On Temporal Filtering Effects caused by the subtraction of temporal average in Dynamic Parallel MRI

I. P. Ponce[1], M. Blaimer[2], F. Breuer[2], P. M. Jakob[1,2], M. A. Griswold[3], and P. Kellman[4]

[1]Experimental Physics 5, University of Würzburg, Würzburg, Bavaria, Germany, [2]Research Center Magnetic Resonance Bavaria (MRB), Würzburg, Bavaria, Germany, [3]Department of Radiology, University Hospitals of Cleveland and Case Western Reserve University, Cleveland, Ohio, United States, [4]Laboratory of Cardiac Energetics, National Institutes of Health, National Heart, Lung and Blood Institute, Bethesda, Maryland, United States

Introduction: Parallel Magnetic Resonance Imaging (pMRI) can be used to speed up image acquisition and is therefore often applied in dynamic imaging studies where high temporal resolution is required to record rapid changes of the dynamic objects. Many pMRI techniques are based on a time-interleaved acquisition (k-t-sampling [1]) and allow dynamic imaging at high frame rates. In dynamic pMRI, missing information is reconstructed by incorporation of inherent spatial information from multiple receiver coils and prior knowledge about the dynamics of the object. In addition, to improve the SNR, the temporal average (also referred to as direct current, DC) is subtracted from the raw data so that only the dynamics of the object is reconstructed [2, 3]. In this work we demonstrate, that DC subtraction may lead to temporal filtering effects in form of signal nulls in the temporal spectra of the reconstructed images. A simple solution is presented, in which the DC is corrected by a GRAPPA reconstruction prior to subtraction from the raw data. In-vivo experiments demonstrate that the temporal filtering effects can be significantly reduced.

Theory and Methods: In contrast to a full data acquisition, the temporal frequency spectra DC component of a given pixel from an undersampled acquisition ($DC_{undersampled}$) becomes the sum of the desired DC component (DC_{full}) and the components caused by the alias, (see Figure 1 a).

$$DC_{undersampled} = DC_{full} + \text{Aliased components} \qquad (1)$$

When subtracting the $DC_{undersampled}$ component from the raw data signal nulls are generated and it is impossible to recover any information at these temporal frequencies [4] (see Figure 1 b). However, it is possible to estimate DC_{full} to avoid the signal nulls in the temporal spectra. Here we propose to estimate the DC_{full} by applying GRAPPA weights to the undersampled $DC_{undersampled}$ signal. This corresponds to a TGRAPPA reconstruction of the entire data set and then integrating over all time frames.

After subtracting the estimated DC_{full}, the remaining signal amplitudes will be the sum of the aliased components (see Figure 1 c) and can be unmixed using dynamic reconstruction methods [2, 3]. For demonstration, in-vivo gated cardiac cine experiments were performed on a 1.5 T clinical scanner (Siemens Medical Solution, Erlangen, Germany) using 32 receiver channels for data reception. A full FOV data set was acquired on healthy volunteers. This data set was retrospectively undersampled (R=4) and reconstructed with k-t SENSE with and without prior DC correction using a GRAPPA filter.

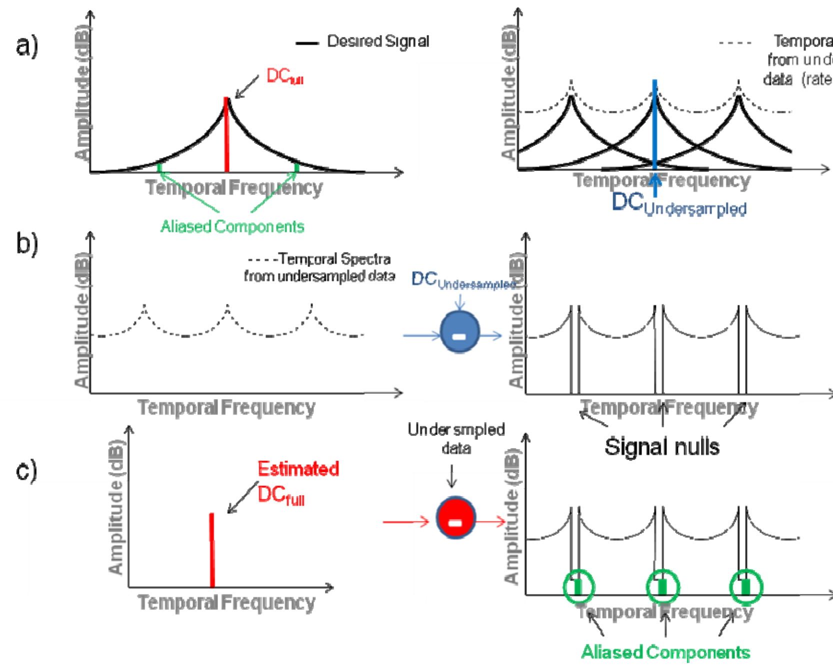

Figure 1. a) DC component of the temporal frequency spectra in the desired signal and in the undersampled signal. b) Subtracting DC component from the undersampled signal. c) Estimation of the full acquired dataDC component by GRAPPA and its subtraction from the undersampled signal

Results and Discussion: The cardiac imaging experiment results, Figure 2 b), demonstrate that the spectrum of the reconstructed data with GRAPPA filtered DC does not exhibit signal nulls and shows improved image quality. The error images Figure 2 a) show that reconstructions without DC filtering have both increased noise and temporal filtering effects, as demonstrated by the residual edges in the error image. It is important to note that the resulting error in the reconstruction without the GRAPPA filter is due to the temporal frequency spectra null signals and not an error caused by an over regularization, as demonstrated by the spectra in Figure 2 b).

In summary, the temporal fidelity (and hence the image quality) of the dynamic pMRI methods can be significantly improved when an adequate estimation of the true DC can be obtained. In this work, we have demonstrated that this can be achieved by an additional GRAPPA reconstruction of the DC obtained from the undersampled raw data.

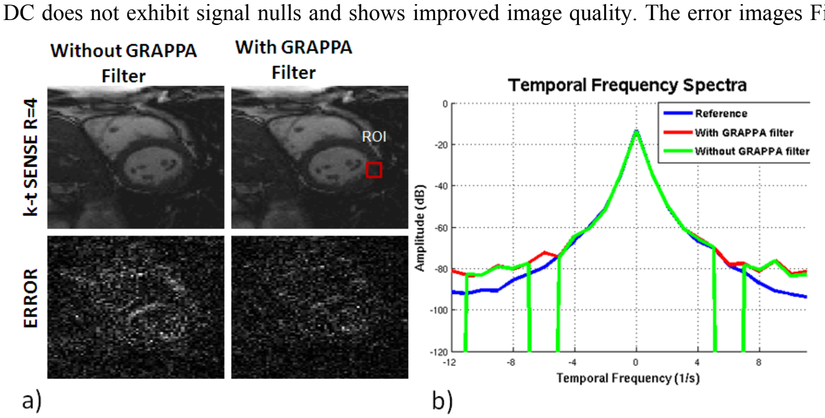

Figure 2. a) k-t SENSE reconstructions of one representative time-frame without (left) and with (right) corrected DC. b) Their Temporal spectra at the indicated ROI

References:[1] Madore B, MRM 2002; 48:493-501 [2] Tsao J. et. al., MRM 2003; 50:1131-1041 [3] Huang F., et. al., MRM 2005; 54:1172-1184, [4] Xu D.,et. al., MRM 2007;57:918-930.

Acknowledgements: I.P Ponce would like to thank CONACyT-DAAD for funding.