B1 shimming with a standard 2 channel headcoil at 7T: possibilities & limitations

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Purpose: To study the possibilities and limitations of RF phase and amplitude shimming with a standard 2 channel head coil at 7T.

Introduction

One of the main problems in high field MRI is the reduced SNR and loss in contrast due to inhomogeneous B_1^+ RF transmit fields. Spatial homogeneity is of primary importance for diagnostic imaging. At 3T the homogeneity problem is mainly limited to regions in the body while at 7T MRI of the head already suffers from this problem. At 3T two channel RF phase and amplitude shimming using a transmit body coil leads to significant improvements in both spatial B_1^+ homogeneity and SAR management [1]. As the ratio between RF wavelength and object size for 3T body imaging is approximately the same as for 7T head imaging, we investigated the possibilities of RF shimming with the standard quadrature head coil used at 7T. Here electromagnetic simulations and in vivo results are presented.

Methods

All simulations were done using a standard 7T Nova Medical T/R head coil. For the measurements this coil was combined with a 16 channel receive array (Philips Healthcare). The T/R coil is a high-pass birdcage coil with two feed points under an angle of 90 degree, located symmetrically with respect to the midline of the head. In the standard setup, a quadrature T/R switch is used to generate a 90 degree phase shift between the RF inputs to the two ports. In the two channel setup, this unit was replaced by an in house developed amplitude and phase modulator which allowed independent phase and amplitude settings on both ports.

Simulations: The B_1^+ fields generated by the two channels of the coil were simulated by an in house developed FDTD simulation tool using a realistic head model [2]. To study the effects of B1-shimming on B_1^+ homogeneity, the resulting B_1^+ fields were added for a range of phase and amplitude settings between the two channels. The phase was varied between 0 and 360 degrees while the relative amplitude was between 0 and 1. The standard deviation of B_1^+ over the whole brain was used to evaluate B_1^+ homogeneity. The SAR distribution was simulated for the setting with maximum homogeneity.

Measurements: A healthy volunteer was scanned with both the standard and two channel setup. A 3D magnetization prepared FLAIR sequence [3] was used as an example to demonstrate the effects of B1-shimming. With the standard setup, the FLAIR images show a reduced SNR and loss of contrast in the temporal pole (figure 3b,d). B_1^+ maps were acquired for both channels independently by using the double TR method of Yarnick [4]. Optimal phase and amplitude settings were determined for a region in the right temporal pole by minimizing the SD in B_1^+ over the ROI.

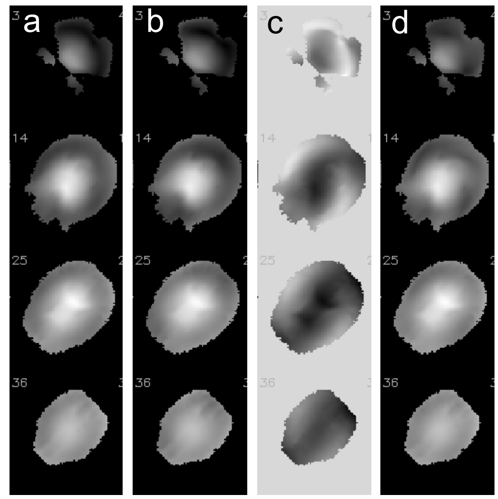

Figure 2: Simulated B_1^+ profiles for (a) quadrature setting, (b) minimal SD setting,(c) difference between (a) and (b) ((b)-(a)) and (d) maximum possible B1.

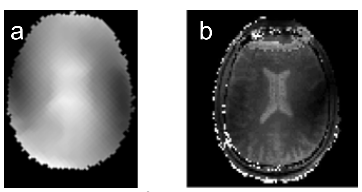

Figure 1: (a) Simulated and (b) measured B1 map for channel 1.

Results & Discussion

Simulations: Figure 1 shows a simulated and a measured B_1^+ field map for one of the channels of the coil. Note the similarity between the simulation and measurement. The result was similar for the other input port. Figure 2 shows the simulated quadrature setting (2a), minimal SD setting (2b) of the coil together with the difference between the two (2c=2b-2a) and the maximum possible B_1^+ per pixel (2d). The optimal setting was reached for a phase offset of 88 degrees of channel 2 with respect to channel 1 and relative amplitudes of 1.0 and 0.44 for channel 1 and 2 respectively. Global and peak SAR for the optimal setting were similar to the quadrature setting. The maximum possible B_1^+ per pixel was calculated by adding the magnitude B_1^+ images of the individual ports (i.e. assuming optimal phase setting in each pixel). The B_1^+ field shows both areas of increase and decrease. It is clear from the simulation that overall homogeneity is not possible with the 2 channel setup. This is in agreement with published simulation results by Mao et al [5] who showed that a 16 element stripline array was needed to adequately shim the human head at 7T. However, the simulations presented here, show that local improvements are possible with the 2 channel setup.

Measurements:

Figure 3 shows coronal (a,b) and transversal slices (c,d) of a 3D FLAIR data set in the same volunteer, scanned in two separate sessions and reformatted at approximately the same locations. On the left (a,c) the data using amplitude and phase shimming with the two channel setup is shown. The phase offset of channel 2 was 335 degrees with respect to channel 1 and the relative amplitudes were 0.38 and 1.0 for channel 1 and 2 ,respectively. On the right (b,d) the default (quadrature excitation) scanner setup results are shown. Although shimming was performed for a region in the right temporal pole, the overall homogeneity improved considerably. Also note the reduced signal in the front and back parts of the brain due to the shimming in figure 3c as compared to figure 3d.

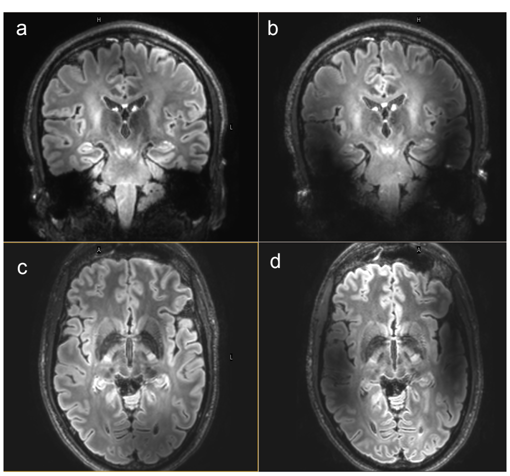

Figure 3: (a,b) coronal and (c,d) transverse reformats of a 3D FLAIR dataset (a,c) with the two channel setup and B1 shimming and (b,d) with the standard setup.

Conclusions

The simulations show that whole brain B1 homogeneity is not possible with the two channel setup using the standard birdcage head coil. However, in vivo results show that uniformity improvements can still be considerable as illustrated in figure 3.

References

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