Feedback-Based Interleaved Reference Spectroscopy

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Introduction

Magnetic resonance spectroscopy (MRS) experiments can be severely affected by frequency drifts, which give rise to increased linewidths in the accumulated spectrum. This is especially the case when a spectroscopy scan is run right after an imaging experiment involving a high gradient duty cycle, e.g. EPI-based diffusion-weighted imaging (DWI) [1]. The resulting line broadening in the spectrum can be corrected with a frequency lock, as implemented on some clinical MR systems. Philips systems use a frequency lock that determines the frequency of the strongest resonance in the spectrum, which is usually the residual water peak, and updates the carrier frequency of RF pulses and ADCs in real time. However, this method is not particularly robust. In the presence of strong lipid contamination the frequency lock can accidentally lock a fat resonance instead of the residual water peak. Thiel *et al.* proposed the interleaved reference scan (IRS) method [2] for frequency correction, but this purely retrospective technique only corrects for frequency drifts in postprocessing. In this work, we extend the IRS method by adding the functionality of a frequency lock for a human MR system, updating the carrier frequency of RF pulses and ADCs with water reference spectra acquired in an interleaved fashion.

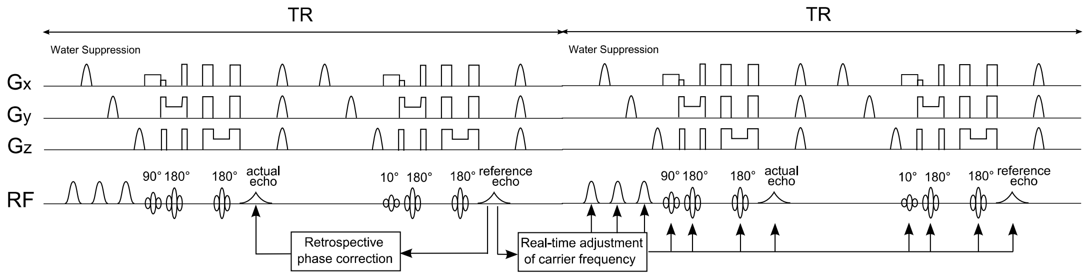

Fig. 1: IRS-PRESS sequence with interleaved water reference acquisition and WET water suppression. In addition to retrospective phase correction of the actual signal, the reference signal is used for updating the carrier frequency of following RF pulses and ADCs in real time.

Materials and Methods

The feedback-based IRS sequence was implemented at a Magnetom TIM Trio 3T system (Siemens Healthcare, Germany). It applies PRESS localization in combination with WET [3] water suppression (Fig. 1). Like the conventional IRS sequence [2] it implies the acquisition of an additional water reference spectrum after each spectral average. However, in contrast to the original method of Thiel *et al.*, the reference signal is not only used for retrospective phase correction of the actual spectrum according to Klose [4], but also for adjusting the carrier frequency of RF pulses and ADCs in the following average. Thus, drift-induced shifts of the PRESS volume are prevented and, in particular, the quality of the water suppression is preserved. A reference excitation angle of 10° yields a sufficiently strong water peak for robust frequency determination and phase correction, while keeping the SNR loss negligible. Spectra were acquired from the occipital cortex of a healthy subject (voxel size: 8 ml) with an echo time of TE = 30 ms and a repetition time of TR = 2.5 s, using water suppression pulses with a typical bandwidth of 35 Hz. An EPI-based DWI measurement (TR = 3100 ms, TE = 85 ms, 23 slices, FOV = 230 mm, base resolution = 128, 3 b-values of (0, 500, 1000) s/mm^2, 3 diffusion directions, 32 averages) was run for about 13 min prior to each IRS scan to heat up the passive shim elements of the magnet. In the same session, data were collected once with the conventional IRS sequence and once with the feedback-based IRS sequence. All corrected and uncorrected spectral averages were stored.

Results

Figure 2 shows the spectral time courses and the accumulated spectra without IRS phase correction (a and b), with IRS phase correction only (c and d) and with feedback-based frequency correction in combination with IRS phase correction (e and f). As can be seen in Fig. 2a, gradient heating gives rise to a roughly linear drift towards lower frequencies for all metabolites during spectral acquisition. Without correction, this leads to significant line broadening and impaired water suppression in the accumulated spectrum (Fig. 2c). With retrospective phase correction, the frequency drifts can be corrected and the resulting linewidths improved. However, the degradation of the water suppression remains. With the feedback-based IRS sequence, the quality of the water suppression stays unaffected over the whole acquisition interval (Fig. 2e). Note that the slightly increased linewidths in Fig. 2f compared to Fig. 2f are due to the fact that the feedback-based IRS spectrum was acquired after the conventional IRS spectrum, suggesting slight subject motion in between scans.

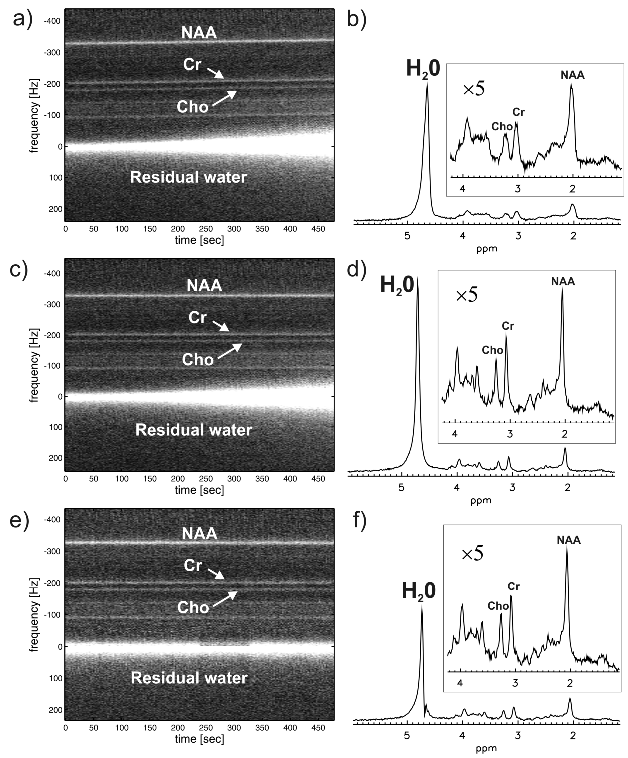

Fig. 2: Spectral time courses and accumulated spectra for PRESS-based IRS measurements without IRS phase correction (a, b), with IRS phase correction only (c, d) and with feedback-based frequency correction in combination with IRS phase correction (e, f).

Discussion

Phase distortions and frequency drifts can be effectively corrected with the purely retrospective IRS method [1, 2]. However, in the presence of severe drifts, the quality of water suppression can deteriorate considerably. The feedback-based IRS method effectively combines the functionality of a robust frequency lock with a retrospective phase correction technique (e.g. for eddy current correction). Furthermore, the method might be used to ensure a stable efficiency of frequency-selective pulses in spectral editing sequences where field drifts can be very critical. The SNR loss through the additional resonance excitation is negligible under typical in vivo conditions. The additional reference acquisition increases the minimal repetition time for MRS with reasonable spectral resolution (2 Hz at 3 T) to more than 1 s, but a TR > 2 s is advisable anyway to avoid a bias through T1 relaxation.

Acknowledgements

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References

1. Lange T, *et al.*, ISMRM 2009 ; #4322.
2. Thiel T, *et al.*, MRM 2002 ; 47 : 1077-1082.
3. Ogg RJ, *et al.*, JRM B, 1994 ; 104 : 1-10.
4. Klose U, *et al.*, MRM 1990 ; 14 : 26-30.