Measuring and Characterizing Short-Term High Order Eddy Currents with a Phantom

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TARGET AUDIENCE

Scientists and clinicians who are interested in eddy current measurement and characterization for improved system performance.

PURPOSE

Eddy currents (EC) on an MR scanner in general include higher spatial order terms, in addition to the linear and constant terms which are typically well compensated with preemphasis. Long term (e.g., time constants ranging from several ms to several hundred ms) high order EC (HOEC) can be measured with phantom based system calibration and corrected to reduce image distortions in diffusion weighted echo planar imaging (EPI) [1]. However, the method in [1] cannot accurately measure short term (e.g., time constants below 5 ms) HOEC because of its relatively long echo time. One could extend the method in [2] to characterize short term HOEC. However, this would require repositioning the local pickup coil fixture multiple times in order to obtain enough samples for high order terms, which can be a tedious and error prone task. In this paper, we propose to extend the phantom based method in [3] to 3D to measure and characterize short term HOEC, which can be useful input to applications such as correction of phase errors in phase contrast imaging where short term HOEC is believed to be one of the main contributors of the errors [4].

METHODS

Figure 1 shows the diagram of the proposed HOEC measurement sequence. Assume Z gradient to be the donor gradient. As originally proposed in [3], a thin slice (e.g., 1-2 mm) selection gradient on Z is first applied along with the excitation RF pulse, which is then followed by the EC donor gradient (~1-2 ms long trapezoid). Data acquisition (labeled as ADC in the figure) is turned on throughout the donor gradient and for 1-2 ms after the EC donor is off. Note that the signal dephasing in the Z direction is effectively minimized by the thin slice selection. Two phase encoding gradients on G_x and G_y are added to encode the signal in the X-Y plane. The sequence is repeated for multiple slice locations to obtain measurements in the 3D space. The sequence is also repeated for opposite polarities of the EC donor amplitudes to obtain EC contribution from the donor alone. Finally, after data collection for donor G_z is done, the sequence is repeated with G_x being the slice select and EC donor (and G_z and G_y being phase encodes), and G_y being the slice select and EC donor, respectively.

After 2D Fourier transform, time derivatives of the phase of the HOEC measurement data are first taken to obtain magnetic field errors. The total field error of the negative EC donor is subtracted from the error of the positive donor to obtain only the EC induced field error. A spatial polynomial fit is then applied at each time point to obtain polynomial basis coefficients as a function of time. Finally, temporal exponential model is used [5-6] to obtain time constant and amplitude of each polynomial basis.

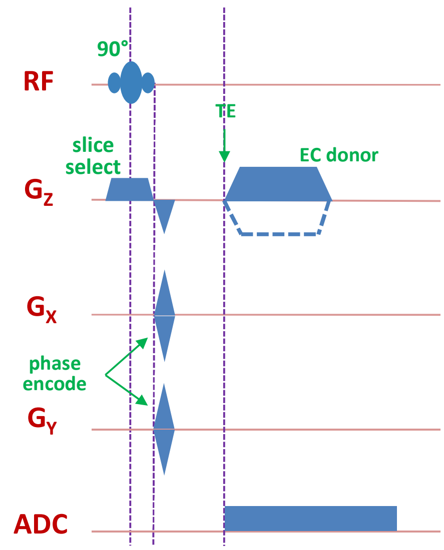

Fig. 1. Pulse diagram of the short term HOEC measurement sequence.

RESULTS AND DISCUSSIONS

Short term HOEC measurements were collected on a GE 3T scanner using the body coil with a 21-cm-diameter spherical NiCl phantom. Other relevant parameters were: slice thickness = 1 mm, in-plane matrix size = 16×16, data acquisition bandwidth = 125 kHz, donor gradient amplitude = 1 G/cm, duration = 1 ms, polynomial fitting order = 3. Figure 2 shows the top 3 components of the EC with X being the donor: an X to X term (linear gradient), an X to B0 term (constant), and an X to XZ2 term. The four dotted lines in each subfigure represents start of the donor gradient, start of the plateau, end of the plateau, and end of the trapezoid, respectively. Red dotted curves represent the raw data before temporal fitting described in the "Proposed Method" section, and blue solid curves represent the exponential fit. Note that the standard preemphasis was turned off before the HOEC measurement, which is why significant linear and constant terms still exist. The linear and constant terms measured by the proposed method were comparable to those measured by local pickup coil based method (results not shown). Although the X to XZ2 term is much smaller than the linear and constant terms, it is the 3rd largest among all 20 bases, and can be significant when evaluated at larger radius for far off centered slices.

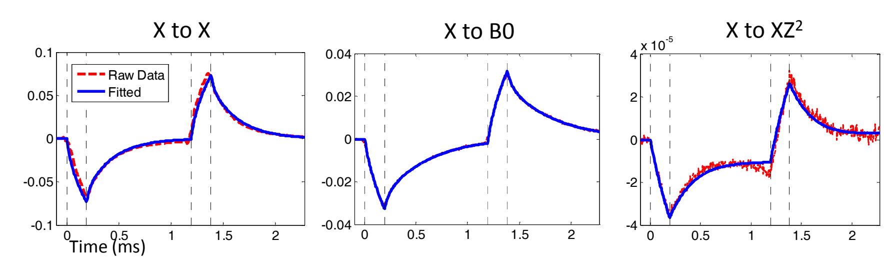

Fig. 2. Top three EC components from analysis of a HOEC dataset acquired on a GE 3T scanner with a 21-cm spherical phantom. Vertical axis represents the coefficients after the polynomial fitting.

CONCLUSION

The proposed phantom based, short term EC calibration method can not only provide an alternative way to current pickup coil fixture based method for measuring linear and constant EC, but also has the capability of measuring higher order components. These measurements may be useful inputs to phase contrast applications to correct for residual EC induced phase errors.

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