Multi-Slice N-fold Acceleration with Scalable Digital Transmit and Receive Systems

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INTRODUCTION: The purpose of this work was to increase the quality of tailored RF phase tagging transmit pulses for multi-slice acceleration as described in Ref. (1). The overall goal is to reduce the time needed for acquisition of a single volumetric gradient-recalled echo-planar image of the brain. For this purpose a Pentek (Upper Saddle River, NJ) PCIe card model 78621 was used. The D/A converter on this card is built around the Texas Instruments DAC5688 chip that creates RF pulses with 2 ns sampling time in up-converting interpolation mode. When developing the original transmit pulse sequence, on a GE Signa EXCITE 3T MR scanner, we found spurious frequencies that gave rise to ghost slices. Unanticipated excitations of amplitude up to 40% in unselected areas as seen in Fig. 1A were encountered. The RF pulse created by the DAC5688 chip has at least two orders of magnitude lower out-of-slice excitation not exceeding 0.1% of full scale spectral amplitude as seen in Fig. 1B. Ghost slices were no longer evident.

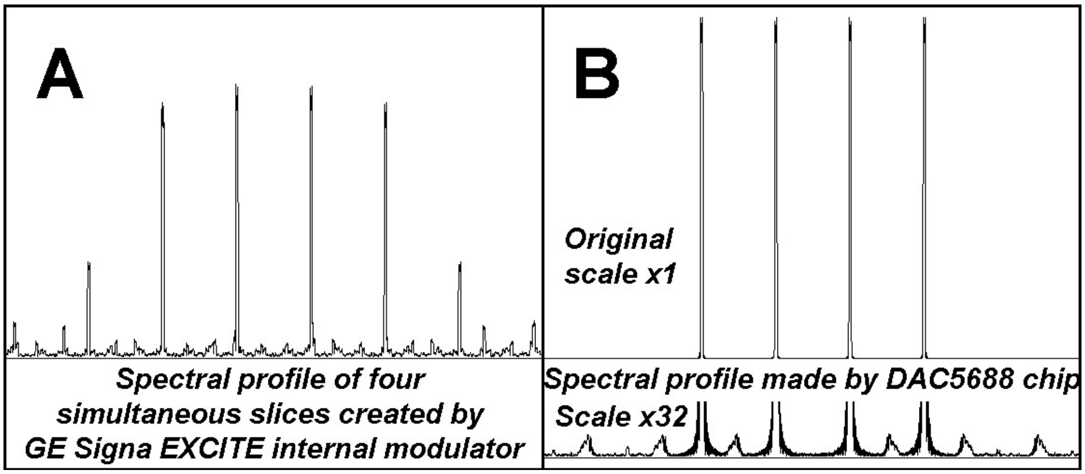

Fig.1. *Multi-slice spectral profiles showing ghost-slices.*

OVERVIEW OF THE METHOD: Tailored pulses were formed from the inverse FT of the required slice profiles including not only positions but also relative phases as described in (1). The same algorithm was used for complex envelope computation. The only difference was the sampling rates: 2 μs for the GE modulator versus 2 ns for the DAC5688 chip. In the latter case the modulating signal was up-sampled from 128 ns step using the on board interpolator to create a stair-step-less waveform at 500 MHz clock that was in sync with the scanner clock.

EXPRIMENTAL METHODS: For detection we used a Nova Medical custom 32 channel (4 x 8 radial configuration) receive-only coil. The acquisition was performed using a 32 channel digital receiver (2) and coil driver made by Tornado Medical Systems, Toronto, Canada. The study was performed on a GE Signa EXCITE 3 T MR scanner. A gradient EPI sequence of our own design (3) was used. Acquisition parameters were: TR = 1 sec, BW = 125 kHz, FOV =24 cm, slice 3 mm, 1 NEX, 64 × 64 resolution and TE = 27 ms. Tailored transmit pulses were 6.4 ms in duration. Twenty image time-courses were acquired as reference slices and twenty images for MRI data.

RESULTS and DISCUSSION: Figure 2 (bottom) shows four separated slices of the phantom acquired with the 32-channel coil. Axial images were acquired because the coil has four elements along Z axis. The eight radial elements can be used for farther acceleration using a SENSE-type method. Four-fold axial acceleration was possible only when assuming a real-valued reconstructed image (1) because only 4 complex, independent equations could be created in the slice encoding direction.

CONCLUSION: The timing of acquisition clocks and triggers was found to be critical for data coherency across channels. The clock and trigger distribution system was carefully adjusted to the same length for each channel. In the process of experiment design, we found that the amplitude of ghost slices depends on how close to the magnet the PCIe 78621 card is placed. The low value of 0.1% of ghost slices, as shown in Fig. 1B, was obtained far away from the magnet. In the equipment room this value increased to 0.5 %. Based in intermediate values of the effect when moving the card (with a computer) farther from the magnet we concluded that miniature output impedance matching transformers built on ferrite cores were saturated causing nonlinearities. The ghost slices were increased even farther, by another 0.5 %, when we added an anti-alias filter to the output. The filter contained ferrite cores also, so we did not used it in our experiments. Even without the filter, the noise floor, barely visible in Fig. 1B, is much lower than that of the scanner standard exciter.

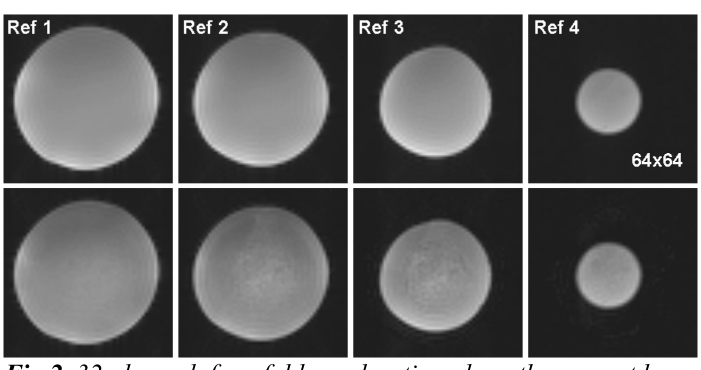

Fig.2. *32-channel, four-fold acceleration along the magnet bore.*

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