Planar gradient system for imaging with non-linear gradients

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Introduction: Non-linear local gradients for MRI have been introduced [1] with the aim to overcome present limitations of gradient performance due to safety limitations from peripheral nerve stimulation (PNS) and to investigate novel non-linear encoding strategies. The PatLoc (parallel acquisition technique using localized gradients) fields used so far have been quadrupolar spherical harmonics [2]. Here we present a concept study of a planar gradient system for body applications. This gradient system intended for imaging of heart, abdomen and pelvis will be implemented in our 3T whole-body scanner equipped with 6 gradient channels.

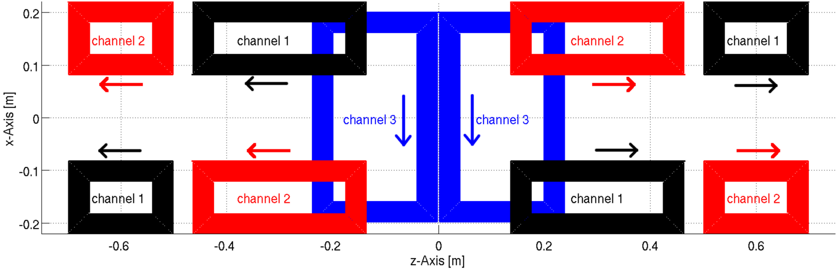

Fig 1: coil arrangement and flow direction of current

Materials and Methods: The coil size is chosen to fit into the patient table of a Siemens 3T Tim Trio (Siemens Medical Solutions, Erlangen, Germany). The size is therefore limited to 0.49 x 0.05 x 1.69 m. This non-shielded PatLoc gradient coil system will consist of 3 channels (channel 1, channel 2 and channel 3). Each channel is built up of 2 to 4 coil elements and will be wound of 2.7 mm insulated copper wire. Magnetic field simulations were performed with Matlab (Mathworks, Natick, USA) in a region of 1 cubic meter with a resolution of 100 voxels in each direction.

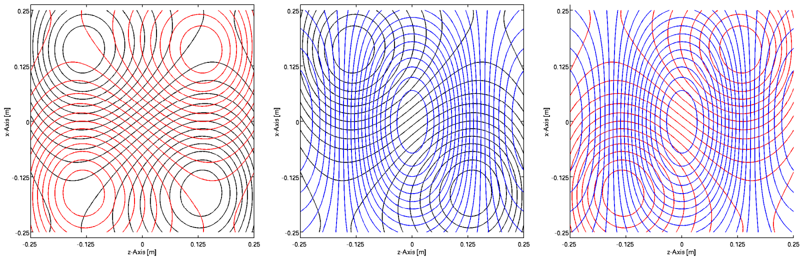

Fig 2: Fields from i) channel 1 (black) & 2 (red) ii) channel 1 & 3 (blue) iii) channel 2 & 3; y=0.24m; 0.02 mT/contour

Results and Discussion: The size of the inner coil elements of channel 1 and channel 2 is 0.141 x 0.331 m. Channel 3 consists of 2 coil elements which have a dimension of 0.401 x 0.241 m. The outer coil elements of channel 1 and channel 2 have a dimension of 0.141 x 0.201 m. They are used to balance torques and forces. Channel 3 is intrinsically balanced.

A 3D region of interest (ROI) of 0.5 x 0.5 x 0.5 m, for later image acquisition, was chosen. Fig 2 displays contour lines of the Bz component of the magnetic field from an xz plane at y=0.24m generated by the different channels of the coil.

The overlay of contour lines of two fields represent effective local voxel shapes achievable when these two fields are used for encoding. Fig 2 i) shows that the resulting fields from channel 1 and 2 generate nearly rectangular voxels around the center of the ROI. In a number of situations, however, the local field gradients become parallel to each other or too weak, which would limit the FOV achievable. The fields of channel 3 were designed in a way to complement the channels 1 and 2, such that in regions where gradients of channel 1 and 2 are parallel, channel 3 produces an approximately orthogonal gradient. This is visualized in Fig 2 ii) and iii). The contour plots in Fig 2 suggest that through the combination of the 3 gradient channels it might be possible to cover the whole ROI with voxels closely approximating rectangular shapes.

Channel 1 and 2 have identical electrical characteristics with resistance of 107mΩ and inductance of 218 μH and a total length of 38m. Channel 3 has resistance of 118mΩ, inductance of 219 μH and a total length of 33.1m. Channel 1 and 2 are designed to be driven with up to 100A. Due to its higher sensitivity, channel 3 is driven with up to 40A.

Simulations of image reconstruction from data encoded using this coil design were performed. 6 RF coil-profiles were simulated to approximate a body receive array. 2D imaging with 3 gradient channels can be performed with a variety of different encoding trajectories [3,4]. As a simple demonstration that useful images can be obtained with this design we concatenated three 64 x 64 2D Cartesian trajectories, one for each pairwise permutation of the 3 gradient channels. The resolution of the object simulated was 256 x 256 pixels. The reconstructed images with a resolution of 128 x 128 pixels of the abdominal region and of a checkerboard pattern can be seen in Fig 3 alongside the original simulated object. For the reconstruction 15 conjugate gradient iterations were performed. The images demonstrate reasonable spatial resolution over the entire FOV even at locations where some of the encoding fields flatten out and provide no encoding.

Conclusions: A balanced planar gradient system is designed which achieves extended FOV for 2D imaging by combining three of its channels. Availability of such a gradient system will open new perspectives for flexible region-specific encoding in different body regions.

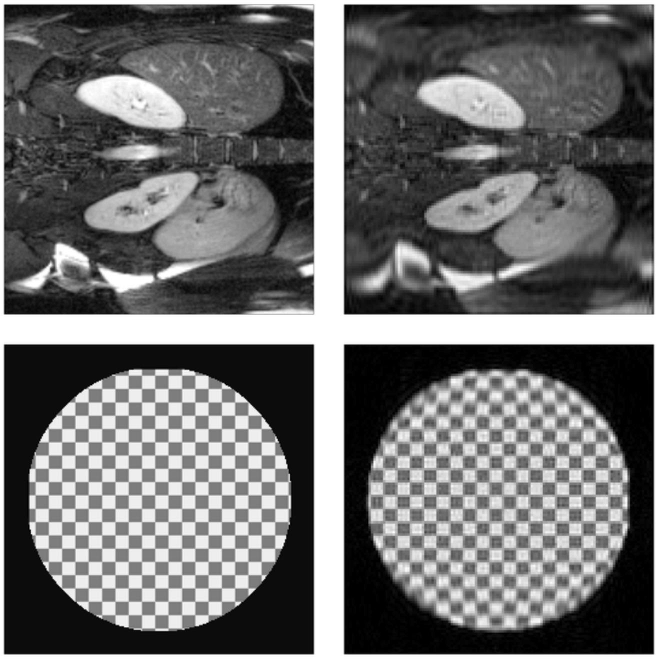

Fig 3: simulated object (left) vs. reconstructed image (right) using 64 x 64 x 3 samples

[1] J. Hennig et al , MAGMA 21(1-2):5-14(2008)
[2] A.M. Welz et al, proc ISMRM 2009, p.3073 [3] P. A. Ciris et al, proc ISMRM 2009, p.4556 [4] D. Gallichan et al, proc ISMRM 2010, p.547

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