# Comparing k-t SENSE and Auto-Calibrating k-t SENSE Transfer Functions

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**Introduction.** Many reconstruction methods in Dynamic Parallel Magnetic Resonance Imaging (pMRI) aim to speed up acquisitions and reconstructions with high temporal and spatial resolution. Compared to the conventional k-t SENSE [1] approach, Auto-Calibrating k-t SENSE [2] saves acquisition time. In this work, the performance in the temporal frequency of conventional and Auto-Calibrating k-t SENSE was evaluated using the 2-D Modulated Transfer Function (MTF) proposed in [3].

**Theory.** The 2-D MTF represents the characterization of a given system in k-f space [3]. In other words, the MTF is an approach that reflects the relationship between the input and the output of an imaging method. In general, the transformation of the truth data (object) during the acquisition and reconstruction process can be seen as: $\hat{\rho} = H\rho + \hat{\eta}$ (1) where $\hat{\rho}$ is the reconstructed data expressed in $(kx, ky, f)$ $\rho$ the truth data and $H$ represents the transformation from the truth object to the image. Considering the reconstruction at each pixel: $\hat{\rho}_i = H_{ii}\rho_{ii} + \sum_{j;i\neq j} H_{ij}\rho_j + \hat{\eta}_i$ (2), where $H_{ii}$ are the coefficients of MTF and the terms $H_{ij}$ represent the artifacts produced by remnants of aliased spatial and temporal frequency pixels that the reconstruction method may not be able to separate. As in eq. (1) $H$ is not known, in order to calculate the MTF and quantify the artifacts, a perturbation approach has been proposed [3]. Here, small perturbations (k) are added to the truth data $\rho_k$. These data are subsequently undersampled and reconstructed: $\hat{\rho}_{p,k} = B_k(\rho_k + P_k) + A_i = B_k\rho_{p,k} + A_k$, where $B_k$ represents the $H_{ii}$ coefficients and $A_k$ the reconstruction artifacts. Both parameters can be determined using linear regression. Figure 1 describes the general process of the MTF calculation. Perfect imaging methods have a homogeneous MTF equal to 1 which means that no filtering effects are produced by the reconstruction technique.

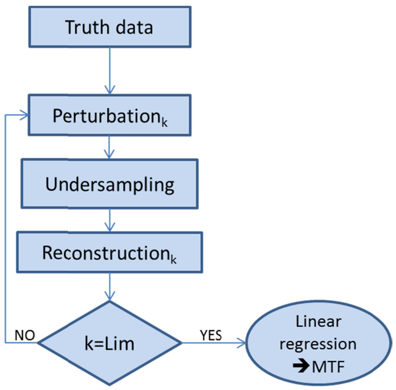


**Figure 1**. MTF calculation process.

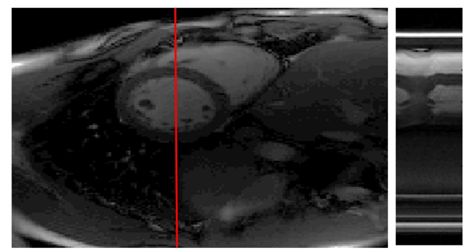

**Figure 2**. Truth data (left) and m-mode (right) plotted along the red line.

**Methods.** 2-D MTF's were calculated in order to compare the ability of conventional and Auto-Calibrating k-t SENSE of mapping each pixel in the k-f space. Fully sampled (matrix size 192x148) in-vivo Cartesian cine data of a healthy volunteer were acquired on a 1.5 T clinical scanner (Siemens Medical Solution, Erlangen, Germany) using a 32 channel receiver array. After adding 20 different linearly increasing perturbations, the data were retrospectively undersampled (acceleration R=4) and subsequently reconstructed with k-t SENSE [1] and Auto-Calibrating [2] using three different regularization parameters ($\lambda = 1e-3, 1e-2, 1e-1$). For the calibration of conventional k-t SENSE, both 11 central lines as well as the full k-space were used. The 2-D MTF's as well as the noise enhancement were calculated following [3].

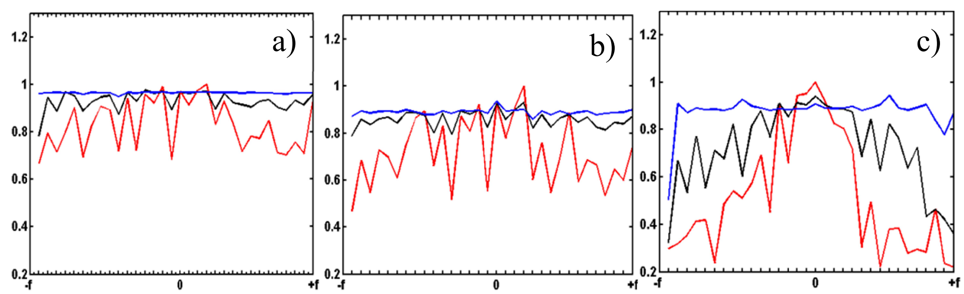


**Figure 3.** a) MTF mean of conventional k-t SENSE using the perfect training data (full k-space) and $\lambda = 1e-3$ (blue line), $\lambda = 1e-2$(black line) and $\lambda = 1e-1$ (red line) b) MTF of Auto-Calibrating k-t SENSE, using $\lambda = 1e-3$ (blue line), $\lambda = 1e-2$(black line) and $\lambda = 1e-1$ (red line) and c) MTF of conventional k-t SENSE using training data of 11 central lines and $\lambda = 1e-3$ (blue line), $\lambda = 1e-2$(black line) and $\lambda = 1e-1$ (red line).

**Results and Discussion.** Fig. 2 shows the truth data used as demonstration. Fig. 3a)-c) show the mean value of the MTF through the ky-space.It is remarkable the lower values of MTF's at higher frequencies in fig. 3c). Fig. 4 shows the mean value of the noise measurements.

**Conclusions.** In this work it was shown that Auto-Calibrating and conventional k-t SENSE using full FOV as training data yield similar 2-D MTF while conventional k-t SENSE with limited amount of training data presents filtering effects at higher frequencies. Furthermore, the noise in Auto-calibrating k-t SENSE is comparable to the noise in conventional k-t SENSE using limited training data except for the rapid increase of noise in the area of the aliased temporal frequencies.

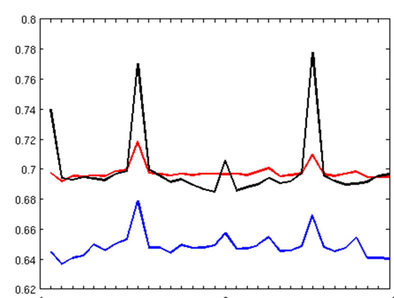

**Figure 4**. The red, black and blue lines are mean signal of the noise enhancement of conventional k-t SENSE using 11 training central lines, Auto-Calibrating k-t SENSE and k-t SENSE using full k-space training data respectively.

**References**. [1].Tsao J., Boesiger P., et al.. Mag Reson Med 2003; 50:1031-42 [2] Ponce I., et al. ISMRM 2008, #2828 [3] Chao T., et al., Mag Reson 2010; 63:407–418.

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