Realtime 3D Imaging with Fast Orthogonal Row-Column Electronic Scanning of Bias-Switchable Crossed-Electrode Relaxor Arrays

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Background, Motivation and Objective

Large fully connected 2D arrays require too many channels to be practical for clinical applications. Electrostrictive Top-orthogonal to top-electrode (TOBE) arrays solve this problem by connecting only the top row and bottom column electrodes, reducing the number of channels to 2N for a NxN array. We recently introduced a Fast-Orthogonal Row-Column Electronic Scanning (FORCES) imaging scheme for TOBE arrays which uses Hadamard bias encoding for 3D imaging and 2D imaging quality equivalent to a linear array. The requirement for fast bias switching presents additional challenges, however, as it increases the complexity of the electronics. Moreover, fast switching of the array was yet to be validated.

Statement of Contribution/Methods

A 10 MHz 64x64 element electrostrictive relaxor array was connected to a custom PCB interface board. We previously demonstrated the utility of the FORCES scheme to produce high-quality 2D and 3D images of wire phantoms and animal tissues by using bias encoding with bias-sensitive TOBE arrays. This approach used relay-based bias switching and CPU-based decoding and beamforming resulting in B-scan imaging rates of >40 minutes. Here we demonstrate the use of solid-state bias switching, along with GPU-based reconstruction to achieve realtime 3D imaging.

Results/Discussion

Figure 1a shows the transmitted phase shift after switching the bias from positive to negative where the time between the bias switch and transmit pulse is varied. The FORCES scheme relies on a 180º phase shift between positive and negative biases. A 179º phase shift was measured at a bias switching speed of 6µs. This allows for FORCES B-scan acquisitions at a rate of 24 fps, shown in Figure 1c with two crossed wires, and volumetric acquisition rates of 3 vol/sec. The azimuthal resolution was measured as 310 µm. Figure 1b shows a comparison of decoding and reconstruction speeds using custom GPU and CPU-based techniques. With a Fourier-based GPU (CUDA) beamforming approach, a reconstruction rate of 20 vol/sec was achieved. This is the first row-column-based 3D ultrasound imaging system capable of real-time imaging with two-way focusing, allowing for image quality equivalent to a linear array. 3D real-time imaging of mouse models and needle guidance will be demonstrated.