Real-Time Indication of Acoustic Window for Phased-array Transducers in Ultrasound Imaging

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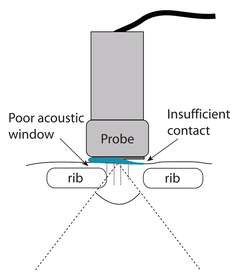
Background

Image quality in phased-array ultrasound imaging is gradually degraded when the acoustic contact or window is reduced, causing lateral smearing and a reduced penetration.

This reduction in *effective aperture* can occur due to a lack of acoustic contact with the skin, or due to obstructions such as a patient's ribs.

The degradation in image quality is often not obvious during imaging, especially for the less experienced user.



Aims

To investigate a method for estimating and visualizing the degree of acoustic contact or acoustic window of phased-array transducers in ultrasound imaging.

To present an algorithm for real-time estimation and display of the acoustic contact or window in phased-array ultrasound imaging.

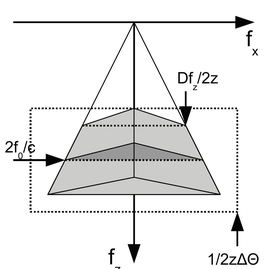
To show the potential of the method through *in vitro* and *in vivo* examples.

Theory

The *Fraunhofer approximation* infers that the two-way beam profile in the focal plane is bandlimited by the convolution of the aperture apodization functions on transmit and receive:

$$P_{TR}(f_x, f_z) = A_T(-2zf_x/f_z) *_{f_x} A_R(-2zf_x/f_z)$$

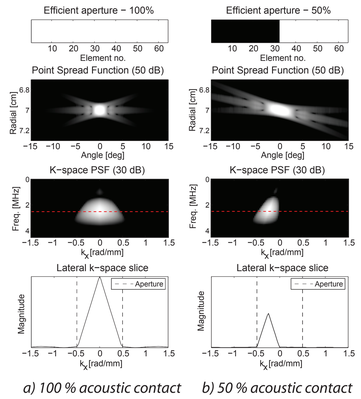
For equal rectangular apodization this effectively bandlimits the lateral signal spectrum towards a triangular shaped lateral spectrum



Method

By estimating and visualizing the lateral spectrum at center frequency in the focal region, a map of the acoustic contact is obtained.

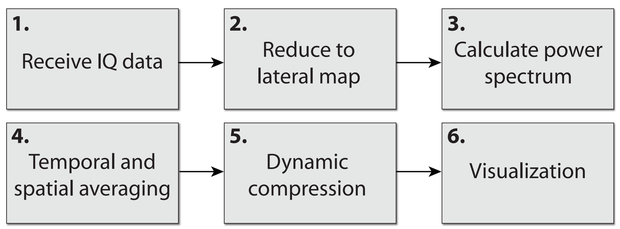
Example: Field II simulations of point spread functions and corresponding k-space representations for a) 100% and b) 50% apertures.



a) 100 % acoustic contact *b) 50 % acoustic contact*

The Real-Time Algorithm

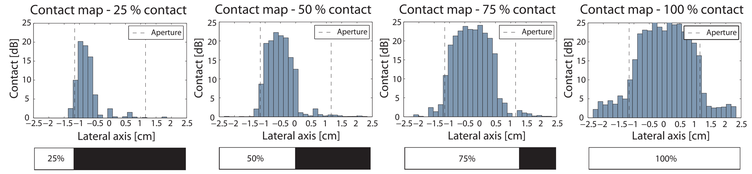
An algorithm for providing real-time feedback of acoustic contact along phased-array transducers has been developed:



1. Processing initiates after a complete frame of IQ-data is ready
   - A spatial data window around focus point is processed
2. Compute Fourier transform of radial window in focus region
   - Can at demodulation frequency be done by summing IQ-samples
3. Calculate lateral power spectrum
   - Discrete Fourier transform of the radial Fourier transformed data
4. Perform temporal and spatial averaging
   - Smooth random fluctuations
5. Logarithmic compression to reduce dynamic range
   - Also, the two-way aperture gets closer to a rectangular shape
6. Visualize spectrum as a histogram on screen during acqusition
   - Flip so that the active aperture corresponds to signal spectrum

Results - *In Vitro*

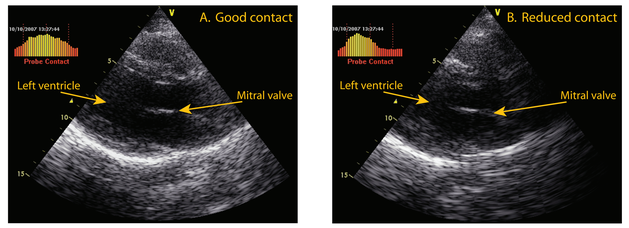
Image data from a tissue-mimicking phantom was obtained while masking the aperture gradually in a controlled manner.



The figure shows the relation between the lateral power spectrum and 25%, 50%, 75% and 100% effective apertures. The total aperture is indicated in dashed lines.

Results - *In Vivo*

Parasternal views of a healthy heart with a) good acoustic contact and b) a reduced acoustic contact due to the human sternum.



The histogram in the upper left corner of b) indicate that the effective aperture has been reduced, and that a more suitable probe position should be sought.

Conclusions

A map of the acoustic contact along phased-array transducers can be obtained directly by spectrum analysis of the received signal.

The bandwidth of the lateral power spectrum closely corresponded to the width of the effective aperture in phantom recordings.

The method further correctly indicated a reduced contact due to the human sternum in real-time cardiac imaging.

We believe the method may help ensure good quality images by aiding the examiner towards finding the optimal probe position.