Hadamard and Sensitivity Encoding (H-SENSE) for Simultaneous Multi-Slice MR Imaging

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TARGET AUDIENCE: MR physicists and clinicians interested in rapid multi-slice imaging methods

PURPOSE: A new two-step approach to simultaneously acquire multi-slice MR images (SMI) is proposed. Simultaneously excited slices are simultaneously encoded by using Hadamard matrix (HE)[1] and parallel encoding method such as SENSE[2]. As previously reported, HE and SENSE for SMI is useful in many applications[3, 4]. However these method has low temporal resolution and/or high g-factors. The proposed Hadamard and Sensitivity encoding (H-SENSE) for SMI seems to be useful to overcome these limitations by optimally choosing slice combinations for SENSE coding. Furthermore, an optimal Hadamard coding combination for better SNR with g-factor reduction.

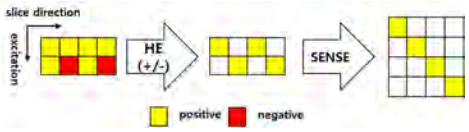

Figure 1 The algorithm of H-SENSE

METHODS: The algorithm of the H-SENSE is illustrated in Fig. 1, which shows an example of four slices excited simultaneously. RF pulses for simultaneous excitation of slices can be rearranged using Hadamard matrix. Firstly, part of aliased slices is encoded/decoded using HE. Secondly, residual aliased slices are decoded by using SENSE. Because the g-factor is strongly dependent on the choice of distance between the simultaneously excited slices, proper choice of combination for Hadamard/SENSE coding is required to minimize the g-factor. For validation of H-SENSE, images were acquired using 32-channel head coil with the Philips Achieva 3.0T MRI system at Korea Basic Science Institute, Ochang, Korea. The following imaging parameters were used: modified T1-FFE sequence, TR=250 msec, TE=4.6 msec, FOV=250mm, matrix size=256X256, NEX=1, slice thickness=5mm, gap between slice excited simultaneously=5mm, and the number of slices excited simultaneously=4.

RESULTS: Figure 2 shows examples of SMI reconstruction using SENSE, HE, and H-SENSE. This figure demonstrates the similarity between the original image and image reconstructed by H-SENSE and can be shown that image reconstructed by only SENSE is noisier than those reconstructed by H-SENSE. Figure 3 shows the comparison results of Hadamard matrix combination.

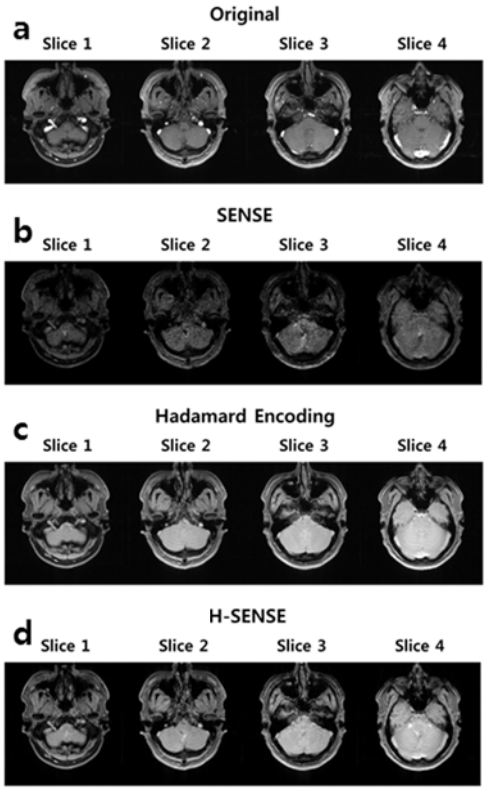

Figure 2 three examples of SMI reconstruction with SENSE (b), Hadamard encoding (c), H-SENSE (d).

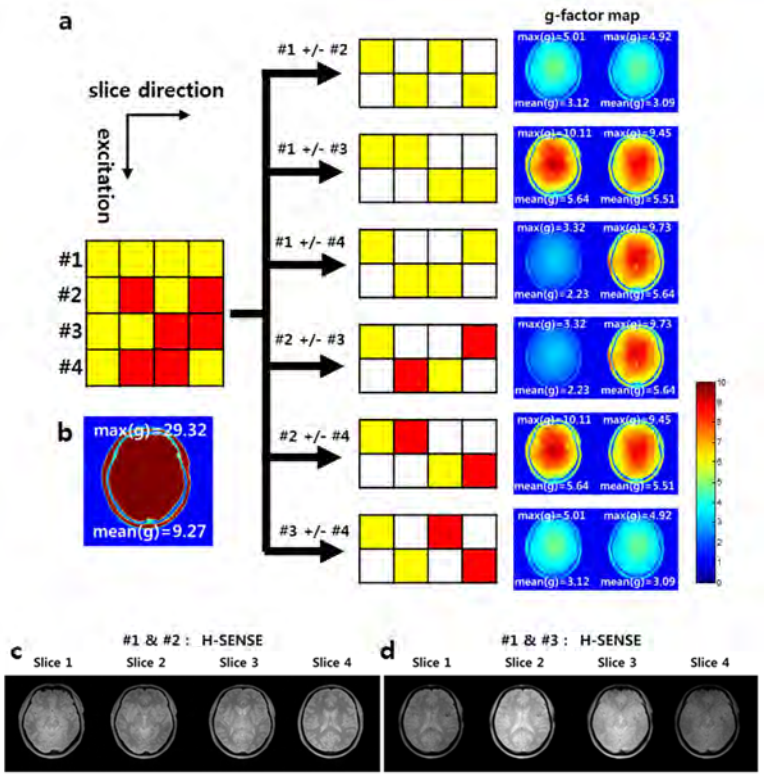

Figure 3 g-factor maps along the different Hadamard matrix combination (a) and only SENSE (b). Reconstructed image using #1 and #2 Hadamrad matrix (c) and #1 and #3 Hadamrad matrix (d) combination.

DISCUSSION&CONCLUSIONS: The proposed H-SENSE is conceptually simple and easy to implement. The H-SENSE can be a good choice to overcome the several limitations of HE and SENSE for SMI. Using H-SENSE for SMI, g-factor of H-SENSE is less than that of conventional SENSE and scan time of proposed method is half compared to the full encoding. The method utilizes the strength of HE and make up for the weakness of HE. Furthermore, using the optimum Hadamard matrix combination, more g-factor reduction became possible.

REFERENCES

1. Souza, S. P., Szumowski, J., Dumoulin, C. L., Plewes, D. P., & Glover, G. SIMA: simultaneous multislice acquisition of MR images by Hadamard-encoded excitation. Journal of computer assisted tomography 1988; 12(6): 1026-1030.
2. Pruessmann, K. P., Weiger, M., Scheidegger, M. B., & Boesiger, P. SENSE: sensitivity encoding for fast MRI. Magnetic resonance in medicine 1999; 42(5): 952-962.
3. Goelman, G., Liu, S., & Gonen, O. (2006). Reducing voxel bleed in hadamard‐encoded MRI and MRS. Magnetic resonance in medicine 2006; 55(6): 1460-1465.
4. Eberhardt, K. W., Degen, C. L., & Meier, B. H. Fast magnetic resonance force microscopy with Hadamard encoding. Physical Review B 2007; 76(18): 180405.

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