Two-voxel Hadamard encoded semi-LASER spectroscopy for *in vivo* MRS at ultra-high field

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Purpose

At ultra-high field strength (UHF, > 3T), the semi-LASER[1] (semi-localisation by adiabatic selective refocusing) sequence is advantageous over conventional methods for localised ^{1}H-MRS, such as STEAM or PRESS, because of its insensitivity to inefficient B_1 transmit fields along with its broadband sharp adiabatic refocusing pulses. These pulses minimise chemical shift displacement (CSD) errors at UHF, which limit SNR due to poor localisation and unexpected J-modulation. CSD is a particular issue for multi-voxel approaches, such as Hadamard encoding[2], where voxel bleed can be as large as 15%[3]. In this study, we aim to significantly reduce chemical shift displacement errors by modifying a CSD-efficient semi-LASER sequence into a two-voxel Hadamard encoded scheme at 7T, thereby reducing inter-voxel bleeding while acquiring highly resolved spectra from two voxels simultaneously.

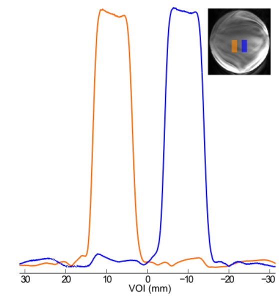

***Figure 1:** Two-voxel excitation profiles from 7T Hadamard encoded semi-LASER in oil phantom.*

Methods

Four volunteers were scanned using a 7T whole body MR system (Siemens, Erlangen) with a Nova Medical 32-channel receive array head-coil. The semi-LASER sequence[1] was modified by replacing the single band excitation pulse with a Hadamard encoded asymmetric 90° dual-banded RF pulse (*duration*=3ms; *bandwidth*=2.2kHz; *peak* B_1 =23µT; *band separation*=4kHz/18mm). For each volunteer, spectra were acquired from the visual cortex in two 10x20x20mm^3 voxels in either hemisphere using a semi-LASER sequence (TR=8s, TE=32ms, NEX=64, *180° bandwidth*=5.3kHz) with VAPOR water suppression and outer volume saturation (OVS)[4]. OVS bands were modified to saturate signals originating from outside of both VOIs. Hadamard decoding was applied to yield the spectra arising from each voxel. Resulting FIDs, including an unsuppressed water FID, were firstly eddy current corrected and then B_0 drift and phase corrected before being averaged (NT=32). Metabolites were quantified with LCModel[5] using the unsuppressed water signal as reference. Only those measured reliably (Cramér-Rao lower bounds (CRLB) < 30%, cross correlation coefficients r > -0.5) from more than half of the spectra were reported. Concentrations were corrected for the amount of CSF present in each VOI and compared using two-tailed, unpaired t-tests.

Results and Discussion

Excitation profiles measured in phantom (*Figure 1*) reveal very low inter-voxel bleed between the VOIs (*voxel 1*: 3.2±1.0% and *voxel 2*: 3.0±0.7%), which are smaller than previously reported values[3] and can be attributed purely to RF pulse imperfection. The large semi-LASER RF bandwidths resulted in low CSD between NAA and Cr of 14% across the excitation direction and 5% across refocusing directions. 7T Hadamard encoded semi-LASER spectra from a single subject are shown in *Figure 2*. Spectra arising from both voxels exhibit near identical water linewidth (*voxel 1*: 14.0±1.2Hz and *voxel 2*: 14.8 ±1.7Hz), SNR and water suppression. We are able to reliably detect metabolites such as GABA, Ins and Glu across all subjects with this method (*Figure 3*). We have shown that the Hadamard semi-LASER method at 7T produces highly resolved, minimally contaminated and almost identical spectra between voxels while remaining insensitive to B_1 inhomogeneity. This new approach has applications in multiband ultra-high field MRSI as well as the detection of simultaneous metabolic changes across multiple voxels during functional studies[6].

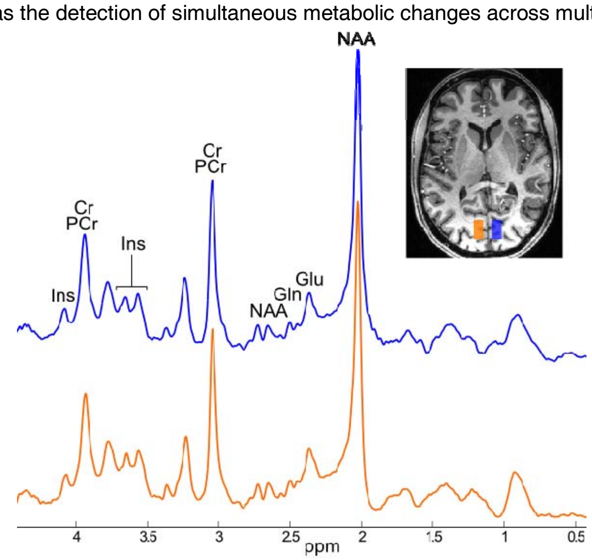

***Figure 2:** Two spectra acquired simultaneously from human visual cortex using Hadamard encoded semi-LASER at 7T. (TE =32ms, TR = 8s, NT = 32, two 10x20x20mm^3 regions.)*

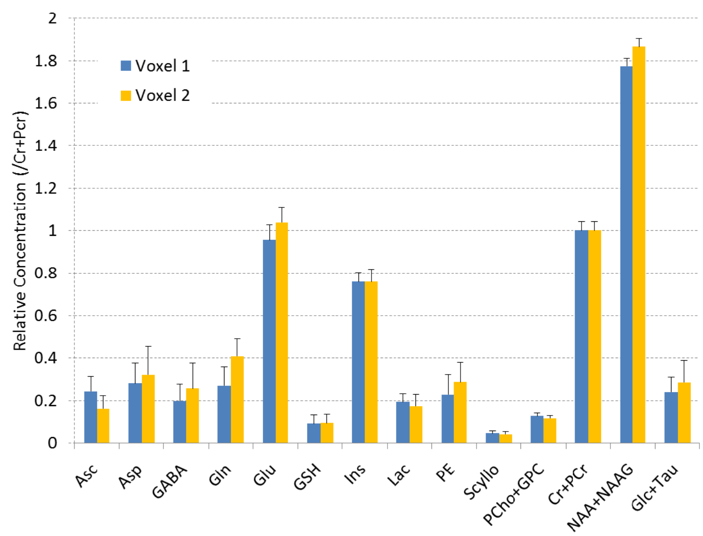

***Figure 3:** Group averages of metabolite concentrations in either voxel relative to total creatine. Cramér-Rao bounds (<30%) are shown as determined by LCModel.*

References

1. Öz, G. & Tkáč, I. (2011) *MRM* 65 (4), 901-10 **2.** Souza, S. & Szumowski, (1988) J. *JCAT*. 12(6) 1026-30 **3.** Goelman, G. et al. (2007) *MRM 58*(1), 167–73 **4.** Tkáć, I. & Gruetter, R. (2005). *Applied MR*, 29(1), 139–57. **5.** Provencher, S. (1993) *MRM* 30(6) 672-9 **6.** Bednarik, P. et al. *ISMRM* (2013) USA.