Reduction of Chemical Shift Artifacts in ^{19}F Imaging utilizing Coil Sensitivities

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Introduction: ^{19}F MRI bears potential as a tracer technique for applications in diagnosis and therapy monitoring when combined with fluorine-labeled agents. For example, the quantification of targeted ^{19}F nanoparticles has shown the potential to uniquely identify unstable atherosclerotic lesions in vivo [1]. Other applications include studying tumor metabolism [2] and tracking immunotherapeutic cells [3]. However, ^{19}F MRI often suffers from strong chemical shift (CS) artifacts due to multi-line spectra of typical ^{19}F imaging agents or the presence of different ^{19}F agents exhibiting different CS. Hence, it is important to find appropriate countermeasures, which do not spoil the SNR or significantly increase the scan time. A concept is presented, which utilizes different coil sensitivities to correct for CS artifacts applying a SENSE-like algorithm in the frequency encoding direction. The method is especially appealing, since surface coils are favourable to improve the SNR of ^{19}F images for applications in vivo, anyway.

Methods: The presented method is based on the fact, that the signal is weighted by the coil sensitivity at its physical location, whereas the corresponding image might appear at a different position due to the CS, where the actual coil sensitivity can be significantly different. Knowing the sensitivity profiles and the existing resonance frequencies, it is possible to reconstruct the signal origins and thus to correct for CS artifacts. Assuming two independent substances (ρ,δ) with different, but known resonance frequencies, the reconstruction problem is given by equation (1). The vector $\vec{c}$ contains the different coil images and the vector $\vec{\mu}$ consists of the unshifted images, $\vec{\rho}$ and $\vec{\delta}$. The corresponding sensitivity matrices S_{ij} are diagonal for resonant signals and off-diagonal for off-resonant signals. Eq. (1) can be solved applying the Moore-Penrose pseudoinverse as in the standard SENSE reconstruction [4].

Eq. (1)

$$\vec{c} = \begin{pmatrix} \vec{c}_A \\ \vec{c}_B \\ \vdots \end{pmatrix} = \begin{pmatrix} S_{A\rho} & S_{A\delta} \\ S_{B\rho} & S_{B\delta} \\ \vdots & \vdots \end{pmatrix} \begin{pmatrix} \vec{\rho} \\ \vec{\delta} \end{pmatrix} = \hat{S}\vec{\mu}$$

If only one substance with known resonance frequencies and relative intensities is present, the reconstruction problem can be simplified. The images $\vec{\rho}$ and $\vec{\delta}$ become linear dependent and thus, $\vec{\delta} = a \cdot \vec{\rho}$ can be used as a priori information in eq. 1. The factor a is given by the intensity ratio of the resonance lines.

Simulated images of a coil array consisting of three rectangular coils are shown in figure 1a. The coil locations are indicated at the top of the image and it is assumed, that two independent substances are present, one is in resonance (with the image pattern "CrownEther", image size 64*15 pixels) and one off-resonance, leading to a shift of 10 pixels (image pattern "PFOB").

Furthermore, initial experiments were performed at 3T (3D gradient echo, FOV 110mm, voxel 0.86x0.86x3 mm^3, TR/TE 12/5.9 ms, α=15°) using a single channel, double resonant (^{19}F/^{1}H) surface transmit/receive coil (figure 2a), which has equivalent sensitivities for both nuclei. Images from two different coil positions were taken to mimic a coil array setup. A small tube (2ml, Ø 1cm) of Perfluoro-octyl-bromide (PFOB) was placed inside a box filled with water. Only two resonance lines of PFOB were excited by limiting the excitation bandwidth to 6kHz. Using a pixel bandwidth of 108.6Hz, the second ^{19}F line leads to an image shifted by 20 pixels. The corresponding ^{19}F images are shown in figures 3a and 3b. ^{1}H images were acquired in both positions as well to determine the sensitivity matrix (figures 2b,2c).

Results and Discussion: The reconstruction of the simulated images and the corresponding g-factors are presented in figures 1b-1e. For this reconstruction, only the resonance frequencies and the sensitivities have been used as a priori information. Both images could be recovered with correct relative intensities (figures 1b,1d). Nevertheless, the corresponding g-factors show, that the method is prone to noise for the simulated coil configuration (figures 1c ,1e).

The reconstructed image of the experimental data and the corresponding g-factor are presented in figures 3c and 3d. The CS artifact is almost completely removed. For this reconstruction, all the available a priori information was used (one substance with known resonance frequencies and relative intensities). Strictly speaking, the image can also be unfolded without knowledge of the coil sensitivities in this case, but at the expense of SNR. Applying eq. (1) for homogeneous coils leads to a corresponding g-factor of 1.46, compared to 1.2-1.4 in the depicted case. It has to be noted, that the situation in the described experiment differs from a real ^{19}F coil array, since combined transmit and receive sensitivities had to be used.

Conclusion: The sensitivity profile of RF-coils was utilized to eliminate CS artifacts. For this purpose, a SENSE-like reconstruction was applied in the frequency encoding direction. The reconstruction quality improves the more *a priori* information is used. If the signals stem from one substance with a known spectrum, as in the case of most ^{19}F imaging agents, the most stable unfolding is achieved. First experiments indicate, that the method has potential to improve the efficiency of multi-line ^{19}F imaging. A further evaluation will follow.

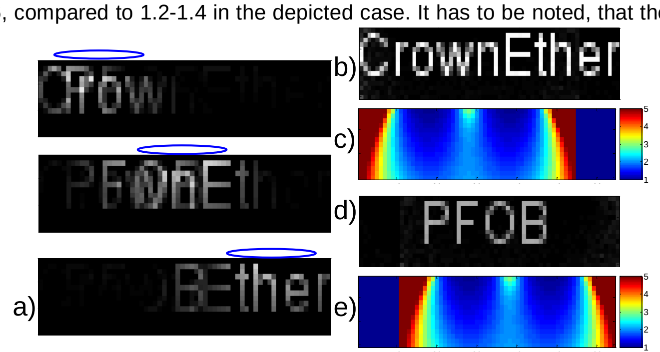

Fig. 1:a) Simulated images of three surface coils. The image of one substance is shifted by 10 pixels due to CS. b), d) Reconstructed images c), e) Corresponding g-factors.

References

[1] A.M. Morawski et al., MRM 52:1255-1262 (2004)
[2] W. Wolf et al., Adv. Drug Deliv. Rev. 41:55-74 (2000)
[3] E.T. Ahrens et al., Nature Biotechnology 23:983-987 (2005)
[4] K.P. Pruessmann et al., MRM 42:952-962 (1999)

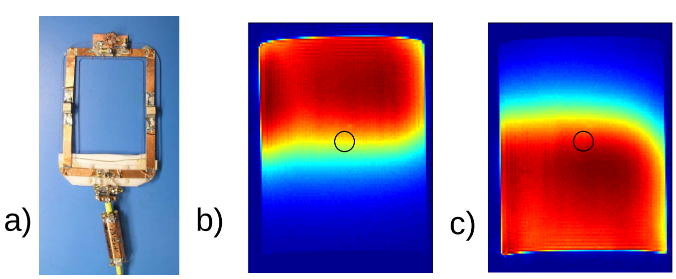

Fig. 2: a) ^{1}H/^{19}F transmit/receive surface coil b),c) Coil sensitivities for the two coil positions as derived from ^{1}H images. The position of the PFOB sample is indicated by the circle.

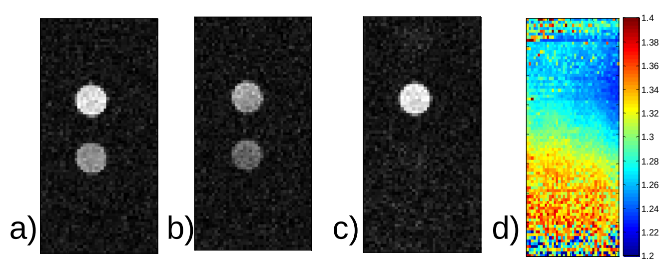

Fig. 3: a),b) ^{19}F images of PFOB taken at two coil positions. Two resonance lines are excited leading to a CS artifact c) Reconstructed image d) Corresponding g-factor.