Improved fast multi-station water-fat imaging at 3T

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Purpose: To show the effect and the increased scan efficiency offered by DREAM-based B_1^+ shimming in fast whole body fat/water imaging at 3T.

Introduction: High field whole-body imaging is a promising technique for quantitative MRI. However, at 3T and above, wave propagation effects can have serious effects on RF field homogeneity (B_1^+). This results in spatially varying image contrast and SNR which can compromise clinical diagnosis and makes quantification very difficult (1). Parallel transmission can mitigate this problem via B_1^+ shimming for which knowledge of transmit sensitivities is needed, making B_1^+ mapping indispensable. The RF distribution within the body can change substantially from station to station, for example between head and abdomen, and very fast B_1^+ mapping to facilitate appropriate RF shimming (2) is critical. Current two-channel B_1^+ mapping methodology requires a 15s breath-hold (2). The recently introduced Dual Refocusing Echo Imaging Mode (DREAM) approach (3) enabling single shot B_1^+ mapping within a fraction of a second, is therefore very promising, meeting the needs of many clinical applications.

Methods: Whole-body fat-water images were acquired in 8 healthy subjects (24-45 years) using a 3T dual-transmit MRI system (Ingenia, Philips Healthcare, Best, the Netherlands). A multi-station, 3D, dual-echo mDixon FFE acquisition with 17 stacks of 24 contiguous axial slices was performed with the following scan parameters: (TR/TE1/TE2: 3.2/1.13/2.0ms, FA:5, voxel size: $1.91\times1.91\times5mm^3$). Each stack was preceded by a 2D B_1^+ DREAM calibration scan, centered in the middle of the stack (DREAM-parameters: voxel size: $5\times5\times10mm^3$, STEAM α: 50°, imaging β: 5°, $TE_{FID}/TE_{STE}/TR$: 1.4/2.4/3.8 ms, shot duration: 150ms). Dual-channel DREAM B_1^+ mapping took roughly 1.3 seconds, with a waiting time of 1s between left and right channel acquisition. Additional DREAM maps were obtained in the conventional quadrature and in the B_1^+ shimmed mode for comparison. This was followed by the 3D mDixon scans B_1^+ shimmed according to the DREAM calibrations and in quadrature mode. Breath-holds were performed for the stacks in the pelvis and chest region with a maximum duration of 19s with the body coil being used for signal reception. For each stack we determined the coefficient of variation (CoV) and the mean for the two B_1^+ maps and entropy of the joint intensity histogram [5] of the 3D fat/water images. After grouping the stacks from all subjects in three zones classified as: legs, upper body and head, differences in CoV and joint entropy were assessed between the two B_1^+ regimes with a paired sample t-test and the Kolmogorov Smirnov test ($p<0.05$).

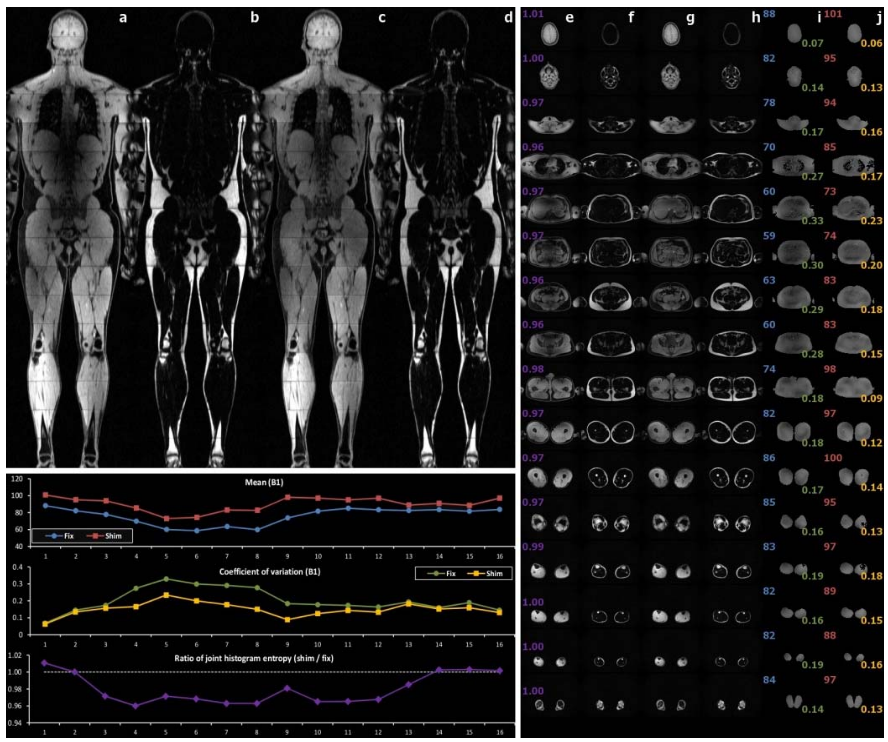

Fig.1. Coronal (a,b,c,d) and axial (e,f,g,h) reformats of whole body f/w images using DREAM-based B_1^+ shimming (c,d,g,h,j) and the conventional quadrature excitation (a,b,e,f,i), together with the adjoining axial DREAM B_1^+ maps (i,j). Graphs: mean B_1^+ (top), CoV (middle) and image entropy ratio (bottom) for each stack (feet:left, head:right) for the two B_1^+ regimes. F/w images in the leg region have been corrected for some station signal swaps during post-processing.

Results: Whole-body fat/water images acquired in all subjects showed a consistent improvement in image quality using DREAM-based B_1^+ shimming (Fig.1). These improvements were visible in the higher image homogeneity and the consistency in image contrast (see the signal drop in the abdominal region in Fig.1a). The ratio of the joint histogram entropy confirms the improvements in image quality in the stacks covering the upper body region (legs p=0.58, upper body p<0.01)but not in the head (p=0.38). The improvement in image and contrast homogeneity was confirmed by an evaluation of the B_1^+ maps. A significant reduction in the CoV, which measures the inhomogeneity, was found especially in the abdominal / upper body region (quad=0.26±0.06, shim=0.15±0.04, p<0.01) with strong reduction in RF shading artifacts. In the stacks covering the legs (quad=0.18±0.04, shim=0.13±0.03, p<0.01), only minor improvements were present and the head region showed no improvements (quad=0.11±0.03, shim= 0.11±0.03, p=0.28). B_1^+ shimming also improved the mean B_1^+ level (Fig.1), which is important to maintain the image contrast homogeneity across the whole body.

Discussion & Conclusion: In this study we showed that DREAM-based B_1^+ shimming per station in whole-body multi-station fat-water MR imaging gives significant improvements in image quality in comparison with the conventional quadrature mode at only minor costs of scanning time for the B_1^+ mapping. DREAM improves the workflow significantly, accelerating B_1^+ mapping by an order of magnitude compared to existing techniques. The improved RF performance, higher image quality and increased workflow will improve all whole-body imaging sequences.

References: [1] Willinek et al. Radiology 2010;256:966-75. [2] Welch et al. ISMRM (2013) #1524. [3] Nehrke et al. MRM 2012;68:1517. [4] Eggers et al. MRM 2011;65:96-107. [5] Jäger et al. IEEE TMI 2009;28,1,137–150.