A 3D Calibration Protocol for 9.4T Human MRI

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Purpose To develop a robust 3D calibration protocol for parallel transmit human MRI at 9.4T with maximum use of the wealth of information acquired during the calibration.

Target Audience High-Field pTX users.

Methods B1 and B0 mapping are an important prerequisite for UHF MRI as they are essential for pulse design and (RF) shimming. We propose a protocol here based on established methods of *hybrid* B1 mapping [1,2]. The basic measurements consist of a series of low tip angle GRE acquisitions to derive the relative B1 map [1] information and one AFI [3] scan with adapted phase cycling [4] acquired with a reasonable initial RF shim to quantify the B1 field. Both sequences are acquired with a dual echo scheme (monopolar) to derive the B0 information. Raw data are transferred from the scanner to an external computer for processing.

AFI data are processed using the real part of the signal reconstructed from the complex multichannel data by retaining the phase difference obtained from conjugate phase reconstruction. This allows for an increased dynamic range of the AFI sequence of approximately 180deg. The flip angle map is reconstructed and an approximated B0 correction [5] is performed to account for the long RF pulse duration (1.2 ms) that no longer uniformly excites all spins within the range of off-resonances encountered at 9.4T (up to +- 400Hz).

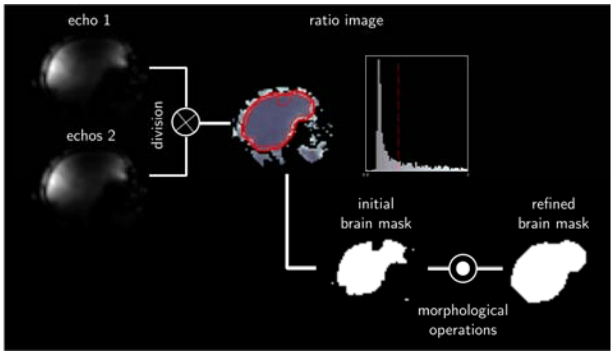

***Figure 1:** Workflow of brain mask generation based on the dual echo dataset*

The low tip angle (it is ensured that the maximum flip angle does not exceed 1 deg to maintain the linear relationship of flip angle and signal) GRE scans are processed using the SVD based calibration approach by Brunner et al. [6], yielding complex RX and TX sensitivities and additionally a combined image from all scans. This combined image is used for mask creation, i.e. a thresholding is applied to supply a background mask, and subsequently the ratio of the combined dual echo magnitude images is used to derive an approximate brain mask from the data (cf. Figure 1) which can be used for ROI-based RF shimming.

All sequences are acquired with identical spatial resolution (4.4 mm isotropic, 64x56x36 matrix), FOV (280mm x 256mm x 160mm) and (high) bandwidth of 1560 Hz/Pixel to minimize distortions, and, if distortions occur, to at least equalise them between the individual scans. Echo times of the GRE and AFI (TE=1.58/3.86ms) acquisitions are chosen to adhere to the water-fat in-phase condition. TR of the AFI sequence was 100 ms (n=5) and TR of the GRE sequence was 6 ms. The total scan time amounts to approximately 5 minutes. The only method of imaging acceleration was elliptical scanning which was used for the AFI acquisition.

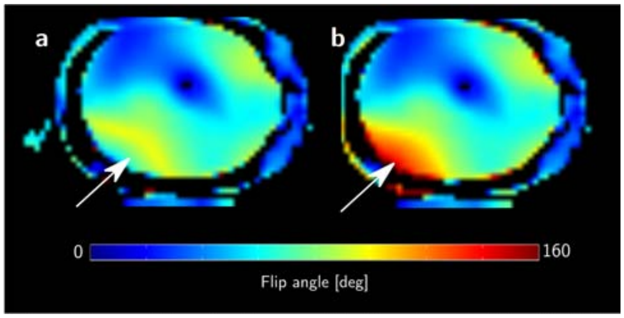

***Figure 2**: Comparison of in vivo AFI flip angle maps with (a) and without (b) real part reconstruction. Severe misinterpretations in the areas of high flip angle are visible*

Results Figure 1 demonstrates the generation of the simplified brain mask that can be further utilised for target ROI selection for, e.g. RF shimming. Figure 2 shows the effect of neglecting the signed nature of the AFI ratio that leads to misinterpretation of B1 amplitude in the outer areas of the brain. The off-resonance correction (not shown) significantly reduces the error in B1 estimation in low B1 amplitude areas with high off resonances. The resulting B1 maps per channel are depicted in Figure 3. Based on these a second RF shim was forward simulated and measured. The comparison of both is shown in Fig. 4 and shows good agreement between both indicating a successful calibration measurement.

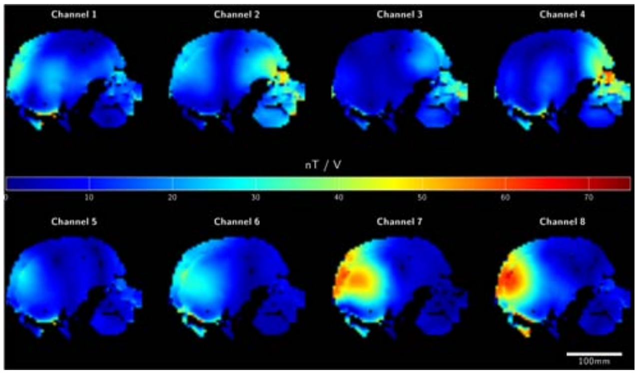

***Figure 3**: B1 magnitude efficiency maps (nT/V) per transmit channel after application of the whole calibration workflow.*

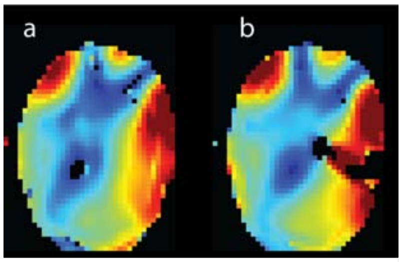

***Figure 4:** Comparison of measured (a) and forward calculated RF field (b). Both on identical colour scale.*

Conclusions Building on established methods, a 3D calibration protocol for 9.4T MRI was designed that yields the necessary set of calibration information within a measurement time of approximately 5 minutes.

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References [1] Van de Moortele et al. Proc. ISMRM 2007:1676 [2] Wu et al. MRM 2010 63(2):524-9. [3] Yarnykh MRM 2007 57(1):192-200. [4] Nerhke MRM. 2009 61(1):84-92. [5] Boulant et al. Proc. ISMRM 2010:4918 [6] Brunner et al. Proc. ISMRM 2010:242