Self-calibrating Cartesian Parallel MRI using Continuous Sampling Sequences

M. Blaimer[1], C. A. Bookwalter[1,2], K. J. Barkauskas[1,2], J. L. Duerk[1], and M. A. Griswold[1]

[1]Department of Radiology, University Hospitals of Cleveland and Case Western Reserve University, Cleveland, Ohio, United States, [2]Department of Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio, United States

Introduction: Reconstruction algorithms for Cartesian parallel imaging require reference data that satisfy the Nyquist criterion along the phase-encoding (PE) dimension. The reference data is commonly acquired by an additional low-resolution 3D experiment prior to the clinical examinations. In other approaches, a small number of fully sampled k-space lines (auto-calibration signal, ACS) are additionally acquired directly in front of, during or directly after the accelerated experiment. In this work, we describe a novel approach for obtaining the reference data during accelerated Cartesian MRI experiments by simply extending the acquisition window. This eliminates the need for a pre-scan or additionally acquired ACS lines.

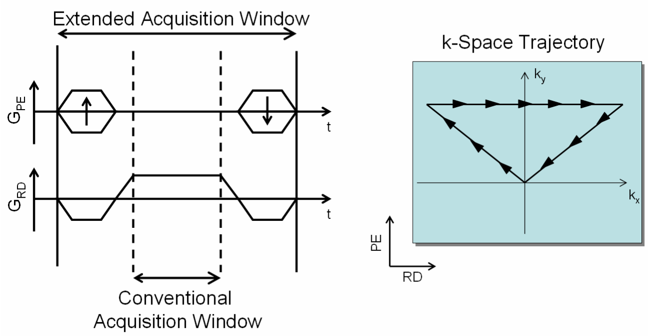


Figure 1: Sequence diagram of a Cartesian continuous sampling sequence and corresponding k-space trajectory

Theory: For radial steady-state free precession (SSFP) sequences, it has been shown that for a given repetition time the SNR can be enhanced by extending the acquisition window [1]. Recently, this continuous sampling idea has been extended for Cartesian MRI sequences [2]. By extending the acquisition window, data is acquired throughout the duration of imaging gradients. Overlapping PE and readout gradients yields a Cartesian/radial hybrid (broad oversampling with time efficiency, BOWTIE [3]) trajectory (Fig 1). The radial parts satisfy the Nyquist criterion in some regions even if the Cartesian part is undersampled along the PE direction. After gridding the radial part onto a Cartesian grid, it can be used as ACS data for a GRAPPA reconstruction process (Fig 2, bottom left). After the calibration, missing data points in the under-sampled Cartesian part can be reconstructed (Fig 2, bottom right) to obtain an artifact-free image.

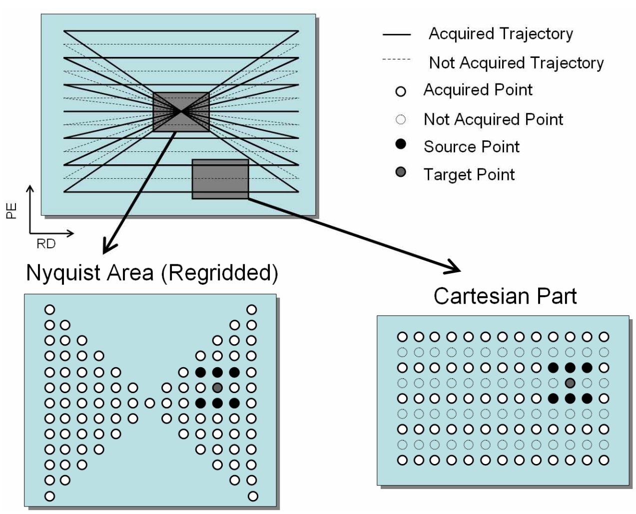
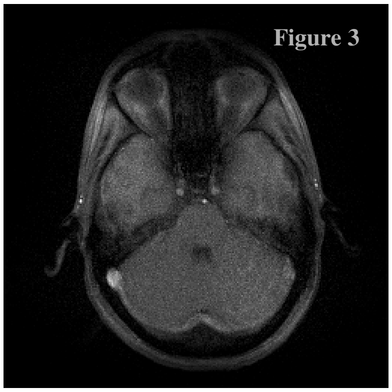


Figure 2: GRAPPA reconstruction scheme using Cartesian continuous sampling sequences.

Methods and Results: A gradient-echo based BOWTIE sequence was implemented on a 1.5 T scanner (Siemens, Erlangen, Germany) equipped with a 12-channel head coil array. Two-fold accelerated experiments were performed on an asymptomatic volunteer. Image reconstruction was implemented according to Fig 2. The radial part was convolution gridded onto a Cartesian grid and then used to compute coil weighting factors for a GRAPPA reconstruction. The coil weighting factors were then applied to reconstruct missing data in the Cartesian part. Figure 3 shows an in vivo result from a two-fold accelerated experiment reconstructed with GRAPPA. No extra pre-scan or additional ACS lines have been used to calculate the reconstruction parameters.



Discussion and Conclusions: By extending the acquisition window in an accelerated Cartesian MRI experiment, additional information is obtained that can be used as reference data for a parallel imaging reconstructions. Therefore, no extra pre-scan or additional ACS lines are necessary allowing a robust parallel imaging performance. This approach can easily be extended to balanced SSFP and RARE/TSE sequences.

References: [1] Winkelmann S et al. IEEE Trans Med Imaging. 2005;24:254-262. [2] Bookwalter CA et al. Proc 13th Meeting of the ISMRM, Miami Beach, FL, USA, 2005: Abstract 2371.[3] Bookwalter CA et al. Proc 14th Meeting of the ISMRM, Seattle, WA, USA, 2006: Abstract 2439.