Continuously moving table SENSE imaging with exact reconstruction using a 16-coil array

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Introduction

Recently, combinations of continuously moving table (CMT) MR imaging with parallel imaging techniques have been introduced [1,2,3], mainly driven by applications in peripheral angiography, where fast and high resolution imaging is required to follow an injected bolus. For high acceleration factors, a large number of coils with complementary sensitivities is needed for simultaneous signal reception in the FOV. Therefore, it can be attractive to fix a receive coil array inside the MR magnet bore, which covers an arbitrarily large imaging region during the table motion. For such a coil array not fixed to the patient, standard parallel reconstruction schemes are not directly applicable. Approximations have been introduced [1], which are restricted to large coil dimensions in the direction of table motion. In this work, an exact reconstruction method is introduced which ensures that the coil sensitivity is correctly accounted for at any table position. Hence, a receive coil array with arbitrary coil dimensions is applicable in CMT parallel imaging. Corresponding results are demonstrated with *in vivo* SENSE measurements using a 16-coil receive array.

Methods

For an exact CMT SENSE reconstruction, individual coil data are first arranged in hybrid space [4] according to the respective position of the table. A total encoding matrix E is set up for the signal m^{hyb}_i in each line i of hybrid space. It is composed of sensitivity values s_γ according to the coil γ and time of data reception t_κ and includes the Fourier encoding term exp(i**kr**):

$$m^{hyb}_{i,\gamma,\kappa,\lambda} = \Sigma_\lambda \; E_{i,\gamma,\kappa,\lambda} \, \rho_{i,\lambda} \qquad (1)$$

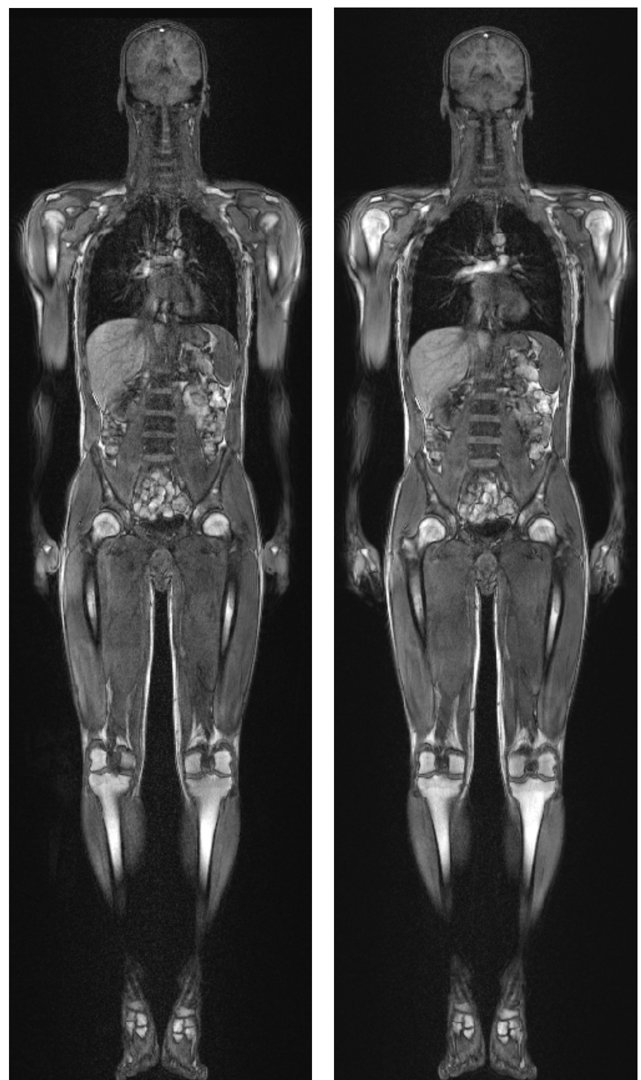
$$E_{i,\gamma,\kappa,\lambda} = s_\gamma(\mathbf{r}_{i,\lambda} - \mathbf{v}\, t_\kappa)\, e^{i\, \mathbf{k}(t_\kappa)\, \mathbf{r}_{i,\lambda}} \qquad (2)$$

Here, **v** denotes the table velocity, $\mathbf{k}(t_\kappa)$ the phase encoding step and $\rho_{i,\lambda}$ the signal density in line i at the lateral position λ. The encoding matrix is not separable for sensitivity encoding and Fourier encoding because of the explicit time dependence and has to be fully inverted. Pseudo-inverse matrices are computed using LU-decomposition, and equation (1) is solved line by line for the signal density.

To validate this approach, measurements on healthy volunteers were performed on a Philips Achieva 1.5 T MR system (32 receiver channels) using 3D gradient echo sequences. The patient support was driven at constant speed ranging from v=20 to 60 mm/s, depending on the SENSE reduction factor, which could be chosen between R=1 and R=3 in the R/L direction. An array consisting of 16 quadratic coils (10×10 mm^2) was mounted on a frame in the upper half of the magnet bore. Coil sensitivities were determined in reference scans at selected body regions prior to the head-to-toe examinations. Typical parameters for the experiments are a total imaging time of 42 seconds at v = 47 mm/s for an enlarged FOV of $2000 \times 512 \times 80$ mm^3 (matrix $1000 \times 256 \times 8$) and a reduction factor of R=2 (TR/TE: 3.7/1.8 ms, α=15°).

Results and Discussion

Good image quality and homogeneous intensity could be achieved throughout the whole body. Figure 1 shows two selected slices out of two 3D head-to-toe continuously moving table SENSE measurements with reduction factors of R=2 (a) and R=1 (b) for comparison. Due to the fast scanning, a breath-hold could be performed, and the diaphragm and liver are sharply imaged. Except for the slightly reduced SNR, the accelerated image quality (R=2) is not degraded. Only minimal local fold-over artifacts can be detected, which could be even further reduced if loading effects are considered for the coil sensitivity. At acceleration factors of R=3 (or higher) in R/L direction, image quality is decreasing due to a sub-optimal coil geometry. A coil array including posterior coils would allow for much higher acceleration using 2D SENSE.



(a) (b)

Figure 1: Selected slices of 3D continuously moving table SENSE measurements using 16 receive coils and a reduction factor R=2 (a) or R=1 (b). Imaging time is 42 seconds (v = 47 mm/s) and 85 seconds (v = 23.5 mm/s), respectively.

Conclusion

Continuously moving table SENSE imaging has been extended for arbitrary stationary coil arrays and strong sensitivity variations in motion direction. Good image quality is successfully demonstrated with *in vivo* measurements with 16 receive coils using exact reconstruction. Important clinical applications are expected in whole body cancer screening and peripheral angiography.

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References

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