# TPI-SENSE for Fast Ultra-Short TE MRI

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## INTRODUCTION

The combination of twisted projection imaging (TPI) (1) with sensitivity encoding (SENSE) parallel imaging is demonstrated here as a means to further accelerate data acquisition in ultra-short TE MRI. We show that the 3D nature of the TPI trajectory has inherent advantages over the conventional 2D and Cartesian implementations of SENSE. Simulations and phantom studies with 4-element coil arrays were used to demonstrate the extent of the available acceleration strategies in TPI-SENSE imaging.

## METHODS AND MATERIALS

Numerical Simulations: Simulations were performed on a computer model for a cylinder (16cm length and 15cm diameter, $T_2$=3ms, intensity=40) with rods of varying diameters inside (diameters=0.2, 0.4, 0.6, 0.8, or 1.0cm, intensity=10). Sensitivity maps were generated for 4 rectangular coil loops (22cm×14cm) bending around the field-of-view with equal spacing. The k-space data were analytically calculated along a TPI trajectory (44 rings, 980 projections, p=0.4, and 1374points/projection for a fully sampling at FOV=22×22×22cm$^3$, matrix=64×64×64, and resolution=0.7×0.7×0.7cm$^3$) (1). The undersampling was achieved by skipping rings and/or rotations (dashed lines, Fig 1.) in the full TPI sampling (solid & dashed lines, Fig. 1). The reduced rotations were uniformly re-distributed on a ring. Images were reconstructed using the conjugate gradient (CG) iterative algorithm for non-Cartesian SENSE (2). Image errors relative to a reference image obtained from a full data set were measured. Experimental Studies: Phantom studies were performed on a 3T scanner (GE Signa, Milwaukee, WI; Gmax=40mT/cm & Smax=150T/m/s) using the same trajectory design as above in conjunction with a 400μs hard rf pulse, 408μs TE, and 32μs data sampling interval. A 4-element head coil array (Nova Medical, Wakefield, MA) was used for all the studies and the images reconstructed using the CG algorithm. The coil sensitivity maps were measured on a large uniform phantom filling the volume within the coil array.

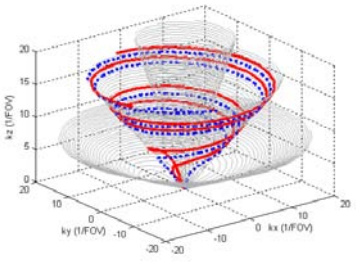


*Fig. 1. 3D TPI trajectory at half k-space for full sampling (solid & dashed lines) and undersampling (solid lines only).*

## RESULTS AND DISCUSSIONS

The sensitivity maps used in the simulations are shown in Fig. 2. Reduction strategies including undersampling from 1 to 2 in the polar direction (Ring reduction) and reducing the number of rotations along the azimuthal direction (Rotation reduction) from 1 to 4 were investigated. This led to a total of 8 different reduction strategies. Images demonstrating these strategies are presented in Fig. 3. The image error was 0.25% for reduction 2×1 (Ring × Rotation), 1.18% for 2×2, 2.85% for 2×3, and 5.58% for 2×4, respectively. Experimental data sets for the coil maps and SENSE reconstructions from a four compartment phantom are presented in Figs. 4 and 5; respectively. The image error was 1.88% for reduction 2×1, 3.59% for 2×2, 8.80% for 2×3, and 17.10% for 2×4, respectively.

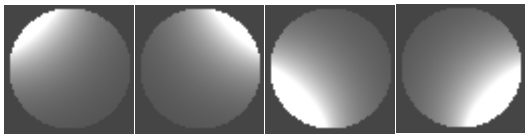

*Fig. 2. Coil maps: simulations.*

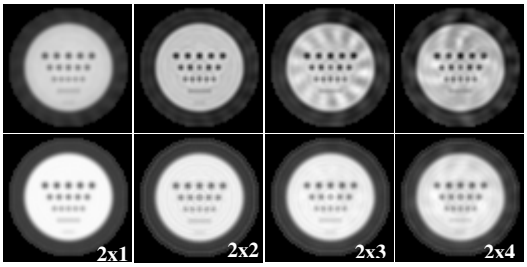


*Fig. 3. Images before (top) and after (bottom) SENSE reconstruction in the simulation. On the low-right corners are reduction numbers.*

Both simulation and phantom studies have illustrated that the TPI trajectory can be combined with SENSE parallel imaging to accelerate data acquisition. The image error increases slowly for small reduction numbers (up to 2x3). These findings indicate that the TPI sampling scheme, because of its inherent 3D nature, tolerates larger reduction factors than comparable 2D sampling schemes.

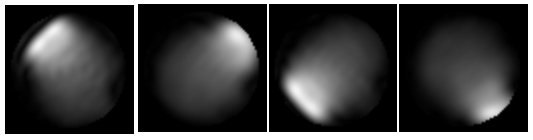

*Fig.4. Coil maps: phantom studies.*

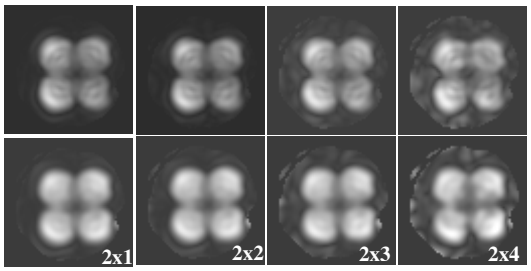


*Fig. 5. Images before (top) and after (bottom) SENSE reconstruction in the phantom studies. On the low-right corners are reduction numbers.*

## REFERENCES

1. Boada FE, et al. Magn Reson Med 1997; 37:706-715.
2. Pruessmann KP, et al. Magn Reson Med 2001; 46:638-651.