High-resolution 3D EPI at 9.4 Tesla with parallel transmit B1+ field homogenisation

Benedikt A Poser[1], Daniel Brenner[2], and Desmond H Y Tse[1,3]

[1]*Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, Netherlands,* [2]*German Centre for Neurodegenerative Diseases (DZNE), Bonn, Germany,* [3]*Department of Radiology, Maastricht University, Maastricht, Netherlands*

Target Audience: MR physicists, neuroscientists and clinicians who are interested in neuroimaging at UHF.

Purpose

MR imaging at ultra-high field (UHF) is plagued by inhomogeneities in the RF transmission field B1+, caused by standing wave interference effect as the RF wavelength at UHF becomes comparable to the size of the object being imaged [1]. The consequence are spatial variations in the excitation (or inversion or refocussing) flip angles leading to strong signal and contrast variations across the image, rendering quantitative image interpretation difficult. The issue can be addressed using parallel RF transmission (pTX) to independently control RF magnitude and/or phase on multiple transmit channels, and a number of pulse designs has been proposed for both 2D imaging based on slice-selective spokes pulses [2,3,4] as well as for 3D non-selective excitations based on kT-points [5] or SPINS [6] excitations. **We here investigate the kT-points technique for use on high-resolution whole-brain 3D echo-planar imaging (3D EPI) and find considerable improvement in image quality.**

Methods

Experiments were performed on a 9.4 T scanner (Siemens, Erlangen, Germany) with a dual-row 2x8 channel transmit coil (run in 2x4 configuration with neighbouring elements combined) operated in pTX mode and 31-channel receive array coil [7]. In vivo images were acquired on a 33-year-old male volunteer according to local ethics approval. An in-house 3D EPI sequence [8] was modified to use externally designed pulses, specifically a full pTx kT-points composite pulse that consisted of 8 sub-pulses with 0.28ms spacing, i.e. an overall pulse duration of 2.24ms. The amplitudes and the phases of the sub-pulses for each transmit channel were calculated using the spatial domain method [9] with magnitude least square optimisation [10], and local B1+ reductions out in the optimised solution were avoided by using the region growing algorithm shown in [11]. For the pulse design, B1+ maps from each of the transmit channels were acquired with a T2* compensated version of DREAM [12] (TE_{ste} = 2.22ms, TE_{fid} = 4.44ms, TR = 7.5s, 4mm x 4mm voxel size, 4 mm slice thickness, 15 slices) using a transmit channel phase encoding scheme [13]. A B0 map was recorded with dual-echo 3D GRE (TE = 1.0/3.2ms, TR = 30ms, nominal FA = 8°, 5 mm iso voxels). High-resolution 3D EPI time series with 0.75mm isotropic voxels were acquired in the coil's CP mode and with the kT-points pulse, using the following parameters: sagittal FoV 192x192x156mm^3, matrix 256x256x208, TE=23ms, TR=75ms, TR_{vol}=15s, PF 6/8, GRAPPA 3 in-plane, nominal FA = 12 deg.

Results

Fig 1 (top) shows flip angle maps of the CP mode and the kT-points pulse, demonstrating the good B1+ homogenisation achieved by the pTX excitation. The high quality of single (non-averaged) 3D EPI images can be seen in Fig 2, which shows images acquired using CP mode (left) and kT-points (right) excitation. The picture insert highlights some of the brain areas on which contrast is lost in CP mode, but recovered in the B1+ homogenised scan.

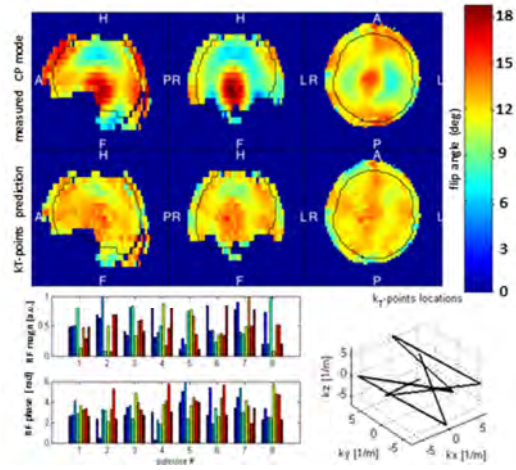

Fig 1. *Flip angle maps for CP modes and kT-points pulse (top), RF magn/phase of the subpulses as well as subpulse locations.*

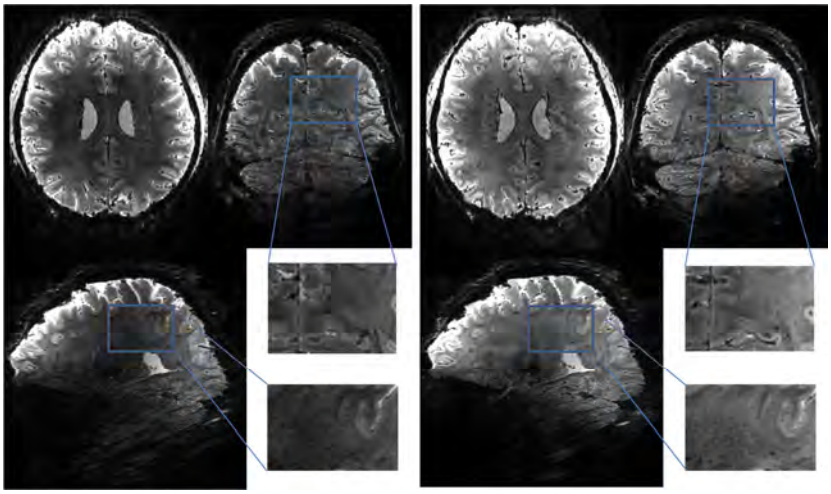

Fig 2. *Identically windowed single 3D EPI images at 0.75mm isotropic resolution acquired in CP mode (left) and using the kT-points excitations (right). Much of the anatomical detail in the CP mode images is lost to the lack of contrast and signal intensity especially in the central brain regions.*

Discussion

kT-points excitation was shown to significantly improve 3 EPI image quality as previously shown for other volumetric acquisitions [5,6]. The longer minimum TE required due to the longer pulse (2.4ms duration) is marginal, and the scan time overhead related to B0/B1 mapping and pulse calculation (~4-5 minutes total) is very acceptable. The 3D EPI images shown hold promise for high-resolution BOLD fMRI, especially in combination with CAIPIRINHA sampling [13,14], as well as fast structural imaging, including applications such as rapid quantitative susceptibility mapping (QSM).

References: [1] Van de Moortele P, MRM 2005; [2] Setsompop K, MRM 2008; [3] Wu X, Plos ONE 8 2013; [4] Guerin B, MRM 2014; [5] Cloos MA, MRM 2012; [6] Malik SJ, MRM 2012; [7] Shajan G, MRM 2014; [8] Poser BA, NI 2010; [9] Grissom W, MRM 2006; [10] Setsompop K, MRM 2008; [11] Poole MS, ISMRM 2014; [12] Nehrke K, MRM 2014; [13] Tse DHY, JMR 2014 ; [13] Breuer F, MRM 2006; [14] Poser BA, ESMRMB 2013