Ultrasound Detection Array via Spatially Multiplexing Masks

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Background, Motivation and Objective

In the field of optoacoustic tomography, the number of ultrasonic detectors that can be read-out simultaneously from a single array is a crucial parameter for 3D tomographic reconstruction.

Previous works increased the measurement dataset obtained by piezoelectric transducers by placing random masks and scatterers between the imaged object and the detector, enabling randomly permutated acoustic measurements from which image reconstruction was performed by compressed-sensing algorithms in combination with preliminary mapping of the acoustic response.

Our work presents a novel method for transforming a single-element ultrasonic detector into an effective detection array by using a binary acoustic mask coded with cyclic Hadamard patterns. In contrast to previous works, our approach achieves semi-isotropic angular sensitivity, optimal SNR and is described by a simple analytical formula with a well-conditioned inversion operator. Thus, it is not required to measure the response of the mask or use complex reconstruction algorithms.

Methods

Multiplexed measurement was acquired by scanning a coded mask in front of a large area detector (Fig.1.A). From this set, a map of the acoustic fields, compatible to an array with 59 elements was analytically extracted. The technique was experimentally demonstrated by measuring the 2D diffraction pattern of a round transmitter by the proposed virtual array and by a single-element ultrasound detector for comparison. In addition, per element sensitivity and angular response of the virtual elements were examined.

Results/Discussion

Good compatibility was seen between the multiplexed and the single detector measurements for the time domain signals and for the recorded diffraction pattern (Fig.1.B-C). The multiplexed results achieved x4 SNR improvement, as expected from the theoretical calculations.

The approach enables a simple, analytic solution for creating a detection array from a single ultrasonic detector with custom element size and geometry. The proposed base configuration achieves the optimal noise reduction.

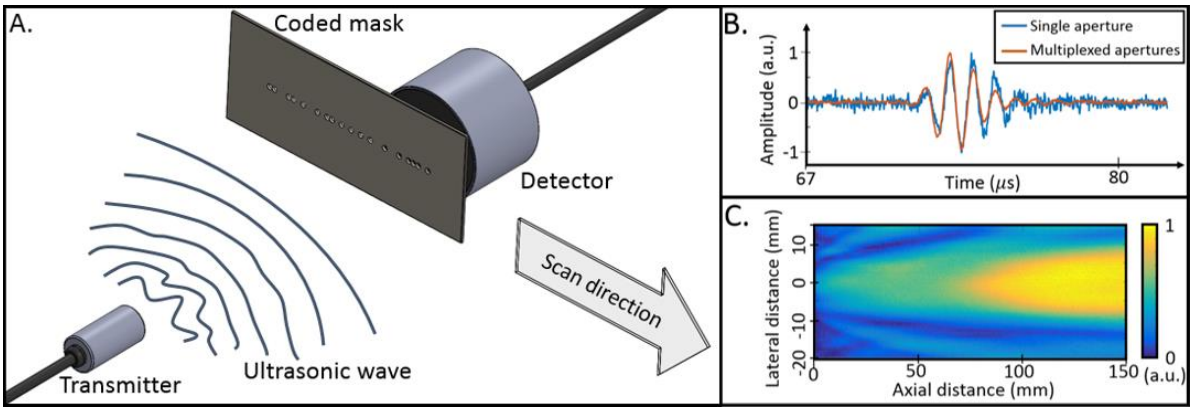

Fig.1. (A) Experimental setup, (B) waveform shape comparison between the multiplexed and the single aperture detection and (C) 2D diffraction pattern recorded by a virtual array with 59 elements.