Multi-Banded T2-Weighted fMRI with a z-Encoding RF Coil Array for Whole Brain Coverage at 7 T

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Introduction. Due to significant B_1 inhomogeneities and SAR limitations at ultra-high fields it is challenging to achieve effective whole brain T_2-weighted fMRI. However, it has recently [1] been demonstrated at 7 T that B_1-shim homogeneity, T_2-weighted contrast and hence activation in different target volumes of the human brain can be improved significantly with a multi-region B_1-shim [2-4]. Here we built upon this technique and present a new integrated approach, consisting of a novel multi banded sequence, a 3D B_1 shim and a z-encoding T/R coil array. The combination of these components allow to effectively address SAR and B_1 inhomogeneity challenges and enable whole head T_2-weighted fMRI.

Methods

Three normal subjects participated in this study. A 16-channel transceiver array (Fig. 1) consisting of two concentric rings (8 plus 8 elements) of short (8 cm) transmission line elements was used [5]. The staggering of the T/R elements in the z direction is essential for efficient B_1 manipulation along the z-direction and additionally allows to unalias ten pairs of simultaneously acquired axial slices [6]. Two elements have been omitted from the lower ring to allow for task presentation. Experiments were performed on a 7T system (Siemens) with 16 independently controlled Tx channels. A motor (finger tapping) and visual (flashing checker board) paradigm was used for fMRI. The slab-selective T_2 magnetization preparation SPIF-T_2 [7], consisted of a (90º |180º|-90º) RF sequence to prepare and flip back the magnetization along the z axis. It was implemented with adiabatic refocusing pulses. It is followed by 10, interleaved GE EPI slices (single band or double band) of 2 mm thickness each. (FOV=19.2x19.2cm^2; matrix=128x128, single shot; α=90°; TE for the preparation slab was 55 ms; TE for the EPI readout with GRAPPA=4 and half-Fourier (5/8) was 6.5 ms). The whole brain B_1 shim was defined based on five axial slices within the entire head. Within each of these five axial reference slices an ROI encompassing the brain in that respective slice was drawn defining the B_1 shim target location [6]

Fig. 1: Shows the 2x8 element z-encoding transceiver coil. The opening on top allows for task presentation within a head gradient coil.

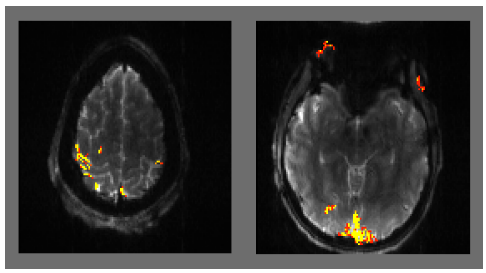

Fig. 2: Activation maps using SPIF-T_2 show one slice (out of ten) in the motor cortex (left) and the visual cortex (right). Slices close to the top of the motor cortex and close to the bottom of the visual cortex were chosen. Voxels with $p \leq .001$, corresponding to 3.3σ, and cluster size threshold of 9 are highlighted.

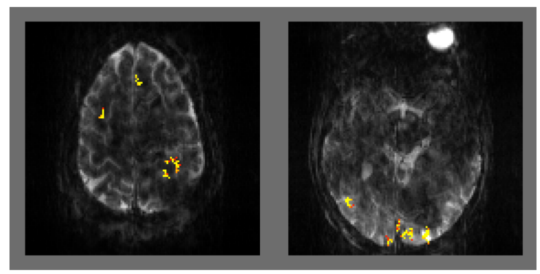

Fig. 3: Two (out of twenty) unaliased slices, that were acquired with the double-banded version of SPIF-T_2, are shown. Robust activation in the motor (left) as well as the visual cortex (right) can be seen. Voxels with p-values ≤ .001, corresponding to 3.3σ, and cluster size threshold of 9 are highlighted.

Results ***(B_1-Shim)*** Whole brain B_1-shim for T_2-weighted fMRI can be accomplished efficiently. Good B_1 homogeneity and T_2 contrast (Fig. 2) are observed. The resulting power requirements stayed well within SAR limitations (between 42% and 83% depending upon subject). This indicates that a coil with segmentation along z offers substantially improved B_1 shim capability for applications involving volumes with large extension along z. ***(z-Encoding Coil)*** G-factors for double-band data sets (axial slices along z) were found to be between 1.16 and 1.31 for g_{mean} and 1.46 and 1.87 for g_{max} indicating good unaliasing capability for multi-banded data. ***(Multi-band data)*** Multi-band reconstruction requires both homogeneous B_1 over large volumes as well as good unaliasing capability along z for axial slices. The z-encoding transceiver array developed for this methodology is very well suited for both. ***(fMRI)*** Significant BOLD responses were detected in the visual- and motor-cortex (including primary sensorimotor cortex and supplementary motor area) using SPIF-T_2 (see Fig. 2 for the activation maps in both areas of the brain). The double-banded version of SPIF-T_2, where two slices (one in the motor cortex and one in the visual cortex) are acquired simultaneously has been demonstrated successfully (Fig. 3). Robust activation in the motor as well as the visual cortex can be seen (Fig. 3). Data acquisition speed has been increased by an additional factor of two.

Discussion Our initial results indicate that this integrated, multi-component approach does address major challenges for T_2-weighted fMRI at Ultra-High field and enables acquisition of T_2 weighted contrast in the entire, B_1 shimmed human brain. Moreover, the arrangement of the 16 channels in z provides additional encoding along that axis. It is ideally suited to acquire T_2-weighted fMRI with multi-banded axial slices. Data acquisition speed has been increased by an additional factor of two, as two slices are acquired at a time. The incurred penalty in SAR for double-banded pulses is more than compensated for by the low SAR feature of SPIF-T_2.

References: 1. Ritter, J. *et al.,*ISMRM 1548 (2009); 2. Van de Moortele, P.-F. *et al*., MRM 54:1503-18 (2005); 3. Yarnykh, VL. *et al.* MRM 57:192-200 (2007); 4. Van de Moortele, P.-F. *et al*., in Proc. 17th ISMRM: 367(2009); 5. Adriany, G. *et al.* in Proc. 15th ISMRM, p166 (2007) 6. Larkman, D.J. *et al*., JMRI 13, 313(2001); 7. Ritter, J. *et al.,*ISMRM 662 (2006),;

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