Rapid MRI System Calibration using 3DREAM

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Target Audience: MRI users in need of a rapid system calibration method for ultra-high field systems

Purpose: DREAM as a rapid B1 mapping method can provide a variety of additional vital system information, such as B_1 efficiency and B_0 maps. Furthermore the DREAM images itself can be utilized to perform atlas based ROI selection and receive bias correction.

Methods: 3DREAM, an ultra-fast three-dimensional variant of the DREAM sequence (1), was recently shown to provide accurate mapping of the whole human head with minimal SAR exposure. Here we demonstrate that the same sequence can provide a high dynamic range B_0 map and a M_0-weighted image, which is suitable for intensity normalization. Further, it can serve as an anatomical prior sufficient for coregistration to common brain atlases for automatic selection of regions-of-interest (ROIs). For this purpose a 3DREAM protocol with 4.4mm isometric resolution, STE first timing with spin-echo-like STE, TS=TE_2-T_1, $TE_1/_2$= 1.00/1.98ms, Bandwidth 1080 Hz/Pixel, FOV = 256mm x 256mm x 176mm, turbo factor 1200, rectangular preparation (200µs duration, nominal α =75deg) and imaging (100µs, nominal β = 6 deg) pulses, was acquired on a 7T research scanner (Siemens Healthcare, Erlangen, Germany) starting from the "*tuneup*" setting of the system. The sequence was repeated twice once using the array receive mode of the 32 channel array and once using the additionally available volume receiver. The total acquisition time for both sequences was approximately 10s. The native dynamic range of the B_0 map computed according to (2) is approximately ±0.5 kHz. The high bandwidth supported successful final spatial unwrapping of the B_0 map. The DREAM flip angle map is also calculated according to (2). Combining FID and STE images according to $I_{FID} + 2I_{STE} = M_0 \sin\beta\,(cos(\alpha)^2 + \sin(\alpha)^2) = M_0 \sin\beta$ yields a proton density weighted image with additional receive and transmit bias (assuming small imaging tip angles). As $\sin\beta$ is known from the DREAM flip angle map this can also be corrected for. Using array and volume coil acquisitions, relative receive contributions can be isolated and applied to correct arbitrary imaging data. Running a segmented 3D GRE-EPI sequence and an MPRAGE scan demonstrated suitability of this approach. Those were additionally approximately corrected for the transmit field influence assuming a signal dependence $\propto \sin\alpha$. The 3DREAM FID image is furthermore suited for coregistration to brain atlases, here demonstrated for the MNI 2.0mm template. Affine registration (12 degrees-of-freedom) was performed using FSL FLIRT(3).

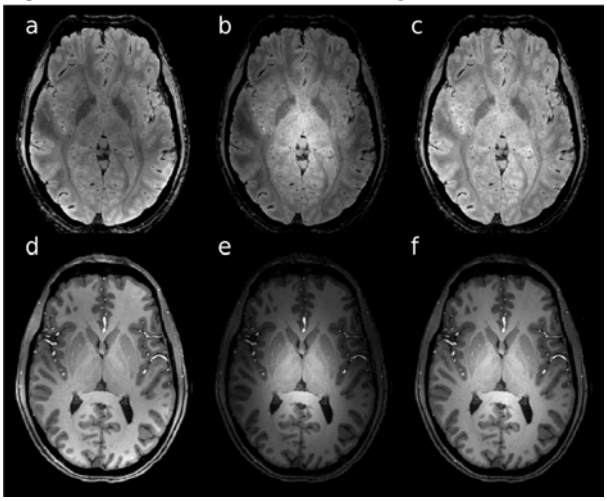

Figure 2: Segmented 3D-EPI (a-c) and MPRAGE images (d-f) without (a,d) and with receive bias correction (b,e) and additional transmit bias correction (c,f).

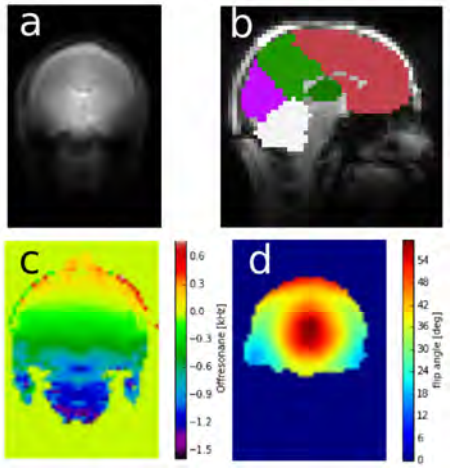

Figure 1: Corrected combined image of the volume coil (a) together with coregistered anatomical labels (b); off-resonance map (c) and measured flip angle distribution restricted to brain mask (d)

Results: Fig.1 shows the corrected FID image with coregistered labels and B_0 and flip angle map. The coregistered labels can be utilized to derive regional transmit voltage calibrations and/or B_0 shims. The available data was used for correction of receive inhomogeneities in an MPRAGE and segmented 3D EPI acquisition (cf. Fig. 2). The increased image inhomogeneity after receive bias correction reflects the commonly encountered *center brightening* effect which is masked without corrections as the receive profile has opposite behavior, i.e. is brighter in the brain periphery and darker in the center. Correspondingly the approximate transmit correction removes the remaining center brightening. Note, that the images in Figs. 2a,d) *appear* flat since transmit and receive profile cancel each other out. However, the respective contributions are unknown but quantified with the proposed method.

Discussion & Conclusion: It was demonstrated that the 3DREAM sequence can provide a wealth of calibration data within a few seconds which are useful for imaging protocols at high field. However, the limited integration of the calibration data in the scanner software hinders fast application in routine workflow. Fully integrated, a 3DREAM prescan calibration procedure has the potential to eliminate otherwise independently performed steps, such as transmit voltage calibration, B_0 mapping and receive array calibration. Combined with registration to anatomical priors this may be especially beneficial for parallel transmit (pTX) applications, such as RF shimming or pulse design which, otherwise, require manual prescription of target ROIs. The here presented method can be readily extended by utilizing the DREAM data as the source for single channel phase normalization (4) which is essential for image combinations (5) that rely on complex image data. The intrinsically coregistered calibration information further enables joint applications, such as B_0-corrected flip angle maps (6).

References: 1 Brenner et al. Proc ISMRM 2014#1455 **2** Nehrke et al MRM2012;68:1517–26 **3** Jenkinson et al. Neuroimage 2012;62:782–90 **4** Jellúš et al. Proc ISMRM 2014#4406. **5** Walsh et al. MRM2000;43:682–690. **6** Boulant et al .Proc. ISMRM 2010#4918.