Automated Gradient Conversion Algorithm for Acoustic-Noise Reduction in MRI

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Introduction: Acoustic noise is one of the main reasons for patient discomfort during an MRI examination. During the scan, gradients are rapidly changed. This leads to physical deformations and vibrations of the gradient coil. The mechanical force is transferred to the system and results in high acoustic-noise pressure. By reducing the gradient slew rates, and optimizing gradient shapes, acoustic noise can be reduced at its source [1]. In this work, we present a generic gradient conversion algorithm that is able to optimize sequences at preserved diagnostic image quality.

Materials and Methods: The gradient conversion algorithm was implemented and tested on a 3T clinical scanner. In a first step, the sequence is subdivided into *KEEP* and *CHANGE* intervals. *KEEP* intervals are those areas, in which gradient shapes must not be changed. This is the case during all read-out and RF objects, as well as during flow-compensation and diffusion-weighting gradients. The *CHANGE* intervals are lying between the *KEEP* intervals. Here, the gradients may in principle have any shape, as long as the following boundary conditions are fulfilled: 1) Start- and endpoint of the *CHANGE* interval as well as 2) duration, and 3) integral of the original gradient shape are to be preserved. In a second step, all gradients within the *CHANGE* intervals are replaced with an optimized shape. We use a fourth-order spline interpolation, with the additional boundary condition that the derivative of the spline must equal zero at the start- and endpoint. This condition results in an optimally smoothed gradient shape. In a last step, the optimized sequence is sent to the measurement system and executed. While gradients have been optimized, all other commands like RF or read-out objects are left unchanged.

As a primary test, we applied the conversion algorithm to the main clinical MRI sequences TSE, SE and GRE. Additionally to the gradient optimization, slight protocol changes were implemented [2]. Volunteer scans were performed after informed consent and acoustic noise was measured and compared to conventional sequences. Image quality of both scans was assessed by three trained radiologists.

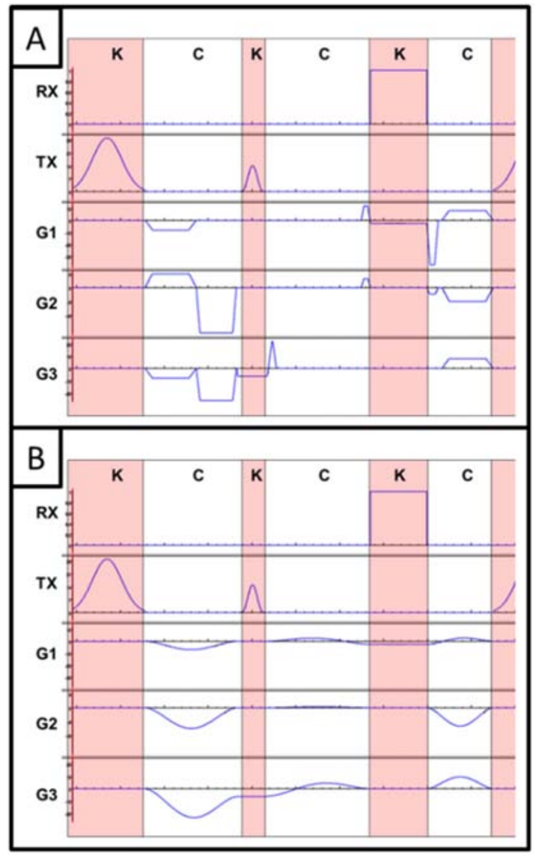

Figure 1: Sequence diagram of an exemplary GRE sequence with fat saturation, without (A) and with (B) gradient optimization. K indicates KEEP, and C CHANGE intervals.

Results: Figure 1 shows an exemplary sequence diagram before (a) and after (b) the application of the gradient conversion algorithm. Images of a T2-weighted TSE sequence are shown in Fig. 2. Using the gradient conversion algorithm, a noise reduction of 6.3 dB(A) was achieved, and another 8.1 dB(A) reduction using protocol changes (bandwidth and echo spacing increased by 10%). Similar noise reductions were found also for SE and GRE protocols. Diagnostic image quality was rated identical by the radiologists.

Discussion & Conclusion: A sequence-independent gradient conversion algorithm was developed that calculates optimized smooth gradient shapes to reduce acoustic noise. The algorithm was successfully tested for the main clinical MRI sequences. Noise reductions of more than 12 dB(A) were found. Incorporating further careful protocol adaptions, further noise reduction of up to 10 dB(A) was achieved, without sacrificing diagnostic image quality. However, it can be expected that noise reduction with gradient optimization in some particular pulse sequences like EPI will only be limited. In conclusion, the results indicate that a substantial reduction of acoustic MRI noise by means of both generic algorithmic sequence optimization and careful protocol optimization can be achieved.

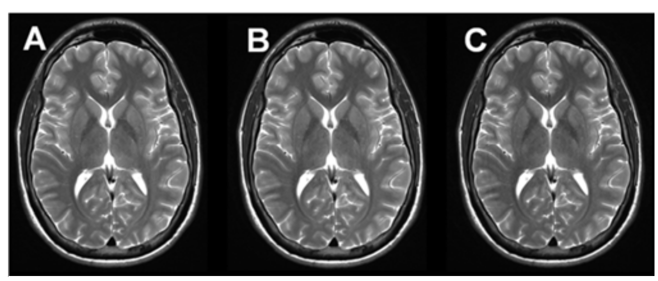

Figure 2: T2 TSE protocol without (A) and with (B) gradient optimization. In (C), bandwidth and echo spacing were increased by 10 %. Noise levels were A: 88.8, B: 82.5 and C: 74.4 dB(A).

References: [1] Hennel F. MRM 1999 Jul 42(1):6-10; [2] Pierre E.Y., Proc. ISMRM 21 (2013): p. 253