Sense Shimming (SSH), first in-vivo results

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Introduction: Due to the direct relationship between frequency and spatial location, a high field homogeneity is paramount for accurate imaging in MRI. In order to adjust the field, several orders of shim coils are usually available, along with a multitude of methods to detect the optimal settings, ranging from manual to automatic methods ([1]). Recently, a proof of concept has been presented of a method capable of detecting B0 field inhomogeneities by observing the temporal evolution of a free induction decay (FID), using sensitivity differences of coil array elements, named Sense Shimming or short ‚SSH' ([2]). The results presented so far were limited to phantom measurements, due to expected complications regarding chemical shift artefacts and physiological noise. We here address these problems and present the first in-vivo results.

Methods: The SSH method uses a concept similar to the well known SENSE technique ([3]), exploiting information inherent in the spatial sensitivities of the elements of a coil array. Unlike in the SENSE approach, in SSH this information is not used for filling in missing image data, but for finding coefficients of field inhomogeneities, described by basis functions. Those basis functions can conveniently be chosen to correspond to the cartesian representation of solid harmonics. The method can be used for detecting optimal shim values, by solving the following equation:

$$-i(\Psi_n(t_0+\Delta t)-\Psi_n(t_0))/\Delta t \approx \int_{dV} \rho_n'(\vec{r},t_0)\,\omega(\vec{r})\,d\vec{r} \qquad (1)$$

$\Psi_n(t)$ is the FID signal recorded at time t from coil n, $\rho_n'(\vec{r},t_0)$ the complex product of spin density and the sensitivity of coil n, and $\omega(\vec{r})$ the unknown inhomogeneities. By expressing the inhomogeneities by means of the mentioned basis functions, Equation 1 can be solved for the unknown coefficients ([2]). Similar to SENSE, the number of coil elements poses a theoretical limit for the number of basis functions.

We here present the first in-vivo results of the method. As mentioned, increased noise due to chemical shift artefacts and physiological noise was to be expected. We therefore decided to test the method with the following setup: a) without fat saturation pulses and without flow compensation, b) without fat saturation pulses but with flow compensation, c) with fat saturation pulses but without flow compensation, and d) using both, fat saturation and flow compensation. For every test case 20 measurements were performed, the first 10 measurements altering the X^2-Y^2 shim component, the second 10 measurements altering the 2XY component. For both, X^2-Y^2 and 2XY, the following settings were used (in µT/m²): 0,-50,-37.5,-25,-12.5,0,12.5,25,37.5 and 50. All measurements were performed on a 3T Tim Trio Magnetom (Siemens Medical Solution, Erlangen, Germany), imaging the brain of a healthy volunteer. A single slice located in the iso-centre was acquired. In order to obtain the necessary FID data, a product GRE FLASH sequence was modified such that FID acquisitions could be appended as additional phase encoding steps to the normal k space trajectory. The sequence parameters were as follows: resolution: 2x2x5mm³, TE=4ms and TR=20ms. In order to calculate error estimates, 128 FID were acquired for every measurement.

Results & Conclusion: Figure 1 shows the results from the described volunteer measurements. a) to d) correspond to the setup depicted above. The dashed lines are the respective applied values, the solid lines the detected ones. As can be seen, results are worst for case a), with no physiological correction. Adding flow compensation reduces artifacts slightly, but best results are obtained by using additional fat saturation.

This of course is not optimal for a shimming method, since fat saturation pulses themselves already require a certain level of field homogeneity. Still, the results positively prove that SSH can be used in in-vivo situations, with fat saturation being an open problem yet to be solved.

References: [1] Hillenbrand et al. AMR 29, 39-64, 2005; [2] Splitthoff et al., ISMRM, Toronto, 2008, #1254; [3] Pruessmann et al. MRM 42, 952-962, 1999.

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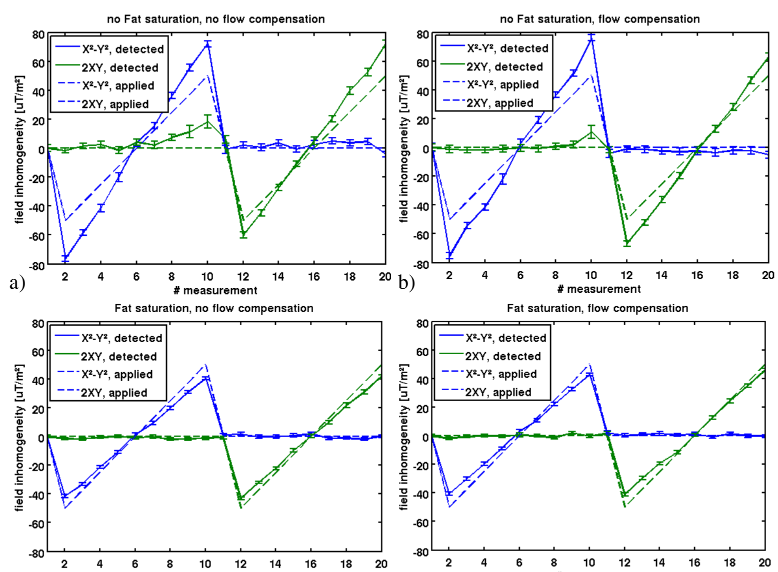

Figure 1: detected versus applied shim settings, for the four test cases. The solid lines are measured values, the dashed curves show the applied ones. The errorbars indicate ±σ.