# 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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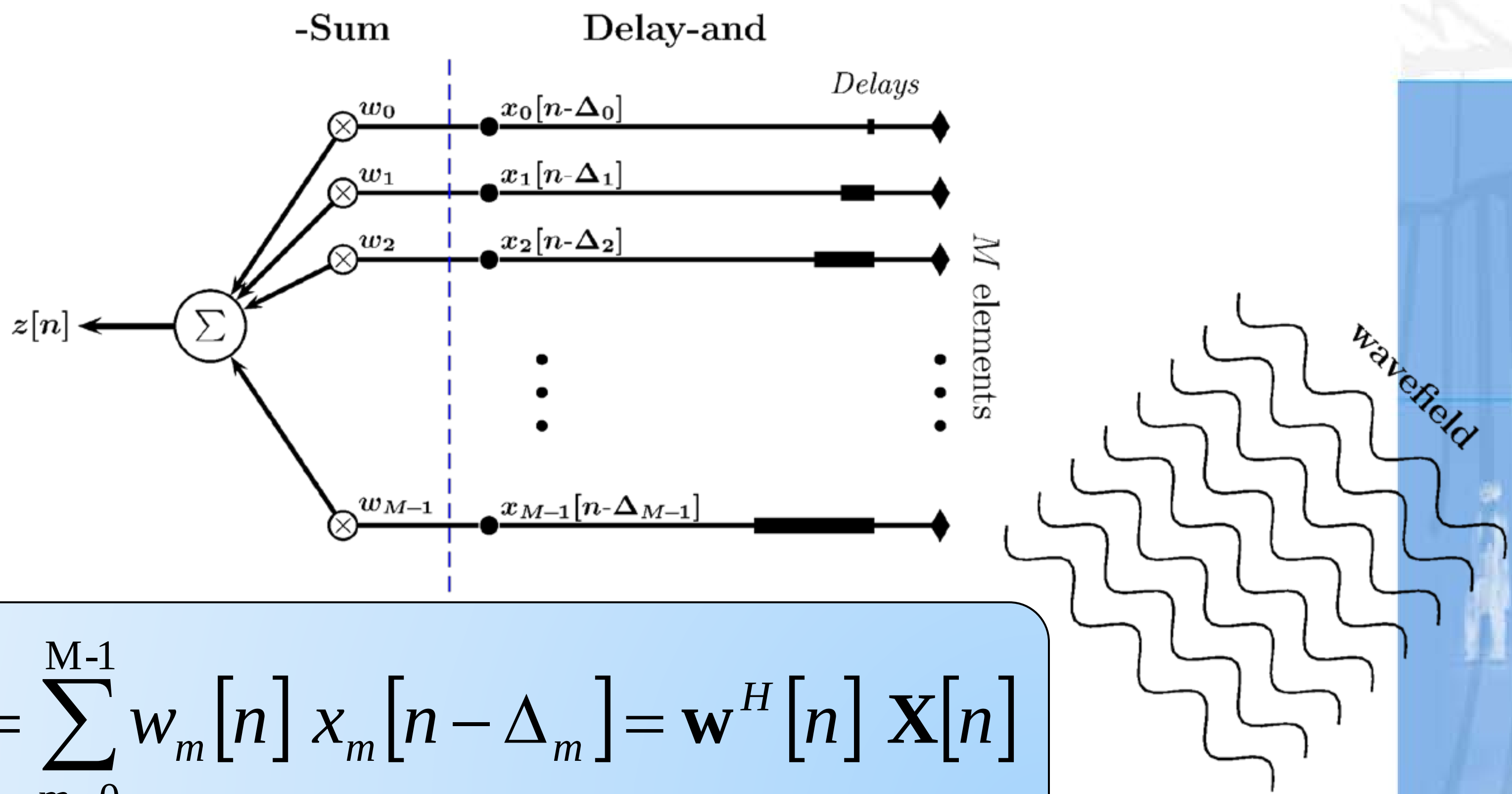
# Outline

- Acoustical imaging
  - DAS beamforming
  - Pulse-echo imaging
  - Building ultrasound or sonar images
  - Beampatterns and image quallty
  - 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




$$z[n] = \sum_{m=0}^{M-1} w_m[n]\, x_m[n - \Delta_m] = \mathbf{w}^H[n]\, \mathbf{X}[n]$$

# Pulse-echo imaging

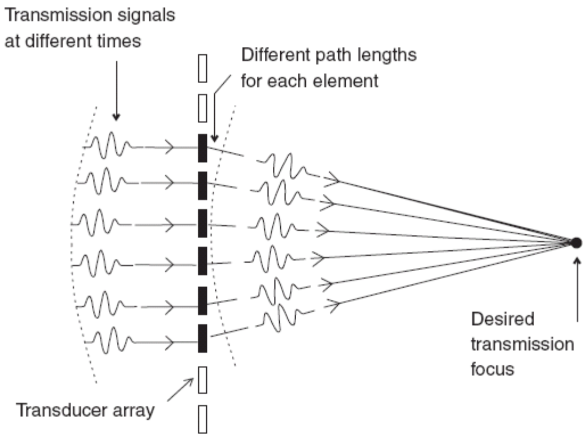



Fig. 8. Focusing in transmission. By having suitable differences in transmission times between outer and central elements of an array, the transmitted pulses from all the elements can be made to arrive at the desired focus simultaneously.

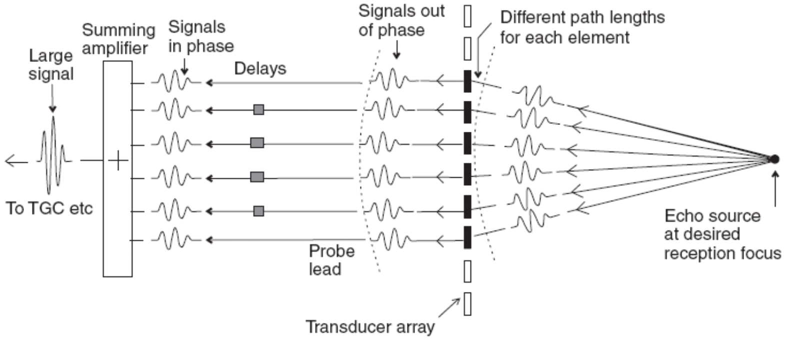



Fig. 9. Focusing in reception. The wavefront from a target on the beam axis will arrive at the central elements of an array earlier than at the outer elements. For a particular receive focus position, the signals from all elements can be made to arrive at the same time at a summing amplifier by having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

# Pulse-echo imaging …

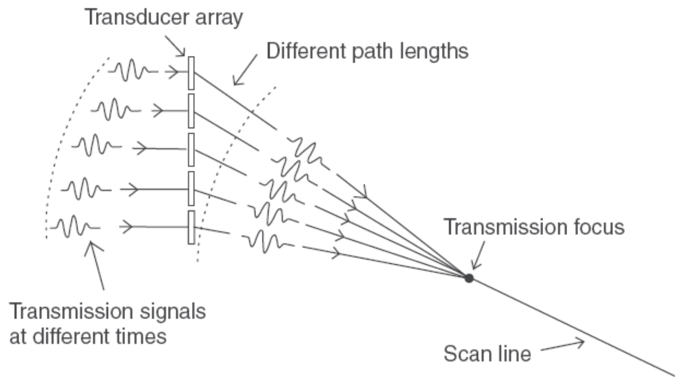



Fig. 12. Steering and focusing of the transmitted pulse in a phased array. The principle is similar to that used in a linear array, except that for all but straight ahead transmissions the focus is not situated on the principal axis of the probe.

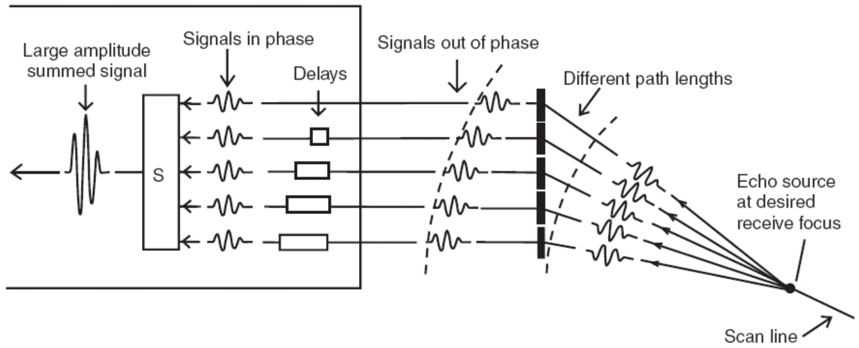



Fig. 13. Steering and focusing in reception in phased array. As for a linear array, the receive focus is automatically advanced along the scan line, although for a phased array the scan line is generally at an angle to the principal axis of the probe.

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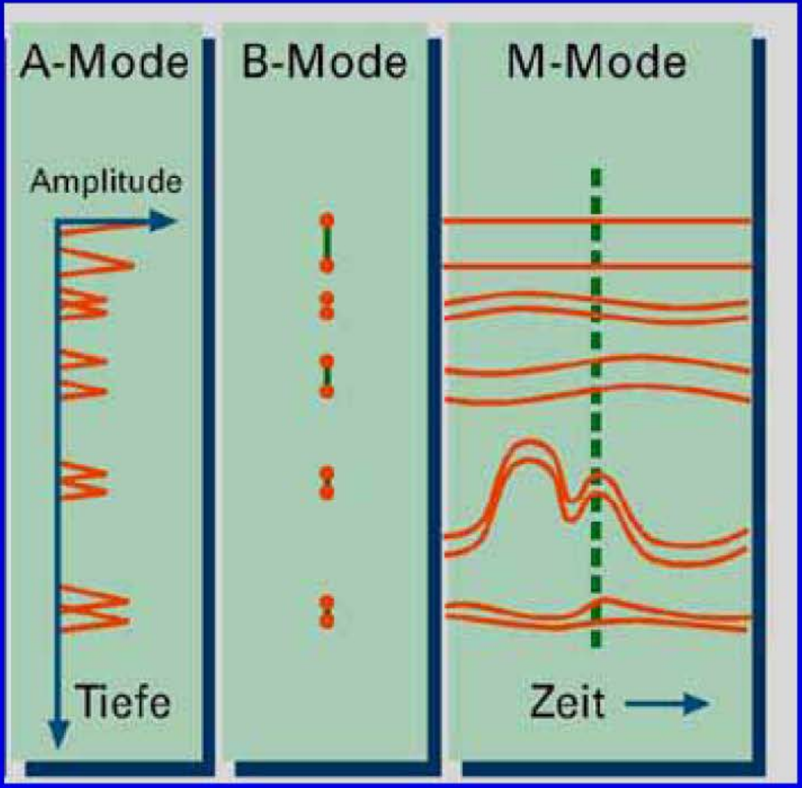
# Measurement Modes

- Transfer reflected „echos“ to images



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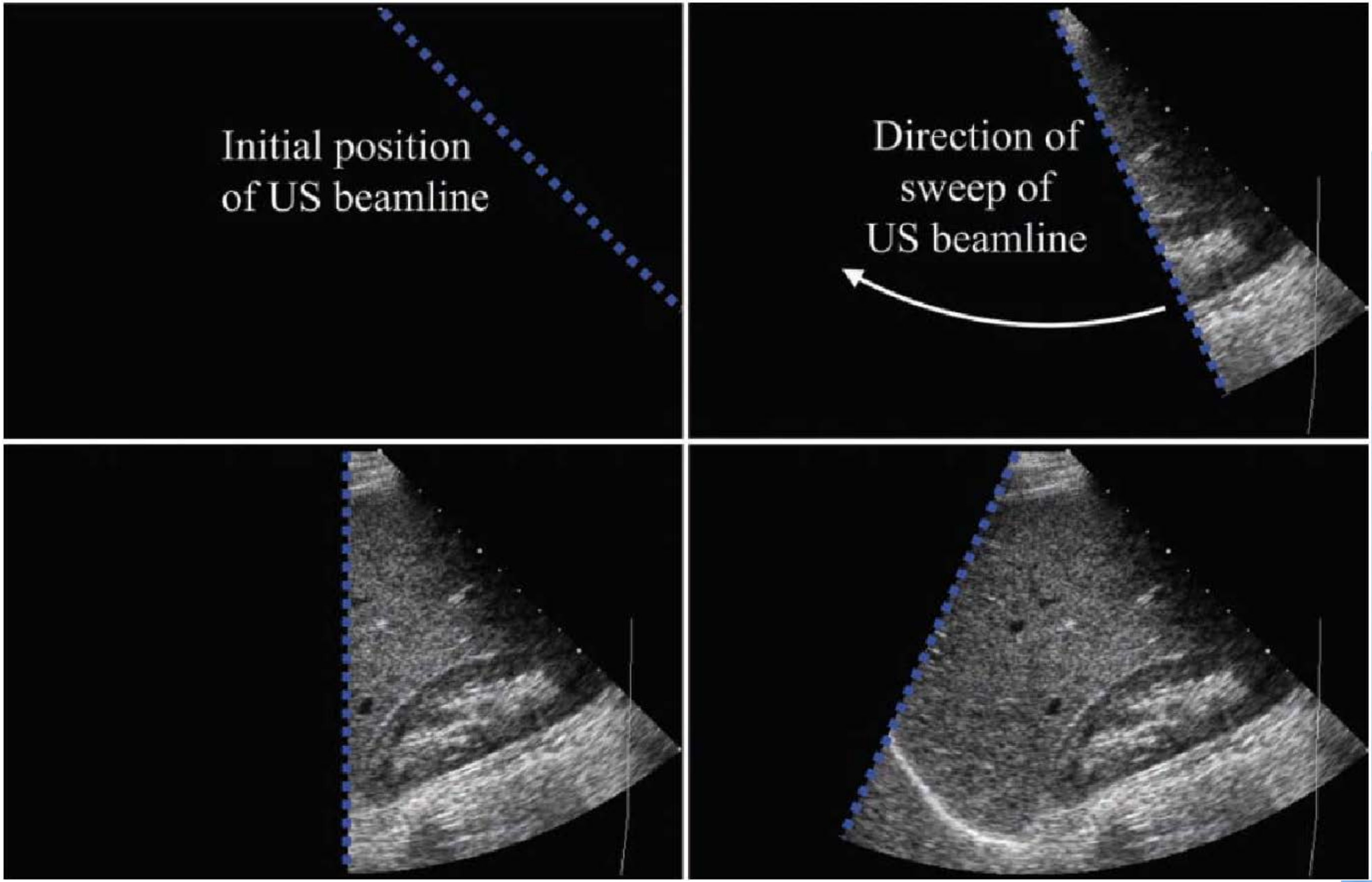
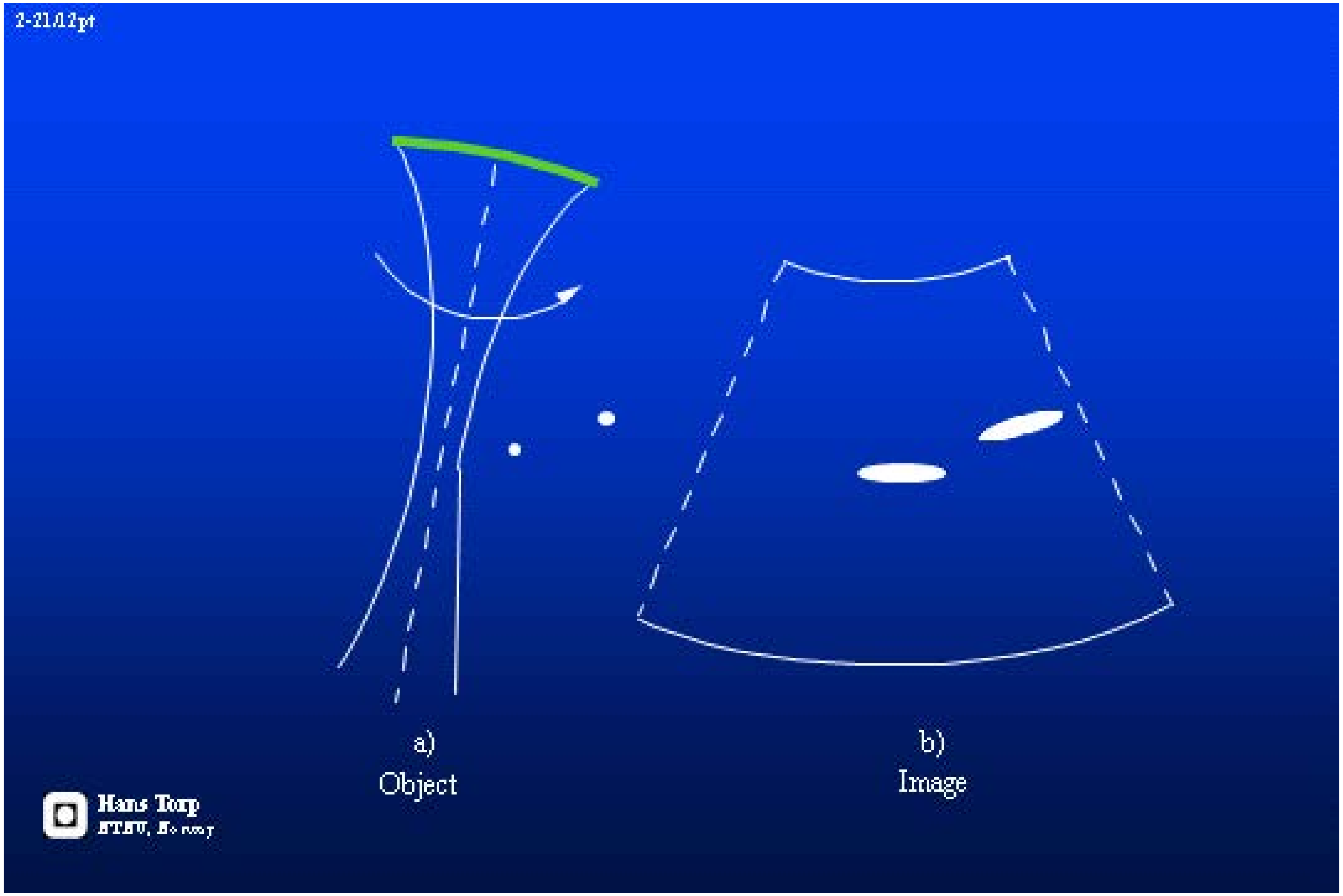
# Building an ultrasound image



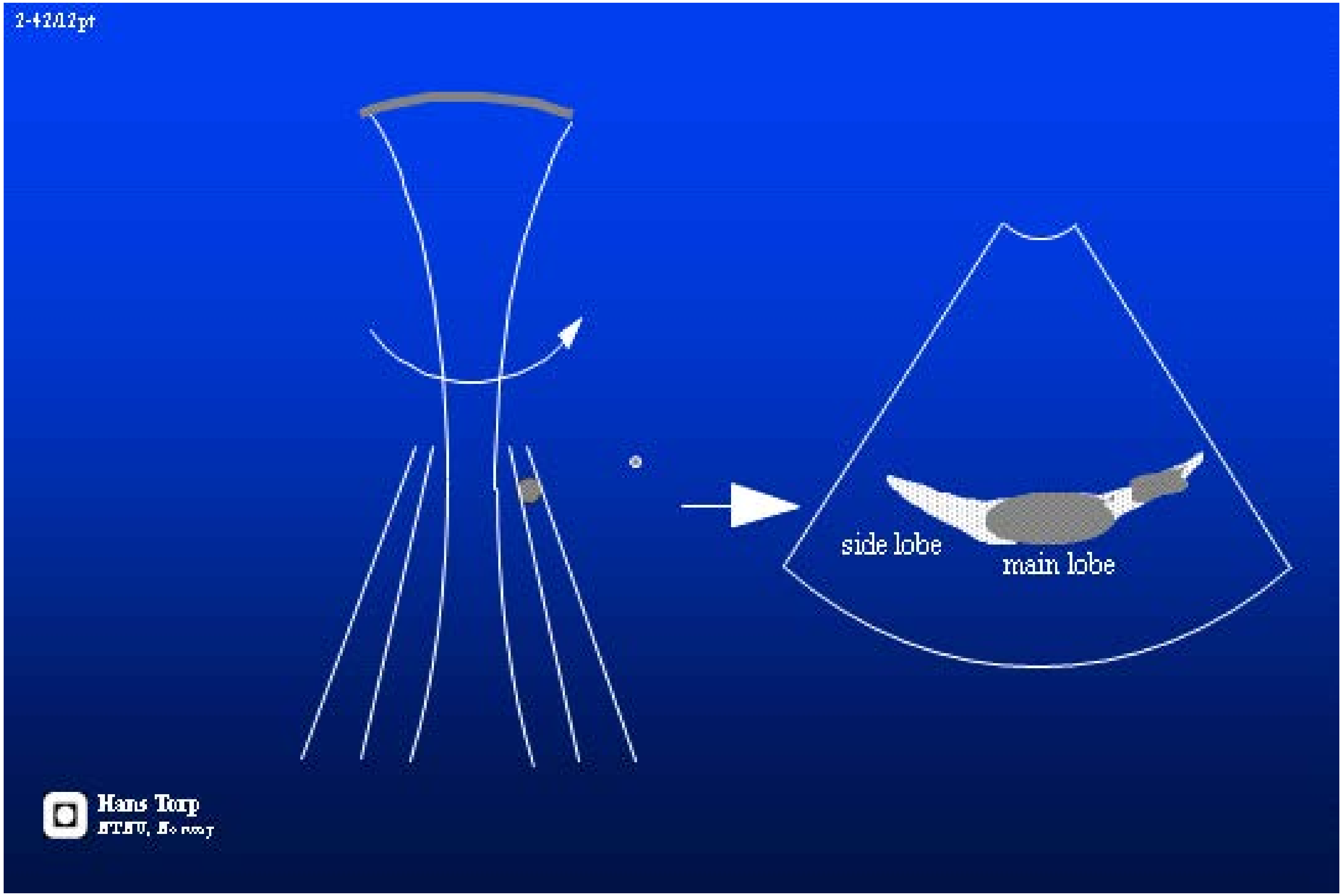
# Image quallity

- Some quantites can be derived from the array beampattern
  - mainlobe width – gives lateral resolution
  - sidelobe heigth – gives sidelobe artifacts
  - sidelobe energy – gives filling of cysts or shadows

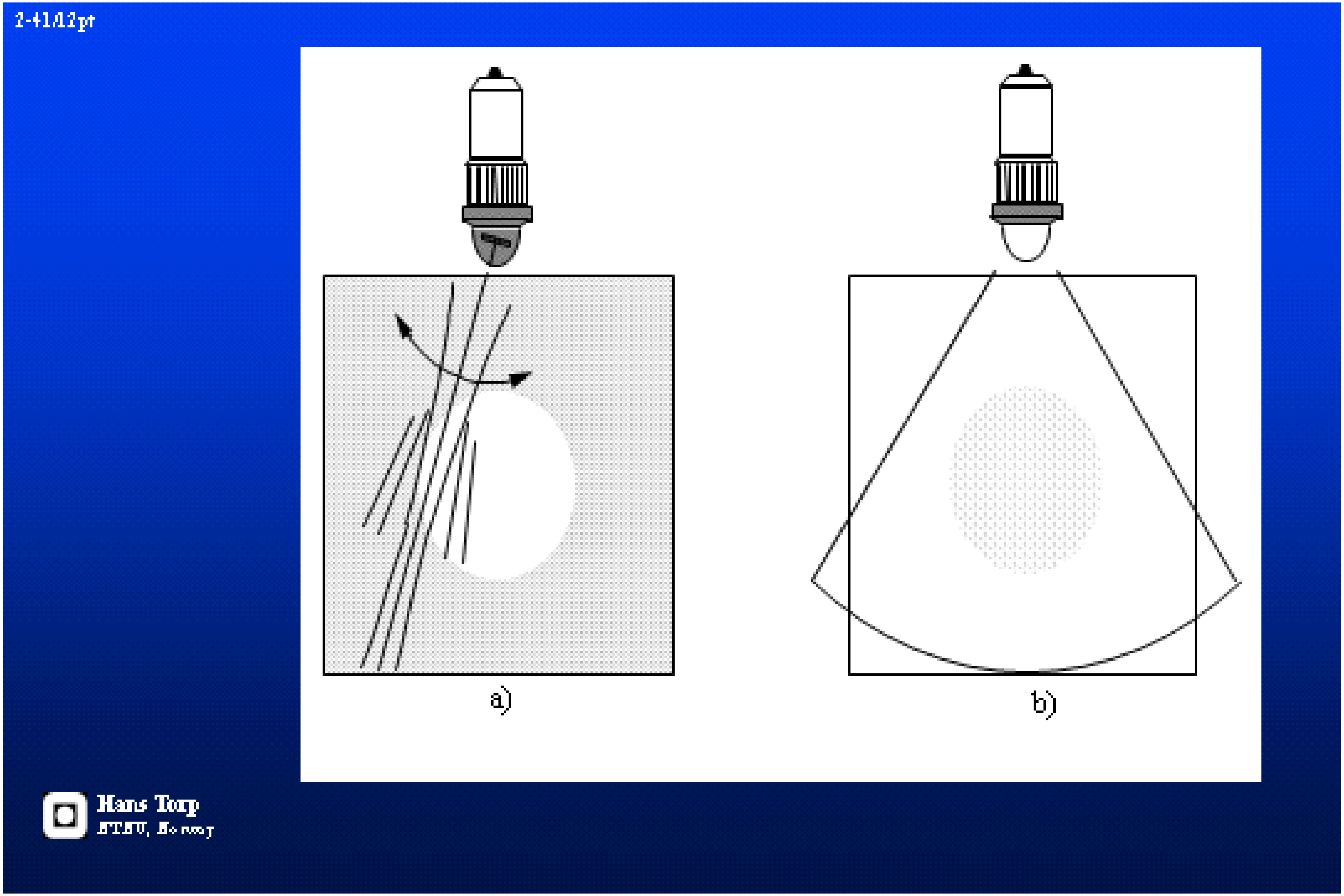
# BP and lateral resolution



# BP and sidelobe artifacts

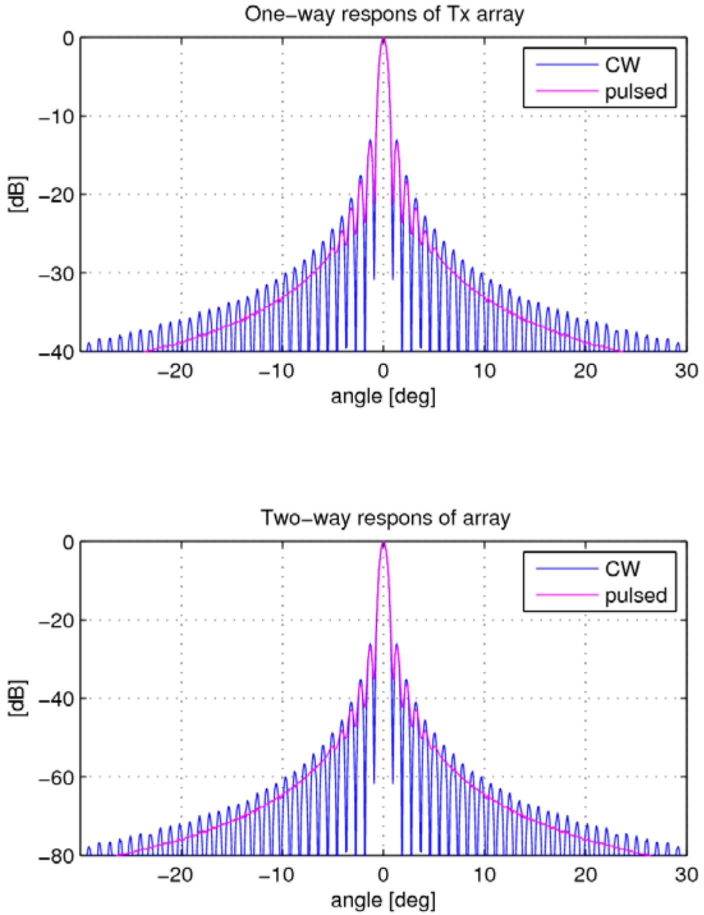


# BP and filling of cysts



# 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)$^2$
- ==> 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

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# Journal publications and book chapters related to sparse arrays


- J. E. Kirkebø and A. Austeng, "Sparse Cylindrical Sonar Arrays," *IEEE J. Oceanic Eng.*, vol. 33, no. 2, pp. 224-231, Apr. 2008.
- J. E. Kirkebø and A. Austeng, "Improved Beamforming Using Curved Sparse 2D Arrays in Ultrasound", *Ultrasonics*, vol. 46, no. 2, pp. 119-128, May 2007.
- A. Austeng and S. Holm, "Sparse 2D Arrays for 3D Phased Array Imaging - Design Methods," *IEEE Trans. Ultrasonics, Ferroelectrics and Frequency Control*, Aug. 2002, pp. 1073-1086.
- A. Austeng and S. Holm, "Sparse 2D Arrays for 3D Phased Array Imaging - Experimental Validation," *IEEE Trans. Ultrasonics, Ferroelectrics and Frequency Control*, Aug. 2002, pp. 1087-1093.
- P. Weber, A. Austeng, S. Holm, and N. Aakvaag, "1D and 2D sparse array optimization," *Instrumentation Science & Technology*, vol. 27, no. 4, 1999, pp. 235-246.
- S. Holm, A. Austeng, K. Iranpour and J. F. Hopperstad, "Sparse sampling in array processing," chapter 19 in "Sampling theory and practice" (F. Marvasti Ed.), Plenum, New York, 2001.
- S. Holm, B. Elgetun, G. Dahl, "Properties of the beampattern of weight- and layout-optimized sparse arrays," IEEE Trans. Ultrasonics, Ferroelectrics and Frequency Control, vol. 44, no. 5, pp. 983-991, Sept. 1997.

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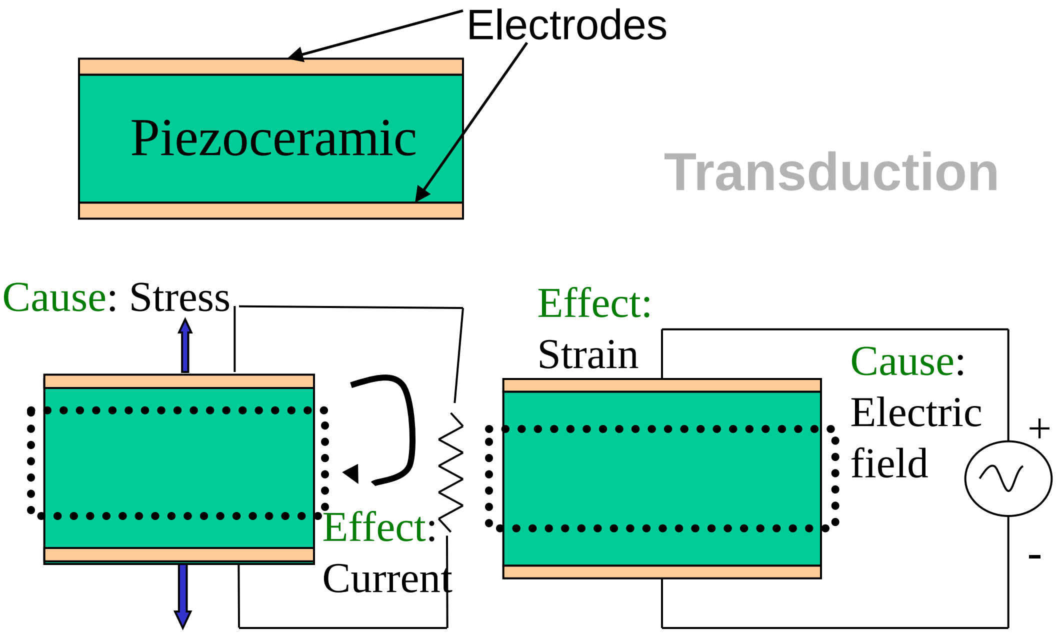
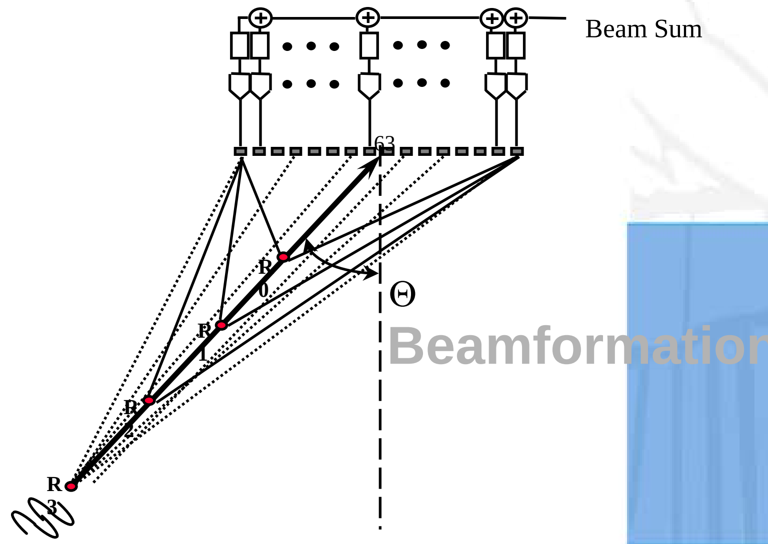
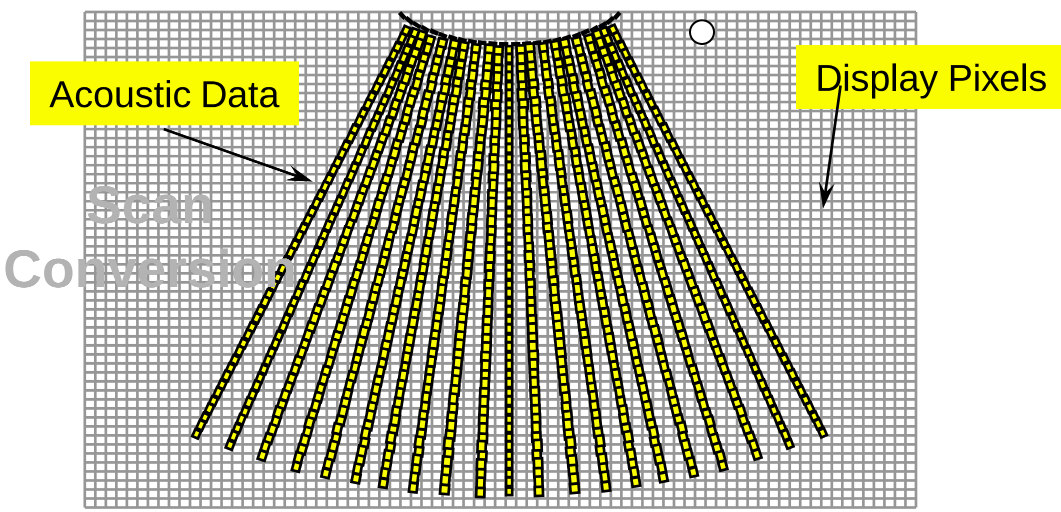
# Ultrasound Imaging

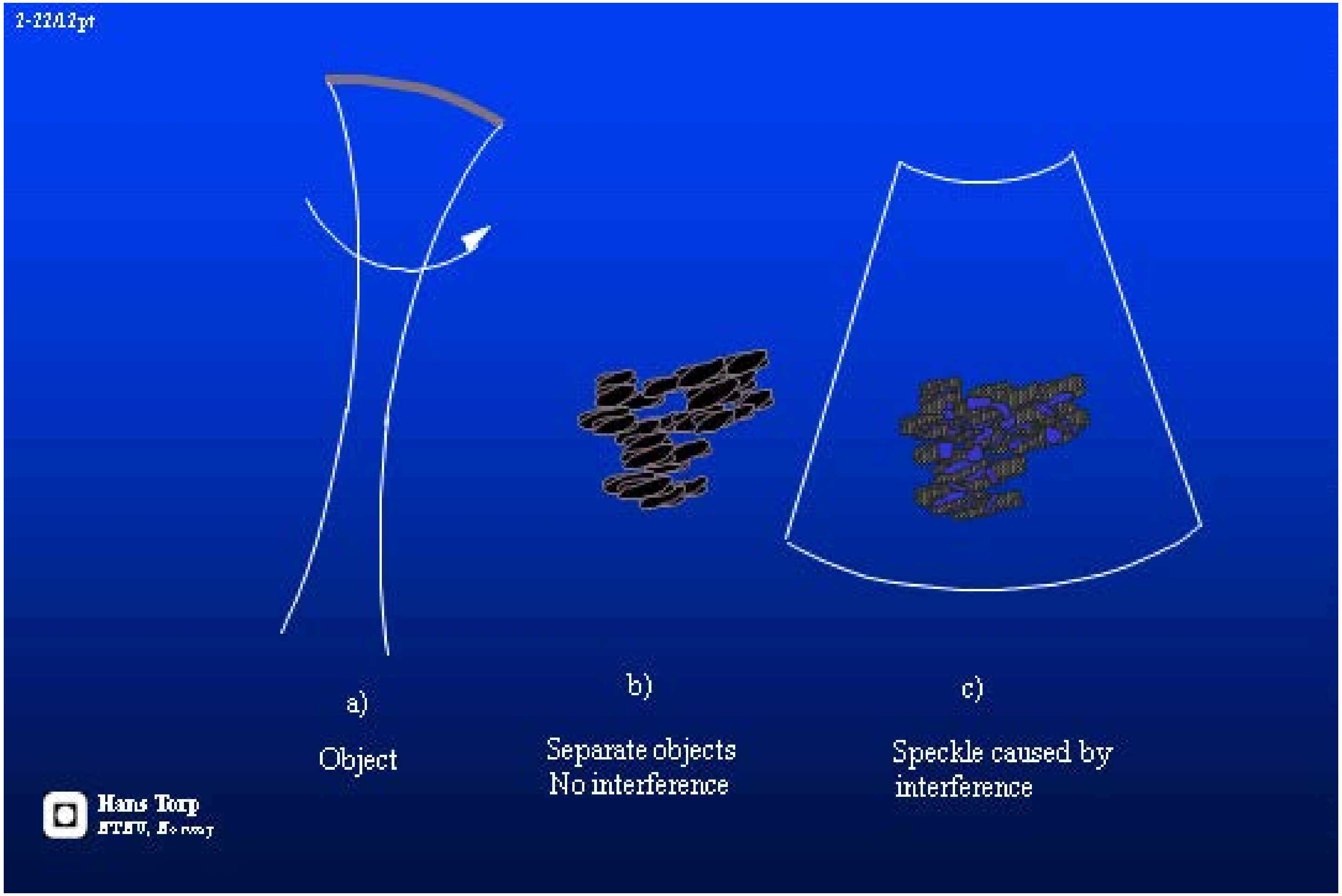




From> K. Thomenius


a)
Object
b)
Separate objects
No interference
c)
Speckle caused by
interference
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