

Artefact minimized spectral editing at 7T: quick and accurate *in-vivo* detection of GABA.

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Introduction: Spectral editing techniques are used in MRS to improve the detection of low concentrated metabolites like GABA [1], of which signals are overlapped with resonances of other highly concentrated compounds, such as Creatine and macromolecules. However, these methods rely on subtraction of two *in vivo* MR spectra and, therefore, are prone to artefacts. MRS at high field benefits from higher SNR and chemical shift dispersion, improving spectral editing comparing to low field. On the other hand, due to increasing chemical shift displacement error (CSDE) at high field, accuracy in voxel localization is hampered. Because of this, the observed signal in localized editing techniques is originating from four compartments that apart from misalignment of the voxel, reduces the editing efficiency substantially. Recently, a semi-LASER localization sequence was shown to enable ¹H-MRS of the human brain at 7T with minimal CSDE [2]. This sequence can be used for spectral editing, however, its four adiabatic inversion pulses limit the duration of the editing pulses within fixed echo time. Fortunately, increased chemical shift dispersion at high fields allows the use of selective editing pulses with shorter duration than at lower fields. Here, we implemented and performed an accurate and efficient spectral editing of the 3 ppm GABA resonance *in-vivo* in the human brain at 7T, utilizing two editing pulses in a semi-LASER localization sequence. High accuracy of this editing technique enabled an estimation of T₂ relaxation time of the 3 ppm GABA resonance based on two edited MR spectra obtained at TE of 74 and 222 ms.

Methods: Two double-banded inversion MEGA pulses (10 ms) were created with MatPulse (Matlab) (Fig. 1A). The left inversion band is intended for water suppression and the right one for either 1) decoupling of 3.0 and 1.9 ppm GABA resonances (MEGA1) or 2) minimization of the co-edited macromolecule resonance by affecting the resonance at 1.7 ppm in the same manner (MEGA2) [3]. Semi-LASER voxel localization was used with four 5 ms adiabatic refocusing pulses at an echo time of 74 ms, which is the optimal TE for the 3ppm GABA resonance in this sequence (based on the simulations) (Fig. 1B). The switch between MEGA1 and MEGA2 pulses was performed in an interleaved manner to minimize artefacts due to phase disturbances between every acquisition. *In vivo* measurements were performed with a 7T MR scanner interfaced to a volume transmit head coil and an integrated 16 channel receiver array. GABA editing with the MEGA-sLASER technique was performed in a phantom (10 mM GABA) with three different echo times to demonstrate that a small extension of echo time has a negligible effect (less than 2% signal loss) on the edited MR spectra as predicted from $\sin^2(\pi TE/J)$ time dependence of the antiphase term $4I_xS_1S_2$ (Fig. 2A), (TR/TE = 4100/72,74,78 ms, NSA 1, voxel 20/20/20 mm³). In the *in-vivo* measurement MEGA-sLASER MR spectra were acquired in the visual cortex of a healthy human volunteer (TR/TE = 4100/74 ms, 64 acquisitions, 30x30x30 mm³ voxel, total acquisition time of 4,5 min). MR spectra corresponding to the even acquisitions were subtracted from the odd without any post-processing. The T₂ relaxation time of the 3.0 ppm GABA resonance was estimated from the ratio of fitted GABA peaks integrals in the edited spectra acquired with TE = 74 and 222 ms.

Results and Discussion: Phantom measurements confirm the minor effect of the extended echo time on the edited spectrum (Fig. 2B). The chemical shift displacement error of coupled 1.9 and 3.0 ppm GABA resonances in MEGA-sLASER sequence was only 10 and 6 % in the excitation and refocusing directions, respectively (Fig. 3). After subtraction of the even MR spectra (Fig. 4C) from the odd MR spectra (Fig. 4B) the edited *in-vivo* MR spectrum shows a clear signal for GABA at 3 ppm with the two side peaks of the triplet separated by ~16 Hz (Fig. 4A). In the edited MR spectrum obtained with TE = 222ms the 3 ppm GABA resonance is still distinguishable from the noise level (Fig. 5). Based on the two edited spectra (Fig. 4A & Fig. 5) the T₂ relaxation time of GABA was approximated to be 82 ms.

Conclusions: Elimination of CSDE artefacts and phase disturbances in the subtracted MR spectra with the interleaved MEGA-sLASER method enables accurate *in-vivo* GABA detection within clinically acceptable measurement time (~ 4 min).

A slight increase of echo time due to the four 5 ms AFPs and two 10 ms-MEGA pulses has only minor effect on the intensities in the edited spectrum. High efficiency of the MEGA-sLASER editing technique preserves 3 ppm GABA resonance in the edited spectrum even obtained with an echo time of 222ms.

References: [1] M. Terpstra et al. Magn. Reson. Med. (2002) 47; [2] T.W.J. Scheenen et al. Magn. Reson. Mater. Phys. (2008) 21; [3] P.G. Henry et al. Magn. Reson. Med. (2001) 45.

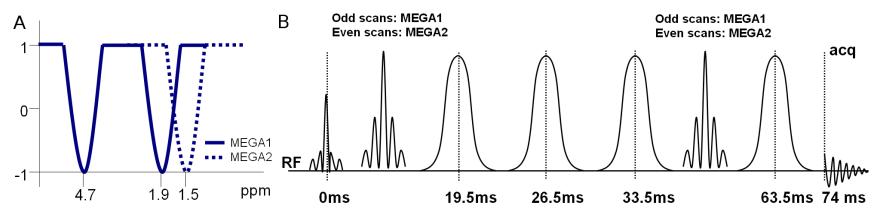


Figure 1. A: Sketched inversion profiles of 10 ms dual-banded MEGA1 and MEGA2 pulses; B: The MEGA-sLASER pulse sequence with alternating MEGA1 and MEGA2 pulses.

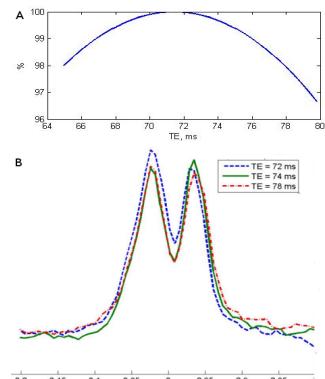


Figure 2. A: Relative signal loss at different echo times; B: edited 3 ppm GABA resonances in the phantom.

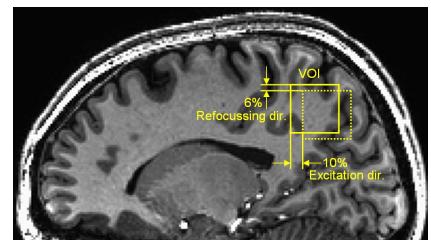


Figure 3. Schematic illustration of CSDE in MEGA-sLASER pulse sequence for 1.9 and 3.0 ppm GABA resonances.

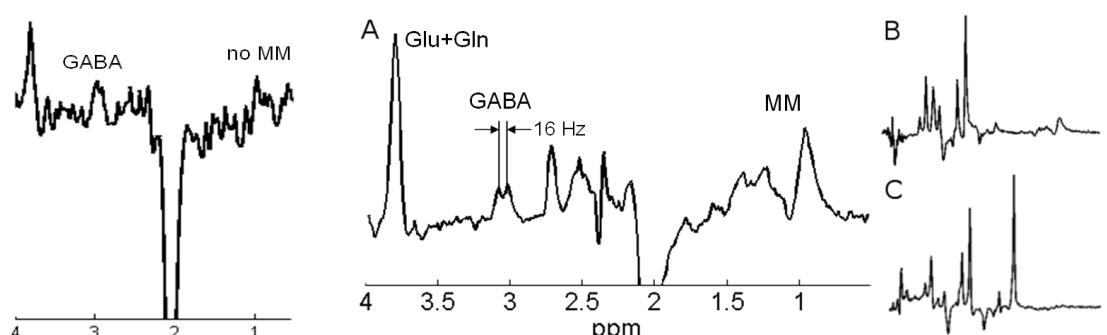


Figure 4. A: In-vivo edited MR spectrum acquired with MEGA-sLASER sequence (TE = 74 ms); B: summed odd scans acquired *in-vivo* with MEGA1 pulse; C: summed even scans acquired *in-vivo* with MEGA2 pulse.