Characterisation of a PatLoc gradient coil

A. M. Welz[1], D. Gallichan[1], C. Cocosco[1], R. Kumar[2], F. Jia[2], J. Snyder[1], A. Dewdney[3], J. Korvink[2,4], J. Hennig[1], and M. Zaitsev[1]

[1]Dept. of Diagnostic Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Baden-Württemberg, Germany, [2]Dept. of Microsystems Engineering – IMTEK, University of Freiburg, Freiburg, Germany, [3]Siemens Healthcare, Erlangen, Germany, [4]4Freiburg Institute of Advanced Studies (FRIAS), University Freiburg, Freiburg, Germany

Introduction: 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. 5) using multipolar fields for in plane encoding [2] was developed recently which fits into a Siemens 3T Tim Trio scanner and has suitable dimensions for human head imaging [3]. For future rapid imaging applications it is important to investigate and optimize the gradient coil imaging performance, therefore this abstract discusses and evaluates the eddy currents of this self build gradient coil and its concomitant fields.

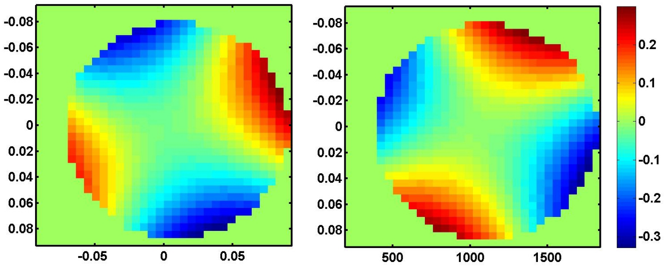

Fig. 1 Maps of the eddy current induced field changes at 217ms after the exciting pulse, both in Hz

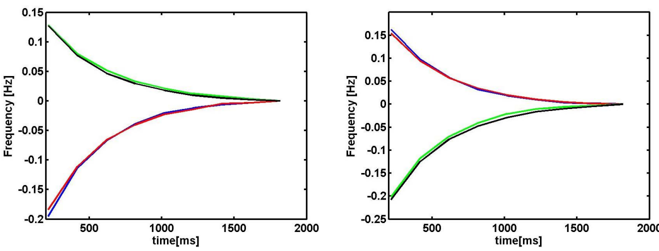

Fig. 2 Frequency shift arising from eddy currents for both Patloc gradients at z = 0cm, for 4 ROI close to the poles, left Read gradient, right Phase gradient

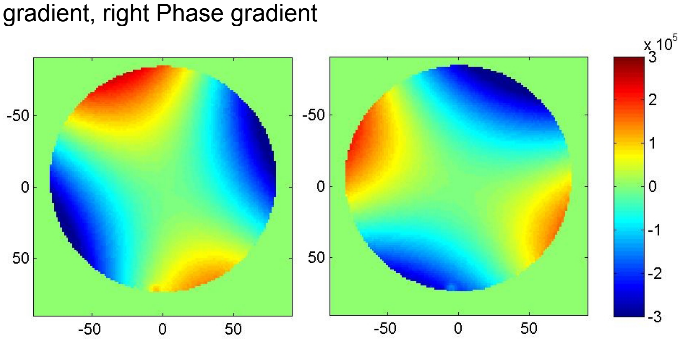

Fig. 3 Measured PatLoc encoding field (Hz at 80A)

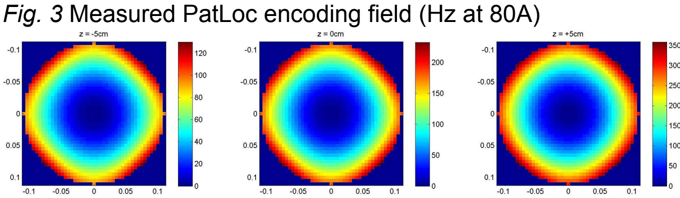

Fig.4 Frequency shift from concomitant fields for PatLoc encoding fields (Hz at 80A)

Fig. 5 The PatLoc gradient coil

Materials and Methods: The Patloc coil was characterised previously to have a sensitivity of 1.4mT/m^2/A and a rise time of 200µs with the nominal current of 80A [3]. Eddy currents were measured by applying a gradient pulse on one of the PatLoc gradients, inserting a delay time and acquiring maps of the residual eddy current induced field at that time point. The gradient echo images where acquired on a 32x32 matrix, with a field of view of 18x18cm and a TE = 12ms. 10 evolution time points starting at 217ms with a step of 200ms were collected. The measurement was repeated with pulsing of the second PatLoc encoding field. The strength of the gradient pulse on the PatLoc gradient coil was chosen to estimate eddy current effects corresponding to the fastest ramp to the maximum nominal current of 80A. A modified scanner setup was used for these measurements, able to control up to 6 gradient amplifiers and the corresponding gradients, so that the linear gradients could be used for field map acquisition while a gradient pulse provoking eddy currents was played out on the PatLoc gradients.

Concomitant fields are calculated using Biot-Savarts law based on a numerical model of the gradient coil for a nominal current of 80A using Comsol (Multiphysics GmbH, Sweden).

Results & Discussion: The first field map acquired at the time point 217ms is shown in Fig. 1. For each of four selected ROI close to the poles, a time series was depicted and is plotted in Fig. 2. The time constants of this field decay is for the PatLoc gradient G1 (left) τ_1= 0.6 ± 0.2s and for the gradient G2 (right) τ_1= 0.6 ± 0.3s. The eddy currents induce undesired fields in the order of ppm of the actual encoding fields (Fig. 3). Eddy current induced fields were also examined at other locations using a small spectroscopic probe, showing comparable results. On the axis of the coil almost no eddy currents were observed, which is due to the high rotational symmetry of the PatLoc gradient coil.

The unwanted concomitant fields (Fig. 4) result in a frequency shifts of up to 250Hz in the imaging plane at z=0. In head direction of the gradient coil, this frequency shifts tend to increase, while in feet direction it decreases. The concomitant fields are highly symmetrical in radial direction as expected from the high symmetry of the multipolar encoding fields. Also the increase of frequency shift in head direction (Fig. 4, z+5cm) corresponds to the unbalanced coil design along the z-direction [1].

Conclusion: Due to the high symmetry of the fields and distance to the magnet bore eddy current effects with the PatLoc coil are insignificant. Concomitant fields account to ~1% of the encoding fields, negligible for most imaging applications.

References: [1] Welz et al, ISMRM, Toronto, p.1163 (2008), [2] Hennig et al, MAGMA 21(1-2):5-14 (2008), [3] Welz et al, ESMRMB, Antalya, p.316 (2009)

Acknowledgment: This work is a part of the INUMAC project supported by the German Federal Ministry of Education and Research, grant #13N9208