Robust Multicoil Reconstruction for Phase-Sensitive Fat-Water Separation

T. Çukur[1], B. A. Hargreaves[2], and D. G. Nishimura[1]

[1]Electrical Engineering, Stanford University, Stanford, California, United States, [2]Radiology, Stanford University, Stanford, California, United States

Introduction: Phase-sensitive (PS) SSFP [1,2] is an efficient fat/water separation method, successfully used in several applications including angiography [1], musculoskeletal [3] and abdominal [4] imaging. It generates and detects a 180° phase-difference between fat and water. In previous work, water images reconstructed from individual coils with PS-SSFP were combined [4,5]. However, abrupt spatial phase-variations from surface-coil arrays can lead to fat-water misclassification. In this work, we propose a simple and robust multicoil PS-SSFP reconstruction. First, individual coil images are combined to yield an image with reliable phase. Fat and water are then successfully separated using this combination.

Methods: If TR = 4.6 ms at 1.5 T, the water and fat resonances are at the centers of adjacent balanced (b)SSFP pass-bands with a 180° phase-difference. The resulting signal is S = (W-F)P, where W and F denote the water and fat signals, and P represents spatial phase-variations. In regular PS-SSFP, the coils are processed independently [5]. First, smooth spatial phase-variations are removed from S with a region-growing phase-correction [2,6]. The sign of (W-F) is then used to separate the two resonances. However, abrupt phase variations at the edges of surface coils can lead to partial fat-water misclassifications within individual images, which may not be correctable by a global sign change [5] (Fig. 1).

In fact, for each spatial location, at least one coil provides accurate phase information. We propose to obtain an improved estimate for the sign of (W-F): $\boldsymbol{\theta_c = \arg(\sum |S'_i| S'_i)}$, where $\mathbf{S'_i}$ is the phase-corrected image from the i^{th} coil. This combination weighs the coils based on their magnitude to yield a minimum-variance estimate and is relatively immune to inter-coil phase cancellations [7]. Each voxel is classified as W or F based on $\boldsymbol{\theta_c}$, and the magnitude image is then formed with a sum-of-squares combination.

Results: 3D dual-acquisition phase-cycled bSSFP [2] images of the lower leg were acquired on a 1.5 T scanner with an 8-channel array: α=90°, 32 cm FOV, 1.73 mm^3 voxel size, TR/TE = 5/2.5 ms. Reconstructions from bSSFP, independent-coil PS-SSFP with global sign change, and the proposed method are displayed in Figs. 1-3. Independent-coil PS-SSFP fails in regions of abrupt phase changes. In contrast, the proposed method accurately estimates the phase and achieves reliable fat-water separation.

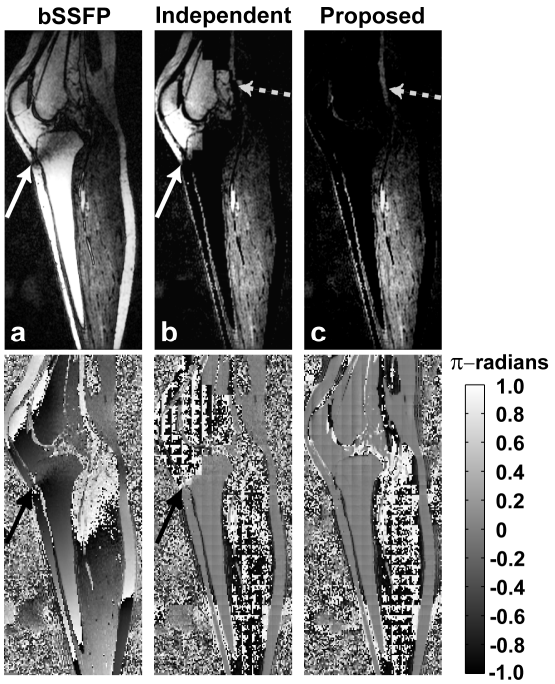

Figure 1. Individual-coil magnitude image with bSSFP **(a)**. Water images reconstructed with independent-coil PS-SSFP **(b)** and the proposed method **(c).** The bottom row shows the corresponding phase images representing fat with gray (0 phase). The rightmost phase image is $\boldsymbol{\theta_c}$. The solid arrows point to the regions of abrupt magnitude and phase variations at the sensitivity edges of the surface coil. The fat-water swaps in independent-coil PS-SSFP are completely corrected with the proposed method, which accurately reconstructs a blood vessel lost by independent-coil PS-SSFP (dashed arrows).

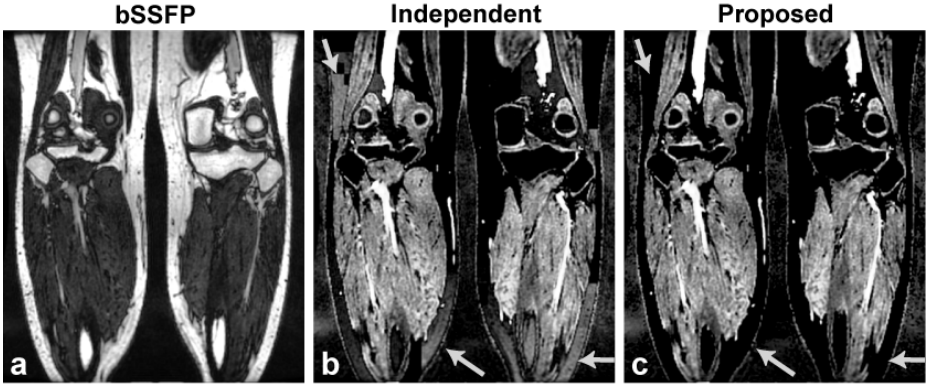

Figure 2. Coronal lower leg image with bSSFP **(a)**. Corresponding water images from independent-coil PS-SSFP **(b),** and the proposed method **(c)**. The remnant fat signal in **b** (arrows) is completely removed in **c**.

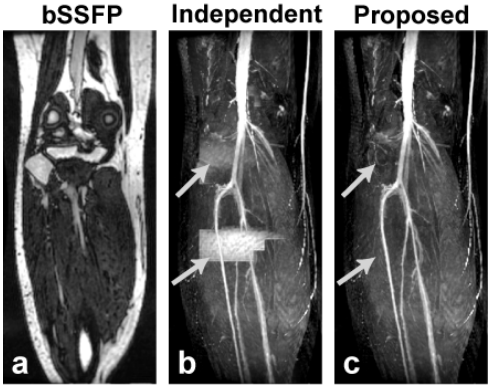

Figure 3. Coronal slice of a lower leg bSSFP image **(a)**. Maximum-intensity projections of water images with PS-SSFP **(b),** and the proposed method **(c).** The independent-coil method leads to regions of residual fat (arrows), which are completely separated with the proposed reconstruction.

References:

1. Hargreaves, MRM 50:210, 2003. **2**. Hargreaves, MRI 24:113, 2006.
3. Vasanawala, AJR 184:1450, 2005. **4**. Wansapura, Pediatr Radiol 37: 69, 2007.
5. Ma, MRM 53:904, 2005. **6**. Ma, MRM 52:415, 2004. **7**. Bernstein, MRM 32:330, 1994.