Optimization and group comparison of RF (B1) mapping methods at 3T

A. Lutti[1], C. Hutton[1], G. Helms[2], J. Finsterbusch[3], and N. Weiskopf[1]

[1]Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London, London, United Kingdom, [2]MR-Research in Neurology and Psychiatry, Faculty of Medicine, University of Göttingen, Göttingen, Germany, [3]Department of Systems Neuroscience, University Medical Center Hamburg–Eppendorf, Hamburg, Germany

Introduction Spatial inhomogeneities in the radio-frequency (RF) field (B_1) increase with field strength as the RF wavelength approaches the dimensions of the human head. B_1 inhomogeneities pose various problems such as spurious signal and contrast changes in MRI, leading to bias in quantitative imaging and difficulties in tissue segmentation. Here, we optimize and compare three methods for flip angle mapping, namely 3D EPI [1], 2D STEAM [2], and AFI [3]. The accuracy of the methods is tested against a reference DAM technique [4]. The stability of the methods is assessed across multiple acquisitions. Variability between subjects is also examined.

Methods Data were acquired on 7 healthy volunteers (6 males, mean age 34 years) using a 3T whole-body Tim Trio system (Siemens Medical Solutions, Germany), operated with a body transmit coil and a 12-channel head-only receive coil. The study was approved by the local ethics committee. For each subject, distributions of B_1 fields were recorded using three different acquisition methods described below with a resolution of 4x4x4 mm^3. Each type of B_1 measurement was repeated four times. In the following, we display flip angle maps normalized to the nominal flip angle (= 100%) after smoothing with an 8 mm FWHM Gaussian kernel. In each method, B_1 maps were extracted from intensity variations of images acquired with different parameter values. **3D AFI:** B_1 maps were extracted from the two images of a dual TR FLASH acquisition (fa = 60°; TR1/TR2 = 50/150 ms) for a total acquisition time of 4min 12s [3]. Flow compensating diffusion weighting gradients were used to optimize image quality. **3D EPI:** B_1 maps were extracted from spin echo (SE; varied between 160° and 200°) and stimulated echo (STE) images recorded with a 3D multishot EPI acquisition over an experimental time of 2min 20s [1]. To improve the quality of the resulting B_1 maps, a map of the main static field B_0 was also acquired for correction of EPI distortions [5] and off-resonance spin excitation, over an additional 2min. **2D STEAM:** The flip angle of the second flip-back pulse was set to 60° and 100° [2]. Three acquisitions per flip back pulse angle were acquired and averaged to improve the SNR, resulting in an acquisition time of 2min. Correction factors for the slice-selective pulses were determined by minimizing the discrepancies between the AFI and STEAM methods on an independent data set (*calibration*). **2D DAM:** An RF hard pulse (fa = 22° and 44°) was followed by an EPI readout. Full longitudinal relaxation of the spins was allowed (TR=20s) leading to an acquisition time of 10min for a resolution of 4x4x10mm^3. We use this method as a reference in order to assess the accuracy of the three methods of interest.

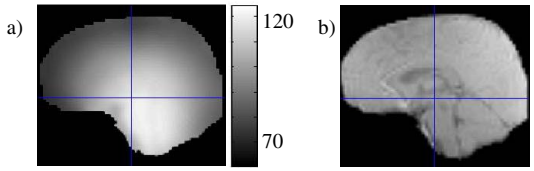

Figure 1. a) Flip angle map obtained using a 3D EPI method. b) SE image used to extract local B_1 values.

Results Fig. 1a) represents a typical B_1 map, acquired using the 3D EPI method. Flip angles were between 70 and 120 % of the nominal value for all methods. Fig. 2 represents mean difference images between the three methods introduced above and the reference DAM method for a typical subject. All methods are within ~3% agreement in the central regions of the brain. However, flip angles obtained using the EPI method are ~6% higher than the reference values in the outer brain regions. Also the presence of identical patterns in all the difference images points towards inaccurate reference values in the corresponding regions. In fig. 3 we display standard deviation maps over the four repeated acquisitions per method. AFI and EPI B_1 maps show only low levels of noise and physiological artefacts below 2% (figs. 3a) and b)). The STEAM method (fig. 3c)) is most affected by physiology, as shown by the stripy artefacts and the bright regions close to the pons. Summary values of the difference and standard deviation images are presented for all subjects in fig. 4 after averaging over the brain volume. Similar results are obtained with the AFI and STEAM methods probably due to the calibration of the STEAM slice-selective pulse from an AFI B_1 map on a separate dataset. While results are stable across subjects for the EPI and AFI B_1 mapping methods, outliers are visible for the STEAM method.

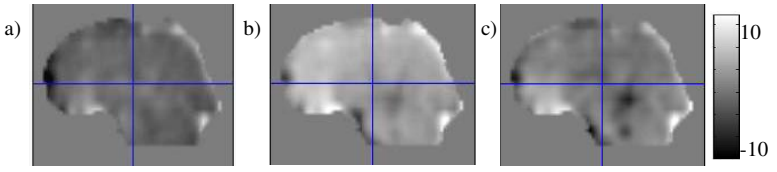

Figure 2. Difference images between the a) AFI, b) EPI and c) STEAM methods and the reference DAM method.

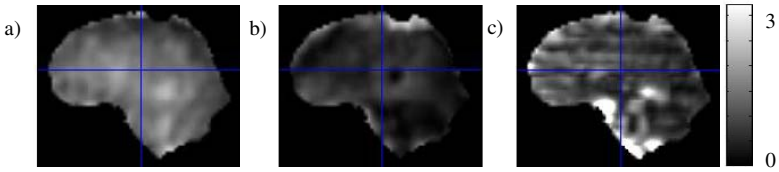

Figure 3. Standard deviation of the B_1 maps taken over four repetitions of the a) AFI, b) EPI and c) STEAM methods.

Conclusions We have optimized three B_1 mapping methods to reduce the level of artefacts arising from B_0 inhomogeneities and physiology. The resulting B_1 maps can be acquired with a satisfactory resolution in an achievable experimental time. We have shown that flip angle maps obtained using the EPI and AFI methods are within 5% agreement and their stability is ~2% over repetitions and even subjects. These methods are therefore ideally suited for correction of B_1 inhomogeneities in quantitative imaging at 3T.

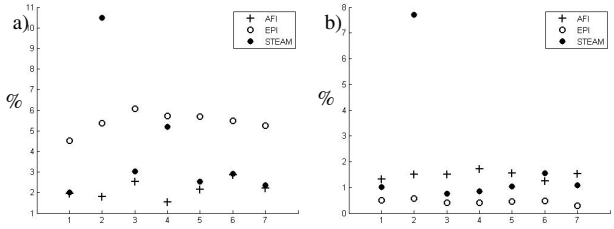

Figure 4. a) Difference and b) standard deviation maps averaged over the brain volume vs subject number.

References [1] F. Jiru and U. Klose, MRM **56**:1375-1379 (2006). [2] G. Helms *et al*, MRM **60**:739-743 (2008). [3] V.L. Yarnykh, MRM **57**: 192-200 (2007). [4] J. Sled and G. Pike, MRM **43**:589-593 (2000). [5] C. Hutton *et al*, NeuroImage **16**:217-240 (2002).