Frequency correction for MR Spectroscopy in the human breast at 7 Tesla with external field monitoring

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Introduction

MR imaging and spectroscopy can be hampered by variations in the frequency of the main magnetic field caused by motion. Particularly at high fields, such as 7T, breathing causes time depending susceptibility changes, even at locations distant from the lungs, e.g. the brain. Without correction of the temporal frequency shift, the addition of signals obtained over multiple acquisitions will broaden line widths that will result in a decrease of SNR and spectral resolution (fig. 1). As shown by van Gelderen *et al.* [1] most of these distortions (which are in the order of a few Hertz) in MRI of the brain can be calibrated and corrected for when synchronizing the frequency shifts with a respiratory belt. However, for tissues closer the lungs, magnetic field distortions are expected to be more severe, as was shown at 4T for the human breast by Bolan *et al.* [2]. Dynamically changing magnetic field distortions can be obtained in real time using field probes as shown by Barmet *et al.* [3]. Therefore, we propose the use of field probes integrated in a dedicated breast RF coil to correct for magnetic field distortion caused by breathing. We demonstrate the feasibility of real time observation of B_0 fluctuations in the human breast with a field probe at a 7T MR system. In addition, we demonstrate that direct observation of field distortions may substantially improve frequency correction compared to the indirect calibration method based on respiratory belt synchronization.

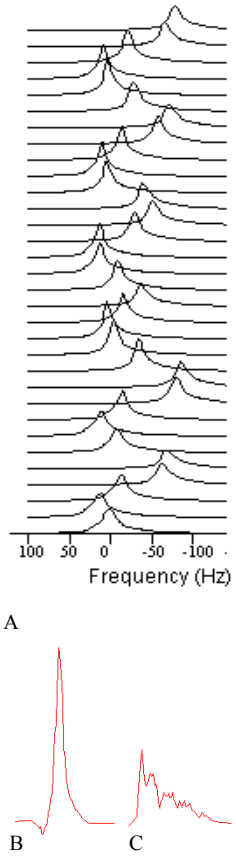

Figure 1: (a) Multiple ^{1}H MR spectra obtained with a STEAM sequence (TR/TE: 1500/5.6 ms, voxel size = 10 x 10 x 10 mm). (b) All spectra added after frequency correction resulting in high SNR gain (c) When All MR spectra are added without a frequency compensation this results in a broad and corrupt line shape.

Materials and methods

For this feasibility study we have developed a transceive ^{19}F field probe to monitor B_0-field deviations in the breast. It consists of a small cylinder filled with trifluoroethanol (TFE) and is surrounded by a small loop coil tuned and matched to the resonance frequency of ^{19}F at 7T. The probe was interfaced via an independent NMR spectrometer, which performed repeated pulse acquire measurements (TR = 100 ms). In addition a respiratory belt was used to monitor respiration.

To demonstrate the effect of the frequency correction, a series of ^{1}H measurements (STEAM, TR=1500 ms, TE = 5.6 ms, voxelsize = 10x10x10 mm) was performed on a phantom inserted and fixed in a unilateral home-built breast coil [4]. A male volunteer was positioned on the coil/phantom. The voxel was located inside the fixed phantom. Since there was no direct contact between the volunteer and the phantom, all frequency offsets measured in the phantom were generated by breathing and/or motion of the volunteer. The acquired ^{1}H-MR data was retrospectively corrected with the ^{19}F frequency data.

Results and discussion

The frequency offset invoked by breathing on locations close to the lungs can be very large (~100-150Hz) (fig. 1A). A hysteresis can be observed when relating the frequency offset, measured by the fieldprobe, with the signal from the respiratory belt (fig. 2). Therefore, correction of the B_0 frequency with the signal of the respiratory belt is compromised. By using field probe data for retrospective correction, high quality MR spectra can be obtained (fig. 1B). The field probe, clearly shows the frequency deviation over time (fig. 3) and the correlation of the frequency offset between the field probe and the ^{1}H spectra is good (fig. 3). Although it is possible to retrospectively correct for frequency offsets in high SNR ^{1}H MR data, this is not the case for low abundant nuclei, such as phosphorous, and MR spectroscopic imaging.

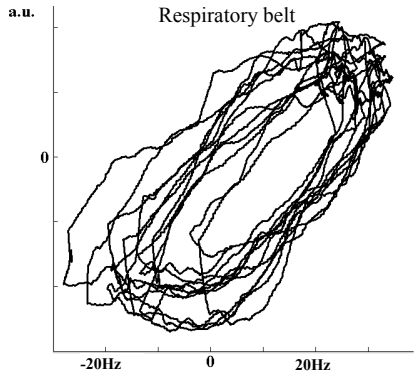

Figure 2: Effects of magnetic field alterations as monitored with a respiratory belt in the human breast at 7T. Due to breathing, the spectral resolution degrades. Field effect corrections using respiratory sensor will be ineffective due to its non linear relation.

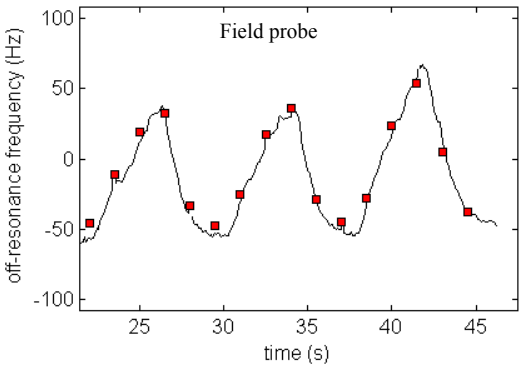

Figure 3: Correlation of the frequency deviation between the data obtained with the field probe (line) and the STEAM data (squares).

Conclusion

Monitoring of temporal frequency variations induced by respiration can be directly observed with an external MR field probe. In fact, without any corrections, it will be questionable if accurate ^{1}H MRS can even be performed from the breast at 7T without frequency corrections. The field probe can be placed in close proximity to the breast to accurately measure local frequency shifts invoked by breathing. This information can be directly used for correction of the actual MR data. Field probes can be used to accurately and directly measure dynamic frequency offsets caused by breathing. In conclusion, field probes can be used to accurately and directly measure dynamic frequency offsets caused by breathing, which enables the use of real time frequency correction during human breast spectroscopy at 7T .

References

[1] MRM, 2007 Feb;57(2):362-368. [2] MRM, 2004 Dec;52(6):1239-45. [3] MRM, 2009 Jul;62(1):269-276. [4] Proc. ISMRM 2010: 2469