Single Echo Acquisition (SEA) Imaging at 125 Frames per Second

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Introduction:

Single echo acquisition (SEA) imaging enables the acquisition of an entire image in a single echo using an array of coils. Using an array of 64 parallel coils aligned along the frequency encoding direction, conventional phase encoding can be replaced in some applications by the spatial information provided by the elements of the coil array [1-3]. We are investigating a number of applications for SEA imaging. This abstract describes using SEA imaging to take MR movies at frame rates of 125 frames/second, a speed limited by the minimum practical repetition time of our GE Omega, approximately 8 msec. On modern clinical systems sustained frame rates of 500 to 1000 frames/second should be possible.

Methods:

A prototype 64 channel receiver [4] was used in conjunction with a 64 channel array coil [5]. The array coil consists of 64 planar-pair elements each 8 cm long by 2 mm wide. The array is placed in the magnet such that each coil element is aligned along the magnet axis (z), which is used for the frequency encoding direction. Slice selection is done parallel to the array. Phase encoding is not done, however a gradient pulse is applied in the phase encode direction to offset the phase introduced by the receiver coil pattern [6].

A 13 cm diameter cylindrical gel phantom containing compartments of gelatin made with distilled water and 1 g/L $CuSO_4$ was placed over the array inside a transmit volume coil. After optimizing the phase compensation gradient pulse, a sequence of 128 echos was obtained with a gradient echo sequence using a TE of 4 msec and a TR of 8 msec, obtaining 125 images in 1 second. Longer acquisitions can be taken if needed. During each echo the signals from all 64 coils were mixed to an intermediate frequency of 500 KHz and then simultaneously digitized at 2.5 MHz during the 1.28 msec acquisition window. Following data acquisition the echos from each coil were digitally demodulated, a 1D-FFT taken on each the echo from each element, and then the magnitude of the 1-D projection stacked into the image matrix. The resultant SEA images were sinc-interpolated to a 256x256 matrix for display. For applications such as rapid flow velocity imaging or partially parallel acquisition with the array the complex data can be retained. All imaging was done on the 4.7 T/33 cm Omega scanner in our lab.

Results and Discussion:

Figure 1 shows the 1st, 34th, and 128th images from a series taken with a tip angle of approximately 3 degrees. Figure 2a shows the relative signal intensity vs. time for two locations in the image corresponding to distilled water and relaxed water. There are 128 time points corresponding to each image in the series obtained during the 1 second acquisition period. As expected the distilled and doped water sections start at the same intensity with the water signal decaying towards steady state. Figure 2b shows the same information, but for a series of 128 8 msec images with a tip angle of 45 degrees. The signals oscillate rapidly before the system begins to approach equilibrium. The oscillations correspond to bands moving through the image. By varying the configuration of the crusher pulses following the echo acquisition significant changes in the evolution of the magnetization was observed.

A possible application of this technique would be to embed a non-phase encoded echo inside other imaging sequences to enable the magnetization evolution to be monitored during phase encoded pulse sequences.

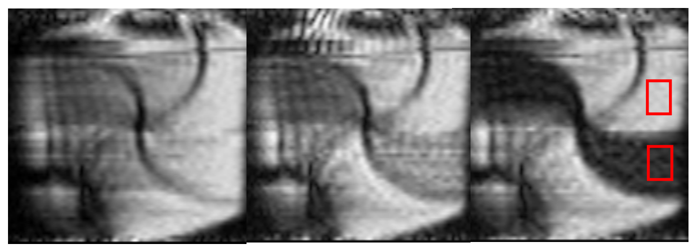

Figure 1. Three images from a series of 128 obtained in 1 second using Single Echo Acquisition imaging. Images shown are the 1st, 34th and 128th in the series. The intensity for all images in the areas indicated are shown in Fig. 2. The compartments that are darker in the final frame are not relaxed.

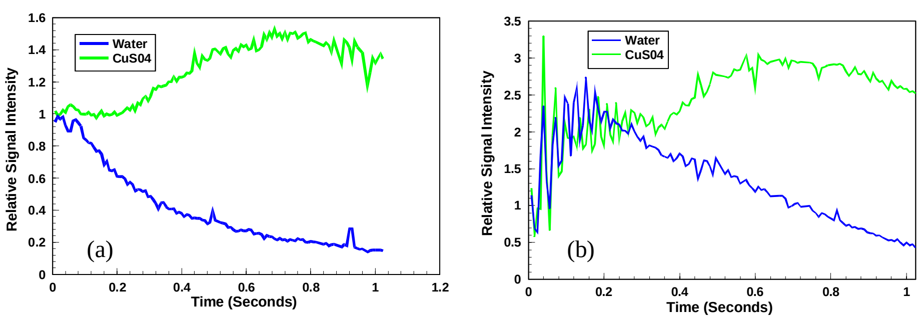

Figure 2. Signal intensity vs. time for two compartments from image series with tip angles of 3 degrees (a, left) and 45 degrees (b, right). The averaging regions in the two compartments are shown in Fig. 1.

Conclusions:

SEA imaging provides a new method for reaching higher frame rates than previously possible while greatly reducing the demands on the gradient system, both by eliminating phase encoding and by requiring fewer acquisitions (one) per image. We have implemented SEA movies at 125 frames per second with reasonable signal-to-noise ratio and resolution. Among many potential applications for this technique, it has the potential to observe the evolution of magnetization during conventional pulse sequences. This could enable extremely rapid determination of T_1 and T_2 maps.

References:

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