# Improved B0 Field Mapping with an Interleaved SE/ASE Acquisition and a Multi-channel Receive Coil

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**Introduction** Echo planar imaging (EPI) is commonly used in studies of functional brain activation. One problem with the technique is its sensitivity to magnetic field inhomogeneities, which produce image distortion. The use of $B_0$ field maps has been proposed to map these inhomogeneities, and subsequently correct distortions in the EPIs[1]. Here we present a method of field-mapping using a flow compensated spin-echo/asymmetric spin-echo (SE/ASE) pulse sequence, with interleaved measurements to reduce motion artefacts. We use a multi-channel receive coil in order to improve the signal-to-noise ratio (SNR), and compared the new sequence with a more conventional gradient echo (GE) $B_0$-mapping sequence, with quadrature body coil reception.

**Methods** The interleaving method was based on a technique previously used for MTR imaging[2]. For each phase-encode step in turn, an SE & an ASE were acquired in different TR periods. The SE was obtained in the usual manner. The ASE was obtained by shifting the 180° refocusing pulse forward by time τ, while leaving the positions of the acquisition window and the frequency-encoding gradient fixed. To ensure the peak of the ASE was within the acquisition window, τ was constrained by 2τ ≤ ½T where T is the sampling duration. The phase difference between the SE & ASE was calculated from[3]

$$\Delta\Phi = \arg\left\{\sum_k Z_{1k} Z_{2k}^* / \sigma_k^2\right\}$$

where $Z_1$ is the complex SE image, $Z_2$ is the complex ASE image, k is the coil number, $\sigma_k$ is a coil-dependent noise factor (here assumed to be 1.0) and * denotes the complex conjugate.

Images were acquired on a 1.5 T General Electric Twinspeed HD scanner (General Electric, Milwaukee, WI) using the body coil to transmit and an eight channel head coil to receive (SE/ASE images) or the body coil to receive (GE images). All images were acquired with FOV = 24 cm, matrix = 64 × 64, forty-three 3 mm thick slices with a 0.3 mm slice gap. SE/ASE images were acquired with TR = 1350 ms, TE = 20 ms and τ = 1 ms (giving an echo shift of 2 ms). GE images were acquired with TR = 1000 ms & TE = 5.6 & 7.6 ms (collected both as separate single echo acquisitions and as a double echo acquisition). One set of scans was acquired of a spherical quality assurance phantom. Two sets of scans were acquired of a normal volunteer. In the first set, the subject remained stationary throughout the acquisition. In the second set, the subject was asked to move halfway through acquisitions of the SE/ASE scan and of the dual echo GE scan. For the single echo scan, the subject remained motionless for the TE = 5.6 ms scan, then moved to a new position before the TE = 7.6 ms scan; the two images were then realigned using flirt (part of the FSL package http://www.fmrib.ox.ac.uk/fsl), prior to calculation of $B_0$ maps[4].

For the phantom scans, the standard deviation of a 3 × 3 voxel region of interest (ROI) was measured in a region where the field gradients were small. The volunteer scans were qualitatively assessed for robustness to motion artefacts. For the SE/ASE data, $B_0$ maps (rad $s^{-1}$) were calculated by phase unwrapping[5] the phase difference image, then dividing by 2τ (0.002 s). For the GE data, phase images for each echo time were individually phase unwrapped, and the difference of the unwrapped phases was calculated. The result was then divided by the difference in echo times (ΔTE = 0.002 s) to give the $B_0$ map.

**Results** The standard deviation of the phantom $B_0$ maps was 0.9 rad $s^{-1}$ when calculated using the SE/ASE method with a multi-channel receive coil, compared with 4.1 rad $s^{-1}$ when calculated using the single echo GE images. Fig 1a shows the SE/ASE field map, fig 1b the single echo GE field map, fig 1c the dual echo GE field map, and fig 1d the dual echo GE field map after subtraction of a linear (left/right) phase ramp that was apparent in the image, confounding the underlying $B_0$ variation. The images were scaled to ± 100 rad $s^{-1}$ except for fig 1c which was scaled to ± 1000 rad $s^{-1}$.

Figs 2a & 2b show the SE/ASE $B_0$ maps with the subject still and moving respectively, while figs 2c & 2d show the corresponding $B_0$ maps produced from the single echo GE images.

**Conclusion** The SE/ASE with array coil receive technique shows improved SNR when compared with the GE method with body coil receive, which should translate into improved distortion correction for EPI. The technique also produces $B_0$ maps without large zero offsets that occur with GE data. The technique was also free from phase ramps that appear in the dual echo GE method due to imperfect echo centring in the acquisition window. This was not corrected by removal of a linear phase term. This is subject to further investigation.

The SE/ASE method showed improved insensitivity to motion compared with the single echo GE method. This can be seen by comparing fig 1b with fig 1d. The “hot spot” behind the frontal sinus is less well defined, and is shifted to the left for the GE acquisition, but not for the SE/ASE acquisition.

**References** 1 Jezzard, P & Balaban, R.S. *Magn Reson Med*, **34**, 65–73, 1995. 2 Barker, G.J., Tofts, P.S. & Gass, A. *Magn Reson Imag*, **14**, 403–411, 1996. 3 Bernstein, M.A. *et al*, *Magn Reson Med*, **32**, 330–334, 1994. 4 Jenkinson, M. & Smith, S.M. *Med Image Anal*, **5**, 143–156, 2001. 5 Jenkinson, M. *Magn Reson Med*, **49**, 193– 97, 2003.

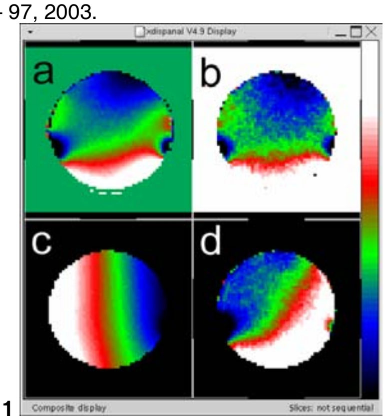


**Figure 1**

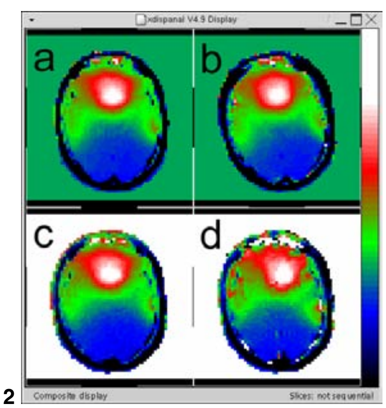


**Figure 2**