Complementary-Coded Multi-Line Transmission for Ultrafast Ultrasound Imaging with Increased Motion and Aberration Robustness

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Background, Motivation and Objective

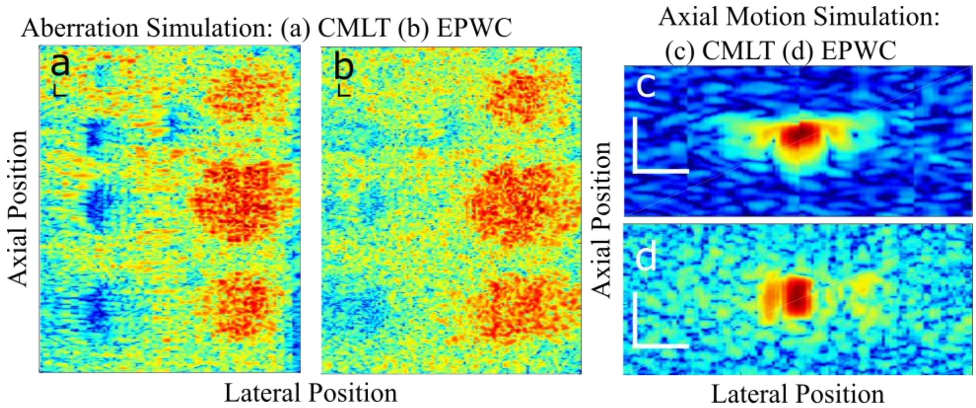
Unfocused transmission methods for ultrafast ultrasound imaging can provide high quality images by synthetically transmit and receive focusing at every point in a target. Unfortunately, these methods perform compounding over numerous transmits, each interrogating much of the target, and this exacerbates image degradation in the context of motion or speed of sound variation. To address this problem, we are exploring coded multi-line transmission (CMLT), which restricts target interrogation over both time and space. Intuitively, using focused beams reduces the motion or aberration 'seen' by interrogations used to beamform a point. In this work, we demonstrate signal-to-noise ratio (SNR) and de-blurring benefits with motion present, as well as increased contrast with aberration present. We also present a snapshot of our progress towards demonstrating these improvements experimentally.

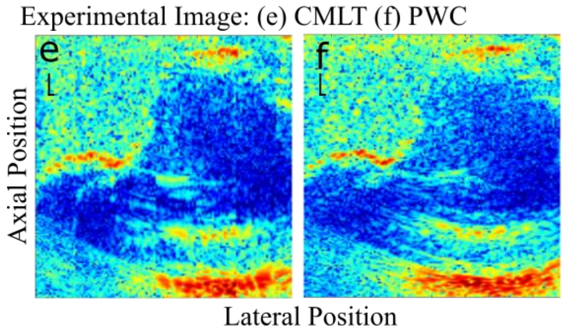
Statement of Contribution / Methods

We begin by analytically developing the intuition that CMLT effectively observes a lower amount of motion or speed of sound variation as compared to unfocused compounding methods. Next, we illustrate image quality improvements in Field II simulations, comparing CMLT to encoded plane wave compounding (EPWC) on point, cyst, and boundary-like phantoms. CMLT was performed using clusters of complementary-code-encoded beams [Egolf et al. IUS 2018] with each cluster having zero cross-talk with adjacent clusters, while EPWC was performed using Golay encoding. Narrow transmit and receive apertures were used for each CMLT beam in the aberrating simulations to further localize effective speed of sound variation. Finally, we implemented CMLT on a Verasonics Vantage system, and provide a sample image of a beating heart phantom.

Results / Discussion

(a)-(b): In the context of severe aberration, CMLT better preserved contrast and structure, resulting in a cyst contrast ratio of roughly 1.5 between CMLT and EPWC. (c)-(d): In the context of 1 m/s axial motion, CMLT reduced blurring (axial resolution improved to 0.2 mm from 0.5 mm) and had higher SNR (improving from 43 dB to 48 dB) than EPWC. (e)-(f): Initial experimental testing in a static context yielded results comparable to plane wave compounding (PWC). Ongoing experimental work is using this implementation to explore the advantages of CMLT observed in simulation.





Scale bars are 1 mm.
Display range is -55 dB.
(a)-(b): CMLT provides improved contrast in presence of aberration.
(c)-(d): CMLT provides reduced blurring and higher SNR in presence of motion.
(e)-(f): Example experimental image of static heart phantom.