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Fourier domain adaptive beamformers for passive ultrasound imaging – *in vitro* study

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Background, Motivation and Objective

The formation of gas bubbles (cavitation) in the tissues is one technique used in ultrasound therapy. Passive imaging using the acoustic signals from such bubbles is a promising candidate to monitor local cavitation in real-time. Special consideration must be given to beamforming to follow cavitation properly and map the treated tissues. Beamforming in the Fourier domain (FD) has been introduced to take advantage of the signal spectrum when characterizing cavitation and to reduce the computation time. In the present work, we propose and compare 4 FD-beamformers to improve cavitation detection: one non-adaptive (FD-PAM) and three adaptive : Robust Capon (FD-RCB), Functional (FD-FB), MUltiple SIgnal Classification (FD-MUSIC).

Statement of Contribution/Methods

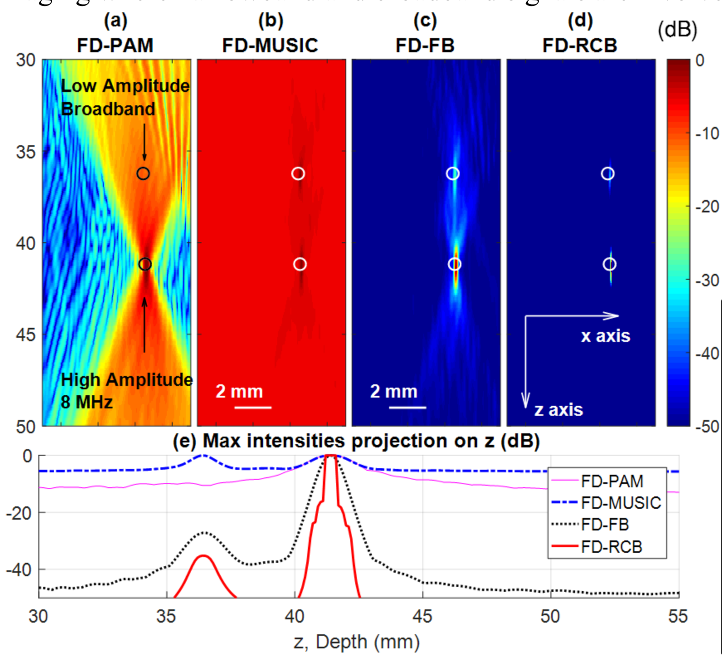
FD passive beamforming can be achieved by 1) estimating the cross-spectra of received data, 2) applying for each pixel a phase delay to the spectrum of each array element, and 3) summing the steered spectra for power estimation [Haworth 2017]. Since adaptive methods suffer from poor stability, we thus introduce in step 1 a robust cross-spectral periodogram. In step 3, FD-PAM averages with uniform weights. To mitigate interferences: FD-RCB uses optimized data-dependent pixelwise weights, FD-MUSIC decomposes pre-steered data into signal and noise subspaces, and FD-FB compresses data using a power law.

In order to test the FD-beamformers, a wire was insonified with a focused mono-element. The backscattered signals were recorded passively with a linear array. A low-power broadband noise was first emitted to mimic inertial-cavitation events. To mimic the presence of bubble reflectors, the received signals were then summed with those acquired using an 8 MHz sine excitation, after an axial shift of the wire. The [7.9 – 8.1] MHz band was considered for FD beamforming.

Results/Discussion

Maps and metrics are presented in the figure (a-d; f). With FD-PAM, the sidelobes of the source masked the weak one. When using adaptive beamforming (b,c,d), the low-power source peak clearly emerged from the background (e). The resolution increased in comparison with FD-PAM (+80% for FD-RCB). The contrast was also enhanced, except with FD-MUSIC (-8 dB decrease).

This *in vitro* study demonstrates the potential of adaptive FD beamformers for passive cavitation imaging where narrowband and broadband signals are involved.



(f) Table of Metrics

	Weak peak emergence (dB)		Resolution (%) with respect to FD-PAM		Contrast gain (dB)
	Lateral	Axial	Lateral	Axial	
FD MUSIC	+6	+5	+15	+2	-8
FD FB	+19	+11	+68	+69	+34
FD RCB	+26	+18	+83	+80	+48

Figure: Passive images obtained for wire localization with (a) FD-PAM, (b) FD-MUSIC, (c) FD-FB, and (d) FD-RCB.
A low amplitude broadband noise excited the wire at the upper position. After an axial shift of 5 mm, a high amplitude sinusoid at 8 MHz excited the wire. The two acquisitions were then summed, and beamformed. The circles centers indicate the positions estimated with B-Mode imaging.
The maximum intensity for each depth is plotted in (e). Metrics for localization are summarized in table (f).