

# B<sub>0</sub> shimming in the human breast for 7 Tesla MR Spectroscopy

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## Introduction

<sup>1</sup>H MR spectroscopy can be used to monitor alterations in choline levels during breast cancer treatments. However with <sup>31</sup>P MRS its specificity may be improved as multiple phospholipid compounds (such as phosphocholine (PC) and -ethanolamine (PE) and their glycerol derivatives (GPC, GPE)) may be distinguished. In contrast to <sup>1</sup>H MRS, with <sup>31</sup>P MRS voxels may encompass the entire tumor, thereby increasing SNR, as signals from surrounding lipid tissue are absent. However, at high magnetic field strengths, when relatively large voxels are considered, spectral resolution will depend on macroscopic susceptibility. In fact it will be questionable if spectral resolution of <sup>31</sup>P MRS in the human breast at 7 T will be sufficient at all to distinguish the phospholipid compounds, particularly considering the large susceptibility differences between glandular and lipid tissue. In addition, spectral stability is influenced by breathing, which may reduce overall spectral resolution even further, particularly for tissues in close proximity to the lungs like the breast. Fortunately, up to third order B<sub>0</sub> shimming is available for 7 T, which may improve spectral resolution. **Aim:** to investigate the effects of susceptibility and breathing on the spectral resolution in the unilateral breast measurements of seven healthy female volunteers. Using third order B<sub>0</sub> shimming at 7T, we demonstrate sufficient spectral resolution to distinguish PE from PC obtained from the entire breast of healthy volunteers. Next to this, correction of zero order dynamic B<sub>0</sub> alterations caused by breathing, results in enhanced spectral resolution and better SNR.

## Methods

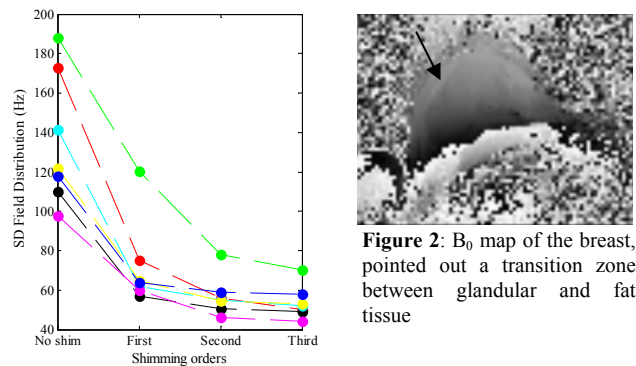
Three dimensional static B<sub>0</sub> maps (breath-hold, res=3x3x3mm, TE1=3 ms and TE2=4 ms, TR=5.2 ms) and two dimensional dynamic B<sub>0</sub> maps (res=2.25x3.0x10.0 mm, acq-time=0.5 s) of the breast of seven healthy volunteers were acquired with a home built <sup>1</sup>H/<sup>31</sup>P breast coil at a 7 Tesla MR system (Philips Medical Systems, Cleveland, USA). Measurements were performed in both maximum inspiration and maximum expiration state as well as during regular breathing. Using 3<sup>rd</sup> order image based B<sub>0</sub> shimming, <sup>31</sup>P MR spectra (pulse-acquire, adiabatic excitation, TR=5s, 10 minutes) were obtained from the entire breast.

## Results and Discussion

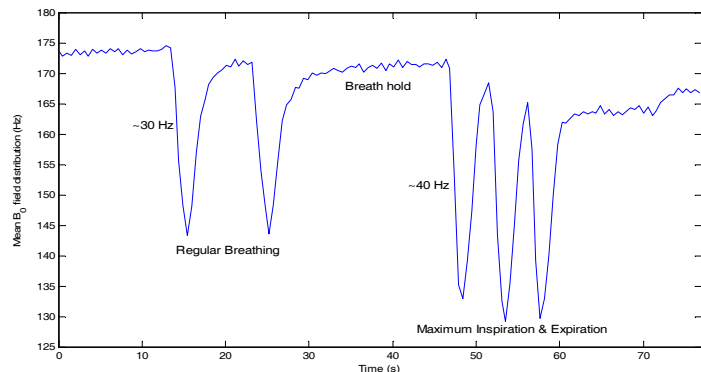
The effect of 3<sup>rd</sup> order shimming of the breast at 7 T results in a minor improvement of 2% compared to 2<sup>nd</sup> order shimming (**Fig 1**). The substantial residual B<sub>0</sub> field inhomogeneity of 0.18 ppm (i.e. 54 Hz), after 3<sup>rd</sup> order shimming is caused by magnetic susceptibility differences between glandular tissue and lipids (**Fig 2**). In addition, a substantial zero order shim effect of another 30Hz is observed during regular breathing, which is strongly correlated with the breathing cycle (**Fig 3**). No significant improvement in spectral resolution was observed when using respiration dependent versus respiration independent higher order shimming (up to 3<sup>rd</sup> order), obtained and applied during maximum inspiration and expiration breath hold state. Correction of zero order B<sub>0</sub> effects, however, results in a significantly enhanced spectral resolution and better SNR (**Fig 4**). Overall, using static 3<sup>rd</sup> order B<sub>0</sub> shimming, the spectral resolution at 7 T is sufficient to distinguish PC from PE in the human healthy breast using <sup>31</sup>P MRS (**Fig 5**).

## Conclusion

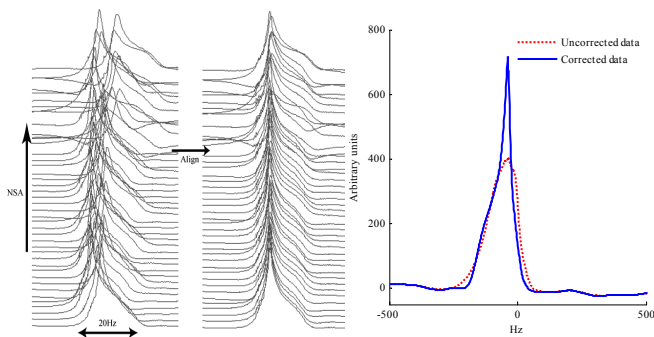
Using static 3<sup>rd</sup> order B<sub>0</sub> shimming, a spectral resolution of 0.18 ppm can be obtained. This allows using <sup>31</sup>P MRS at 7 T to investigate phospholipid metabolism in the entire human breast in e.g. the assessment of cancer treatments. Furthermore, substantial dynamic B<sub>0</sub> field alterations that strongly correlate to breathing are observed, which can be corrected for to improve spectral resolution and SNR even further.



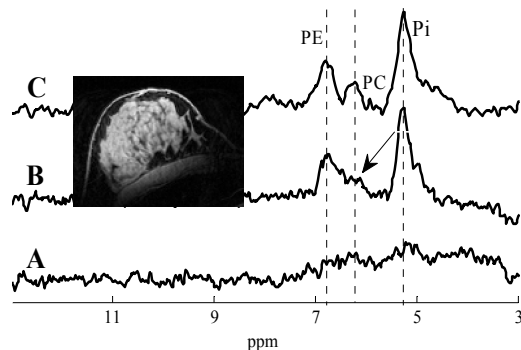
**Figure 1:** Effect of first, second and third order shimming in the breast at 7 T measured in 7 volunteers, shown as mean of the SD of the B<sub>0</sub> field distribution inside the breast.



**Figure 3:** Average frequency shift (Hz) in the breast during breathing.



**Figure 4:** Correction of the respiration induced frequency shift results in about factor 2 gain in SNR and a better spectral resolution.



**Figure 5:** <sup>31</sup>P MR spectrum of the breast of a healthy volunteer (inset) without (A) and with (B,C) third order shimming obtained sequentially in time (due to limited bandwidth of the adiabatic excitation pulse, only signals between 5-7 ppm are displayed). After third order shimming, dynamic alterations in B<sub>0</sub> can still affect the spectral resolution (B versus C), depending on the acquisition windows with respect to the breathing cycle.