Temporal Filtering Effects in Dynamic Parallel MRI: Comparing Radial and Cartesian Sampling

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Introduction. In Auto-calibrated Dynamic Parallel Magnetic Resonance Imaging (pMRI), such TSENSE or kt-SENSE, the missing information is reconstructed using the spatial sensitivities of multiple receiver coils. The coil sensitivities are derived from the full FOV temporal average image (also known as direct current, DC) that is obtained by averaging the undersampled time frames. In Cartesian sampling, the averaging leads to aliasing artifacts and therefore to errors in the coil sensitivities estimates [2, 3]. As a result, the reconstructed images exhibit temporal filtering effects. In this work, we demonstrate that these temporal filtering effects are not significantly present in accelerated dynamic parallel MRI experiments using Radial sampling.
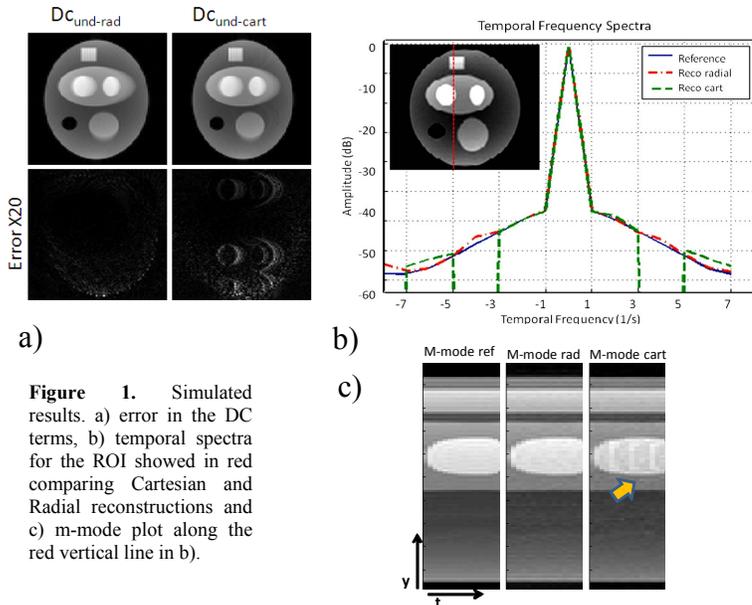

Figure 1. Simulated results. a) error in the DC terms, b) temporal spectra for the ROI showed in red comparing Cartesian and Radial reconstructions and c) m-mode plot along the red vertical line in b).
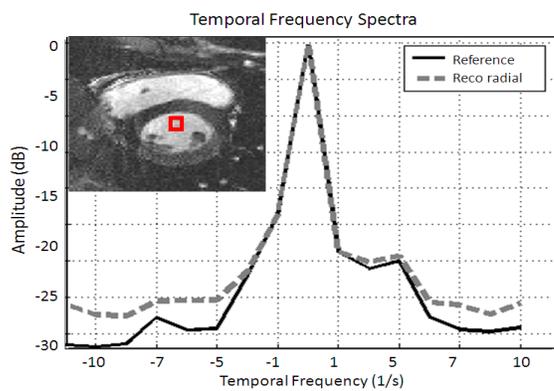

Figure 2. In-vivo results. Temporal frequency Spectra, for the ROI showed in red, comparing the fully sampled radial reference data with the CG-SENSE reconstruction.

Methods. It has been shown that in Cartesian interleaved acquisitions, the DC term from the undersampled data ($DC_{und-cart}$) will be the sum of the fully sampled DC (DC_{full}) and aliased components (DC_{alias}) [2,3]. The use of $DC_{und-cart}$ results in errors in the coil sensitivities and leads to temporal filtering effects in the reconstructed images. These filtering effects can be observed by the appearance of signal nulls in the temporal frequency spectra (Figure 1 b).

In contrast to Cartesian sampling, the incoherent aliasing artifacts generated by interleaved radial sampling do not significantly introduce errors in the DC image ($DC_{und-rad}$). Therefore, more accurate coils sensitivity maps can be computed and the reconstructed image series do not exhibit temporal filtering effects.

For demonstration, computer simulations using a synthetic phantom were used. In addition, fully sampled in-vivo radial cine experiments with 192 projections and 192 read out points per spoke were performed on a 1.5 T clinical scanner (Siemens Medical Solution, Erlangen, Germany) using 15 receiver channels for data reception on healthy volunteers. Cartesian and Radial data sets were retrospectively undersampled to yield interleave acquisitions (acceleration R=4 resulting in 32 (simulations) or 48 (in-vivo) projections) and reconstructed with TSENSE [1] and CG-SENSE [4] respectively. For the estimation of the coil sensitivities the DC term from the undersampled data ($DC_{und-cart}$ and $DC_{und-rad}$) were used.

Results. The DC terms of simulated data with Cartesian (32 phase encoding lines) and Radial undersampled (32 projections), $DC_{und-rad}$ and $DC_{und-cart}$, were compared with the DC_{full} of the fully sampled reference data (Figure 1 a). The errors in $DC_{und-cart}$ illustrate the aliased components apparent in Cartesian sampling; on the contrary the $DC_{und-rad}$ that was obtained from the undersampled radial sampling suggests a good estimate for DC_{full}. The temporal frequency spectra for both reconstruction methods, Cartesian and Radial, were compared with the fully sampled reference data. As expected, the signal nulls due to the DC estimation appeared in the temporal spectra of the Cartesian reconstruction (Figure 1 b). The artifacts can be seen in the reconstructed image (Figure 1 c).

In-vivo results confirm the theory and the simulated results. Signal nulls cannot be observed in the temporal frequency spectra for radial acquisition (Figure 2). SNR loss due to parallel imaging or residual artifacts is apparent at higher temporal frequencies.

Conclusions. The quality of the reconstructions in auto-calibrated dynamic parallel MRI using SENSE depends on the estimation of the coil sensitivities. In contrast to Cartesian sampling aliasing artifacts in the DC from interleaved radial acquisitions are not significant. Therefore, a better reconstruction quality and temporal fidelity can be achieved in radial MRI.

References. [1] Kellman P. et al., Magn Reson Med. 2001, 45(5):846-52. [2] Kellman P, et al. ISMRM 2009, #2732 [3] Ponce I., et al. ISMRM 2010, #2933 [4] Pruessman, et al., Magn Reson Med. 2001, 46(4), 638-651.