Tier-specific weighted echo sharing technique (WEST) for extremely undersampled Cartesian magnetic resonance fingerprinting (MRF)

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Introduction
Magnetic resonance fingerprinting (MRF) is a powerful technique for fast magnetic resonance (MR) parameter (M0, T1, T2, ΔB) mapping [1]. But the variable density spiral (VDS) trajectory used in the MRF is not widely used for clinical systems because its implementation is not robust depending on the stability of MR systems. For the robustness of the MRF in the clinical systems, well-established Cartesian trajectory needs to be considered. In the Cartesian MRF, however, severe aliasing or blurring artifacts on images appear because extreme undersampling should be applied for fast data acquisition. To reduce these artifacts, therefore, the effective data sharing method had been developed to fill the empty phase encoding (PE) lines (ky lines) through all over the time points. [2] This technique fills the empty PE lines with a weighted combination of acquired PE lines in the same k-space position at other time points. We call this technique as ‘weighted echo sharing technique (WEST)’ hereafter. This WEST method showed successful results making it possible to undersample the Cartesian k-space data up to the reduction factor R=32. However, still some of detail tissues and structures in each map are hard to be distinguished due to the noise-like artifacts. Finally, the maps obtained by the conventional WEST show substantial reduction of the noise-like artifacts compared to the conventional WEST case. The results show that the introduction of tier-specific weights to the WEST resulted in substantial reduction of the noise-like artifacts in the estimated parameter maps.

Methods
For in vivo experiments, one slice of brain was scanned with inversion-recovery balanced steady state free-precession sequence in 3T MRI system. Used flip angle (FA) and repetition time (TR) patterns were similar to [1]. Number of time points was 500, and the ranges of FAs and TRs were 0~80° and 8~12ms, respectively. Slice thickness was 5mm and matrix size was 256x256. Total two scans were performed for fullsampling case (256 PE lines) and undersampling case (8 PE lines, R=32). All image reconstruction and processing were performed using MATLAB (The MathWorks, Inc., Natick, MA).

Fig 1. Basic idea of the WEST method is introduced. Acquisition of weights is indicated as dash curves. And the empty y-th PE line at the t-th time point is filled with weighted combination of acquired y-th PE lines at other time points. This is indicated as full curves.

Fig 2. Basic idea of the tier-specific WEST method is introduced. A k-space is separated to center (low frequency) and outer (high frequency) tiers. And the WEST is performed for two different tiers by using two different parts (center and outer) of center PE lines.

Fig 3 shows the estimated T1, T2, and enlarged T2 maps from fullsampled data (a,e,i), random undersampled data (b,f,j), the conventional WEST (c,g,k), and the tier-specific WEST (d,h,l). The aliasing and blurring artifacts due to random undersampling in the maps were highly reduced in the conventional WEST case compared to the random undersampled case (non-sharing). Also, the maps show more detailed and accurate structures of the brain. However, still some of detail tissues and structures in each map are hard to be distinguished due to the noise-like artifacts. Finally, the maps obtained by the tier-specific WEST show substantially reduced noise-like artifacts compared to the conventional WEST. And they are very similar with maps estimated from fullsampled data. The standard deviations in selected homogeneous ROI in fig 3-(d) show the noise level in maps was sufficiently reduced in the tier-specific WEST case.

Conclusion
Proposed tier-specific WEST method could sufficiently suppress the noise-like artifacts in the maps obtained by the conventional WEST. Consequently, this method enables acquisition of accurate maps from extremely undersampled Cartesian MRF data.

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