EPI Artifact Correction in Electro-mechanical Resonance Regimes

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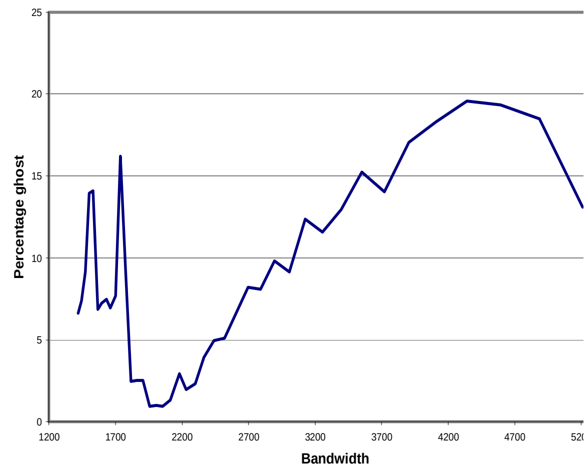
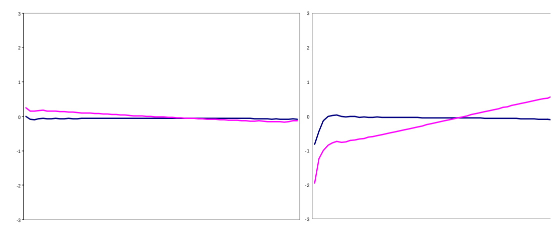
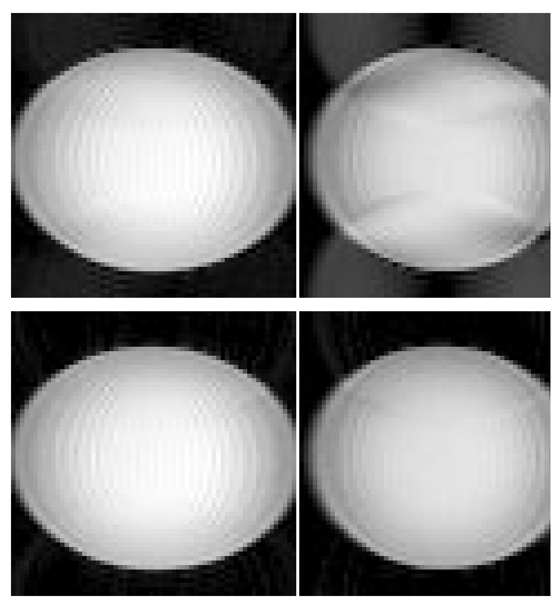
Echo Planar Imaging (EPI) [1] has found increasing application due to its extremely short imaging times (<100ms/image). This is despite its relatively high level of image artifacts such as distortion due to off-resonance effects and Nyquist ghost images [2] due to imperfections in sequence timing. While the degree of image distortion can be reduced by increasing the bandwidth, which reduces the inter-echo timing, this also influences which switching frequencies are being applied to the gradient system. If these frequencies coincide with electro-mechanical resonances [3] of the coil, additional timing imperfections arise resulting in higher ghost levels.

Many schemes exist for minimizing the Nyquist ghosting, often involving the collection of non-phase encoded navigator data. Phase information from these navigators can then be used to correct the real image data. These navigators can either be collected as a separate scan, which reduces scan time efficiency, or within a single scan. In the latter case, the navigators can be acquired immediately after slice excitation. However, as shown to the right, different acquisition bandwidths can still produce high Nyquist ghost levels. A possible source for this is some disturbance of the positive/negative gradient lobe symmetry during the image echo train. This could arise from the gradient waveform being near a mechanical resonance of the system, and so gradually reaching a steady state during the initial parts of the echo train.







An approach to examining and correcting this effect is to collect the navigator data at the center of the image echo train, where k_p=0. Such a scheme of 'internal' navigators has previously been used to stabilize time courses of segmented EPI data [4]. A sequence was written that collected these navigators in addition to the 'external' (i.e. before the image echo train starts) navigators. Images could then be reconstructed with either set of navigators for comparison. Data were acquired on a Siemens Trio system.

The smaller plots show the phase profiles from the 'external' navigators (blue) and 'internal' (purple) navigators for bandwidths of 2004 Hz/pixel (left) and 4340 Hz/pixel (right), which correspond to the best and worst case for ghost level (plot scales are from -3 to 3 radians). It is clear that, at 2004 Hz/pixel, both navigators give similar results. However at 4340 Hz/pixel there is a strong, additional first order term in the internal navigator. This is also apparent in the reconstructed images where the first row is reconstructed using the 'external' navigators and the second the 'internal' navigators. While the ghost level is similar in the 2004 Hz/pixel data, in the 4340 Hz/pixel data the high ghost level (34%) is reduced significantly (down to 5%). The visible ringing artifacts are due to ramp sampling, which is not yet incorporated in the in-house reconstruction software.

This data indicates that the use of 'internal' navigation can reduce Nyquist ghost levels compared to 'external' navigators. This then implies that low-ghost images may be acquired in bandwidth regimes that have not previously been considered usable. We have not, however, addressed other issues that may arise at these bandwidths such as mechanical stress, sound pressure levels, and nerve stimulation.

References:

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