COMPENSATION OF EDDY CURRENT BY AN R-L-C CIRCUIT MODEL OF THE GRADIENT SYSTEM

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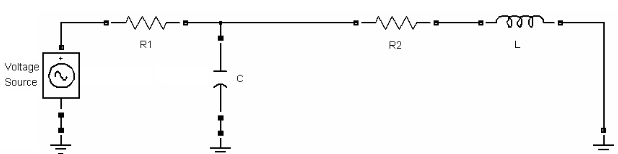
Abstract
The k-space trajectory is important in the design of spiral pulse sequence as well as in the reconstruction of the image. The real trajectory is, however, usually deviated from the theoretical trajectory obtained from the gradient waveforms due to the eddy currents and non-ideal performances of the gradient systems such as finite bandwidth and slew rate. Such deviations inevitably result in distortions in the reconstructed image. In this paper, we derived an R-L-C circuit model to estimate the real k-space trajectory, by which a significant improvement of reconstruction was achieved at 3 Tesla MRI system.

Method
Imaging with a non-Cartesian k-space trajectory usually involves simultaneous application of gradient fields during the data acquisition period. The deviation of the actual k-space trajectory from the ideal trajectory due to the eddy currents or non-ideal performances of the gradient systems introduces image artifact in the reconstruction that has much more complicated characteristics compared to those in the Cartesian trajectory. To solve this problem, measurements of real k-space trajectory have been attempted by various schemes[1-2]. These measurements are usually based on the imaging gradient fields, which are prone to measurement errors. Consequently, accurate measurements of k-space trajectory have not been very successful. In this paper, we propose an R-L-C circuit model to estimate the real k-space trajectory. Instead of gradient waveform shaping, actual k-space trajectory is estimated for the input waveform. The actual k-space trajectory is used in the reconstruction. This approach is adequate for spiral scan imaging, since the resampling of the measured data is proceeded in the gridding algorithm, and such modification of k-space trajectory does not impose additional computational burden, nor degrade resolution.
Real gradient field waveforms and corresponding k-space trajectory are estimated from the current waveforms of the simplified circuit model of the gradient system as shown in Fig.1 using the Simulink in Matlab. The resistor and capacitor model the gradient system with a finite bandwidth, and L is the inductance of the gradient coil including the mutual inductance between the gradient coil and the main magnet. The values of R, L, and C are determined from a series of quantitative evaluations of the reconstructed images. The transfer function of the circuit model is given in Eq.[1]



$$H(s) = \frac{1}{(R_1 L C)s^2 + (R_1 R_2 C + L)s + (R_1 + R_2)} \quad [1]$$

Fig.1 A simplified circuit model for gradient system

Results
The usefulness of the proposed model of the gradient system is experimentally verified at 3.0 Tesla MRI system. Figure 2 shows both of reconstructed images from the ideal k-space trajectory without modeling (left) and the derived trajectory estimated by the proposed circuit model (right). The model parameters: R1 = R2 = 1 Ω, C= 4 μF, and L = 180 μH. They were reconstructed from the same raw data acquired by the spiral-scan imaging at 3 Tesla MRI. From the reconstructed images, much improved image quality is observed in the image using the circuit model (right). For example, the outer dark ring (artifact) is disappeared, intensity is more uniform, and detailed inner structures are seen more clearly in the right image. In-vivo images with and without the circuit model of the gradient system are also shown in Fig.3.

Reference
[1]). Y. Zhang, H. Hetherington, et. al. Magn. Reson. Med. 39:999-1004 (1998). [2] M.T. Alley, G.H. Glover, Magn. Reson. Med. 39:581-587 (1998).

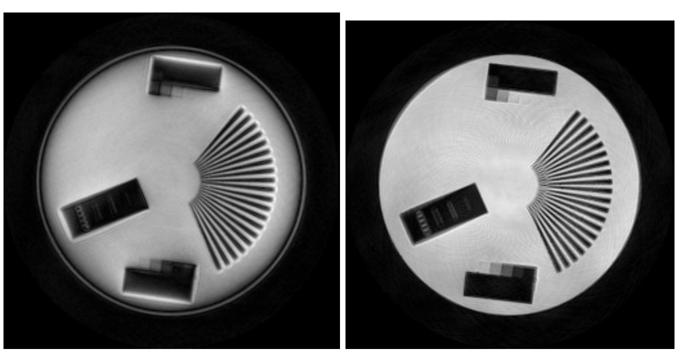


Fig.2 Reconstructed images from an ideal k-space trajectory (left) and an estimated trajectory with the proposed circuit model (right).

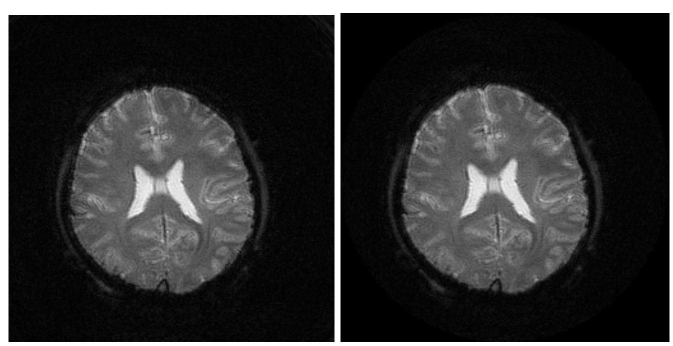


Fig.3 In-vivo reconstructed images from an ideal k-space trajectory (left) and an estimated trajectory with the proposed circuit model (right).