Field-Map-Free First-Order Dynamic Shimming

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INTRODUCTION

Dynamic shimming (DS) has demonstrated the capability of providing a more homogeneous magnetic field than static shimming, reducing distortion and signal dropout in EPI[1]. Since field distortions scale with background field strength, it is even more important at ultra high field[2]. Typically, a field map is acquired on the subject and appropriate shim compensation fields are calculated for every slice in a multi-slice data set. For such field map based dynamic shimming approaches (FM-DS), high-resolution B0 field maps are required, particularly to estimate the through-slice compensation[3]. However, the field map acquisition step is time consuming. **In this work we present** a field map free dynamic shimming (FMF-DS) method to estimate shim settings to the first order, using a model of average field distortions in the brain, and demonstrate the feasibility of the method in EPI acquisitions.

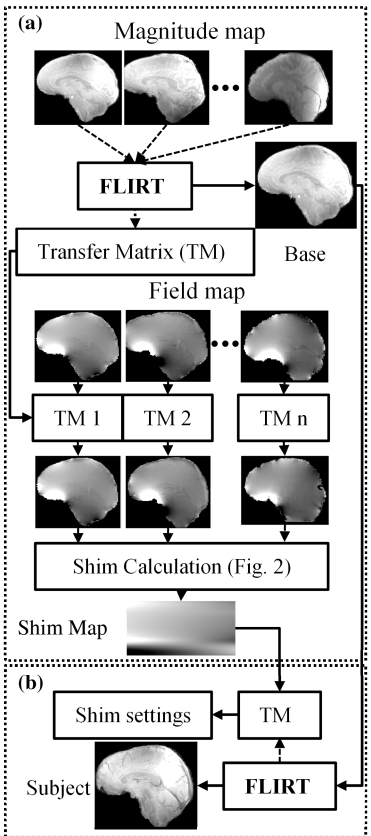

Figure 1: Schematics of (a) template generation stage and (b) FMF-DS shim determination stage

MATERIALS AND METHODS

The experiments were performed on a Siemens whole-body 7T MRI scanner (Erlangen, Germany), equipped with 70 mT/m gradients, and a 32-channel head coil (Nova Medical). The first-order dynamic shimming was carried out by updating the gradient coils on a slice-by-slice basis. Image acquisitions were performed on healthy volunteers. High-resolution field maps were acquired using a gradient echo (GRE) pulse sequence (Voxel size=2mm*2mm*1.2mm, Slices=128, TR=885, TE1=4.08ms, Δ TE=1.02ms, FOV=220*220mm) used for slice wise shim calculation. Echo-planar images (Voxel size=2mm*2mm*2.4mm, Slices=64, TR=3000ms, TE=25ms, FOV=220*220mm, PAT2) were used to evaluate distortion and dropout. The through-slice thickness of the GRE sequence was double that of the EPI sequence to adequately estimate the shim required in this dimension.

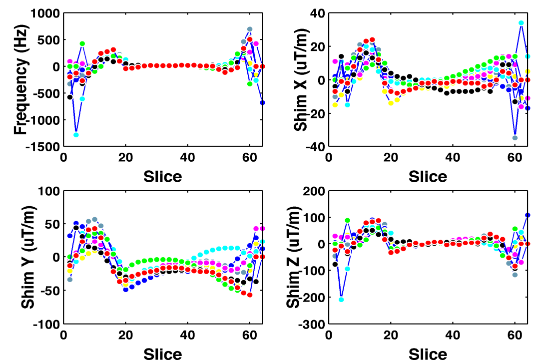

Figure 2: Slice-wise shim settings for 10 different subjects

The average shim field template was created based on 10 whole-brain field maps acquired on the 7T scanner. In order to build the template, FLIRT (FMRIB's Linear Image Registration Tool)[4] was used to register all 10 field maps to one subject and the slice-wise shim settings were calculated by a least square fit of fields up to first order (Figure 1). To calculate through-plane shim fields, one extra slice in each direction was included in the fit. A generalized field map was created by taking the average of the 10 shim values at corresponding slices. Subsequently, for each new subject the FMF-DS method was carried out in the following steps: (1) Acquire a structural scan of the subjects (2) register the base structural map to the subject's structural map and apply the registration transformation matrix to the compensation shim map (3) calculate the slice-wise shim based on the registered compensation shim map (4) apply the calculated slice-specific shim values to do the dynamic shimming. For comparison, FM-DS was also carried out on the subjects.

RESULTS AND DISCUSSION

The calculated slice-wise shim settings for the 10 different subjects are plotted in Figure 2. It can be seen that, despite individual differences, there are strong similarities in the shim settings from subject to subject. Figure 3 shows a comparison between static shimming, FM-DS and FMF-DS in an example slice, affected by signal dropout due to the susceptibility difference of the frontal sinuses. As expected, FM-DS outperforms static shimming, reducing signal loss in frontal areas. However, the FMF-DS is also able to regain signal in areas showing almost total signal loss when using static shimming. Comparing the results of FM-DS and FMF-DS shows a slight advantage of the FM-DS as expected.

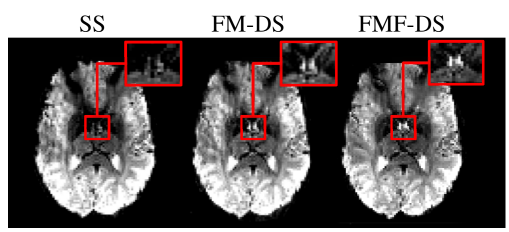

Figure 3: Comparison between EPI images using static shimming (SS), FM-DS and FMF-DS

The time it takes to acquire high-resolution field maps is one of the limiting factors in dynamic shimming methods being adopted more widely. Whilst a subject specific field map is never likely to perform as well as a template field map, the similarity in gross anatomy between subjects suggests that in time-limited applications, particularly in the use of fMRI in patient populations, their use may be justified to improve image quality. Moreover, FMF-DS may be further improved by incorporating a larger number of field maps into the template[5], by using non-linear registration methods, or by incorporating information from a low-resolution field maps acquired in minimal time. If a large database of field map templates is available, it may also be possible to incorporate other factors such as age, weight or height of subjects.

In **CONCLUSION**, we have demonstrated the feasibility of FMF-DS to produce a more homogeneous field than static shimming without a significant time penalty in acquisition.

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