A Wireless Ultrasound Imaging System Utilizing Xampling and Frequency Domain Beamforming

Alon Eilam, Tanya Chernyakova, Samuel Londner, Armand Chocron, Maya Levy, Yuval Ben-Hur, Amir Burshtein, Michael Birk, Goel Samuel, Lior Weizman, Arcady Kempinski, Yonina C. Eldar

***Abstract*— In this work we utilize frequency domain beamforming and Xampling to demonstrate the feasibility of a wireless, high resolution medical ultrasound imaging system. Beamforming in the frequency domain allows bypassing the oversampling dictated by digital implementation of beamforming in time, while Xampling provides further rate reduction since only a portion of the signals' bandwidth is required for its high resolution reconstruction. Our results show that the quality of an image reconstructed at a remote site from low-rate data, transmitted over a wireless link, is similar to that of a state of the art commercial ultrasound imaging system.**

I. Introduction

In previous works [1] [2] we have shown that a considerable reduction both in sampling rate and processing time can be achieved in ultrasound imaging by applying the ideas of Xampling and frequency domain beamforming, leading to sub-Nyquist sampling rates of ultrasound signals. In this work we show how the reduced rate sampling can be exploited in the context of wireless ultrasound. In particular, we introduce a wireless ultrasound system in which the low rate raw data is transmitted to a remote site for processing. Part of our work was the design of a hardware component for efficient frequency domain sub-Nyquist sampling of ultrasound signals which reduces the rate prior to wireless transmission.

II. System Configuration

A top level scheme of the system configuration is shown in Figure 1. The signal received by the ultrasonic transducers is amplified, sampled and transformed to the frequency domain by a hardware component referred to as a "Xampler". The low rate data output of this component is transmitted over a wireless link to a remote computer, where scan lines are reconstructed by utilizing frequency domain beamforming, processed and displayed by an imaging module. The low data rate at the output of the Xampler is what enables the wireless transmission.

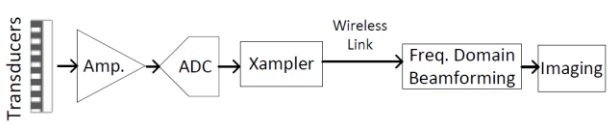

Figure 1: Wireless ultrasound system configuration.

In our demo, we utilized the processor of a commercial ultrasound system to perform the Xampler functionality. Low rate data was transmitted over a standard, 802.11n wireless link, to a computer where frequency domain beamforming was implemented in C language, utilizing Intel's Integrated Performance Primitives (IPP) library to enhance performance. The lab setup of the system is shown in Figure 2.

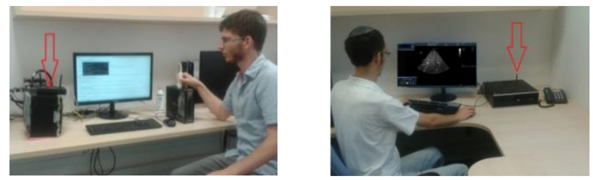

Figure 2: Wireless ultrasound system lab setup

A detailed description of the Xampler for ultrasound imaging can be found in [2]. A block diagram is shown in Figure 3. The design was implemented partly in Verilog and partly in VHDL. Simulations and synthesis were performed with VCS-MX and Design Compiler of Synopsys respectively. The physical design was done using Cadence's Encounter tool.

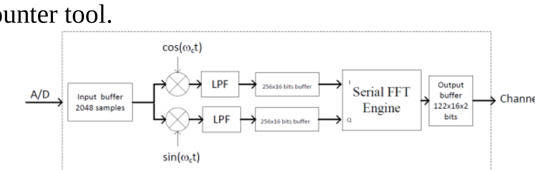

Figure 3: Xampler block diagram.

III. Results

A Phantom image reconstructed at the remote site from 122 complex valued samples per scan line, transmitted over a wireless link, has a quality similar to an image obtained by a state of the art commercial ultrasound imaging system with 2048 real-valued samples per scan line. Imaging results are shown in Figure 4. The saving of $244/2048 \approx 1/8$ in raw data rate has enabled the wireless operation.

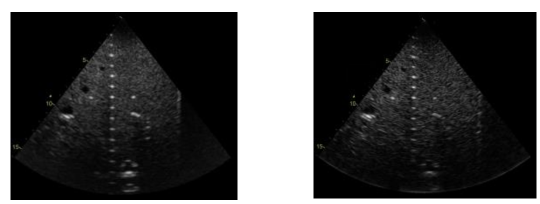

Figure 4: Ground Truth Phantom image (left) Vs. image reconstructed from low rate wireless data (right).

References

[1] A. Eilam, T. Chernyakova, Y. C. Eldar and A. Kempinski, "Sub-Nyquist Medical Ultrasound Imaging: En Route to Cloud Processing", GlobalSIP 2013.

[2] T. Chernyakova and Y. C. Eldar, "Fourier Domain Beamforming: The Path to Compressed Ultrasound Imaging", IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, vol. 61, no. 8, August 2014.