Navigator-stabilized GRASE imaging for high magnetic fields

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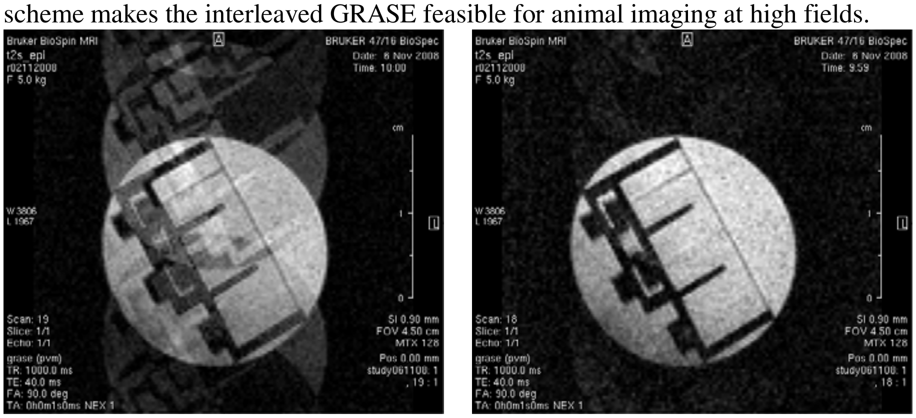
Introduction: The GRASE imaging technique [1] allows a flexible combination of gradient- and spin echoes to gather a maximum of spatial information within a single T2 decay. A source of ghosting in this technique is the combined modulation of the k-space data by the relaxation decay and resonance offsets. Various sampling schemes have been proposed to reduce the ghosting by smoothing the modulation [2] or splitting its components to different imaging dimensions [3]. The trade-off of these approaches is an increased sensitivity to resonance offsets making them problematic at high magnetic fields, where the susceptibility-induced offsets become critical. The original interleaved scheme of Feinberg and Oshio [1] that converts resonance offsets to minimal pixel shifts is the most promising at high fields. We demonstrate that the ghosting due to the T2 decay (the main drawback of interleaved GRASE) can be alleviated using navigator signals.

Method: Single shot GRASE with 16 gradient-echoes generated for each of the 8 spin echoes of a CPMG sequence was used to produce a data matrix of 128×128 points with an interleaved sorting scheme and echo time shifting [4]. The implementation allows a flexible choice of the matrix size, and the number of spin echoes as well as the partial-FT encoding in the blipped gradient direction. At the beginning of each CPMG period, before the imaging gradients are started, a short section of the spin echo signal is acquired without spatial encoding as a navigator. From each navigator the average signal amplitude and phase are calculated. The difference in phase and amplitude between the continuously measured navigators and an initial navigator is used to equalize the phase and amplitude of the gradient echo trains to reduce the T_2-weighting. Measurements on a structure phantom have been performed on a Bruker BioSpec 4.7T system (eff. spectral bandwidth=150kHz, 128×128 matrix, 4 spin-echoes, TE=40ms, FoV=4.5cm/4.5cm, slice tickness 0.9mm). Invivo measurements have been performed on a rat (Bruker BioSpec 7T system, eff. spectral bandwidth=300kHz, FoV: 2cm/2cm, 1.5mm slice thickness, 128×128 matrix, 8 spin-echoes, TE=12.4ms). For comparison, a single-shot spin-echo EPI with the same gradient echo spacing (with TE=31.4ms), and a single shot RARE with the minimum gradient spacing allowed by the system (2.7ms) were acquired with identical resolution.

Results and Discussion: The navigators represent an average contribution of all image components. Therefore, the T_2 correction may not be accurate for all pixels. The phantom has a single T2 value of 80ms and its image is virtually ghost free, when the navigators are used. The rat image has some residual ghosting due to the T2-averaging effect of the navigator. However, its quality is superior to the single shot EPI, which is more distorted, and single-shot RARE, which shows more blurring. In conclusion, the proposed navigation scheme makes the interleaved GRASE feasible for animal imaging at high fields.



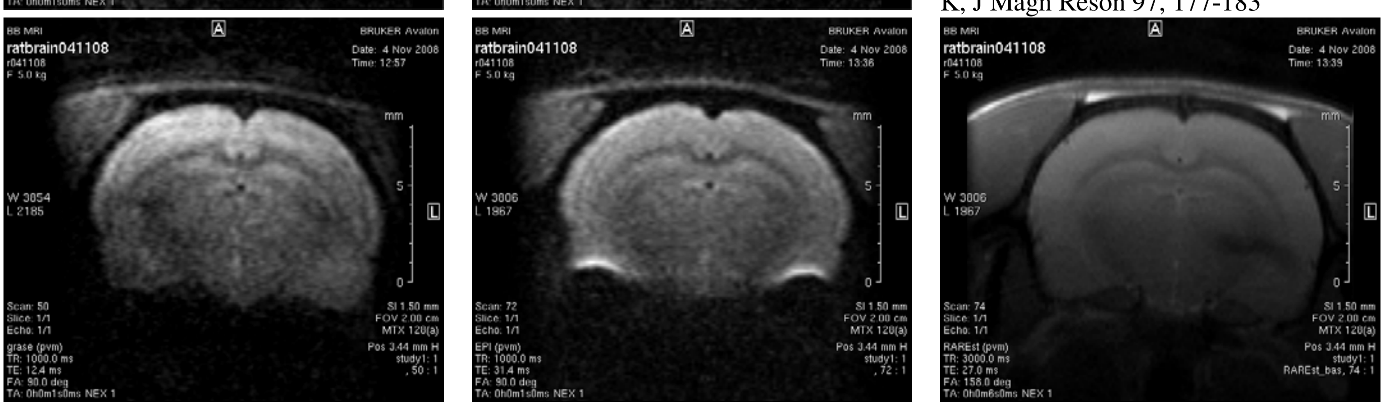


Fig.1: Imaging results. Top: Axial GRASE image of a structure phantom (l: without, r: with navigator measurement. Bottom: Axial slice image of a rat brain (l: GRASE, m: SE-EPI, r: RARE)

References: [1] Oshio K, Feinberg DA, Magn. Reson. Med. 20, 344-9 (1991) [2] Feinberg DA, Johnson G, Kiefer B, Magn Reson Med. 34,149-55 (1995) [3] Mugler JP, J Magn Reson Imaging. 9,604-12 (1999) [4] Feinberg DA, Oshio K, J Magn Reson 97, 177-183