

# Correction of Frequency Drifts Induced by Gradient Heating in 1H Spectra Using Interleaved Reference Spectroscopy

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## Introduction

In many clinical studies investigating neuro-disease, magnetic resonance spectroscopy (MRS) may provide valuable metabolic information, e.g. complementing functional magnetic resonance imaging (fMRI) or diffusion weighted imaging (DWI) experiments, which are typically based on echo planar imaging (EPI) sequences. Such EPI scans involve frequent gradient switching giving rise to heating of the passive shim elements, which can result in considerable field drifts. Afterwards it may take up to 15 minutes until these shim elements have cooled down again and the field has drifted back to its original value. When a spectroscopy scan is carried out right after an EPI experiment, these field drifts can severely impair the spectral quality by broadening the resonance lines considerably. In this work, the interleaved reference scan (IRS) method [1] was applied to correct these field drifts in vitro and in vivo.

## Materials and Methods

The IRS method implies the acquisition of an additional water spectrum after each spectral average. This water signal is acquired with the same sequence as the actual scan, but RF pulses for water suppression are switched off (Fig. 1). Additionally a reduced flip angle of 10° for the water reference acquisition is used in order to limit the SNR loss. During reconstruction the water reference signal is used for phase correction of the actual signal in the time domain according to the Klose method [2]. This technique can be used for eddy current correction, but it is also particularly well suited for correcting spectral frequency drifts, which translate into first-order phase distortions in the time domain signal. Such frequency drifts can arise from subject motion and from unstable magnetic fields. Since the reference signal is acquired interleaved with the actual signal, the phase can be assumed to be approximately the same for both acquisitions. In this work an EPI-based DWI measurement was run for about 10 min prior to the IRS experiments, respectively, to heat up the passive shim elements of the magnet. Using the IRS method, single voxel PRESS spectra were acquired from a phantom containing a solution of acetate and lactate as well as from the occipital cortex of a healthy subject. Phase correction using the reference signal was integrated into the scanner reconstruction. All experiments were carried out on a Magnetom Trio 3T system (Siemens Medical Solutions, Germany) equipped with a phased array head coil for signal reception.

## Results

Figure 2 shows a phantom PRESS spectrum, a) with and b) without IRS phase correction. The significant line broadening of the resonance peaks through frequency drifts is obvious. IRS phase deconvolution can effectively correct these field drifts, reducing the line width of the acetate peak from 6.2 Hz to 1.6 Hz. Consequently, the lactate doublet is far better resolved in the corrected spectrum. The PRESS spectrum acquired from the occipital cortex of a healthy subject (Fig. 3) exhibits the major singlet resonances of N-acetylaspartate (NAA), creatine (Cr) and choline (Cho). The line widths of all peaks are drastically reduced in the corrected spectrum (b) compared to the uncorrected one (a), e.g. from 13.1 Hz to 6.2 Hz for the NAA peak, giving rise to an improved SNR.

## Discussion

Spectroscopy scans in clinical studies are often combined with high-resolution anatomical scans or imaging methods such as fMRI and DWI utilizing high gradient duty cycle. A high-quality imaging series is always required for the proper placement of the spectroscopy voxel and sometimes the region of interest for the MRS scan is even to be identified with the help of a preceding MRI experiment (e.g. in tumor or functional studies). Therefore MRS scans are normally carried out at the end of a combined MRI/MRS session. Since an MRS experiment already lengthens the overall scan time substantially, a waiting period of 10-15 minutes between the MRI and the MRS experiment for field stabilization is usually unacceptable for clinical studies. As has been shown in this work, the IRS method can overcome this problem by effectively correcting frequency drifts and thus improving peak resolution and SNR considerably. Thus it may allow a valid analysis of data sets which have to be discarded otherwise, in particular when neighbouring and low intensity resonances are to be investigated. Additionally, the water reference signal can be used for a real-time correction of the carrier frequency, which may ensure a stable water suppression even in the presence of severe frequency drifts. As a beneficial side effect, the IRS method also corrects motion-induced frequency drifts in regions with large susceptibility gradients. However, frequency drifts caused by subject motion are usually masked by the deterioration of the shim. A combination of IRS with real time prospective voxel position correction can therefore further improve the spectral quality [3].

## Acknowledgement

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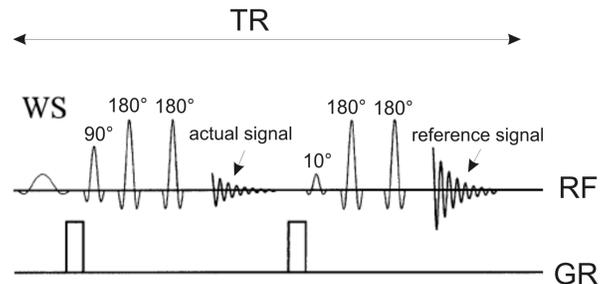


Fig. 1: IRS pulse sequence: After the actual acquisition an additional water reference spectrum is acquired using a smaller excitation angle and without water suppression, but otherwise identical sequence

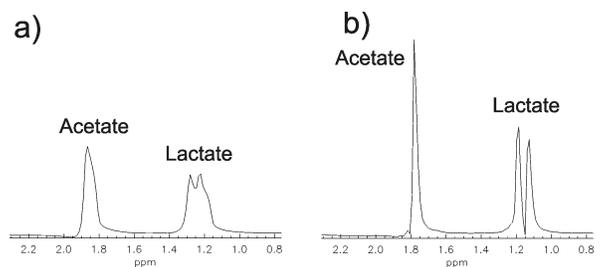


Fig. 2: PRESS spectrum acquired from phantom solution after a long EPI measurement: a) without IRS phase correction, b) with IRS phase correction.

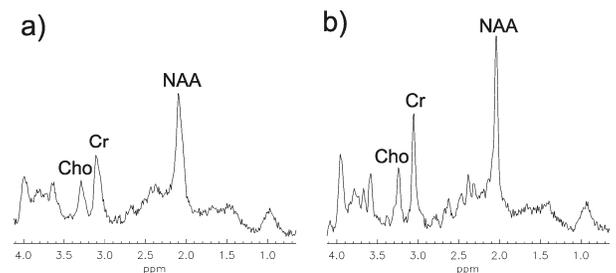


Fig. 3: PRESS spectrum acquired from the occipital cortex of a healthy subject after a long EPI measurement: a) without IRS phase correction, b) with IRS phase correction.

## References

1. Thiel T, *et al.*, MRM 2002 ; 47 : 1077-1082.
2. Klose U, *et al.*, MRM 1990 ; 14 : 26-30.
3. Büchert M, *et al.*, ISMRM 2006 ; #324.