Multi-echo EPI with parallel transmission z-shimming for increased sensitivity in BOLD fMRI

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Introduction

One of the most confounding limitations of GE-EPI based BOLD functional MRI is through-plane signal dephasing [1], most prominent in brain regions with large susceptibility variation such as the frontal lobe where the detection of activation induced BOLD signal changes is notoriously difficult. Beyond simple protocol optimization for a specific brain region of interest (TE, slice thickness and angulation), the use of single-shot multi-echo (ME-) EPI [2,3] has been shown to be a highly practical way to improve BOLD sensitivity for the entire brain by pixel-wise optimized echo weighting [3]. Alternatively, a technique known as z-shimming [4] actively corrects signal dephasing, but is impractical since it requires multiple scans at different z-gradient moments to compose the final image. Parallel transmission (pTX) z-shimming [5,6] exploits each coil's sensitivity profile to achieve a local signal loss compensation in a single shot, by appropriately time shifting the excitation pulses w.r.t. the slice select gradient; this creates a 'local' z-shim moment on the transmitter channels closest to the susceptibility artifact.

Methods

A multi-echo EPI sequence with pTX capability was implemented on a clinical Siemens Magnetom 3T scanner (controlling gradients and acquisition) and a custom built Tecmag NTNMR eight-channel transmission system (controlling the RF, triggered by scanner). Spin excitation is performed using eight uniquely time-shifted *sinc* pulses of 1.5ms duration over a 2.5ms slice-select gradient; the optimal time shift that minimizes signal loss is obtained in a pre-scan by progressively time shifting the pulses on each transmitter [6]. ME-EPI images with and without parallel z-shim were acquired on 2 subjects after obtaining informed consent, using the following imaging parameters: matrix size 64x64, FoV 220mm, 3.4mm voxels, 8 slices of 5mm thickness (20% gap), TE=[13,35,57]ms, 6/8 partial Fourier, TR=1.5s. The multi-echo imaging data were submitted to weighted summation as described in [3]. Image quality was assessed by means of visual inspection and region of interest analysis.

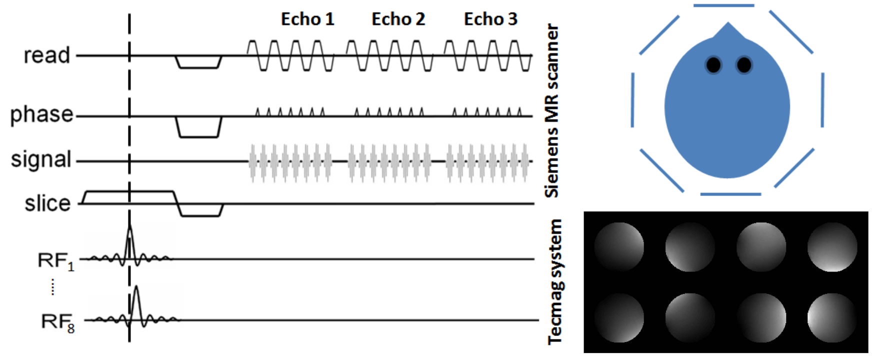

Figure 1: (a) ME-EPI sequence with 8ch-pTX. The eight uniquely time shifted RF pulses are sent from the Tecmag NTNMR system, the scanner controls the gradients and receivers;
(b) arrangement of the eight TX/RX coil elements around subject's head; (c) coil sensitivity profiles representing the spatial extent of the local z-shim.

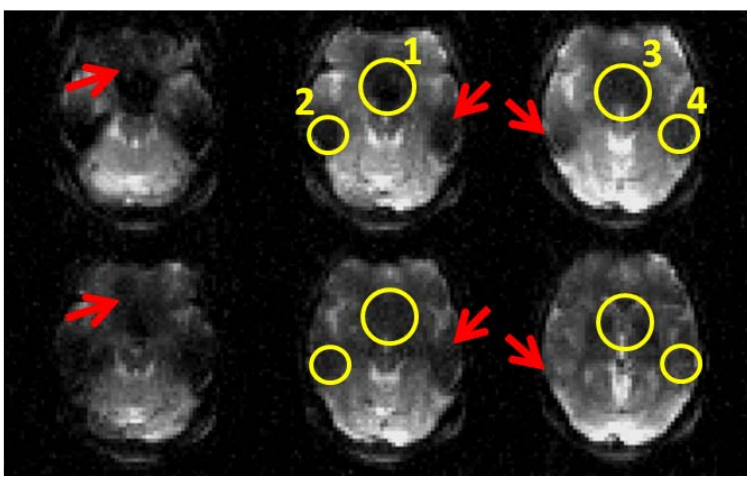

Figure 2: (a) ME-EPI imaging slices acquired without (top row) and with parallel z-shim (bottom row). Note the reduced susceptibility artifacts indicated by the arrows; the circles mark the ROIs used in the analysis.

Results

Figure 2 shows ME-EPI imaging slices covering the frontal lobe, without (top) and with (bottom) parallel z-shimming enabled. The red arrows indicate regions where the susceptibility-induced signal loss is reduced by the application of parallel z-shimming. The table shows the mean signal intensities in the ROIs marked by the yellow circles.

z-shim	ROI 1	ROI 2	ROI 3	ROI 4
without	599	566	596	692
with	686	686	826	873

Discussion and Conclusion

A parallel transmission method for BOLD fMRI is presented that combines the benefits of ME-EPI and parallel z-shimming. We observe additional signal recovery in the ME data when using parallel transmission; improvements are demonstrated for the notoriously problematic frontal lobe (orbito-frontal cortex) and near the auditory canals. Further improvements are expected from slice-by-slice optimization of the simultaneous z-shim which will be addressed in future work.

References [1] Constable RT, JMRI 1995;5:746 [2] Posse S, MRM 1999;42:87 [3] Poser BA, MRM 2006;55:1227 [4] Frahm J, JMR 1994;103:91 [5] Deng W, MRM 2009;61:255 [6] Deng W, proc ISMRM 2009;17:17

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