INFONET Seminar Application Group
Two-dimensional ultrasound detection with unfocused frequency-randomized signals

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Background

General US imaging use bandwidth and frequency to determine image resolution

- High frequency –> narrower beam –> better resolution
- High frequency –> higher beam attenuation –> lack of deep imaging

Therefor present US technique turned to increasingly grows of frequency range. Current frequencies for medical imaging is 2-20 MHZ

Introduction

Technique should be turned from focused to unfocused to escape frequency grows

- For each element randomly selected individual frequencies, resulting signal is includes large bandwidth.
- Single point is used to record time history
- Reconstruction of ROI is performed from analysis of acquired signal from single element
- Process is repeated with different frequency patterns to increase performance of reconstruction
- Signal analysis consists of a Fourier-based approach

Theory

- First emitter approximated as an array of simple sources radiating on unique frequency.
- Another approximation that we can describe pressure at any point in a homogeneous space given by

$$p_w(r,t) = -ic_0 k_0 \rho_0 S_w g_w(r_{s_w} | r_0), \quad (1)$$

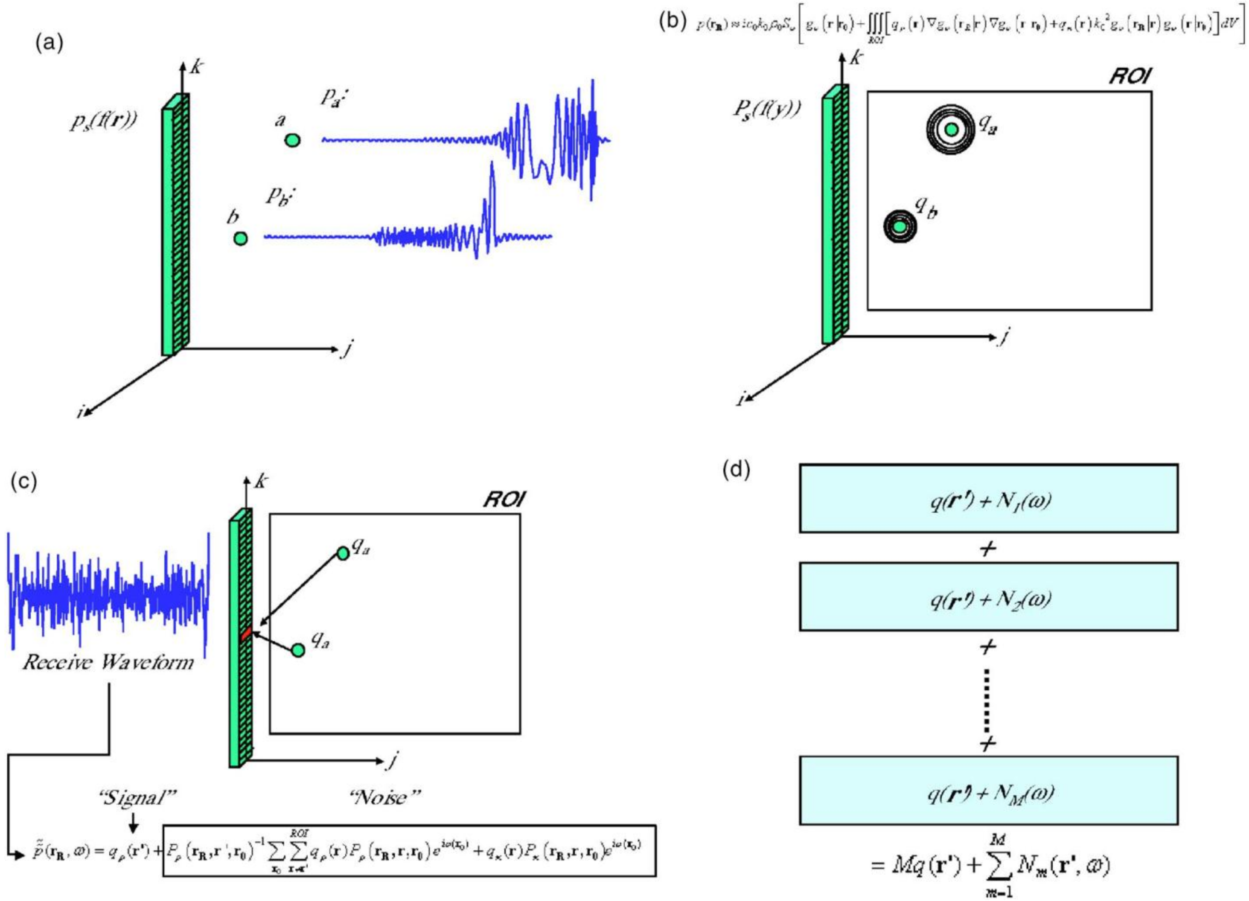
- Acoustic pressure for wave encounters a varying density may be described

$$\rho \nabla \left(\frac{1}{\rho} \nabla p_w\right) + \frac{w^2}{c^2} p_w = 0$$

- To improve SNR process with new random frequency distribution can be repeated M-times. With M signal strength will increase linearly while noise N will further randomized

$$\tilde{\tilde{p}}_M(r', w) = Mq(r') + \sum_{m=1}^{M} N_m(r', w)$$

Theory



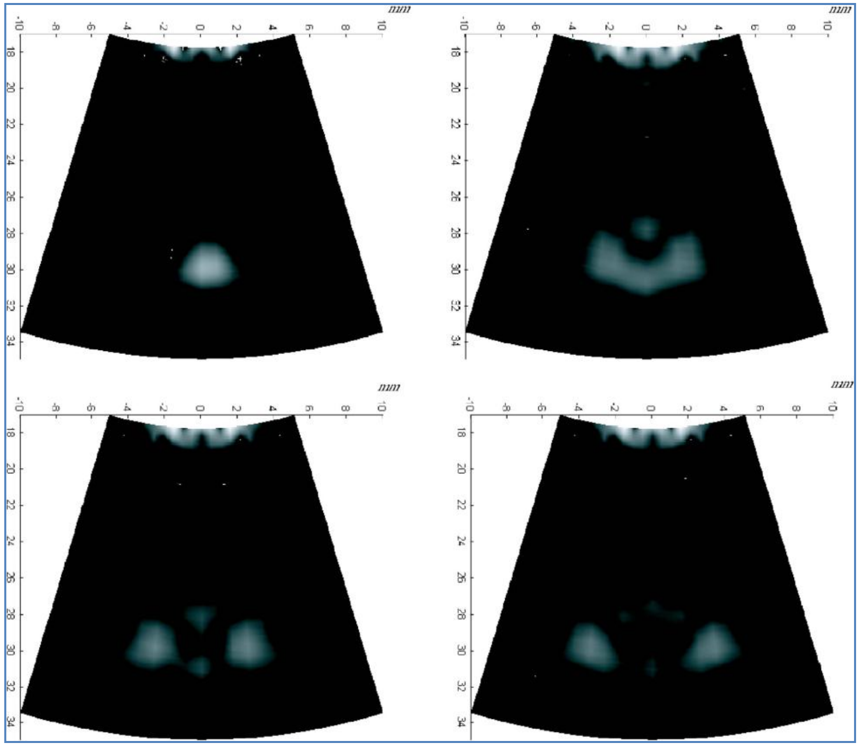
$$p(r_R, w) = q_p(r') + Pp(r_R, r', r_0)^{-1} \sum\nolimits_{x_0} \sum\nolimits_{x \to x^{-1}}^{ROI} q_p(r) P_\rho(r_R, r, r_0) e^{iw(x_0)} + q_k(r) P_x(r_R, r, r_0) e^{iw(x_0)}$$

'Signal' 'Noise'

Simulation model

- An operating frequency range between 0.1 – 1.25 MHz
- Simulated array is 40 mm in length and 10 mm in width
- Array segmented in to 202 linear sources with no kerf
- A linear distribution of 202 frequencies between 0.1-1.25 MHz with a frequency resolution of 5.7 kHz
- Each time randomly only one frequency assigned to element
- Also randomly single element selected to record signal
- Scattering field is placed within ROI
- Scattering signal at the receiver is discrete approximation of Eq. (10)

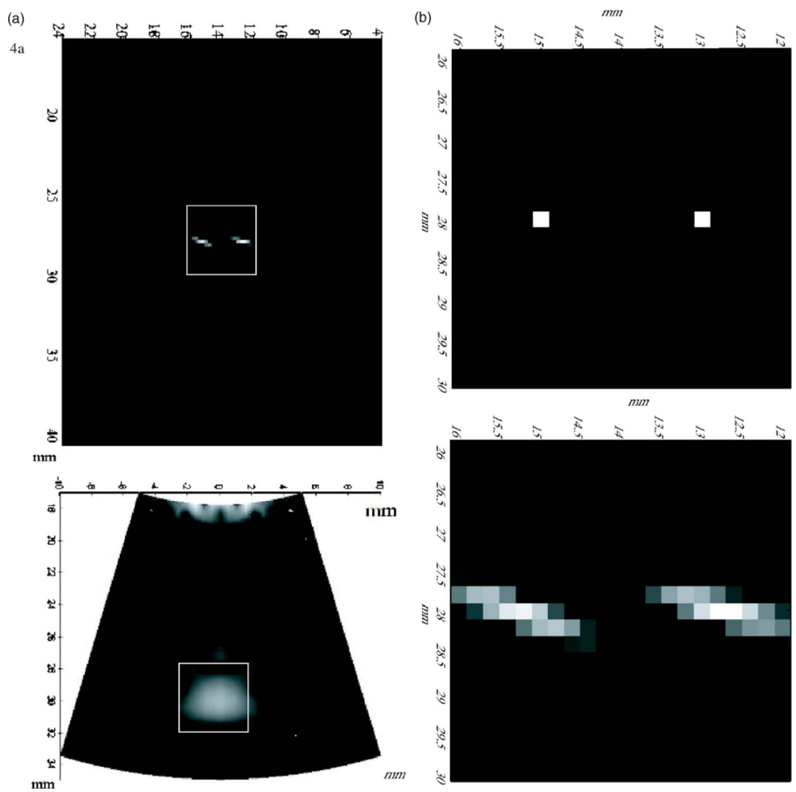
Results



Simulated B-scan images f_c=0.67MHz. Two wires with (diam=0.2mm) separated by a) 2mm, b) 4mm, c) 6mm, d) 8mm.

- Simulated B-scan via k-space projection algorithm using 200 ns resolution. Simulation was repeated for each of 21 scan directions
- ROI 40x40 mm
- Two objects with diameter 0.2mm was given sound speed of 3500 m/s
- Only on 8mm separation objects are clearly separated

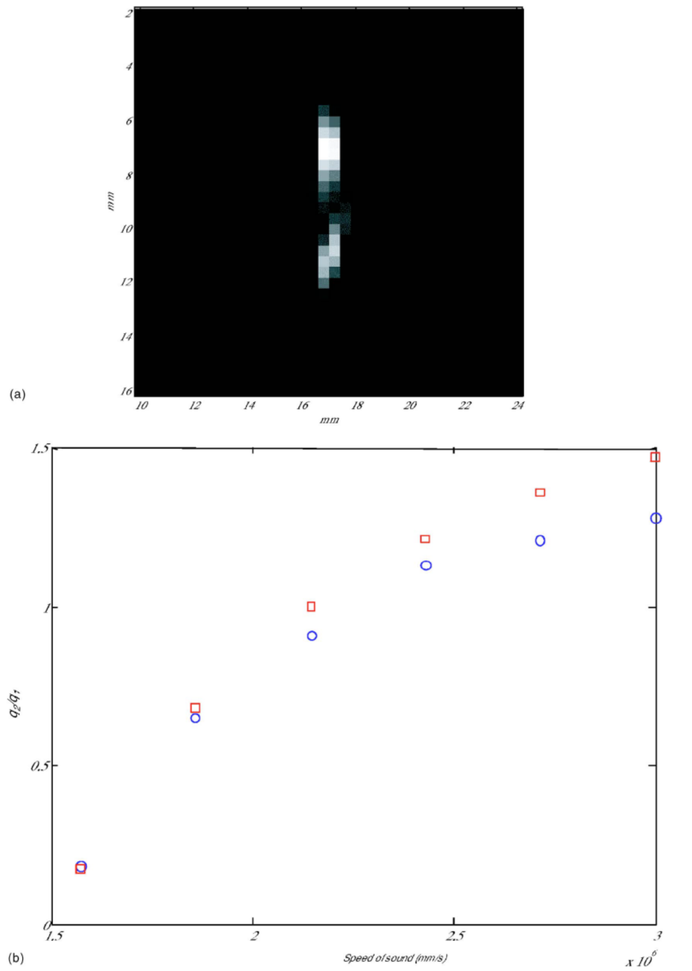
Results



Comparison a) random frequencies (top) B-scan (bottom) b) more magnified view

- Comparing with B-scan method with randomized frequencies has better performance.
- Two objects can be imaged separately with 1.35 mm distance. Vertical 0.5mm
- Simulation was repeated with 15 randomized signals

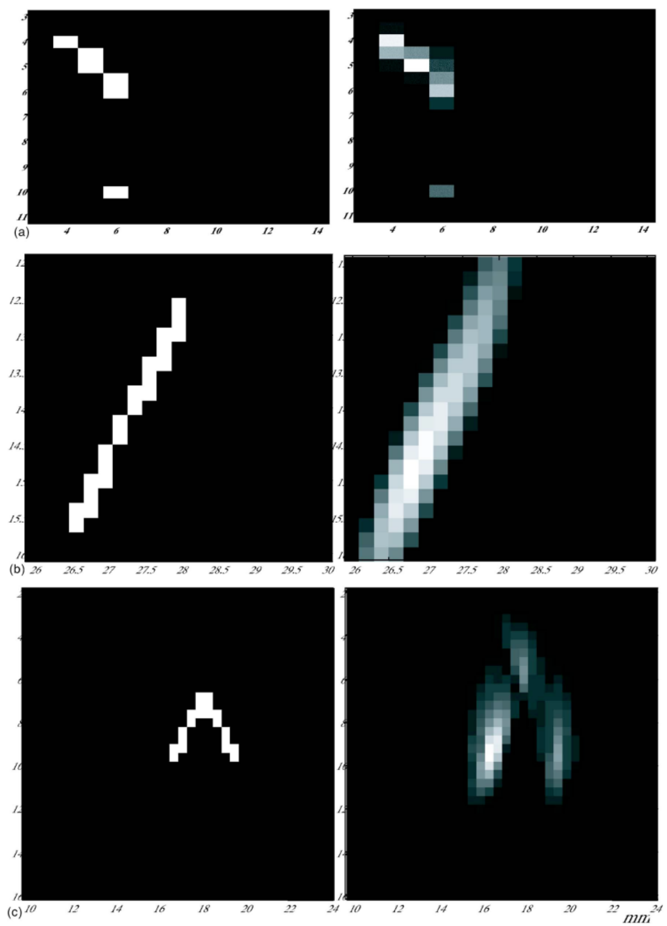
Results



Two reconstructed objects in the ROI with scattering strengths q1= 0.51 and q2=0.62 (top) Scattering ratio of q2/q1 is plotted as fn of frequencies (squares). Reconstructed values (cycles)

- Object placed 4 mm apart and 17 mm distance from transducer
- The plot shows trend of increased distortion with higher sound speed. Corresponding error ranged from 4.3% at 1857 m/s to 13% at 3000 m/s

Results



Simulation with multiple scatters (left column) and their reconstructions (right column). Distance from transducer a) 3-14 mm b) 10-24 mm c) 26-30 mm

- Object placed 4 mm apart and 17 mm distance from transducer
- The plot shows trend of increased distortion with higher sound speed. Corresponding error ranged from 4.3% at 1857 m/s to 13% at 3000 m/s
- Three scatterers placed diagonally in 8x8 ROI and additional object 4 mm apart
- Object as an inverted “V” was situated 18 mm from the ultrasound source.

Conclusion

- Large variation in image field makes it possible to localize the position of targets
- In numeric investigation objects where better defined and more spatially localized
- Small objects, which can be hard to detect, and even hard to localize using present methods may be both detected and localized.
- Only single receive channel was used.

Discussion

Thank you