Parallel RF Excitation Design and Testing with an 8 Channel Array at 3T

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Introduction

RF excitation in the presence of time-varying gradients for multi-dimensional selective excitation (1) offers several interesting applications, including flexibly shaped excitation volumes, and spatial modulation of the B1 profile to counter RF field inhomogeneity at high field. Due to limitations on gradient hardware, the pulse design can result in long waveforms that may limit the performance and applicability of such RF pulses. With parallel excitation design for coil arrays capable of simultaneous, independent RF transmission, the pulse duration can be shortened by taking advantage of variations in spatial excitation profiles among coils in the array (2-5).

We designed and tested low flip angle two-dimensional RF pulses for parallel transmission on an 8 channel array (6) constructed for a 3T Siemens Tim Trio scanner modified to handle 8 simultaneous independent RF transmit channels (7).

Methods

The RF pulse design was formulated with an image-domain approach (8) where the desired profile is assumed to be a linear combination of low flip angle excitation from each coil in the array, modulated by the B1 transmit profiles. B1 maps of individual coils in the 8-channel array were acquired by exciting one coil at a time with a non-selective pulse at a low flip angle and receiving with the system body coil. The RF design was based on the transverse B1 maps at the center of the excited volume.

Computation of waveforms used Matlab, and relied on an SVD-based pseudoinverse to solve for a low-flip-angle approximation of the 8 RF pulses, b, from Ab=m, where A is a matrix that contains the profile-weighted phase across space due to gradient encoding as well as RF coil profile, and m is the target profile (8). The pseudoinverse was supplied with a tolerance level to exclude contributions to the inverse from very low singular values. Computation time depended on the applied resolution in time and space, but was typically less than 3 minutes. The design of the two-dimensional excitation pulses employed spiral k-space trajectories in (*kx*,*ky*) subject to a slew rate and amplitude constraints of 170 T/m/s and 38 mT/m. The B1 maps were masked based on the magnitude of the combined coil maps, but were not otherwise fitted or filtered. Two target profiles were tested: 1) a "low-resolution" square with a 10-mm resolution and FOV=20cm, with duration 3.56 ms without parallel excitation acceleration and 1.8 ms with a two-fold acceleration; 2) a "high-resolution" square in *x* and *y* with a 5 mm resolution and duration of 5.03 ms with two-fold acceleration.

The RF pulses were used for simultaneous excitation of the 8 transmit channels and the resulting transverse magnetization was observed with the body RF coil using a 3D gradient-recalled echo sequence with TE=6ms, and 40 4-mm partitions in *z*. , The experimental profiles were evaluated on the central axial partition.

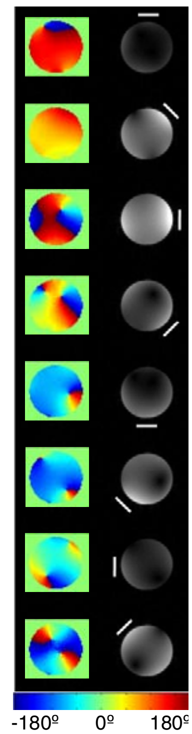

Fig. 1 Phase (left) and magnitude (right) of array coil maps. Coil locations are indicated (white).

Results and Discussion

Fig 1 shows experimental phase and magnitude profiles of the acquired B1 maps. A variable amount of coupling among coils is visible. Fig 2 shows the experimental profiles (top row) for the low resolution square without acceleration, with two-fold acceleration, and the high-resolution square with two-fold acceleration. The bottom row shows the numerically predicted profiles obtained during the design by Bloch-equation simulation of the waveform on all 8 channels. The experimental results agree with the predicted profiles of the excited central square, but the accelerated profiles display artifacts near the edges of the phantom, likely due to incomplete signal cancellation among the coils in those regions. While the simulated profiles show some degree of enhancement near the edge of the phantom, the experimental data exaggerate those artifacts.

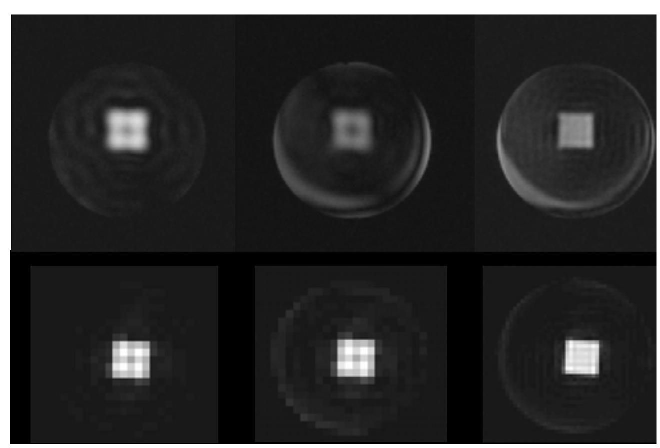

Fig 2. Top row: Acquisition of two-dimensional excitation for a low-resolution square without acceleration (left), two-fold acceleration (center), and a high-resolution square with two-fold acceleration (right). The bottom row shows simulated profiles.

Conclusion

Accelerated and non-accelerated spatially tailored RF pulses were designed and tested on an 8-channel transmit system to demonstrate multi-dimensional selective excitation pulses.

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References 1. Pauly, J. et al, JMR, 81, **2.** Katscher, U. et al, MRM. 49, p 144, 2003; **3.** Ullmann, P MRM 54, p. 994, 2005; **4.** Zhu, Y et al, ISMRM, p. 14, 2005; **5.** Zhu, Y et al, MRM,. 51, 775, 2004; p. 43, 1989; **6.** Alagappan V., et al "An 8 channel TX coil for TX Sense", submitted, ISMRM 2006; **7.** Fontius, U. et al, "A flexible 8-channel RF transmit system for parallel excitation", submitted ISMRM 2006; **8.** Grisson, WA et al, ISMRM, p. 19, 2005.