K. Z. ABD-ELMONIEM[1], J. L. PRINCE[1]
[1]ELECTRICAL AND COMPUTER ENGINEERING, JOHNS HOPKINS UNIVERSITY, BALTIMORE, MARYLAND, United States

QuickCANSEL: Reduced Scan time CANSEL to Eliminate Artifact-Generating Echoes in Cardiac MRI

Introduction: Harmonic phase imaging (HARP) (1) employs spatial cosine tagging of the longitudinal magnetization at the end-diastole. The first harmonic peak is filtered later on at each cardiac phase to extract both in-plane displacement and strain. HARP works in CSPAMM dataset because there is no interference from the DC peak into the harmonic peak. However, still interference occurs from the conjugate peak and therefore, the resolution of the computed strain map is very sensitive to the selection of the filter. Ringing artifact is also common. Recently, CANSEL (2) method was advised to eliminate the T_1-relaxation echo (DC peak) and the complex conjugate echo (conjugate peak). CANSEL acquired five acquisitions for each tagging direction for canceling the two extra peaks and obtain displacement-encoding phase map. In this work, we suggest an improvement to the method that achieves the same goal in only five acquisitions in both tagging directions.

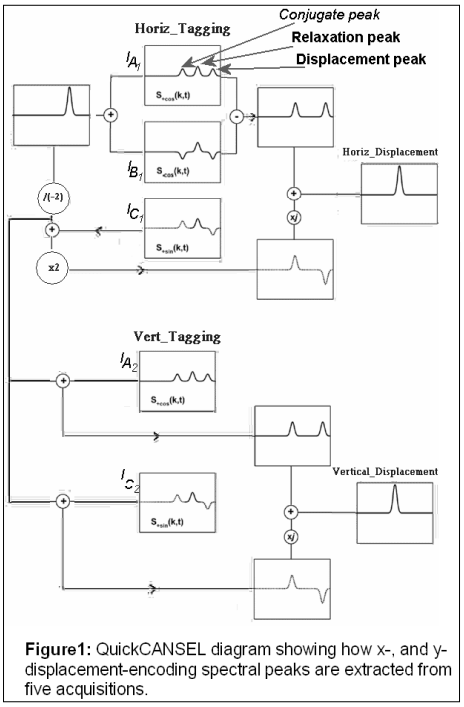

Figure1: QuickCANSEL diagram showing how x-, and y-displacement-encoding spectral peaks are extracted from five acquisitions.

Theory: A cosine-modulated SPAMM image has an intensity $I_{A_1}(x,y)$ where

$$I_{A_1}(x,y) \propto \rho(x,y)e^{j\varphi_E(x,y)}(1+\cos(\varphi_x)) = \rho(x,y)e^{j\varphi_E(x,y)}\left[1+\frac{e^{j\varphi_x}+e^{-j\varphi_x}}{2}\right],$$

φ_x is the displacement-encoded phase contrast, resulting from tagging (this case is in x-direction), and $\varphi_E(x,y)$ is the phase from inhomogeneity and other nonidealities.

In addition to I_{A_1}, the following sets are acquired with all have tagging in x-direction

$$I_{B_1}(x,y) \propto \rho(x,y)e^{j\varphi_E(x,y)}(1-\cos(\varphi_x)),\quad I_{C_1}(x,y) \propto \rho(x,y)e^{j\varphi_E(x,y)}(1+\sin(\varphi_x))$$

and

$$I_{A_2}(x,y) \propto \rho(x,y)e^{j\varphi_E(x,y)}(1+\cos(\varphi_y)),\quad I_{C2}(x,y) \propto \rho(x,y)e^{j\varphi_E(x,y)}(1+\sin(\varphi_y))$$

From these sets, x-, and y-displacement-encoding peaks and conjugate peaks are extracted as follow

$$\rho e^{j(\varphi_E \pm \varphi_x)} = \frac{I_{A_1}-I_{B_1}}{2} \pm j\left[I_{C_1}-\frac{I_{A_1}+I_{B_1}}{2}\right],\qquad \rho e^{j(\varphi_E \pm \varphi_y)} = \left[I_{A_2}-\frac{I_{A_1}+I_{B_1}}{2}\right] \pm j\left[I_{C_2}-\frac{I_{A_1}+I_{B_1}}{2}\right]$$

$$\varphi_x = \angle\rho e^{j(\varphi_E+\varphi_x)} - \angle\rho e^{j(\varphi_E-\varphi_x)},\qquad \varphi_y = \angle\rho e^{j(\varphi_E+\varphi_y)} - \angle\rho e^{j(\varphi_E-\varphi_y)}$$

Methods: The procedure was applied to simulated phantom data with 60 cpm, temporal resolution 25 ms, 40 cardiac phases simulated with the five acquisitions. Figure 2 shows the first cardiac phases of the five acquisitions. Peak extraction is shown in figure 3. The phase and magnitude images of the harmonic peak at different cardiac phases are shown in figure 4.

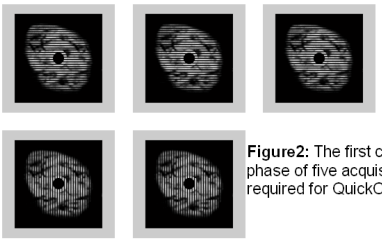

Figure2: The first cardiac phase of five acquisition required for QuickCANSEL.

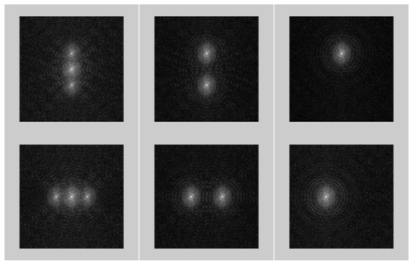

Figure 3: Example of peak extraction. Left col. Original SPAMM image. Middle: CSPAMM. Right: Harmonic peaks.

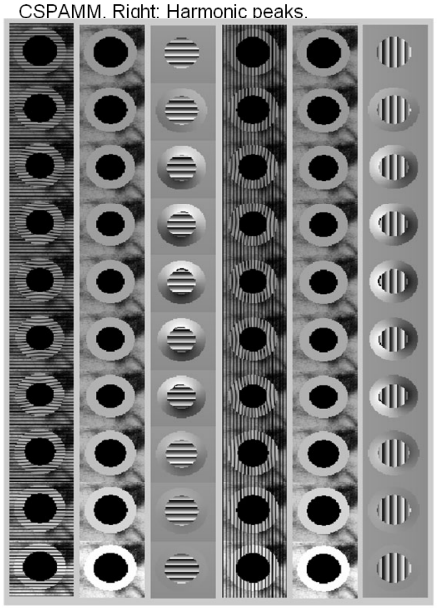

Figure 4: Simulated results. From top to down: frames taken at time step=100 ms. Left: 1) Horizontal tagging, 2) Magnitude images of the extracted harmonic peak. 3) Phase images. 4) Vert. Tagging. 5) Magnitude. 6) Phase

An experiment was conducted using a Philips 1.5T-Intera system using a moving water-filled-bottle phantom. The phantom was moving sinusoidally along the B_o field direction and tilted by 45° about the anterior-posterior axis. 29 cardiac phases were acquired per cycle. Image processing was performed off-line on a personal computer. Hi-Resolution tagged CSPAMM were acquired with delayed reconstruction and the three acquisitions ($I_{A_1}, I_{B_1}, I_{C_1}$) were reconstructed. Due to the ramp flip angle used was not optimized for the T_1 of the water, SNR of the first frames was very low. The phase maps generated from the extracted harmonic peaks are shown in Figure 5C

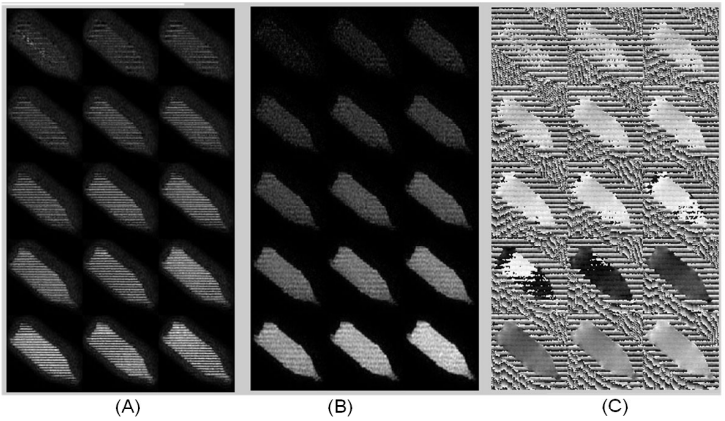

Figure 5: QuickCANSEL applied to a moving phantom. CINE images are shown. (A) The CSPAMM tagged images. (B) The magnitude of the extracted harmonic peaks. (C) The phase of the extracted harmonic peaks.

Discussion and Conclusion: QuickCANSEL is a modification of the CANSEL method. The proposed method extracts the harmonic peak without the need of k-space filtering this has a potential advantage of producing displacement-encoding phase maps with fewer artifacts. The simulated results and the first phantom results conform to the theory and crisp phase maps were obtained. The procedure requires the five data acquisitions half the number required by CANSEL.

References: 1.)Osman:TMI'00, 2.)Epstein:MRM'04