Program Digest, 2019 IEEE International Ultrasonics Symposium (IUS)
Glasgow, Scotland, October 6-9, 2019

High-Resolution 3D Ultrasound Imaging using Bias-Switchable Row-Column Arrays and Orthogonal Plane Wave Compounding with Hadamard-Biased Full Aperture Readout

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Background, Motivation, and Objective

A fully wired N×N 2D array would become impractical for large arrays. Top-orthogonal-to-bottom electrode (TOBE) arrays (Fig. 1E) greatly reduces the number of active channels needed to acquire an image from N×N channels down to 2N. Previous TOBE imaging schemes suffered from poor image quality owing to unfocused apertures on transmit or receive. Recently we introduced novel improved imaging schemes taking advantage of bias-switchable TOBE arrays. However, these approaches did not yet achieve high isotropic volumetric resolution and were not yet capable of addressing a sub-array within a larger array. To remedy these deficiencies, we here propose a new imaging scheme involving orthogonal plane wave compounding with multiplexed Hadamard-biasing.

Statement of Contribution/Methods

The imaging scheme first biases columns using Hadamard bias patterns, transmits a sequence of steered plane waves on columns and receives the RF data on rows. Transmit polarity is reversed on columns with a negative bias. The roles of rows and columns are then electronically reversed and the sequence is repeated. This approach enables readout from every element of the array for each plane wave angle. After Hadamard decoding of channel data, low-resolution images are formed from each plane-wave transmit angle and these images are additively compounded for each orientation. The final image is obtained by either adding (Fig. 1C) or multiplying (Fig. 1D) of compounded images from each orthogonal orientation. Initial results were validated using Field II simulations. Experimental implementation is developed using a 64x64 element 10MHz electrostrictive array & custom electronics.

Results/Discussion

For TOBE array simulations without Hadamard coding, we measured the axial resolution of 90µm & 55µm, lateral resolution of 390µm & 260µm, and SNR of 45dB & 70dB for additive (Fig. 1A) and multiply (Fig. 1B) methods, respectively. For the Hadamard coding, we measured the axial resolution of 110µm & 75µm, lateral resolution of 300µm & 180µm, and SNR of 62dB & 108dB for additive (Fig. 1C) and multiply methods (Fig. 1D), respectively. Experimental results will be presented. With a 20KHz pulse-repetition-rate and 7-angles in each direction, the proposed imaging scheme is theoretically capable of volumetric imaging rate of 48 Vol/s and should enable scanned sub-array readout from a larger TOBE array.

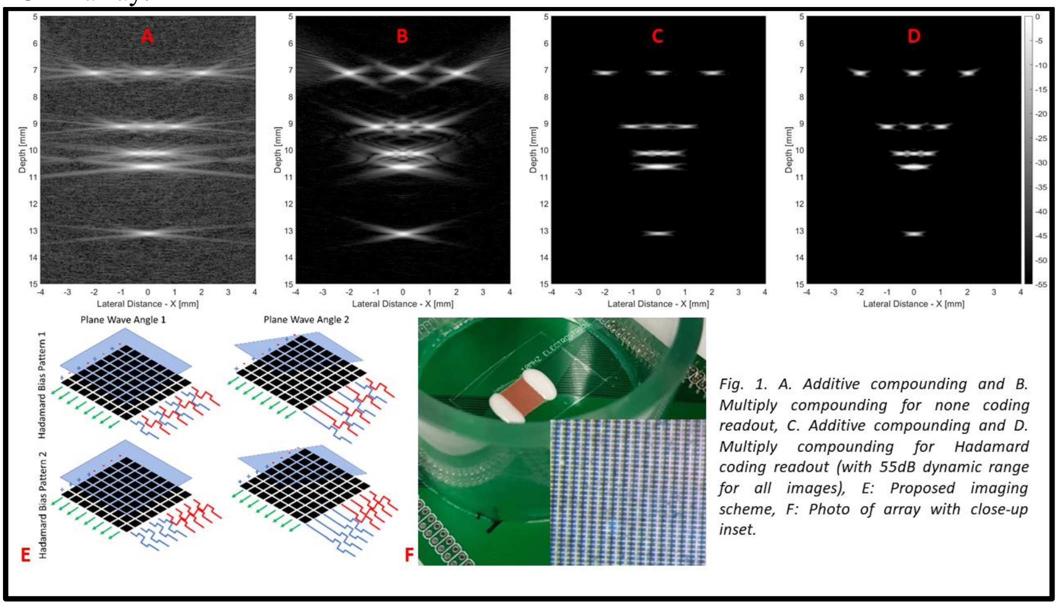

Fig. 1. A. Additive compounding and B. Multiply compounding for none coding readout, C. Additive compounding and D. Multiply compounding for Hadamard coding readout (with 55dB dynamic range for all images), E: Proposed imaging scheme, F: Photo of array with close-up inset.