MRS localization in the human brain at 7T with adiabatic refocusing at short echo time using RF focusing with a dual channel volume transmit coil

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Introduction

At ultra high B_0 field strengths such as 7 telsa the use of spatial localization methods for in vivo ^{1}H-MRS can be hampered by severe chemical-shift-displacement artefacts, especially when B_1^+ fields are low and traditional refocusing pulses are used.
STEAM (1) and SPECIAL (2) sequences have been proposed, the STEAM sequence comes at a 50% SNR penalty and the SPECIAL sequence relies both on a traditional refocusing pulse and a subtraction scheme with a prepulse, resulting in chemical shift artifacts and sensitivity to motion and MT effects.
A promising alternative for localization in high field MRS is the semi-LASER sequence (3) which uses four high bandwidth adiabatic refocusing pulses, resulting in a very small chemical shift displacement artefact and full signal acquisition. However, with low B_1^+ fields, the adiabatic refocusing pulses can become long, and so far the semi-LASER sequence was only employed at echo times of >50 ms at 7T using a volume coil. In this work we show that by driving a standard head coil with two 4kW amplifiers, combined with short adiabatic refocusing pulses and optimized crusher gradients, it is possible to perform a semi-LASER acquisition at a short echo time of 25 ms in the human brain at 7T.

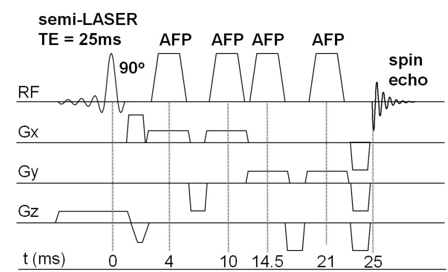

Figure 1. short echo time semi-LASER sequence using four short (3.2ms) adiabatic refocusing pulses, generating a spin echo at 25 ms.

Methods

MR experiments were performed on a 7 tesla whole body MR scanner. A birdcage transmit head coil with two input channels was used in combination with a 16-channel receive coil. After selecting the volume of interest in the occipital grey matter, the transmit phase of both channels was optimized to create a local constructive interference between the two channels, generating the highest possible B_1^+ field with the available power of 4 kW each. The phase between the two transmit channels was varied while performing a series of B_1^+ measurements (4) on the volume of interest to find the phase setting with highest transmit efficiency.
Electromagnetic (FDTD) simulations were performed to determine RF power deposition and applicability to other regions of the brain.
The semi-LASER localization (TE=25, figure 1) was designed with high BW adiabatic refocusing pulses; 3 ms - 8.2kHz, (trapezoid amplitude modulation, with a linear and quadratic frequency sweep respectively under the constant part and ramps) and compared to a STEAM (TE=6ms) and SPECIAL (TE=11ms) localization. The STEAM localization pulses had a BW of 4.1 kHz, the SPECIAL refocusing pulse was at maximum 2.8 kHz, resulting in a large chemical shift displacement artifact. A TR of 8 seconds was used, leading to a maximum local SAR of 4-6 W/kg for the semi-LASER localization, depending on the optimization region (figure 2c).

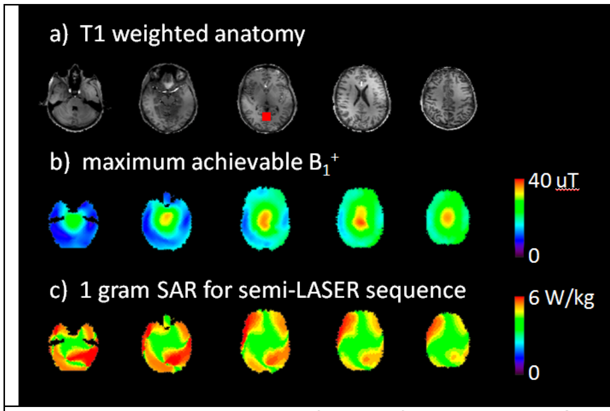

Figure 2. FDTD simulations of the B1 field and global SAR for the semi-LASER sequence, after a voxel by voxel optimization of the transmit phase.

Bandwidth of refocusing pulse	
STEAM	4.4 kHz
SPECIAL	2.8 kHz
semi-LASER	8.2 kHz

Results

By focusing the two transmit fields in the region of interest, a B_1^+ field of 30 uT was generated in the occipital lobe. FDTD simulations (figure 2) show that most of the brain is accessible with similar or higher B_1^+ levels, excluding the temperal lobes and cerebellum where a very poor transmit efficiency is seen with a volume coil. With the high available B_1^+, short adiabatic refocusing pulses can be used, resuling in the highest refocusing bandwidth and thus the lowest chemical shift displacement artifact. Similar or double the SNR was acquired compared to the SPECIAL and STEAM sequence respectively. (figure 3)

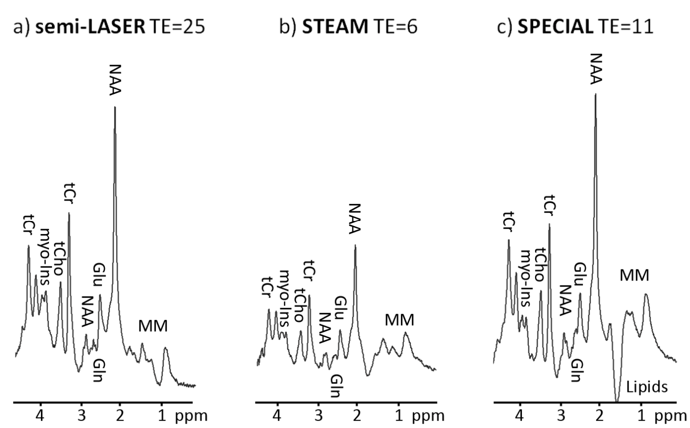

Figure 3. semi-LASER (left) STEAM (middle) and SPECIAL (right) localizion voxel in the occipital lobe of a healthy volunteer. 2x2x2cm voxelsize, 16 averages. Dispite the longer echo time of 25 ms in the semi-LASER seqeuence, Glu signal is retained due to the inherent J-refocusing during the four adiabatic refocusing pulses.

Conclusion

Single voxel localization at short echo time at 7 tesla is possible with full signal acquisition and high bandwidth refocusing pulses, by using a two channel birdcage coil to focus the B_1^+ field. The semi-LASER sequence provides twice the SNR compared to the STEAM sequence, is less prone to motion artifacts compared to the SPECIAL sequence and has the lowest chemical shift displacement artifact.
Therefore, the semi-LASER sequence is a good candidate for studying in vivo metabolism, particularly at high field strengths.

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