Abstract

Ultrasound imaging is the most popular imaging technique being least hazardous and capable of continuous imaging at a real-time frame rate. Beamformers play an important role in the formation of high-quality ultrasound images. The goal of the beamformers is to focus the beam at an angle during transmission while combining the echoes in a controlled manner such that the gain corresponding to the desired focal point remains high. Focusing of the beam at a scan point requires applying delays to the signals transmitted or received by different elements of the array. These delay values change with every scan point for each element of the array. Therefore, a dynamic delay calculator is needed for on-line computation of the delay values. Apodization is used to reduce the amplitude of the signals from the direction other than the focal point by applying appropriate weights to the response of each array element. Fixed window functions can be used for apodization, however, they broaden the mainlobe which reduces the image resolution. An effective adaptive apodization technique is required to avoid this trade-off, and its low power architecture is needed for a portable ultrasound imaging system. In ultrasound imaging, convex phased arrays are largely used in obstetrics and gynecology as they provide larger Field of View (FOV) with minimal contact area. The aim of this dissertation is to develop a hardware-efficient beamformer for a real-time convex array based ultrasound imaging system. A real-time dynamic delay calculation algorithm and its architecture are proposed to focus the multi-element convex phased array at a large number of scan points dynamically. The proposed algorithm reduces the number of calculations and provides parallelism by splitting the delay equation into two parts, with one remaining constant and the other changing with the array elements and the scan points. An apodization algorithm is proposed to enhance the image contrast and resolution by selecting the window functions having minimum and maximum variances from the multi-window functions, and Dual Apodization with Cross-correlation (DAX) algorithm. Its IEEE single precision arithmetic based resource-optimized hardware architecture is also furnished. Finally, a phased array receive-beamformer architecture for multi-element phased array is presented which is implemented for 64-element convex phased array using the proposed apodization architecture, proposed delay calculator, Dual port Block RAMs and interpolation filters. Hardware requirement in the proposed beamformer is reduced by introducing resource sharing at different levels. Hardware complexity in terms of NAND-2 equivalent gates and total dynamic power consumption for the proposed beamformer are found to be 1370 k and 252.90 mW respectively in UMC 90 nm CMOS standard cell library.

Keywords: Ultrasound Imaging, Beamformer, Convex Phased Array, Delay Calculator, Apodization, DAX.