B_0 Shimming Methods for UHF MRI

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B_0 Shimming Algorithm

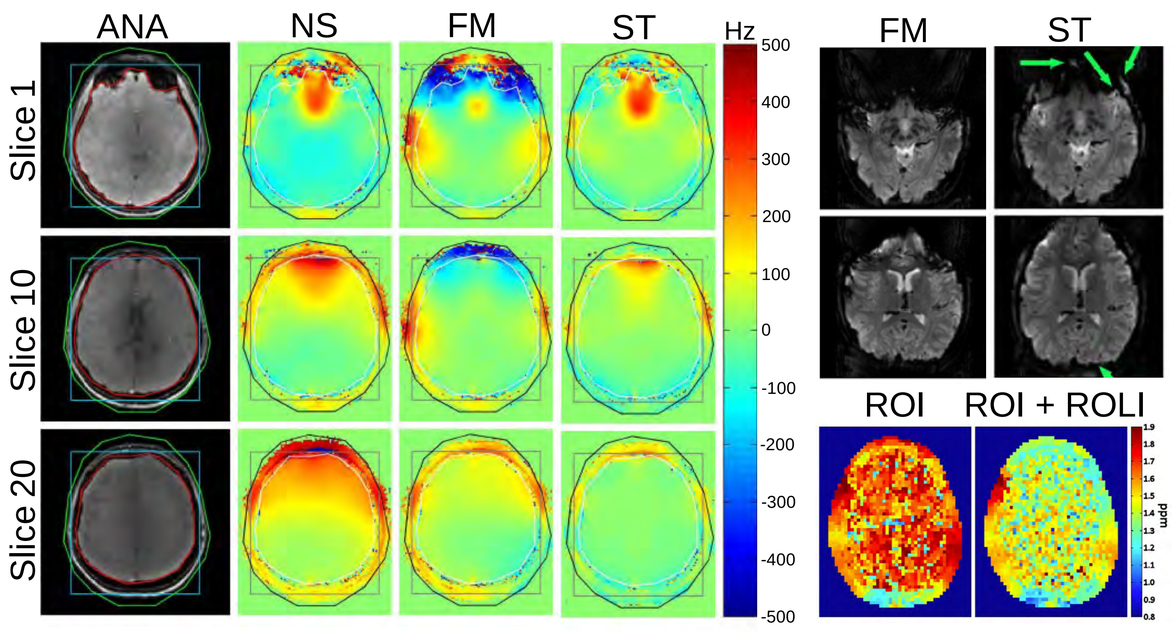


Figure 1: A comparison of the performance of a custom implemented constrained, image based B_0 shimming algorithm (ST) that considers a region of interest (ROI, red) and a second region of less interest (ROLI, green) that might lead to artifacts in MRI and MRSI data in case of poor B_0 shimming versus the vendor implemented B_0 shim algorithm (FM) indicated a superior performance of the ST algorithm. Frequency-shift maps of the $(CH_2)_n$ lipid resonance derived from brain MRSI data considering only the ROI (left) versus ROI and ROLI (right) demonstrate the positive impact of the ROLI on lipid artefacts in brain MRSI.

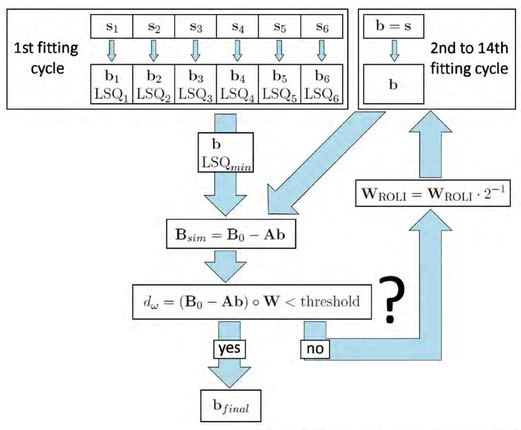
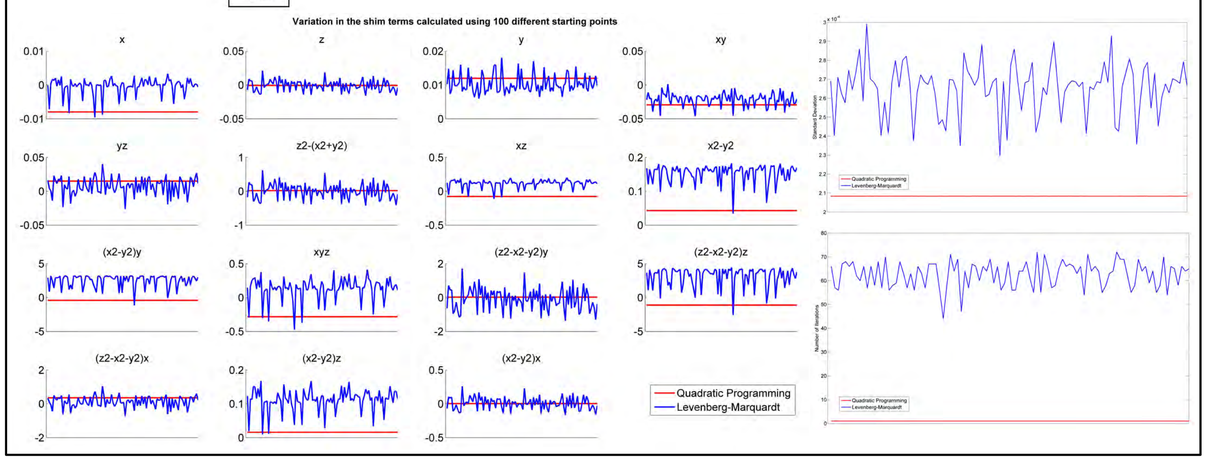


Figure 2: Schematic representation of the ST algorithm indicating an iterative weighting scheme of the ROI and ROLI (left). Investigation of the convergence of different optimization routines used in the ST on 100 starting points. Quadratic Programming proved to be superior in comparison to the Levenberg-Marquardt algorithm as indicated by shim term results up to third order harmonics (bottom left), standard deviation of residuals for each result and number of iterations to convergence (bottom right).



Magnetic Field Monitoring

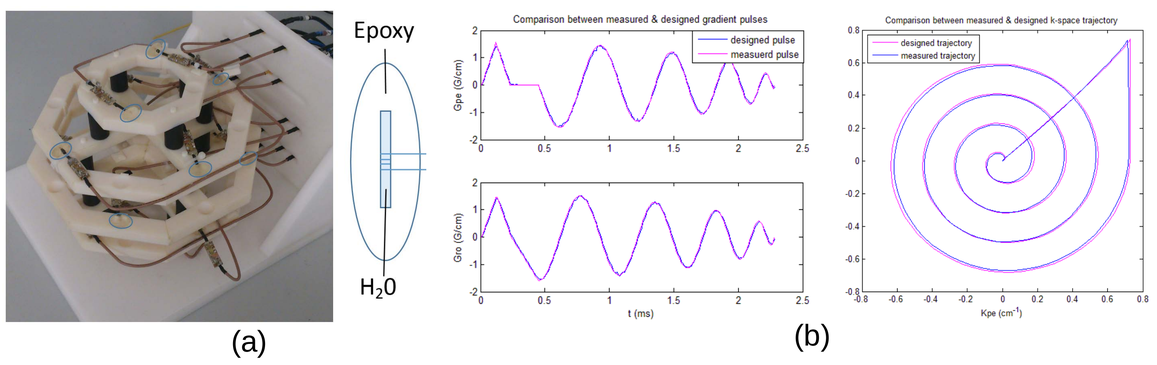


Figure 3: **(a)** 16 channel 9.4T ^{1}H field camera mounted on a 250mm-diameter sphere. **(b)** Field monitored spiral trajectory as used for pTX pulses at 9.4T.

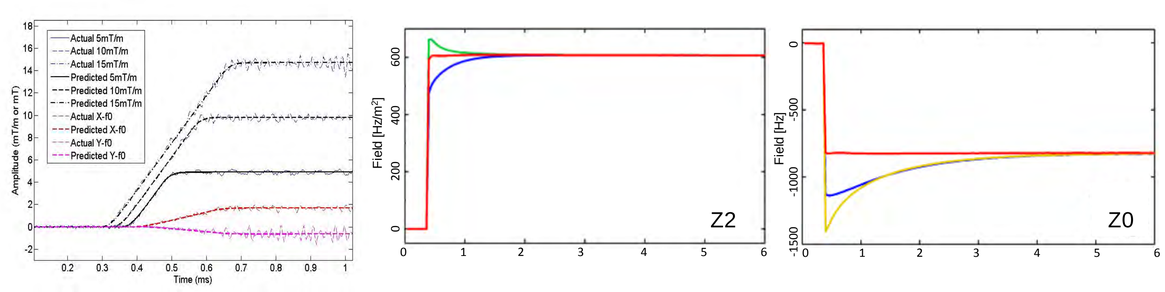


Figure 4: **(a)** Gradients measured with field camera (including cross-terms) for different amplitudes. **(b)** B_0 shim terms switched with and without pre-emphasis as used for DSU.

Dynamic B_0 Shimming with Pre-emphasis

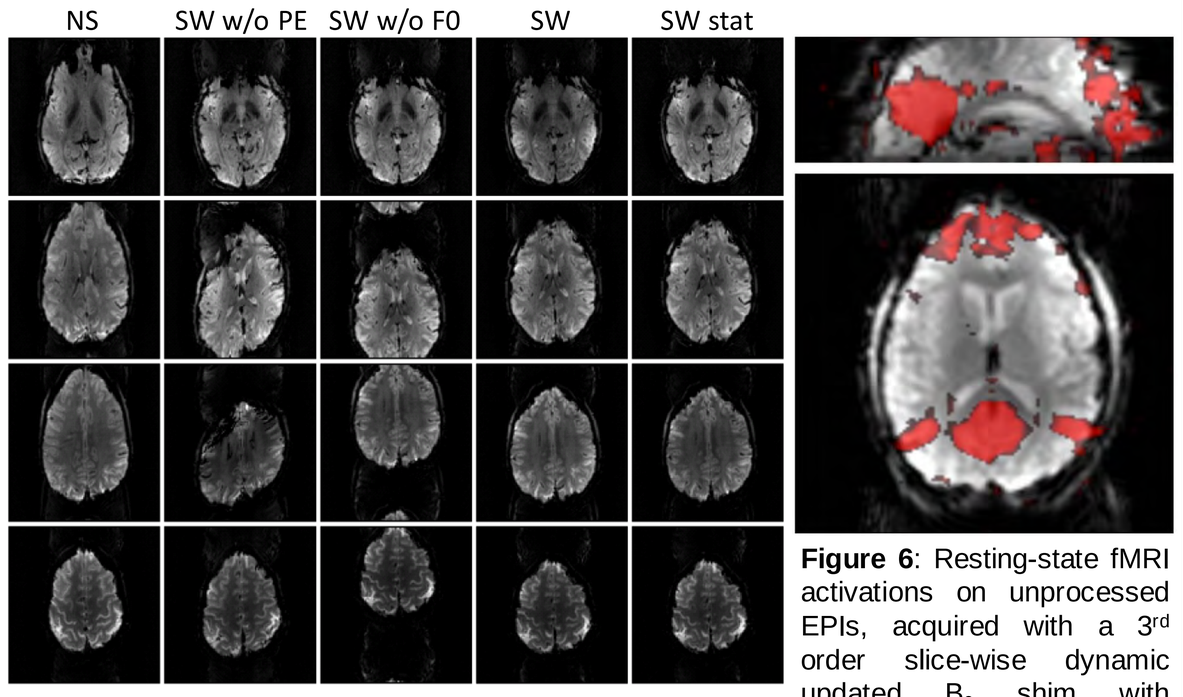
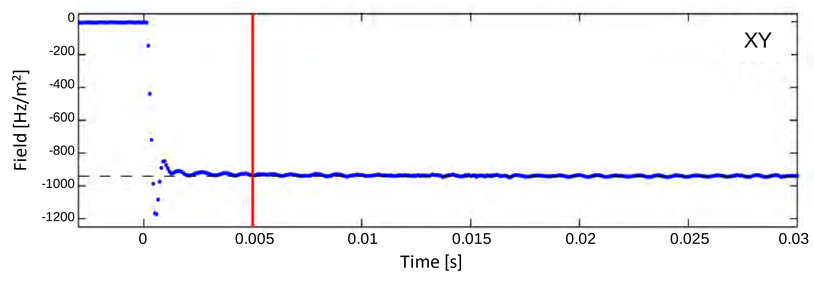


Figure 5: EPIs of four slices using 1) no shim, 2) 3rd order dynamic slice-wise updated (DSU) shim without pre-emphasis, 3) DSU without F_0 determination, 4) DSU and 5) static slice-wise shim.

Figure 6: Resting-state fMRI activations on unprocessed EPIs, acquired with a 3rd order slice-wise dynamic updated B_0 shim with dynamic F_0 determination at 7T.

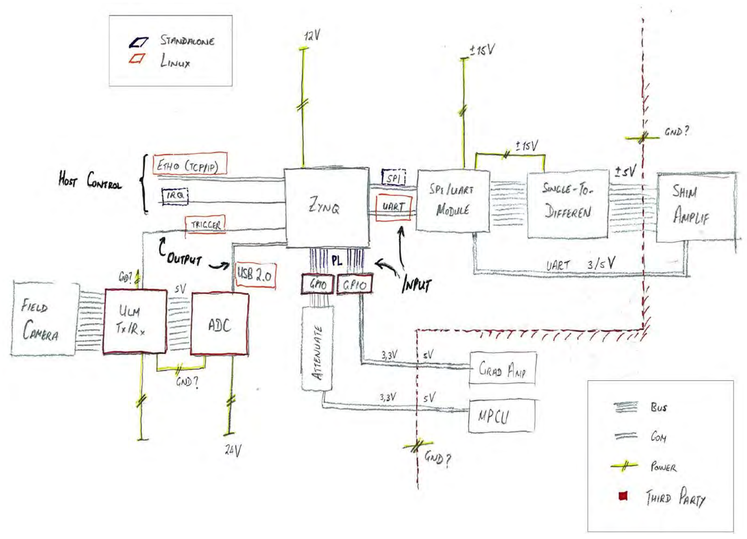
Figure 7: Iterative spatio-temporal field monitoring based pre-emphasis calibration leads to settling of eddy currents in about 1.5ms.



Real-time Feedback B_0 Shimming

Work in progress at 9.4T:

- very high order (up to 4th order and partial 5th and 6th order) static B_0 shimming using insert shim coil and amplifiers (right figures) from Resonance Research Inc.
- consideration of real field distribution of these shim coils in the B_0 shim algorithm
- closed loop control real-time feedback system for stabilization of the magnetic field in presence of physiological motion and dynamic switching of shim currents in the very high order B_0 shim system based on field probes to monitor the B_0 field and a digital controller as shown in the schematic below



References

[1] A. Fillmer et al. (2014), "Constrained image-based B_0 shimming accounting for "local minimum traps" in the optimization and field inhomogeneities outside the region of interest", *Magnetic Resonance in Medicine*.

[2] Fillmer A, Vannesjo SJ, Pavan M, Scheidegger M, Pruessmann KP, Henning A. "Fast Iterative Pre-Emphasis Calibration Method Enabling Third-Order Dynamic Shim Updated fMRI." Magnetic Resonance in Medicine: in press.

[3] Y. Chang et al. (2014), "System Identification and Signal Processing for PID Control of B0 Shim Systems in Ultra-High Field Magnetic Resonance Applications." In *World Congress* (Vol. 19, No. 1, pp. 7517-7522).