Improved SNR Efficiency in MR Spectroscopy with the Fast Pade Transform

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Introduction: Low signal levels in MR spectroscopy (MRS) necessitate averaging of multiple acquisitions in order to achieve acceptable signal to noise ratio (SNR). Since the NMR spectrum is calculated by fast Fourier transform (FFT) of the free induction decay (FID) signal, a long signal acquisition window is required to produce a spectrum with high resolution. The combination of long readout length and multiple signal averages leads to long examination time, which limits the clinical usefulness of MRS. Thus optimization of SNR is of great importance in MRS.

The fast Padé transform (FPT) has been presented as an alternative to the FFT for the calculation of NMR spectra from FID data (1,2). Spectra calculated by conventional FFT have a spectral resolution equal to the inverse of the total data acquisition time. In contrast, the FPT can calculate spectra with the same high spectral resolution with a much shorter acquisition window. Belkić has demonstrated the robustness of the FPT to generate accurate high resolution spectra with the correct number of resonances from signals much shorter in length than the FID required for equivalent spectrum calculation with FFT (3). We show similar results of spectra calculated from actual FID data from a brain spectroscopy experiment in Figure 1. This shows near equivalence of the spectra calculated with the FPT from a truncated FID to the spectrum calculated from the full FID by FFT.

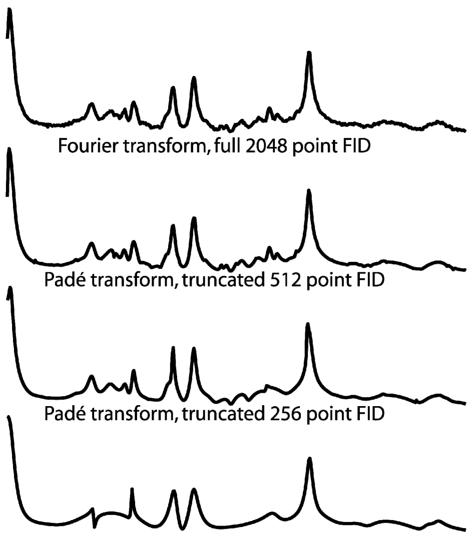

Figure 1: Spectrum calculated by FFT from full 2048 point FID (top spectrum) and spectra calculated by FPT with truncated FIDs. Data is from an in-vivo brain spectroscopy examination at 3T**.**

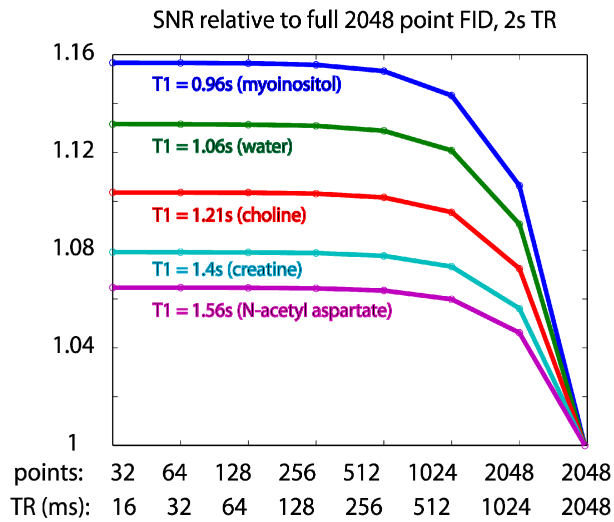

Figure 2: Relative SNR of reduced TR truncated FID for various degrees of FID truncation. Relative SNR is compared to that of the conventional 2s TR scan with 2048 FID data points in a 1.024s acquisition window. The fast Padé transform allows calculation of high resolution spectra from truncated FIDs. Truncation of FIDs allows shorter TR acquisition, with improved SNR efficiency.

The possibility of calculating high resolution spectra from truncated FIDs raises the question of whether spectroscopy can be better performed with a short TR, low flip angle, short readout approach rather than the traditional long TR, high flip angle, long readout approach currently used for MRS. We have investigated one aspect of the feasibility of fast short TR spectroscopy by comparing the SNR available with this approach to the SNR of conventional long TR spectroscopy.

Theory and Methods: We compare the SNR obtained in a brain spectroscopy sequence utilizing conventional spectroscopy parameters (TR of about 2 seconds, flip angle of 90 degrees, 2048 data points with a sampling interval of 500 microseconds) with a faster low flip angle short TR spectroscopy sequence with varying degrees of FID truncation. For example, shortening the FID acquisition to 256ms (512 data points) allows a short TR of slightly more than 256ms, allowing approximately eight times as many signal acquisitions as the conventional long TR sequence. However, the signal available for each of these truncated acquisitions is reduced according to the GRE signal equation. Assuming that the flip angle is optimized at the Ernst angle for the T1 of the metabolite of interest, the signal acquired at a given TR is $M_0\left(1-e^{-TR/T_1}\right)\Big/\sqrt{1-e^{-2TR/T_1}}$. This decrease in signal intensity is balanced by the SNR gain achieved by signal averaging of the multiple short TR acquisitions. The interplay of these factors gives rise to the well-known concept of SNR efficiency in GRE imaging.

Results and Discussion: In Figure 2 we summarize the SNR gains possible with varying degrees of truncation of the FID for brain metabolites with various values of T1 (4), for constant total imaging time. SNR is increased with decreased TR and shorter FIDs, with little incremental improvement in SNR for FIDs truncation shorter than 256 points. SNR improvement is greatest for shorter T1 species. These results suggest that some gain in SNR is possible with a short TR spectroscopy sequence utilizing the FPT to calculate spectra from truncated FIDs. Whether this results in more accurate estimation of spectral peaks depends largely on the noise behavior of the FPT, which is a topic of continuing investigation. Calculation of spectra from truncated FIDs with the FPT makes signal acquisition with optimal SNR efficiency possible, which may improve the accuracy of measured spectra.

References: 1. Belkić, *Nucl. Instr. And Meth. A*. 2004; 525:372-378. **2.** Kim et al., *17th Meeting ISMRM, Hawaii*. 2009; 2352. **3.** Belkić, *Phys. Med. Biol.* 2006; 51:2633-2670. **4.** Ethofer et al., *Magn. Reson. Med*. 2003; 50:1296-1299.