Preserving Phase Information in Propeller Imaging

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Introduction

Propeller imaging samples k-space on a Cartesian-radial grid to permit a retrospective correction of rigid in-plane motion during the acquisition [1]. The associated reconstruction usually involves an initial phase correction. The method proposed for this purpose first weights the data from each Cartesian sub-acquisition, a so-called blade, with a triangular window, then transforms them to image space, and finally removes the resulting phase in image space from the original data. Obviously, it suppresses most phase errors, including those from subtle motion in the presence of diffusion gradients [2], but it discards in this process all low-frequent phase variations regardless of their origin. Since several applications would likely benefit from a preservation of phase information, this work investigates an alternative method known from radial imaging and demonstrates its advantages.

Methods

A number of methods have been developed for radial imaging that selectively remove phase errors arising from gradient system imperfections [3,4]. In this work, we follow the first, which dispenses with separate calibration measurements. This method demands similar projections to be acquired with opposite readout gradient polarity. To apply it to Propeller imaging, we reverse the direction in which k-space is traversed for every other blade, as schematically illustrated in Fig. 1. Provided that the angle between adjacent blades is sufficiently small, the conjugate complex multiplication of corresponding data from adjacent blades will mostly eliminate phase information. Errors caused by gradient system imperfections, however, will in general not cancel out due to the opposite readout gradient polarity. Therefore, gradient delays can, for instance, be determined by fitting linear phases to the resulting data and then be compensated in the original data. In contrast to radial imaging, anisotropic delays may be addressed similarly.
We evaluated this method in volunteer experiments without deliberate motion on a 1.5 T Philips Achieva scanner using an 8 channel head coil. The images presented below were acquired with a phase sensitive inversion recovery protocol with 25 blades, 15 lines, 5 echoes, and a TR/TE=3.1 s/15 ms, ΔTE = 15 ms, TI = 400 ms.

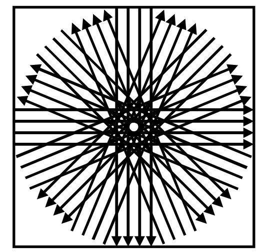

Fig. 1. Readout directions used for individual blades.

Results

Two selected slices from one of the experiments are compared in Fig. 2. The original phase correction gives rise to considerable artifacts, in particular at the interfaces between fluids, namely the vitreous humor and the cerebrospinal fluid, and tissues. These are efficiently suppressed by the proposed phase correction. The preservation of phase information also permits a simple coil combination with sensitivity-based weights in image space [5], which leads to improved homogeneity of signal strength across the field of view and enhanced signal-to-noise ratio. Moreover, in combination, the production of real images is made feasible.

Discussion

The elimination of phase information not only prevents the production of complex images, but also introduces artifacts in magnitude images if applied with certain sequences. Especially strong local phase variations appear to be problematic. In case of the presented example, the comparatively short inversion time causes the signal from fluids and tissues to have opposite signs, as evident from the real images, and thus such variations at their interfaces. Similar difficulties are encountered in steady-state free precession imaging in the presence of field inhomogeneity, for example [6].
Since wider blades increase the vulnerability to intra-blade motion, the small angle between adjacent blades required by the proposed phase correction is not perceived as a major restriction in practice. However, the possibility to accurately estimate anisotropic delays is usually undermined by the highly non-uniform spatial resolution individual blades support.

References

1. Pipe JG. Magn Reson Med 1999; 42:963-969. 2. Devaraj A, et al. Proc ISMRM 2006; 2956. 3. Rasche V, et al. Magn Reson Med 1999; 324-334. 4. Peters DC, et al. Magn Reson Med 2003; 50:1-6. 5. Pruessmann KP, et al. Magn Reson Med 1999; 42:952-962. 6. Barkauskas KJ, et al. Proc ISMRM 2005; 2287.

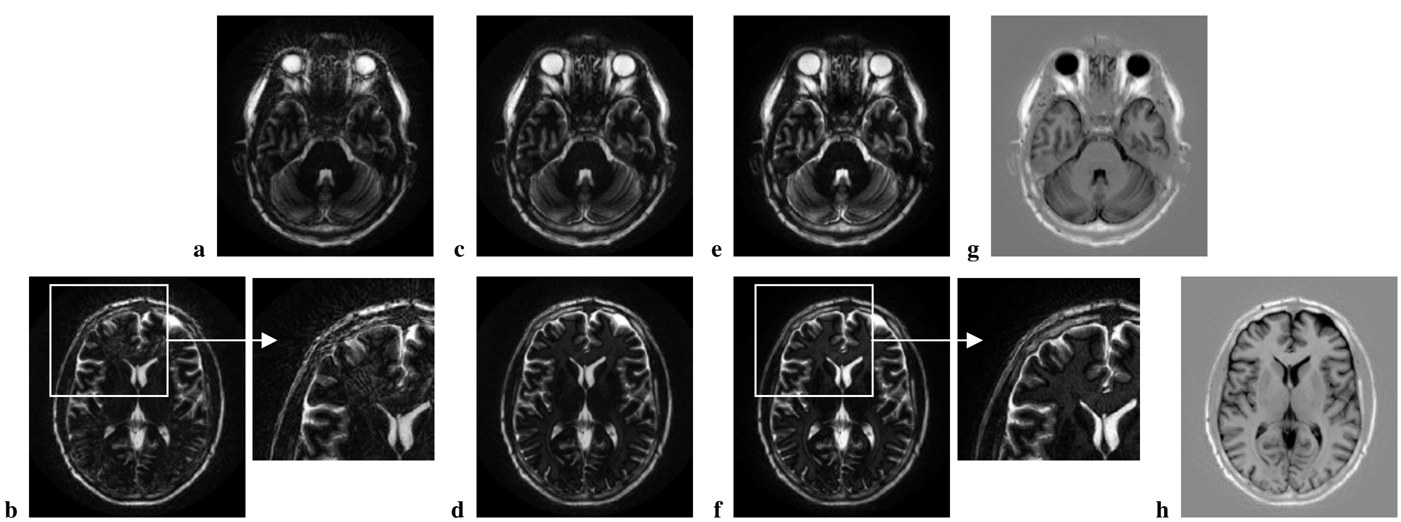

*Fig. 2. Phase sensitive inversion recovery images of the brain. (**a-h**) Magnitude (a-f) and real (g-h) images reconstructed with the original (a-b) and the proposed (c-h) phase correction, using a conventional magnitude (a-d) and an optimal complex (e-h) coil combination.*