Selective Excitation of Arbitrary Three-Dimensional Targets on a Human MR System using Parallel Transmit

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Introduction

Three dimensionally selective RF pulses for excitation of arbitrary 3D shapes, accelerated with parallel transmission (PEX) [1-3] have recently been demonstrated on small animal systems [4]. The advantages of single shot 3D volume selection include zoomed inner volume imaging, artifact reduction from sources outside the region of interest (ROI) [5] and reduction of partial volume effects in spectroscopy. In contrast to two-dimensionally selective excitation and subsequent perpendicular refocusing, regions adjacent to the ROI are not saturated when using 3D selective excitation, and in principle signal acquisition can start immediately after the end of the excitation pulse, i.e., the FID of a 3D ROI could be sampled.

In this work, the feasibility of single shot selective excitation of an arbitrary 3D shape, accelerated with 8-channel PEX is demonstrated in a watermelon on a human scanner. A reduced FOV experiment using these pulses is used to demonstrate the increase of imaging resolution without aliasing artifacts or increased measurement time.

Methods

The 3D target shape was defined as depicted in Fig. 1 on a Cartesian grid with 16^3 points on a field of excitation (FOX) of $(22\ \text{cm})^3$ containing the watermelon. Spatially selective RF pulses were designed in the small tip angle regime using a 3D "shells" transmit k-space trajectory [4], as shown in Fig. 2. Its total duration is 14.89 ms corresponding to an acceleration of 2.75. This was achieved using PEX based on a measured multi-slice B_1 map (Fig. 2 right), acquired with a pre-saturated turbo flash sequence [6]. The RF design algorithm [7] was extended to 3D and implemented in multithreaded GNU C++ linked to Matlab (The MathWorks Inc., Natick, MA) via mex. Typical pulse design times including three-dimensional B_0-maps and B_1-maps are about 30s on a dual core 2.6 GHz 64 bit Linux computer. Experiments were carried out on a 3 T human MR scanner (Siemens MAGNETOM Trio, A Tim System) with 8-channel TxArray extension and an 8-channel parallel transmit body coil, similar to [8], integrated into the system in place of the product body coil. A ~20 cm diameter watermelon was placed inside a standard 12-channel Siemens RX head coil. A 3D FLASH sequence modified for the use of arbitrary RF and gradient shapes was used with the parameters TR=21.1 ms, TE=10.1 ms, matrix=128x128x22, resulting in an acquisition time of 59 s. Full FOV settings were $(22\ \text{cm})^3$ (slice thickness=10 mm); reduced FOV was $(11\ \text{cm})^3$ (5 mm slices), resulting in a doubling of the resolution in each spatial dimension.

Results

The full FOV images in Fig. 3 show good excitation of the volume of interest and good suppression outside. The transition between regions of high and low signal appears smooth due to the lower TX resolution of $(1.4\ \text{cm})^3$/voxel compared to the in-plane acquisition resolution of 0.17 cm/pixel. The reduced FOV images (Fig. 4) show the result of the same measurement with only the FOV adjusted as illustrated in Fig. 3. Due to the good suppression no aliasing is observed. Fig. 5 shows the resolution gain by two in every direction of the reduced FOV experiment for equal measurement times.

Conclusion and Outlook

Spatially selective excitation of an arbitrary 3D shape in a single shot, accelerated with parallel transmit, has been demonstrated on a human MR scanner at 3 T. Then, reduced FOV imaging was shown to achieve an 8-fold increase in resolution while maintaining the measurement time. For planned studies in vivo a suitable fat suppression using dual-band RF as well as SAR evaluation are currently under investigation.

References [1] U. Katscher et al., MRM **49**, 144 (2003). [2] Y. Zhu, MRM **51**, 775 (2004). [3] P. Ullmann et al., MRM **54**, 994 (2005). [4] J. T. Schneider et al., Proc. ISMRM, p103 (2010). [5] J. T. Schneider et al., Proc. ISMRM, p4606 (2009). [6] H.-P. Fautz et al., Proc ISMRM, p1247 (2008). [7] W. Grissom et al., MRM **56**, 620 (2006). [8] J. Nistler et al., Proc. ISMRM, p1027 (2007).

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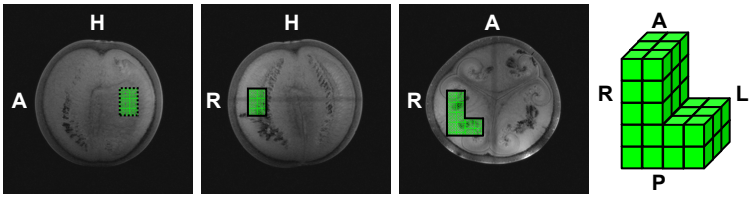

Fig.1: Localizer images of a watermelon (overlay indicates the excitation target region) and three-dimensional target shape, defined on a 16x16x16 grid encompassing the whole object.

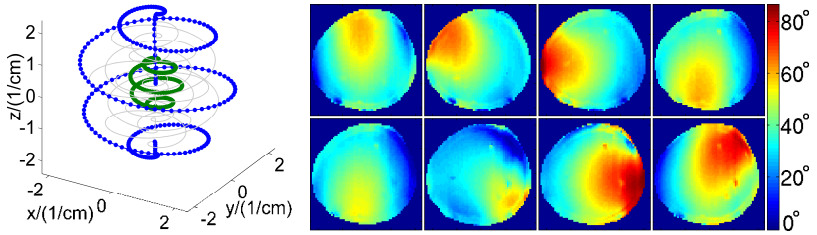

Fig. 2: Single shot 3D "shells" trajectory in TX k-space with 6 shells (first and fifth shells highlighted) and 4 revolutions each (left); central slice of a multislice 8-channel B1map (right).

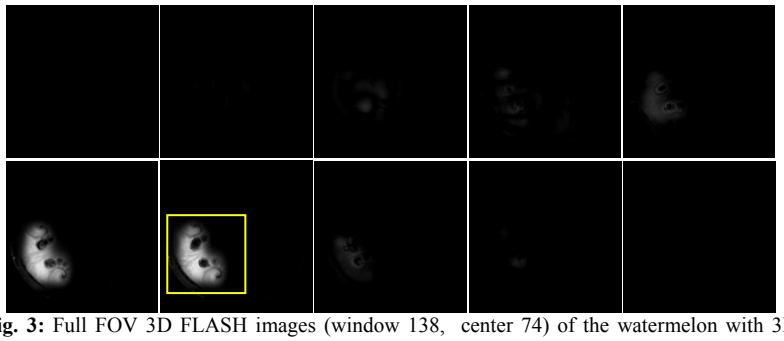

Fig. 3: Full FOV 3D FLASH images (window 138, center 74) of the watermelon with 3D selective excitation pulses. Every second out of 22 slices is shown. The yellow square marks the FOV for the reduced FOV measurement.

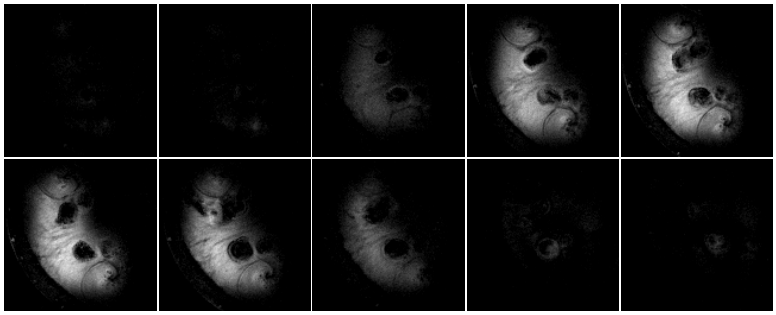

Fig. 4: Reduced FOV 3D FLASH images (window 136, center 79, every second out of 22 slices). The FOV extension is one half of the values used for Fig. 3 in all three dimensions.

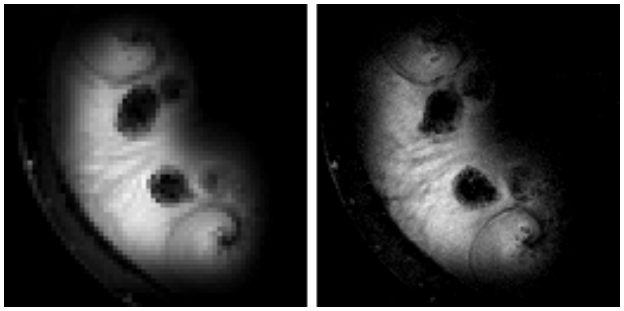

Fig. 5: Comparison of image resolution for one corresponding slice in full FOV (left) and reduced FOV (right) experiments. The full FOV image is zoomed (without interpolation) and cropped; both images are displayed on a 128x128 matrix.