Parallel imaging technique using localized gradients (PatLoc) reconstruction using orthogonal mode decomposition

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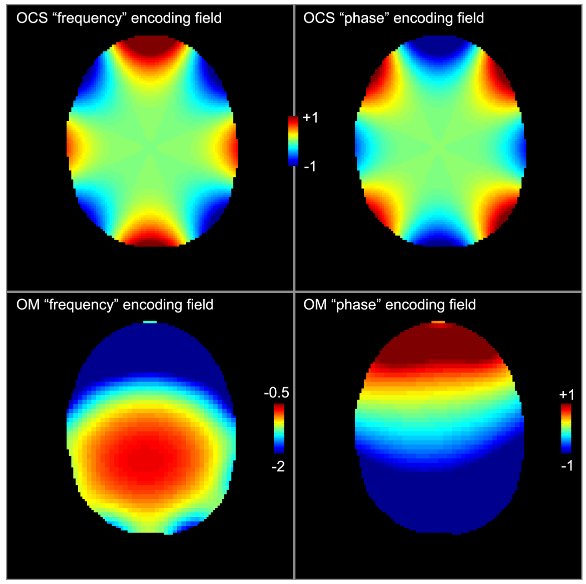
INTRODUCTION

Parallel imaging technique using localized gradient (PatLoc) uses the combination of surface gradient coils and an RF receiver array to further improve the efficiency of gradients and to reduce the peripheral nerve stimulation hazard [1]. PatLoc is a generalization of non-Cartesian gradient encoding, such as MR-encephalography [2] or inverse imaging [3]. The imaging and reconstruction algorithm of PatLoc system has been previously reported using two orthogonal sets of linearly combined gradients with circular symmetry and a spin echo imaging sequence [4]. The reconstructed PatLoc image shows reduced sensitivity at the center of FOV as the result of lacking encoding information from both the gradient system and the RF sensitivity. We hypothesize that other linear combinations of gradients can improve the quality of image reconstruction. Specifically, rather than using two sets of polarity reverse gradients [4], we use singular value decomposition (SVD) to reveal two most significant linear combinations of the gradients as the "frequency" and "phase" encoding gradients. We demonstrate the advantage of this mode selection by using 8-channel gradient and RF coil array PatLoc system together with up to 4-fold acceleration using the iterative time-domain reconstruction (iTDR).

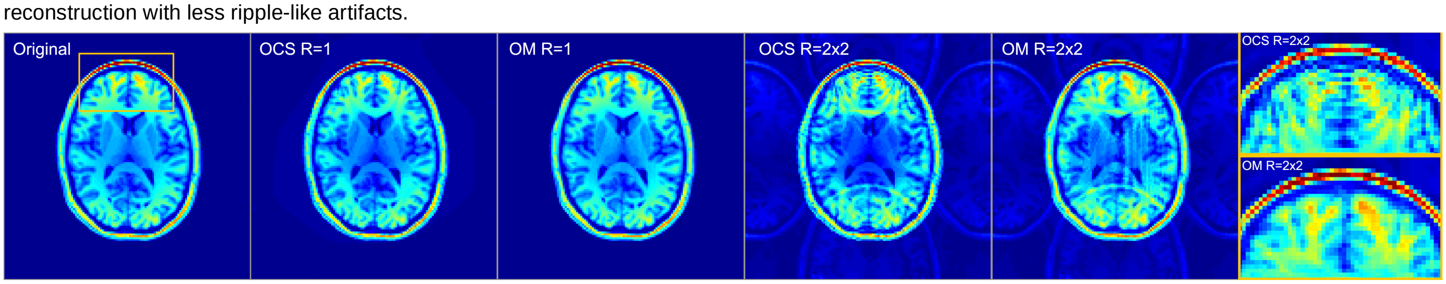
METHODS



We used Bio-Savart's law to simulate the B_1 sensitivity maps and the gradient fields of 8-channel PatLoc system. The figure at right shows two sets of the gradient fields for PatLoc: a set of orthogonal circular symmetric (OCS) gradient fields, which was used in the initial realization of PatLoc [4], and a set of orthogonal mode (OM) gradient fields, which was calculated by singular value decomposition (SVD). The imaging sequence was simulated as a convention spin-echo sequence, which used the respective "frequency" and "phase" encoding fields to collect k-space data. We simulated the image reconstruction using a 128-by-128 image matrix. The reconstructions were simulated for full phase/frequency encoding steps (R=1) and 2D "accelerations" (R=2x2), where only alternating phase and frequency encoded PatLoc data were acquired. The iterative time-domain reconstruction (iTDR) method is a generalization of the SENSE reconstruction with arbitrary k-space trajectory [5], where the Fourier transform was replaced by explicit calculation of spin phase evolution along pulse sequence timing and the provided frequency and phase encoding gradient fields in the time domain. The anatomical image was obtained from an axial slice MPRAGE image (TR/TE/flip angle= 2530 ms/3.49 ms/7^o, 1mm3 isotropic spatial resolution) measured on a 3T system (Tim Trio, Siemens Medical Solutions, Erlangen, Germany).

RESULTS

The first two modes of the OM fields consist of one rather homogeneous mode and one rather vertically linear mode. These two modes individually take 48% and 25% of total variance of the magnetic fields generated by the 8-channel parallel gradient system. The reconstructed images using OCS and OM gradient fields are shown in the figure below. Without skipping any data and collecting a complete set of spin echo signals (R=1), the OCS and OM reconstructions are similar, while the PatLoc with the OM gradient fields gives less signal degradation at the center of the FOV, potentially due to more independent spatial encoding from the OM frequency and phase fields. For the 4-fold accelerated case (R=2x2), the OM fields yeild higher reconstructed image intensity at the center of the FOV but a more severe aliasing artifact, since the linear mode is not capable to resolve the spatial information along the left-right direction. The magnified portion at the frontal lobe (indicated by the orange rectangle) was also shown in the figure. The advantage of OM fields over OCS fields to make a better reconstruction with less ripple-like artifacts.



DISCUSSION

Using SVD to reveal orthogonal mode to further improve the image reconstruction efficiency was previously reported in the context of compressing array coil data [6]. Here we further generalized this concept to investigate the effect of using two most significant orthogonal modes of the PatLoc system to encode images using a conventional spin echo sequence. Compared to the previously reported gradient fields with circular symmetry, SVD automatically suggests linear combinations to generate orthogonal fields with optimal partitioning of the total variance inside the gradient fields. This may improve the image reconstruction quality as demonstrated here in fully sampled and skipped sample data.

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REFERENCES

1. Hennig J., et al., MAGMA, 2008. 21: p. 5-14.
2. Hennig J., et al., NeuroImage, 2007. 34(1): p. 212-219.
3. Lin, F.H., et al., Magn. Reson. Med., 2006. 56(4): p. 787-802.
4. Schultz G., et al., Proc. Intl. Soc. Magn. Reson. Med., 2008, p.786.
5. Pruessmann, K., et al. Magn Reson Med. 2001. 46: p. 638-651.
6. Buehrer, M., et al. Magn Reson Med. 2001. 57(6): p. 1131-1139.