Parallel excitation of a 3D ROI inside a post mortem brain

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Introduction

Spatially restricting the excitation of magnetisation to a desired volume is of enormous value for ROI imaging and spectroscopy. These excitations can be easily performed on slabs. The excitation of arbitrary shaped volumes involves expensive computations and is generally unfeasible for *in vivo* application as the computations are necessary with changing sensitivity maps and thus movement of the subject. This work demonstrates the excitation of a 3D ROI employing parallel RF transmission at 4T whilst the calculation time was reduced to just a few minutes. Excitation of arbitrary patterns in MRI is achieved by the simultaneous action of gradient and RF pulses. There exists thus far no analytical derivation of the appropriate pulse shapes. With the crucial simplification in the small tip angle regime (STA) [1], the transverse and longitudinal components of local magnetisation are decoupled to allow one to numerically approximate a near optimal solution for a chosen k-space trajectory of appropriate sampling density and dimension. Excitation of 3D patterns easily results in very long RF pulses of tens of microseconds; these pulses are problematic in two regards in the high and ultra-high field domains. On the one hand, SAR limits might be exceeded whilst on the other hand, T_2* decay might degrade the excitation pattern fidelity well within the excitation duration.

Materials and Methods

The Transmit SENSE formalism [2,3] extends the STA by engaging sensitivity maps of multiple transmit elements of a transmit array in very much the same way as it is done in PPI. In image domain the resulting excitation may be formulated in arbitrary units of contrast weighting as

$$\mathbf{p}_{xy} = \sum_{N} \mathbf{E}(\mathbf{s}_n(\mathbf{r}), \mathbf{k})\mathbf{b}_{1,n}$$

where $\mathbf{E}(\mathbf{s}_n(\mathbf{r}),\mathbf{k})$ represents the encoding matrix carrying the k-space trajectory and the sensitivity maps over the regions-of-interest. The incorporation of the sensitivity maps allows the undersampling of the excitation trajectories depending on their orthogonality, o(**r**), which is a function of spatial position. An 8-channel, 5.12 ms, 6.5-fold undersampled 3D spiral trajectory (Fig 1) was designed to suffice the Nyquist sampling theorem for a field of excitation of 256mm and an isotropic resolution of 6mm on a 32 cubic pattern matrix while the travelling speed along the k-space trajectory was to remain as constant as possible [4]. Coil sensitivity maps (Fig 2) where acquired with AFI [5] and recently suggested extensions [6]. Furthermore, B1DER [5] was used to reconstruct the excitation vector $\mathbf{b}_{1,n}$ on 1024 CPUs [7] within a few minutes.

Results

Lacking parallel transmit hardware at 4T, a pseudo parallel setup was investigated where a surface coil was positioned at 8 equidistant positions around the phantom container. b_1 maps where acquired for individual elements. The excited raw data was then superposed in post processing to reconstruct the excited pattern. A post mortem brain in formalin (dimensions) was used for measurement to zoom (reduce the field-of-view) into the limbic system without visible artefacts (Fig 3,4).

Discussion

The aim of this work was to extract an ROI representing an "anatomical structure" from a whole post mortem brain; the boundaries of this structure were to be defined as closely as possible to enable reduced FOV imaging or spectroscopy. Feasibility of this task was demonstrated with a 3D excitation by drastically reducing the computation time for the individual pulses with help of heavily parallel computer hardware. The experimental data were acquired with a setup with perfect decoupling. This is not the case with real parallel transmit hardware. Coupling between array elements will violate the orthogonality of the sensitivity maps and will thus limit the excitation acceleration factors achievable.

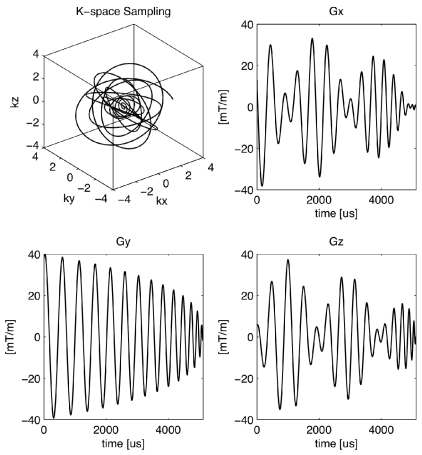

Figure 1: 6.5 fold undersampling 3D spiral trajectory

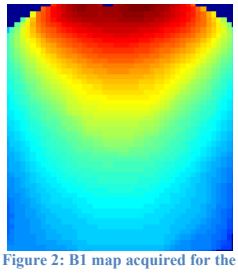

Figure 2: B1 map acquired for the surface coil at position 0

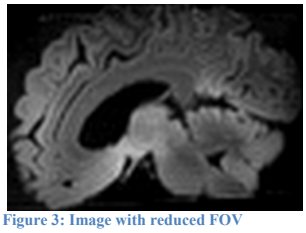

Figure 3: Image with reduced FOV

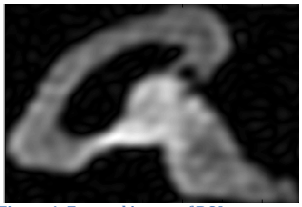

Figure 4: Zoomed image of ROI

[1] Pauly et al, JMR 81(1), 1989, pp42-53 [2] Katscher et al, MRM 49(1), 2003, pp144-50 [3] Zhu, MRM 51(4), 2004, pp775-84 [4] Block et al, JMRI 21(6), 2005, pp657-68 [5] Yarnykh. Magn Reson Med 57(1), 2007, pp. 192-200 [6] Nehrke et al. Magn Reson Med 61(1), 2009, pp. 84-92 [7] Vahedipour et al, ESMRMB 2009, Antalya, TR, pp161