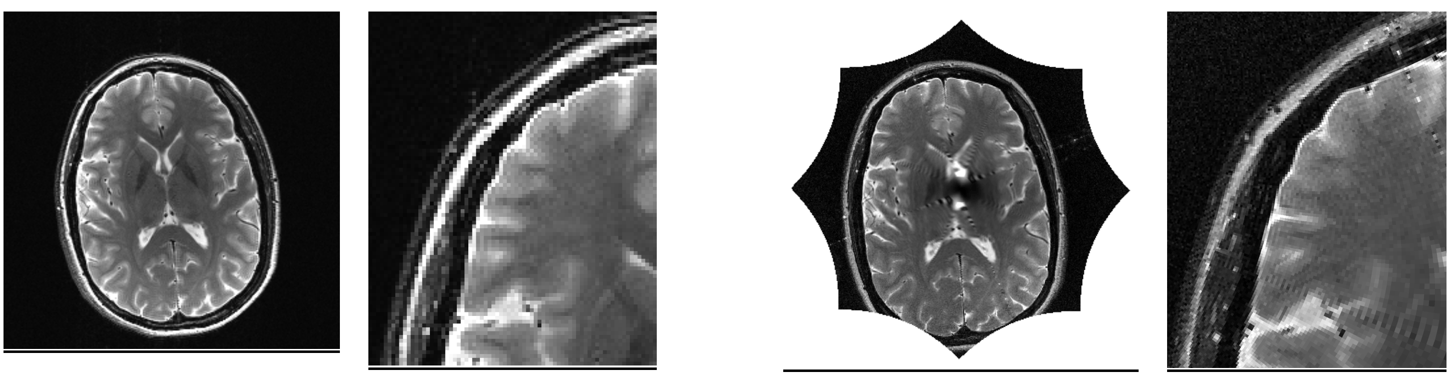
First In-vivo Results with a PatLoc Gradient Insert Coil for Human Head Imaging

C. A. Cocosco[1], D. Gallichan[1], A. J. Dewdney[2], G. Schultz[1], A. M. Welz[1], W. R. Witschey[1], H. Weber[1], J. Hennig[1], and M. Zaitsev[1]
[1]Dept. of Radiology, Medical Physics, University Medical Center Freiburg, Freiburg (i.Br.), B.W., Germany, [2]Siemens Healthcare Imaging, Erlangen, Germany

Introduction: We report on the first in-vivo results with a prototype PatLoc (Parallel Acquisition Technique using Localised Gradients [1]) gradient insert coil designed for human head imaging on a clinical 3T scanner [2,3]. The PatLoc concept has the potential to allow higher gradient switching rates while not exceeding the Peripheral Nerve Stimulation (PNS) limits [1]. PatLoc also provides a spatially varying image resolution that can be better matched to the anatomy of interest [5]. We also report new evaluation measurements regarding the safety of this insert coil for human imaging.

Methods: This asymmetric, unshielded PatLoc insert coil consists of two concentric layers of wiring (400mm and 412mm diameter) configured to produce two quadrupolar orthogonal non-linear gradient encoding fields in the axial plane [2]. The coil was integrated in a Siemens MAGNETOM Trio Tim 3T scanner, and connected to an additional set of (standard product) gradient power amplifiers. The construction features and preliminary safety evaluation of this gradient insert were previously presented [3]. Two aspects remain important for the safe use of this system for in-vivo imaging: Peripheral Nerve Stimulation (PNS), and Sound Pressure Level (SPL). PNS: The integrated gradient coil is capable of a rise-time of 0.1ms to a current I=50A, and of 0.2ms to 80A. Using 3D simulations of the generated B vector field (also validated experimentally [2,3]), we estimated a conservative upper bound on the maximum magnitude of the B vector within the volunteer accessible space inside the bore. Then, we adjusted the imaging pulse sequences for dB/dt < 20T/s (the regulatory acceptable limit until a formal volunteer stimulation study is performed [6]). SPL: Using a Brüel & Kjær 3560-L ADC and calibrated Type 2671 microphone, we measured Leq [dBA] (human ear corrected SPL) at the volunteer's possible ear positions, for a variety of common pulse sequences suitable for anatomical and functional human head imaging. We also evaluated sequences that use both the linear X&Y gradients and PatLoc gradients simultaneously [4]. PNS / Human volunteer imaging: After obtaining local IRB (Ethics) approval, we imaged so far seven volunteers, some multiple times (all volunteers had prior experience inside a clinical MRI scanner). The PatLoc gradients were not turned on simultaneously with the linear gradients, and their change time and magnitude was limited such that dB/dt < 20T/s. Also, adequate ear protection was in place.

Results: SPL (Leq): The normal imaging pulse sequences (e.g. FLASH, GRE) with typical parameters did not exceed 109dBA for I=80A. Moreover, we did not observe any increase in SPL when switching both the PatLoc and linear X&Y gradients simultaneously. The regulatory acceptable maximum SPL is 129dBA, i.e. 99dBA with earplugs in place. EPI and TSE sequences can exceed the acceptable limit if I > 25A and the echo spacing approaches the known mechanical resonance frequencies of this insert coil (~490 and ~650Hz). However, these resonances can be avoided in the sequence design. PNS / Human volunteer imaging: This asymmetric PatLoc coil produces magnetic fields that decay steeply in the shoulder/torso region of a volunteer, i.e. where PNS is typically induced by the standard body gradients. None of the volunteers reported any PNS, or any other unusual or painful sensations. Compared to the standard body (linear) gradients, higher acoustic noise levels and stronger low-frequency vibrations were reported, but these were considered acceptable.



Sample in-vivo images: TSE 256x256, TR 5000 ms, slice thickness 2mm, acquisition time ~3min for 5 axial slices, slice-selection using the Z linear gradient (1 slice shown). **[Left]:** with standard linear X&Y gradients. **[Right]:** with PatLoc gradients instead of linear X&Y gradients (reconstructed as in [6]). Note in the magnified view the increased spatial resolution in the cortex & skull area for the same acquisition time.

Conclusion: We found imaging human volunteers with this PatLoc system to be safe, feasible, and to deliver locally improved image quality. Moreover, we are currently seeking IRB approval for measuring with simultaneous in-plane PatLoc and linear X-Y gradients (e.g. [4]); this should also improve the centre image resolution. Additionally, we are in the process of performing a volunteer study to study the switching rates (dB/dt > 20 T/s) attainable with this combined five gradient system without noticeable PNS effects. Since these PatLoc fields are local to the head, the induced voltages in the volunteer are expected to be lower than those caused by the standard body gradients, and we expect to be able to go significantly beyond the current limit of 20 T/s.

References:
[1] Hennig J. et al., MAGMA 21(1-2):5-14 (2008). [2] Welz A. et al., ISMRM 2009 #3073. [3] Cocosco, C.A. et al, ISMRM 2010 #3946.
[4] Gallichan D. et al., MRM (in-press 2010). [5] Schultz G. et al., MRM 64(5):1390-403 (2010). [6] Schaefer D. et al., JMRI 12:20–29 (2000).
Acknowledgement: INUMAC project supported by the German Federal Ministry of Education and Research, grant #13N9208.