Phase Correction with Asynchronous Digitizers

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Targeted Audience: Researchers interested in custom receive hardware.

Purpose: In some MR system configurations, the receiver hardware must operate asynchronously from the rest of the scanner. This may be the case when implementing a custom, standalone receiver based on commercially available high speed digitizer cards [1,2], some of which may not provide an input for an external clock. However, even with a reference clock from the scanner, phase changes in the transmitted RF carrier must be known upon data processing, otherwise jitter will be present in the images. In an integrated system in which the same carrier is used to mix up for transmit and to mix down for receive, this phase cancels, or the transmit/receive system keeps track of it internally. Another potential application of asynchronous receive hardware may as part of a "wireless" receive coil [3], in which part of the receiver is physically isolated from the rest of the scanner, making it more difficult to share clocks. Whenever the phase of the received signal varies in an unknown way between acquisitions, due to phase changes in the transmit pulse, an asynchronous digitizer clock, or a local oscillator that is not locked to the MR system clock, jitter will be present in the reconstructed images. By digitizing an additional signal which is synchronized to the transmit RF carrier, these phase variations can be accounted for and corrected in post-processing, eliminating jitter. In this paper, two correction methods allowing the use of asynchronous receivers are presented.

Methods: Direct digitization of the received RF was performed at 1.0 T and 4.7 T using similar test setups. At 1.0 T, a National Instruments PXI-5122, 14-bit, 100 MS/s digitizer card was used for direct digitization of the 42.595 MHz signal. Transmitted RF and gradients were generated using a custom imaging console which was built in house for use with an ONI OrthOne extremity magnet. At 4.7 T a NI PXI-5152, 8-bit, 2 GS/s digitizer card was employed to digitize the RF at 200.128 MHz. A Varian Unity/INOVA imaging console was used to control the transmitted RF and gradients. In both cases, the digitizer cards employed a high stability reference oscillator (50 ppb) provided by a PXI-6653 timing card located in the same PXI chassis. There was no connection between the PXI chassis and the spectrometers. The experiment at 1.0 T employed a 42.0 MHz "pilot signal", generated by an AD9959 DDS which was synchronized to the reference oscillator of the custom-built imaging console. To simulate true "wireless" receive, the pilot signal was injected into the bore of the magnet using a small non-resonant loop probe. A signal level far less than 1 mW was readily detected through the birdcage coil and LNA. There were no phase shifts applied to the transmit carrier during this experiment. The experiment at 4.7 T acquired a phase reference by digitizing part of the residual FID produced by the 180 pulse in a spin echo sequence. This required placing the readout refocus and phase encoding gradients immediately before the acquisition window and starting the digitization several milliseconds earlier. In both cases, the phase of the reference signal was tracked vs. acquisition number and an opposite phase shift was applied to the detected echo prior to the FFT.

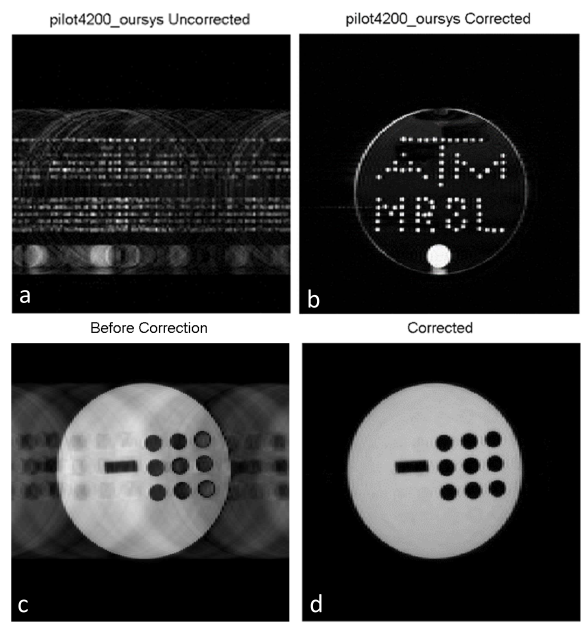

Fig. 1. a) Asynchronously acquired 1.0 T image without phase correction, b) corrected using a 42.0 MHz pilot signal, phase locked to the transmit carrier, injected into the bore of the magnet, c) asynchronously acquired 4.7 T image without phase correction, d) corrected using phase information from residual FID produced by the 180 pulse.

Results and Discussion: By digitizing a reference signal which provides information about the phase of the RF transmit pulse for each acquisition, jitter artifacts due to asynchronous signal reception were removed, as shown in Fig. 1. Because the pilot approach uses a signal approximately 500 kHz off resonance, a linear phase ramp was left after the correction, requiring a circular shift of the image. The approach of digitizing a residual FID places additional constraints on the pulse sequence, but it requires no additional hardware. Both methods have the advantage of not requiring the sacrifice of a receiver channel for phase correction.

References: [1] J. Bodurka, et al., Mag. Reson. Med., vol. 51, pp. 165-171, 2004. [2] A. Jesmanowicz and J. S. Hyde, in Proc. Intl. Soc. Mag. Reson. Med., 2006, p. 2027. [3] G. Scott and K. Yu, in Proc. Intl. Soc. Mag. Reson. Med., 2005, p. 330.

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