Spectrally Selective Crossed-Pair Navigator

Zarko Celicanin[1], Oliver Bieri[1], Klaus Scheffler[2,3], and Francesco Santini[1]
[1]*Division of Radiological Physics, Department of Radiology and Nuclear Medicine, University of Basel Hospital, Basel, Switzerland,* [2]*MRC Department, MPI for Biological Cybernetics, Tübingen, Germany,* [3]*Dept. Neuroimaging and MR-Physics, University of Tübingen, Tübingen, Germany*

Introduction: Recently, Köhler *et al.* published a spectrally selective pencil-beam navigator method for motion compensation of MRgHIFU therapy of abdominal organs [1]. The suggested spectral navigator consisted of a spiral 2D pencil-beam using 1-$\bar{2}$-1 binomial pulses and was proposed for the tracking of abdominal organs, such as the liver or kidney, based on the surrounding adipose tissue signal. Generally, the separation in time for 2D binomial pulses has to allow fat and water to accumulate an opposite phase and an accrual of a 180° phase difference would only allow for the acquisition of two spiral turns at 1.5 T (due to constraints of maximum gradient strength and slew rates) resulting in an extremely poor spatial resolution. As a result a 540° phase advance between water and fat was used providing improved spatial resolution, but not without affecting the spectral selectivity of the pulses. The duration of subpulses in 1-$\bar{2}$-1 binomial pulse was 6.9ms, which is significant. Here, we present a novel spectrally selective navigator technique being based on a spin echo with orthogonal planes for the excitation and refocusing pulses [2], also called crossed-pair navigator, but using 1-$\bar{1}$ binomial pulses for excitation and refocusing.

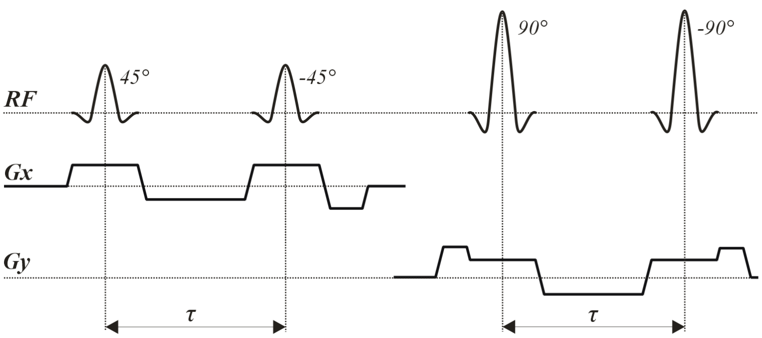

Figure 1 Pulse sequence diagram

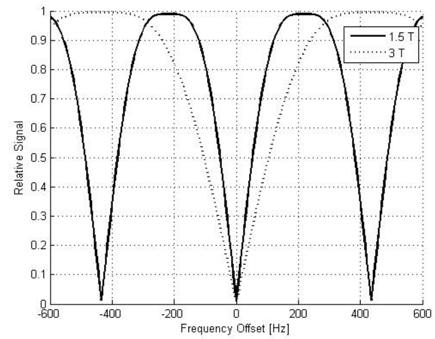

Figure 2 Spectral characteristics of 1-$\bar{1}$ binomial pulse

Methods: A spectrally selective crossed-pair navigator was designed and implemented for organ tracking on 1.5 T and 3 T clinical whole-body scanners. The two orthogonal planes for excitation and refocusing have a completely separate planning and protocol setup. Spatial positioning of the planes is not constrained and in the cross section of the planes an echo is formed. The readout field-of-view (FOV) is controlled by readout gradient, also defining spatial resolution. On Fig. 1, spectrally selective 1-$\bar{1}$ binomial crossed-pair excitation and refocusing pulses are shown with corresponding slice selection gradients. The binomial subpulse separation is indicated by the parameter τ. The sequence allows arbitrary values of parameter τ to be selected, and so to allow different spectral characteristics of the pulse. For the subpulses, sinc-shaped excitation pulses of 1ms duration with time-bandwidth of 2.7 were used. Overall, spectrally selective crossed-pair navigator was completed within approximately 8ms, using a TR/TE 250ms/5ms, 200mm readout FOV, and a voxel size of $10 \times 10 \times 1.5 mm^3$. This is significant reduction as compared to the 26.5ms reported in [1] for the spectrally selective pencil-beam navigator.

Measurements have been performed on one healthy volunteer on 1.5 T and 3 T clinical scanners two times on different days using six channel surface body coil. For the spectrally selective crossed-pair navigator, phase accrual between water and fat of 180° and 540° was used at 1.5 T and 3 T, respectively.

Results & Discussion: The spectral selectivity of a 1-$\bar{1}$ binomial pulse is shown for 1.5 T and 3 T in Fig. 2 using Bloch simulations [3], assuming a chemical shift between water and fat nuclei of 3.5ppm (223Hz at 1.5T and 446Hz at 3T).

The tracking signal of navigator is shown in Figures 3 at 1.5 T (left) and 3 T (right). Positioning of navigator planes could be achieved without any problems after running a localization scan. The navigator has been positioned in the lower part of liver, where a visceral fat is located. Overall, the noise level in the navigator data was very low and tracking was stable and showed no significant errors. Furthermore, balanced steady state free precession (bSSFP) images of a phantom that have been acquired interleaved with the proposed navigator technique are showed on Fig. 4 and no significant saturation effects or other artifacts can be observed.

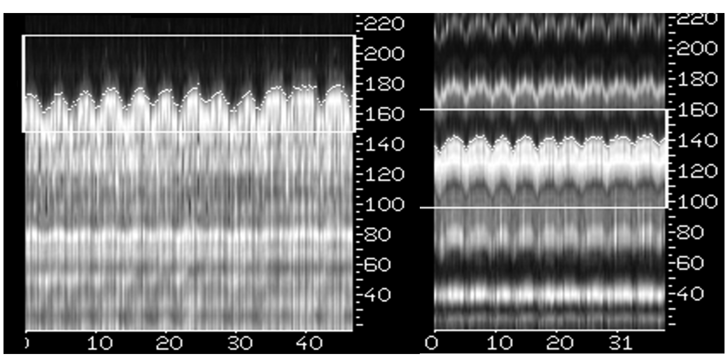

Figure 3 Navigator tracking signal at 1.5 T (left) and 3 T (right)

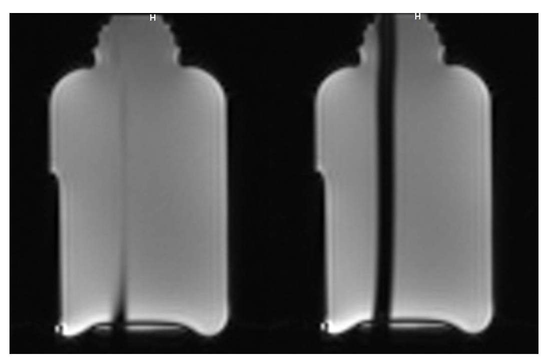

Figure 4 bSSFP images interleaved with proposed (left) and standard crossed-pair navigator (right)

Conclusion: Successful tracking of organ motion using a spectrally selective crossed-pair navigator technique has been demonstrated at 1.5 T and 3 T. Tracking has been stable and robust with high signal-to-noise in the projection data. Generally, our approach is expected to be more robust against B_0 field inhomogeneities and shimming errors, as compared to a spiral 2D pencil-beam solution, and thus might be especially beneficial for high-field applications.

References: [1] Köhler *et al.*, MRM, 66:102-111 (2011); [2] Feinberg *et al.*, Radiology, 156:742-747 (1985); [3] http://www-mrsrl.stanford.edu/~brian/bloch/