K-Space SENSE Reconstruction

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Introduction

In iPAT application scan, the entire receiver channels, such as 8, and a rather low iPAT factor (*r*), such as r=2, is commonly used to reach a compromise between the SNR and scan speed. In this case, GRAPPA [1] has shown its convenience of higher image reliability compared to mSENSE. In SENSE reconstruction [2],

$$\mathbf{F} = \left(\mathbf{E}^H \psi^{-1} \mathbf{E}\right)^{-1} \mathbf{E}^H \psi^{-1}$$

the SENSE de-aliasing procedure can be divided into 3 steps in *k*-space view: 1) combine the entire receiver channels into *r* virtual channels with optimized SNR; 2) fit the missing lines; 3) concatenate the sub-images. So SENSE can be regarded as 2-channel GRAPPA with optimized SNR in k-space view. If we define the freedom of fitting system by the channels' sensitivity map, the fitting freedom of SENSE is 2 and that of GRAPPA is 8 in this case. That is why GRAPPA can give lower artifact than mSENSE in some cases. But the expense of high reliability is the longer reconstruction time when the number of receiver channel is great. In GRAPPA, the images are combined by Sum of Square (SOS) after fitting, the SNR is not optimized. A new *k*-space SENSE reconstruction method based on the coil combination and k-space fitting, named KSENSE, is presented. The convenience of this technique includes the SNR optimization of image and higher reconstruction speed than that of GRAPPA.

Methods

The procedure of KSENSE can be divided into 4 steps: 1) calculate the sensitivity maps of each coil from measurement lines; 2) merge the *k*-space data of *nRealChannels* to *r* virtual channels in *k*-space, where *nRealChannels* is the number of the entire real receiver channels and *r* is the iPAT factor; 3) fit the *k*-space missing lines of the *r* virtual channels. 4) IFFT and combine the *r* images. The channel mergence in step 2 is realized by 2D convolution. And step 3 is similar to the conventional GRAPPA. The difference is that GRAPPA uses *nRealChannels* channels to fit one real channel, but KSENSE uses *r* or (*r*-1+ *nRealChannels*) channels to fit one virtual channel. When *nRealChannels* is much more than *r*, the advantages of reconstruction time of KSENSE become obvious.

Results

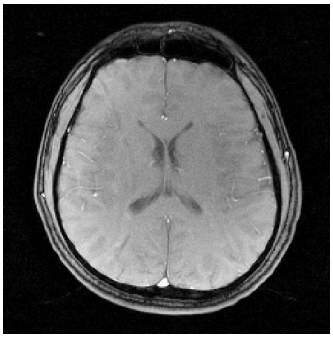

Fig.1 a

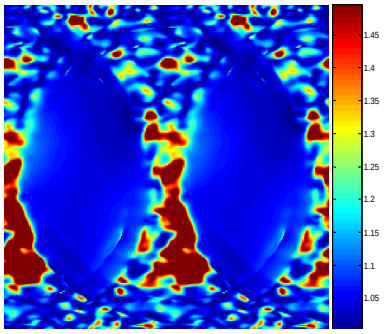

Fig.1 b

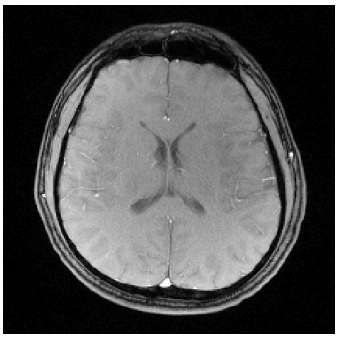

Fig.2 a

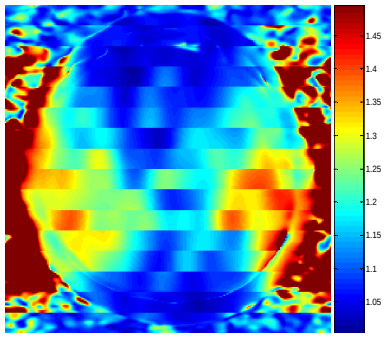

Fig.2 b

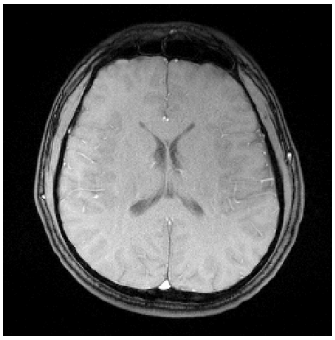

Fig.3 a

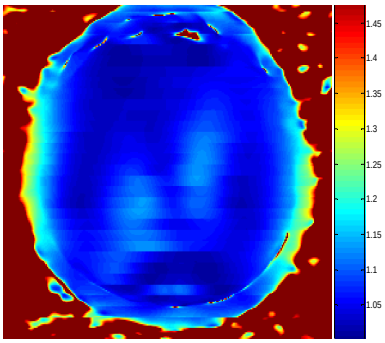

Fig.3 b

The raw data of the figures comes from the Siemens Trio system with 8-channel head coil array in Beijing MR Center for Brain Research. Fig.1, Fig.2, and Fig.3 are reconstructed using mSENSE, GRAPPA and KSENSE respectively. *R* is 2 and the measurement lines are about 10% of fully sampled phase encoding lines. The (b) figures are the related g-factor of the images in the left. The method of GRAPPA and KSENSE g-factor calculation is mentioned in [3]. Fig 1 (b) shows that SENSE method can give the optimized SNR in the area of aliasing. But some artifact is observed in the edge of aliasing area. The g-factor of GRAPPA is not optimized in the aliasing area. And some jumping in the direction of fitting segment can be seen in Fig.2 (b). The SNR of GRAPPA in the area of aliasing is lower than that of SENSE. KSENSE in Fig.3 can give the optimized SNR in the area of whole tissue compared with SENSE. The problem of jumping of g-factor in the readout direction is much lower than that of GRAPPA. And the SNR of KSENSE is also higher. Here 2 virtual channels are used for fitting.

Discussion

The conveniences of KSENSE include the fast reconstruction speed when the iPAT factor is less than the receiver channels and the optimized SNR in the whole tissue area.

Reference

[1] Griswold, M.A., et al., *MRM*, 47,1202, 2002
[2] Pruessmann, K.P., et al., *MRM*, 42, 952, 1999
[3] Wang, JM, et al., *Image Domain Based Fast GRAPPA Reconstruction and relative SNR degradation Factor.*