

Comparison of the B0 Field and Shimming in Human Brains at 3T and 7T

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Introduction

At higher field strengths the B0 field suffers large perturbations due to the effect of magnetic susceptibility differences between tissues, which scale linearly with field strength. These field inhomogeneities lead to signal dropout in large-voxel methods such as spectroscopy and geometric distortions in rapid k-space methods such as EPI. The field must be shimmed to make the B0 field as uniform as possible over the volume of interest. A complication for mapping the B0 field with multichannel coils, which are desirable for their high sensitivity, is that the most common method of combining signals from the coil elements does not preserve phase information [1]. This study introduces ROMP, "Reconstruction of Multichannel Phase", a robust phase-sensitive method for multichannel phase imaging that can be used to map the B0 field prior to shimming. ROMP leverages the increased sensitivity of multichannel systems and can be used for scan sessions using a multichannel coil. This study uses ROMP to compare the B0 field and the effect of linear and second-order shimming of the B0 field in brains at 3T and 7T.

Method

Image acquisition: Field maps were acquired for 5 volunteers on a 3T GE Signa Echospeed system with EXCITE platform using an 8-channel phased-array coil and for 3 volunteers on a 7T GE Signa Echospeed system using a prototype USAI 16-channel phased-array coil. Informed consent was obtained for all volunteer scans. Gradient echo images (TR 30ms, flip 15°, FOV 24cm, 3.75mm isotropic voxels, 68s scan) were acquired at echo times of 6ms and 8ms at 3T and 5ms and 6ms at 7T.

Multichannel Phase Reconstruction: B0 field maps were found for each channel by taking the complex phase difference of the GRE scans. These maps were unwrapped using a region-merging algorithm that optimizes the cost-function at boundaries [2] and the resulting images were shifted to set the phase of the magnet isocenter to 0 radians. The maps from the individual coils were combined by a weighted average using the corresponding magnitude coil sensitivity profiles. These coil sensitivity profiles were acquired by smoothing and correcting the magnitude image using in-house software.

Shimming: Shim coil calibration maps were acquired for the three linear shims (X,Y,Z) and the five second-order shims (XY, ZY, ZX, Z2, X2-Y2). Optimal shim currents were calculated by a least-squares fit for the shim currents to minimize the root-mean-square (RMS) value of the B0 inhomogeneity over an 8cm×8cm×4cm volume using singular value decomposition (SVD) [3]. Shim currents generated by this algorithm were within the acceptable range for the shim drivers. Field mapping and shim calculation takes under one minute on a SunBlade 1500.

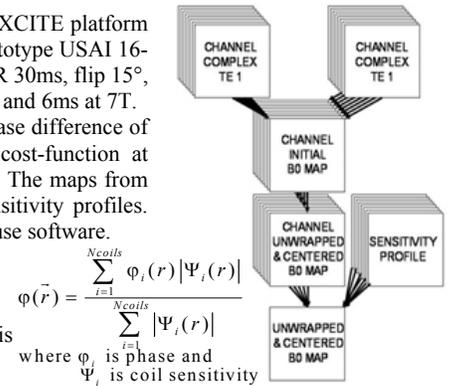


Figure 1: ROMP equation and data flow

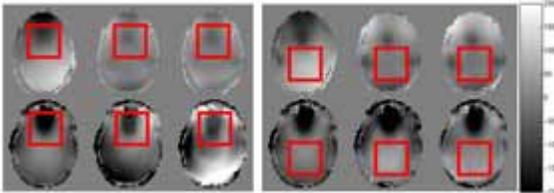


Figure 2: Effect of shimming on the B0 field (Hz) with at the front (LEFT) and back (RIGHT). The top/bottom rows are at 3T/7T and along each row is the unshimmed / linear shimmed / second order shimmed.

Field Strength	Volume Location	RMS (Hz)		
		No Shim	Linear Shim	Second Order Shim
3T	Front	74±13	35±4	34±3
7T	Front	88±18	60±17	49±14
3T	Back	56±11	22±1	21±2
7T	Back	42±5	32±5	24±5

Conclusion

Multichannel B0 field map reconstruction by ROMP can be used to map the field for shimming in multichannel coil scans. The method has improved noise statistics since the weighted sum suppresses noise in phase in voxels with low SNR at a particular voxel. The same method could be used in many other phase-based imaging methods such as temperature mapping, elastography, EPI distortion correction and susceptibility-weighted imaging. ROMP mapping has proved to be successful in demonstrating the increased inhomogeneity of the field at 7T as compared to 3T and the need for higher-order shimming at higher fields or for volumes placed over the sinuses.

References:

- [1] Roemer et al. MRM, **16**, 192 (1990), [2] Jenkinson et al. MRM, **52**, 471 (2004), [3] Kim et al. MRM **48**, 715 (2002). [4] Gruetter et al. MRM **43**, 319 (2000).

Acknowledgements :

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