ABSTRACT

The challenge of producing high-resolution and high frame-rate ultrasound video streams while maintaining a high-quality image through signal processing algorithms requires a multi-individual channel processing. Whether these algorithms are implemented at the front-end (FE) or back-end (BE) modules, they drive up power consumption in the FE module. Power-demanding ADCs, and either a high-power FE CPU or a high-power intra-module communication are used to support the increase in data throughput. Radio telescope designers have faced similar challenges and have used multiplicative beamforming for the construction of thinned antenna arrays. Accordingly, through nonlinear multiplicative processing we approximate the beam profile of an evenly spaced ultrasonic array by multiplying and then filtering two sub-arrays of elements: one consisting of a short-filled array of elements and a centered-aligned thinned array. The reduction in the number of channels allows computationally intensive signal processing algorithms that would have been otherwise unfeasible in power restricted systems, e.g. in battery-operated ultrasound systems. The coherence factor (CF) is a Wiener post filter of the form: 

\[ \text{CF} = \frac{\sum_{\text{elements}} \text{signal}^2}{\sum_{\text{elements}} \text{signal}^2} \]

METHODS

Retrodictive Transmit Beamforming:
• Adjacent transmit beams are scattered as spherical waves off a point reflector
• After time corrections all spherical waves “emitted” from the “point reflector” are coherently added
• Reduces reverberation noise
• Partly compensates loss in contrast resolution

The following methods were used to compensate for the SNR degradation, these methods are far less computationally complex for a smaller number of elements:

RESULTS

Coherent Noise
This type of noise comes from “off-axis” reflectors in the image and presents the same challenge as in the full array

Incoherent Noise
This noise can be reduced either by increasing the number of channels or by coherently summing contribution from successive transmit events (RTB).

In battery operated systems, only one of the choices is practically feasible (either a full array with an ASIC hardware beam-former – no RTB or a significantly smaller number of individual channels available at the back-end).

Coherence Factor
The coherence factor (CF) is a Wiener post filter of the form: 

\[ \text{CF} = \frac{\sum_{\text{elements}} \text{signal}^2}{\sum_{\text{elements}} \text{signal}^2} \]

The coherence factor may be assessed either from the coherence between elements or from the coherence between successive overlapping transmits. In either mode the coherence factor can practically be calculated only in systems in which individual channel data is available at the back-end.

\[ CF_{\text{th}} = \max (7 \cdot h \cdot CF, 0) \]

– Calculated after the delay, but before the sum
– Multiply sum by CF in order to cancel incoherent noise
– Reduces side lobes and main lobe width
– “Weak reflectors” close to “strong reflectors” are “darkened”
– Practical in systems where individual channel data is available at the BE

Processing strong and weak signals separately. DAS stands for Delay and Sum.

– “Weak reflectors” close to “strong reflectors” no longer “darkened” due to CF multiplication

As seen in Figure 3, we are able to match the quality of the full array (with or without signal processing) using a quarter of the elements.