Robust Susceptibility Weighted Imaging using Single-Slab 3D GRASE with Removal of Background Phase Variation

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Introduction: In susceptibility weighted imaging (SWI) (1), it is important to remove background phase variations while retaining only local field information. The projection onto dipole field (PDF) method (2) was recently introduced, employing image-based convolution with ROI masks to decompose a background field within the ROI into one originating from dipoles outside the ROI. However, the image-based convolution is sensitive to rapid field variations at the boundaries of the ROI, leading to loss of important phase information particularly at the air-tissue interfaces. To regionally correct rapid phase aliasing at the boundaries while locally removing smoothly varying background phases, we develop a robust SWI method employing: 1) Single-slab 3D GRASE (3) to simultaneously acquire both artifact-free magnitude images from spin echo (SE) and phase images from free induction decay (FID) signals, 2) Removal of rapid background field at the boundaries using forward field calculation (4), and 3) Removal of local background field with the ROI extended to the boundaries to preserve susceptibility induced phase information over the entire image.

Sequence design and Reconstruction: The proposed single-slab 3D GRASE for robust SWI is shown in Fig.1, consisting of: 1) slab-selective excitation RF pulse, 2) short, non-selective refocusing pulses trains with variable flip angles, 3) EPI readout gradients. Multiple echoes (SE in the 2^{nd} echo, FID GRE in 1^{st} and 3^{rd} echoes) are grouped and then each image is generated using phase-independent reconstruction as in (3). Spin echo image (grouped e_{2nd}) provides artifact-free magnitude images even at air-tissue interfaces while FID GRE images (grouped e_{1st}, e_{3rd}) substantially possess susceptibility induced phase information. Fig. 2 shows the proposed, two-step background phase removal method exploiting single-slab 3D GRASE images: 1) Removal of regionally rapid field change using Forward field calculation (4) and 2) Removal of local background phase using the adapted PDF algorithm. In the forward field calculation, grouped e_{2nd} echo data are used for geometry extraction. Near the sinus regional susceptibilities are obtained when the calculated field is close to the measured field in the ROI. After subtracting the measured field from the calculated one, rapid field variations at tissue boundaries are eliminated. Then, the local background phases are removed using the adapted PDF algorithm with the ROI extended to the boundaries, thus preserving susceptibility induced phase information over the entire image.

Materials and Methods: Brain data is acquired in a healthy volunteer at 3T whole-body MR scanner (MAGNETOM Trio, Siemens Medical solutions) using both conventional flow-compensated 3D double echo spoiled-GRE and the proposed 3D GRASE for comparison. The imaging parameters of the proposed imaging were: TR/TE = 680/52ms; FOV = 256x270x120 mm^3; resolution = 1x0.9x2mm^3; echo train length (ETL) = 9; shots = 18; EPI factor = 3; echo spacing (ESP) = 13.22 ms; average = 2 to remove FID artifact; bandwidth = 781Hz/Pix. The imaging parameters specific to conventional imaging were: TR = 44ms; TE1/TE2 = 5/15ms; FOV = 256x256x60 mm^3; resolution = 1x1x2 mm^3. SWI process deals with composite phase data, calculated by SENSE equation. High pass filter is used to remove global background phase in the conventional SWI process. Our proposed method is also used for a performance comparison.

Result: Fig.3 (a) shows that conventional SWI process corresponding to 3D spoiled GRE sequence. Fig.3 (b) represents proposed sequence and SWI result. The GRE image has T2* effect in magnitude and induced phase aliasing due to the boundary effect near the sinus as compared to the proposed images. This effect does not avoid after high pass filtering, and result in signal dropout in SWI image. Our two-step background phase removal method eliminates boundary effect near the sinus and then avoid signal dropout in SWI.

Conclusion: The proposed robust SWI, which combines single-slab 3D GRASE with the two-step background phase removal, effectively preserves important phase information over the whole ROI, outperforming conventional GRE based SWI with phase correction.

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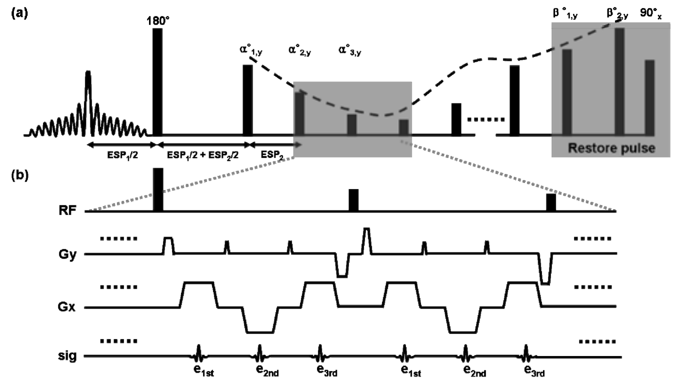

Fig. 1. Timing diagram of the proposed slab selective 3D GRASE pulse

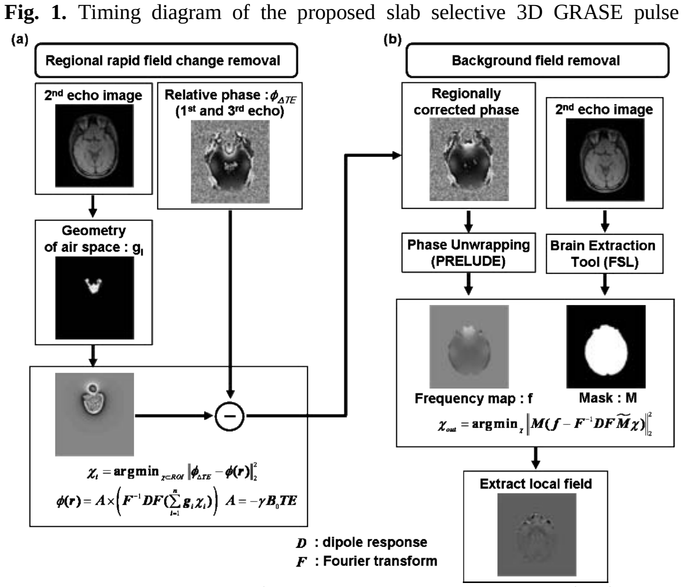

Fig. 2. Two-step background field removal method is composed of a) forward field calculating part, and b) projection onto dipole field (PDF).

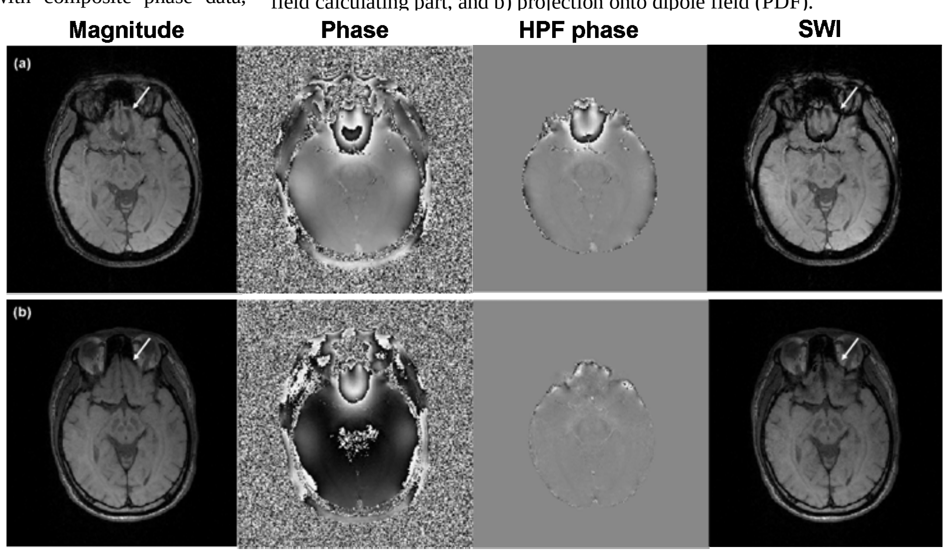

Fig. 3. Conventional flow-compensated 3D spoiled GRE (a), and proposed sequence (b).