# Multi Slice Localized Parallel Excitation for EPI applications: first results in vivo

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**Introduction**

Echo-planar imaging (EPI) offers major advantages over conventional MR imaging due to its fast scanning speed and thus its ability to image rapidly changing physiologic processes [1]. However, applications of EPI in clinical and preclinical routine are often limited, as high sensitivity to B0 inhomogeneities and long minimum echo times (TE) may lead to strong ghosting and distortions on the reconstructed images. For example, B0 inhomogeneities from the Maxillary sinus may often result in artifacts overlapping with the medulla and brain stem (Fig. 1) and poor shimming in the abdomen can lead to the ghosts overlapping with the liver. These artifacts may be particularly severe in diffusion-weighted imaging, despite of the numerous sophisticated correction techniques.

The recently introduced method of parallel transmission made spatially selective excitation (SSE) applicable for realistic MRI protocols [2-4]. In previous works [5-6] parallel transmit SSE was combined with a reduced field of view (FOV) in the phase encoding (PE) direction, which allowed for a significant reduction of the echo train length, thus minimizing distortions in EPI. This imaging principle was demonstrated in phantoms for human DWI of the abdomen [6] and for rodent DWI of the brain [5].

The purpose of this study is to demonstrate this method in vivo on a system with a parallel transmit extension and thus investigate application of 2D parallel excitation combined with a reduced FOV in PE for multi slice DWI applications in the brain and abdomen.

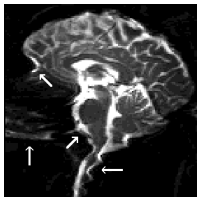

Fig.1. Sagittal SE-EPI image of the brain with residual distortions and ghost artifacts.

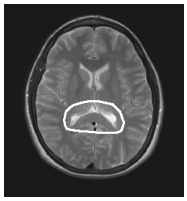

Fig. 2. Example of a ROI containing ventricles. The ROI is later cut into parallel bands (Fig. 3A).

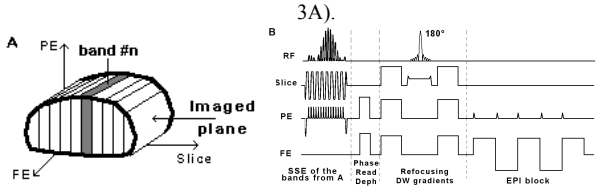


Fig. 3. Principle of the experiment. A. The sketch showing the bands excited. B. The corresponding sequence diagram. The 2D selective pulse in every TR corresponds to a new band from A.

**Methods**

The experiments in this work were carried out on 2 different human MRI scanners (both 3T SIEMENS MAGNETOM TRIO systems): 1) the brain imaging - on a scanner with an 8 channel TxArray extension combined with an 8 channel parallel transmit body coil; 2) the abdominal experiments - on a scanner with a standard single transmit channel.

As presented in [5-6] the following multi slice inner volume imaging (IVI) algorithm was used in order to avoid the magnetization saturation in SSE with multiple repetitions. In this method a set of parallel bands, constituting a region of interest (ROI, Fig. 2, 3A), is excited so that they are limited in the PE direction of subsequent EPI readout and extend across the whole object along the frequency encoding (FE, Fig. 3A), which is accomplished by playing out one of the excitation gradients on the slice axes (Fig. 3B). The bands are later refocused in the slice direction (Fig. 3B); hereby the band shift in the slice direction corresponds to the refocusing frequency. The imaging plane is thus the FE-PE plane, which is perpendicular to the one the ROI was defined in (Fig. 2, 3). In this manner a multi slice SSE-EPI method was applied for imaging the bands limited in PE.

The 2D pulses were calculated with the help of a small tip-angle algorithm combined with conjugate gradient-optimization using B1 maps for the central axial slice. As described in [6] the EPI excitation trajectories with the grid size 16 (PE) × 128 (FE) were preferred, since they allow for a smaller minimum band thickness with the system gradient limits. The field of excitation was 19.2 cm for the brain imaging and 38.4 cm for the abdominal imaging.

As it was impossible to simulate the SAR distribution produced by the multi channel transmit coil, very low power limits had to be set to obtain the IRB approval, which lead to lower transmit voltages for the shimming adjustments during the experiments and long repetition times (TR>10 sec) for the SE-EPI-sequence described above. The refocusing pulses of the SE-EPI-sequence were made 2 times longer to further decrease SAR, which resulted in longer minimum TE values. These limitations are not intrinsic to the described method and are solely due to the available hardware.

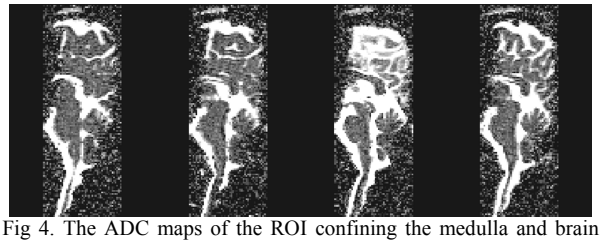

Fig 4. The ADC maps of the ROI confining the medulla and brain stem acquired on the system with the parallel transmit extension. The imaging parameters: band thickness = 3 mm, FOV = 20 cm (FE) × 7.5 cm (PE), matrix = 128 (FE) × 48 (PE), TE = 71 ms, TR = 10 s.

**Results and Discussion**

The resulting ADC maps for several bands excited in the brain are presented in Fig. 4. As can be seen, the present approach produced images of acceptable quality and it was possible to reduce the FOV in PE by a factor of 2.67, which allowed shortening of TE from 91 ms to 71 ms and in this manner minimized ghost and distortion artifacts in the brain stem and medulla, with the spatial resolution being kept the same. A better selective excitation of the bands can be easily accomplished with an improved shimming, which will be undertaken as soon as higher power limits become available for the system.

Due to the technical difficulties with synchronizing multiple RF channels with respiration and due to long TR values required for parallel transmission, the abdominal experiments were carried out on the standard system (Fig. 5). The FOV reduction in PE by a factor of 2 allowed for decreasing of the minimum TE from 82 ms to 66 ms and thus minimized the ghost and distortion artifacts inherent in conventional DWI of the abdomen (Fig. 5). As follows, the presented imaging principle produced abdominal ADC maps of a very good quality.

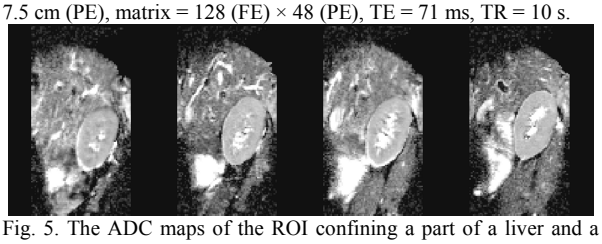

Fig. 5. The ADC maps of the ROI confining a part of a liver and a kidney obtained on the scanner with the standard single transmit channel. The imaging parameters: band thickness = 6 mm, FOV = 25 cm (FE) × 13.2 cm (PE), matrix = 128 (FE) × 68 (PE), TE = 66 ms, TR = 1.5 s.

**Conclusions and Outlook**

Parallel excitation in combination with the multi slice inner volume imaging concept was experimentally demonstrated in vivo and gives advantage to novel applications of EPI. Abdominal and brain DWI are clear examples of this method and will be investigated further, as soon as higher power limits and triggering methods for the TxArray become available.

**References**

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