The use of coil sensitivity variations in the read-direction for improved parallel imaging

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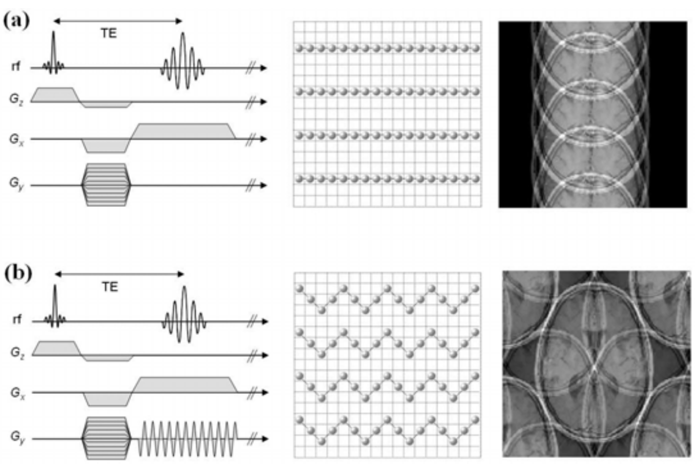
Introduction: In all previous parallel imaging techniques, sensitivity variations have only been exploited in the direction in which undersampling is performed. Thus, potential sensitivity variations in the read-out direction are unused in parallel imaging reconstruction. Therefore, an alternative strategy is required to take advantage of sensitivity variations in the read-out direction provided by the coil array. In contrast to conventional read-out trajectories (Fig. 1a) read-out samples can be shifted in the phase encoding direction by employing rapidly oscillating phase encoding gradients during the actual read-out process (see Fig 1b), thereby creating 2D CAIPIRINHA-type sampling patterns [1]. This type of sampling additionally modifies the appearance of aliasing in the read-out direction, thereby exploiting additional sensitivity variations in the read-out direction, resulting in improved reconstruction performance yielding better image quality.



Methods: Starting from a fully encoded gradient echo in-vivo head experiment (1.5T Symphony, 8 channel head coil array, Siemens, Erlangen, Germany), various reduced sampling patterns showing different zig-zag trajectories were simulated by simply removing unwanted sampling points from their sampling position. While all sampling positions in this work lie on a Cartesian grid, other trajectories using non-Cartesian sampling could also be used. The parallel imaging reconstructions were performed using an adapted Cartesian GRAPPA [2] reconstruction algorithm.

Figure 1: (a) Schematic pulse sequence (left) of a conventional accelerated parallel imaging experiment with normal read-out trajectory and corresponding aliased image. (b) Pulse sequence with oscillating phase encoding gradients during the read-out process resulting in a zig-zag trajectory (middle) and the corresponding image showing modified aliasing conditions (right).

Results: In Fig. 2 the reconstruction performance of various R=4 undersampled sampling patterns using different zig-zag trajectories are displayed. It is obvious that shifting sampling positions by an amount Δ in the phase encoding direction from their original position results in significantly improved image quality after parallel imaging reconstruction is performed. All zig-zag like sampled experiments result in significantly improved image quality compared to conventional undersampled data. Image (c) shows best image quality, but requires highest gradient performance. While (b) and (d) share the same gradient requirements the latter performs better, because the maximum shift achieved is 2 Δk , thereby exploiting sensitivity variations more efficiently.

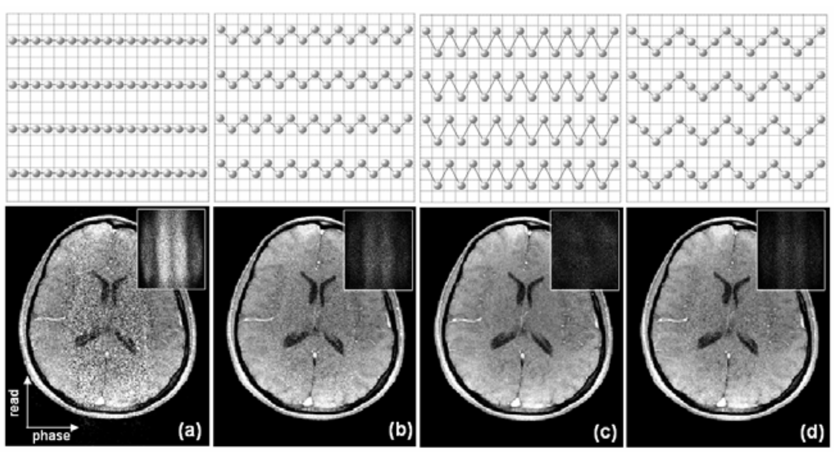


Figure 2: GRAPPA reconstructions after accelerated (R=4) (a) conventional sampling and various zig-zag sampling trajectories (b,c,d). In the right corner the difference to the fully encoded reference image is given in each case.

References:
[1] Breuer F et al. MRM 2005, [in Press]
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Discussion: Although no real zig-zag trajectories were acquired, the simulation results presented here indicate the great benefit of this approach. The zig-zag-type sampled experiments shown here share the same number of excitations and read-out samples and therefore provide the same root SNR. Thus, improved image quality (lower noise enhancement) is achieved by a more efficient usage of the sensitivity information. It is clear that this type of zig-zag sampling requires very fast gradient switching times even for sequences with moderate acquisition bandwidths. However, in previous work, such zig-zag read-out trajectories have already been implemented on modern scanners equipped with accurate gradient systems [3]. Using this concept, sensitivity variations are exploited in two (compared to one) spatial dimensions in conventional single-slice imaging and in all three dimensions (compared to two) in volumetric parallel imaging, yielding improved image reconstruction quality.