Bilateral shimming of the breast at 7T

Vincent O. Boer[1], Mariska P. Luttje[2], Peter R. Luijten[1], and Dennis W.J. Klomp[1]
[1]*radiology, UMC Utrecht, Utrecht, Utrecht, Netherlands,* [2]*radiotherapy, UMC Utrecht, Utrecht, Utrecht, Netherlands*

Introduction: The increased magnetic susceptibility effects at high magnetic field increases the demands in shimming the B_0 field for in vivo magnetic resonance imaging and spectroscopy. Especially the large B_0 field distortions in the human breast can lead to failures in clinically relevant scans, like fat suppressed imaging, distortions in DWI scans and loss of signal and spectral resolution in MRS. Therefore higher order shimming is routinely performed at high field to compensate for B_0 field inhomogeneities. Although the field can be compensated accurately with 2nd order shimming in a single breast, the question remains how bilateral shimming should be performed, since the large field of view would require more degrees of freedom in B_0 shimming. Third order shims, that are available on some high field scanners might be sufficient. Alternatively, insert shim coils have been developed for the brain, which might be extendable to body imaging. Furthermore, recent developments in dynamic shimming have made it possible to switch between shim settings during a sequence [1], where two breasts could be scanned interleaved with two sets of second order shims. In this work we compare unilateral shimming with bilateral shimming of up to fourth order, and compare the use of alternative shim coil design for breast shimming, as first explored by Lee et al [2].

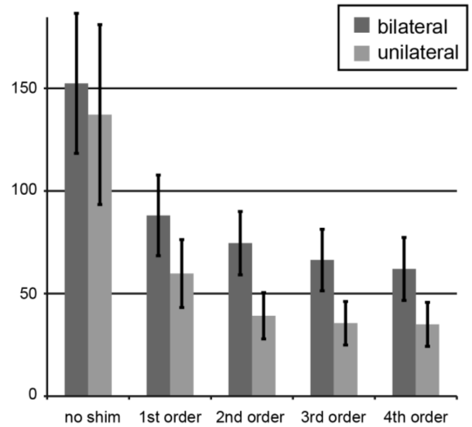

Figure 1. Shimming performance over volunteers. Bilateral shimming performs significantly poorer than unilateral shimming, even with up to fourth order shimming, indicating that spherical harmonic function do not describe the encountered field distortions accurately.

Methods & Results: Field maps were acquired on a whole body 7T scanner (Philips, Cleveland, US) both with a unilateral and bilateral coil setup (MR Coils BV, Drunen, The Netherlands). Unilateral shimming was performed in 48 volunteers, where the field homogeneity did not improve significantly when going beyond 2nd order shimming (38 Hz standard deviation over the breast). Bilateral shimming was performed in 22 volunteers, where the field homogeneity is significantly worse (70 Hz std for 2nd order shim, fig 1), and only slightly improves by going beyond 2nd order spherical harmonic shimming. In view of that, we can conclude that the field distortions encountered in bilateral breast shimming have a shape that is not well described with up to fourth order spherical harmonics, where especially the asymmetry in the field between the breasts seems to be difficult to fit for the shallow spherical harmonics. To overcome this, an additional shim coil was developed and was placed in the midline between the breasts. It was interfaced to one of the non-used shim amplifiers of the system. The midplane shim coil generated a very asymmetric field between the left and right breast (fig 2), which could compensate the significant asymmetry observed in the breast (fig 3). On this slice the field homogeneity was improved by 19% on top of second order spherical harmonic shimming.

Conclusion: Requirements for bilateral shimming of the breast at 7T are significantly different than for unilateral shimming. Up to fourth order shimming does not seem to lead to significant improvements in field homogeneity. Dynamic shimming can be performed by interleaving acquisitions on two sided with two sets of 2nd order shims. Alternatively, different shim coil designs can be explored, where we show here the first results of a midplane shimcoil that can already compensate part of the field distortions encountered in bilateral shimming. Residual fields tend to show more localized distortions in the magnetic field that cannot be compensated for, even with 4th order spherical harmonic fields. For this, extension of the midplane coil with an array of closely positioned coils may increase uniformity in the B_0 field further.

References: 1. Koch JMR 2006 2.Lee ISMRM 2011,715

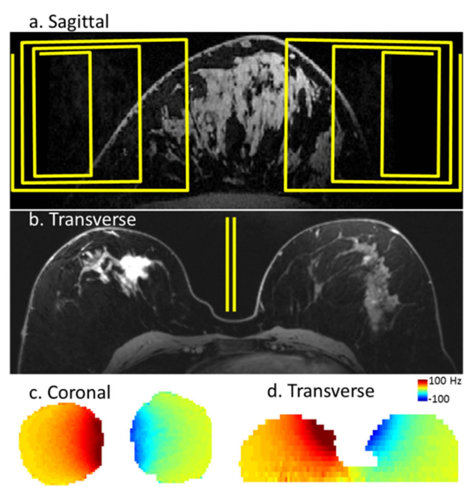

Figure 2: Design of an midline shimcoil in a sagittal (a) and transverse (b) with in yellow the windings of the coil. The coil generates a local compensation of the magnetic field (c,d).

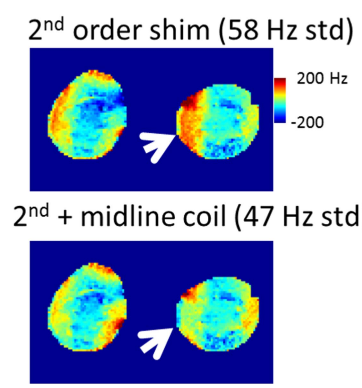

Figure 3: Field distortion in the breasts after 2nd order shimming without (top) and with (bottom) the midline shim coil results in an 23% increase in field homogeneity with a 800 mA current through the coil.