Implementation of a new composite pulse for excitation in fast proton spectroscopic imaging at 1.5 T

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Introduction

In clinical brain examinations using proton MRSI, measuring spectra from small voxels is of great benefit because of the possibility to provide direct matching of metabolic and anatomical information. It has been shown that at high spatial resolution MR spectra of superior quality can be obtained [1,2]. Because of practical experimental time limitations, short repetition times (TR) are required. In order to exploit the increased spectral resolution related to small voxels, quite long acquisition times should be employed. Therefore, all excitation functions of a pulse sequence should be as compressed as possible. Typically a considerable part of TR, particularly at lower field strengths, is taken by water and lipid saturation and outer volume suppression. Fast MRSI techniques implemented so far have often used chemical shift-selective hard pulse sequences, such as 1(x)–2t–5.4(-x)–t–5.4(x)–2t–1(x) and 1(x)–t–1(x)–t–8(-x)–8(x)–t–1(-x)–t–1(-x) [3] for the excitation of the bandwidth between water and lipids [4-6]. Some improved pulses have been theoretically designed recently [7] to increase the excitation bandwidth and/or improve the excitation profile at lower flip angles. One important problem that these designs have not dealt with is generation of spectra with a suitable reference signal.

Methods

The new pulse 1(x)-t-3.5(x)-t-3.2(x)-t-4.0(-x)-t-36.7(-x)-t-36.7(x)-t-4.0(x)-t-3.2(-x)-t-4(-x) has been developed using computer simulation based on Bloch equations. Because of the presumed long acquisition times, full destruction of transversal magnetization after acquisition was supposed. The pulse has been implemented as an amplitude-modulated pulse with 0.2-ms blips separated by 4-ms gaps. The highest γB_{1max} of 800Hz is well below the instrumental limit of 1050 Hz. Using the IDEA development environment a suitable pulse sequence program has been developed, making various combinations of presaturation and excitation possible. In this study, spin echoes generated by 2 (PRESS) or 4 pulses from the transversal magnetization excited by the composite pulse have been measured. Spectral width of 625 Hz, TR=550-2000 ms, TE=136 ms and acquisition of 256 or 512 points have been used to acquire data for voxel sizes 330-1500 nl. One presaturation Gaussian pulse has been optionally applied to enhance water suppression. Experiments have been carried out on 2-compartment phantoms (oil, water+ethanol 250 mM) and on healthy volunteers. Standard head coil was used.

Results

Excellent excitation profiles (Fig. 1 and 2) are predicted by calculation, which has been confirmed by phantom tests. In human head, the spectrum quality may suffer from low signal-to-noise (Fig. 3) or from lipid contamination if very high spatial resolution is used (Fig. 4). With suitable parameters, however, even such spectra are suitable for analysis.

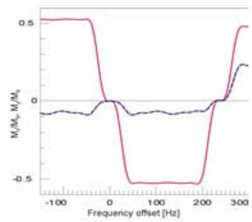

Fig. 1. Calculated steady-state transverse magnetization of metabolites (T_1=1200ms, T_2=400ms) excited by the 65° composite pulse in a sequence with TR=650ms.

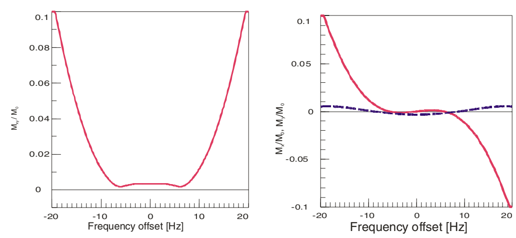

Fig. 2. Calculated steady-state transverse magnetization of water (T_1=1000ms, T_2=100ms), excited under the same conditions.

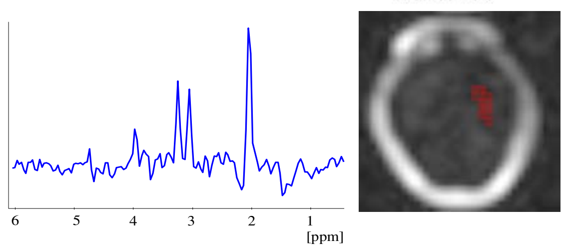

Fig. 3. Spectrum of the aggregated voxels indicated (12×250nl) acquired by double spin-echo. One presaturation pulse used, TR=650 ms, total measurement time 421 s. Anatomical matching possible.

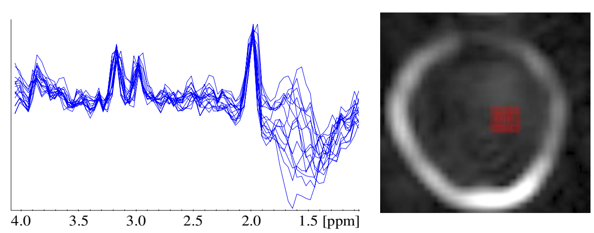

Fig. 4. Overlapped spectra of neighboring voxels (330nl). No presaturation used, TR=625ms, total measurement time 664 s.

Discussion and Conclusions

Our experiments have demonstrated that at 1.5T, long-TE spectroscopic imaging with short TR (e.g. 625 ms) is feasible. Thanks to the reduced TR the measurement can be shortened, the spatial resolution increased, or more signal (optionally with phase cycling) accumulated. Increased T_1 and T_2 weighting is a consequence that has to be taken into account in quantitation. The sequence parameters need to be carefully chosen to ensure sufficient signal-to-noise ratio. For this purpose, voxel aggregation optionally preceded by B_0 correction has been found useful. Sequences of the presented type may be also beneficial if the effect of magnetization transfer is a question. Improving the quality of spatial localization and testing the suitability for quantitation are the issues for future work.

Acknowledgements

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References

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