Spiral imaging trajectory mapping using high density 25-channel field probe array

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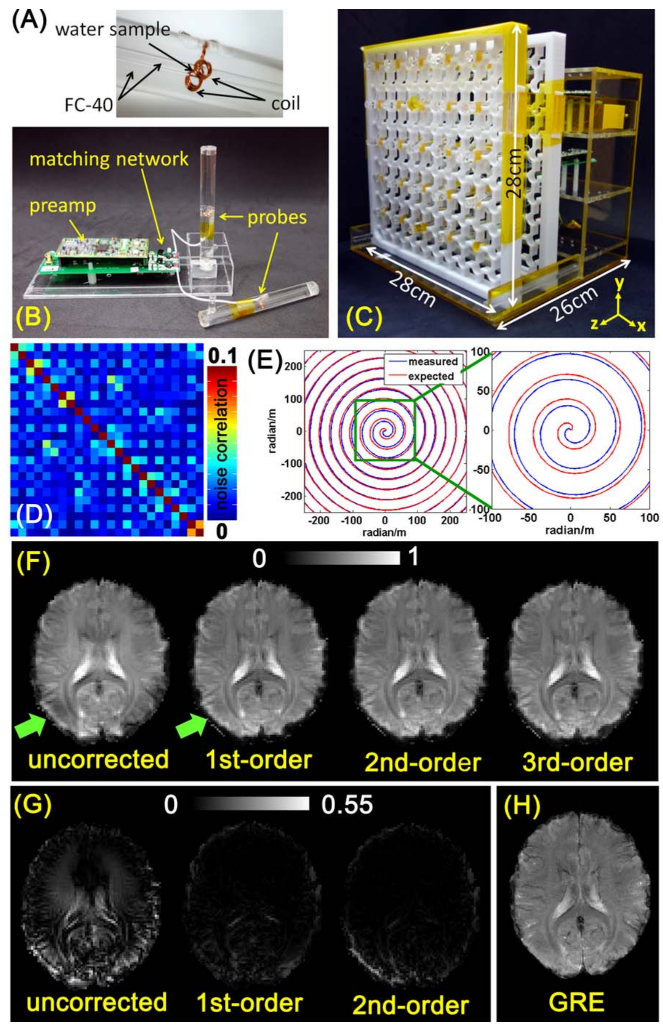
TARGET AUDIENCE Scientists interested in field monitoring and *k*-space trajectory calibration to improve image reconstruction quality.

PURPOSE Fast MRI typically requires fast switching of the gradient coils in order to traverse the *k*-space with the minimal encoding time and complete the data acquisition in a fraction of a second. However, fast switching gradient can cause serious eddy current, which can deteriorate the reconstructed image if the effect is neglected. While there are methods of gradient pre-emphasis adjustment[1] and *k*-space trajectory calibration[2], an accurate estimate of the *k*-space trajectory is still challenging, because the data acquisition parameters do not match between the calibration scan and the actual imaging scan completely. Magnetic field probes are promising hardware in estimating the spatial distribution of magnetic field disturbance[3].

Here, we developed a 2D 25-channel probe array in order to monitor the *k*-space trajectory and to use the calibrated *k*-space trajectory to improve the reconstruction of a spiral scan. The motivation of developing this dense 2D probe array was to dynamically estimate the magnetic field distribution during *k*-space traversal with polynomials up to the 3rd order. Our results show that images reconstructed using magnetic field estimates up to the 1st order polynomial show the most prominent improvement in homogeneity and anatomical details. Further information from the 2nd and 3rd order field distribution estimates only improved the reconstruction marginally.

METHODS Our probe used two 3-turn loop coils (31 AWG copper wire) to pick up the NMR signal. A cylindrical glass capillary tube (1.0 mm diameter) holding a water sample (3 mm length) was placed between two 3-turn loop coils (Figure (A)). We filled both ends of the water sample with FC-40 (3M, St. Paul, MN, USA) in order to match the susceptibility between air and the water sample. The capillary tube was placed at the center of an acrylic tube filled with FC-40 to further improve the susceptibility matching. Each field probe was actively detuned by a PIN diode during RF transmission. Probes were connected to a low noise pre-amplifier integrated with a mixer (LNC, Siemens, Erlangen, Germany; Figure (B)). Twenty-five field probes were positioned on a 5×5 grid structure (PC-ISO, Fortus 400mc, Stratasys, MN, USA; Figure (C)) with 5 cm separation from each other.

A noise correlation matrix was measured using a gradient echo sequence (GRE) without RF transmission. A single-shot spiral pulse sequence (TR = 500ms, $\alpha = 60^o$, TE = 60ms, and resolution = 2mm x 2mm x 5mm; 110 T/m/s slew rate) was used to measure the brain image of a subject. A high resolution GRE image (TR = 100ms, $\alpha = 25^o$, TE = 60ms, and resolution = 1mm x 1mm x 5mm) was acquired as the reference image. Magnetic fields were estimated by fitting the 1st, 2nd, and 3rd-order polynomial to the local magnetic field estimates from probes. Images were reconstructed using weighted correlation[4]. All measurements were performed on a 3T system (Skyra, Siemens).



RESULTS The average and the maximum of the noise correlation matrix were 0.015 and 0.07, respectively (Figure (D)). Figure (E) shows the expected (red) and the measured (blue) *k*-space trajectories. Clear difference was found at the center of the *k*-space. Compared with the reference image (Figure (H)), the reconstruction without calibrating the *k*-space trajectory (Figure (F)) had unexpected dark areas at the lower right and left corner of the brain. This artifact disappeared when the reconstruction accounted for the magnetic field estimated with the 1st order polynomials. Marginal improvement was found for reconstructions using magnetic field estimates up the 2nd and 3rd order (Figure F; middle right and right most). Figure (G) shows the difference image between the each reconstruction and the reconstruction with up to the 3rd order polynomial magnetic field estimate and supports our observation in Figure (F).

DISCUSSION Our results suggest that a spiral scan can be benefited significantly from calibrating the magnetic field up to the 1st order. Magnetic field estimates accounted by the 2nd and 3rd order mostly brought high spatial frequency information (Figure (G)). While our results show marginal improvement in further adding the field estimates with 2nd or 3rd order, such high order calibration can still be useful in experiments using other imaging parameters, pulse sequences, or MRI systems. Our 2D probe system can be further extended in multi-slice or 3D imaging by shifting the probe arrays along the z-direction.

REFERENCES

1. N. G. Papadakis, et al. Magnetic Resonance in Medicine 2000;44(4):616-624.
2. J. H. Duyn, et al. Journal of Magnetic Resonance 1998;132(1):150-153.
3. C. Barmet, et al. Magnetic Resonance in Medicine 2008;60(1):187-197.
4. A. Maeda, et al. Ieee Transactions on Medical Imaging 1988;7(1):26-31.