Noise Amplification in TPI-SENSE Parallel Imaging

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INTRODUCTION

Noise amplification is one of the major potential concerns when twisted projection imaging (TPI) (1) is used together with sensitivity encoding (SENSE) parallel imaging (2) for fast sodium MRI. Both the sampling pattern in the TPI trajectory and the sensitivity maps in a coil array used in SENSE imaging contribute to the noise amplification in final images. This study quantitatively investigates noise amplification in the TPI-SENSE imaging using a numerical model and coil maps measured from a 4-channel head coil array on a 3T scanner.

METHODS AND MATERIALS

The g-factor is usually used to describe noise amplification in Cartesian SENSE (3). This factor is, however, not applicable to non-Cartesian SENSE in which there is not analytical formula for the g-factor (4). Multiple noise trials were used in this study to calculate the noise amplification in the TPI-SENSE imaging. A routinely-used TPI trajectory was employed and reductions in the number of rings and rotations were then made to produce undersampling acquisitions for parallel imaging (Tab. 1). Coil maps of a 4-channel head coil array (Nova Medical, Wakefield, MA) were measured on a 3T scanner (GE Signa, Milwaukee, WI) using a uniform phantom filled with water. A numerical sodium model (cylinder with rods of varying diameters, T_2=3ms) was used to analytically calculate the k-space data along the TPI trajectory (FOV=22×22×22cm^3, matrix=64×64×64). Gaussian noise $N(0,\sigma^2)$ was then added to the calculated data. Images were reconstructed using the conjugate gradient algorithm (2). A noise image was obtained by complex subtraction of the image reconstructed from the noise-free k-space data from the image reconstructed from the noisy k-space data. For each of reductions in ring and rotation directions, 500 trials were performed and the standard derivation (SD) of the noise was calculated on a pixel-by-pixel basis. The SD images were used to describe the noise amplification in the TPI-SENSE.

Tab.1. Average SD and standard derivation (Δ)

Reduction number	Total projections	Reduction factor	CG iterations	SD±Δ	Change (%)
1×1	984	1.00	3	0.781±0.684	0.0
2×1	508	1.94	4	0.855±0.798	9.5
2×2	260	3.78	4	1.197±1.111	53.3
2×3	178	5.53	5	1.552±1.447	98.7
2×4	138	7.13	6	1.899±1.785	143.1

RESULTS AND DISCUSSIONS

The measured coil maps are shown in Fig. 1. The SD images of the noise are illustrated in Fig. 2. The average and standard derivation of an individual SD image over the region of interest is shown in Fig. 3 and in Tab. 1. The distribution pattern of the noise SD was heavily dependent on the coil maps for all tested reductions from 2×1 to 2×4 (Fig. 2 bottom). Large intensity in the coil maps corresponded to low SD values or small noise amplification (dark areas in Fig. 2 bottom). Conversely, small intensity located between neighboring coils (Fig. 1) produced large noise amplification (bright areas in Fig. 2 bottom). As the reduction number increased from 2×1 to 2×4, the average of the noise SD increased from 9.5% to 143.1% (compared with the full sampling, i.e., reduction number 1×1) (Fig.3 & Tab.1). The average noise SD at the most interesting reduction number 2×3 increased by 98.7% relative to that of full sampling, which corresponds to 27% decrease relative to the expected theoretical result in the Cartesian case (135%). This indicates that the TPI trajectory leads to smaller noise amplification than Cartesian sampling. This behavior is also manifested for all other reductions tested (75%, 44%, and 14% less for the reductions 2×1, 2×2, and 2×4, respectively). In conclusion, the noise amplification in the TPI-SENSE was smaller (27% less at reduction 2×3) than that expected for Cartesian sampling, and closely associated with the coil maps.

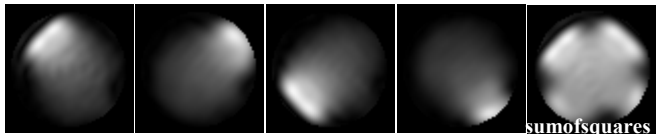

Fig.1. Coil maps of a 4-channel head coil array.

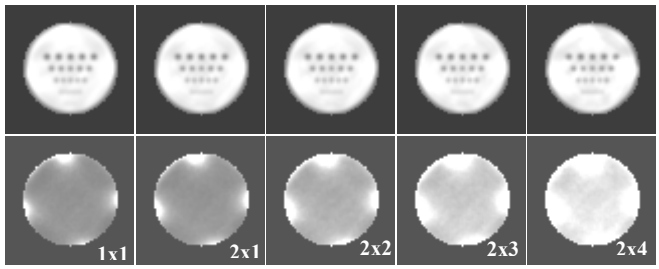

Fig.2. SENSE images of the model (top) and SD images of the noise (500 trials) (bottom). On the low-right corners are reduction numbers.

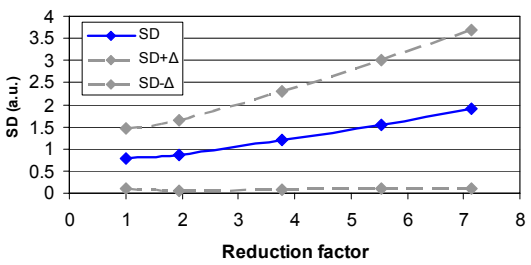

Fig.3. Noise SD vs. Reduction Factor.

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