Simulation of SNR Limit for SENSE Related Reconstruction Techniques

Arne Reykowski, Wilfried Schnell, Jianmin Wang
Siemens Medical Solutions, D-91052 Erlangen, Germany

Parallel acquisition techniques, suffer from loss in SNR when compared with optimum array imaging. This loss can be explained through additional constraints imposed on the choice of array weighting factors. In standard array coil imaging, weighting factors are chosen to maximize SNR at a given point P_m. SENSE reconstruction has the same requirement, but in addition to that, SNR has to be minimized at a number of points P_n. The ultimate sensitivity limit for SENSE reconstruction can be calculated from sensitivity maps for optimum SNR imaging. This paper shows numerical results for ultimate SENSE sensitivity for the cases of a lossy half space and a lossy cylinder.

Parallel acquisition techniques, like e.g. SENSE, suffer from loss in SNR when compared with optimum array imaging. This loss can be explained through additional constraints imposed on the choice of array weighting factors. In standard array coil imaging, weighting factors are chosen to maximize SNR at a given point P_m. SENSE reconstruction has the same requirement, but in addition to that, SNR has to be minimized at a number of points P_n. The ultimate sensitivity limit for SENSE reconstruction can be calculated from sensitivity maps for optimum SNR imaging. This paper shows numerical results for ultimate SENSE sensitivity for the cases of a lossy half space and a lossy cylinder.

Theory

The complete theory on which the given simulations are based is explained in a first paper [1]. In order to calculate the sensitivity limit for a SENSE reconstruction with reduction factor N, the N ultimate sensitivity profiles for each of the N points which are involved in the reconstruction have to be known. These ultimate sensitivity profiles are equivalent to the field maps of N ideal coils where each coil receives ultimate possible SNR from the corresponding location. Several previous publications deal with the issue of ultimate sensitivity limits for the lossy half space and lossy cylinders, both in the quasi static and the full wave case [2-5].

Based on these publications, MathCad™ and MatLab™ scripts were written to calculate ultimate SENSE sensitivity field maps for these geometries.

Results

Fig. 1 shows the case of two points aligned on a vertical axis in a lossy half space under quasi static conditions. Using the formulas presented in [3] the ultimate SENSE SNR for a reduction factor of 2 was calculated for a variable spacing between the two points. Due to the scalability of the quasi static half space problem, the ratio z_1/z_2 determines the so called g factor which reflects the loss over the optimum array SNR which can not be attributed to the shortening in scan time.

$$g^{ult} = \frac{SNR^{ult}}{SNR^{SENSE}} \qquad (1)$$

Fig. 2 shows the ultimate g factor for $0 < z_1/z_2 < 1$. As can be seen, the g factor increases with decreasing relative spacing between the two points. This can be simply explained by the fact that the optimum SENSE coil has to receive signal from P_1 while having no sensitivity at point P_2. Nulling the sensitivity at P_2 has an increasing effect on sensitivity in point P_1 for decreasing spacing between both points.

Fig. 3 shows a set of N equally spaced points in horizontal direction. Fig. 4 shows the corresponding ultimate g factors for reduction factors of R=N=2,3..6 as function of relative spacing D/z.

Summary

Using ideal sensitivity profiles for SENSE coils, ultimate g-factors and ultimate sensitivity of the SENSE experiment can be calculated for given geometries. The authors have calculated various cases for the lossy half space and lossy cylinder both for quasi static and full wave assumptions.

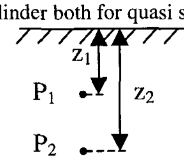

Fig. 1 Two points along a vertical axis in a lossy half space

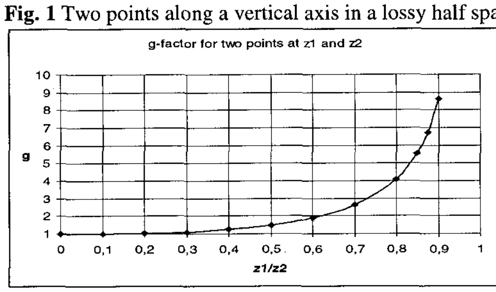

Fig. 2 Corresponding ultimate g factors for Fig. 1

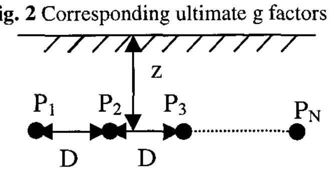

Fig. 3 N points along a horizontal line in a lossy half space.

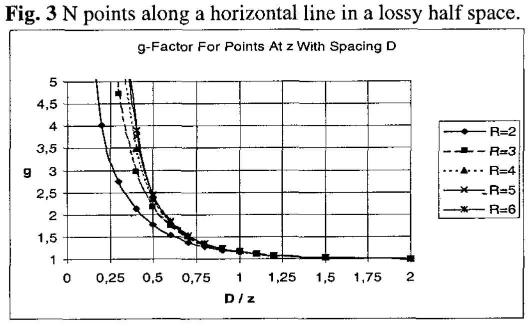

Fig. 4 Corresponding ultimate g factors for Fig. 3 with reduction factors of R=1,2...6

References

[1] Reykowski A., Submitted to ISMRM 2002
[2] Roemer P.B. et al., Magn. Reson. Med. 16, pp. 192-225 (1990).
[3] Wang, J/ Reykowski, A./ Dickas, J., IEEE Trans. Biomed.
[4] Reykowski, A.: „Theory and Design of Synthesis Array Coils for MRI", Texas A&M Univ., Dissertation, 1996.
[5] Schnell, W./ Renz, W./ Vester, M./ Ermert, H., IEEE Trans. Ant. Prop. (2000), Vol. 48, No. 3, p. 418-28.