Calibration Procedure of 2D RF Excitation Pulses using Echo-Planar K-Space Trajectories

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Introduction

Monitoring the respiration state is mandatory for high-resolution 3D imaging of the thorax or abdomen if it cannot be performed in breathhold. For respiratory triggering or gating it is usually sufficient to determine the z-coordinate of the tip of the diaphragm. This may be achieved without external hardware by a respiratory navigator MR measurement, e.g. by two-dimensional excitation of a beam-shaped region through the diaphragm with gradient echo readout. Use of a low flip angle has the advantage of being barely noticeable in the images, which is important in liver imaging or whole-chest angiography. However, timing errors and gradient imperfections degrade the quality of 2D RF excitations. Echo-planar k-space trajectories may show prominent N/2 ghosting. A number of sophisticated calibration approaches have been described to compensate for these errors [1-3]. In our experience, a temporal mismatch between the RF and gradient waveforms is the main source or error. Figure 1 shows the effect of even small RF delays. Therefore, we implemented a simple delay calibration approach and tested its performance in sequences using 2D RF respiratory navigators.

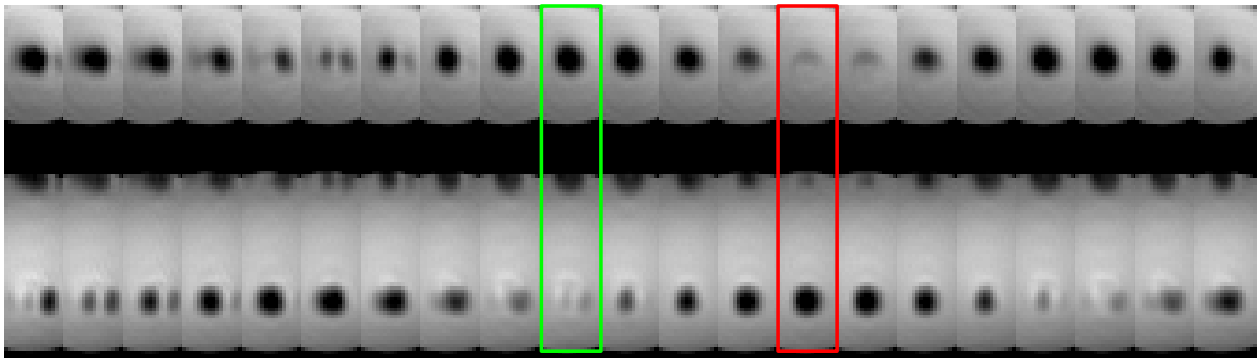

Figure 1: 2D RF excitation was used to saturate a circular region prior to standard 2D GRE imaging. The RF – gradient delay was varied from -10 µs to +10 µs from left to right. The delay with minimal N/2 ghosting is +3 µs (red box). Even a small mismatch (e.g. -2 µs) puts almost all power into the N/2 ghost (green box).

Materials & Methods

The method was implemented on a 1.5 T clinical scanner capable of real-time sequence feedback (MAGNETOM Avanto, Siemens Medical Solutions). During a prescan, the optimal delay between the RF and gradient waveforms is determined, i.e. the delay that excites a maximum of transverse magnetization at the intended navigator position. The 2D excitation is played out with varying delays between RF and gradients. In its current implementation, the RF waveform is shifted from -15 to +15 µs in steps of 1 µs and the excited magnetization is read out along the phase encoding direction of the 2D k-space trajectory to evaluate the quality of the excited profile. It is assessed by computing the magnitude integral inside the desired region of excitation and subtracting the magnitude integral computed outside. The result of calibration is the delay which maximizes this number. It is used during all 2D excitations in the subsequent imaging sequence. With a TR of 100 ms, calibration takes 6 s including 3 s of dummy scans at the beginning to reach a steady state.

Results & Discussion

The method determines reproducible RF-gradient delays in-vivo. A typical prescan result is shown in figure 2. In clinical routine navigators are almost exclusively oriented in head-feet direction to determine the position of the diaphragm. Here, 2D RF gradients coincide with the main axes of the gradient system and inter-gradient delays are unimportant. Our calibration approach accounts for the two main contributions to excitation errors remaining: temporal mismatch between RF and gradient chain and linear eddy currents of the echo-planar 'read' gradient. Although the simple approach presented here cannot compensate for all imperfections as figure 1 demonstrates, it is sufficient for a number of applications in clinical practice, e.g. respiratory navigator acquisition. Advanced techniques like parallel transmission or B_1 shimming may require different calibration procedures.

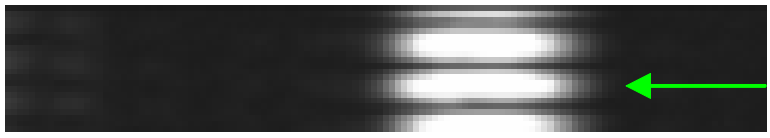

Figure 2: Excitation profiles displayed from left to right acquired during calibration in a volunteer. Delays range from -15 µs (top row) to +15 µs (bottom row). The best excitation profile is achieved using a delay of +2 µs (green arrow).

References
[1] Reese TG et al., JMRI 1994, 4(4):569-76
[2] Oelhafen M et al., MRM 2004, 52(5): 1136-45
[3] Davies NP et al., MRM 2004, 53(1): 231-236