Improved EPI at 7T with Dynamic Multi-coil Technique (DYNAMITE) Shimming
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INTRODUCTION: Echo-planar imaging (EPI) and its variants form the core of many functional and structural imaging studies. Image quality of these scans deteriorates drastically with increasing B0 inhomogeneities. Although post-processing can correct aspects related to image distortion, the only way to prevent signal dropout is by improved shimming. Commonly, higher-order static spherical harmonic (SH) shims are used to address this issue. Further gains have been reported with dynamic SH shimming, wherein the shim settings are optimized on a per-slice basis and updated during imaging in a slice-specific fashion.1 Recently, even better results were reported when dynamic shim fields were generated by an array of small individual coils placed around the subjects’ head.2, 3 In this study, we demonstrate that this dynamic multi-coil technique (DYNAMITE) leads to less distortion and reduced signal dropout in EPI of the human brain at 7 Tesla, in comparison with those acquired with SH shims.

METHODS: Five healthy volunteers aged 25-45 yrs (4 males) were scanned at 7 Tesla using EPI, multi-gradient-echo T2* mapping and B0 mapping scans to assess the benefits of DYNAMITE, compared with 3rd order SH shimming. Correction fields for SH and DYNAMITE shimming were derived from a B0 field map that was based on a whole-brain 2d multi-slice gradient-echo acquisition.2 Under both shim conditions, the EPI images and T2* maps were acquired at 3 isotropic resolutions (3 mm, 2 mm, 1.56 mm) and at identical slice positions, with full brain coverage (13 axial slices, 20x20 cm2 FOV and 9 mm slice spacing). The EPI images were obtained with TE= 30 ms, TR= 4.175 s, using single shot (3 mm isotropic, 16 averages), 2 shot (2 mm, 8 averages) and 4 shot (1.56 mm, 4 averages) sequences. The T2* data were acquired with 6 echo-times between 4 and 46 ms. The residual B0 maps were also acquired using the same scan (5 echoes, inter-echo spacing of 2.5 ms) at 1.56 mm isotropic resolution and at the same slice positions as EPI and T2* maps. To compare EPI distortions under SH and DYNAMITE shims, an outline of the brain was derived from an anatomical reference image and overlaid on the EPI images. Average B0 inhomogeneity and T2* were calculated globally and per slice.

RESULTS: Figure 1 shows the residual B0 inhomogeneities and the corresponding single shot and four shot EPI images of two example slices from one of the subjects (with overlaid brain boundaries). We find substantial residual B0 variations with SH shimming (mean/SD of 33/49 Hz and 17/24 Hz for the top and bottom slices, respectively) in comparison with DYNAMITE (11/17 Hz and 8/13 Hz, respectively). We observe significant distortion and signal voids in EPI images with SH shimming (more in 1-shot than 4-shot) in the Posterior-Anterior direction (see arrows; different colours denote opposite directions of the distortion), in comparison with DYNAMITE. Similar improvements were observed in all the datasets and across brain regions. These results are corroborated by our B0 mapping results and histogram analysis of T2* maps (results not shown).

DISCUSSION: We observe that B0 homogeneity can be substantially improved by using DYNAMITE instead of SH shims. This leads to significant improvement in EPI image quality (reduced distortion and signal drop-out) without the need for distortion correction. This is desirable for functional MRI and structural EPI scans at high fields.

![Fig. 1: Residual B0 inhomogeneities and EPI images from a volunteer scanned at 7 Tesla using SH (3rd order static spherical harmonic shimming) and DYNAMITE (dynamic multi-coil technique-based shimming) approaches. White arrows point to EPI distortions in the Posterior-Anterior direction and yellow arrows indicate the Anterior-Posterior pixel shifts.](image-url)

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