Inherent Reduction of Residual Lipid Aliasing in SENSE-accelerated ^{1}H MRSI at 7T by Spatially Selective SRF Optimization

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Introduction

Due to scan time limitations and to achieve a sufficient level of SNR, typical spatial resolutions in Magnetic Resonance Spectroscopic Imaging (MRSI) are low compared to Magnetic Resonance Imaging (MRI). This leads to the specific artifacts commonly referred to as *voxel bleeding*, which means that a given spectroscopic image voxel will display spectral contributions from other regions of the Field of View (FOV). Most notably, lipid signal originating in the skull region is often found in the center of the brain due to voxel bleeding and/or residual spatial aliasing (incomplete unfolding) in case of SENSE [1] acceleration. Although less immediately visible, metabolite peaks will be affected in the same manner and spectroscopic quantification will become deceiving. Previous work demonstrated that by means of directly optimizing the Spatial Response Function (SRF) on an overdiscrete spatial grid [2, 3] a better spatial specificity and higher SENSE-acceleration can be achieved, proving advantageous over conventional Hamming ***k***-space apodization. ***In this work***, we extend this MRSI reconstruction approach by taking into account anatomical spatial prior knowledge and demonstrate that suppression of residual lipid artifacts can be further improved.

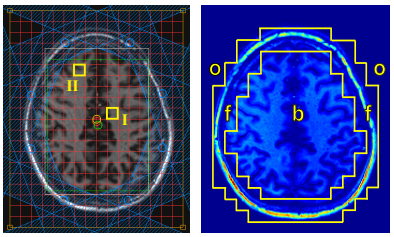

***Figure 1**: **left**: 20x16 MRSI localized by Outer Volume Suppression slabs; **right:** coarse separation of* b ("brain"), f ("fat"), *and* o ("outside") *tissue (schematic). Two representative voxels I and II are chosen for further analysis*

Theory and Methods

Data Acquisition: Using Cartesian ***k***-space sampling with fourfold SENSE acceleration (R=2 in both AP and RL), an MRSI data set of a transversal brain slice of a healthy volunteer was acquired on a 7T MR scanner (Philips Healthcare, Cleveland, USA) with a 32 channel head coil (NOVA Medical, Wilmington, USA). A 200 x 160 mm^2 FOV with voxel size 10x10x10 mm^3 was chosen (Fig. 1). We utilized the FIDLOVS [4] sequence incorporating efficient VAPOR [5] water suppression with optimized interleaved Outer Volume Suppression (OVS) together with image based $\boldsymbol{B}_0$ shimming [6] (TR=8s due to SAR limitations, acquisition delay TE=3.8ms). Examination time for the MRSI scan was 21:20 min including a second, non-water suppressed acquisition for eddy current reference of the same resolution.

Reconstruction: The MRSI reconstruction operator is given by the explicit solution F of the cost function

$$\Delta_\pi = \left\| [(FE - T)A]_\pi \right\|_2^2 + (F\Psi F^H)_{\pi,\pi} ,$$

where SRF optimization (first term) is regularized by the noise level (second term) for pixel π [7]. E contains the sensitivity and phase encoding information and T the Gaussian SRF target functions, both with a ζ^2=9-fold overdiscretization in real space [2]. The entries of the diagonal matrix A are spatial weights – one for each voxel – and introduce a prioritization of SRF optimality across the FOV. Here, the three coarse tissue types *f (fat)*, *b (brain)* and *o (outside* the object*)* are distinguished from an anatomical T_1-weighted MR image by an automatic masking script (Fig. 1). Different weights are then assigned to the tissue types. Reconstruction results from the same data set are compared among various possible choices for spatial weights and against conventional SENSE reconstruction with Hamming filtering.

Spectral Processing comprises eddy current correction [8], broadline suppression, HLSVD residual water suppression and 2 Hz Gaussian noise filtering as well as zero and first order phase correction.

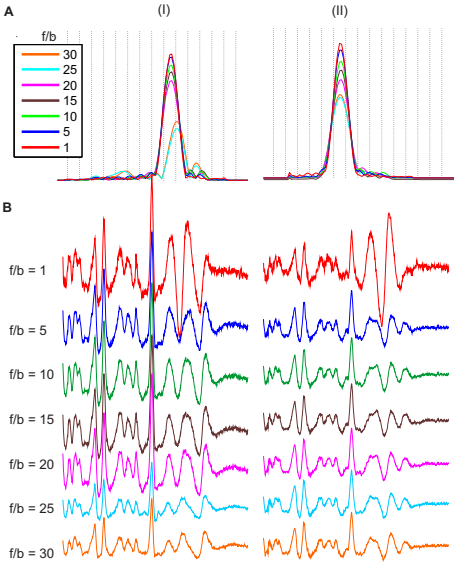

***Figure 2**: **(A)** Resulting SRF along the RL direction and **(B)** spectra from 0 to 4.0 ppm in the three voxels designated in Fig. 1 for different relative weightings of* fat (f) *tissue compared to* brain (b) *tissue in the two voxels I and II designated in Fig. 1*

Results

If SRF optimality is given higher priority for region *b* (*brain*) than for region *f (fat)*, the desired SRF shape quickly deteriorates and causes the *fat* content in the *brain* voxel under consideration to rise to multiples of the original content (Fig. 3). On the other hand, with higher priority of SRF optimality on *fat* than on *brain*, a major decrease of relative *fat* content in any given voxel is observed. This is reflected accordingly by a drop of lipid signal intensity in representative spectra from brain regions where such contamination may otherwise still be visible due to imperfect OVS based lipid suppression (outer cortical voxels) and any residual SENSE aliasing (mid brain) (Fig. 2B). The effective spatial resolution decreases only slightly for moderate weighting factors *f/b*<10 as indicated by the weighting dependent FWHM of the SRF main lobe (Table 1) and stays well below the value of 1.85 achieved with conventional Hamming filtering. Fig. 4 gives an indication of the distribution of residual lipid signal (after suppression by OVS) for different reconstruction schemes. In the region of interest, i.e. the brain region, a decrease of lipid signal spread due to residual SENSE aliasing or voxel bleeding can be achieved if spatial prior knowledge (*f/b* =10) is taken into account, in comparison to not considering spatial prior knowledge using the same overdiscretized reconstruction (*f/b*=1) or conventional SENSE reconstruction with Hamming filtering. In some instances (here: voxel I), a breakdown occurs when the relative weights *f/b* are chosen too high, shifting the SRF main lobe out of its intended position (Fig. 2A and Fig. 3). This detrimental behavior can easily be avoided by restricting the range of the weight variation.

f/b	(I)	(II)
1	1.37	1.35
5	1.44	1.42
10	1.48	1.49
15	1.50	1.54
20	1.54	1.64
25	(1.41)	1.75
30	(1.41)	1.75

***Table 1**: FWHM of the main lobe of the resulting SRF depending on* f/b *for the voxels I and II*

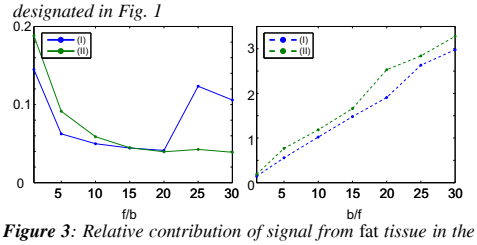

***Figure 3**: Relative contribution of signal from* fat *tissue in the* brain *area around the two voxels I and II (voxels + nearest neighbors). These ratios are determined directly from the SRF. A value close to zero is desired.* **left:** f *weighted heavier than* b, **right:** b *weighted heavier than* f

Conclusion

In conventional Hamming-filtered SENSE reconstruction of MRSI, residual aliasing and voxel bleeding is still present and most prominently seen in the lipid spectral range. Adapted target-driven, overdiscretized reconstruction largely reduces those artifacts through direct optimization of the SRF [2]. We demonstrate that a further suppression of any residual lipid artifacts in ^{1}H brain spectra can be achieved by assigning a moderately elevated priority to SRF optimality in the region of subcranial lipids of ^{1}H MRSI. This facilitates a better spectral quality when SENSE acceleration is used.

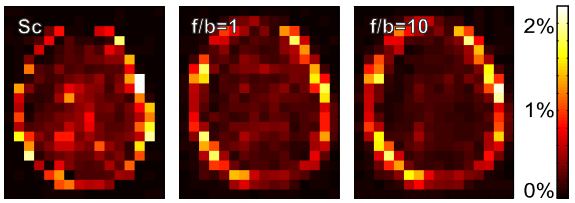

***Figure 4**: Maps of the integral over the modulus spectra between 0 and 1.8 ppm: Comparison of vendor pre-implemented reconstruction with Hamming filtering* (Sc)*, the non-weighted overdiscretized reconstruction [2] (*f/b=*1) and with spatially selective weighting (*f/b=*10). Additional suppression of residual lipid artifacts at moderate levels of* fat *tissue prioritization during SRF optimization is observed. All maps are normalized to the total* fat *signal in the entire FOV.*

References

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