2D EPI at 9.4T with slice-specific spokes pulse RF excitation for B1+ homogenisation

Benedikt A Poser[1] and Desmond HY Tse[1,2]

[1]*Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, Netherlands,* [2]*Department of Radiology, Maastricht University, Maastricht, Netherlands*

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

Purpose: MR image quality at ultra-high field (>3T) is hampered by B1+transmission field inhomogeneity, caused by RF interferences as the wavelength reduces becomes comparable to the dimensions of the object being imaged [1]. The consequence is strong signal intensity and signal-to-noise variations across image, in many cases disallowing quantitative interpretation of the images. This includes the application to functional MRI (fMRI), in particular when imaging of the entire brain is required and the application a single simple RF shim is no solution. We here demonstrate the use RF B1+ field homogenization by means of slice-specific 2D spokes excitation for a whole-brain 2D EPI protocol and show the application to a cognitive functional fMRI paradigm.

Methods: All experiments were performed with a 9.4T human MR scanner (Magnetom 9.4T, Siemens Medical Solutions, Erlangen, Germany) with a 8-channel transmit (16 elements in two rows combined to 2x4) and 31-channel receive array helmet coil [2], operated in parallel transmission mode. An fMRI protocol with a pTX-enabled 2D EPI was set with 1mm isotropic voxels, 50 slices (gap 50%), TR=2.5s, matrix 192x192mm, 6/8 partial Fourier, GRAPPA 3 with 63 ACS lines nominal flip angle 40 degrees. For the spokes pulse design, B1+ maps from each of the transmit channels were acquired with a T2* compensated in-house implementation of DREAM [4] using a transmit channel phase encoding scheme [5], and B0 map were recorded separately using a low-resolution dual-echo GRE. Spokes pulses with three subpulses each of 4ms duration were designed using custom Matlab routines, employing the spatial domain method of Setsompop [3] with magnitude least square optimisation [6, 7]. A separate pulse was created for groups of 5 adjacent slices, so ten pulses in total. To invoke fMRI activation, a Stroop task was used as previously described in ref [8]. All vivo images were acquired in conformance with the local IRB protocol.

Results:

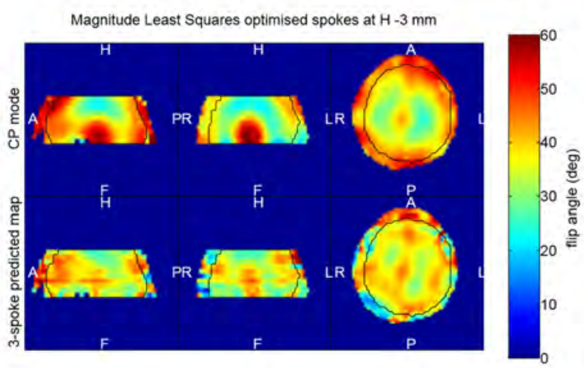

Fig 1. Measured flip angle map in the coil's CP mode (top). The bottom shows the predicted flip angle distribution for the 10 different slice-dependent spoke pulses (SAG/COR view), the TRA view shows one of the pulses

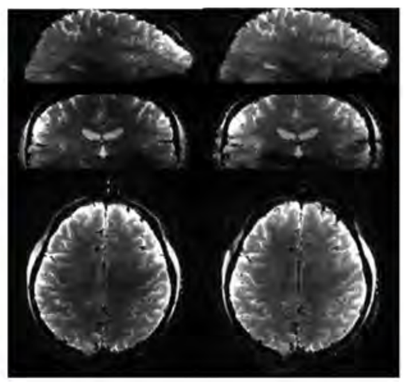

Fig 2. EPI images acquired in the 8ch-pTX coil's CP mode (left), and with the slice-group wise three-spokes pulses (right) which greatly reduces B1+ inhomogeneity.

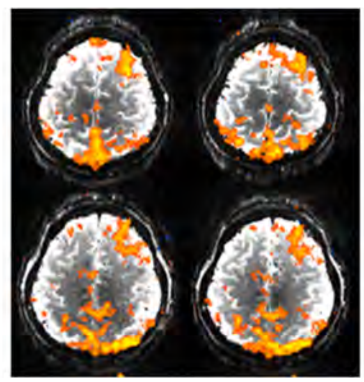

Fig 3. fMRI activation maps for some of the slices acquired with a functional Stroop task design

Figure 1 shows three-plane views of the measured flip angle map in the coil's CP mode (top row) as well as the predicted flip angle distribution (bottom row). The axial view on the right shows the result for one of the slices, and the effect of all slice-wise spokes shims along the head foot direction can be appreciated in the coronal and sagittal views. Flip angle maps of the pulses confirmed the prediction. Figure 2 shows EPI images acquired in the CP mode (left) and with spokes excitation. The signal loss especially in the central image region that is present the CP mode excitation is almost entirely absent with the three-spokes excitation. Some example slices with BOLD activation overlay are shown in Figure 3.

Discussion: Spokes excitations improve the 2D EPI image quality, as expected from previous reports on GRE imaging with spokes. To what degree this helps improve fMRI acquisitions with GE-BOLD contrast in practice remains to be investigated. Considerable benefits are however expected for high-resolution fMRI in the image noise (rather than physiological noise) dominated regime, where arguments relating to the "flip angle independence" of the BOLD contrast [9] do not hold. The short scan durations for DREAM B1+ maps (2 minutes) and B0 map (1 minute), as well the pulse calculation times of only approx. 5 seconds per pulse on a simple desktop PC easily allow for integration into a "routine" fMRI scanning protocol.

Conclusion: Slice-specific spokes pulses for high-res 2D EPI and their use to improve image quality of EPI at 9.4 Tesla were shown.

References:

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