4-channel transceive surface coil array for reduction of EPI-induced artifacts using SENSE and GRAPPA

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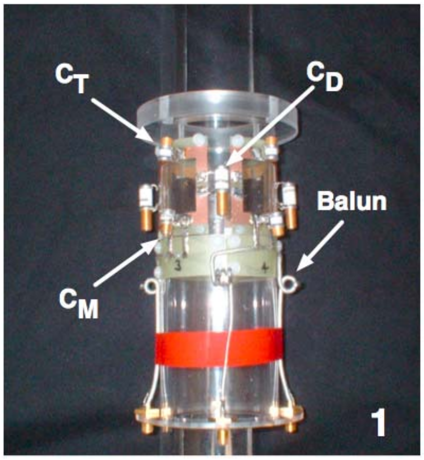
Introduction

In single-shot echo planar imaging (sshEPI) all of the data is acquired following a single RF excitation. Unfortunately, in sshEPI image blurring may occur, due to reduced signal at the edges of k-space; significant geometric distortions can also appear in the final image, because of tissue susceptibility mismatch and off-resonance effects. In functional MRI (fMRI), sshEPI is the preferred technique, because multi-shot EPI may lead to data inconsistency due to sample motion. Therefore, it is necessary to investigate means to reduce the above-mentioned artifacts in sshEPI. Phased array coils are necessary for parallel imaging (PI), which can be applied to EPI acquisitions to reduce geometric distortions, by decreasing the inter-echo time. Although the application of PI to sshEPI acquisitions has been shown at 1.5T/3T (in human studies [1]), unfortunately this application has not been widely investigated at ultra-high fields. For this reason, we present a novel multi-coil array design for parallel imaging to determine the feasibility of EPI-induced artifacts reduction at 9.4T.

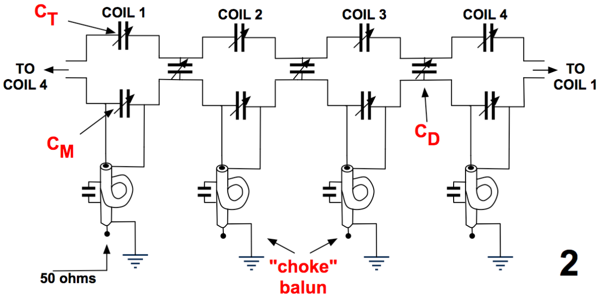
Methods

We performed all experiments with a Varian 9.4T animal system MR magnet, 205/120 HD gradient coil and imaging console interfaced with a 1-KW RF amplifier. Since only one single transmitter channel was available, a four-way feed network was used. The 4-channel transmit/receive (transceive) phased array coil (see Fig. 1) was designed and built on an acrylic cylindrical former of 63.5 mm inner diameter, with the four square surface coil elements “wrapped” around the former. Tuning (400 MHz) and matching ($50\ \Omega$) were achieved with two variable capacitors (C_T and C_M). To reduce the mutual inductance, we inserted a variable decoupling capacitor between two adjacent elements in a “T” configuration (C_D) [2] (see Fig. 2). Finally, parallel imaging reconstruction was implemented using SENSE [3] and GRAPPA [4] reconstruction techniques, with sensitivity maps and auto calibration signals (ACS) lines acquired before the main acquisition. The geometric artifacts (or fractional displacement, $\Delta S/S$) in EPI depend on the off-resonance frequency Δf and the inter-echo time T_{inter}, as such: $\Delta S/S = \Delta f \bullet T_{inter}$. Therefore, PI can be used to reduce geometric artifacts by reducing T_{inter}.



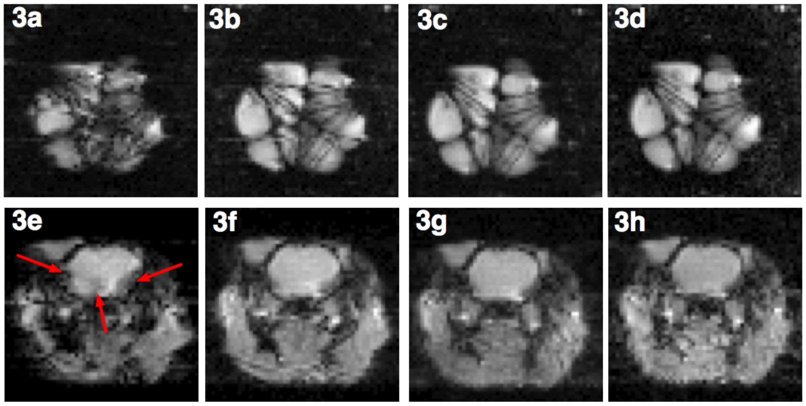
Results

For coil validation an SNR comparison was performed between the transceive phased array and an 8-rung hybrid birdcage coil of the same size. The mean SNR for the two coils within a phantom ROI was comparable (~ 9.3% divergence). As shown in Fig. 3(a), we acquired a full FOV sshEPI of cucumber seeds with 128 phase encoding steps, and using GRAPPA (Fig. 3(c)) and SENSE (Fig. 3(d)) methods we were able to reconstruct the same image by acquiring only 64 phase encoding steps, with reduction factor R=2 and 5 ACS lines (GRAPPA). These images show significant reduction in geometrical distortion, because we were able to decrease the inter-echo time. For further validation of inter-echo time reduction benefits, images attained via EPI-PI were comparable to the 2-shot EPI conventional image (Fig. 3(b)). Similar results were obtained with in-vivo experiments. The rat head acquisition presented additional complexities because of the non-uniform physiology of the subject (i.e. varying biological tissue, air cavities), which amplified EPI-induced susceptibility artifacts. In the single-shot 64 phase encoding steps EPI acquisition (Fig. 3(e)) the animal brain region is heavily distorted (unusable for an fMRI study), however the single-shot 32 phase encoding steps EPI-PI reconstructed acquisitions, show a suitable brain region with GRAPPA (Fig. 3(g)) and SENSE (Fig. 3(h)). These results show again a sensible improvement comparable to the 2-shot EPI acquisition of Fig. 3(f), with a decrease of potential motion artifacts.



Discussion

The disadvantage of multi-shot EPI acquisitions lies in the fact that it can be susceptible to phase discontinuities and motion-induced artifacts between successive k-space readouts, which leads to geometric distortions. To obviate such problems the single-shot acquisition combined with parallel imaging reconstruction techniques may be used. Our results suggest that at 9.4T with SENSE and GRAPPA EPI acquisitions, the geometric distortions can be greatly reduced and are comparable to the 2-shot acquisition. Also, SNR improvement in the EPI-PI images can be achieved by g-factor optimization through flexible coil element arrangement, which could be well suited for our design since it does not implement signal decoupling by element overlap.



Conclusions

We were able to design and implement a transceive phased array coil suitable for parallel imaging. The advantages of this design were confirmed by the successful reduction of EPI-induced artifacts at 9.4T, which can be applied to fMRI studies in small animal imaging.

References [1] Eur Radiol **13**(10):2323 (2003), [2] ISMRM **4**:1434 (1996) ,[3] Magn Reson Med **42**(6):952 (1999), [4] Magn Reson Med, **47**(6):1202–1210, 2002