Phase Sensitive SSFP Parallel Imaging

S. S. Vasanawala[1], B. A. Hargreaves[2], D. G. Nishimura[2]
[1]Radiology, Stanford University, Stanford, CA, United States, [2]Electrical Engineering, Stanford University, Stanford, CA, United States

Purpose: Two avenues of recent progress in rapid MRI are balanced steady-state free precession imaging (SSFP, True-FISP, FIESTA, balanced FFE) and parallel imaging (SMASH, SENSE). Short scan times of parallel imaging demand the high SNR efficiency of SSFP. As fat is bright in SSFP images, several methods of fat/water separation in SSFP have been proposed [1-5]. The fastest is PS-SSFP, previously described for imaging with a single coil [6]. We hypothesize that since signal phase is retained in SENSE reconstruction through complex coil sensitivity maps and complex reduced FOV images, fat/water separation will still be feasible with the PS-SSFP method. The novel combination of PS-SSFP and SENSE will permit ultrarapid fat-suppressed 3D imaging.

Method: Fig. 1 shows the spectral response of SSFP. With short TR and a center frequency set between that of fat and water, both fat and water resonance peaks are in high signal regions of the spectral response. If TE = TR/2, the MR signal phase has a sharp transition exploited by PS-SSFP to distinguish fat and water. As with the SENSE technique, aliased high-resolution SSFP images from an array of coils are obtained along with a low-resolution reference image [7]. A nonaliased full-FOV high-resolution complex-valued image is reconstructed, which is then partitioned into water and fat images based on the phase transition of the MR signal.

Results: Phantoms of corn oil and of saline were imaged with SSFP: 35 x 17.5 cm FOV, 256 x 256 matrix, 32 slices, 5mm slice thickness, torso phased array (four coils). Also, coronal breathheld abdominal 3D SSFP images of normal volunteers were obtained in 19 seconds: 14 x 28 cm FOV, 256 x 256 matrix, 32 slices, 3 mm slice thickness, flip angle 60 degrees. These were then unfolded to full 28 x 28 cm FOV with a PS-SSFP SENSE reconstruction (acceleration factor = 2).

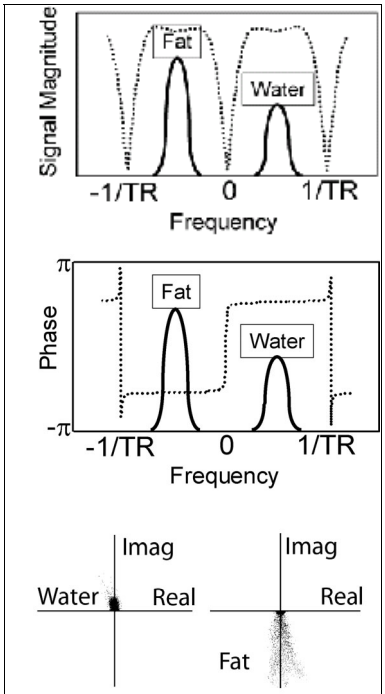


Fig. 1. *Top graphs show spectral response of balanced SSFP. Bottom scatterplots demonstrate PS-SSFP partitioning of voxels to fat and water images based on phase transition in spectral response.*

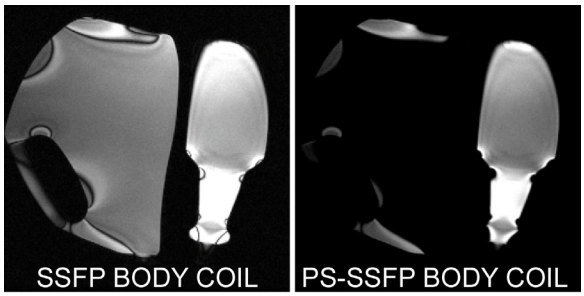
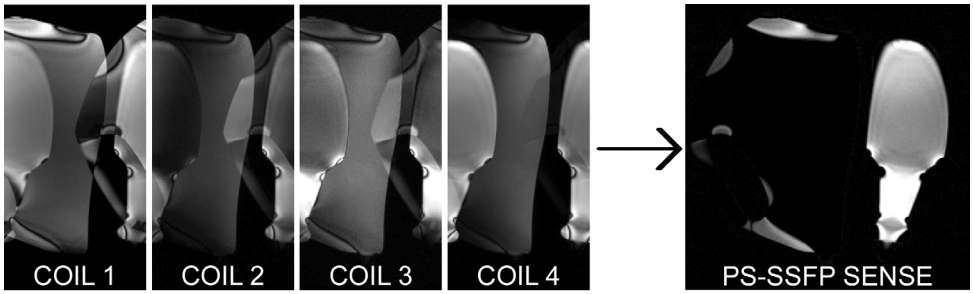
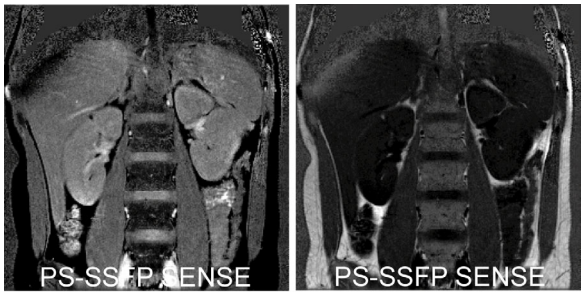


Fig. 2. *Top row: full FOV body coil SSFP image and PS-SSFP image of fat (larger) & water (smaller) phantoms. Note PS-SSFP suppression of fat phantom. Banding artifact from inhomogeneity results in persistent signal at edges of fat phantom. Middle: SSFP aliased half-FOV images acquired with phased array coil in half the scan time are combined in PS-SSFP SENSE reconstruction to generate a full FOV fat-suppressed image. Note similarity with PS-SSFP body coil image. Bottom: water and fat 3D PS-SSFP SENSE abdominal images: 256 x 256 x 32 matrix in 19 seconds.*



Discussion: This work introduces a new fat/water resolved rapid imaging method that combines parallel imaging and phase sensitive detection SSFP. Despite SENSE reconstruction, phase-based separation of fat and water with the PS-SSFP method is still feasible. Excellent fat suppression is demonstrated in both phantoms and in vivo. Potential applications of a fast high SNR efficiency fat-suppressed 3D sequence with T2-like contrast include cholangiography, where a SENSE acceleration factor of two distinguishes impractical and feasible times for suspended respiration.



References: **1.** Vasanawala SS, et. al. MRM 42:876-83, 1999. **2.** Vasanawala SS, et. al. MRM 43:82-90, 2000. **3.** Scheffler K, et. al. MRM 45:1075-80, 2001. **4.** Hardy CJ, et. al. 10th ISMRM, 473, 2002. **5.** Reeder SB, et. al. 10th ISMRM, 736, 2002. **6.** Hargreaves BA, et. al. MRM 50:210-3, 2003. **7.** Pruessmann KP, et. al. MRM 42:952-62, 1999.