Acoustical imaging and transducer array optimization

Introduction to recent and current research within array signal processing at Centre for Imaging, Department of Informatics, University of Oslo, Norway.

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Outline

• Acoustical imaging
  – DAS beamforming
  – Pulse-echo imaging
  – Building ultrasound or sonar images
  – Beampatterns and image quality
  – Near-field vs Far-field, Pulsed vs CW and 1-way vs 2-way beampatterns

• Sparse array optimization
  – 1-way beampatterns
  – 2-way beampatterns
  – References
Delay-and-sum (DAS) beamformer

\[ z[n] = \sum_{m=0}^{M-1} w_m[n] x_m[n - \Delta_m] = w^H[n] X[n] \]
Pulse-echo imaging

Fig. 8. Focusing in transmission. By having suitable differences in transmission times between outer and central elements of an array, the transmitted pulses from all the elements can be made to arrive at the desired focus simultaneously.

Fig. 9. Focusing in reception. The wavefront from a target on the beam axis will arrive at the central elements of an array earlier than at the outer elements. For a particular receive focus position, the signals from all elements can be made to arrive at the same time at a summing amplifier by having an appropriate electronic delay in each channel.
Pulse-echo imaging ...

Fig. 12. Steering and focusing of the transmitted pulse in a phased array. The principle is similar to that used in a linear array, except that for all but straight ahead transmissions the focus is not situated on the principal axis of the probe.

Fig. 13. Steering and focusing in reception in phased array. As for a linear array, the receive focus is automatically advanced along the scan line, although for a phased array the scan line is generally at an angle to the principal axis of the probe.
Measurement Modes

- Transfer reflected „echos“ to images
Building an ultrasound image

Initial position of US beamline

Direction of sweep of US beamline
Image quality

• Some quantities can be derived from the array beampattern
  – mainlobe width – gives lateral resolution
  – sidelobe height – gives sidelobe artifacts
  – sidelobe energy – gives filling of cysts or shadows
BP and lateral resolution
BP and sidelobe artifacts
BP and filling of cysts
Near-field vs Far-field, pulsed vs CW and 1-way vs 2-way BPs

- Far-field BP and near-field BPs close to focus are very similar
- Max SL of CW BPs are usually worse than SL of pulsed BPs
- 2-way BPs are close to (1-way BP)$^2$

$\Rightarrow$ Choose to optimize one or the other
Research on sparse arrays optimization

- Optimized the 1-way CW beampattern in infinity
  - Can be calculated by using an FFT
  - We have usually used matrix multiplication and a much faster updating scheme.
- Optimizing the 2-way CW beampattern in infinity
  - Combined sparse periodic Tx and Rx arrays
- Optimized various 1D, 2D and curved arrays for ultrasound and sonar applications
Journal publications and book chapters related to sparse arrays

Ultrasound Imaging

Piezoceramic

Electrodes

Cause: Stress

Effect: Current

Effect: Strain

Cause: Electric field

Transduction

Acoustic Data

Display Pixels

Scan Conversion

From: K. Thomenius
a) Object
b) Separate objects
No interference
c) Speckle caused by interference