Optimization of Flow-Compensation Gradients in SWI and TOF Scans for Acoustic Noise Reduction in MRI

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Target audience: This work targets readers interested in acoustic-noise reduction and optimizing gradient shapes

Purpose: Acoustic-noise is one of the main reasons for patient discomfort during an MRI examination. During the scan, fast-switching gradients lead to physical deformations and vibrations of the gradient coil. These mechanical forces are transferred to the system, resulting in high acoustic-noise pressure. It has been shown that gradient shapes optimization significantly reduces acoustic-noise [1, 2]. The previous optimization algorithms, however, cannot be applied to special gradients such as the flow compensation which is a critical component in sequences such as TOF and SWI. There, the M1 moment needs to be preserved at the intended value. In this work, we present a novel automated gradient conversion algorithm that does not only smooth gradient shapes but also preserves their M1 moment.

Methods: In [2], an automated gradient conversion algorithm is described. It acts completely independent of the sequence and subdivides a given sequence into *KEEP* and *CHANGE* intervals. While gradients must remain unchanged in *KEEP* intervals to preserve read-out modules and excitation pulses, gradients in *CHANGE* intervals may be optimized. During the optimization, the shape of the gradient curve is replaced by a fourth-order spline that keeps the M0moment within the interval, as well as start- and end-point of gradients and duration constant. M1-sensitive gradient blocks like flow compensation gradients cannot be optimized with the method described in [2] and so far need to be handled as a KEEP interval.

In our novel extended approach, the M1 moment is calculated and kept constant in the local spline fit. Due to the additional condition, a fifth-order spline is used. The algorithm was implemented as a prototype on a 3T clinical scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) and tested with clinical TOF- and SWI protocols on healthy volunteers. Acoustic-noise was measured.

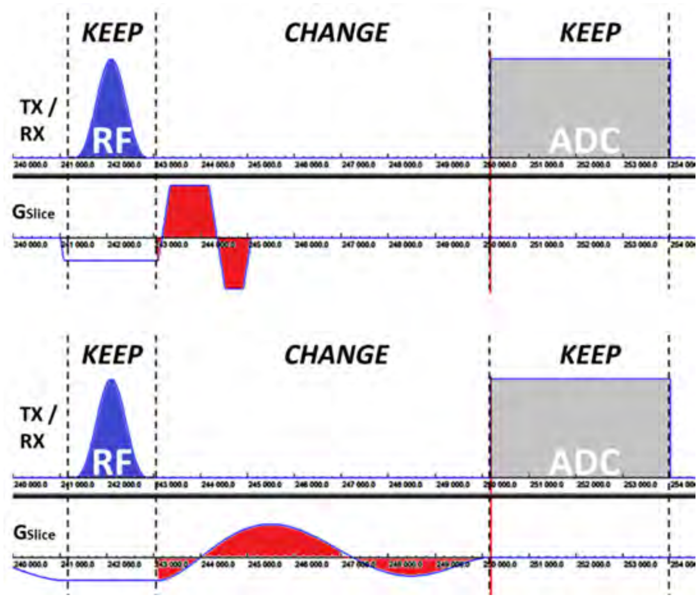

Fig. 1: *Schematic sequence snippet with a flow compensation gradient (red). Top row: conventional gradient shape. Bottom row: Optimized gradient shape. The M0- and M1 moments in the CHANGE interval are identical.*

Results: Fig. 1 shows a schematic snippet of a sequence with flow compensation without and with optimization. In Fig. 2, an image comparison between a conventional SWI and an SWI with optimized gradients is shown. Timing parameters (TE, TR,…) were kept identical. Acoustic-noise was 15 dB(A) lower in the optimized SWI compared to the conventional SWI. Compared to [2], a reduction of 7 dB(A) was achieved with our extended approach. For the TOF sequence, a reduction of 6 dB(A) was measured. Images were rated diagnostically identical in a blinded review by a trained radiologist.

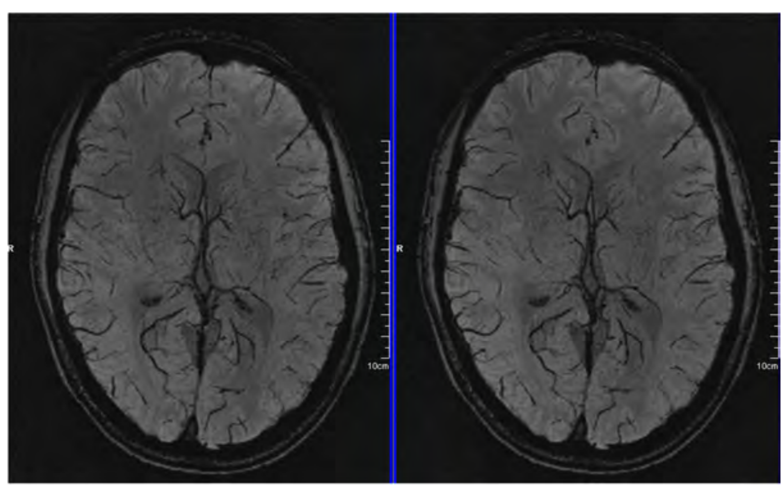

Fig. 2: *SWI image comparison between conventional (left) and optimized (right) gradients. All other imaging parameters (TE, TR, BW, …) were kept constant.*

Discussion & Conclusion: A sequence-independent gradient conversion algorithm is presented that allows also for the optimization of M1-sensitive gradients like flow compensation. As it is shown in Fig. 1, the gradient shapes are smoothed with maintained M0 and M1 moments and strongly reduced gradient slew rates. Acoustic-noise reduction of up to 15 dB(A) was found compared to the conventional SWI- and TOF-sequences without degrading image quality. Compared to the previous optimizations, tests showed an additional reduction of acoustic-noise by 7 dB(A). Further noise reduction can be achieved with careful changes to the imaging protocol.

In conclusion, we have shown that significant noise reduction is feasible also in sequences with M1 sensitive gradients like flow compensation.

References: [1]: Hennel F. MRM 1999 Jul 42(1):6-10; [2]: Heismann, B. MRM 2014.