A Method for Removing Off-Resonance Artifact in Turboprop

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Introduction: Turboprop[1] is a fast method for PROPELLER imaging. It is a hybrid of the FSE sequence with EPI-like echo trains centered on each spin echo. It has two significant advantages over standard FSE-based PROPELLER: (1) it can collect more lines for a given echo train duration, which increases the stability of motion correction and reduces the minimum scan time, and (2) it uses fewer rf pulses, which reduces SAR and Magnetization Transfer effects and increases sampling efficiency. The disadvantage of this turboprop is the presence of additional phase due to off-resonance, which cause artifacts in both the blade-images (reducing the robustness of motion correction) and in the final image. This work presents a method for mitigating these off-resonance artifacts. This abstract uses an illustration of five gradient echoes between each pair of refocusing pulses, at times -2T, -T, 0, T, and 2T from the spin echo.

Methods. The five gradients echoes per spin echo (e.g. A-E) have a contaminate phase from off-resonance of -2α, $-\alpha$, 0, α, 2α (Fig. 1a). These gradient echoes are encoded so that gradient echoes with conjugate phase are collected on the same phase encoding lines. When forming blades for motion correction, these conjugate-phase echoes are averaged together; this removes the off-resonance phase and introduces local loss in signal magnitude by the cosine of that phase (Fig. 1b). Magnitude corruption of the data is more benign than phase corruption. These combined echo, artifact-reduced blades are only used for motion correction, then discarded. The data from each gradient echo are gridded separately onto k-space, as illustrated in Fig. 1c, using the motion estimates, to create the final image. The gaps in k-space coverage seen in Fig. 1c are easily filled with a single blade collected with different phase ordering. Each k-space sets then forms an image, and the images are combined using a phase-insensitive method (e.g. rms of magnitude).

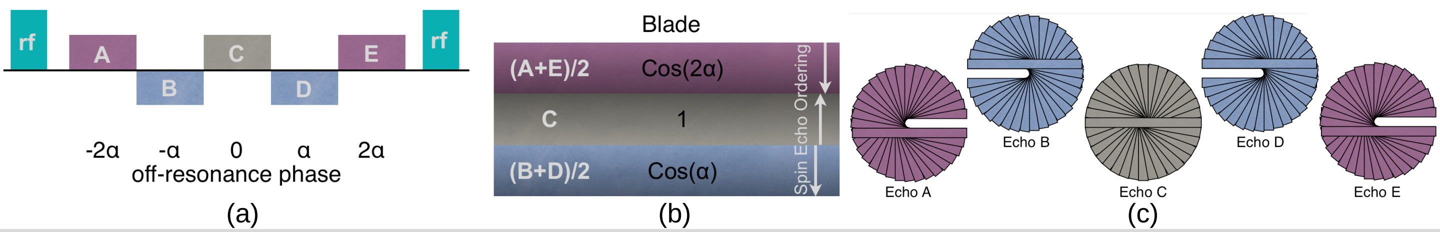

Figure 1. Off-resonance creates phase in the gradient echoes (a). Data are ordered along the blade so that overlapping echoes have opposite off-resonance phase (b), and the averaged gradient echoes remove the phase (but create signal loss), creating a more robust blade for motion correction. Each gradient echo is also kept separate, forming an image with completely consistent off-resonant phase (c), which eliminates most of the artifact in the old version of turboprop.

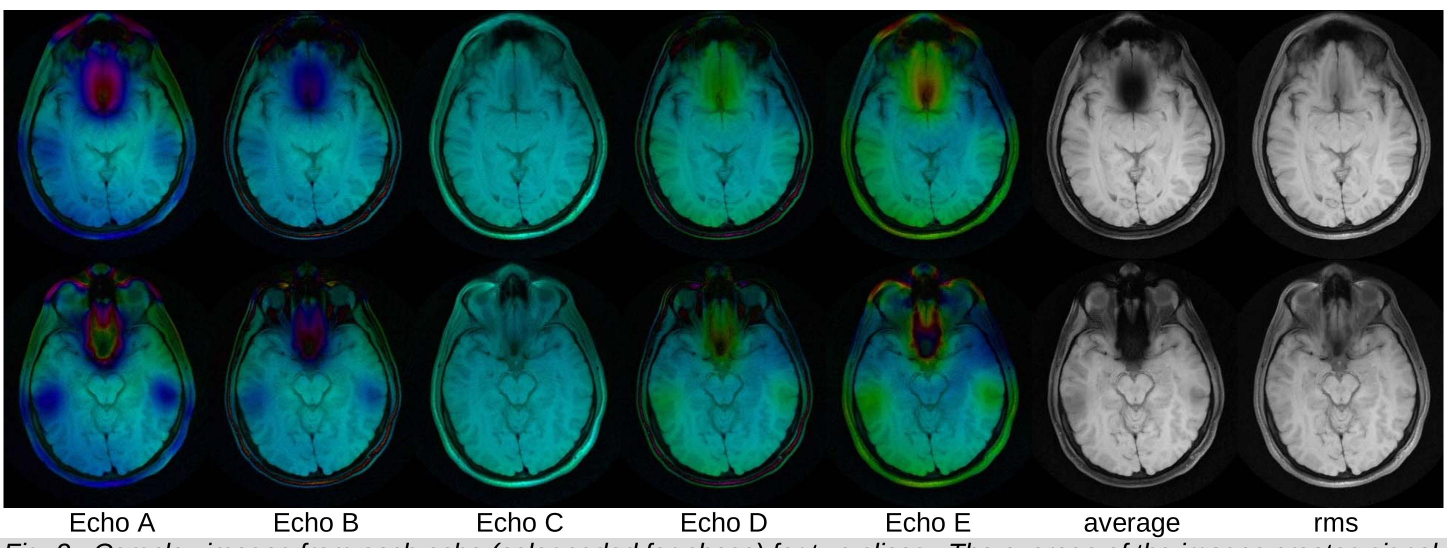

Fig. 2. Complex images from each echo (color coded for phase) for two slices. The average of the images creates signal loss from dephasing as in the old turboprop reconstruction, but the rms combination eliminates this signal loss.

Conclusions: The proposed method is a tradeoff between conventional turboprop and a method similar to that presented by Zhou[2], reducing bladewidth by almost half but strongly mitigating off-resonance artifact.

References: 1. Mag Res Med 55(2): 380-5, 2. ISMRM 2005 meeting, abstract 291.