Eddy current compensation for a PatLoc gradient coil

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Introduction:

To investigate methods to overcome today's limitations of gradient performance for rapid imaging, a multi-channel, non-linear PatLoc (parallel acquisition technique using localized gradients) gradient coil [1] was proposed. A more powerful gradient coil (see Fig. 1) using multipolar fields for in plane encoding [2] was developed recently which fits into a Siemens MAGNETOM Trio Tim 3T Scanner [3] and was designed for human head imaging. For future rapid imaging applications it is important to investigate and optimize the imaging performance of the gradient coils. This abstract studies the eddy currents and calibrates the system pre-emphasis for this PatLoc gradient coil to reduce eddy currents.

Materials and Methods:

The developed PatLoc gradient coil is driven simultaneously to, but independently from, the existing linear gradients of the Siemens MAGNETOM Trio Tim 3T Scanner (Siemens Medical Solutions, Erlangen, Germany). The pulse sequence used for acquisition of the eddy currents is presented in Fig. 1.

Fig. 1 PatLoc gradient coil

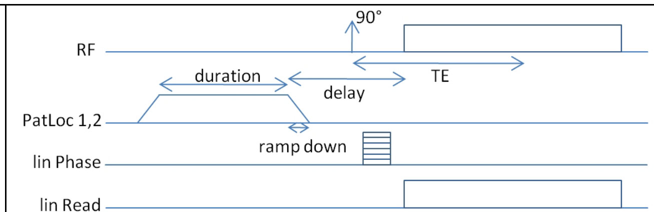

Fig. 2 Pulse sequence for measuring eddy currents

Slice selection was performed with the linear z-gradient and is not displayed in the figure. The gradient lobe inducing the eddy currents from the PatLoc gradients was switched on for 3,000ms before it was ramped down in 500µs. Then a 90° RF-pulse was followed by the acquisition of actual gradient echo fieldmaps (32 x 32) with the linear gradients with a short TE (3.8ms) and long TR (9,000ms) leading to a total acquisition time of 3:12h. This was repeated for 40 different delay times from 1ms to 3,000ms for both PatLoc gradient channels 1 & 2 using a bottle phantom with 16cm diameter. All fieldmaps were acquired at the isocenter of the scanner. For each fieldmap an analysis of the spherical harmonics terms, up to second order, was performed in order to describe the eddy currents and also for calibration of the pre-emphasis of the gradient amplifiers. The eddy currents are calculated with respect to what their maximum amplitude would be if they persited.

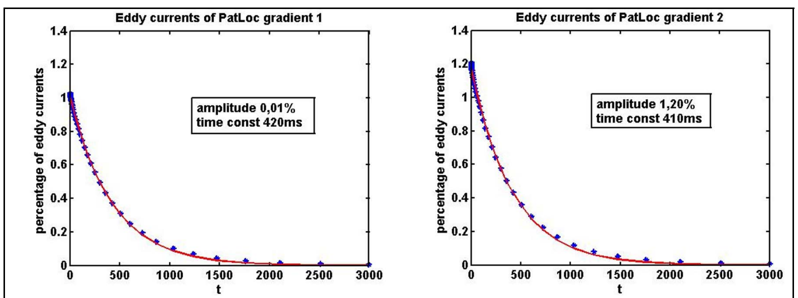

Fig.3 eddy current decay and fit, left for the Read encoding gradient, right for the Phase encoding gradient [%]

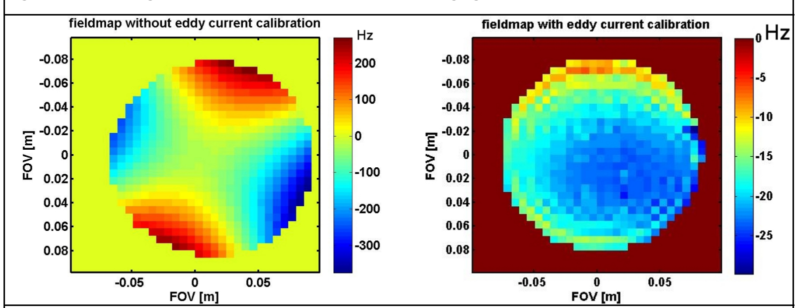

Fig. 4 GRE fieldmaps of the eddy currents for PatLoc gradient 2 for the first time point of the time series without (left) and with compensation of second order terms (right) in Hz for the maximum current of 80A

Results:

Figure 3 displays the decay of the eddy currents of second order and its exponential fit to determine the timing constant and amplitude. The maximum amplitude of the eddy currents is 1,01% with a time constant of 420ms for PatLoc gradient 1 and 1,20% with a time constant of 410ms for the PatLoc gradient 2. After calibration of the pre-emphasis, though the build in interface, the amplitude of the eddy currents where reduced to 0.01% for both encoding gradients.

Discussion:

The marginally larger amplitude of the eddy currents for PatLoc gradient 2 is simply explained by the closer distance of the gradient coil elements to the magnet bore opening and therefore to the conducting material. Within the used phantom the eddy currents are suppressed from around 300Hz to below 30Hz, which is displayed in Figure. 4. This has to be evaluated against the total frequency range of 6000Hz for this phantom with maximum amplitude. Since only the eddy currents of second order have been evaluated and corrected for the remaining field can be explained by higher order eddy currents with time constants of 200ms.

Conclusion:

The eddy currents could be suppressed sufficiently and will further improve imaging quality especially for rapid imaging applications relying on fast switching of the gradients and accuracy in data acquisition. Further improvement requires a full evaluation of the remaining eddy currents.

References: [1] Hennig et al, MAGMA 21(1-2):5-14 (2008); [2] Welz et al, ISMRM 2009, p.3073; [3] Welz et al, ESMRMB 2009, p.316

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