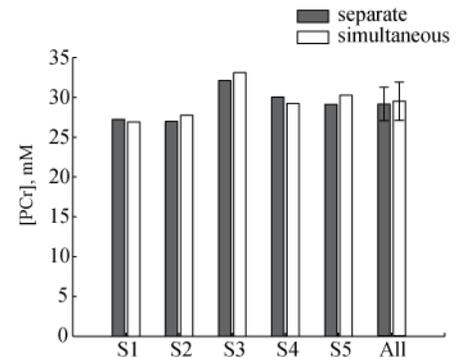


Figure 2. PCr content from 5 subjects (S1 to S5) and the mean +/- standard deviation from all subjects (All). There was high correlation ($r = 0.94$, $p = 0.02$) between the two methods, validating that separate acquisition does not reduce accuracy or precision.

Conclusion

Simultaneous acquisition of a pFID requires a second RF channel since the dynamic range of typical amplifiers used in MR systems does not cover both the high power needed for effective excitation of the real signals and the much lower power needed for the pFID. In our implementation, an in-line 60 dB attenuator was required to reduce the amplitude of the pseudo-signal to the same order of magnitude as the signal arising from excited nuclei within the sample. The separate acquisition method allows pFID injection with a single RF channel, reducing the complexity and cost of implementation. The results in Figure 1 highlight the increased flexibility offered by the separate acquisition method, which can be used to increase the SNR of the pseudo-signals. The results in Figure 2 demonstrate that separate acquisition does not reduce accuracy or precision of the concentration estimates.

1. Barantin L, LePape A, Akoka S (1997) A new method for absolute quantitation of MRS metabolites. *Mag Reson in Med* 38: 179-182.

2. Marro KI, Lee D, Shankland EG, Mathis CM, Hayes CE, et al. (2008) Synthetic signal injection using inductive coupling. *J Magn Reson* 194: 67-75.