2D and 3D Parallel RF Pulse Design for Inhomogeneity Correction and Volume Localization

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Introduction: Parallel RF excitation (1-3) offers the potential to directly address several important issues in high-field imaging, including RF inhomogeneity at high field strengths, and the selection or suppression of arbitrarily shaped imaging volumes. In this work we demonstrate three different designs of 2D and 3D spatially tailored RF waveforms and evaluate their performance in single-channel phantom imaging and simulation of 8-channel array incorporating experimental B1 field profiles. The RF pulses were developed for 1) accelerated 2D excitation with spiral trajectories on an 8 channel array; 2) slice selective B1 inhomogeneity compensation on a single channel with a "spokes" trajectory; and 3) slice selective B1 inhomogeneity compensation on an 8 channel array with an accelerated spokes trajectory.

Methods:

1) Accelerated RF pulses for the spiral trajectory were designed based on the image domain approach presented by Grissom (4). This method formulates the small tip approximation as $m(x) = i\gamma \sum_{r=1}^{R} S_r(x) \int_0^T b_{1,r}(t) e^{i\gamma x \bullet k(t)} dt$, where S_r and $b_{1,r}$ are the sensitivity profile and the RF waveform for coil r, and m is the desired profile. This can be rewritten into a matrix form, $m = Ab$, and solved by regularized pseudoinverse via SVD decomposition.

B_1-field maps collected with an 8-channel array (5) on a 3T parallel excitation system (6) were used to demonstrate the proposed design and the results were evaluated by numerical simulation of the Bloch equation. Spiral trajectory for a 20 cm FOV and 5mm resolution was used to design a square target of 3.2x3.2cm in-plane.

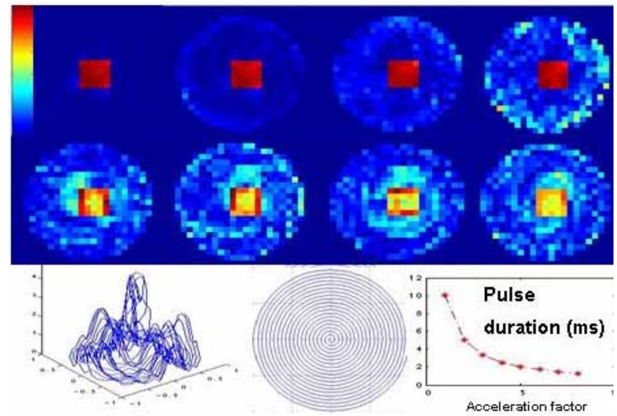

Fig 1 Profiles of square excitation, one RF waveform as a function of (k_x, k_y), k-space trajectory, and pulse length vs acceleration factor.

2) A method of 3D single-channel excitation to select a slice in *z* with B1 compensation in *x,y*, was demonstrated by Ulloa et al (7) and Saekho (8). We modified the proposed "spokes" trajectory to sample a spherical volume in excitation k-space, thus reducing the duration of the pulse at the cost of an insignificant increase in the sidelobe magnitude in *z*.

3) The single-channel slice selective pulse in 2) is 8ms long, which is too long for some applications. An alternative approach to achieve B1 compensated slice-selective excitation is to use parallel excitation with reduced RF duration by accelerating the spokes trajectory (i.e. with fewer spokes). The B1 maps from the 8-channel array were incorporated into our design of the slice-select RF with a flat target profile in-plane and the results evaluated by numerical simulation. We formulated the RF design in the same way as we did for the spiral in 1). However, for our coil array, the B1 profiles do not differ much in z, hence there is limited room for acceleration in z. Thus, for each spoke in z, we lay down a sinc RF for slice selection. The problem is then reduced to finding the RF magnitude of these sinc spokes for each coil, saving substantial computation time.

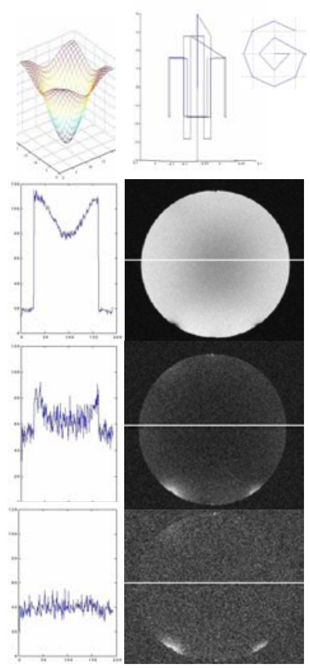

Fig 2 Gaussian dip profile for single-channel spokes trajectory with reduced peripheral kz extent. Images of 3T excitation of oil phantom at center slice and adjacent 2.5 mm thick slices.

Results and Discussion: For the spirals in 1), Fig 1 shows the resulting simulated profiles for acceleration factors of 1-8, showing progressively deteriorating performance. The excitation profile degradation may derive from a violation of the small tip angle approximation as larger tip angles are required for high acceleration.

Fig 2 shows the k-space trajectory and data collected at 3T of an oil phantom to demonstrate the 3D pulse for application 2) above, an in-plane Gaussian "dip" of 1/3 from peak during a 0.5cm thick slice selection.

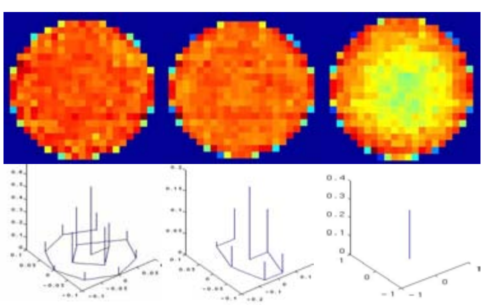

Fig 3 Simulation of flat target profiles with successively accelerated spokes trajectory.

For the accelerated spokes in 3), Fig 3 shows simulated in-plane profile for the 8-channel array for 8.3 ms (no acceleration), 4.9 ms (2X acceleration), and 1.2ms (DC only) pulses. Also shown are magnitude plots of the RF as a function of (k_x,k_y) for one of the 8 coils. Note that at 2X acceleration, the profile remains quite uniform.

Conclusion: Experimental results on a single-channel system, and simulated waveforms with measured B1 maps on an 8-channel array, suggest that multidimensional RF pulses can excite useful B1 profiles in clinically relevant excitation time.

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References: **1.**U. Katscher, et al. MRM 49:144-150,2003; **2.** Y.Zhu, MRM 51:775-784,2004; **3.** Ullmann, P MRM 54, p. 994, 2005; **4.** Grisson W, Proc. 2nd workshop parallel imaging 2004 p95; **5.** Alagappan V., et al "An 8 channel TX coil for TX Sense", submitted, ISMRM 2006; **6.** Fontius, U. et al, "A flexible 8-channel RF transmit system for parallel excitation", submitted ISMRM 2006; **7.** Ulloa J. et al, ISMRM, p. 21, 2005. **8**. Saekho S. et al, ISMRM, p.22, 2005.