Suppression of Residual Transverse Magnetisation in SPI Sequences Using Phase Cycling Filter

J. B. Kaffanke[1], T. Stoecker[1], S. Romanzetti[1], T. Dierkes[1], and N. J. Shah[1]

[1]Institute of Medicine, Research Centre Juelich, Juelich, Germany

Abstract

A method for suppression of residual transverse magnetisation was developed for use in single point imaging (SPI) sequences such as SPRITE (Single Point Ramped Imaging with T_1 Enhancement). The residual magnetisation causes artefacts that can be explained by different phase encoding resulting in images of different FOV. The new phase cycling filter approach for SPRITE sequences annihilates these signal components efficiently.

Introduction

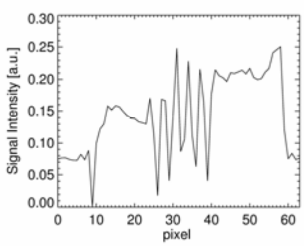
Residual magnetisation is one of the major sources of artefacts in single point imaging sequences with short repetition times [1]. The unwanted signal is caused by non-dephased transverse magnetisation excited in preceding acquisition cycles. Therefore, the problem emerges mainly around the centre of k-space and was solved by additional spoiling gradients in the past [2]. A strategy of using long TRs to avoid build up of residual magnetisation is problematic because of long acquisition times and high gradient duty cycles. In this work unwanted residual magnetisation, acquired with the SPRITE sequence [3], was investigated and a new method for suppression of residual magnetisation is presented. The residual magnetisation experiences a different phase encoding leading to residual images with different FOV. A phase cycling filter is able to annihilate the unwanted signal. An extended phase encode graph (EPEG) theory is able to predict residual images, the related FOV and signal intensity weighting as well as the capability of phase cycling to suppress these signal components.

Methods

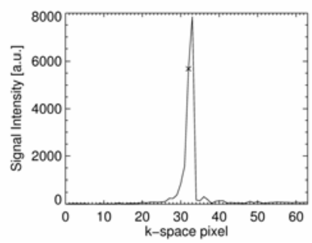
The phase cycling filter was implemented by changing the phase of the local oscillator by a fraction $2\pi n/N$ following each acquisition point of the SPRITE sequence. The scan is repeated N times with n=0,1,..,N-1 and the data sets are averaged. The first order FID signal is always in phase with the receiver whereas the residual transverse magnetisation excited by the preceding RF pulses is cycled within 2π. In the final averaged data set the residual signal components are summed to zero.

SPRITE proton imaging was performed on a 4 Tesla whole body scanner with a VARIAN UNITY Inova console using a resolution phantom filled with transformer oil. For demonstration purposes, a repetition time, TR, of 8.0ms was chosen for the SPRITE sequence with a phase encoding time of t_p=7.5ms per excitation pulse. These timing parameters imply a minimal FOV ratio of ~2 between the image of the first order FID and the residual image of the second order FID. The FOV was 256×256×256mm^3 and a matrix size of 64×64×32 pixel was acquired. The receiver filter bandwidth was accordingly set to 11kHz. Broadband pulses with a length of 50µs and a flip angle of 2° were used to excite the whole volume. A series of 12 average SPRITE scans were acquired with phase cycling from 0° to 330° using a stepping of 30°.

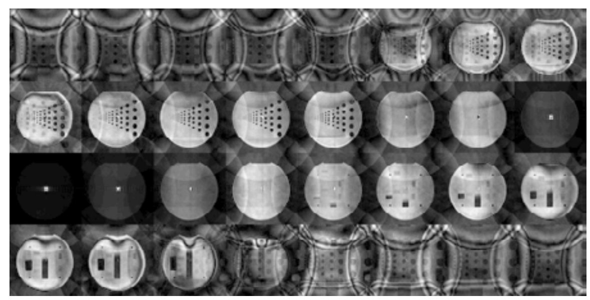
Results



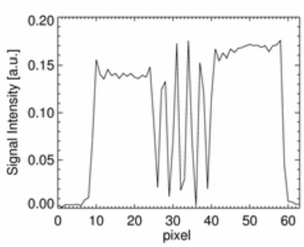
(a)



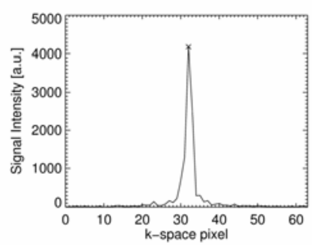
(b)



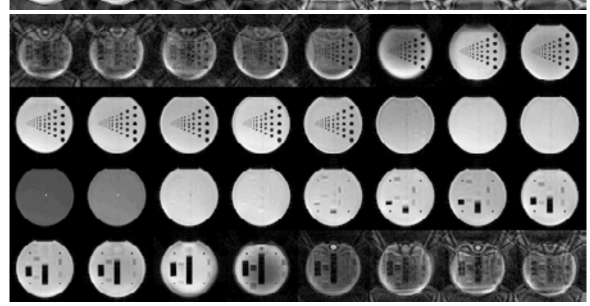
(c)



(d)



(e)



(f)

The Figures show SPRITE proton imaging results from a single scan (a)-(c) and an average of 12 phase cycled scans (d)-(f) with phase cycling steps of 0° to 330°. The vertical profiles through a single slice of the single scan in (a), and of the averaged phase cycled scan in (d) clearly show the improvement by the use of the phase cycling filter. The profiles through the k-space centre (marked by cross) in (b) for the single scan and (e) for the averaged phase cycled scan show the residual magnetisation acquired around the k-space centre (b) which is suppressed by phase cycling (e). All acquired 32 slices are depicted in Figure (c) and (f) where each image is scaled separately to maximum (linear grey scale) such that artefacts outside the object are shown with enhanced intensity. Without phase cycling (c) a pronounced residual image having a factor ~2 smaller FOV appears whereas with the proposed phase cycling method (f) the artefact is almost completely suppressed. Note also the Gibbs ringing in the first (1-5) and last (29-32) slices outside the phantom which become visible with the use of phase cycling and the DC that is left in the centre slice.

Conclusions

Phase cycled averaging is a suitable solution for suppression of the unwanted signal components of residual magnetisation in SPRITE and other SPI sequences. For imaging of nuclei with low SNR, such as sodium, signal averaging is needed in any case, and therefore the method can be used without additional expense of acquisition time. Suppression of residual magnetisation by phase cycled averaging is particularly important for quantitative imaging such as spin density and relaxation time mapping.

References

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