Dynamic Control of the First and Second Order Shim Coils by LabVIEW at 4T

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Introduction

Shimming is important for a number of highly demanding MR applications, such as EPI, that suffer from local field inhomogeneity. Current MR hardware, however, provides only for global B_0 adjustments which correct a selected volume as a whole and these adjustments cannot be changed over the course of a scan. Functional MRI, for example, would greatly benefit from real-time shim adjustments updated for local volumes or slices. Dynamic shimming, a method in which optimal shim values are set for each slice, has been previously reported using only first order shim compensation [1,2] and more recently using first- and second- order shim coils [3]. Since in the first case the shim adjustments were performed using the imaging gradient coils and in the second case the gradient diameter was considerably smaller compared to the magnet bore, both methods resulted in artefact-free multislice images. In this paper a setup based on an external dynamic shim controller (DSC), running LabView software, located between the console and the shim amplifiers is presented. This DSC is capable of first and second order shim coils adjustments. Further, potential artefacts arising from long stabilization delay times of high order shim coils have been investigated.

Methods

Figure 1 shows a schematic representation of the experimental set-up. A PC running a LabVIEW (National Instruments) application developed in our lab was used as an external DSC and was placed between the MR console (Varian Unity*Inova*) and the shim amplifiers (Resonance Research). The software was developed to transfer sets of shim values, optimised for each individual slice, to the shim amplifiers every time the console generated a trigger signal from the pulse sequence. The connection between the PC and the shim amplifiers was through a serial RS-232 port and the transfer rate was 9600 BPS (bits per second). The average time to transfer a complete set of shim values (3 first order and 5 second order) was 70 ms. For image data acquisition, a modified gradient-echo multi slice sequence, which generated a trigger signal each time a new slice is acquired was used. Testing of the efficacy of the DSC system was performed by imaging the head of volunteers (FOV = 256 x 256 mm, matrix size 128 x 128, TE=20 ms, slice thickness 5 mm, 3 slices). Moreover, to investigate the appearance of image artefacts due to the switching of the shim coils via the DSC system, a *post mortem* human brain was used and the TR was adjusted equal to 5, 3, 2 s (TE=10 ms, 5 slices). Optimal sets of shim values for each slice were obtained interactively by minimization of the peak linewidth (~16Hz *in vivo*, ~8Hz *post mortem*) obtained with a STEAM pulse sequence selecting a voxel corresponding to each slice.

Results

Figure 2 shows the globally optimized shims (left) and the dynamic shims, (right). An improvement of image quality was observed in the dynamic shim image, as shown by the arrow. Similar results were observed in the other slices. In Fig. 3 a), b), c) the effect of the decreasing TR on the dynamically shimmed images is shown. Aliasing artefacts are present in the TR= 2s, indicating non-optimal stabilisation of the shim coils prior to slice excitation and acquisition. This effect is critical since it may generate eddy currents in the system leading to artefacts as shown in Fig. 3c. A straightforward correction is to use a longer TR as shown in Fig. 3a. Here the selected TR of 5 s allows the shim coils to stabilize before the imaging gradients are pulsed. Figure 3d shows that the globally shimmed image (TR=2s) does not suffers from this effect.

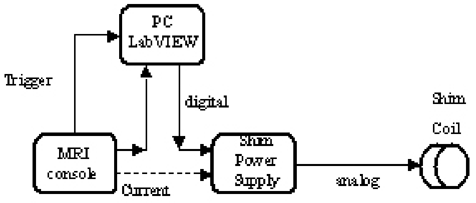

Figure 1: Schematic representation of the set-up for dynamic shimming

Discussion

The implementation of an external shim controller providing dynamic shimming functionality has been described. Testing of the DSC system with *in vivo* human brain has shown that the DSC system gives better performance compared to the global shimming for a TR>2s. It has also been shown that applying the dynamic shimming in an inappropriate manner (TR<2s) leads to erroneous results. In particular, the presence of eddy currents has been determined which compromises the quality of the images. The application of dynamic shimming, therefore, requires the knowledge of the effects of pulsing the shim coils in a very precise manner, especially in those cases where a high speed acquisition is required, such as in the EPI sequence. However, methods for eddy currents compensation such as gradual ramping of the shim coil currents seem feasible.

References

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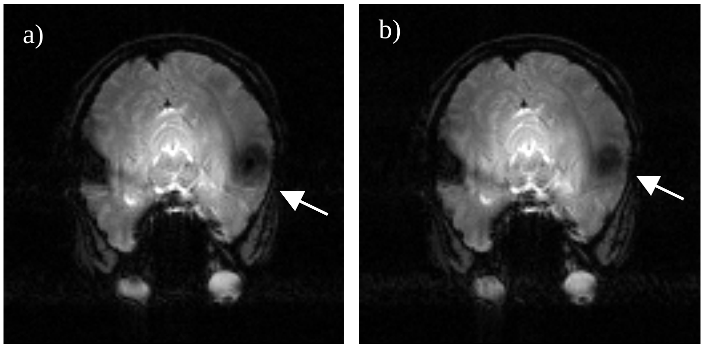

Figure 2 a) globally optimized shims, TR=3s, TE=20 ms; b) dynamic shims, TR=3s, TE=20 ms. The arrow show the region where the dynamic shimming improves image quality.

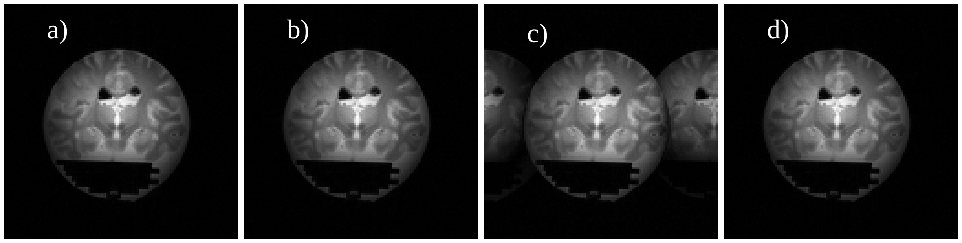

Figure 3. a) dynamic shims and TR=5 s; b) dynamic shims and TR=3s, c) dynamic shims and TR=2s and d) globally optimized shims and TR=2s.