Ultra-short echo time imaging using an independent spectrometer and coil insert

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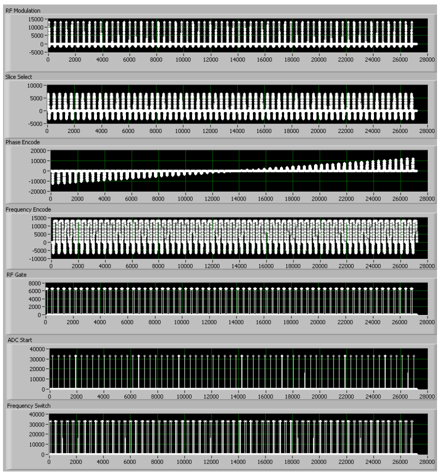
INTRODUCTION

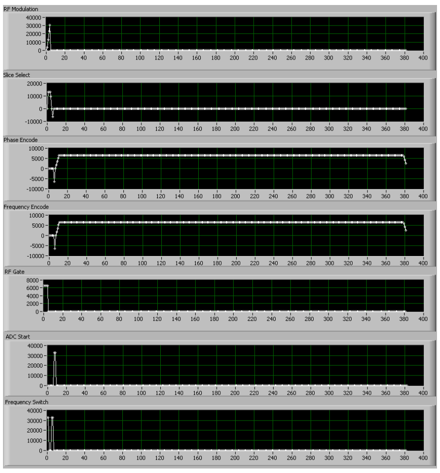
Reducing echo time and in some cases repeat time provides access to imaging of previously MR invisible tissues such as ligaments and tendons. This study investigated techniques to achieve very low TR and TE for multi-channel acquisition on a specialized independent MR spectrometer and imaging coil insert.

METHODS

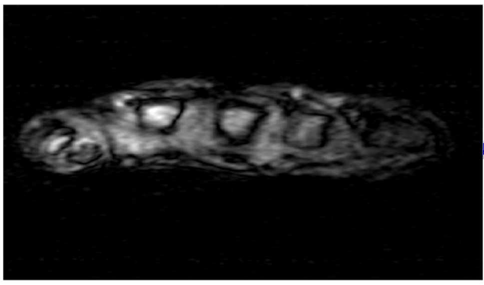
A 32 channel data acquisition system with 8 active RF channels was used to acquire data from a 3T magnet. The system used NI acquisition and control hardware (National Instruments, Austin, Texas) and was programmed in LabView. A 150mm inside diameter cylindrical insert gradient and birdcage RF coil were used to acquire MR data using an outbound data rate of 700kHz for the eight output channels and an inbound data rate of 700kHz for each of 32 channels. To create a very short TR sequence, profiles for sixty-four phase encode steps were programmed into each waveform file with a total of 27800 points per channel (Figure 1). As the system uses digital quadrature reception (after analogue downmixing), the offset frequency must be rapidly switched in between excitation and reception for each phase encode step, achieved by hardware triggering of the synthesiser frequency using a dedicated frequency offset file. A hard coded sequential phase order FLASH sequence with a minimum TR of 680 µs and TE of 180µs was created which simultaneously acquired 32 channels of data for a 64x210 matrix image in 38.8ms. The burst data transfer rate was 5.12 MS/s for 32 channels of 14 bit demodulated quadrature data. The insert gradient set had a sensitivity of 2.5mT/m/A and was used with a 100A power supply. A passive crossed diode TR switch was used to create very short switching time for the 1.2KW RFPA. In addition to the short TR/TE sequence, an ultra-short echo time radial sequence was also built with an echo time of 10µs from the end of the 25µs half RF pulse (Figure 2).

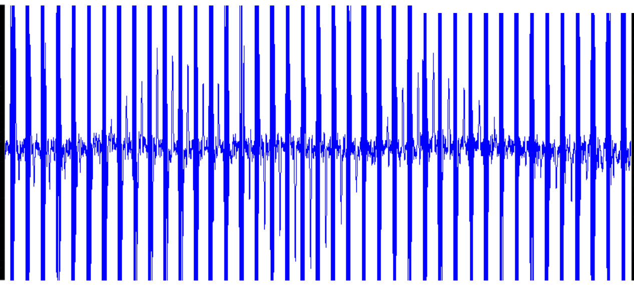
RESULTS

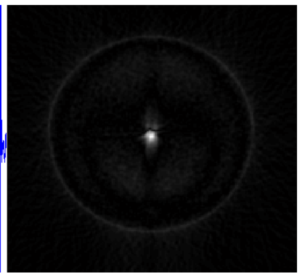




Waveforms for short TR/E acquisition (STREACQ) (Figure 1 left) and UTE radial sequences (Figure 2 right). From to bottom profiles are for RF modulation, slice, phase, frequency, RF gate, ADC start and frequency switch. Figure 3 (below left) shows a conventional TR/E 50/5 ms gradient echo image of a hand acquired at 1.5T using the insert showing the overall image quality achievable. Figure 4 (below middle) shows the central section of a TR/TE 680/180µs STREACQ data set acquired from a uniform rectangular phantom. The series of phase encoded gradient echos can be seen in between the RF pulse breakthrough which is edited out in reconstruction. A relatively low phase amplitude was used here for demonstration purposes. Figure 5 (below right) shows a UTE TE 10µs radial acquisition image from from a vial containing Gd-DTPA with distilled water at a dilution factor of 10, also showing signal from the plastic coil former.







DISCUSSION

The hard coded STREACQ sequence is less flexible in terms of allowing on-the-fly modification of the output waveforms but results in very short TR and TE times and reduces TR jitter considerably as there is no software delay for updating phase encode waveforms. The sequence could be easily extended to 3D to produce sub-second volumetric images. The UTE radial sequence achieved an ultra short echo time of 10µs in conjunction with the gradient and RF coil insert which can switch extremely rapidly. Even with such high gradient strength the acoustic noise was significantly quieter than the Philips whole body gradients operating at a tenth of the gradient field strength. As the acquisition hardware is modular and simultaneously samples each channel, the number of receive channels can be increased to at least 256 with no time penalty (but with a severe financial penalty!). The insert is currently being further developed as an independent high performance orthopaedic imaging system including an MR-compatible magic angle movement device and as the basis of a low acoustic noise independent neonatal incubator for use at 1.5T and 3T.