Review: Design of Low-Cost Portable Ultrasound Systems

Jonathan Baran and John G. Webster , *Member, IEEE*
Department of Biomedical Engineering
University of Wisconsin, Madison, WI

Abstract

Ultrasound continues to be one of the major imaging modalities used for the diagnosis and treatment of a number of medical conditions. Therefore emphasis on innovation is continually increasing the quality of the ultrasound systems. However focus is just beginning to shift into the low-cost and portable applications of ultrasound. These systems present interesting constraints which must be considered to transform a standalone system into a portable version. This review takes a look at some of the attempts which have been published, as well as some of the issues which have still yet to be resolved. In conclusion, low-cost portable ultrasound has the capability to be developed and commercialized, but until a suitable replacement to piezoelectric crystals has been developed (possibly CMUTs?) low-cost portable ultrasound system will be held back by the high cost burden associated with the cost of piezoceramics.

Need

- The creation of a low-cost, portable ultrasound system to be implemented in emerging countries, military operations, and emergency situations.

Transducer Design

A. Current Problem

- Current array designs put strict limitations on PCB layouts. When low-cost, portable applications are developed there is difficulty shrinking designs while still maintaining functionality.

B. Solution

- Girard *et al* at the University of Virginia [3] developed a low - cost method for the creation of a printed circuit board (PCB) to facilitate 1024 surface pads for each element. A gold plated polyester sheet covered all 1024 transducers to complete the connection. Due to the PCB traces that crossed over each other, crosstalk was a large portion of the overall signal. However this design was sufficient to generate a proof of concept.
- Eames *et al* [5] furthered the work by Girard *et al* at the University of Virginia with the creation of a 60 x 60 (3600 element) transducer array. Eames *et al* looked to improve transducer design by creating 3600 straight through holes. The design resulted in a slightly lower resonance frequency of the piezoceramics than was anticipated, probably due to the element thickness.
- Capacitive micro - machined ultrasonic transducers (CMUTs) hold the promise of dramatically reducing the cost associated with ultrasonic transducers along with providing revolutionary advances in current technology. Oralkan *et al* [6] was the first to present a pulse - echo phased array B - scan sector image using 128 CMUT elements in a 1D transducer array.

Transmit Circuitry

A. Current Problem

- Traditional ultrasound systems rely on high voltages and currents to drive the piezoelectric transducers.

B. Solution

- Owen *et al* [8] has developed a 12 lb plug - in class D switch mode amplifier to drive single element high intensity focused ultrasound transducers. The system provided 140 W of acoustic energy to a 70% efficient PZT transducer. Owen *et al* concluded their device was comparable to available commercial applications.
- According to Lewis *et al* [9] the majority of ultrasound drivers and RF amplifiers are generally built with an output impedance of 50 ohms. In order to obtain the maximum power transfer matching circuitry must be used to transfer power to the transducer. However, in matching impedances which are generally complex, systems incur additional costs and complexity. Lewis *et al* worked to develop driving circuitry with an output impedance of 0.3 ohms which transferred power with 95 % efficiency to the transducer.

Beamforming Algorithm

A. Current Problem

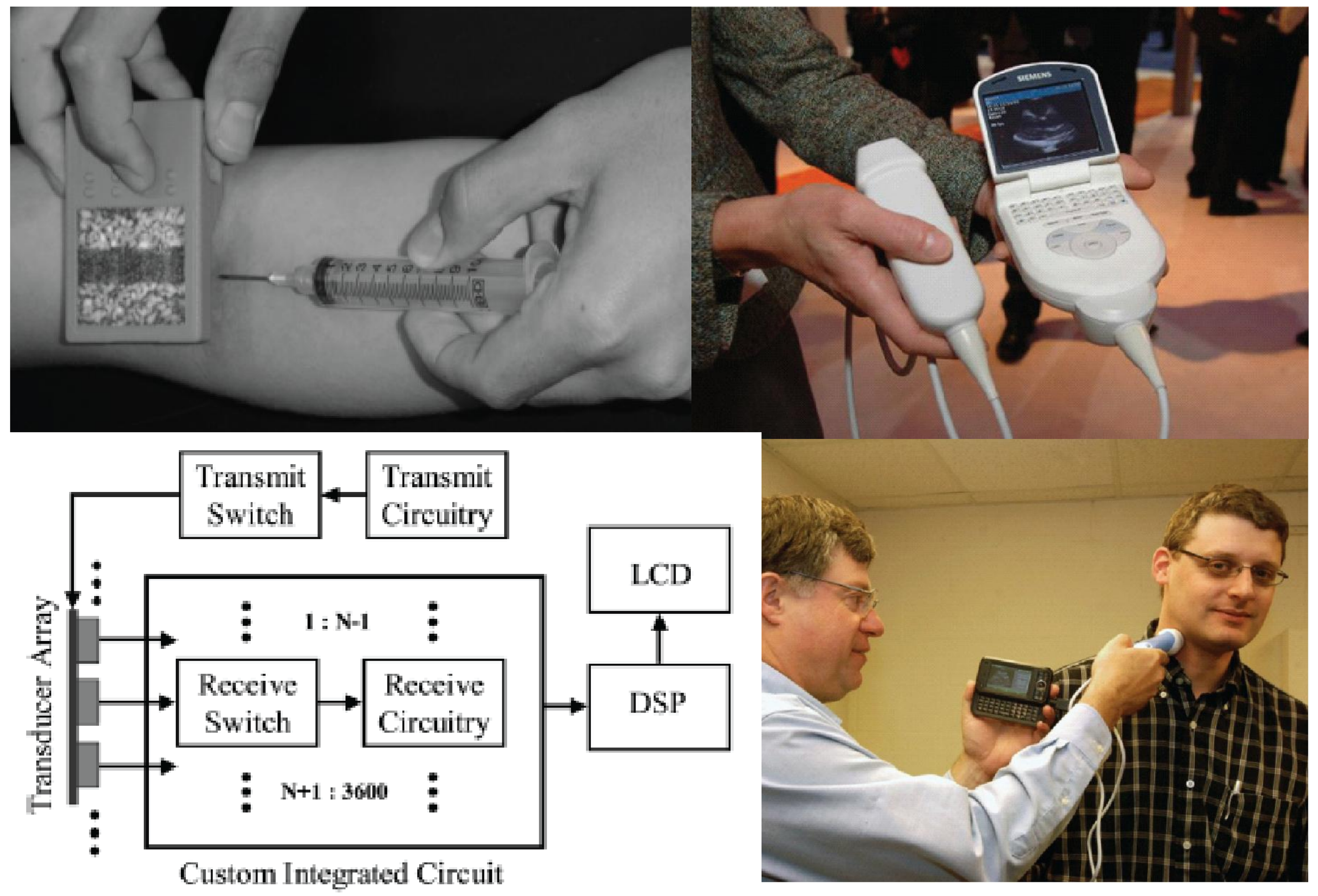
- Traditional ultrasound systems rely on sophisticated DSP algorithms. Since low-cost, portable applications are unable to perform this algorithms, new methods need to be developed.

B. Solution

- Traditionally three different methods were used to implement a time delay. 1) RF modulation onto an intermediate frequency [12]. 2) Upsampling the incoming signal using an interpolation filter [13]. 3) Nonuniform sampling of the RF signal according to the needed time delay.
- Freeman *et al* [11] corrected this problem with the creation of the Delta - Sigma Oversampled ultrasound beamformer. This method, now serves as one of the best low - cost beamforming options available.
- Ranganathan *et al* [14] looked to further develop beamforming algorithms by reducing the image quality for a large tradeoff in cost. The goal was to determine the simplest beamforming algorithm which yielded image quality, thus developing the direct sampled I/Q (DSIQ) algorithm.

Solutions

(Left) Sonic Window developed by Fuller et al from the University of Virginia. Low-cost ultrasound system developed to perform a C-scan. (Top-Right) Siemens next generation portable machine. (Bottom-Right) Portable USB which connects to a smartphone (Prof. Richard U of Washington-St. Louis)



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