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MEDT8002 Ultrasound Imaging

Ultrasound Probes

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ISB

Outline

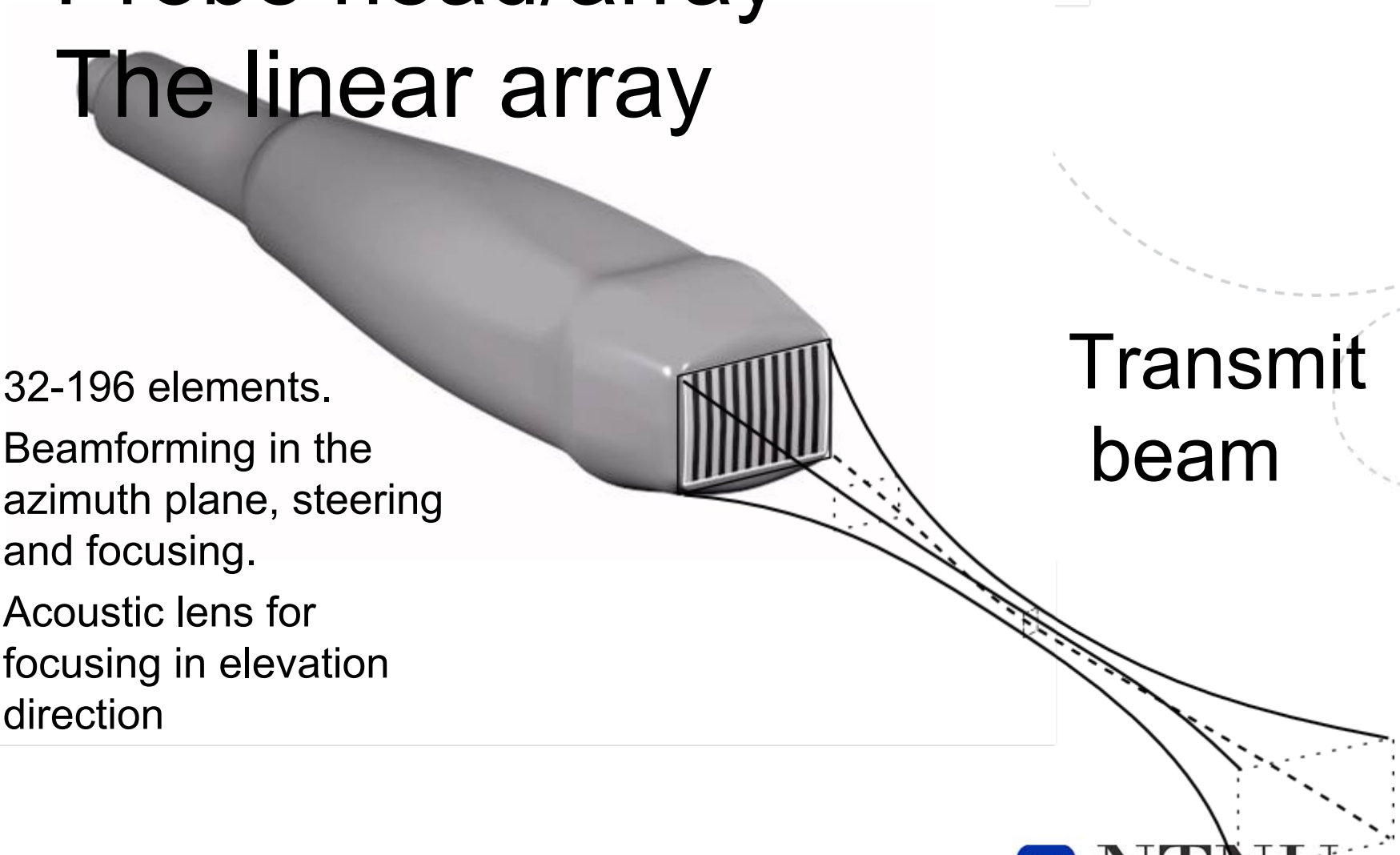
- Overview of ultrasound probes
  - Definition/what is the probe
  - Geometry/ Organs
  - Transducer mechanism
- Quality factors of ultrasound probes
  - Frequency/bandwidth
  - Resolution
  - Sensitivity
- Different trends for ultrasound probes
  - Electronics in the probe
  - 3D imaging
  - New imaging applications

Definition of probe assembly

Probe head/array
The linear array

- 32-196 elements.
- Beamforming in the azimuth plane, steering and focusing.
- Acoustic lens for focusing in elevation direction

Probe head/array
The linear array



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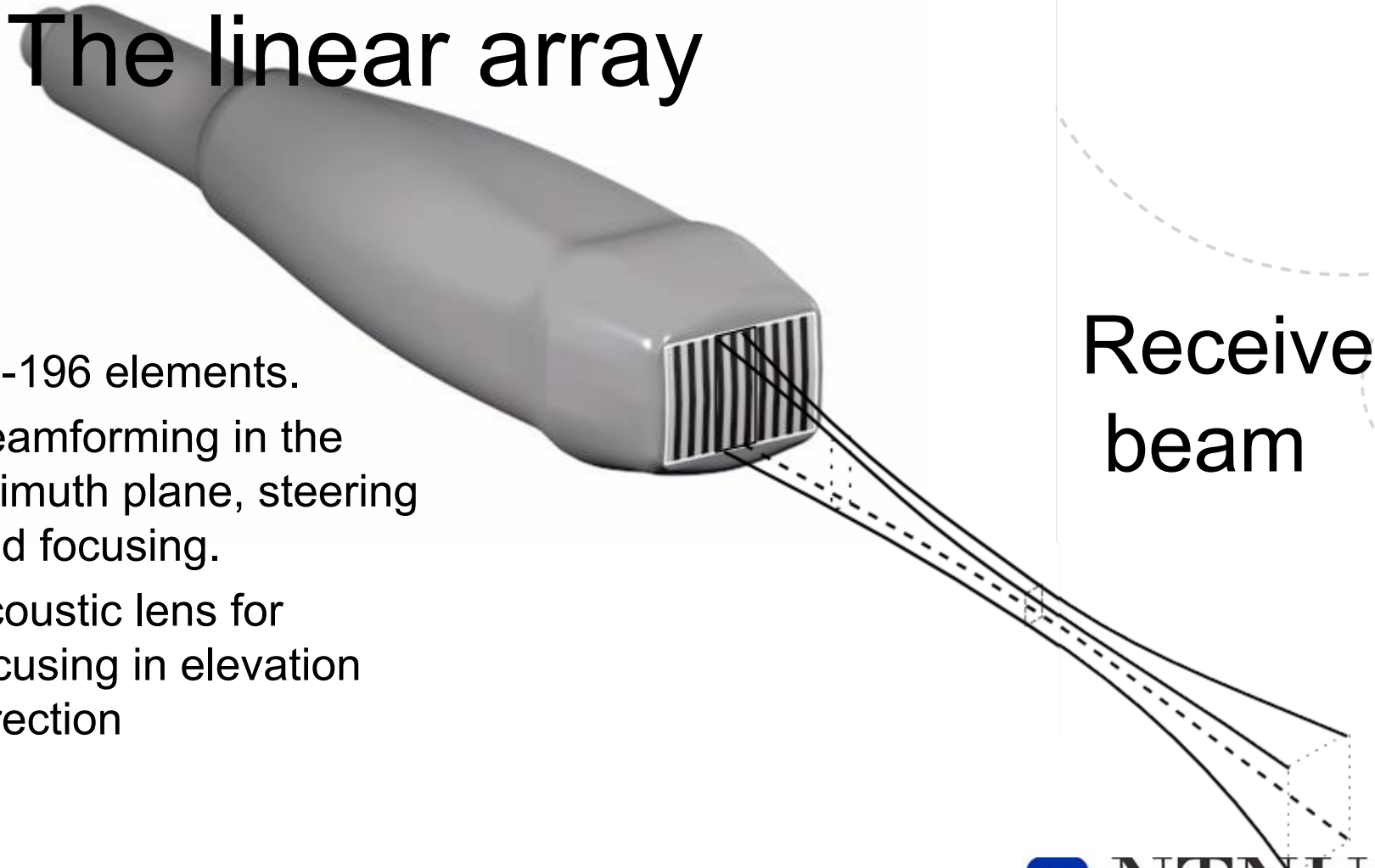
Probe head/array
The linear array



- 32-196 elements.
- Beamforming in the azimuth plane, steering and focusing.
- Acoustic lens for focusing in elevation direction

Receive beam

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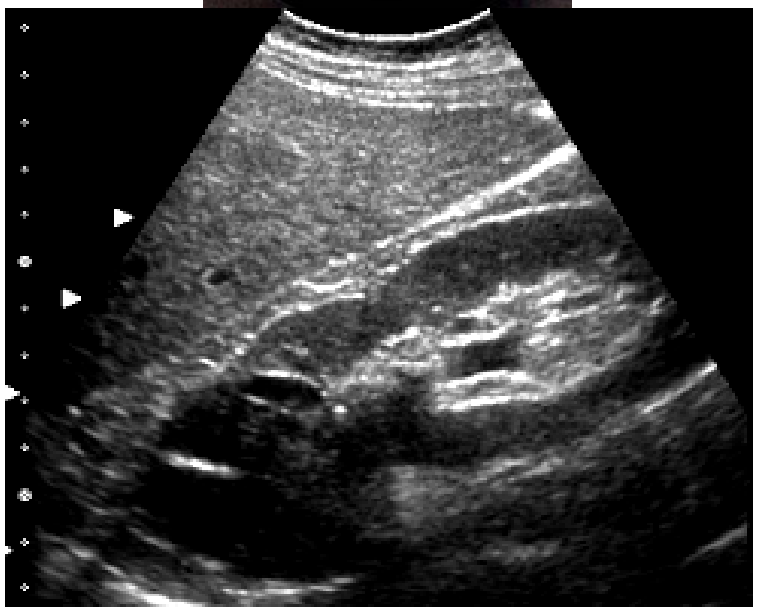
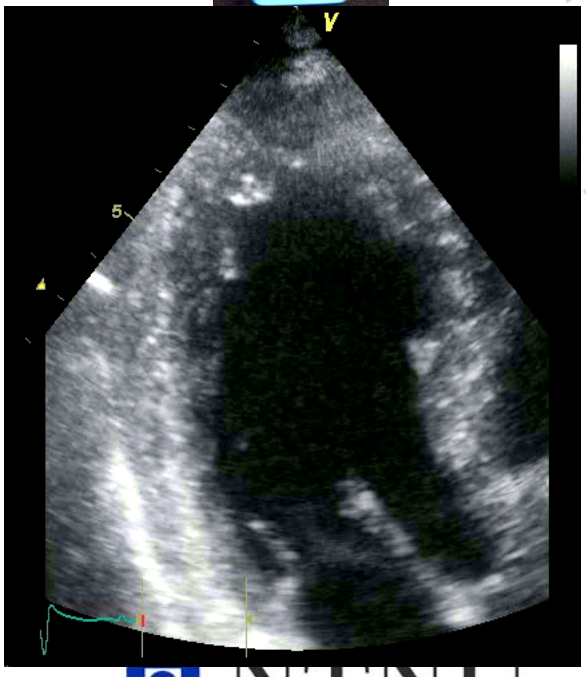
Hans Torp
NTNU, Norwa

rasou bes





Linear array
High resolution
Limited width

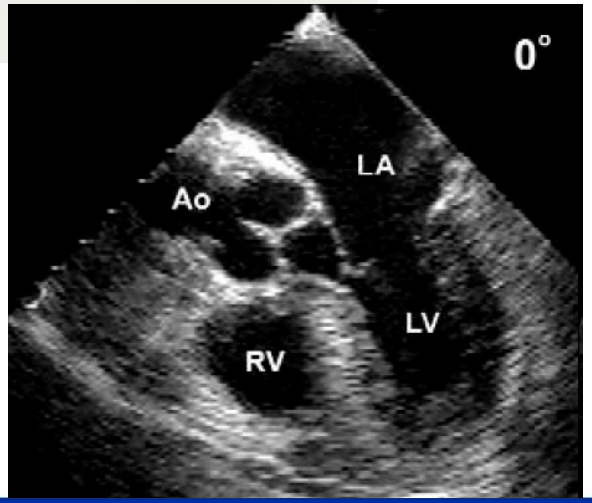
Curve-linear array
Large image width
Large near field

Phased array
Small footprint
90 deg. sector format

Ultrasound Probes part 2

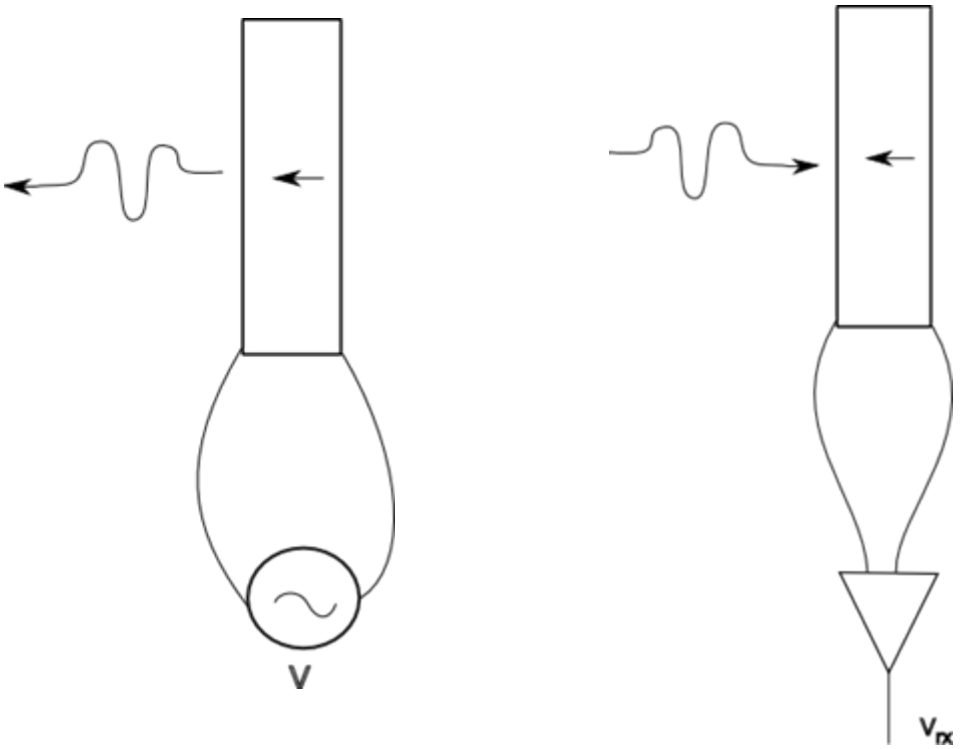
Endo cavity
Tightly Curved array
Large image width
Lower lateral resolution

Endo cavity
Small phased array
High resolution
No body wall

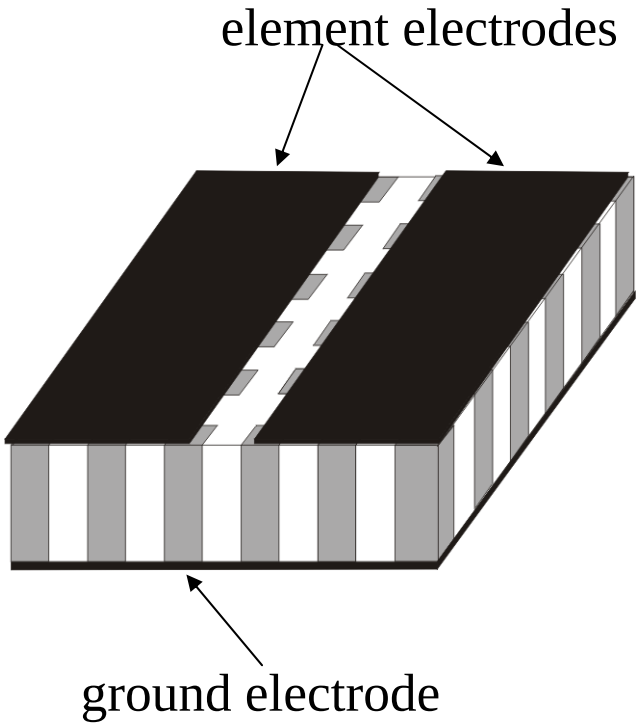


Transducer mechanism

- Piezoelectric effect
  - Voltage applied on transmit →vibration of surface → transmitted wave
  - Echo reaching surface→vibration of surface → received signal



Overview, ultrasound transducer array piezo composite.



Piezo ceramic – diced filled with polymer

New ”equivalent material”

- better mechanical matching
- geometrical shaping
- less lateral coupling

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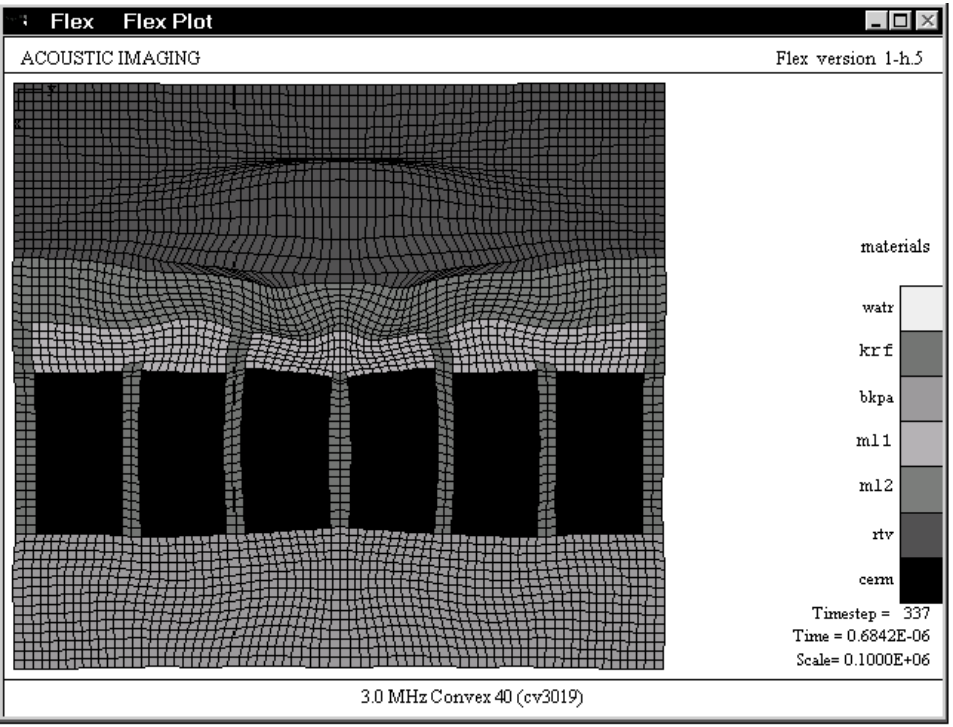
Overview, ultrasound transducer array piezo composite, cntd.



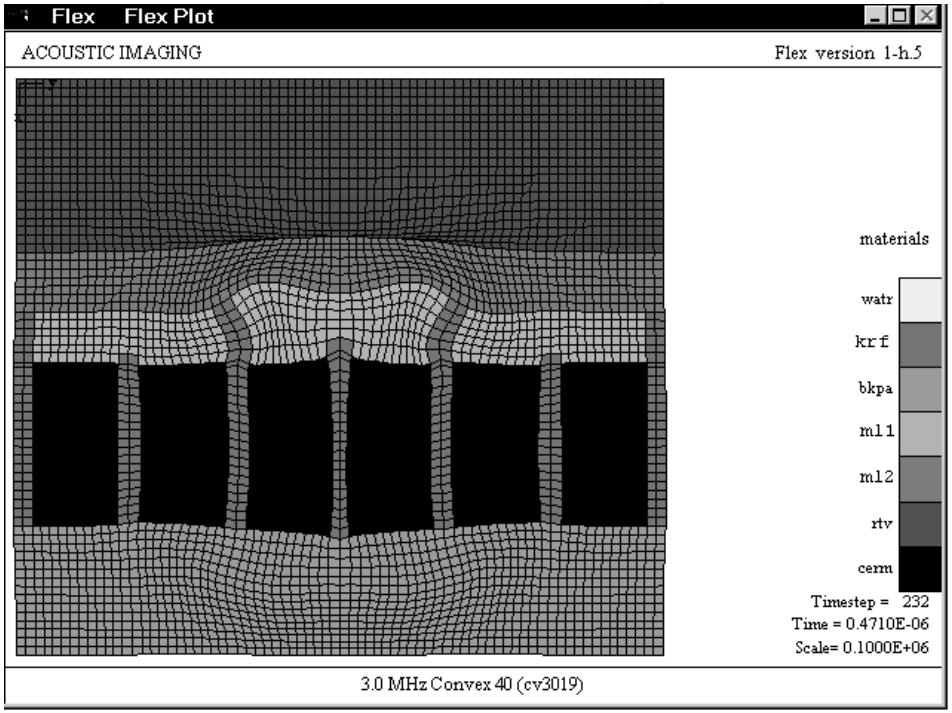


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Image quality, resolution

- Resolution ↔ frequency
  - Radial – pulse length
  - Lateral – Aperture size
  - Line density, pitch
- Attenuation proportional to frequency →Deeper organs lower frequencies

$$c = f\lambda \quad , \quad f = \frac{1}{T_p}$$

$$l_r = \frac{cN_pT_p}{2} = \frac{cN_p}{2f} = \frac{N_p\lambda}{2}$$

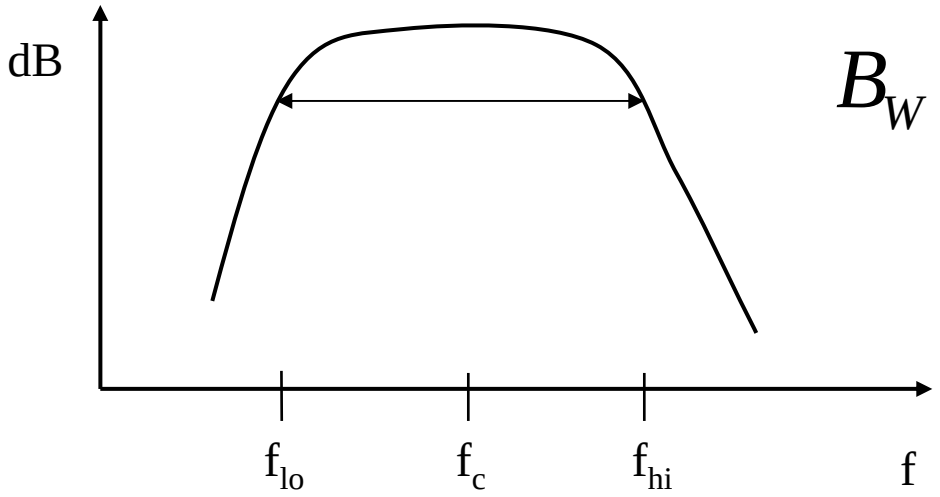
$$l_l = 2f_{\#}\lambda = \frac{2z\lambda}{D} = \frac{2zc}{Df}$$

Image quality bandwidth

- High bandwidth offer possibility to have short pulses, resolution
- High bandwidth offer flexibility to use wide selection of frequencies with one probe, several applications.
- Tissue Harmonic Imaging (THI), reduce acoustic noise significantly in several imaging applications
  - Transmit one frequency, receive at the double.

- Trade off between sensitivity and bandwidth (gain bandwidth product)

Image quality bandwidth



$$B_W = \frac{f_{hi} - f_{lo}}{f_c}$$

Bw	
67%	2.harmonic
100%	3.harmonic
120%	4.harmonic
133%	5.harmonic

Gain-bandwidth

G*Bw ~ constant

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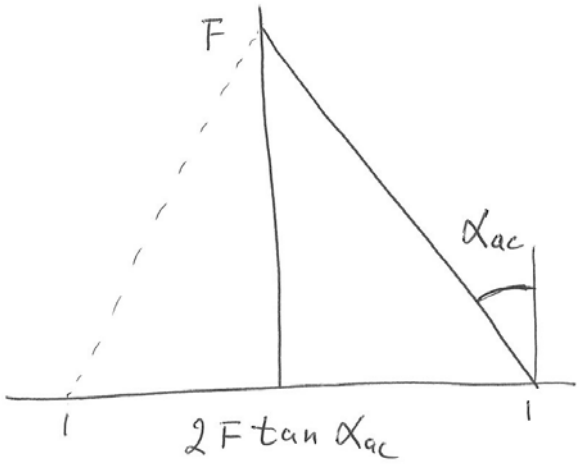
Image quality - pitch

- Steering and beam quality dependent on array pitch.
  - Avoid grating lobes.
  - Maximum aperture size dependent on element angularity.

- Phased array: $p=\lambda/2$ @f_c
- Flat linear array: $p\approx1.2\lambda$ @f_c
- Curved linear array: p smaller than FLA

- More grating lobes the more steering.

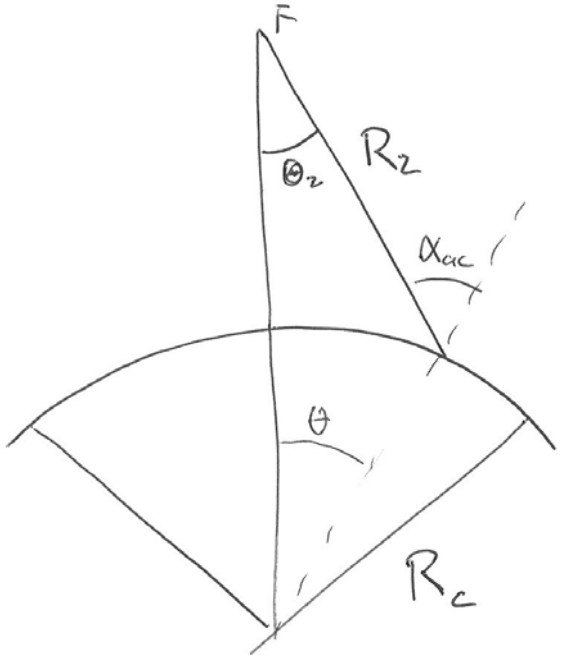
FLA



$$D = 2R_c \sin\theta$$

$$f_{\#} = \frac{F}{2R_c \sin\theta}$$

CLA



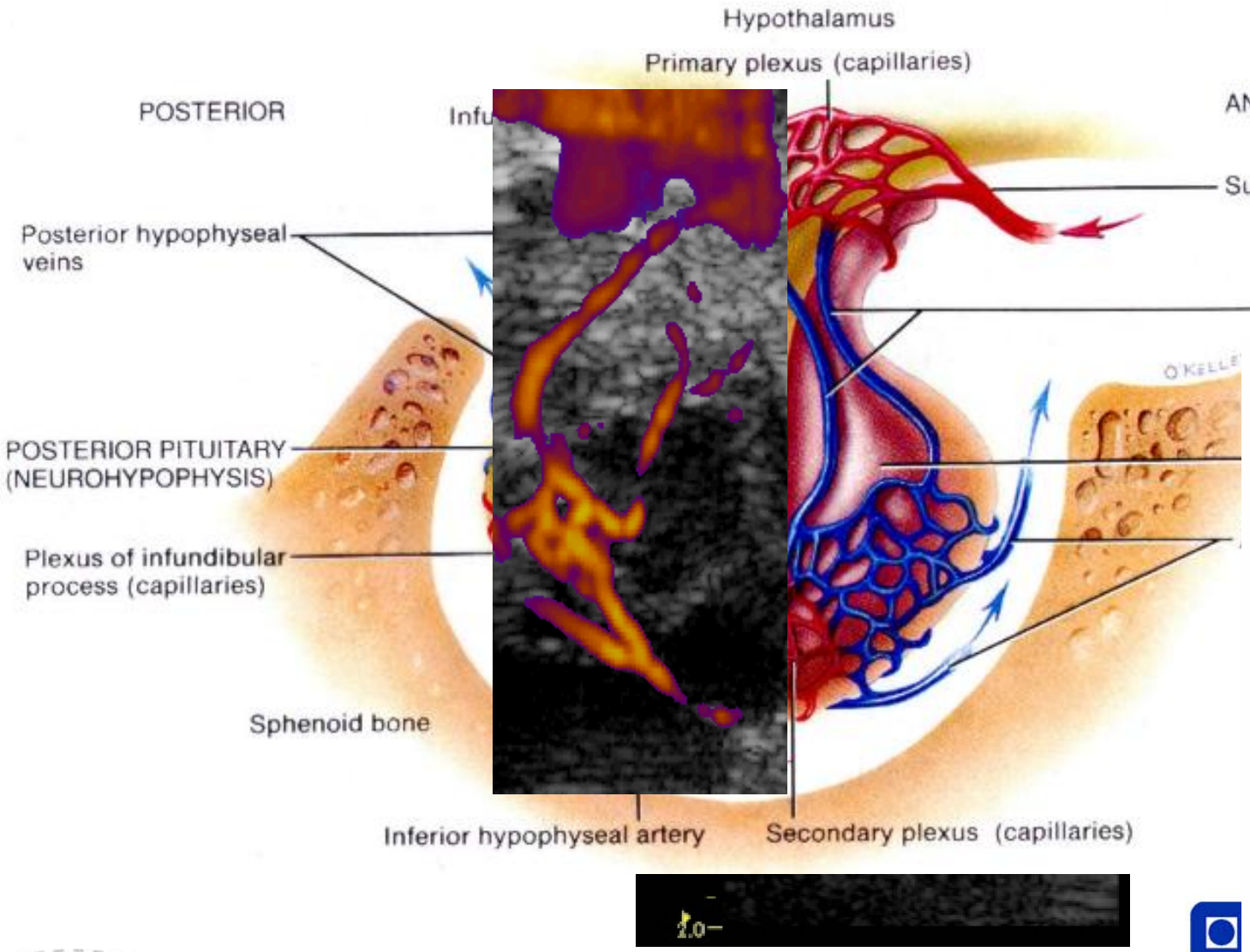
$$D = 2F\tan\alpha_{ac}$$

$$f_{\#} = \frac{1}{2\tan\alpha_{ac}}$$

Observe that $\theta_2 = \alpha_{ac} - \theta$

and the distance from the focus to the "projected aperture" $> F$

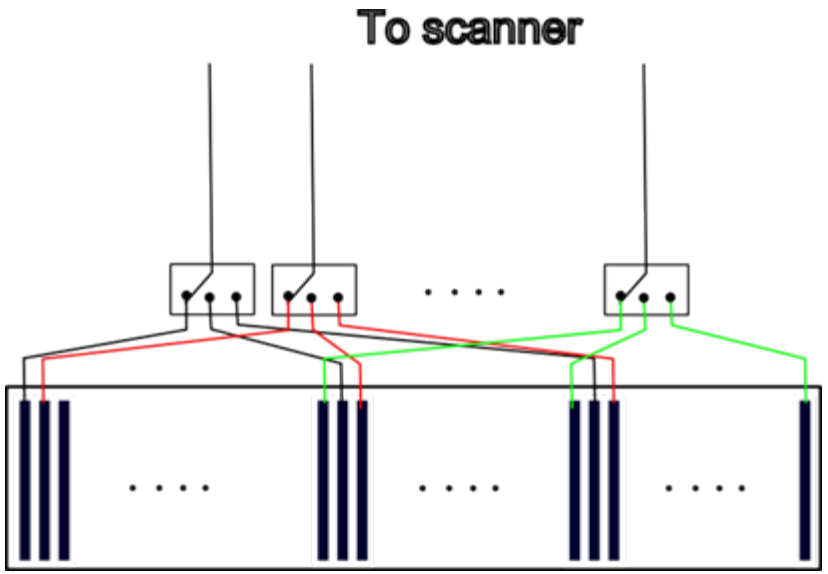
so for a given α_{ac} one has $f_{\#,FLA} < f_{\#,CLA}$



Courtesy Ole Solheim et.al.

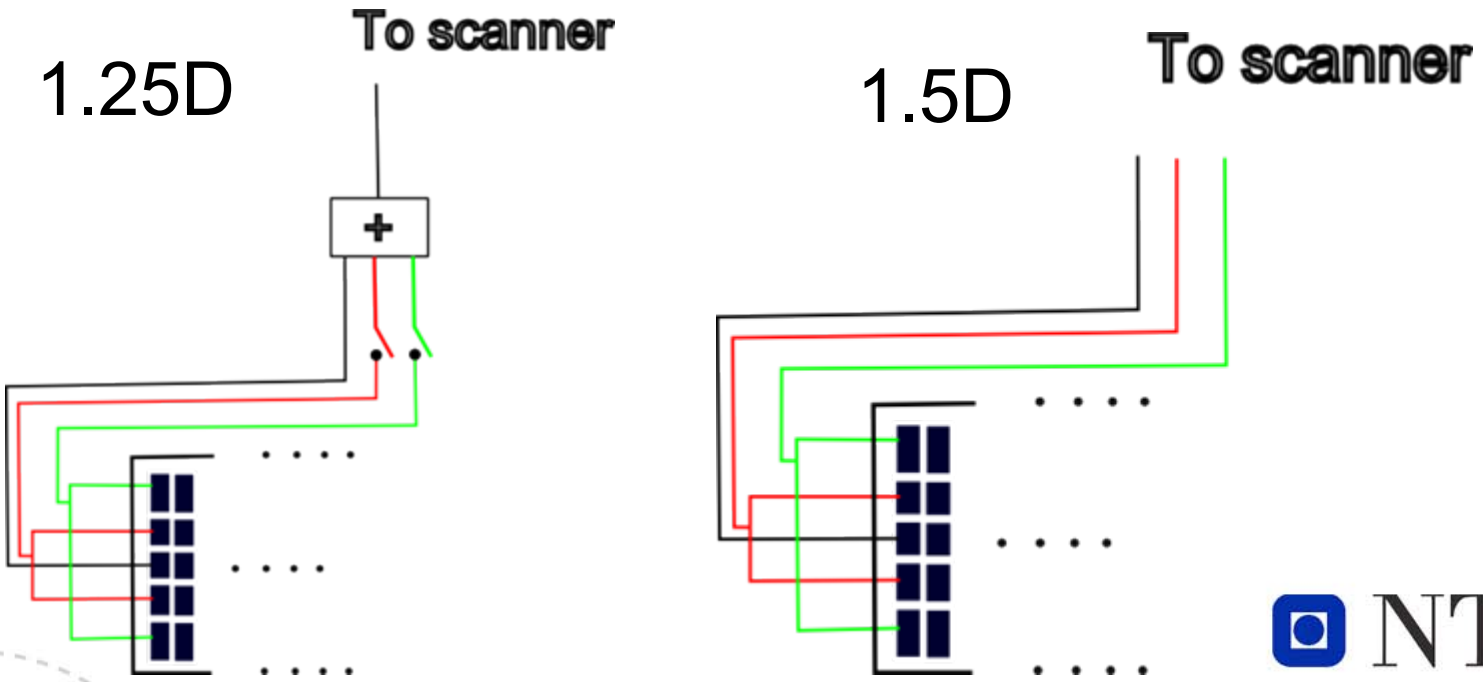
Electronics in probe

- Traditional: sliding aperture – switches in the probe/or in the skanner.
  - Limited #channels in skanner
  - large total aperture/lines in image



Electronics in probe

- Matrix array, 1.25D and 1.5 D arrays, switching
  - Control over elevation beamwidth with depth (focusing in elevation)
  - No steering in elevation direction



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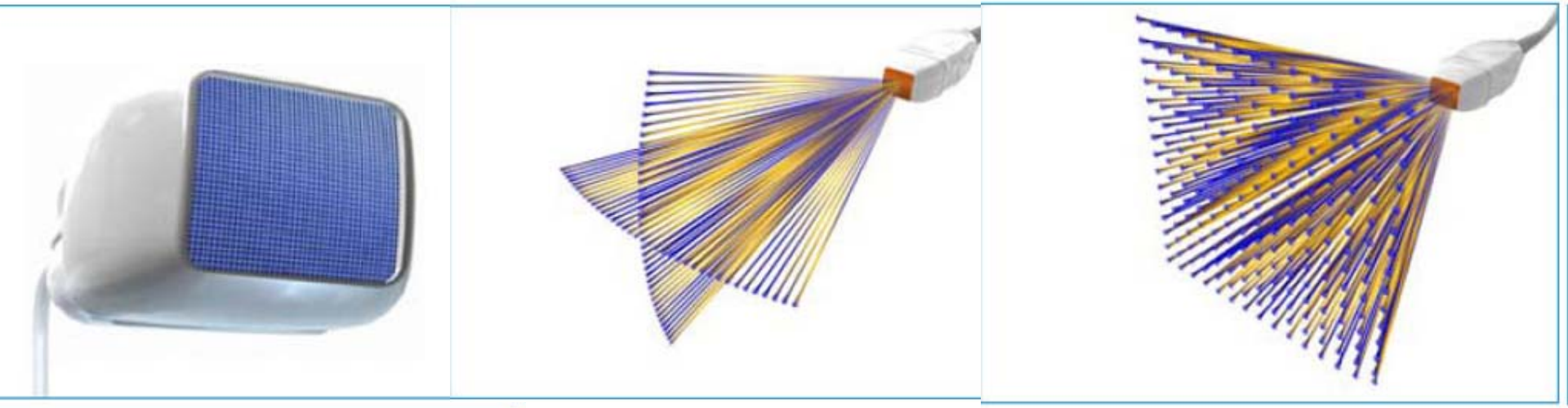
Electronics in probe, 2D array

- Able to steer and focus in both directions
  - (Almost) Real time 3D imaging
  - Real time multiple planes



http://www.healthcare.philips.com/no_no/products/ultrasound/technologies/xmatrix.wpd

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Electronics in probe, 2D array

- +2500 elements
  - Cable count
  - Analog electronics for signal conditioning and preprocessing in probe

Courtesy GE Healthcare (GE VingMed)

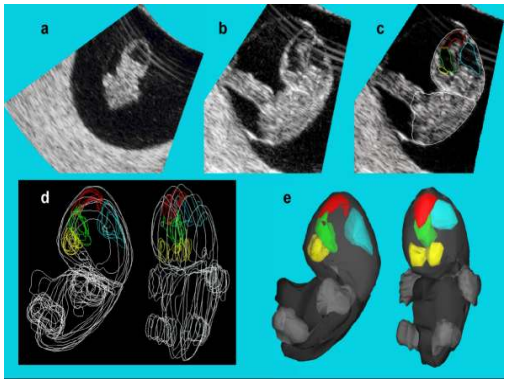
Electronics in probe, miniturization, high frequecies

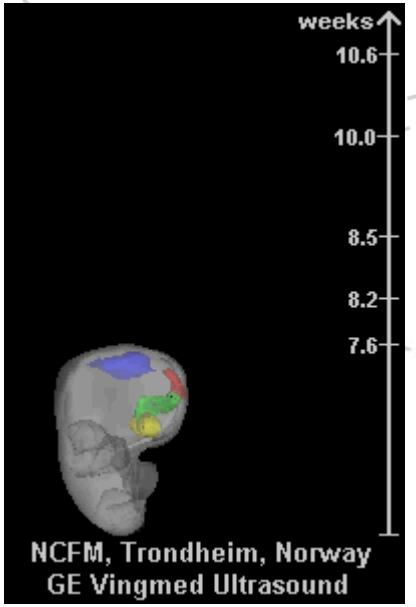
- Analog electronics for signal conditioning and preprocessing in probe
- Low #coaxes in cable

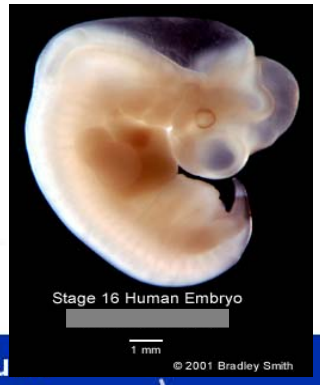
- Better signal conditioning at high frequencies

Transducer/probe small cavities

- 3D imaging of early featus
- Annular array,
  - mechanical steering
  - Symmetric beam/focus

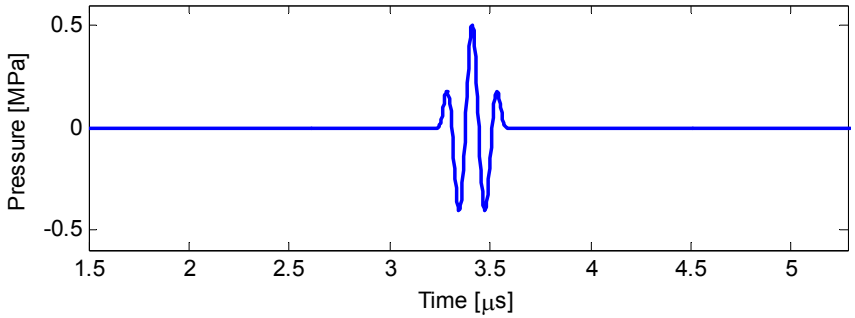


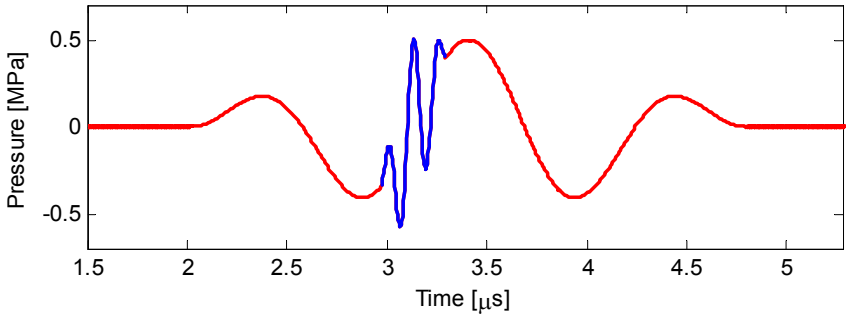


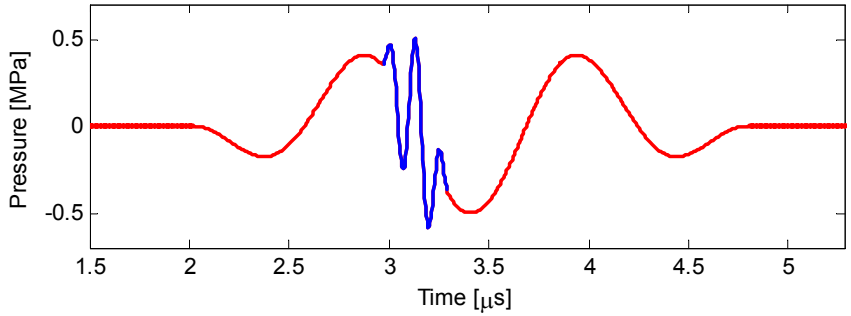


Acoustic noise, reverberation
Surf imaging

Second-order UltRasound Field imaging







Imaging pulse = 7.5 MHz

Manipulation pulse = 0.9 MHz

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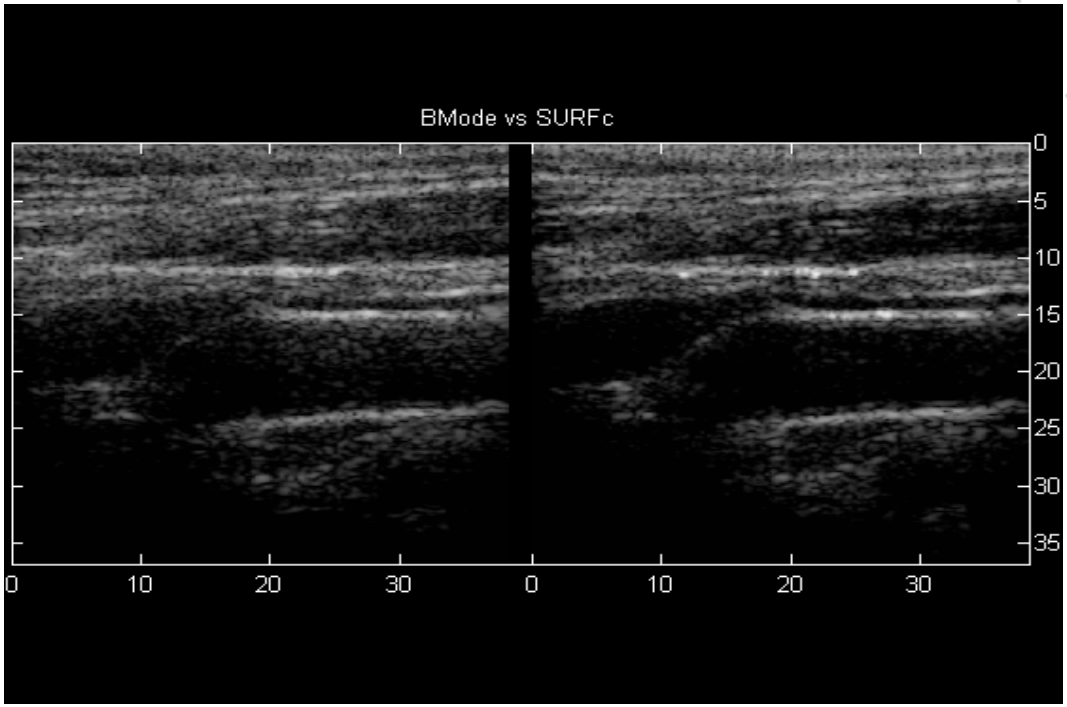
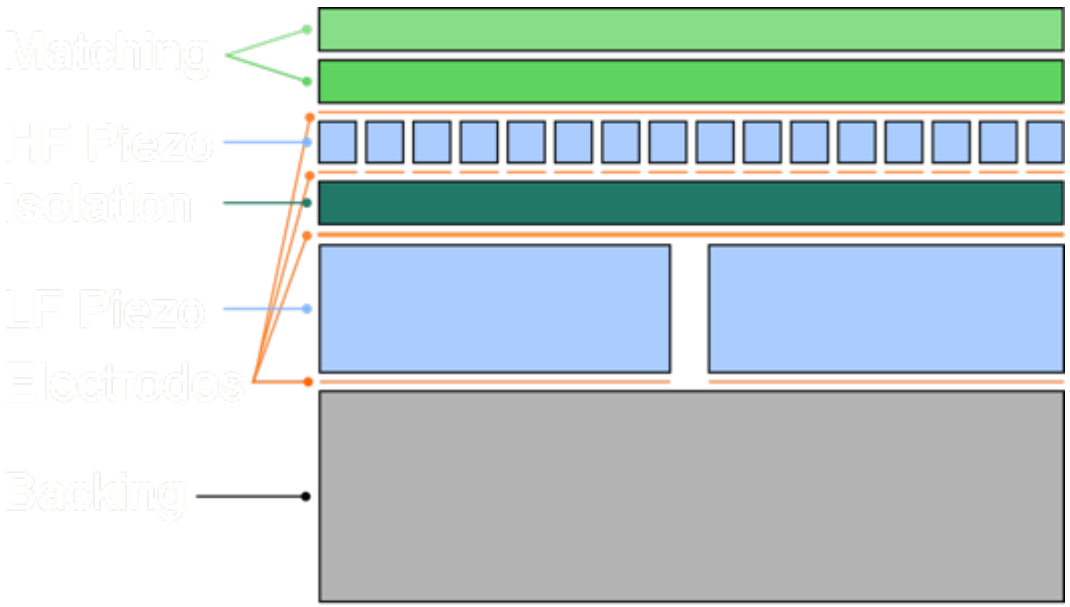
Acoustic noise, reverberation
Surf imaging



Transducer/probe - SURF

Layer structure 2 frequency transducer, linear array, composite



Composite made of piezo el. Ceramic and polymer

hf elements either on ceramic or polymer.

Homogenized with thick electrode