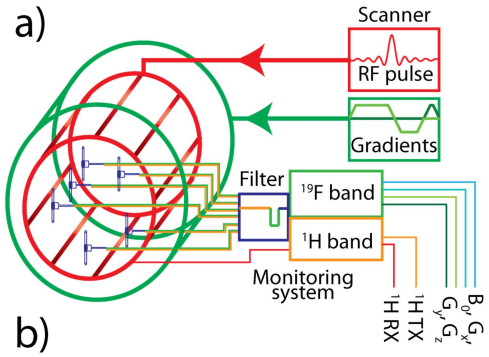
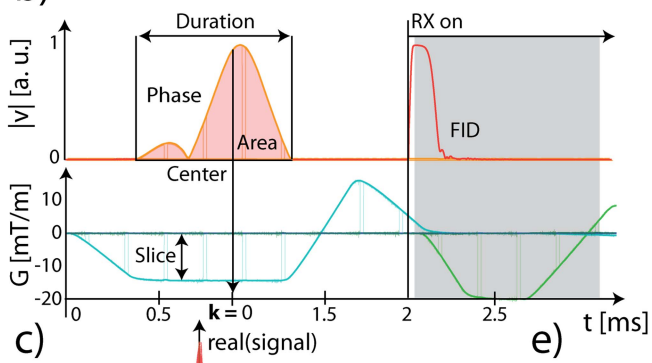
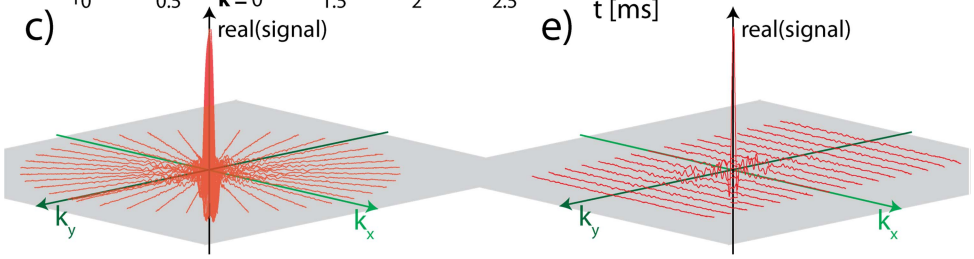
Automatic Reconstruction of Gradient Echo Imaging Sequences by Concurrent and Continuous Monitoring of Gradient and RF Waveforms

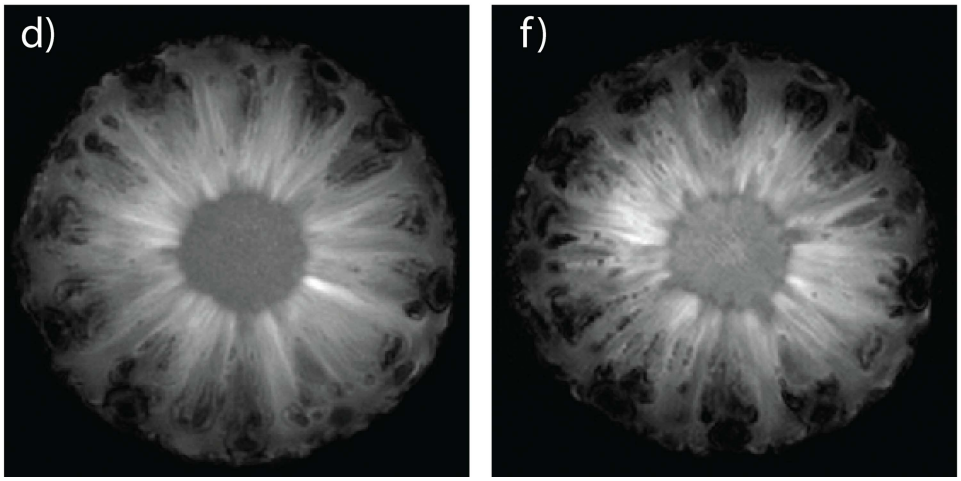
David O Brunner[1], Benjamin E Dietrich[1], Christoph Barmet[1,2], Simon Gross[1], Bertram Wilm[1], and Klaas P Pruessmann[1]

[1]*Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Zurich, Switzerland,* [2]*Skope Magnetic Resonance Technologies, Zurich, Switzerland*









a) Schematic of the system, b) measured gradient and RF field evolution for the UTE, c) e) Spin signal phased and gridded to the k-space, d) f) finally reconstructed images of a pineapple.

Introduction: Spatio-temporal (low frequency) magnetic field monitoring by NMR field probes[1] was shown to be an effective means for enhancing image reconstruction in situations of imperfect encoding fields or patient-induced field aberrations. Two major shortcomings of conventional monitoring are limited image resolution (≈probe diameter/2) as well as finite acquisition and dead time due to the relaxation properties of the field probes. Therefore the monitoring approach needed to be closely entangled with the image acquisition and was bound to sequences with low repetition times. In this work these constraints are overcome by continuous concurrent magnetic field monitoring[2] based on a continuous ^{19}F NMR dynamic field camera (3). Additionally also the radio-frequency (RF) fields were acquired by the camera[3] exploiting the stray coupling of the scanner's transmitter to the probe channels. The information on RF field dynamics was used for automatic sequence parsing allowing for automatic reconstruction of various sequences.

Methods: A continuous monitoring system[2] was complemented by narrow band (-20dB in ^{1}H band, -0.85 dB in ^{19}F band) input filters protecting the first stage low noise amplifier from being driven to non-linear states by the stray coupled high power RF transmit pulses of the MRI system. This enabled the signal acquisition from heavily doped (T_2~T_1~150µs, ø2.2mm) ^{19}F compound based probes equipped with low-eddy current RF shields even while the scanner transmits RF pulses (Fig. a). The ^{19}F and the ^{1}H band where simultaneously acquired by a single high speed digitizer per probe channel. Subsequently both bands are individually demodulated and filtered to 1 MHz bandwidth. The field probes where re-excited every 200 µs. The NMR signals of the sample were acquired by a separate digitizer hosted in the monitoring spectrometer via a T/R head coil.

The monitored ^{1}H transmit signal was parsed for the excitation pulses whose phase and the magnetic center was determined automatically. The magnetic center of the pulse set the k-space origin from which the trajectory was calculated by a band-limited extrapolation of the gapped (due to re-excitation) probe data (Fig. b). The MR signal acquired from the subject was phased according to the excitation pulse's phase and gridded according to the concurrently monitored k-space trajectory.

Standard protocols for RF spoiled 2D UTE (TR/TE=30/0.9ms) and Cartesian gradient echo (30/2ms) with 1 mm in-plane resolution were performed on a Achieva 7T system (Philips, Cleveland, USA).

Results: Fig b) shows the monitored gradient fields (before and after interpolation), the RF excitation pulse and the recorded FID for the UTE. c) and e) show the MR signal gridded to the monitored k-space (every 20th echo is plotted). (UTE d) and (Cartesian f) show the finally reconstructed images of a pineapple, no filters where applied.

Discussion: Solely the knowledge that a gradient echo (GRE) is generated after each RF pulse is injected into the reconstruction. All remaining required information –actually a comprehensive description of the spin evolution in the system – is extracted from the dynamic field camera. This capability opens up the possibility of unifying image reconstruction for a large class of sequences, as shown here for GRE acquisitions. Also, continuous concurrent low-frequency and RF field monitoring fully disentangles the monitoring process from MR sequencing and signal acquisition, rendering its integration trivial, both from a sequence and acquisition methods perspective. Concurrent RF pulse monitoring could potentially also be used to perform signal amplitude correction or rejection of corrupted profiles, making up for transmit pulse fluctuations and drifts.

References: 1) Barmet et al. MRM 2008, 2) Dietrich et al ISMRM 2011, 3)Dietrich et al ISMRM 2012