Demonstration of recovery of signal loss at 7T in Gradient Echo EPI using Tailored-RF pulses

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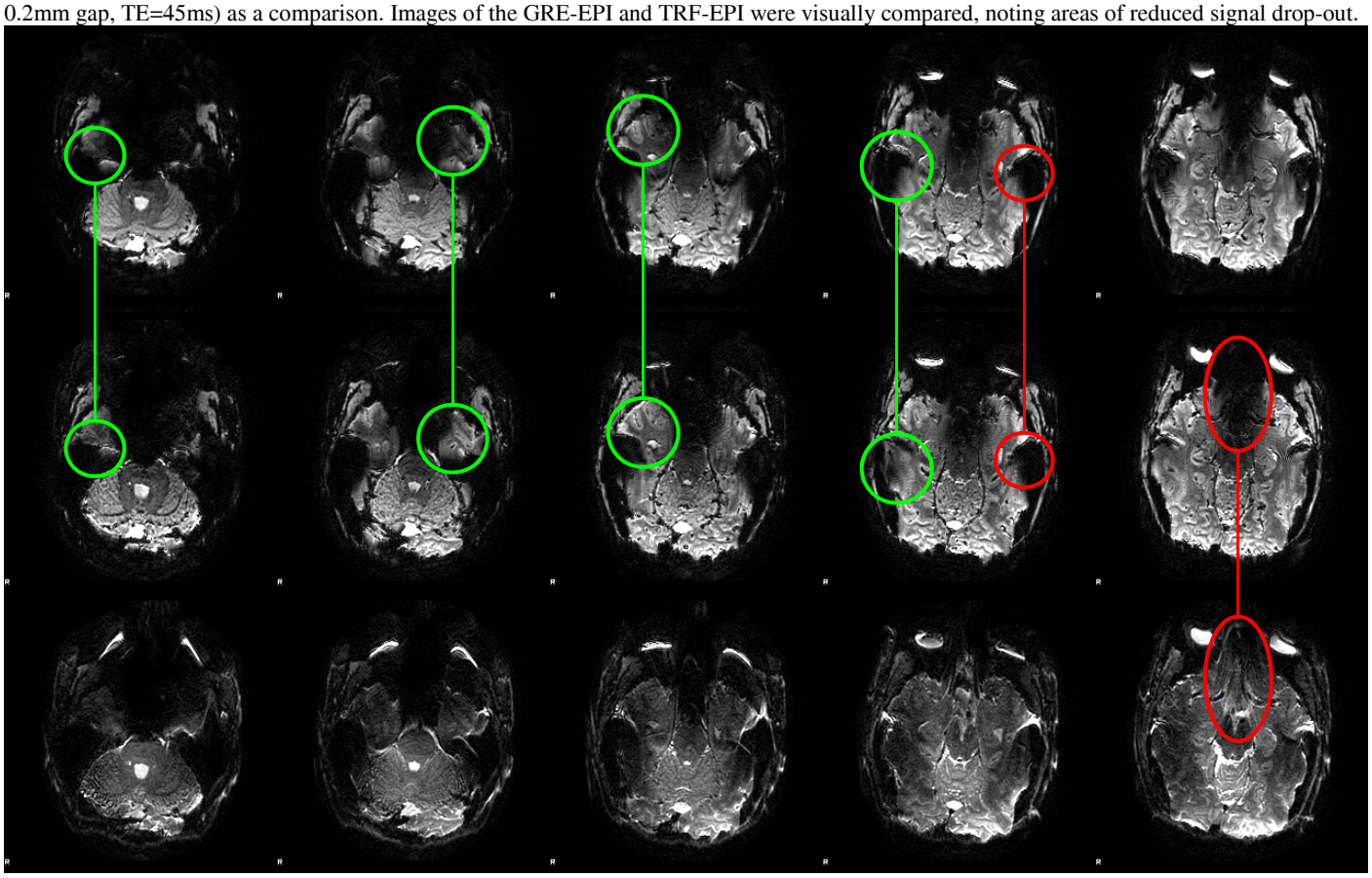
Target Audience: This work will be of interest to researchers and clinicians performing fMRI on regions of the brain commonly affected by susceptibility-induced signal dropout at 7T.

Purpose: The gradient echo EPI (GE-EPI) BOLD signal alterations associated with brain activity are typically used for functional MRI studies. However, the EPI technique is sensitive to differences in magnetic susceptibility of air and tissue, which will manifest in image distortions and signal losses around orbitofrontal and inferior temporal regions of the brain[1]. These effects scale with increasing static field. Recently the effective application of a Tailored-RF (TRF) based approach for signal recovery using hyperbolic secant excitation pulses with quadratic phase profiles[2] has been demonstrated in GE-EPI images at 3T[3]. In this study we examine the feasibility of a TRF approach to GE-EPI at 7T.

Methods: Using the algorithm described in Wastling et al. [4] we designed two TRF pulses to achieve a near uniform signal response from grey matter (T1=1.94s[5]) over the range of susceptibility gradients observed in the human head at 7T (-500□Tm^{-1}<Gsus<500□Tm^{-1}). The pulses were optimised for either 2mm or 3mm thick slices acquired with TR=3000ms and TE=~25ms. The manufacturer's GE-EPI sequence was modified to play out either the standard excitation pulse (modified sinc), or the TRF pulse.

Three subjects were scanned on a MR950 7T scanner (GE Healthcare, Milwaukee, WI, USA) equipped with a 2ch-transmit/32ch-receive coil (Nova Medical, Wilmington, MA, USA). Conventional GE-EPI and TRF-EPI data-sets were acquired with the following parameters in common: TR=3s, parallel imaging factor = 3. Images were obtained at three different resolutions: 1) 64x64 matrix, 3x3mm in-plane voxel size, 3mm slice thickness, 0.3mm gap, FA=70º, TE=27ms 2) 128x128 matrix, 2x2mm in-plane voxel size, 1.9mm slice thickness, 0.2mm gap, FA=83º, TE=20ms, 3) 224x224 matrix, 1x1mm in-plane voxel size, 1.9mm slice thickness, 0.2mm gap, FA=78º, TE=27ms.

In one subject, Spin-Echo EPI (SE-EPI) was taken at a similar high resolution (224x224 matrix, 1x1 in-plane voxel size, 1.9mm slice thickness, 0.2mm gap, TE=45ms) as a comparison. Images of the GRE-EPI and TRF-EPI were visually compared, noting areas of reduced signal drop-out.



Results: Figure 1 shows selected slices from a single subject at 1x1x2mm voxel size. Conventional GE-EPI (top row), TRF-EPI (middle row), and SE-EPI (bottom row) are displayed. Green circles outline areas in the inferior temporal lobe and regions bordering the auditory sinus where signal is recovered in the TRF-EPI (middle row) compared to the GE-EPI (top row). Not all signal is recovered in the TRF-EPI – see the area outlined by red circles. Comparison with SE-EPI (bottom row) shows that signal is not completely recovered in the orbital frontal cortex (red ellipses). Similar patterns of signal recovery were also observed in the 2x2x2 and 3x3x3mm voxel size data-sets.

Discussion: Ojemann et al[1] made the simple, powerful, observation that an EP image used for fMRI cannot possibly give a BOLD response if there is no signal in the raw images due to signal drop-out. The ability of TRF-EPI to recover signal in areas of the brain that are normally prone to signal loss suggests that this technique could be used to perform fMRI at 7T. As predicted from theory, the TRF-EPI does exhibit approximately 40% signal loss, but as most techniques to recover signal drop-out involve an increase of a factor of two or more in acquisition time, this SNR loss can be acceptable for certain fMRI paradigms where activation is sought in these "problem areas".

Conclusions: We have shown that TRF-EPI can recover signal in some areas of the brain that commonly exhibit signal loss in standard GE-EPI at 7T. In future work we hope to demonstrate that BOLD signal changes are significantly higher in these regions.

References:

[1] Ojemann J G, et al. Anatomic localization and quantitative analysis of gradient refocused echo-planar fMRI susceptibility artifacts. NeuroImage. 1997: 6(3): 156-167. [2] Cho Z, et al. Reduction of susceptibility artifact in gradient-echo imaging. MRM. 2014; 23:193-200.

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