Parallel imaging performance of 16 channels dedicated breast coils at 3T

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Purpose

In recent years, parallel imaging has revolutionized breast MRI. Faster scanning has allowed for more accurate evaluation of contrast kinetics in the breast. However, even faster acquisition times are needed in order to quantitatively assess tissue perfusion and permeability in DCE (dynamic contrast-enhanced) MRI [1, 2]. Parallel imaging factors higher than 3 are rarely used in clinical practice, while higher factors would allow for increased acquisition speed. Improved coil technology and higher magnetic field strengths help overcome the SNR penalty of higher acceleration factors. The goal of this work is to quantitatively assess the parallel imaging (PI) capability of a 16 channel breast coil at 3T.

Methods and Materials

The g-factor in sensitivity encoding (SENSE) PI

The availability of an optimized coil array is an essential prerequisite for parallel imaging techniques, as PI makes use of differences in the spatial sensitivity distribution of receiver coil elements to reduce the number of necessary phase-encoding steps required for magnetic resonance imaging, thus shortening the scan time. Most commonly used PI algorithms are SENSE, SMASH and GRAPPA [3] and are subdivided in two domains (k-space/image-space) in which processing is mainly performed. For this project we used the SENSE method described as an image domain reconstruction technique. The reconstruction of images acquired by parallel imaging require the resolution of an inverse problem, and the g-factor appearing as a consequence of the resolution describes the ability with the used coil configuration to separated pixels superimposed by aliasing. In practice it is a rough estimate of the noise amplification in the spatial domain, and is related to the SNR_p of SENSE reconstructed images and the SNR_f, which would be obtained without acceleration, by

$$SNR_p = \frac{SNR_f}{g_p \cdot \sqrt{R}}$$

Fig.: Relation between SENSE SNR and non-accelerated SNR
References: Pruessmann et al. Magn Reson Med 1999; 42:952-62.
where R denotes the acceleration factor and g_p is the g-factor. Therefore an optimization of g_p would be beneficial in term of SNR. The calculation of g_p is done from [4]

$$g_p = \sqrt{[(S^H \psi^{-1} S)^{-1}]_{p,p} (S^H \psi^{-1} S)_{p,p}}$$

Fig.: g-factor equation
References: Pruessmann et al. Magn Reson Med 1999; 42:952-62.

where S is the $n_c x n_p$ sensitivity matrix, S^H is the transposed complex conjugate of S and # is the $n_c x n_c$ noise covariant matrix, n_c is the number of channels and n_p is the number of overlapping pixels.

High-sensitivity 16 channels breast coils

A 16 channel variable coil geometry breast imaging system (Sentinelle Medical, Toronto, Canada) consists of coils embedded in a fixed medial coil housing and two L/R and A/P adjustable lateral coils, figure 1.

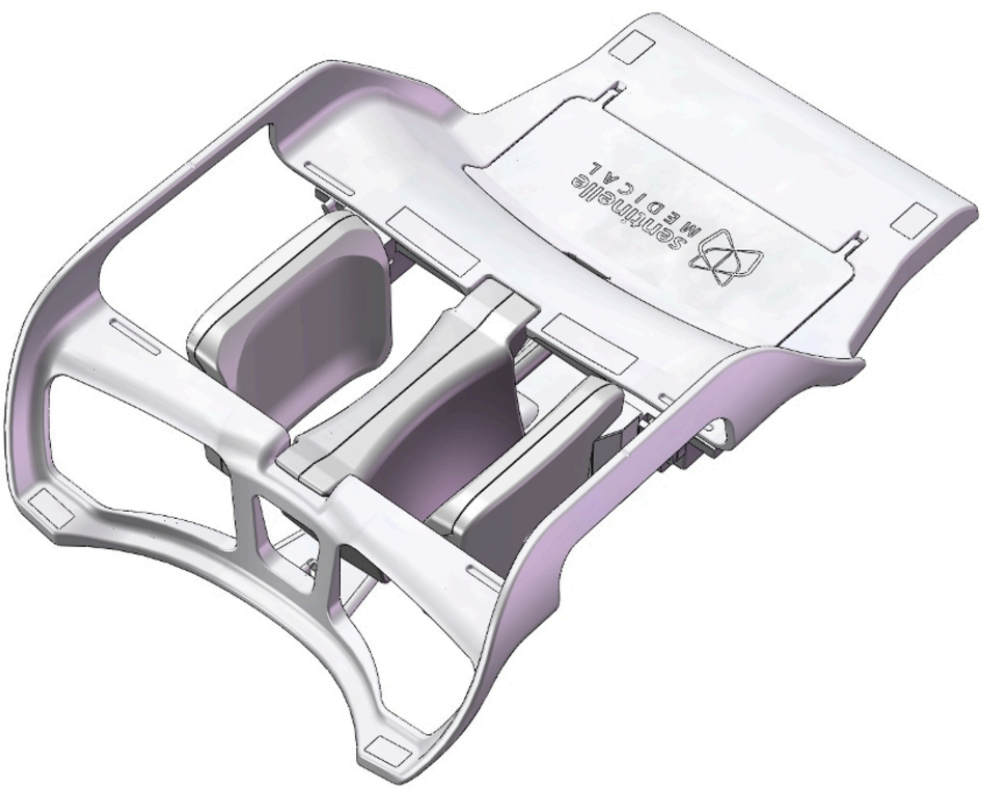


Fig.: 16 channels variable geometry coil system design to accommodate a range of breast sizes and shapes. The coil can be adjusted in the LR and AP direction.

References: Sentinelle Medical, Sentinelle Medical - Toronto/CA
The two lateral coils can be moved to gently compress the breast tissue during scanning. This serves to immobilize the breasts during acquisition to minimize motion artifacts and also to reform the breasts to fit into the most sensitive volumes of the coil. These adjustable coils have been shown to provide high SNR and perform well for SENSE acceleration [5].

Customized phantom

A breast shape-like phantom was designed and manufactured to fit within the 16 channel coil array (figure 2), and to represent average breast dimensions as determined by measurements performed on a sample of previous breast images. The choice of the phantom design was important in that it had to be of a shape that was appropriate for realistic breast imaging. The phantom simulates both breasts and a chest wall component and was chosen to emulate bilateral imaging.

Fig.: Customized phantom designed to mimic the breast shape
References: Sentinelle Medical, Sentinelle Medical - Toronto/CA

The phantom was filled with distilled water doped with $MnCl_2$ at a concentration of 0.245mM to achieve a T_1 relaxation time of approximately 500ms, as well as NaCl at a concentration of 150mM to simulate the conductivity of breast tissue and give realistic coil loading.

Phantom scans were used to generate g-factor maps for quantitative evaluation of parallel imaging performance. Coil sensitivity data was acquired using an axial 3D SPGR sequence (FOV=36x36cm, matrix: 64x64x86, TR/TE/# = 6.4ms/3.0ms/15^o, BW = 31.25 kHz). RF excitation was disabled for noise coupling measurements using 2D SPGR (matrix: 256x256, BW = 31.25 kHz). Various degrees of acceleration were simulated by sub-sampling the original data in the LR and SI directions.

3D SPGR volunteer images were obtained using: TR/TE = 4.5/2.0ms, # = 12^o, BW = 167 kHz, FOV = 35 cm, 124 slices, 1.4 mm slice thickness, matrix = 320x320, and IDEAL fat suppression. The coils were tested on a 3T scanner (General Electric Inc. Waukesha,WI). All data were analyzed off-line using Matlab (Mathworks Inc. Natick, MA).

Images for this section:

$$SNR_p = \frac{SNR_f}{g_p \cdot \sqrt{R}}$$

Fig. 0: Relation between SENSE SNR and non-accelerated SNR

$$g_p = \sqrt{[(S^H \psi^{-1} S)^{-1}]_{p,p} (S^H \psi^{-1} S)_{p,p}}$$

Fig. 0: g-factor equation

Results

Within an image, the g-factor is dependent on the specific coil array, the spatial location and the acceleration factor. The SNR loss is commonly the main limiting factor in acceleration speed due to rapid growth of the g-factor beyond an acceleration factor of 4 in one direction. However, accelerations in two directions have a multiplicative total acceleration factor that cannot be achieved along one direction without increasing the geometry factor and, hence, the local noise amplification. This would be beneficial on 3D imaging techniques that have two phase-encoding directions. Figure 3 shows the noise amplification when acceleration is done in one direction (LR) and in two directions (LR/SI).

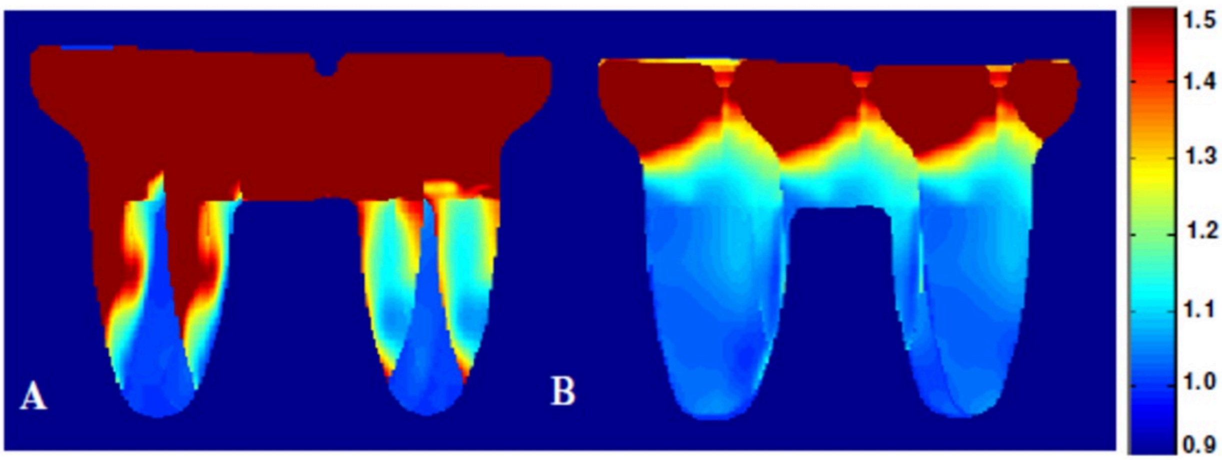


Fig.: Effect of the acceleration direction on g-factor. A) Acceleration applied in one direction (LR=8). The g-factor is amplified in the chest wall region and extends to the breast area. B) Acceleration in two directions (LR = 4 and SI =2). The multiplicative total acceleration factor causes a decrease of the g-factor contributing to less local noise amplification.
References: Sentinelle Medical, Sentinelle Medical - Toronto/CA

This result shows a considerable increase in noise in the chest wall and part of the breast when R=8 is applied in one direction (LR), while for the same acceleration distributed along two directions (LR/SI), the noise amplification is reduced. Based on these results, one-dimensional acceleration factors higher than 4 were not used.

Using an acceleration factor of 4 resulted in a mean g-factor of 1.25 well within acceptable limits. Acceleration factor of 8 (LR = 4 and SI =2) resulted in a mean g-factor of 1.75. We used R=3 as the baseline, as this would represent the maximum acceleration used in a clinical setting. Figure 4 shows g-factor maps and corresponding volunteer images. High resolution images did not show any parallel imaging artifacts, For R=8, that is 4 in the LR and 2 in the SI, the scan time was 20s.

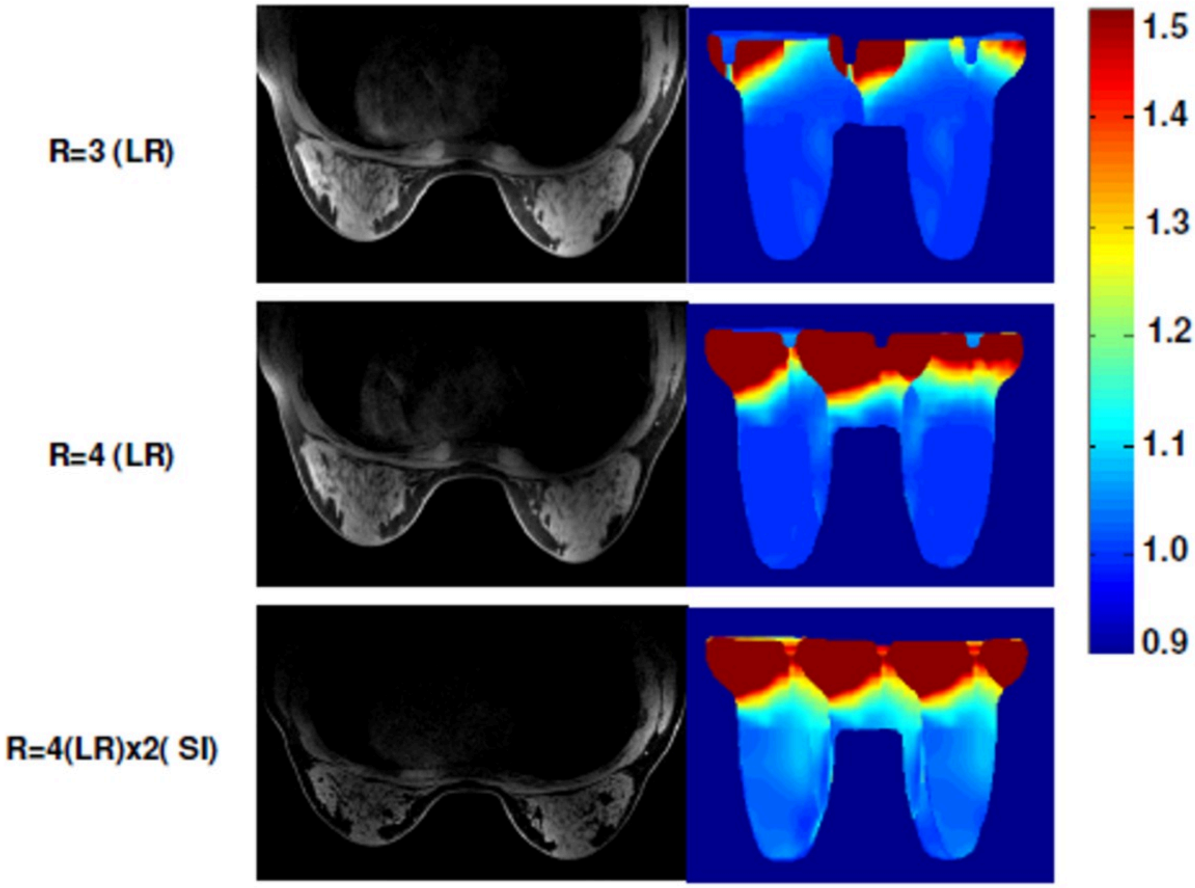
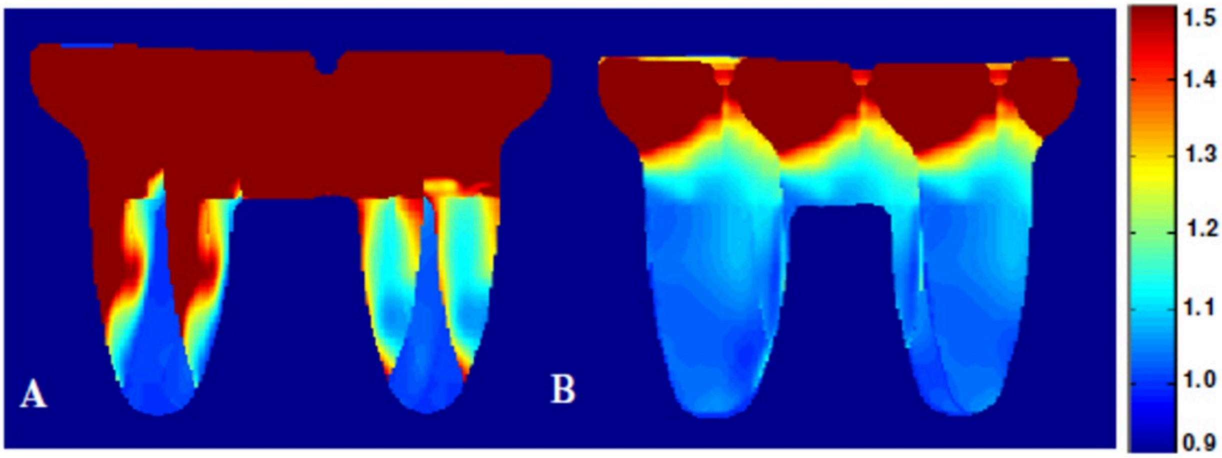


Fig.: The first column represents the acceleration factor. The second column corresponds to the actual high resolution, fat suppressed breast images. The g-factor color scale is provided for reference. The g-factor map indicates that there is no significant change from R=4 to R=4x2. The average g-factor over the volume was 1.25 vs. 1.75. The volunteer images do not show any PI artifacts.

References: Sentinelle Medical, Sentinelle Medical - Toronto/CA

Whereas parallel imaging involves a penalty in SNR, high resolution images did not show any parallel imaging artifacts using the high-sensitivity 16 channels breast coils at 3T.

Images for this section:



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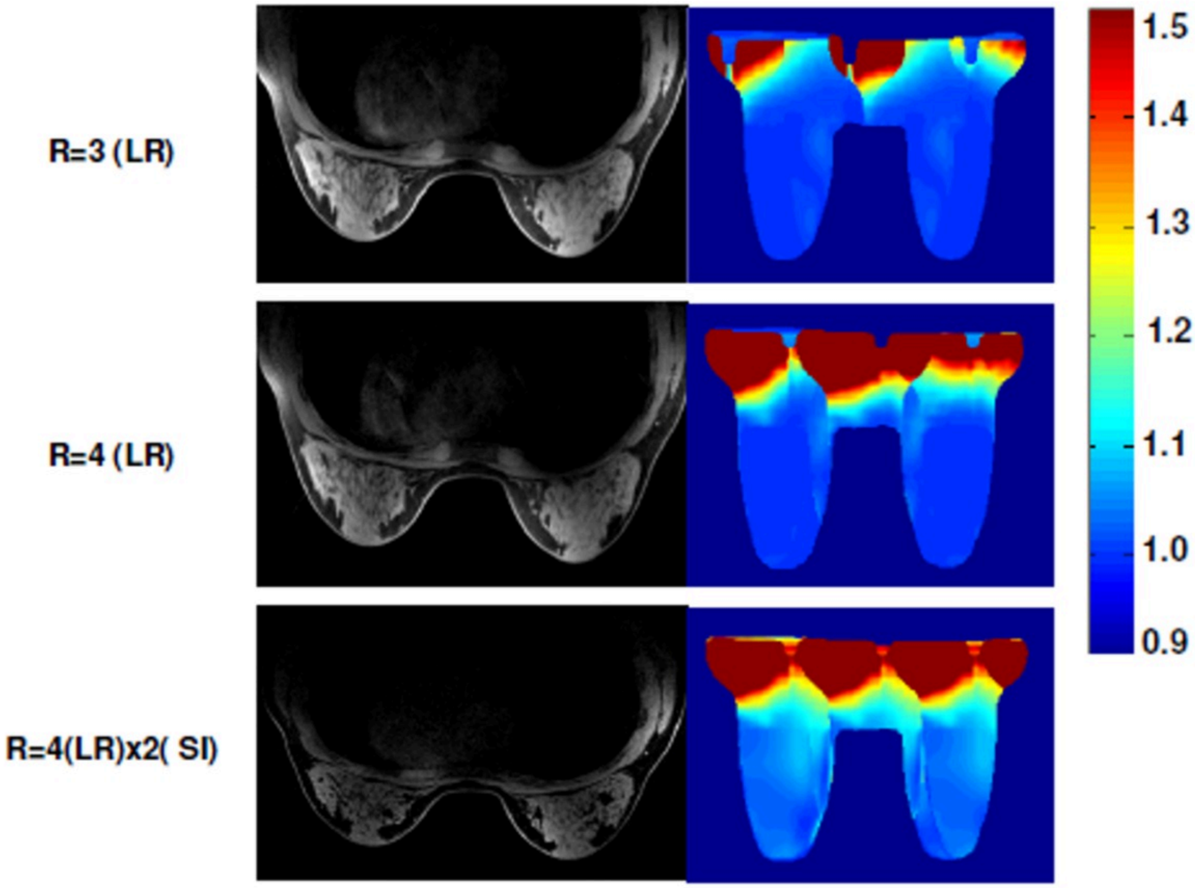

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Conclusion

Our results with the 16 channel design indicate that, high quality bilateral breast images with near isotropic resolution can be obtained in as little as 20s at 3T. This opens the door for more detailed analysis of contrast kinetics to aid in predicting response to chemotherapy and improving pharmacokinetic analysis to characterize breast lesions.

References

[1] Moon, M., Cornfeld, D., & Weinreb, J. Dynamic contrast-enhanced breast MR imaging. Magn Reson Imaging Clin N Am 2009; 17:351-62.

[2] Yankeelov, T. E., Lepage, M., Chakravarthy, A., Broome, E. E., , K. J., Kelley, M. C., et al. Integration of quantitative DCE-MRI and ADC mapping to monitor treatment response in human breast cancer: initial results. Magn Reson Imaging 2007; 25:1-13.

[3] Blaimer, M., Breuer, F., Mueller, M., Heidemann, R. M., Griswold, M. a., Jakob, P. M., et al. Smash, Sense, Pils, Grappa. Top Magn Reson Imaging 2004; 15:223-236.

[4] Pruessmann, K. P., Weiger, M., Scheidegger, M. B., & Boesiger, P. SENSE: sensitivity encoding for fast MRI. Magn Reson Med 1999; 42:952-62.

[5] Marshall, H., Devine, P. M., Shanmugaratnam, N., Fobel, R., Siegler, P., Piron, C. a., et al. Evaluation of multicoil breast arrays for parallel imaging. J Magn Reson Imaging 2010; 31: 328-338.

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