Whole Brain fMRI in Human at Ultra-High Field with Parallel SENSE Imaging

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Introduction

While Ultra-High magnetic fields are much promising for many MR application fields (high signal to noise, high chemical shift, high BOLD contrast), there is still a debate about some inherent limitations related either to electromagnetic issues (dielectric resonance, RF penetration) or to B0 inhomogeneities and reduced T2*. Because of those constraints, most fMRI studies of the human brain at ultra-high magnetic field (>4Tesla) have been focusing on a limited portion of the brain, utilizing surface coils, EPI segmentation and different techniques of field of view reduction (along the phase encoding direction) in order to shorten echo time (TE) and readout time. In this paper, we demonstrate fMRI of the whole brain at 7Tesla with parallel imaging, taking full advantage of: **a)** the intrinsic higher signal to noise at higher field (the available signal to noise ratio being one of the fundamental limits in parallel imaging), **b)** the higher potential reduction factor obtainable at higher magnetic field[1], **c)** a coil design based on microstripe transceive arrays for parallel imaging. A reduction factor of 4 allowed to acquire 40 slices every 6 seconds with a 2x2mm^2 in plane resolution with no EPI segmentation.

Acquisition:

Imaging was performed at 7Tesla (magnet: Magnex®, console: Varian®). An elliptical 16-channel Transceive array coil was used for RF transmission and reception[2,3], with an in –house developed 16 channel digital receiver system including an Echotek (Huntsville, AL) ECDR-814 board. While the RF power was distributed through the 16 elements, only 8 channels were measured in the present EPI study due to current data transfer limitation. This study was designed to image the whole brain with parallel imaging and SENSE reconstruction [4], relying on a four-fold FOV reduction (we obtain robustly a reduction factor of 4 with this coil in standard imaging [5]). Functional series consisted in a block designed finger taping task, with OFF/ON period of 30 sec each, for a duration of 3.5 minutes (35 volumes). Two categories of data were acquired:

1) Full FOV fMRI : Gradient echo EPI images were obtained with 10 axial slices, FOV=25.6x25.6cm^2, matrix = 128 x 128, in 4 segments (32 phase steps per segments). Each volume (40 RF pulses) was obtained in 6 seconds. Slice thickness was 3mm, with a 9mm gap.

2) Reduced FOV fMRI : Reducing the number of segments allows to increase the number of slices keeping all other parameters identical. ***One-segment series*** were obtained with 40 slices, 3mm thk, no gap, FOV=25.6cmx6.4cm. In all series the TR per volume was kept constant (6 sec). Prior to each functional series obtained with a reduced FOV, full FOV 4-segments EPI images (40 slices, 4 segments) were first obtained to assess the sensitivity of the coils needed for SENSE reconstruction.

SENSE reconstruction:

Before combining the 8 channel data of a given EPI series, a unique EPI reference scan (without phase encoding) was derived from the 8 channels to correct data from all channel. Phase correction based on a navigator echo was also performed before SENSE. For Full FOV data, the first image of the series was used to assess coil sensitivity, the rest of the series being then reconstructed by taking either the full 4-segments data set (r=1), or taking only one segment out of 4. Because in EPI each segment is a one shot, separate acquisition, this undersampling scheme is virtually identical to a true undersampled acquisition. For reduced FOV fMRI data, coil sensitivity was derived from the full FOV data set obtained prior to the series. After SENSE reconstruction, activation map were obtained by computing the cross-correlation coefficient of each pixel time course with a hemodynamic model function convolved with a box car function.

Results and discussion:

The main observations are the following:

- in all series, activation were observed in expected locations from the top to the bottom of the brain, including motor cortex, SMA, basal ganglia, cerebellum
- activation pattern were very reproducible when undersampling the Full FOV (10 slices) series, and quite comparable when comparing the 10 slices (out of 40) from the the one-segment data matching the 10 slices Full FOV data series.
- over all, image quality for reduction factor=4 in one-segment, 40 slices EPI series is encouraging, with very little residual aliasing in the final reconstructed images (Fig.1). Undersampling the 10-slices Full FOV series (data not shown) still provided somewhat better image quality than acquiring 40 slices one-segment images. This seems likely related to some motion occuring between the coil calibration scan and the reduced field of view fMRI series.
- there was an expected decrease in signal intensity in reduced FOV data; however, in the lowest part of the brain (along Z), segmentation induced fluctuations were quite high in the Full FOV series, with ghosting artifacts clearly visible in a movie mode. Those typical fluctuations were not observed in the one-segment series, suggesting that avoiding segmentation balance to some degree the reduced signal intensity

This study represents a first attempt to cover the whole brain with EPI fMRI at 7 Tesla. Significant improvement are needed to specifically address residual signal losses and geometric distortions still present, especially in the lower part of the brain. However, we believe that those preliminary results strongly support the expectation that parallel imaging can substantially widen the range of fMRI studies benefiting from ultra-high magnetic fields.

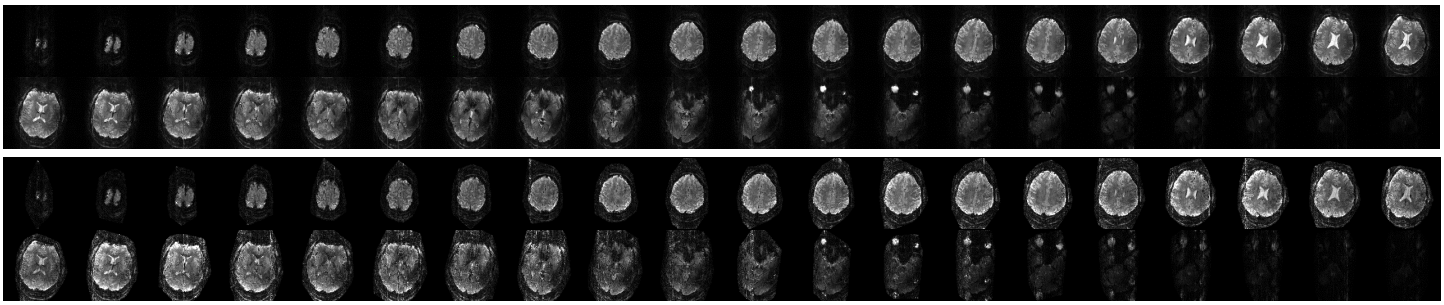

Fig 1. *Upper two rows*: Full FOV (25.6 x 25.6 cm^2) EPI data, 40 slices, 4 segments, used to assess coil sensitivity (acquisition: 24 sec/vol). *Lower two rows*: same 40 slices, reduced FOV (25.6 x 6.4 cm^2) data set acquired with only one segment for fMRI series and reconstructed with SENSE (acquisition: 6 sec/volume). FOV reduction occurs along Y axis.

[1] Wiesinger, F., et al, Proc ISMRM 10 (2002) p.191 [2]. Vaughan, J.T.: RF Coil for Imaging System US Patent Serial No. 6,633,161(2003) [3] Vaughan T., et al. (*submitted in a separate abstract*) [4]Pruessmann, K.P., et al, MRM 42:952-962 (1999). [5] Moeller S., et al. (*submitted in a separate abstract*)

Acknowledgement: Supported by NIH P41 RR08079, MIND Institute, and the W.M. Keck Foundation