Correction of B0 field fluctuations in the breast at 7 tesla by fitting a dipole field to field probe data – A simulation study

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Introduction: Respiration causes motion of boundaries with large susceptibilities differences, such as the shoulders, the heart and the diaphragm. The motion of these boundaries causes B_0 field fluctuations during scanning and results in a range of artefacts in MR scans such as ghosting, loss of SNR or decrease of spectral resolution. Several methods exist to correct for these breathing induced artefacts, such as triggering or respiratory belt based or phase navigator based field corrections. Recently, field probes have been suggested to monitor the B_0 field in real time. This information can be used to correct for the B_0 field fluctuations like has been shown for MRS of the brain[1]. However, since the field probes sample the field outside the region of interest, a transformation has to be made to the field inside the body. This might be particularly challenging for breast applications since probes cannot be positioned fully around the ROI. In this study we have investigated how field probe based field estimation can be used to correct for field fluctuations in breast MR scans at 7 tesla.

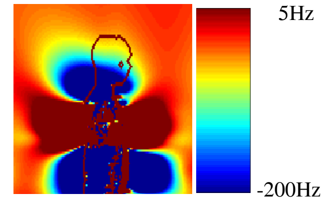

Fig 1: Field fluctuations at 7 tesla in and around the body over the respiration cycle. Note the dipole shaped distortion around the chest area.

Methods: To simulate the field fluctuations over the respiratory cycle in and outside the body, two whole-body scans, one in inspiration and one in expiration, were obtained at 1.5 tesla. The air and tissue were segmented and a forward B_0 field calculation was performed and extrapolated to 7T since susceptibility effects scale linear with field strength.

Field fluctuations in the breast at 7T were assessed with a unilateral breast coil (MR Coils BV, Drunen) in healthy female volunteers and in phantoms by placing a sphere inside the coil with a male volunteer on top of the coil to induce field fluctuations. Up to ten ^{19}F field probes[2] were placed in and around the breast coil. Field probe data and 3D B_0 field maps were acquired simultaneously in inspiration and expiration. A difference B_0 field map, ΔB_0, was calculated by subtracted the B_0 map obtained in inspiration from the B_0 map obtained in expiration. First order shim terms were fitted to the ΔB_0 map with a least squares algorithm to obtain the best achievable first order shim term fit as a reference for the field probe performance. The information from the field probes was fitted in two ways. First a direct first order fit to the probe data was performed. Second, a dipole function was fitted by simulating a dipole field with a origin (x, y, z) and a variable size and current. The obtained fields were applied to the ΔB_0 map to assess the potential of fitting first order fields with field probes.

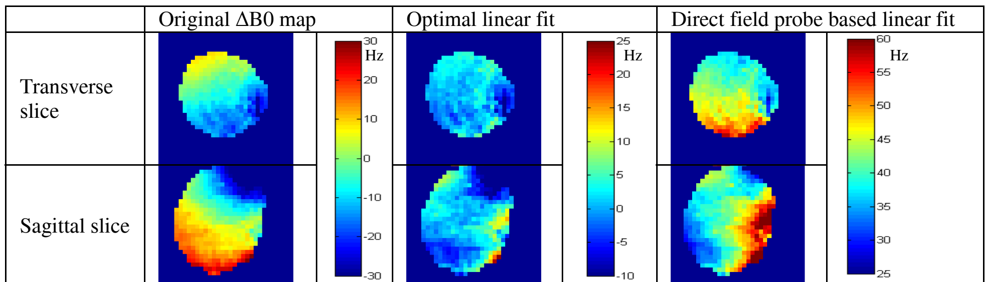

Fig 2: Left column: field fluctuations in a phantom in the breast coil at 7 tesla over the respiratory cycle. Middle column: Optimal linear fit. Right column: Fit obtained with field probes inside the breast coil.

Results: Figure 1 shows field fluctuations in and around the body at 7 tesla which resemble a dipole field around the diaphragm. Figure 2 shows images of a transverse and sagital slice of the ΔB_0 map in phantom experiments, the corresponding slices when the optimal first order fit is applied and when the direct linear field probe based fit is applied. Table 1 shows the corresponding values of these fits. Figure 3a shows a field fluctuation of in vivo scans in a sagittal slice of the breast with dipole field correction in figure 3b. The dipole field used for this correction is shown in figure 4.

	Optimal linear fit	Field probe based linear fit
F0	-27 Hz	-81Hz
X (AP)	-6.82 μT/m	-13.0 μT/m
Y (LR)	3.70 μT/m	2.2 μT/m
Z (FH)	11.1 μT/m	-10.6 μT/m

Table 1: Fields fitted to correct for the fluctuations shown in figure 2.

Discussion: As can be seen in figure 1, dipole shaped field fluctuations occur in and around the body due to the motion of chest and diaphragm. Simulations on the phantom data show that fitting first order fields from field probe data are not always sufficient to correct for these fluctuations. A more complex function, the dipole function, is better able to describe the fluctuations inside the breast, even if the field fluctuations are observed outside the body.

Conclusion: Correcting for field fluctuations in the breast by direct fitting of a first order field to field probe data does not seem to be sufficient. Therefore we suggested to fit a dipole shaped field to the field probe data. The dipole field in the region of the breast can be converted to traditional spherical harmonics for real time correction.

References: [1] Wilm et al. MRM 2013 [2] De Zanche et al. MRM 2008

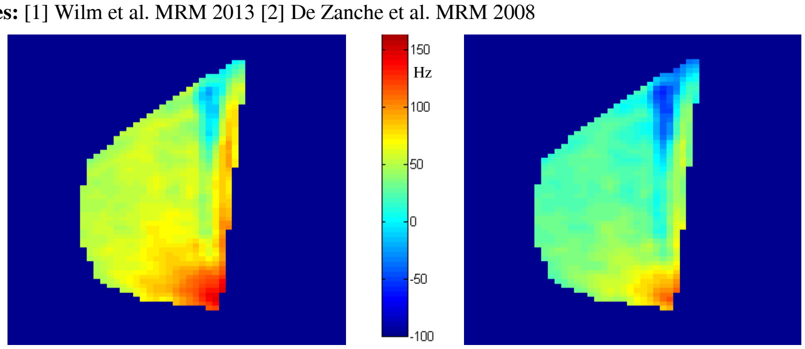

Fig 3: The left image shows a respiration induced fluctuation in a sagittal slice of the breast. The right image shows the field fluctuation when a dipole shaped field is fitted to field probe data and applied to the region of interest.

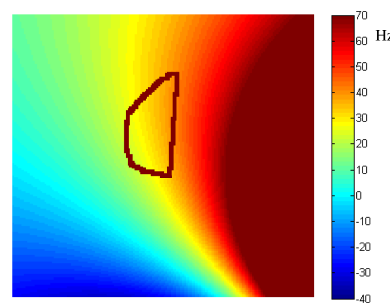

Fig 4: The dipole shaped field fitted to field probe data to correct for the fluctuations seen in figure 3. The red outline shows the location of the breast.