High Resolution *Carr-Purcell* MR Imaging with *Spiral* Readout

Shalom Michaeli[1], Josef Pfeuffer[1,2], Kamil Ugurbil[1] and Michael Garwood[1]
[1]Center for Magnetic Resonance Research, University of Minnesota School of Medicine, Minneapolis, MN, USA
[2] Max-Planck-Institute for biological Cybernetics, Tuebingen, Germany

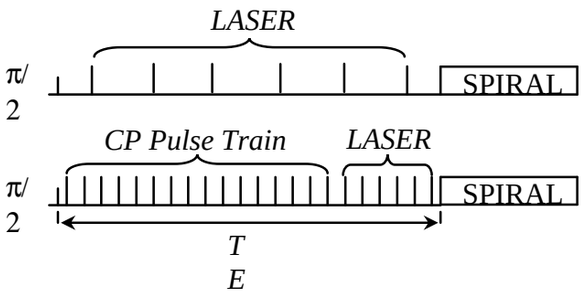
Abstract In this study a fully adiabatic volume selection sequence *(LASER)* with *SPIRAL* readout was developed to acquire high resolution (zoomed) T_2 – weighted images with reduced acquisition time. Thus, high temporal resolution combined with high spatial resolution was achieved. When adiabatic full passage pulses were inserted prior to the *LASER* localization to generate Carr-Purcell pulse train (*CP-LASER* sequence), this allowed detection of the images with different inter pulse delays (t_{cp}) at the same echo time. Here we demonstrate how the *CP-LASER-SPIRAL* sequence can be implemented for the fast MRI, and the application to functional MRI is presented.

Introduction The importance of spin echo techniques (Carr-Purcell (*CP*) and Hahn Spin Echo) in the applications to the biological systems is straightforward. In particular, by exploiting the spin-refocusing capability of the *CP* technique,[1] the MR signal loss due to dynamic dephasing by local susceptibility-induced field gradients (LSIGs) might be strongly suppressed, giving an opportunity to investigate the system that is described by an apparent transverse relaxation time that approaches intrinsic T_2 (with *CP*) and eliminating contributions of diffusion and exchange to the MR signal decay. It is possible to reduce the effect of the LSIGs, which increase with magnetic field magnitude. Therefore, this approach may be particularly important at 4T and 7T.

Spiral methods are known to have several advantages in comparison to other techniques for fast MRI applications, including low sensitivity to motion and efficient gradient utilization. Because spiral readout starts at the center of k-space, T_2* weighting is shifted to the higher spatial frequency components. In addition, the total spiral readout duration is shorter comparatively to that of single-shot EPI.

In this work, a *CP-LASER*[2] sequence with *SPIRAL*[3,4] readout was developed and implemented for the fast T_2-weighted MRI acquisition. An example of the application to functional MRI is presented.

Methods Imaging studies were conducted with *4T* whole body MRI/MRS systems. A 10 cm ^{1}H surface-coil probe was used for the measurements of the human brain visual cortex. Visual stimulation was performed for functional studies. TurboFlash images were acquired to define the voxel position for localized MRI. The length of the *CP* train (*n*) was increased by adding additional 180° pulses to *LASER-SPIRAL* using initial phases prescribed according to MLEV. This latter sequence is referred to as *CP-LASER-SPIRAL*.



CP-LASER-SPIRAL and *LASER-SPIRAL* images were acquired at four echo times (*TE*=37 ms, 62 ms, 86 ms and 136 ms) by using 0, 4, 8 and 16 CP pulses respectively. The time interval t_{cp} in CP train was ~6.2 ms. In both sequences, voxel selection (zoom imaging) was performed by the six slice selective HS2-R15 adiabatic pulses in *LASER*, while HS1-R10 were used in CP train. Images were recorded using *SPIRAL* readout with:

(1) in-plane resolution 1 mm: (i) FOV = 12.8 cm, 128-matrix and 4 segments, acquisition time *at* = 29 ms/segment;

(2) 0.5 mm in-plane resolution 0.5 mm: FOV = 12.8 cm, 256-matrix and 8 segments, *at*= 41 ms/segment.

Results and Discussion

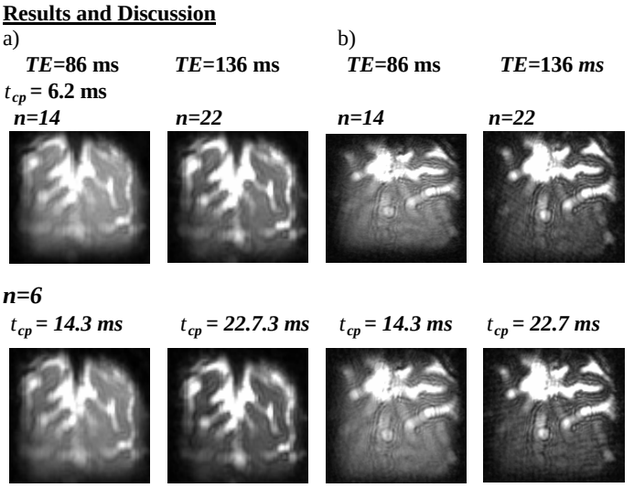
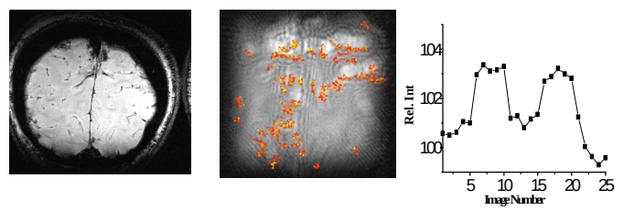


Figure 1: a) *CP-LASER/LASER* images with *SPIRAL* readout detected at 4T at *TE* = 86 (left) ms and 136 ms (right), respectively; thickness = 4 mm, 1mm in-plane resolution. b) 0.5 mm in-plane resolution, other parameters as in (a).



a) **b)** **c)**

Figure 2: a) FLASH image: in plane resolution 0.25 mm, slice thickness 2mm, *TE*=17 ms; b) 0.5 mm in-plane resolution (thickness 2.5 mm) activation map created with *LASER-SPIRAL* at *TE*=61ms (p=0.012); c) Timecourse for (b).

The ability to vary the contributions by dynamic dephasing in fMRI is important for investigations of the BOLD mechanism. The localized changes observed in signal intensity as a function of t_{cp} can be used to identify tissue regions on the basis of susceptibility variations. By comparing measurements with *CP-LASER* using short t_{cp} and *LASER* using long t_{cp}, it is possible to separate the contribution of the *intrinsic* T_2 to the apparent $T_2^{\dagger}$ and differentiate the contributions of processes that occur over different time scales such as diffusion and exchange that are expected to contribute to functional signals. We have demonstrated that the application of the *CP-LASER-SPIRAL* technique to the functional study can provide activation maps with high spatial resolution and high statistical significance.

Acknowledgment This research was supported by NIH grants P41 RR08079, NS38070 and NS39043, Keck Foundation and National Foundation for Functional Brain Imaging and the US Department of Energy.

References

1. S. Michaeli et al. Magn Reson Med (accepted for publication)
2. M. Garwood and L. DelaBarre J. Magn. Reson. 153, 155-177 (2001).
3. J. Pfeuffer et al. Magn Reson Med (in press, 2002)
4. G. Glover et al. Magn. Reson. Med. 46, 515-522 (2001)