# Rapid Flow Imaging using Single Echo Acquisition MRI

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**Introduction:**

Imaging and characterization of turbulent flow remains an active area of research. The chaotic nature of turbulence can make gating impractical or ineffective, leading to the investigation of flow imaging with ultrafast imaging sequences [1-4]. Single shot imaging approaches in which an entire image is collected in an echo train have enabled single slices to be obtained with acquisition windows of tens of milliseconds, but faster methods could be of use for such applications as characterizing flow patterns near stenoses [2,4] or in developing microfluidic technology [5]. Single echo acquisition (SEA) imaging enables the acquisition of an entire image in a single echo using an array of coils [6]. Because an entire image is acquired in a single signal acquisition, SEA MRI provides an extremely fast "shutter speed" for snapshot flow imaging. This abstract demonstrates phase contrast imaging of a gel phantom rotating at approximately 140 revolutions per minute, using SEA imaging at 100 frames per second.

**Methods**:

A prototype 64 channel receiver and receiver coil array developed in house were employed. The receiver and array have been described previously [6]. A real-time DSP unit was added to support essentially continuous data collection. The echos from each coil, output from each receiver at an intermediate frequency of 0.5 MHz are digitized and passed to the DSP boards by front-panel-data-port (FPDP) interface, where they are digitally demodulated and stored. Presently, the system supports the real-time demodulation of 64 coils with TRs as short as 8 ms. The entire system is contained in a single computer. To demonstrate real-time flow imaging, a rotating gel phantom was constructed as shown in Fig. 1. The phantom was rotated using an analog controlled motor driving a string and wheel system. Continuous single echo acquisition magnetic resonance imaging was performed for approximately 13 seconds, at 100 frames per second. A spoiled gradient echo sequence was used, with TR = 10 ms., TE = 5.5 ms. The FOV was 14 x 14 cm, with an acquired matrix size of 128 in the frequency encoding direction, and 64 in the 2$^{nd}$ direction due to the use of 64 elements for image encoding. Final images were interpolated to 256x256. During the initial two to three seconds of the 13 second data collection the phantom was still, to enable calibration, after which the phantom was rotated at approximately 140 rpm in the clockwise and then the counterclockwise directions. Following phase correction of the individual elements and combination, phase images were displayed, as in Fig. 2.

Figure 1. Flow phantom in place over a 64 element phased array designed for SEA imaging. The gel phantom contains four 2.2 cm diameter compartments filled with gelled 1 g/L $CuSO_4$ solution. Velocity encoding was done in the readout (horizontal) direction and was calculated to be approximately 24 deg./cm/sec.

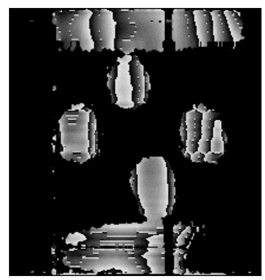

Figure 2. Single frame from the series of 1280 phase contrast images of the phantom. In this frame, the phantom is not rotating. Orientation of the coil is the same as in Figure 1, with freq. encoding along the elements, in the left-right direction. Phase variation in the left-right direction is due to shim. All 64 channels are set for identical phase with no motion, resulting in no phase ramp in the vertical direction.

**Results and Discussion:**

Fig. 3 shows a section of the phase image corresponding to the rotating compartment in the bottom position for clockwise, none, and counterclockwise rotation (three frames from a series of 1280 acquired in 13 seconds). When rotating, the linear velocity in the flow-encoded direction increases from top to bottom in the figure, causing the phase ramp which reverses with the direction of rotation. Profiles are plotted in Fig. 4. Because of the rapid motion of the phantom, subtraction techniques typically used to eliminate the effects of shim and RF coil phase effects can not be used. SEA imaging has the potential to provide "snapshot" imaging of flow at shutter speeds limited only be the time required to digitize a single echo. This should enable characterization of turbulent flow with greater temporal resolution than previously possible.

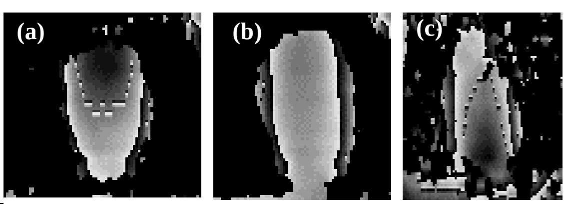


Figure 3. Phase contrast images from one of the gel filled dishes over the bottom section of coils. (a) Rotation at approximately 140 rpm clockwise. (b) No rotation (c) Rotation at approximately 140 rpm counterclockwise. The phase ramp reverses with the rotation direction .change.

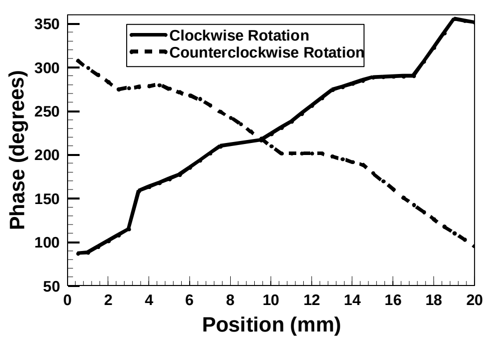


Figure 4. Phase along a vertical line through Fig. 3(a) and (c). The linear velocity ranges from app. 25 to 50 cm/sec from the top to outer of the compartment. Expected phase variation (assuming only linear motion) is app. +/- 350 degrees (cw/ccw). Observed variation was somewhat smaller than expected, but showed the expected linear variation with distance from center, reversing with rotation direction. The single echo acquisition avoids phase encoding artifacts and blurring.

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