Outer Volume Suppression (OVS) for Single Voxel Spectroscopy (SVS) at 7 Tesla using interleaved B1 shim settings

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Introduction

High-field magnetic resonance spectroscopy (MRS) has the potential to provide enhanced neurochemical information based on increased sensitivity and higher spectral resolution. However, problems arising in high-field magnetic resonance imaging (MRI), such as more pronounced B_0 and B_1 inhomogeneities, may decrease spectral resolution and ultimately the quantification accuracy. A multi-channel transmit RF system is an emerging technology to mitigate B_1^+ inhomogeneity during RF transmission. With RF shimming, an optimized combination of different RF amplitudes and phases per transmit channel results in a higher uniformity of the B_1^+ field. Previous work has shown the successful implementation of B_1 shimming localization in spectroscopic imaging [1]. The purpose of this work is to utilize this method for outer volume suppression (OVS) in single voxel spectroscopy (SVS) using interleaved RF shim settings.

Methods

For this study a 7T whole-body MR system (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) was used, which has been extended with a custom-built eight-channel B_1 shimming system [2]. The shim system allows fast switching between shim settings based on an externally applied trigger pulse. Two B_1 shim settings were used in these examinations (Fig. 1). The first shim setting has a B_1^+ distribution with a signal void at the desired voxel position with about the size of the voxel (Fig. 1a, b). For the second shim setting, the conventional birdcage circularly polarized mode was chosen, which has an overall homogenous distribution in the head (Fig. 1c, d). MRS was performed with a ^{1}H single voxel optimized 7 T PRESS sequence with WET water suppression (scan time: 1:36 min., voxel size: 10 x 10 x 10mm^3, TR/TE: 1500/37.5 ms, averages: 64) on a phantom and a healthy volunteer. The phantom was a large cylinder with water and sodium acetate at a concentration of 0.1 mol/l. Inside the cylinder was a small cube filled with water and 0.1 mol/l lithium lactate and 0.1 mol/l creatine. Voxel selection by slice-selective excitation and two orthogonal slice-selective refocusing pulses was performed with the CP^+ mode. Outer volume suppression just before voxel selection was achieved using a 90° non-selective adiabatic (tan12) pulse with the first shim setting followed by crusher gradients, thereby exciting and crushing all signals outside the signal void of this B_1^+ shim. To test the efficiency of the suppression pulse, an additional spectrum with suppression throughout the phantom was acquired. The efficiency of the method in suppressing everything besides the selected voxel was estimated by comparing the acetate/lactate ratio in the phantom.

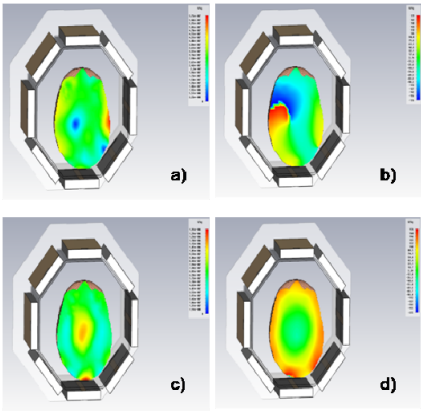

Fig. 1: Head B_1^+ shim distributions:
a) B_1^+ magnitude of first shim
b) B_1^+ phase of first shim
c) B_1^+ magnitude of CP^+ mode
d) B_1^+ phase of CP^+ mode

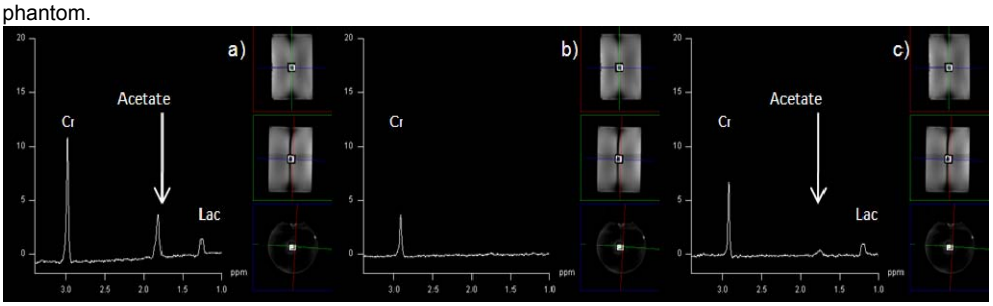

Fig. 2: Phantom spectra:
a) without OVS
b) signal suppression in voxel
c) OVS with interleaved B_1 shims

Results and Discussion

Figure 2 shows the comparison between spectrums obtained in the phantom without any OVS, with suppression throughout the complete phantom, and with OVS using the method with interleaved RF shim settings. The center frequency of the adiabatic saturation pulse was set to 0 ppm and achieves a reduction of about 93% of acetate signal intensity in comparison with the spectra acquired without any OVS (Fig. 2a). Looking at Fig. 2b where the complete signal in the voxel should have been suppressed, it is evident that the suppression pulse has a narrow spectral bandwidth because the creatine signal is not fully suppressed. The method achieved a significant reduction of the outer acetate signal at 1.9 ppm. However, it also reduced the inner lactate signal by 36% due to imperfect edge steepness of the signal void of the first shim setting (Fig. 1a).
Figure 3 shows the application of this method in the brain of a healthy volunteer. The voxel position is depicted in Fig. 3b over a transverse image of the brain with the adapted RF shim. Large lipid signals in spectra without any OVS (Fig. 3a) strongly decreased in spectra with OVS using interleaved shims (Fig. 3b). The lipid signal is reduced by at least 90% by application of the proposed method. A complete suppression is not possible at 1.3 ppm because of the macromolecular signals inherently present inside the voxel around 1.2 ppm. Compared to the phantom results, we achieved a reduction of about 10% of the inner metabolites signal in vivo. The negative intensities between 2-3 ppm may be due to the spectral shape of the strongly coupled resonances at the echo time of 37.5 ms.

Conclusions

The OVS method using an adiabatic 90° pulse for excitations with a particular RF shim setting achieves a reduction of outer volume signals by more than 90% at a cost of 10-36% of signal within the voxel of interest. This method with only one short suppression pulse reduces the power deposition necessary for OVS compared to other OVS methods where multiple high-bandwidth slice-selective suppression pulses are played out, making additional RF power available for accurate excitation before SAR limits are reached. Future work will include the implementation of an adiabatic pulse with higher spectral bandwidth.

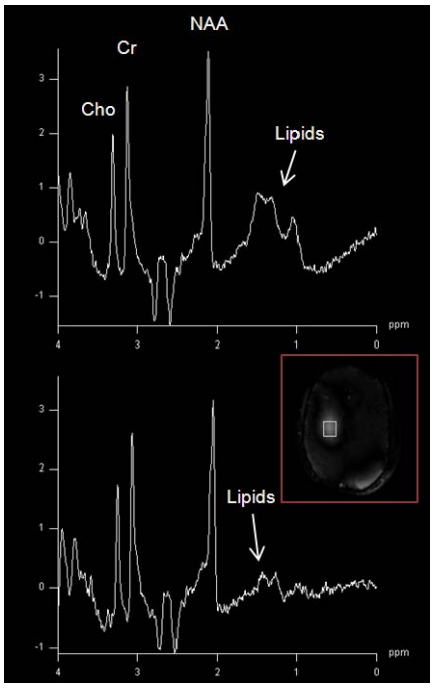

Fig. 3: In vivo spectra of the desired voxel:
a) without OVS
b) with OVS using interleaved B_1 shims

References:
[1] Avdievich NI, MRM 62:17-25 (2009), [2] Bitz A, ISMRM 2009 # 4767