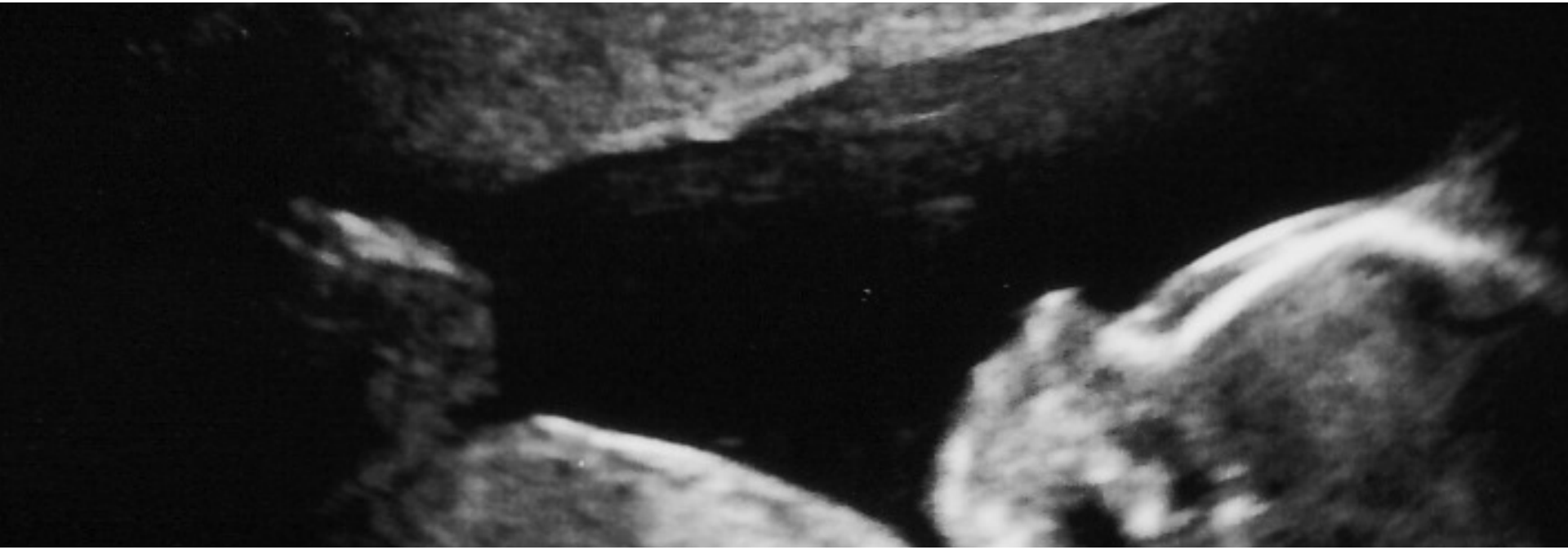
Ultrasound Physics (BWHRR.US)

2. Transduction and Beamforming



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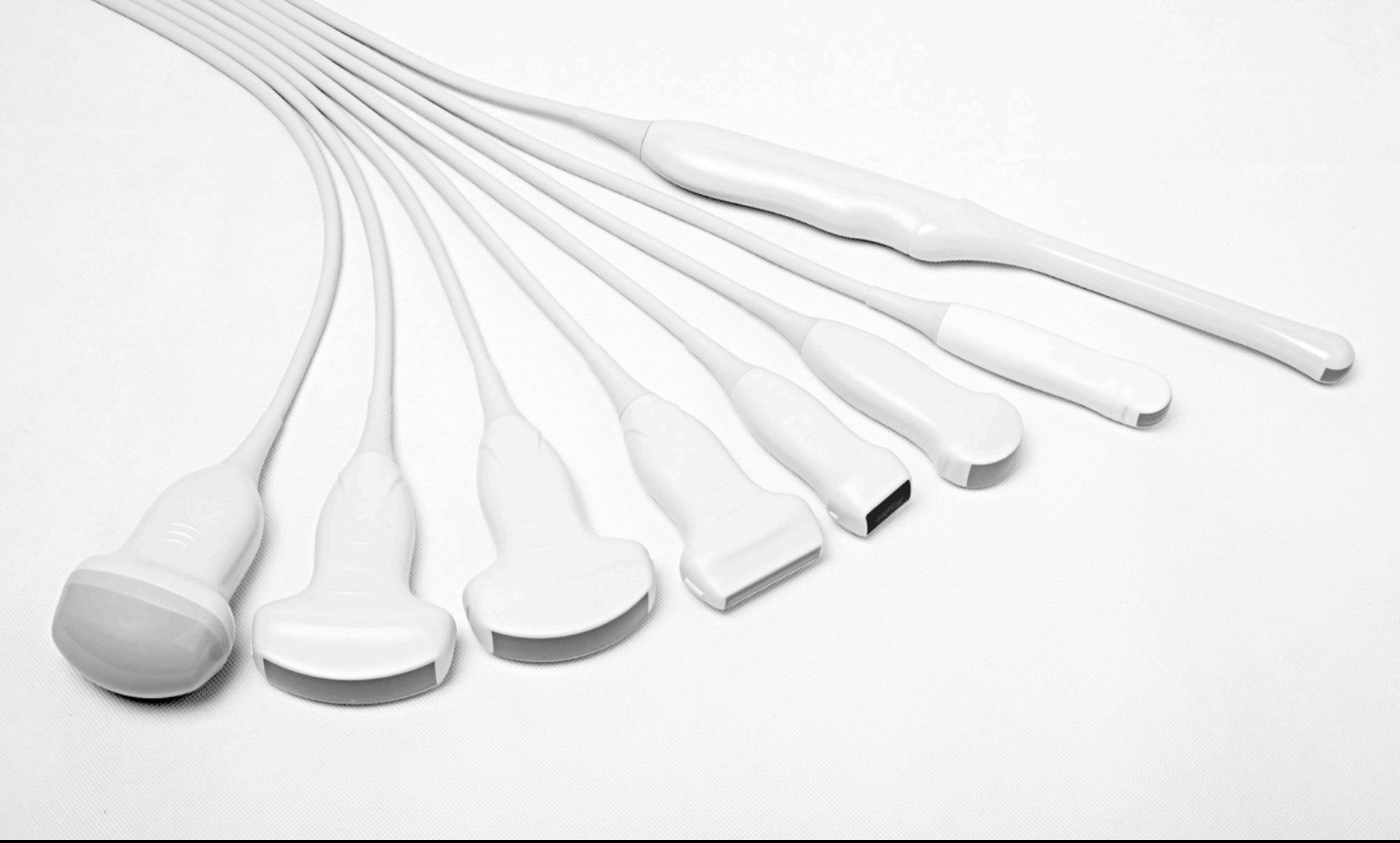
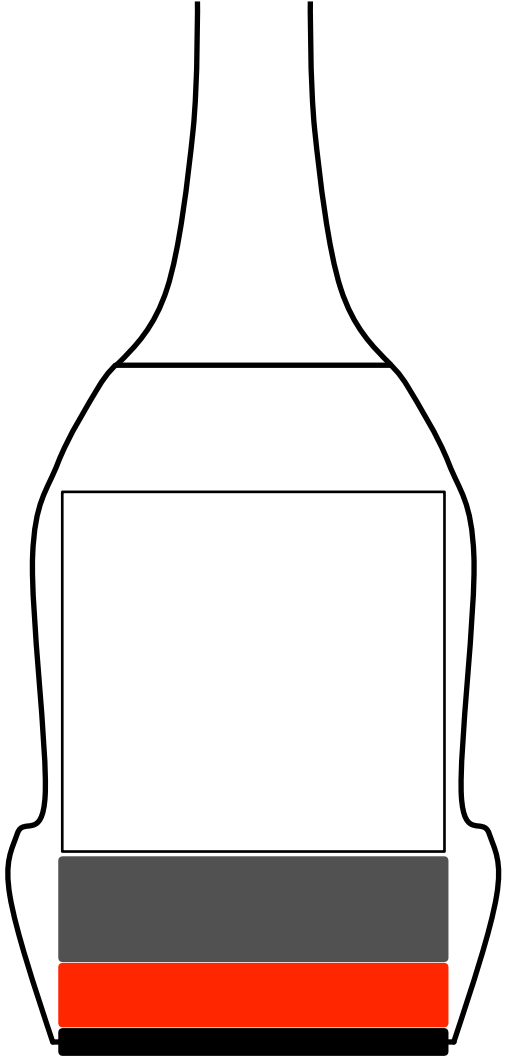
Boston, MA 02115

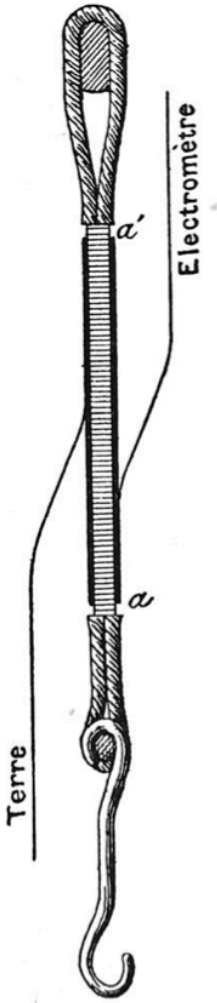
Contact: (617) 525-7465, white@bwh.harvard.edu



Ultrasound Probe



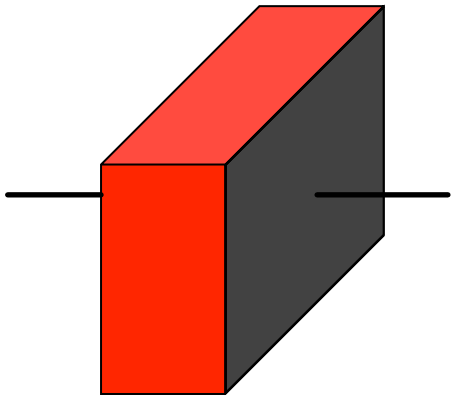
Ultrasound Probe



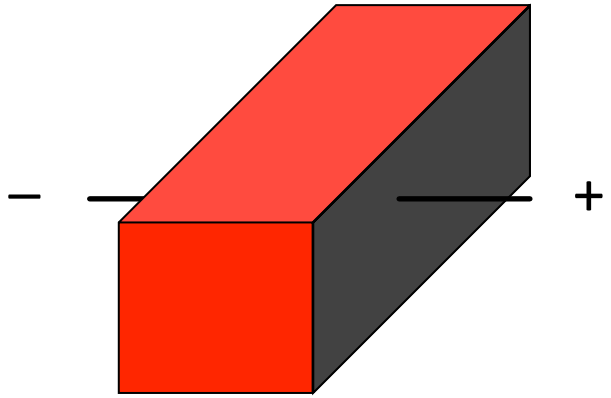
Quartz piézo-électrique.

Piezoelectricity

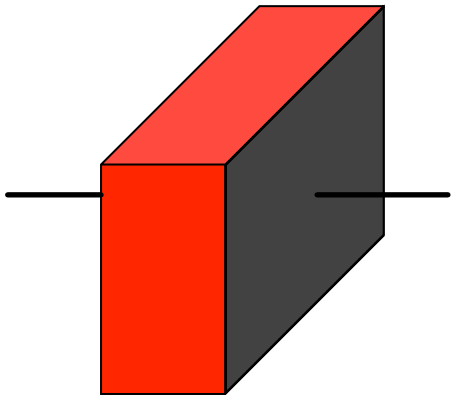
Piezoelectricity



The Piezoelectric Effect



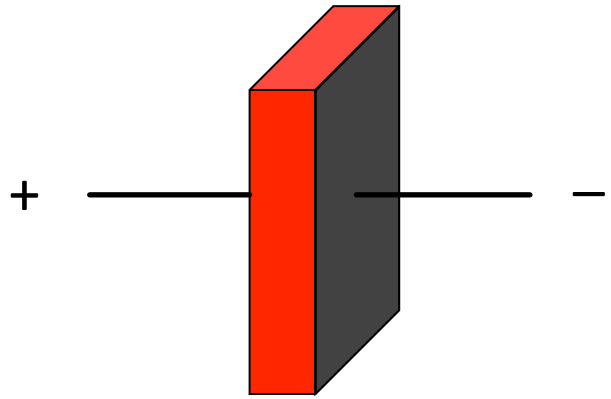
The Piezoelectric Effect

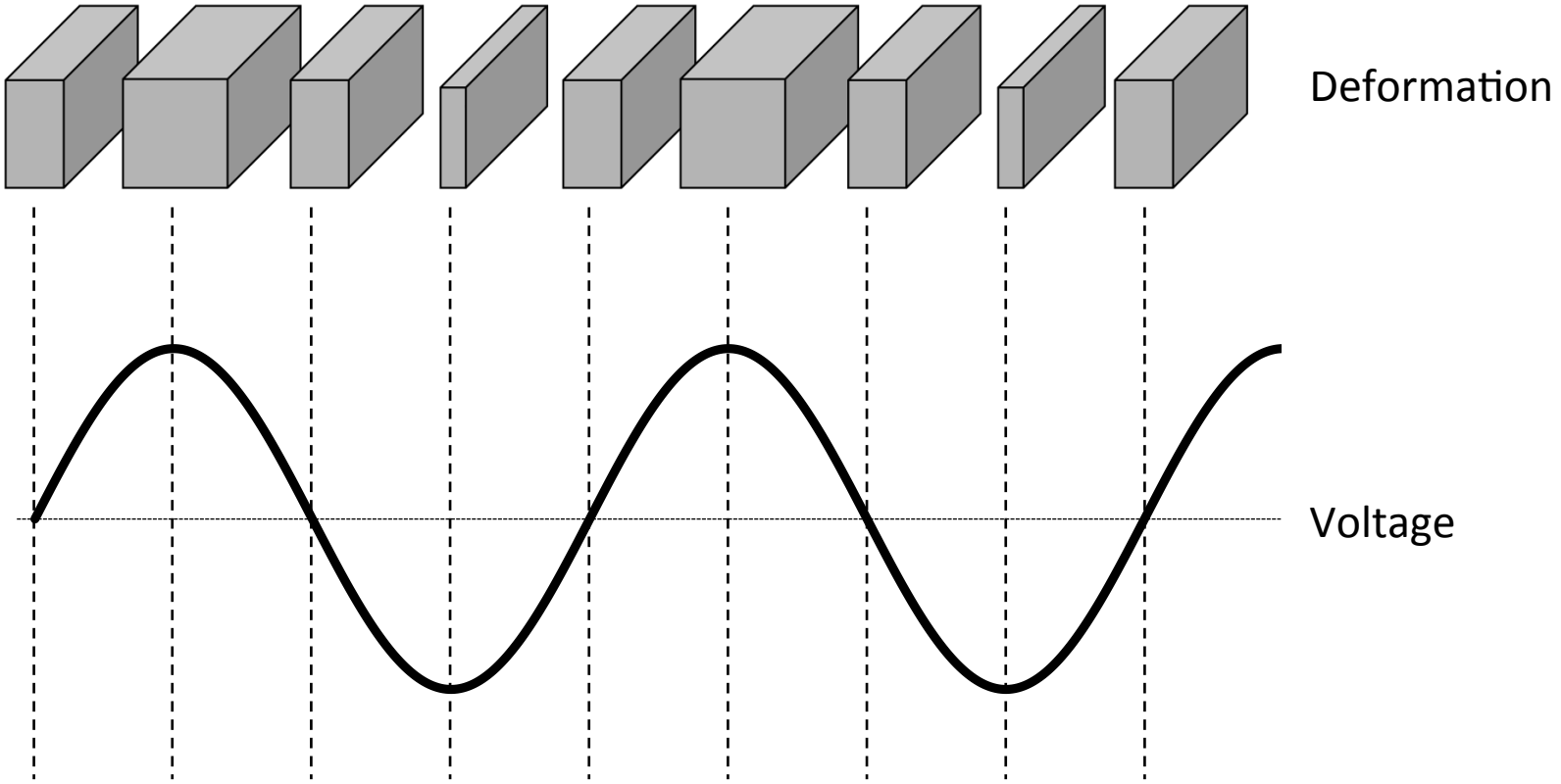


The Piezoelectric Effect

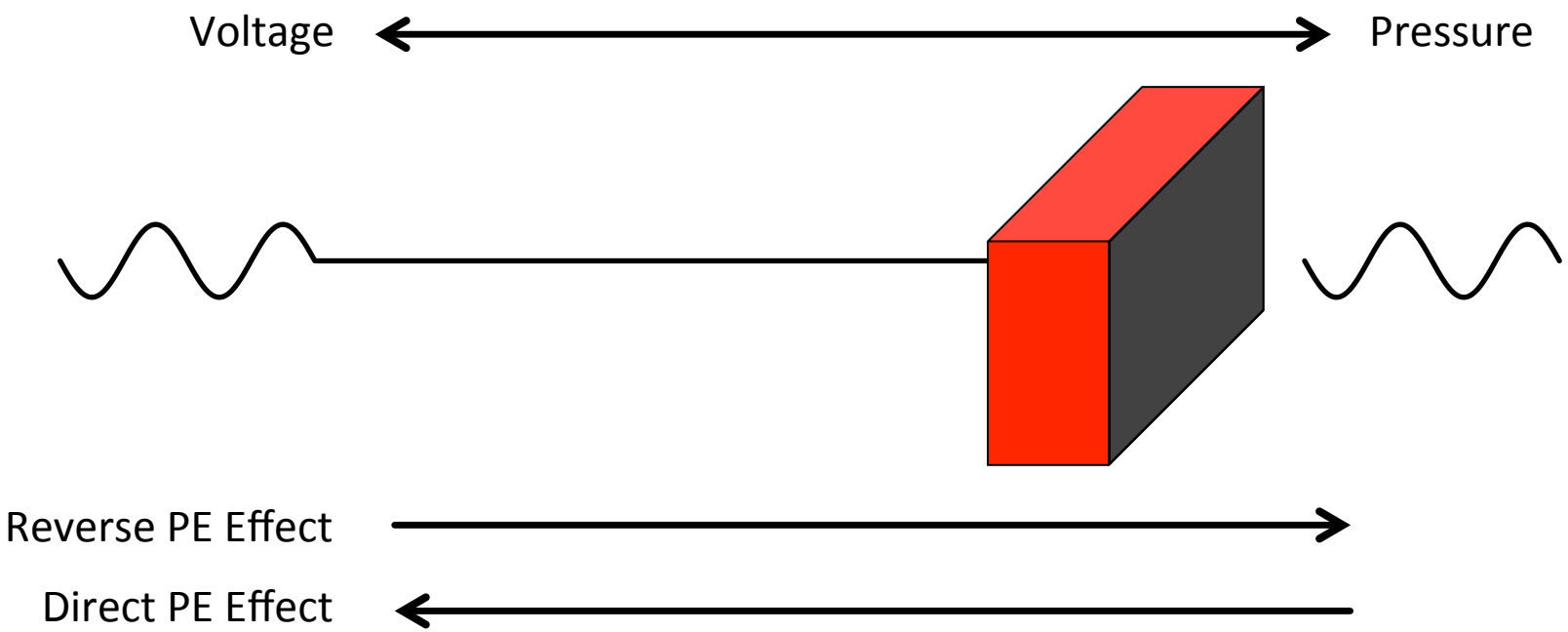
The Piezoelectric Effect

- Quartz
- Sucrose
- Bone
- PVDF
- PZT
- etc.

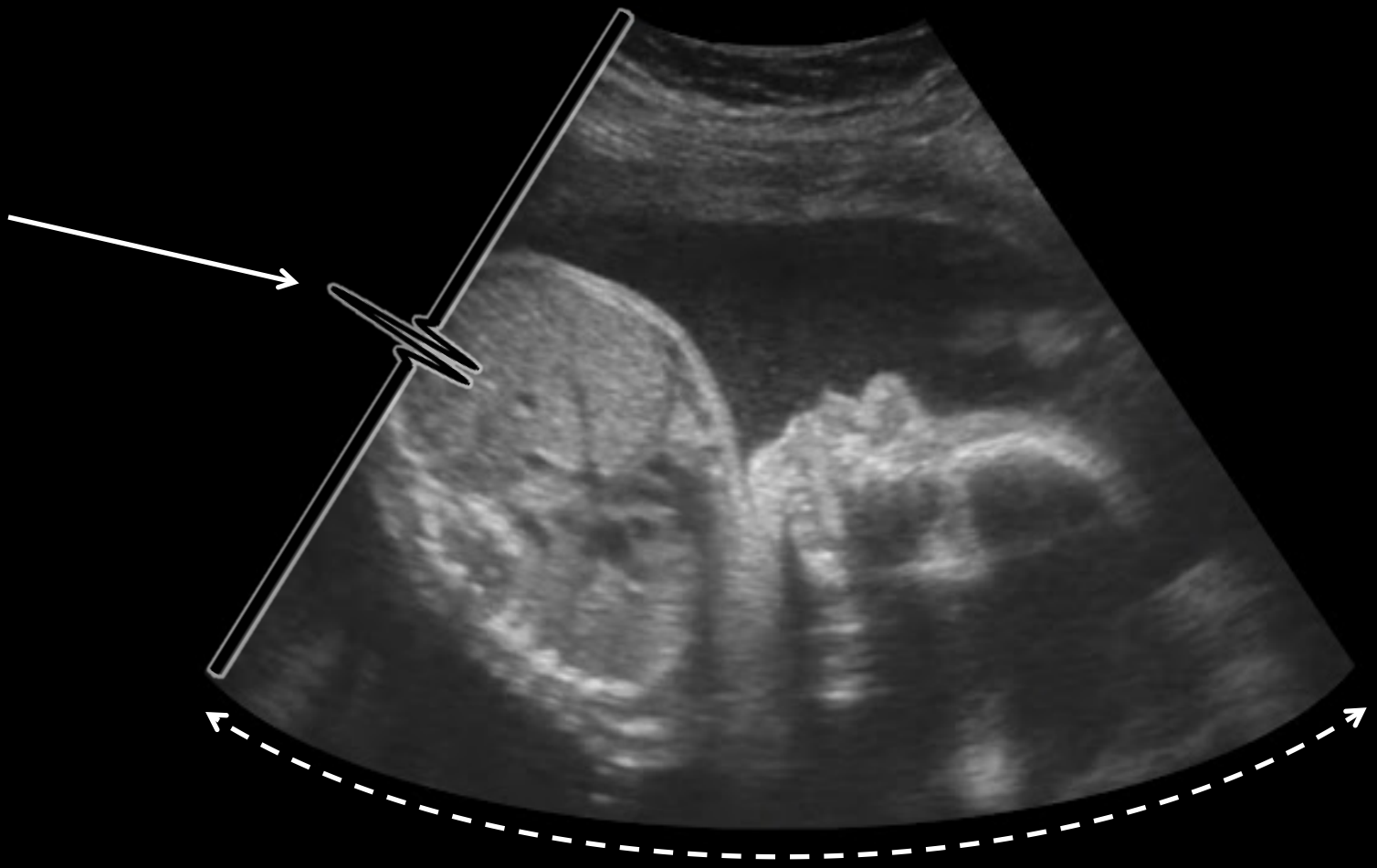




Transduction

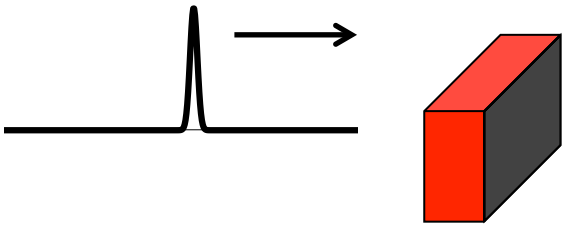


Transduction

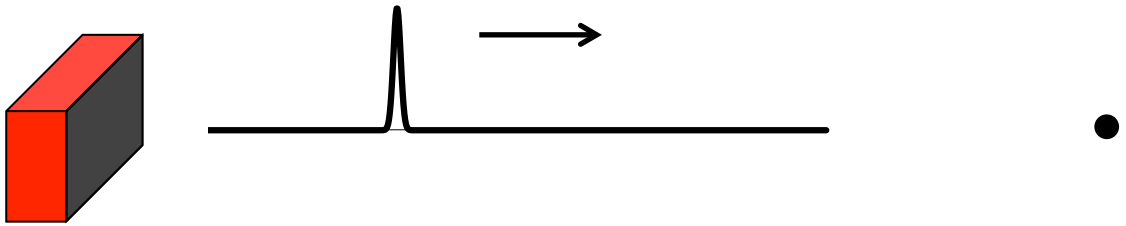


Ultrasound Imaging

Ideal Response

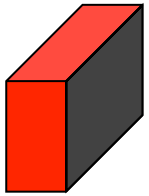


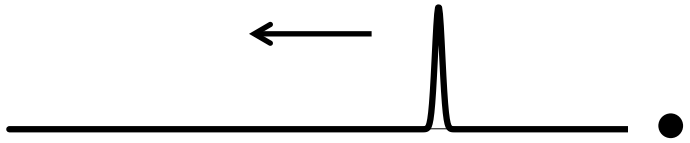
Ideal Response



Transducer Response

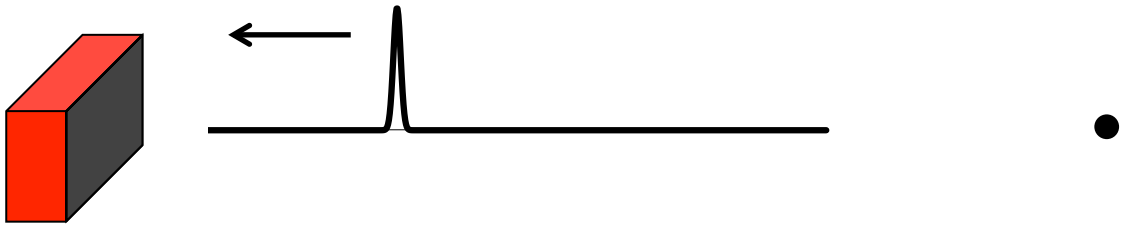
Ideal Response





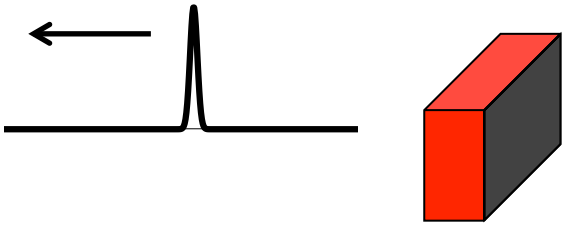
Transducer Response

Ideal Response

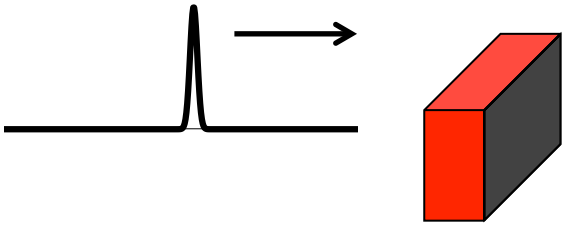


Transducer Response

Ideal Response

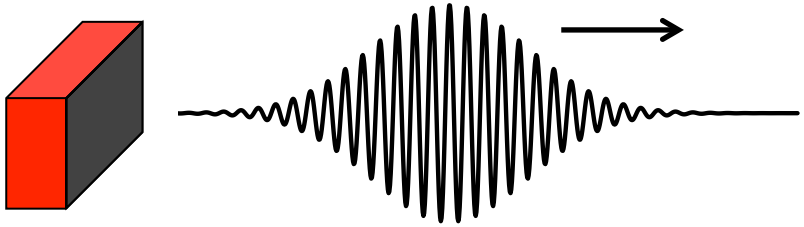


Actual Response



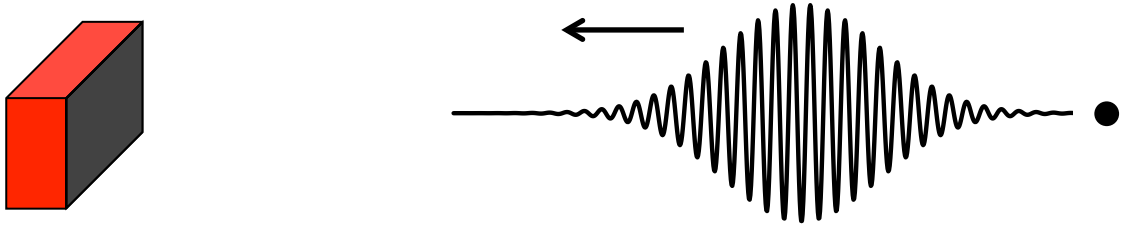
Transducer Response

Actual Response



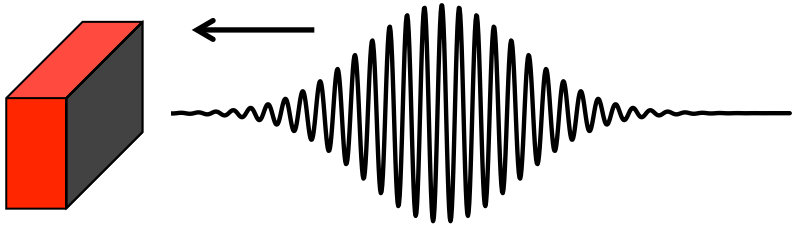
Transducer Response

Actual Response



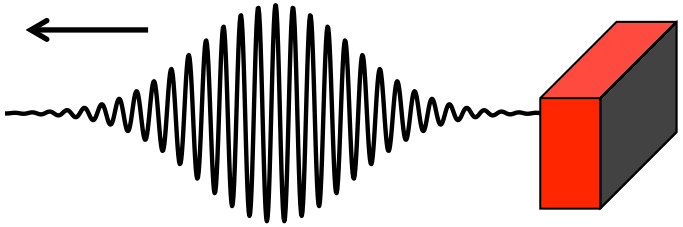
Transducer Response

Actual Response

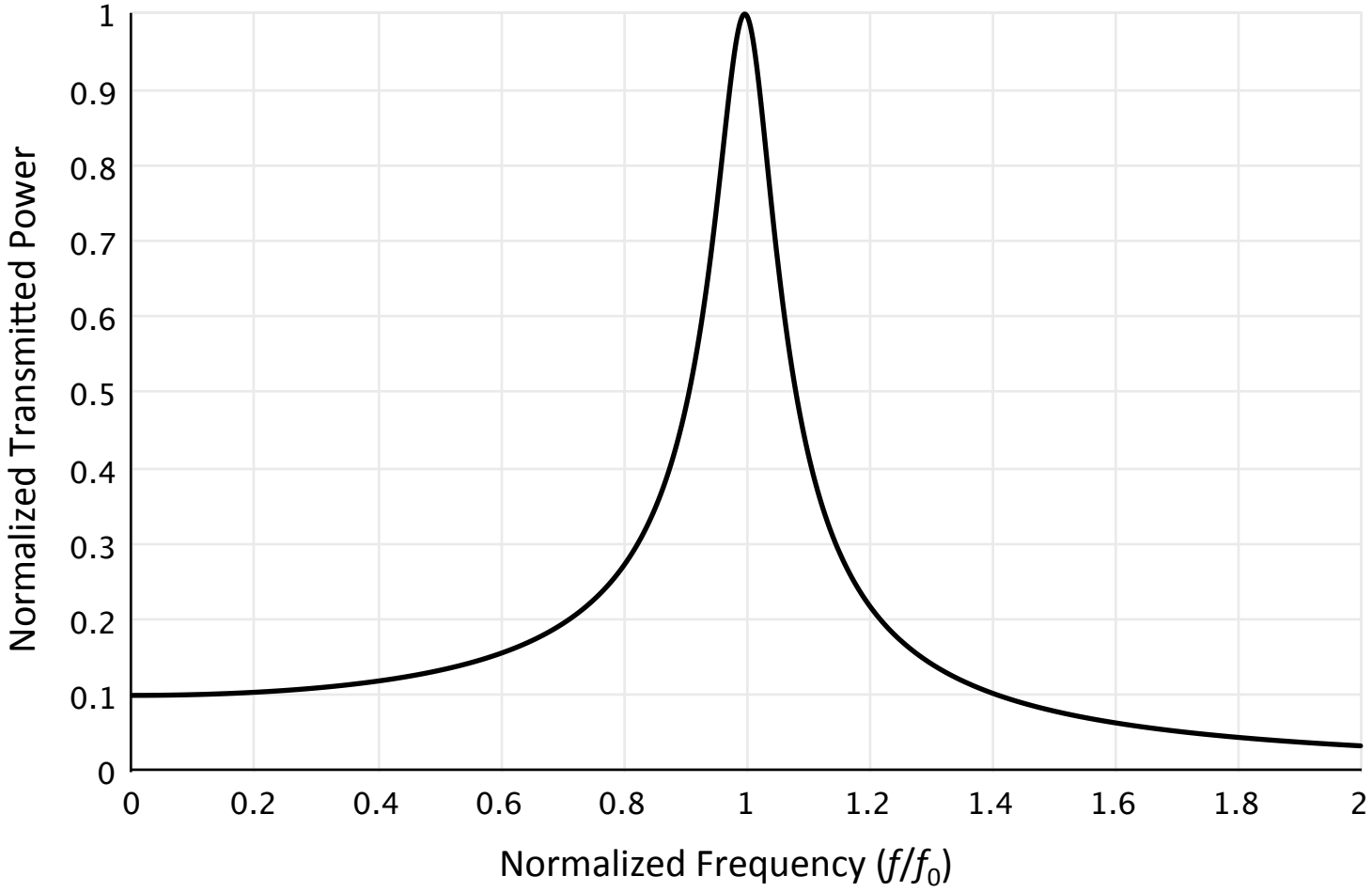


Transducer Response

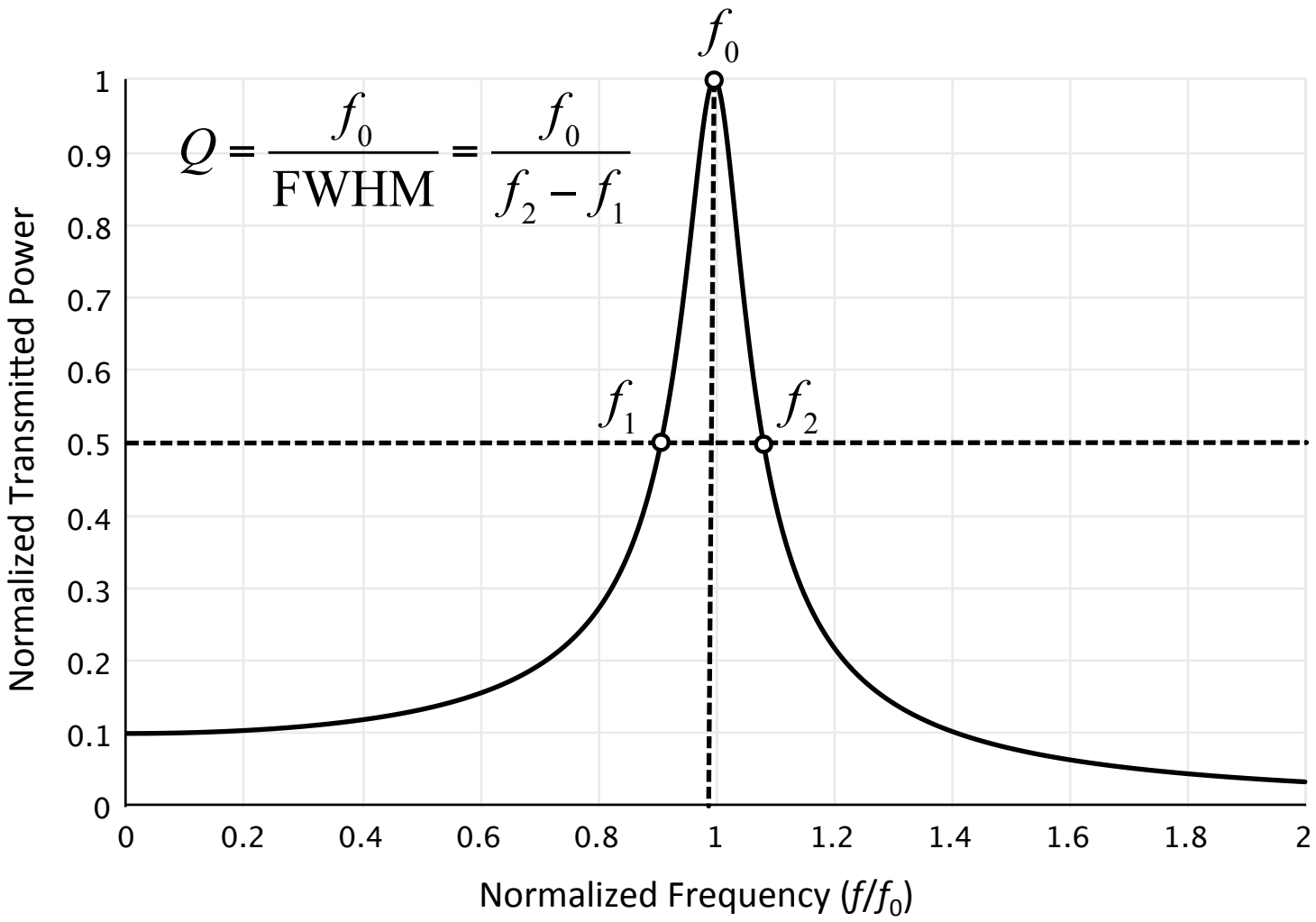
Actual Response



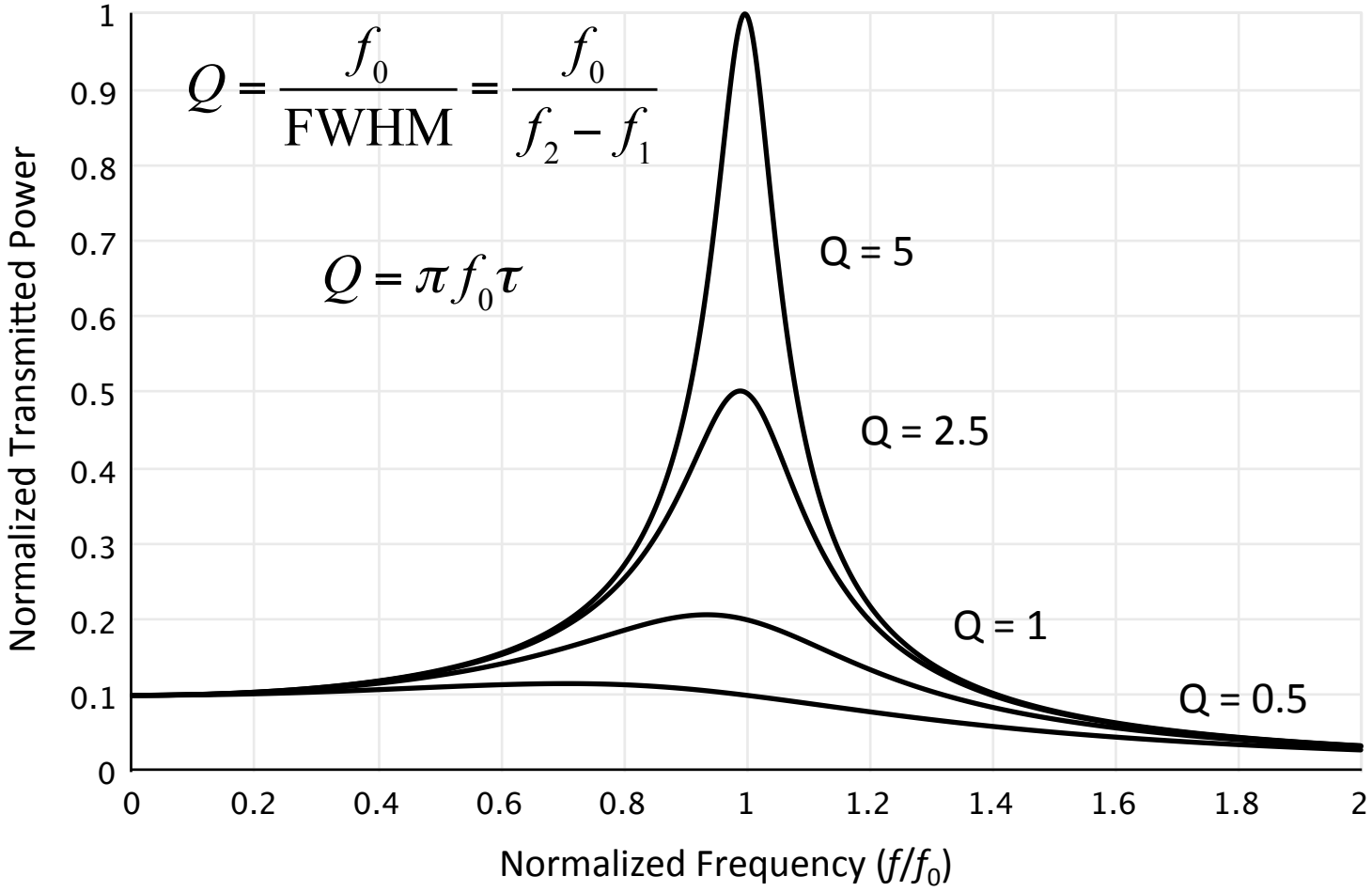
Transducer Response


Normalized Transmitted Power
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Normalized Frequency (f/f_0)

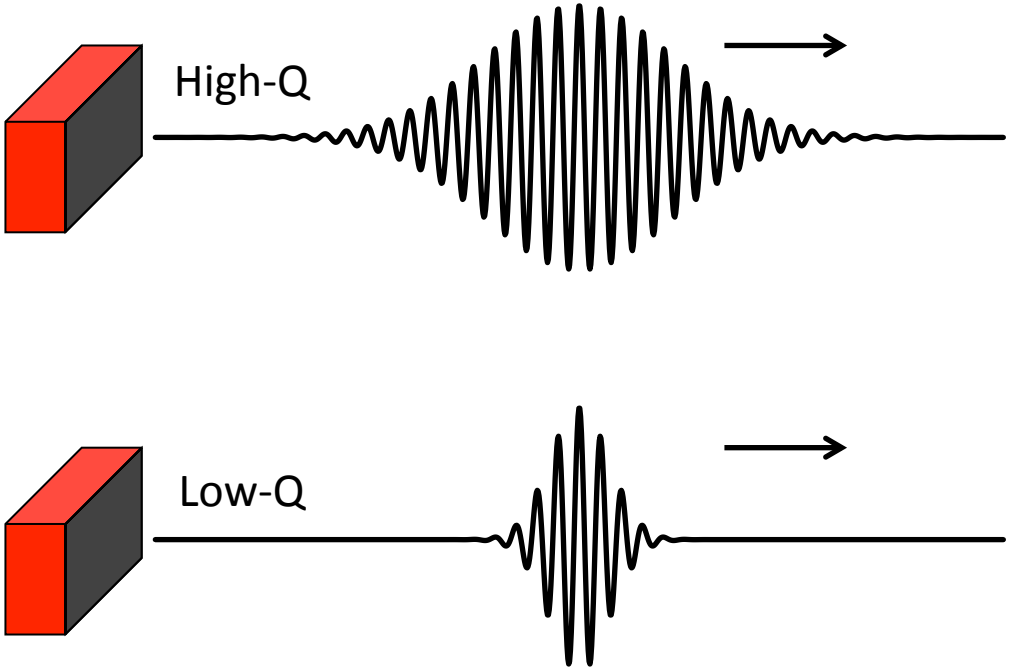
Resonance


f_0
$Q = \frac{f_0}{\text{FWHM}} = \frac{f_0}{f_2 - f_1}$
f_1
f_2
Normalized Transmitted Power
Normalized Frequency (f/f_0)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

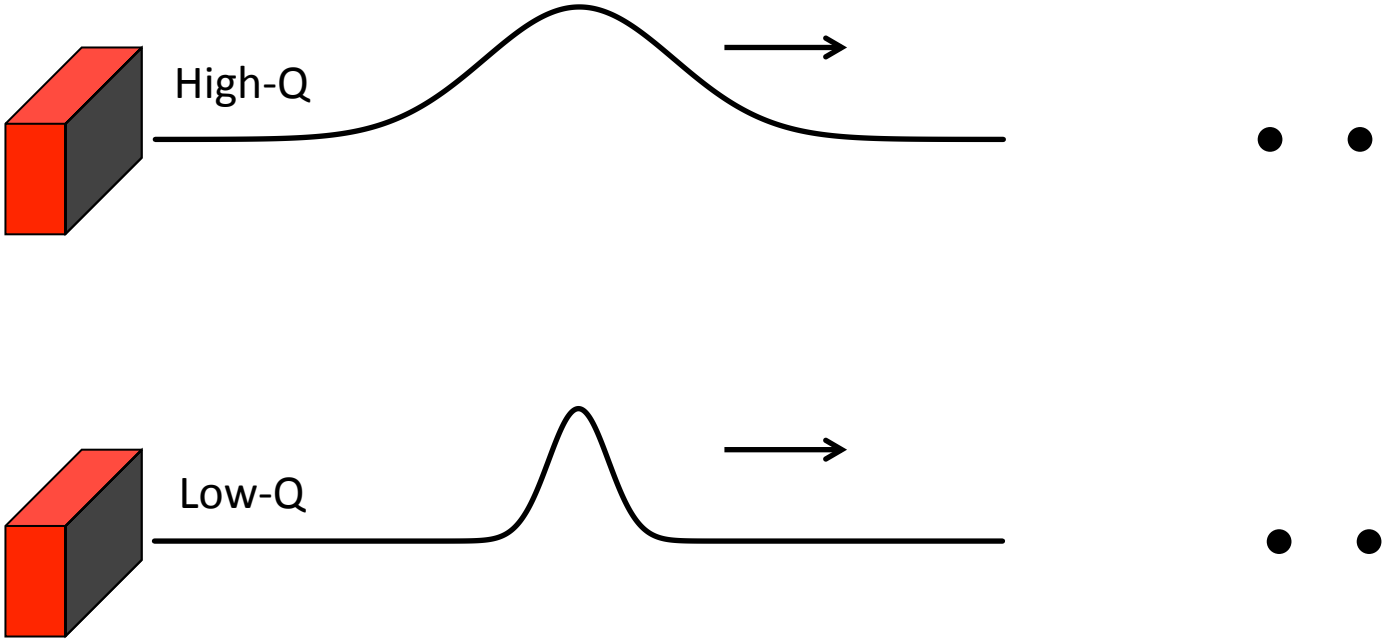
Resonance


$Q = \frac{f_0}{\text{FWHM}} = \frac{f_0}{f_2 - f_1}$
$Q = \pi f_0 \tau$
Q = 5
Q = 2.5
Q = 1
Q = 0.5
Normalized Transmitted Power
Normalized Frequency (f/f_0)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

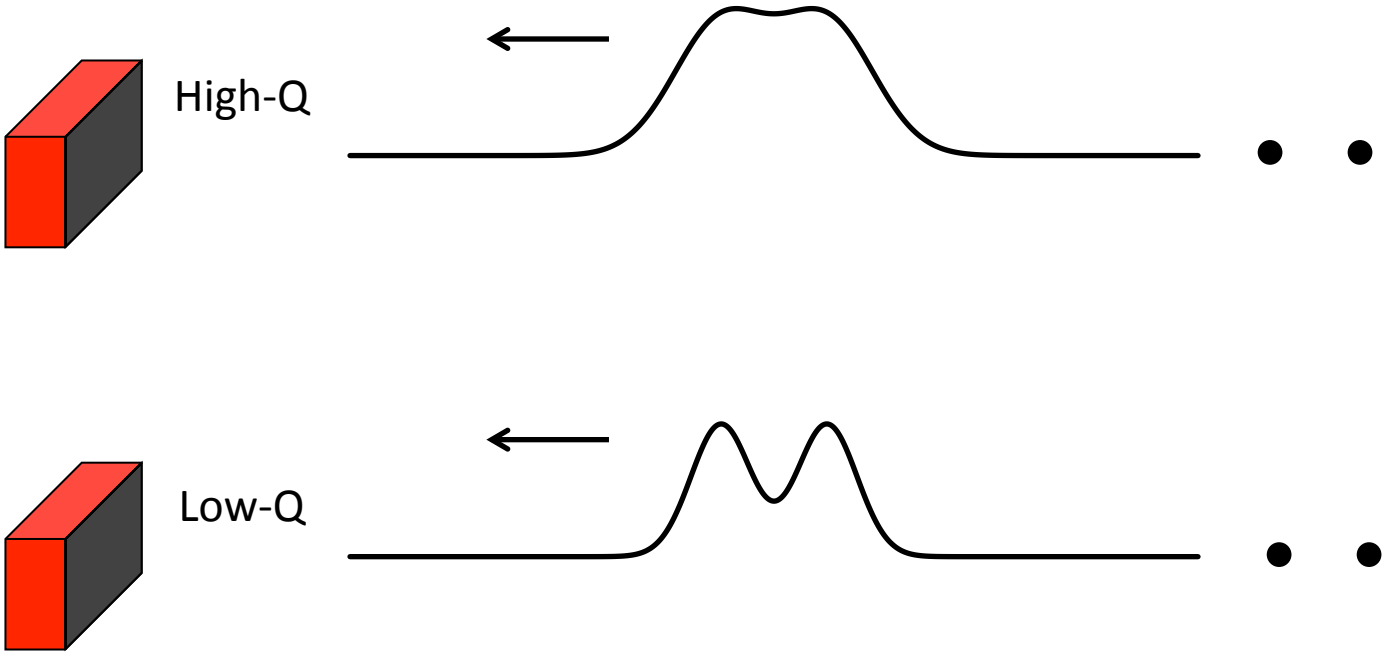
Resonance



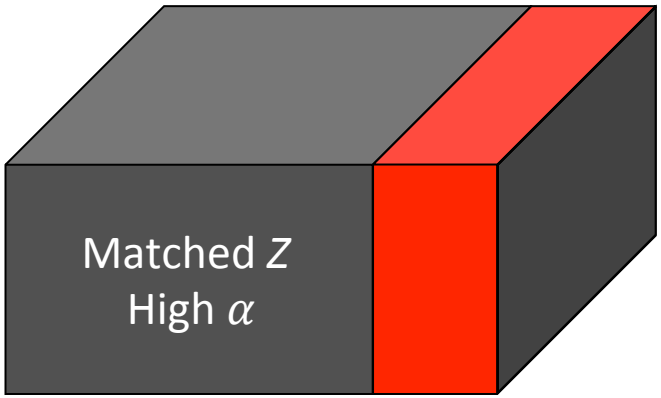
Axial Resolution



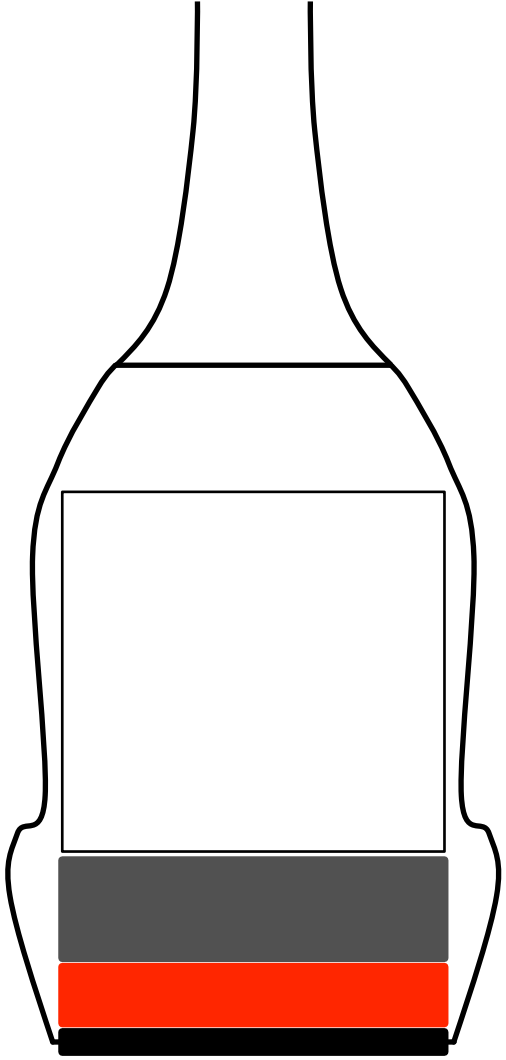
Axial Resolution



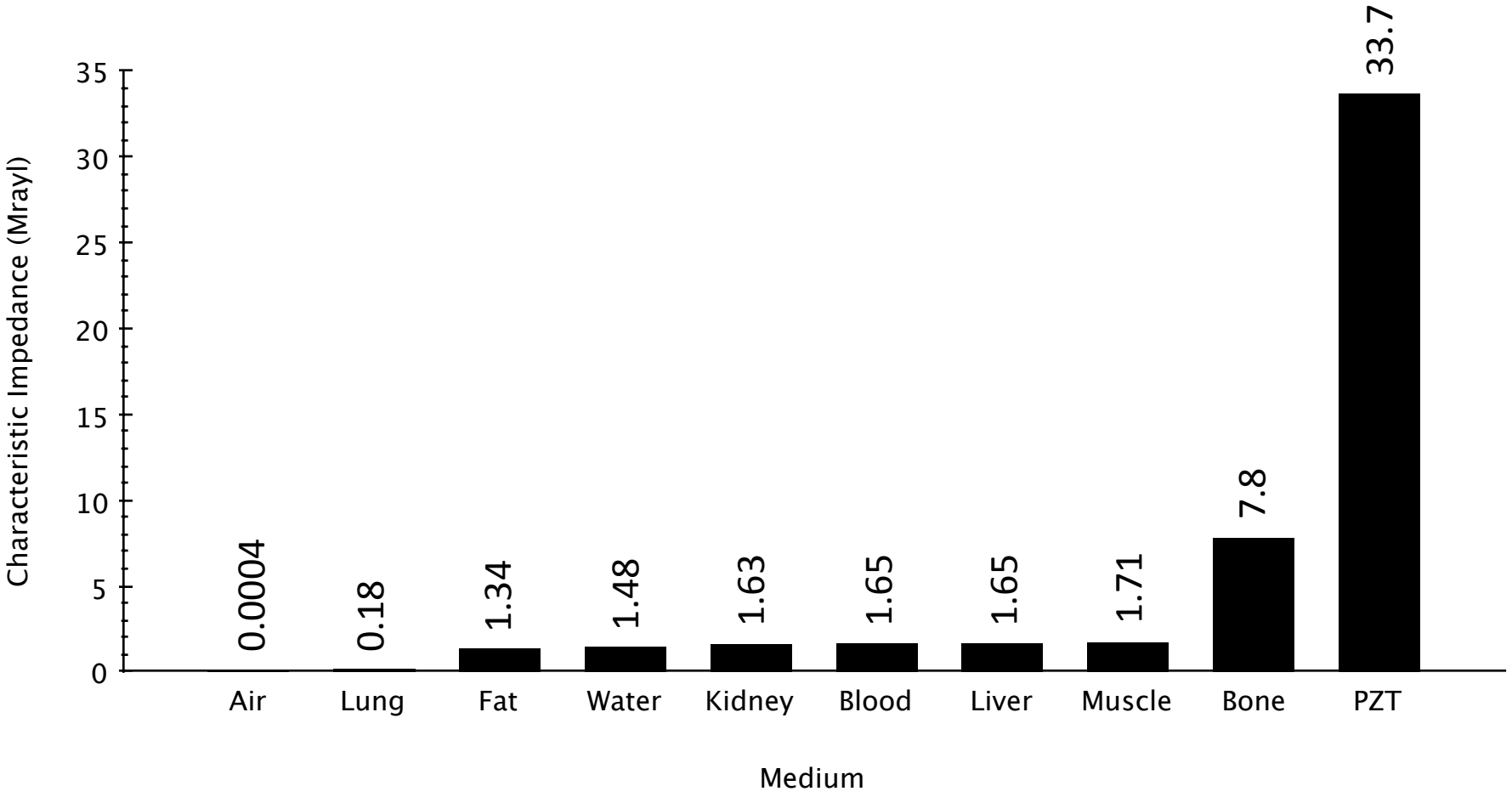
Axial Resolution



Transducer Backing

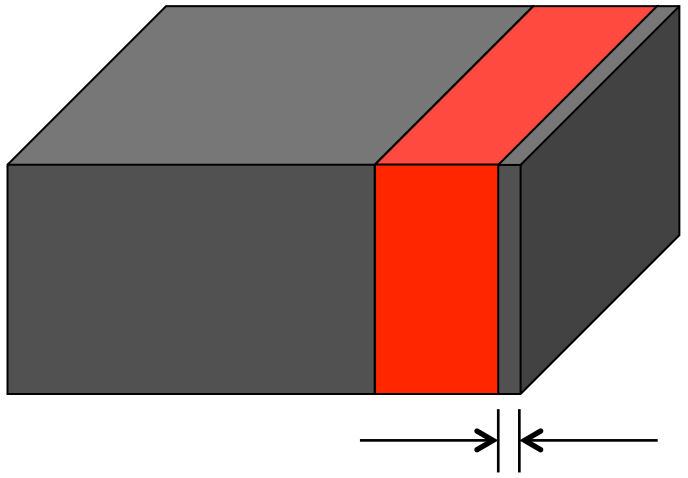


Transducer Backing



(Cobbold 2007)

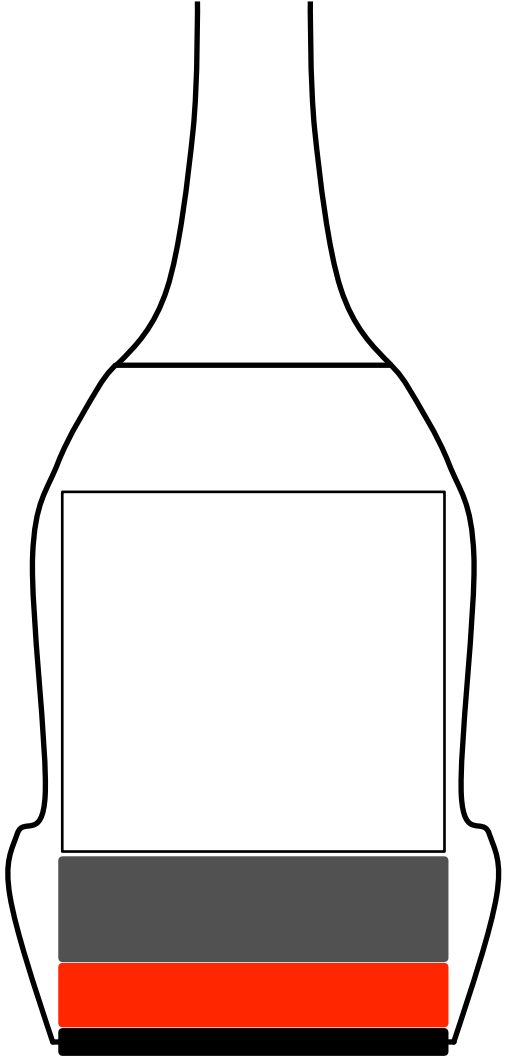
The Matching Layer



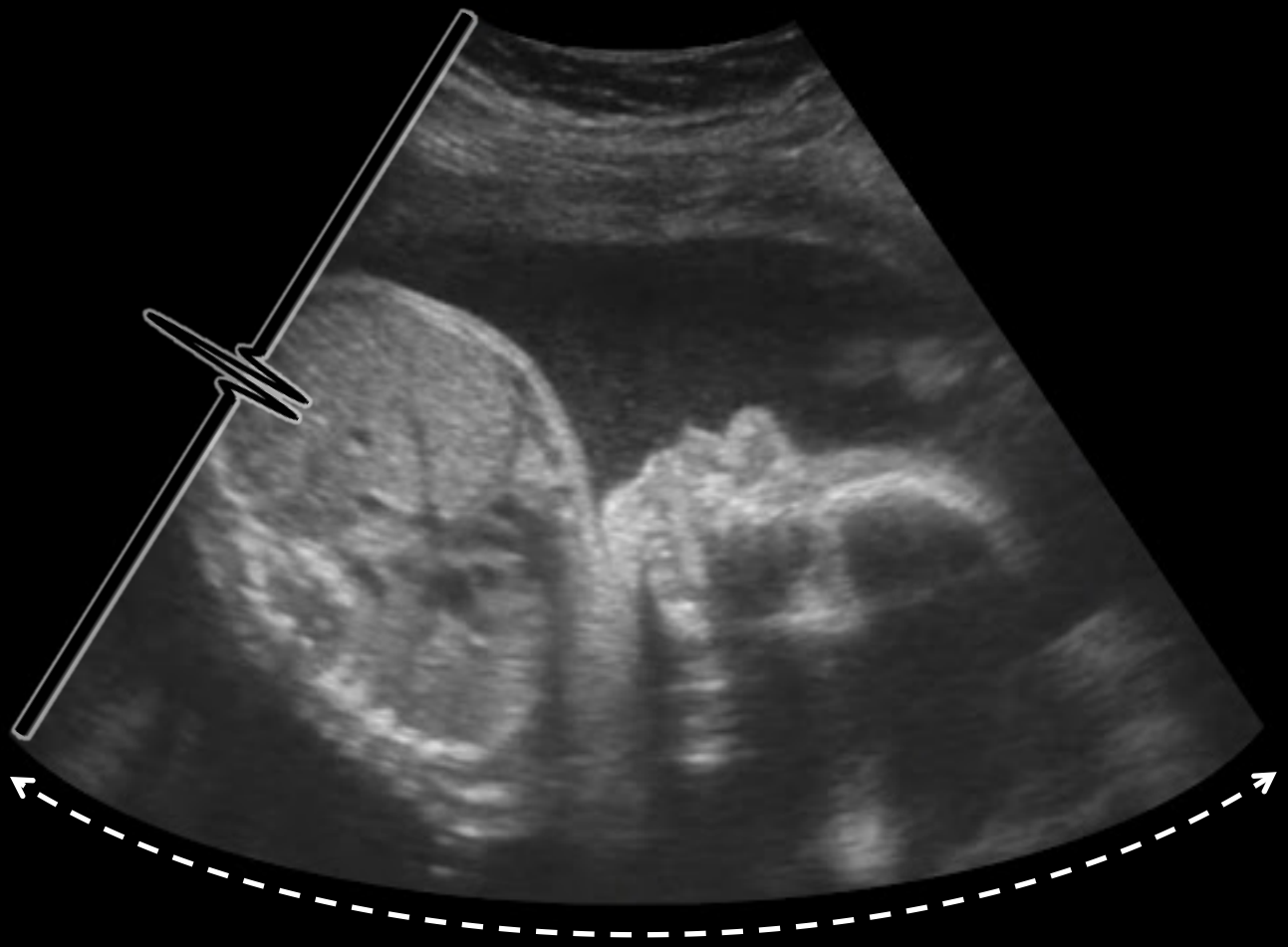
$$d = \frac{1}{4}\lambda$$

$$Z_m = \sqrt{Z_1 Z_2}$$

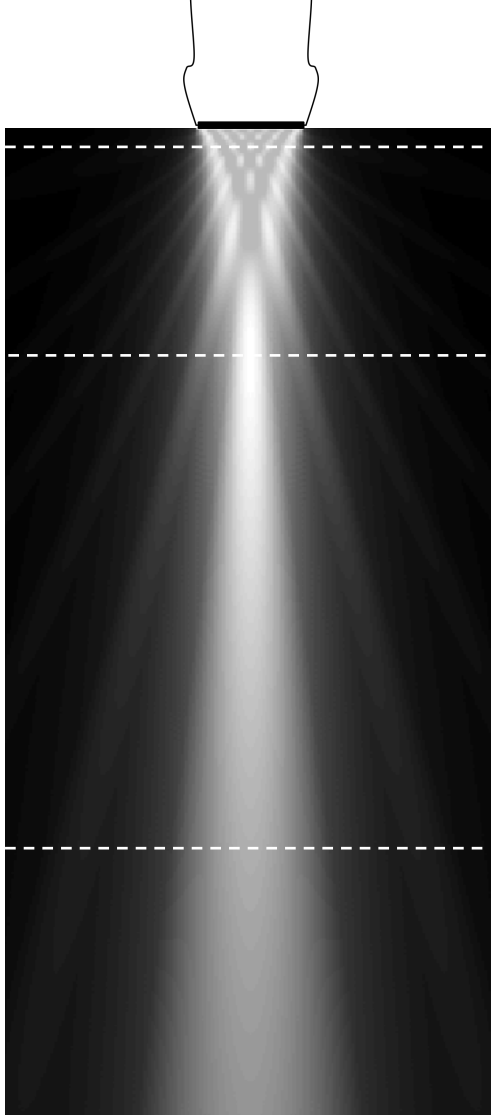
The Matching Layer



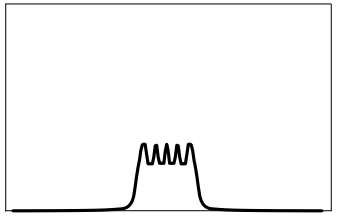
Ultrasound Probe



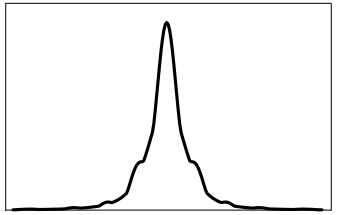
Lateral Resolution and Sensitivity



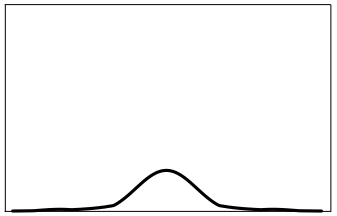
Near field



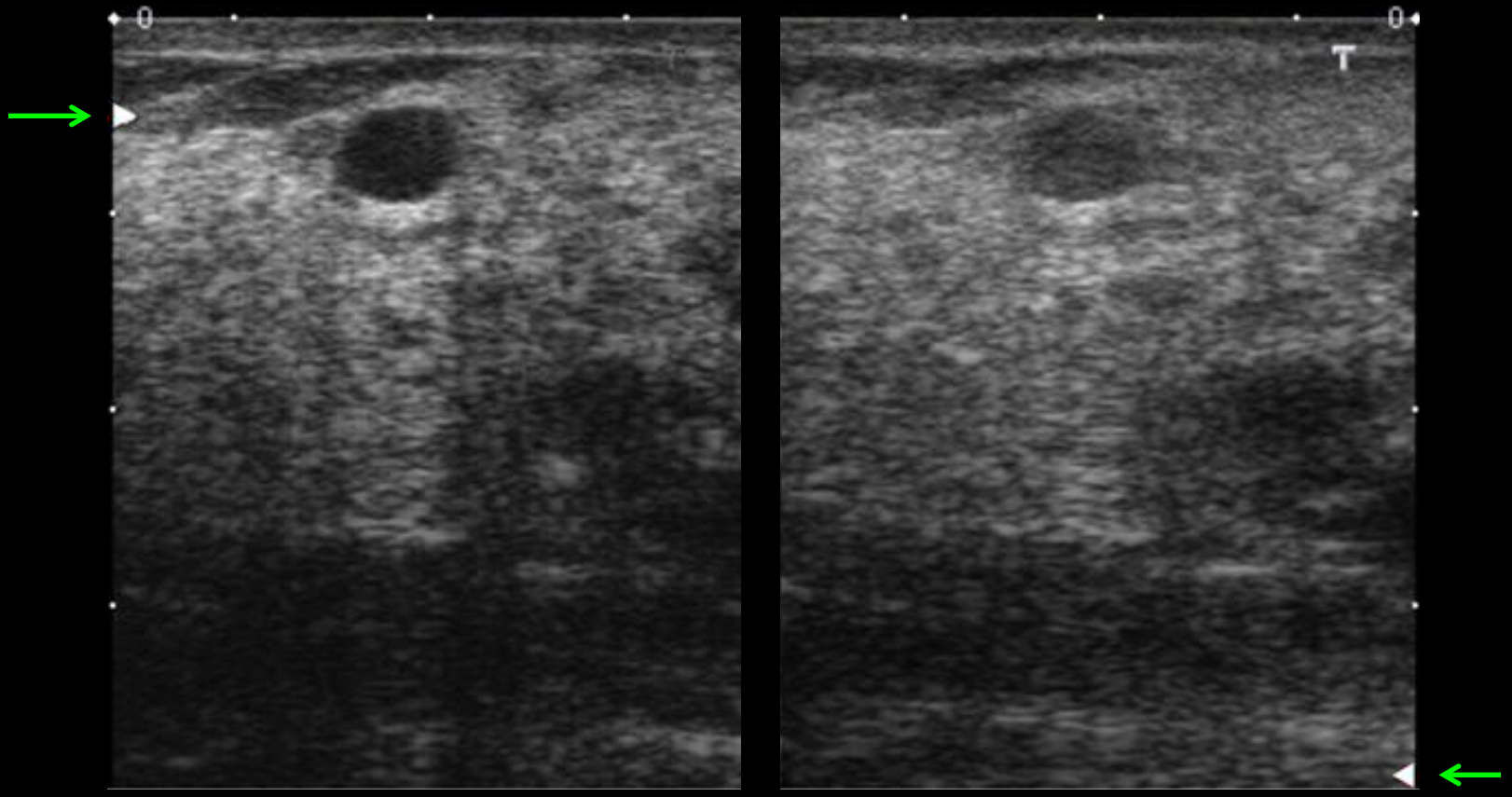
Focal Plane



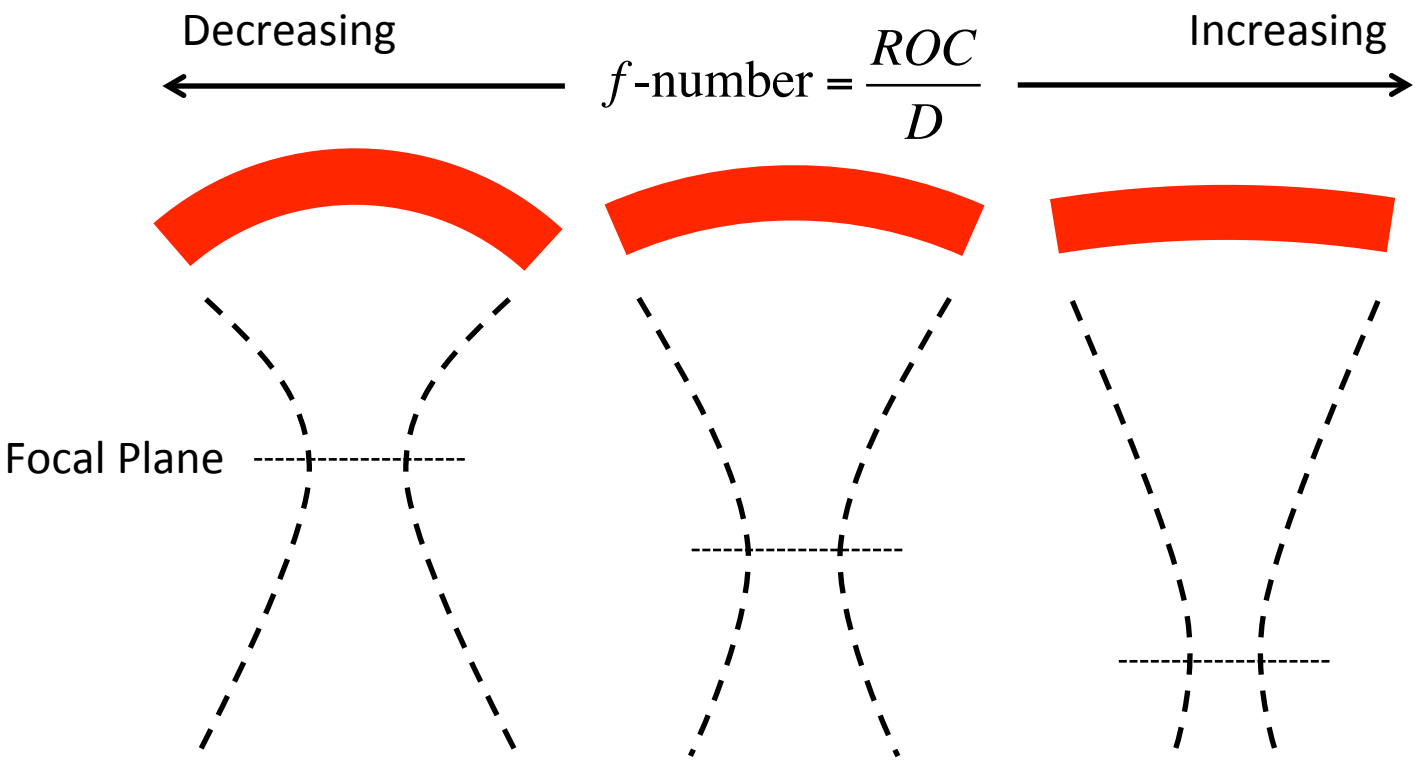
Far field



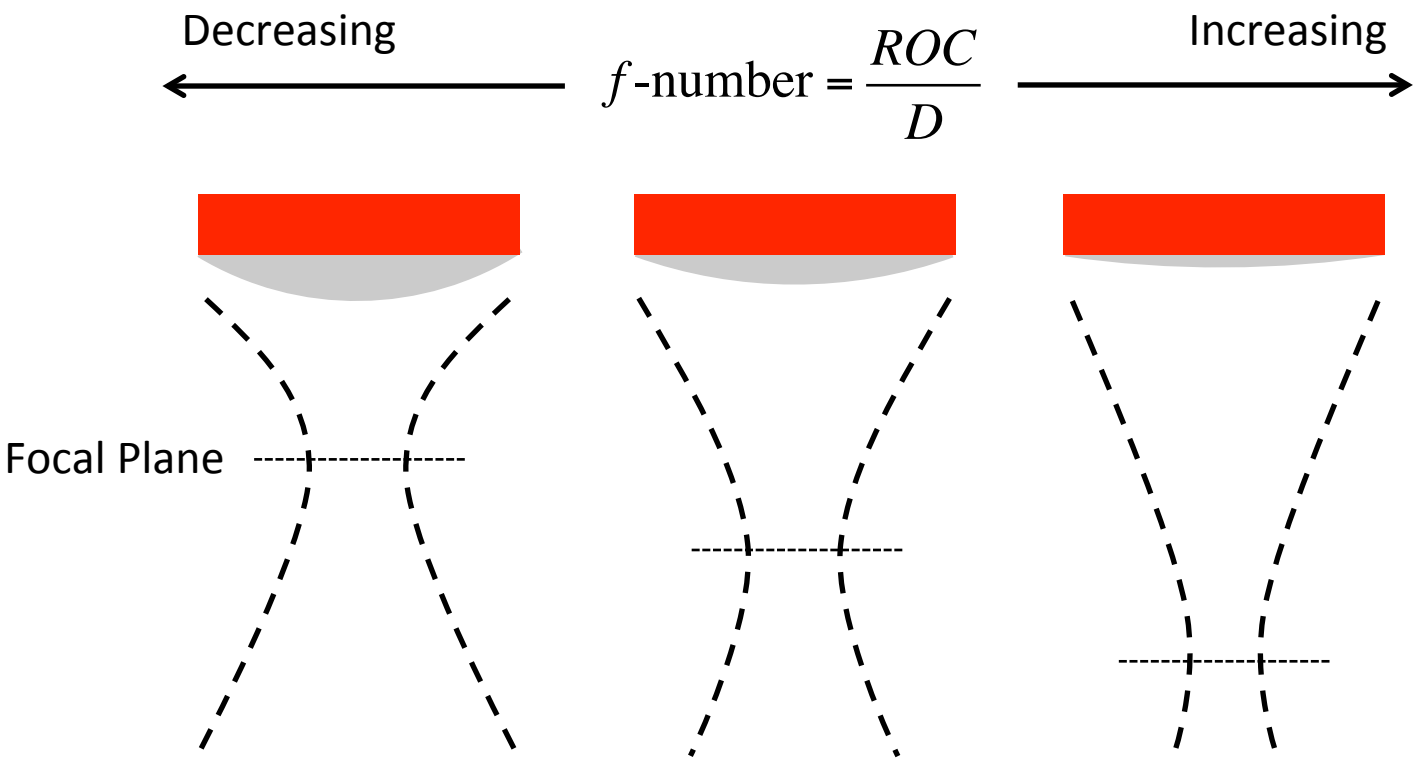
Lateral Resolution and Sensitivity



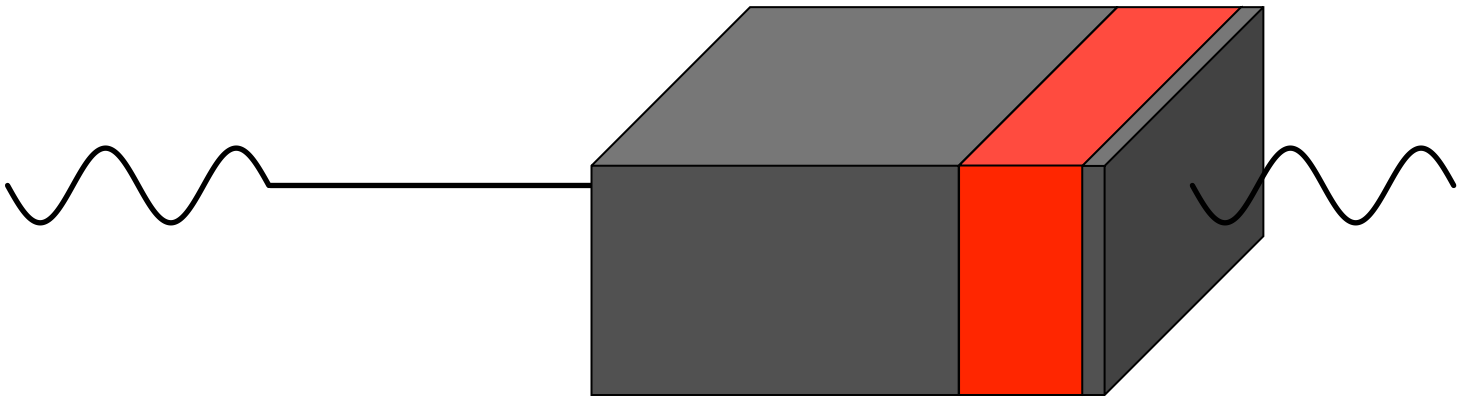
Lateral Resolution and Sensitivity



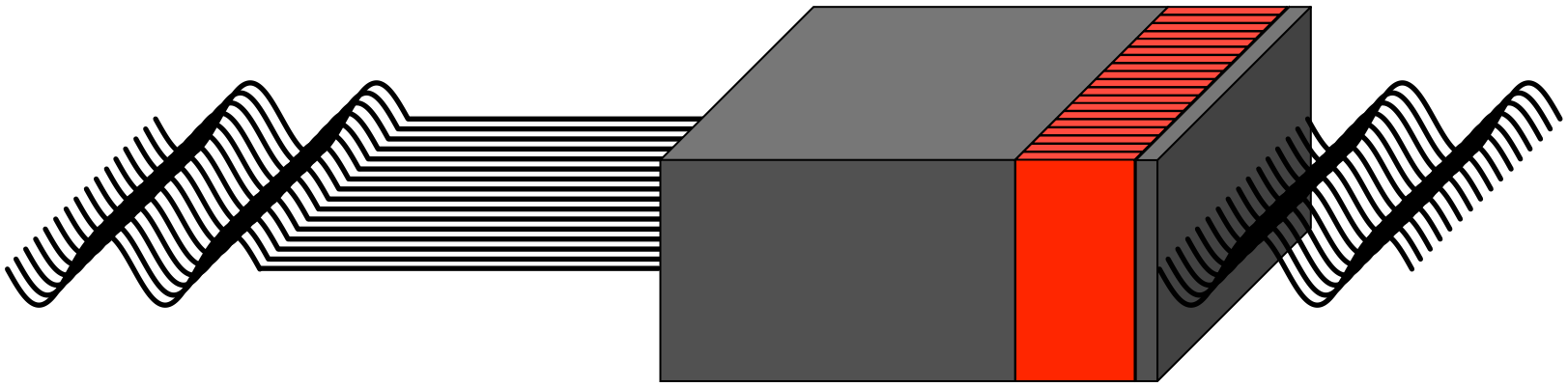
Focal Length Adjustment



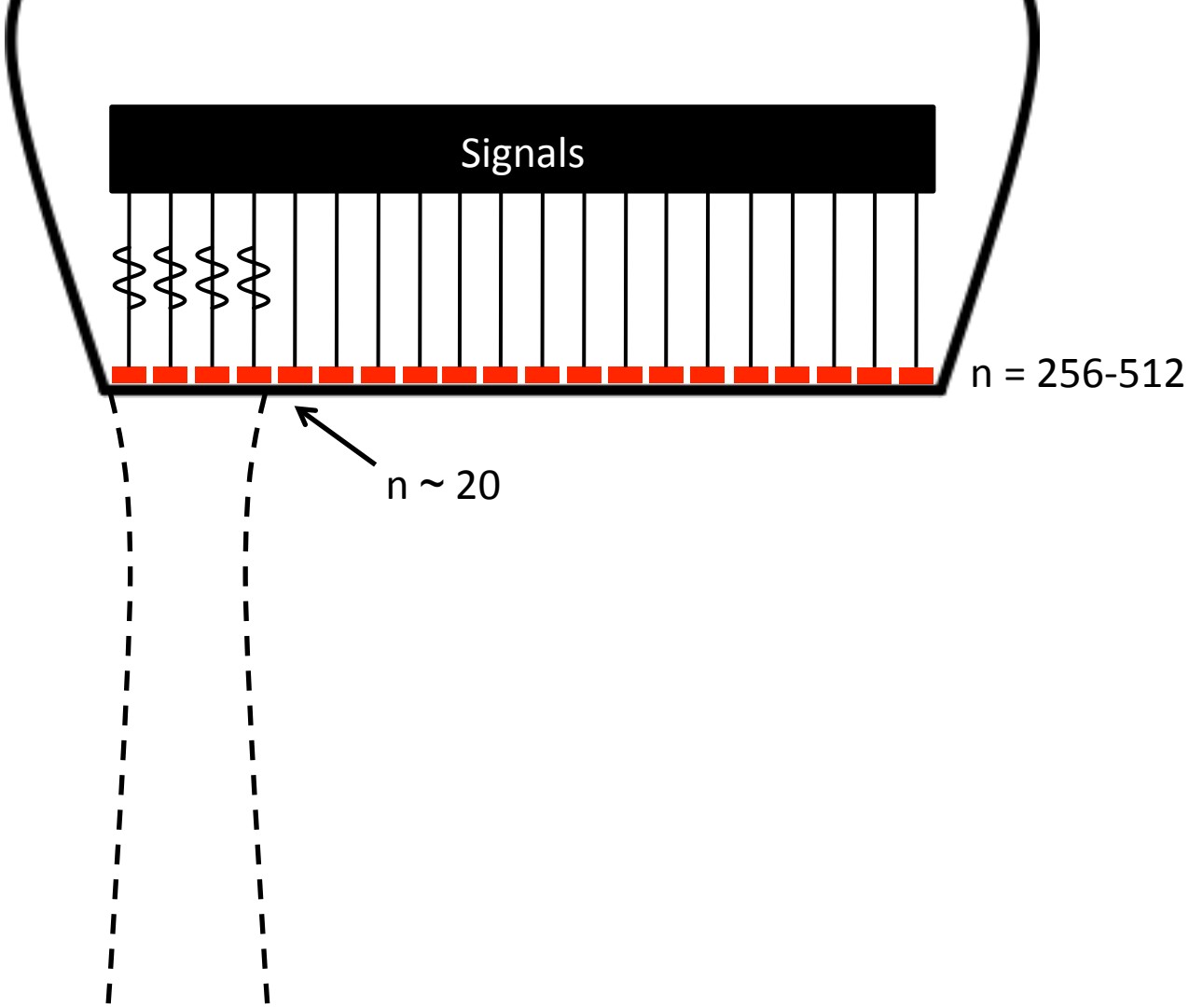
Focal Length Adjustment



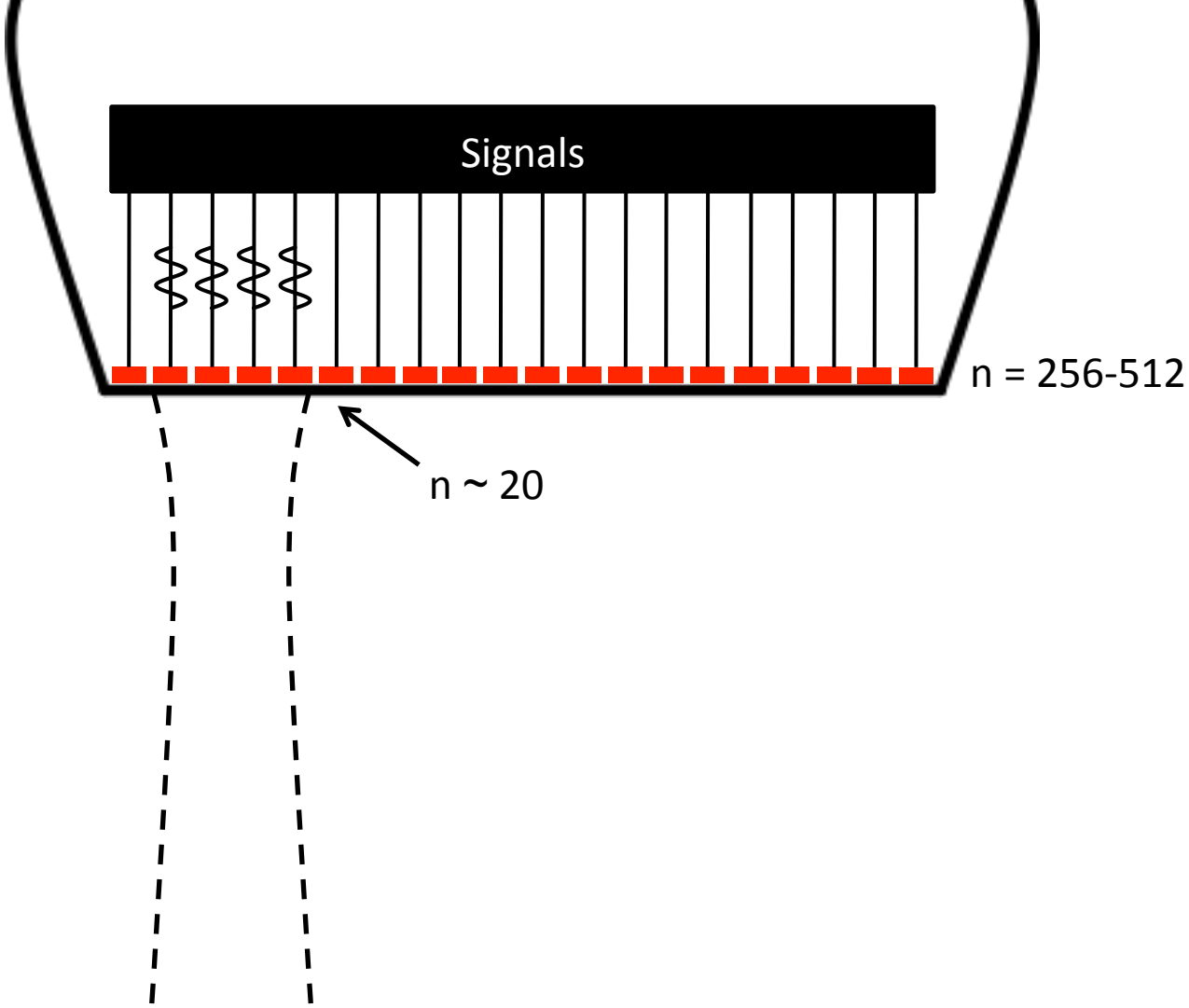
Single-Element Transducer Construction



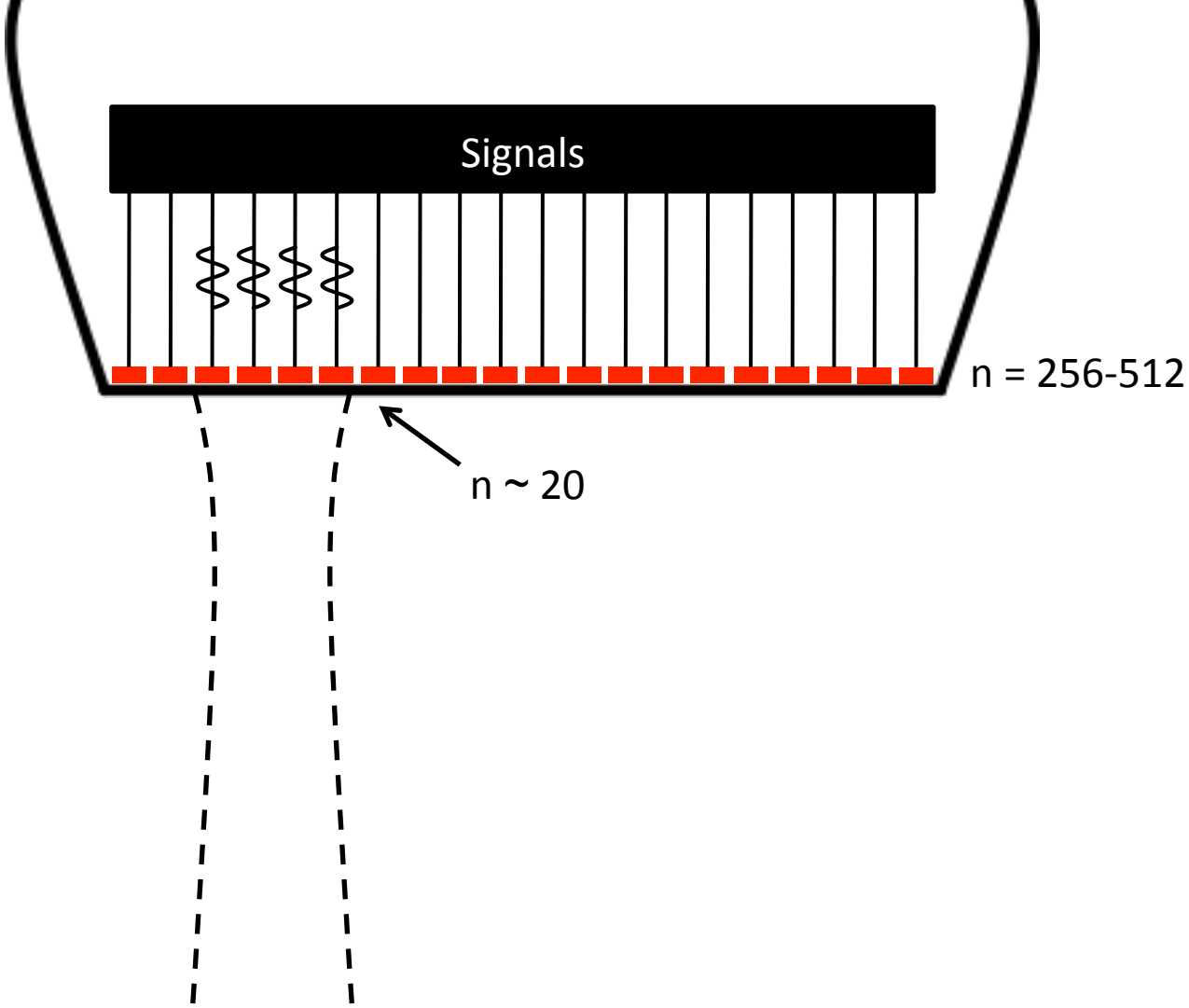
Transducer Segmentation



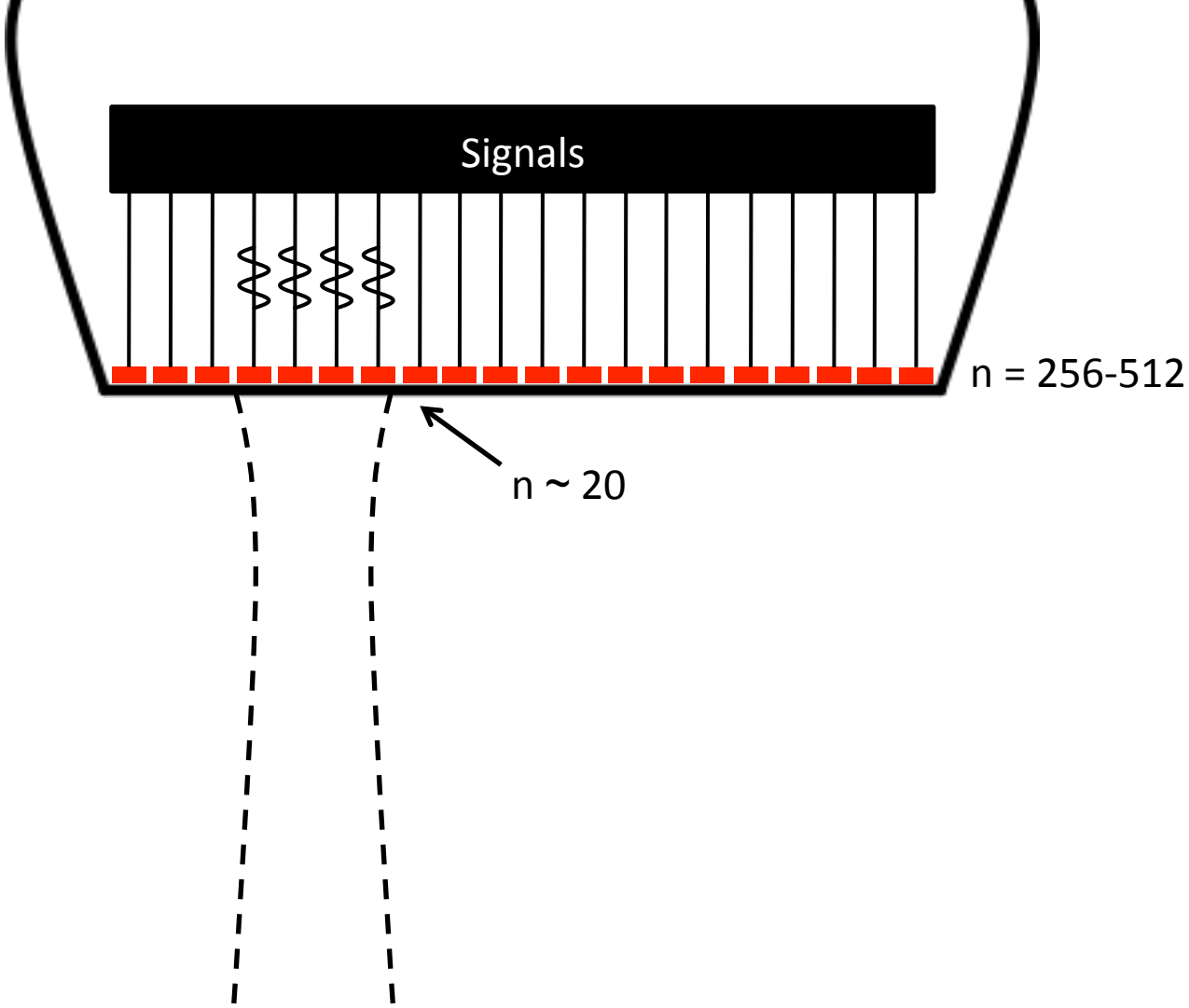
Linear Arrays



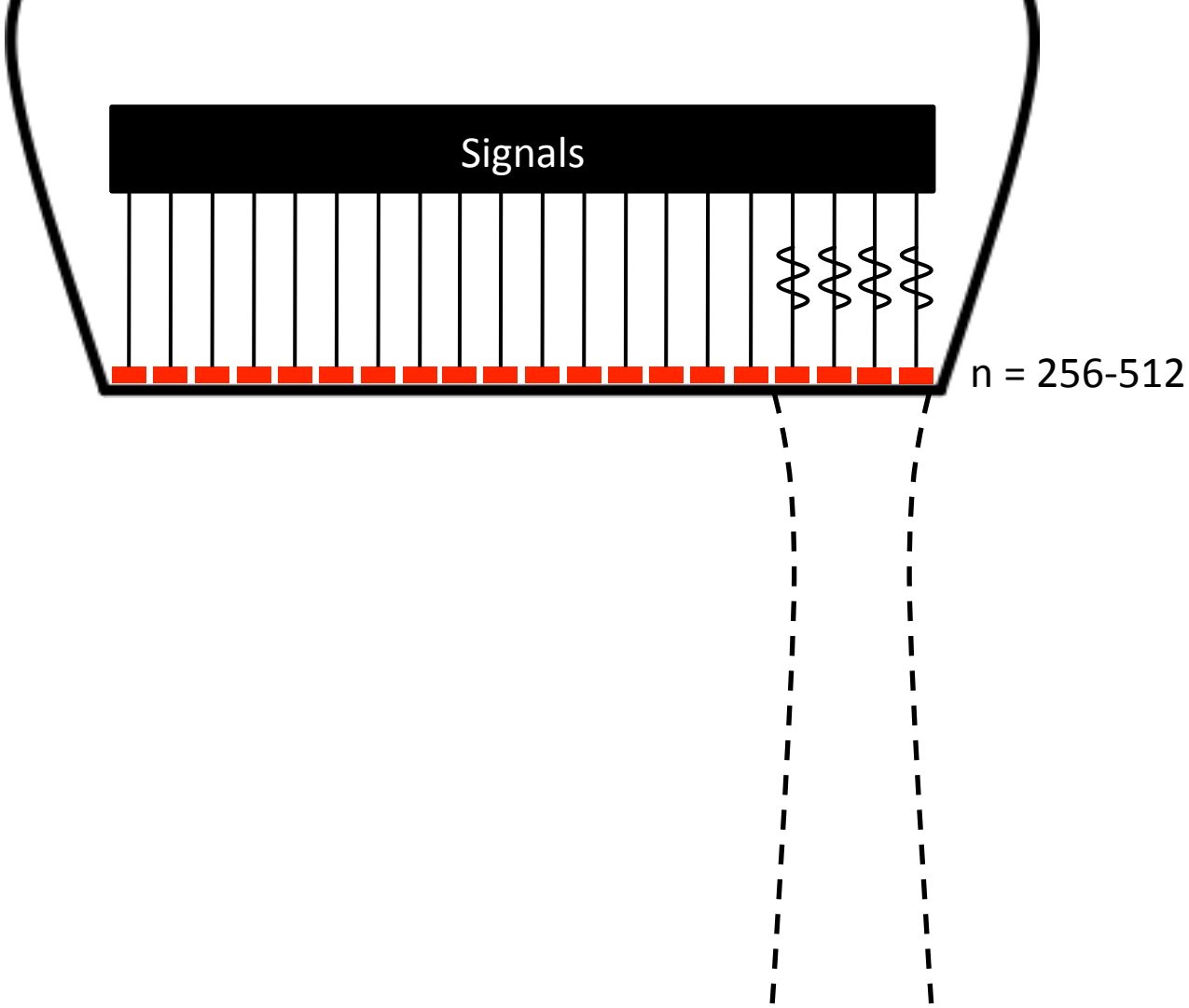
Linear Arrays



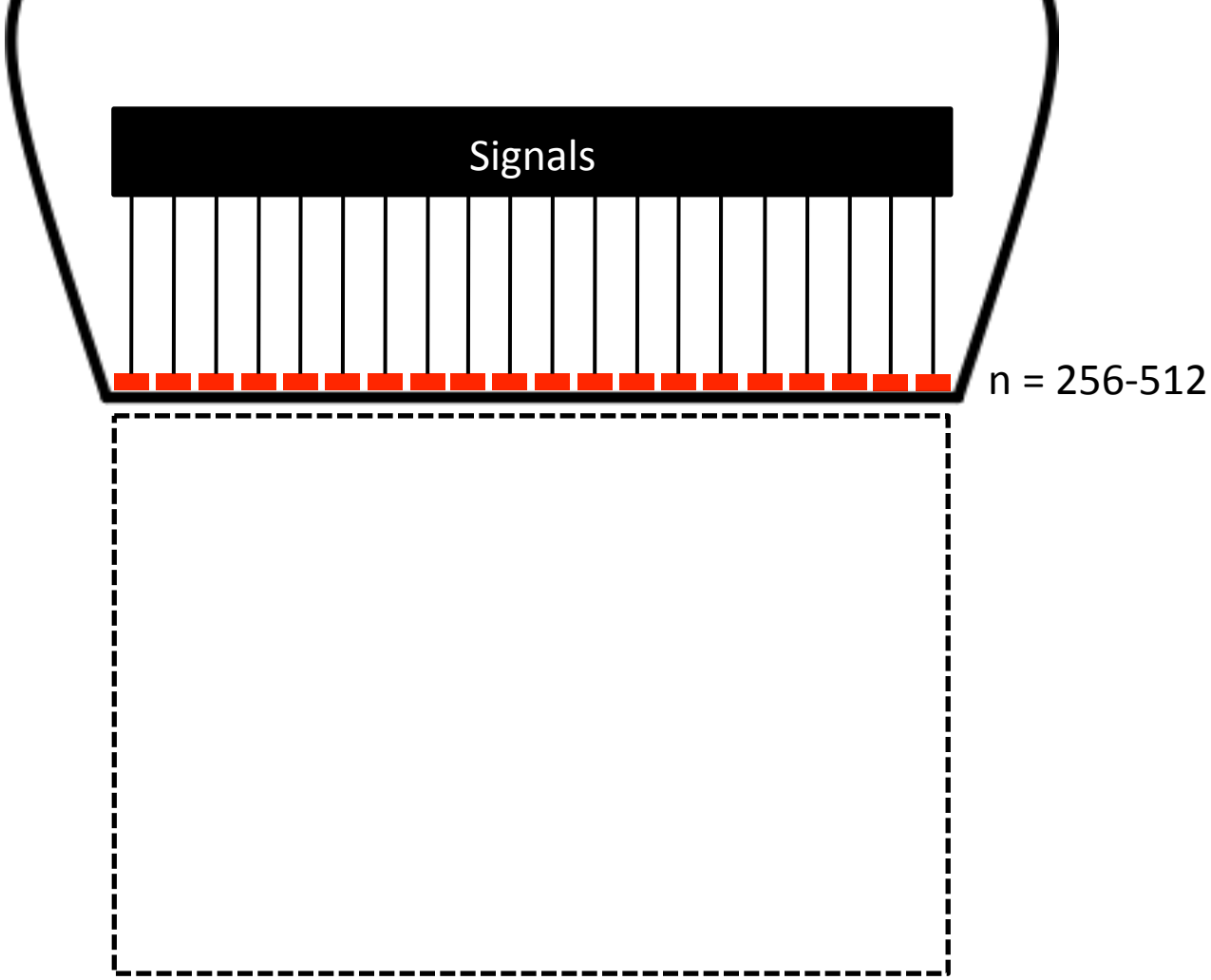
Linear Arrays



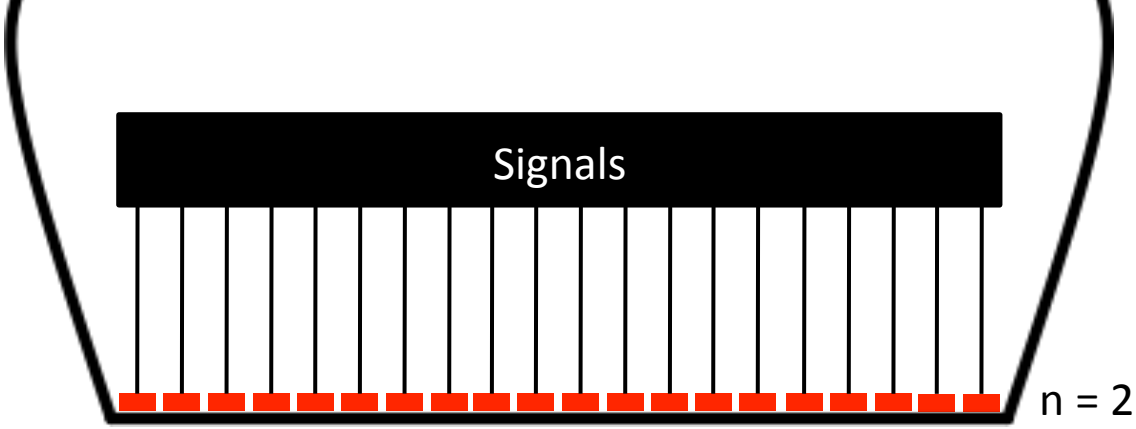
Linear Arrays



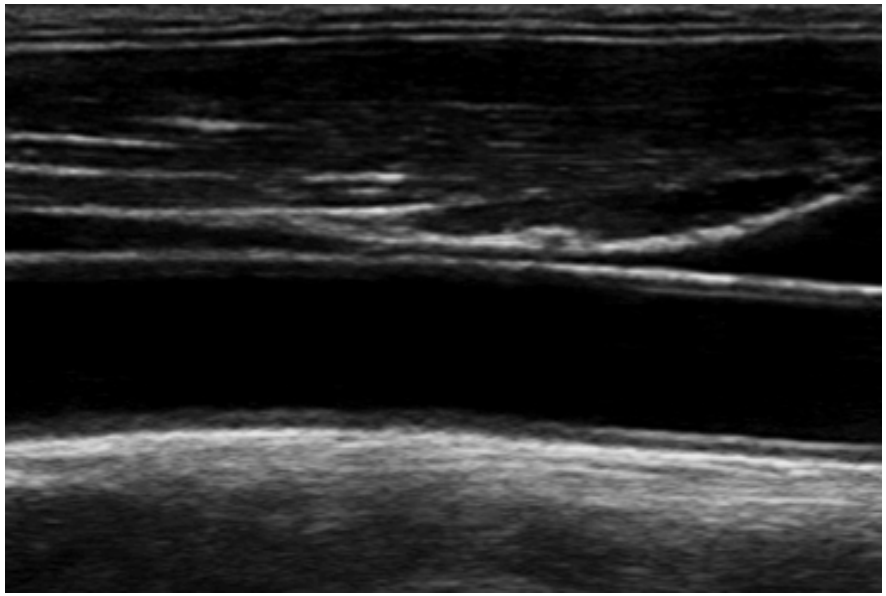
Linear Arrays



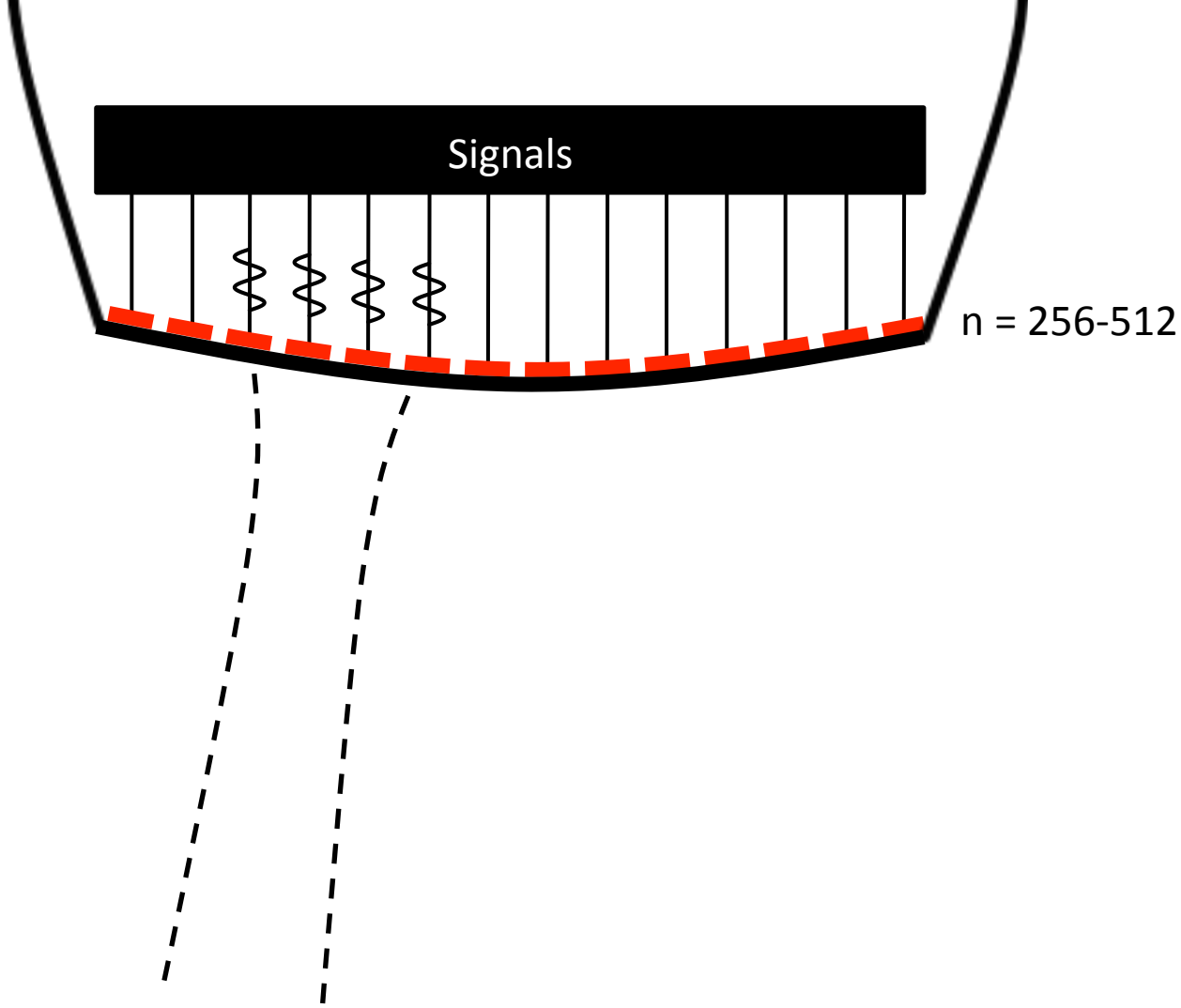
Linear Arrays



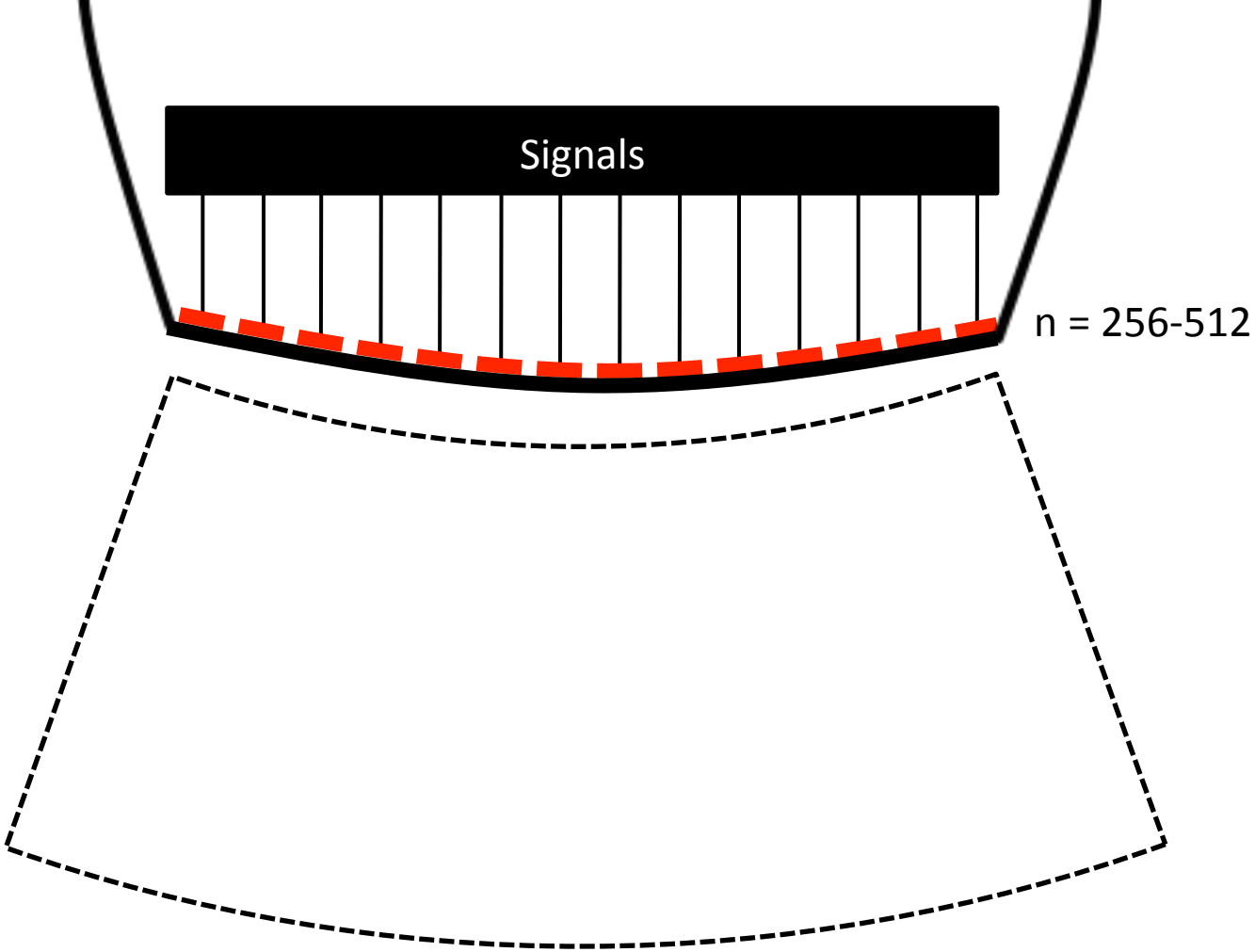
n = 256-512



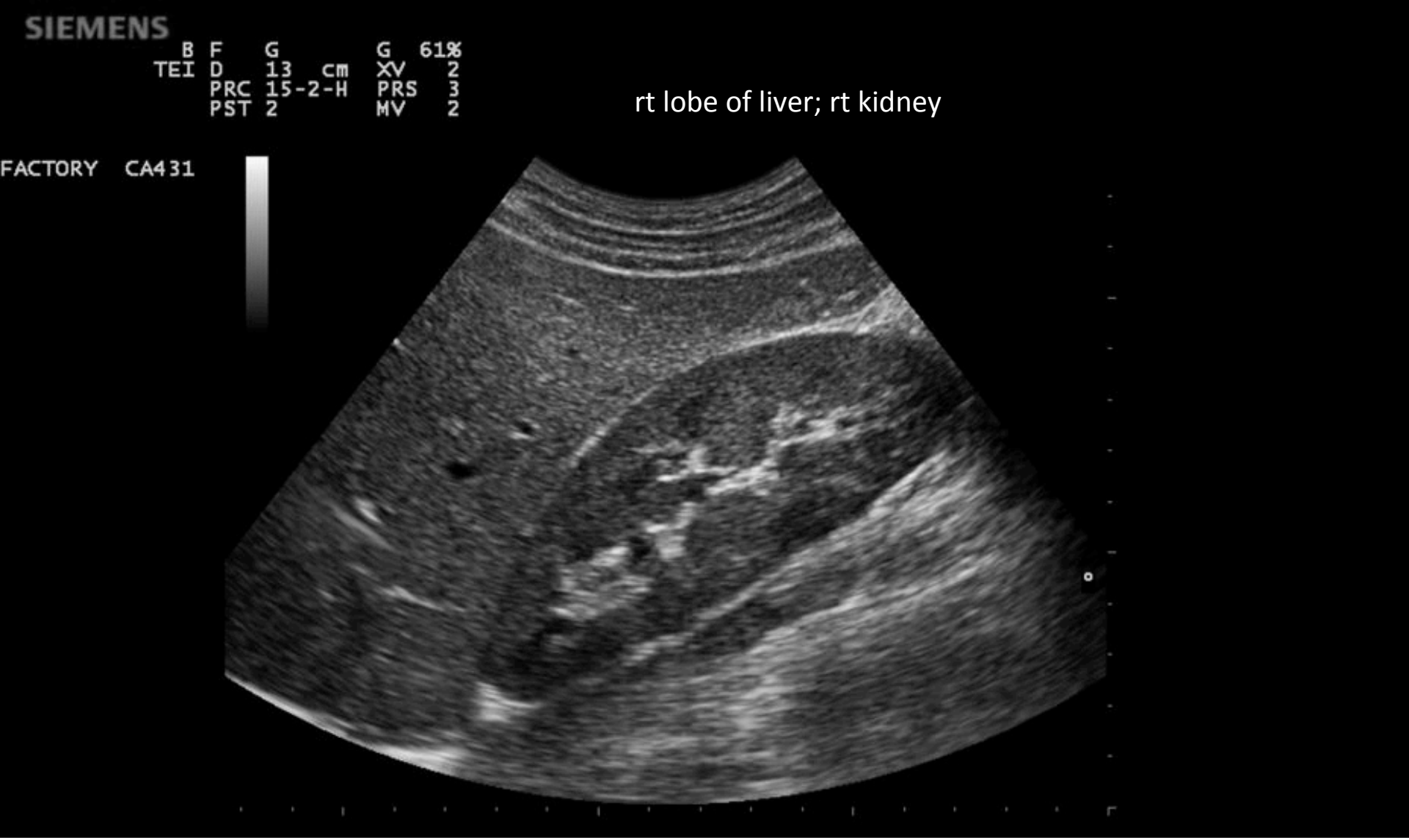
Linear Arrays



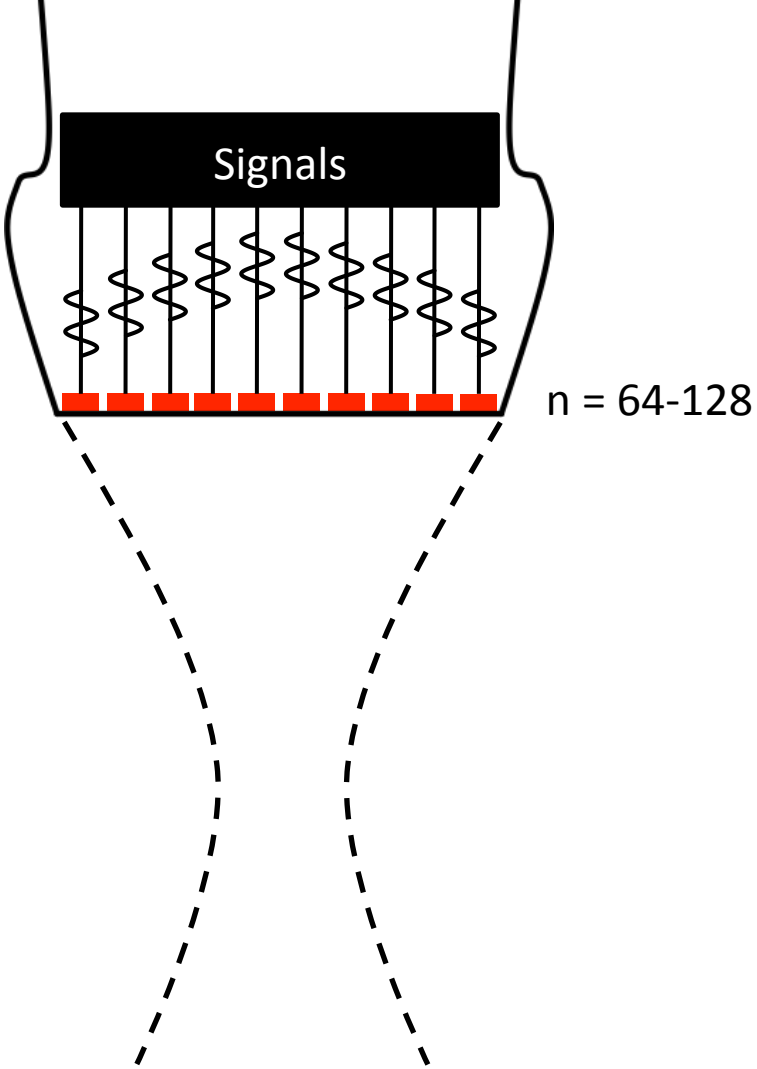
Curvilinear Arrays



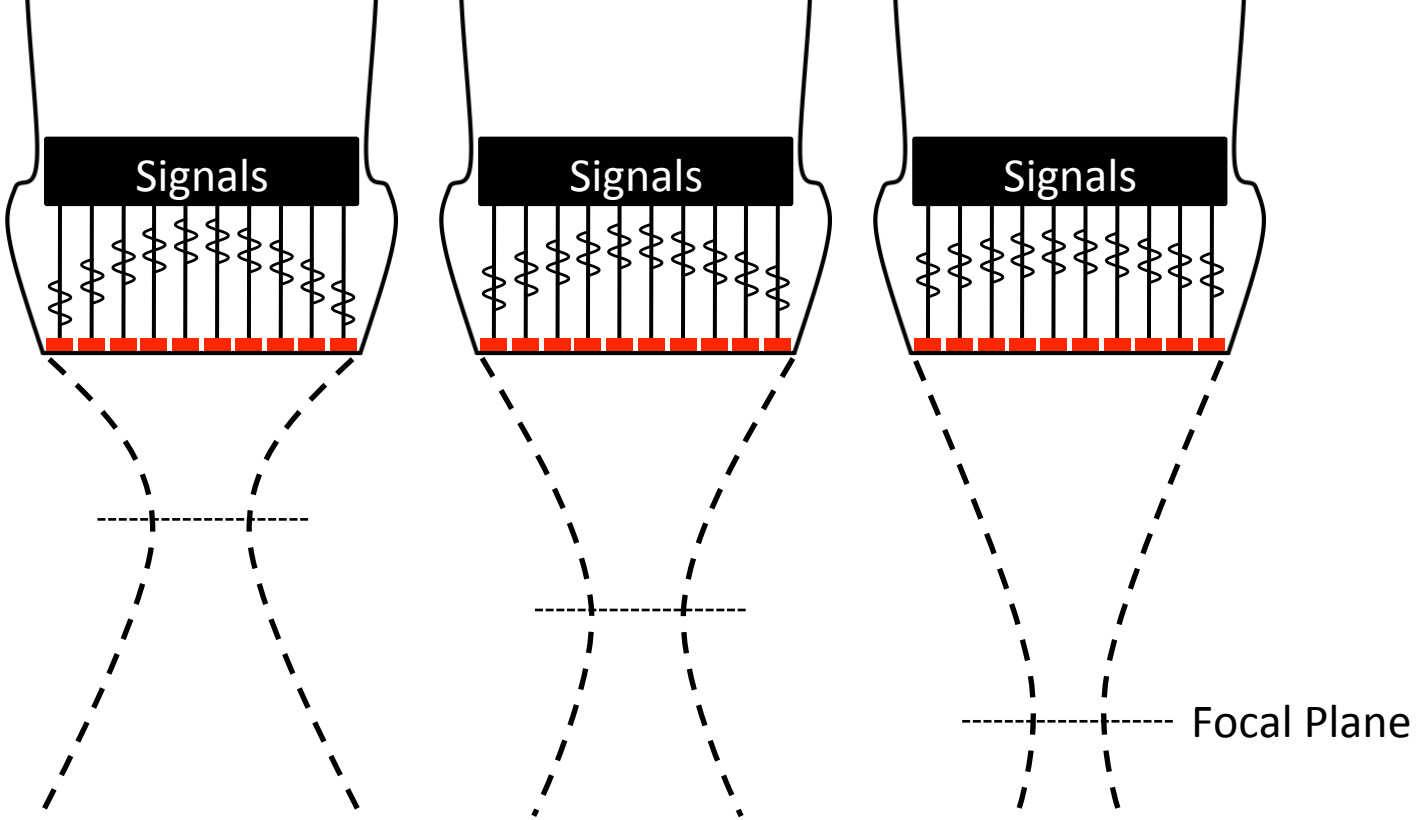
Curvilinear Arrays



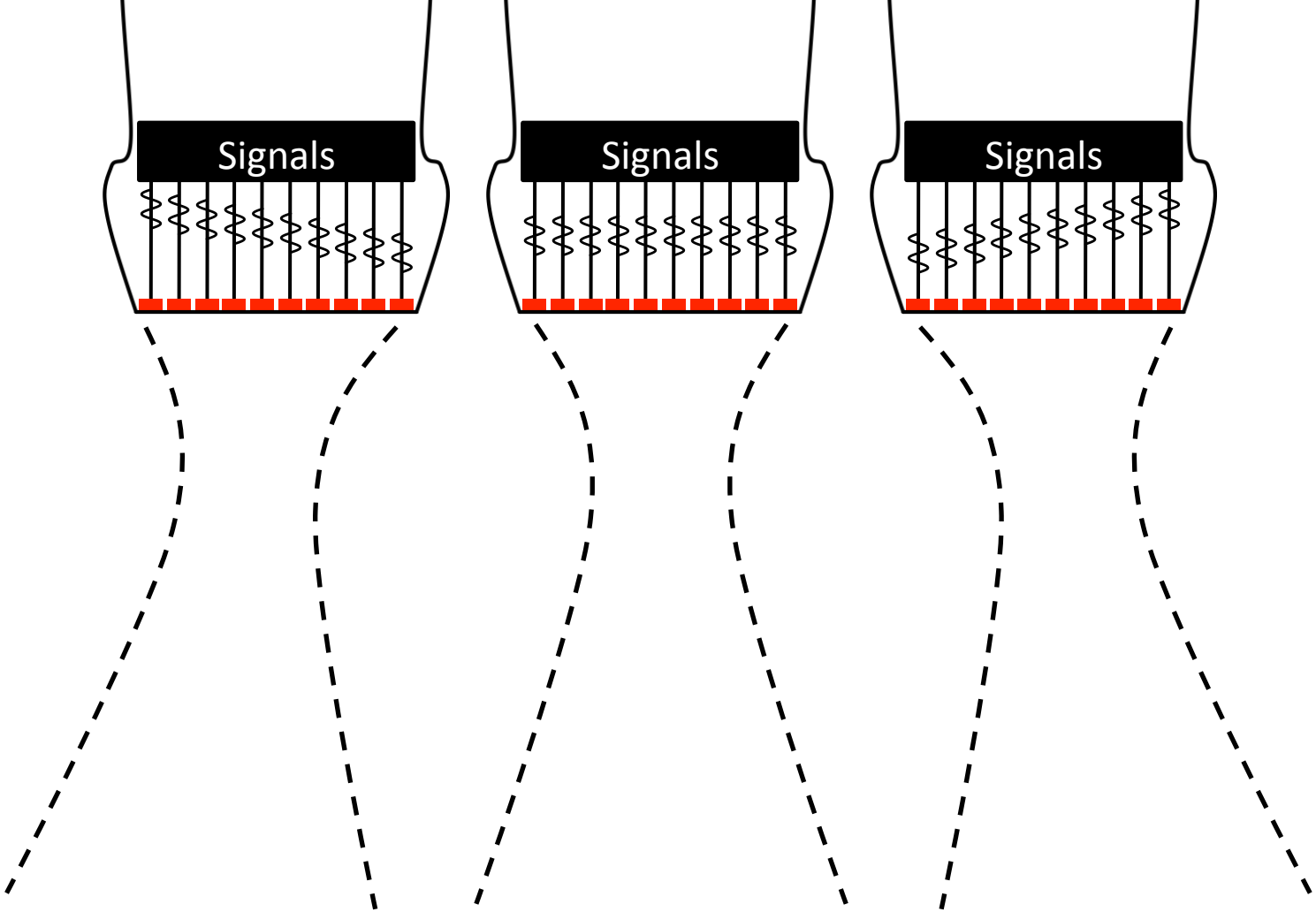
Curvilinear Arrays



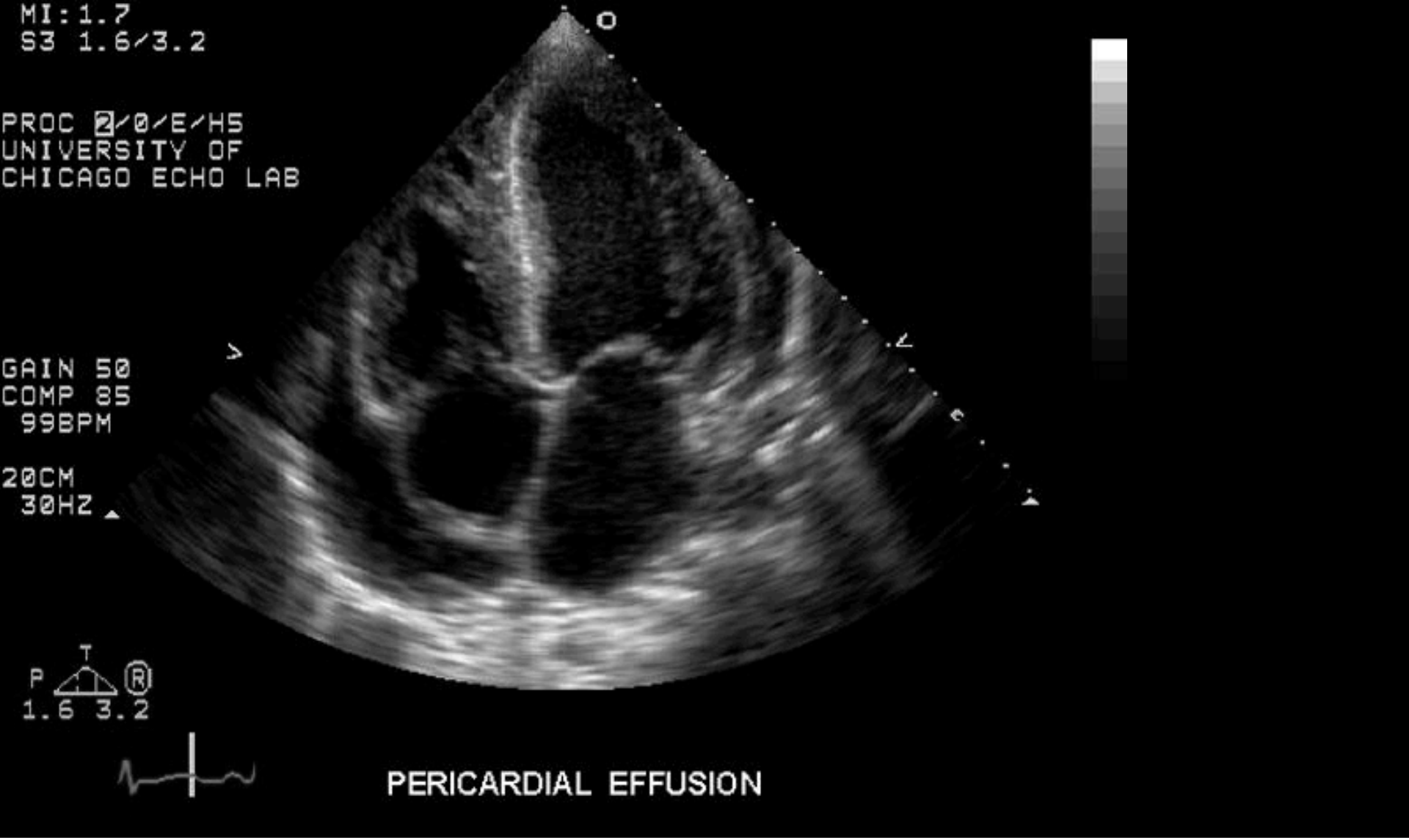
Phased Arrays



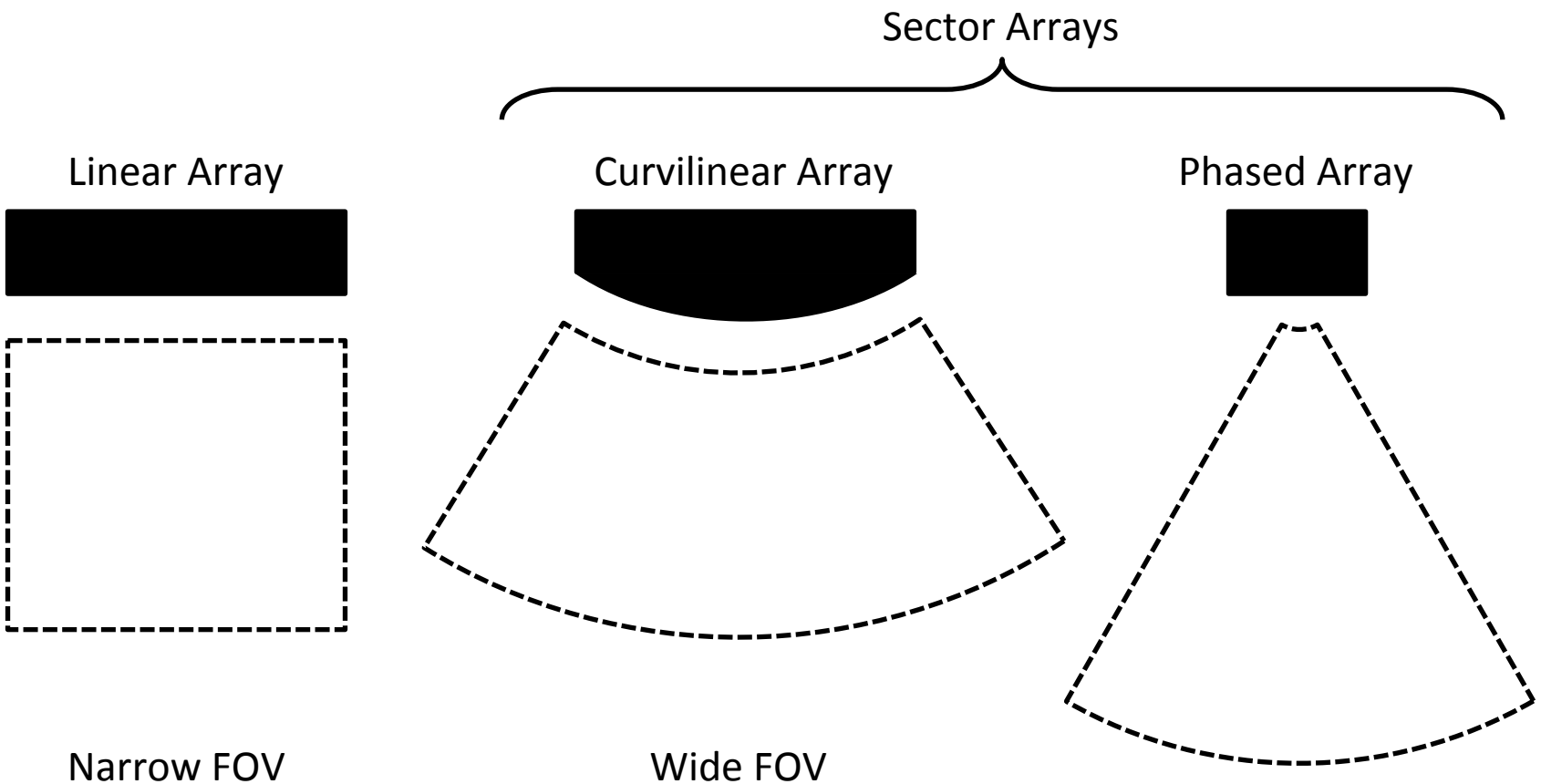
Phased Arrays



Phased Arrays



Phased Arrays



Ultrasound Probe

Sector Arrays

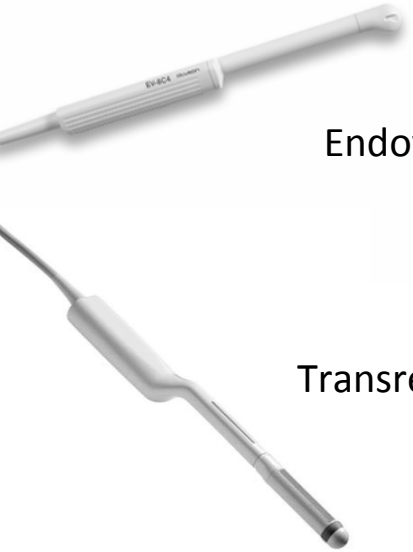
Linear Array

Curvilinear Array

Phased Array

Ultrasound Probe

Semi-invasive

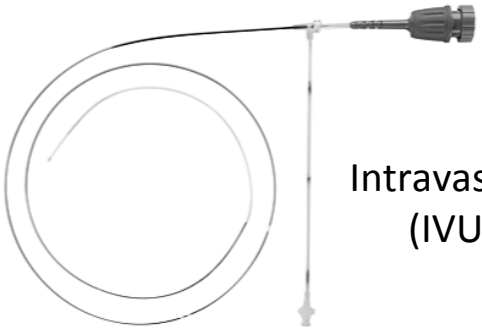


Endovaginal

Transrectal

Transesophageal

Invasive



Intravascular (IVUS)

Intracardiac

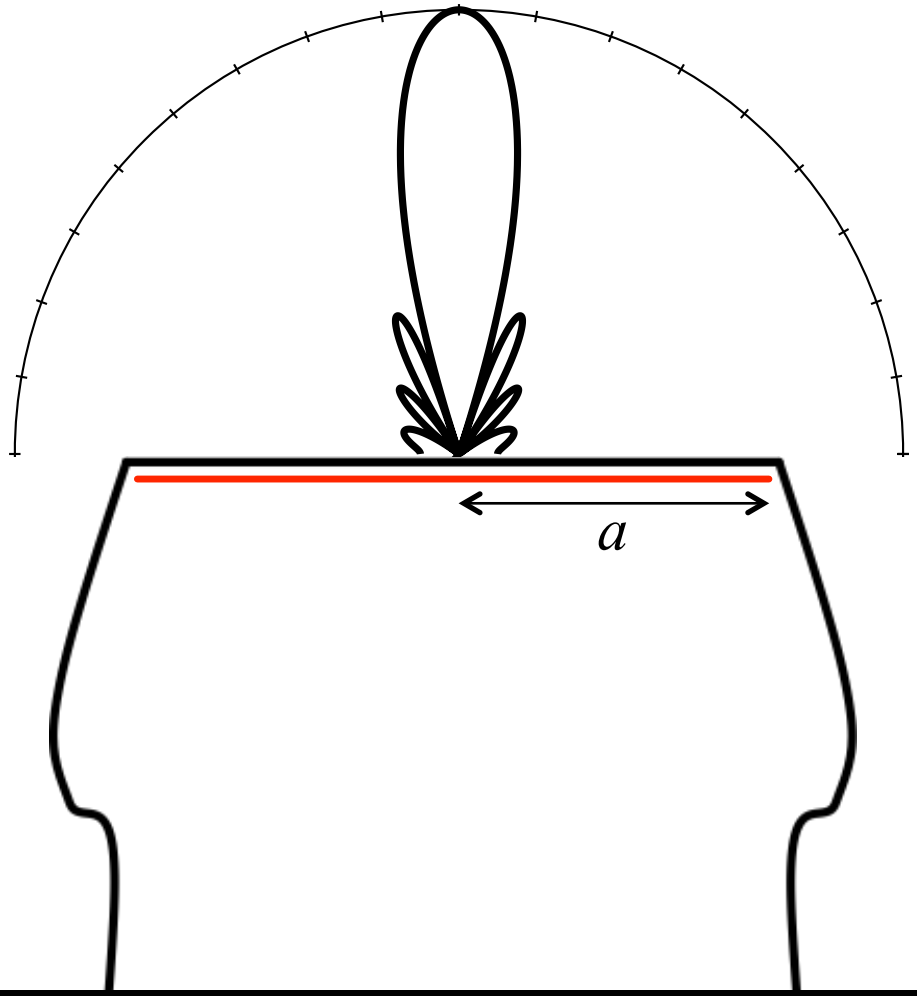
Intraoperative

Burr hole

Laparascopic

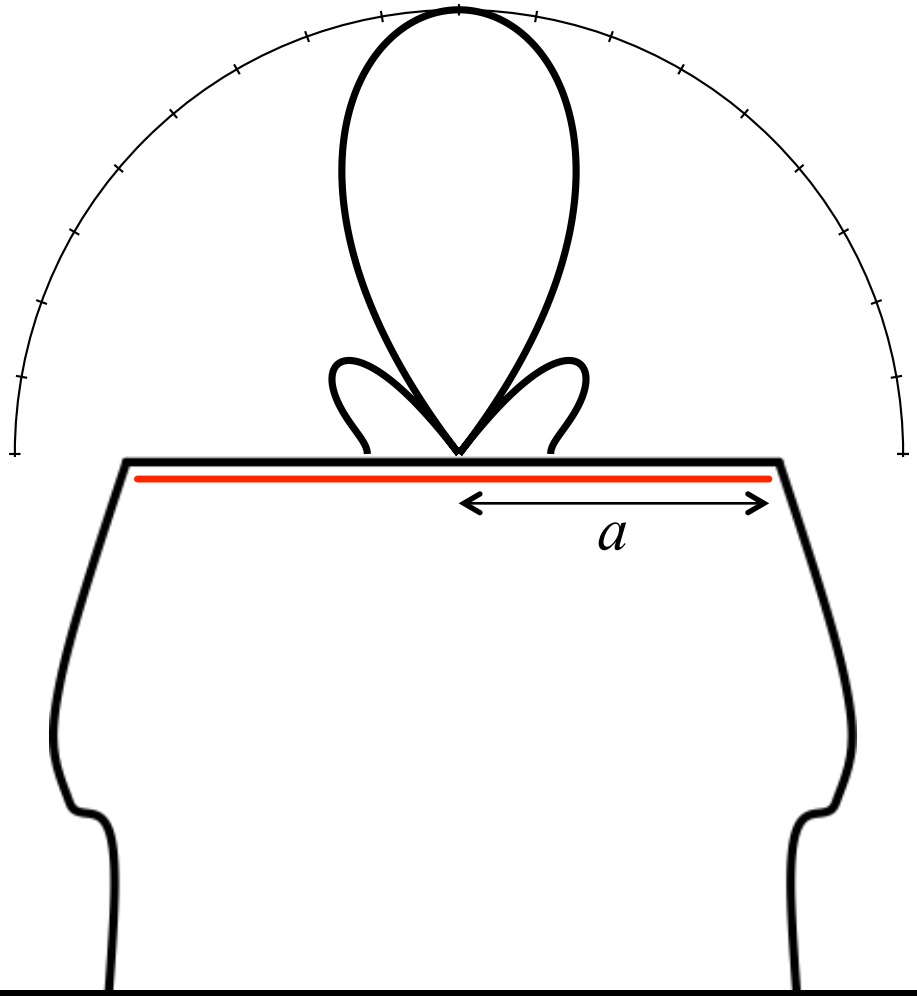
Robotic drop-in

Ultrasound Probe



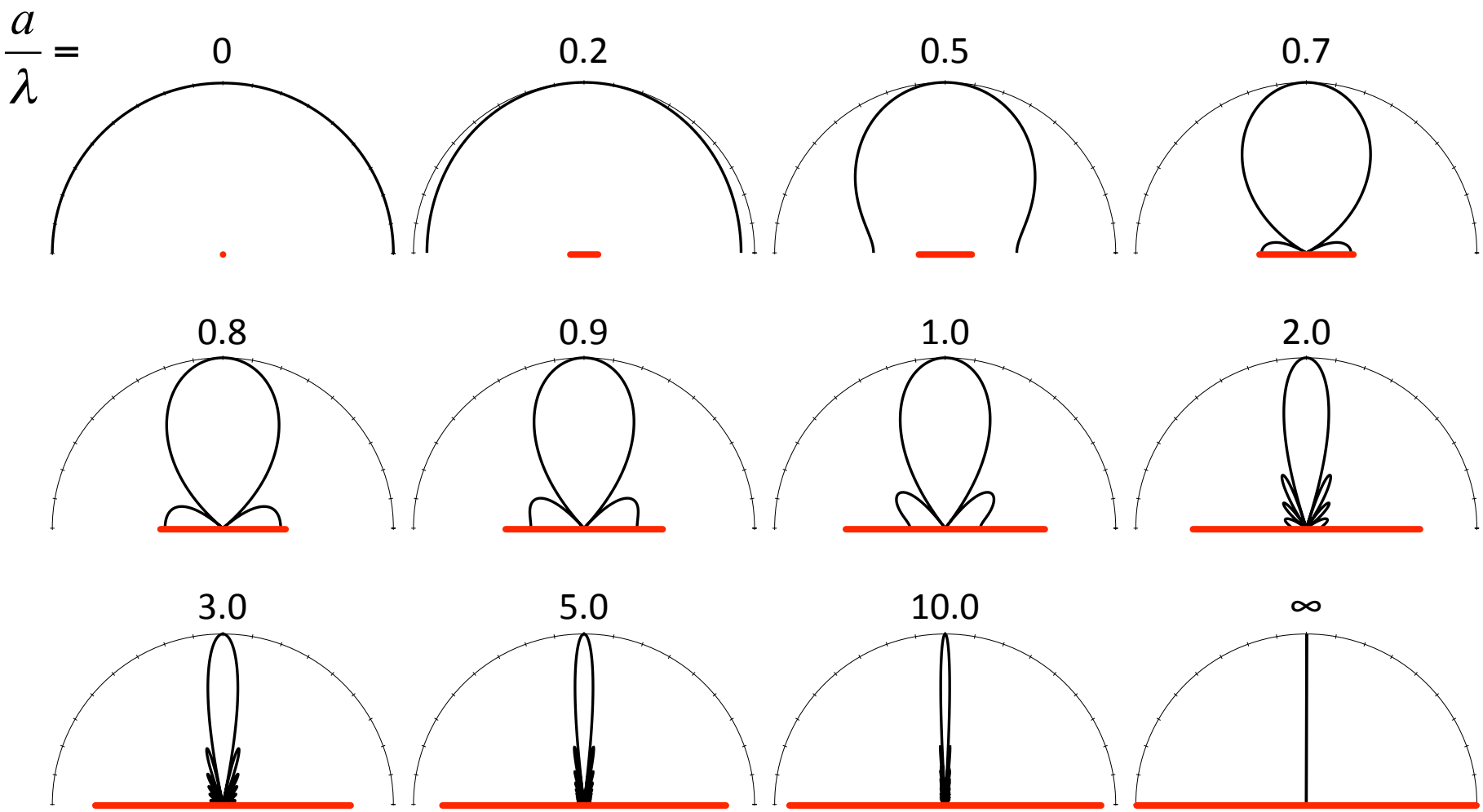
$$\frac{a}{\lambda} = 2.0$$

Beamforming (Sidelobes)

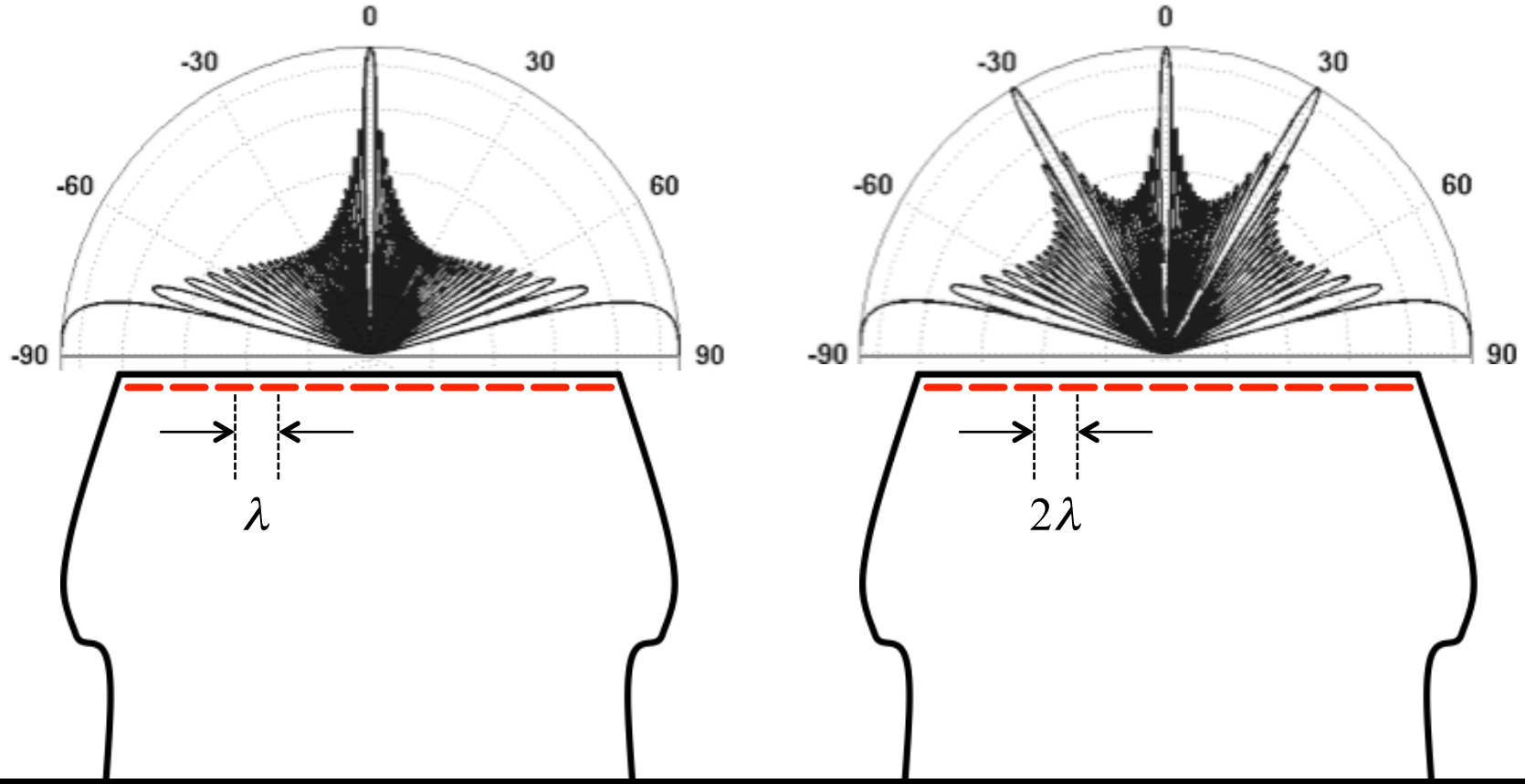


$$\frac{a}{\lambda} = 1.0$$

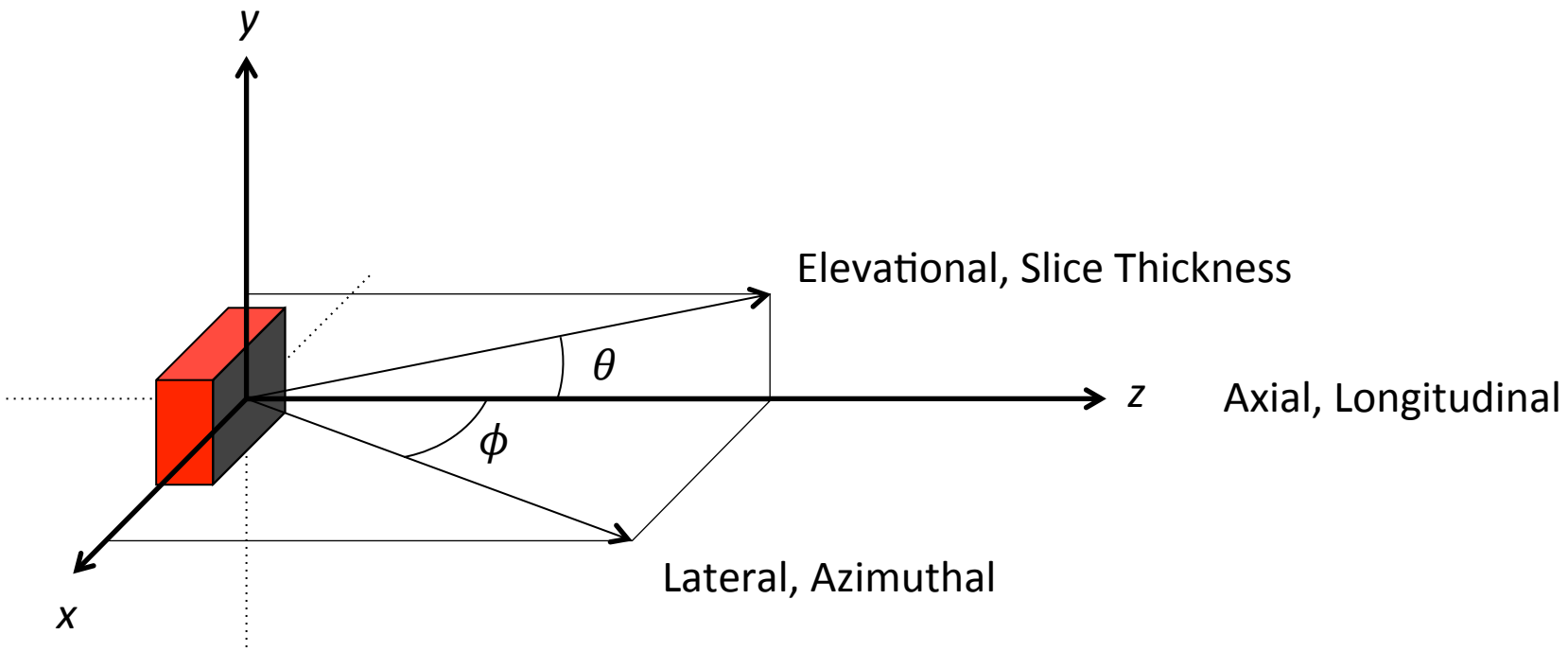
Beamforming (Sidelobes)



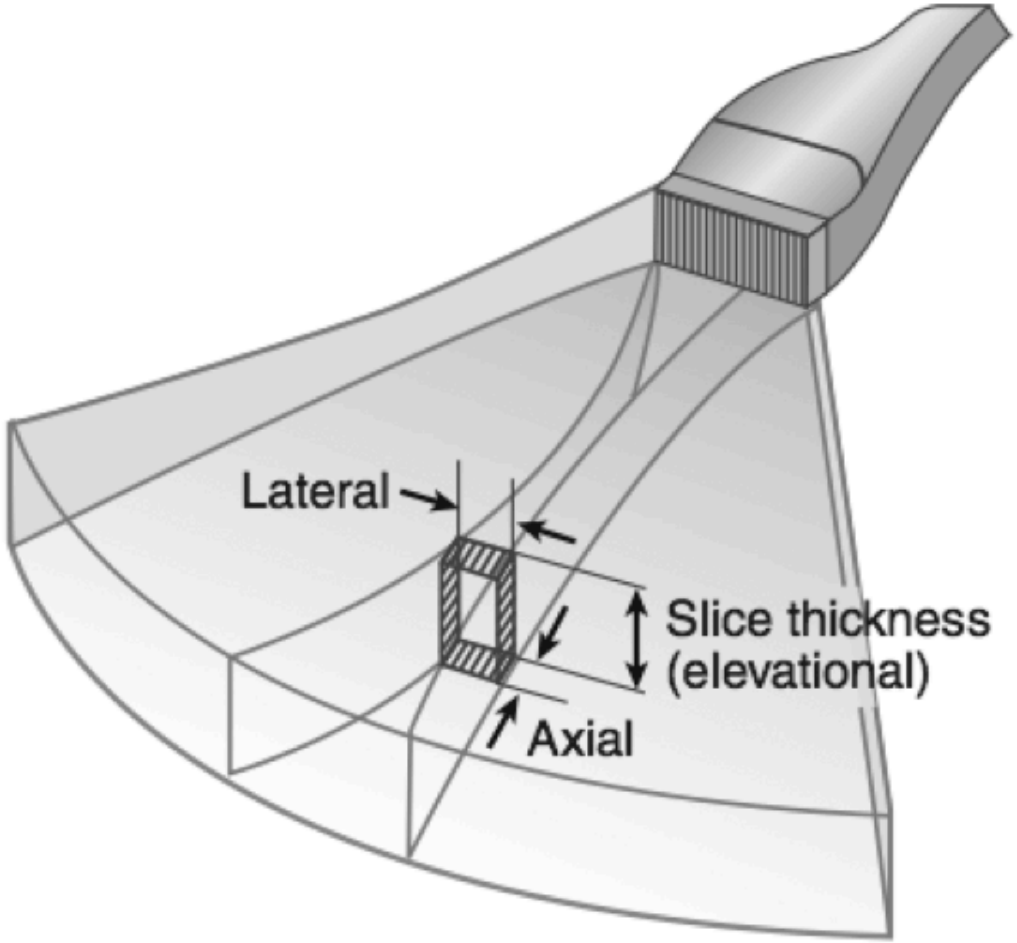
Beamforming (Sidelobes)



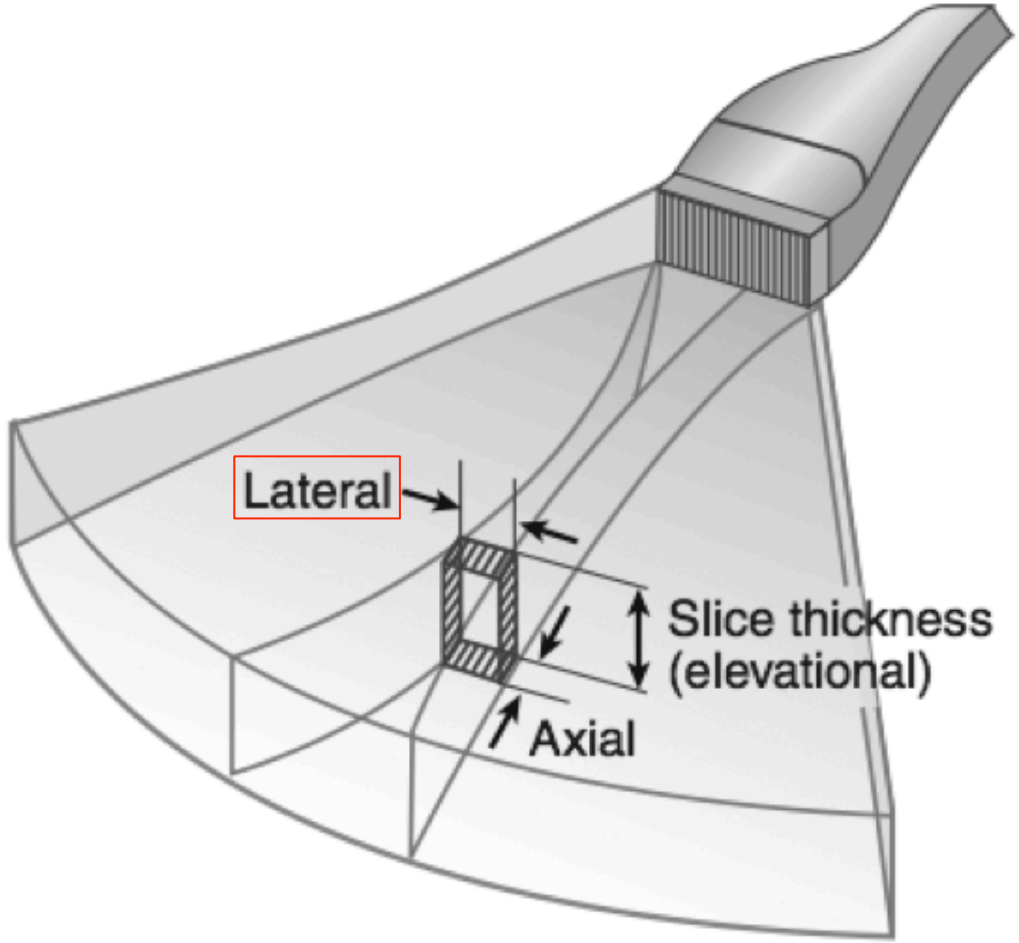
Beamforming (Grating Lobes)



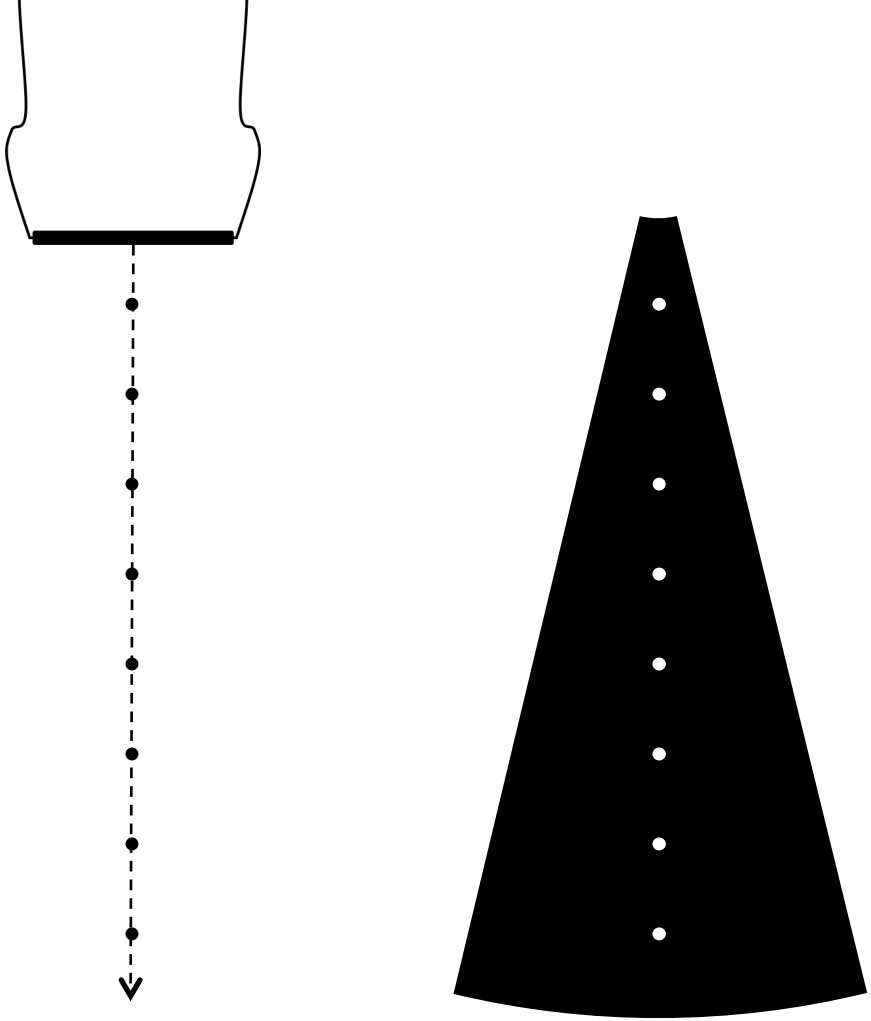
Spatial Resolution



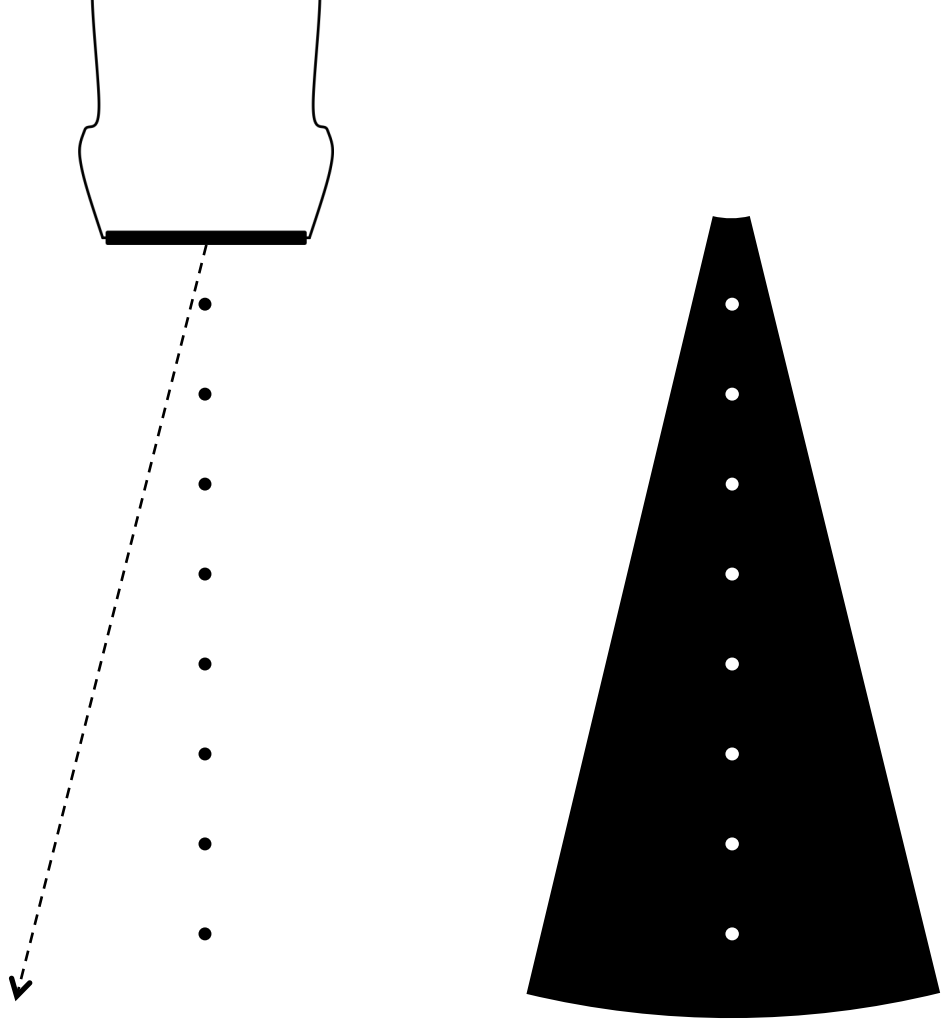
Spatial Resolution



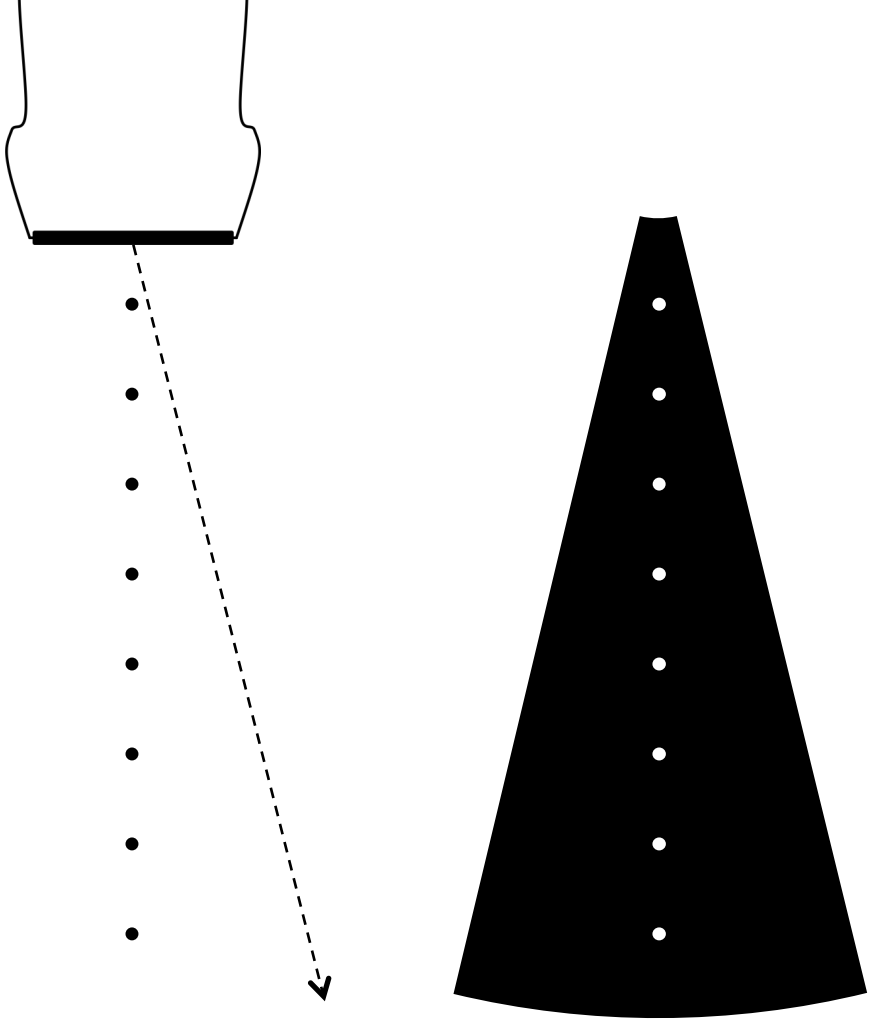
Lateral (Azimuthal) Resolution



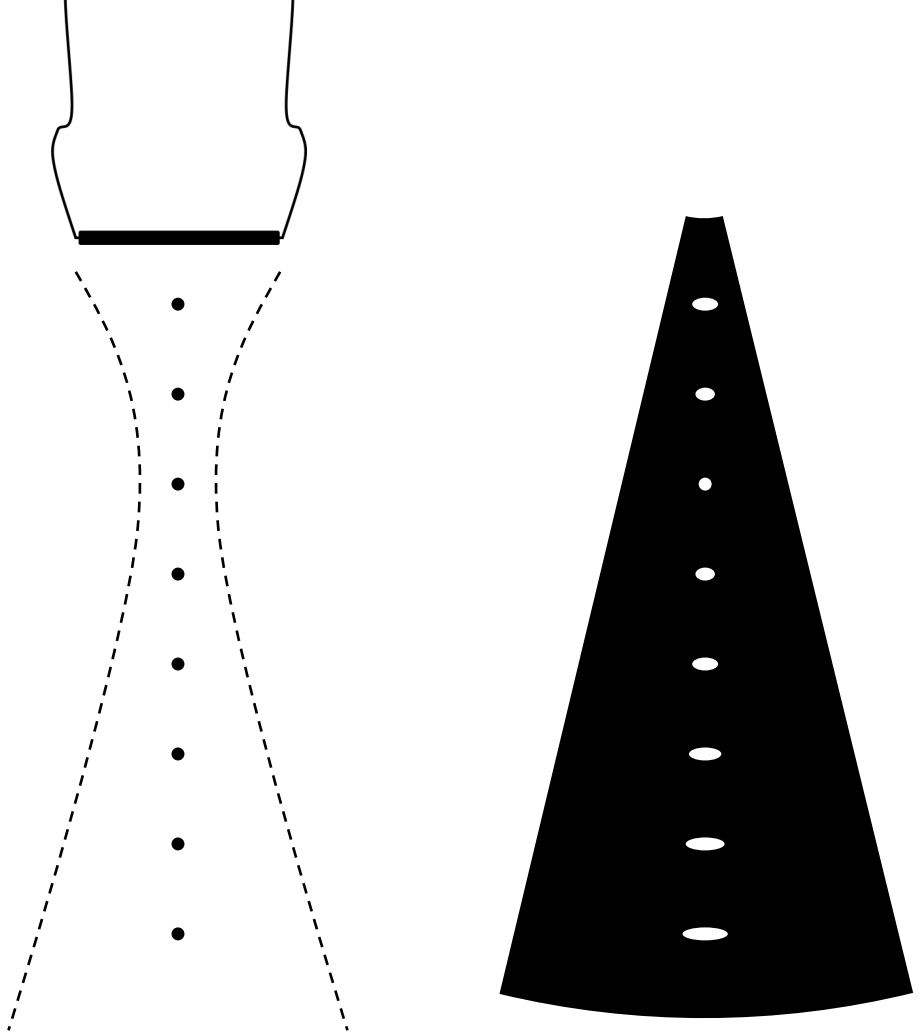
Lateral (Azimuthal) Resolution



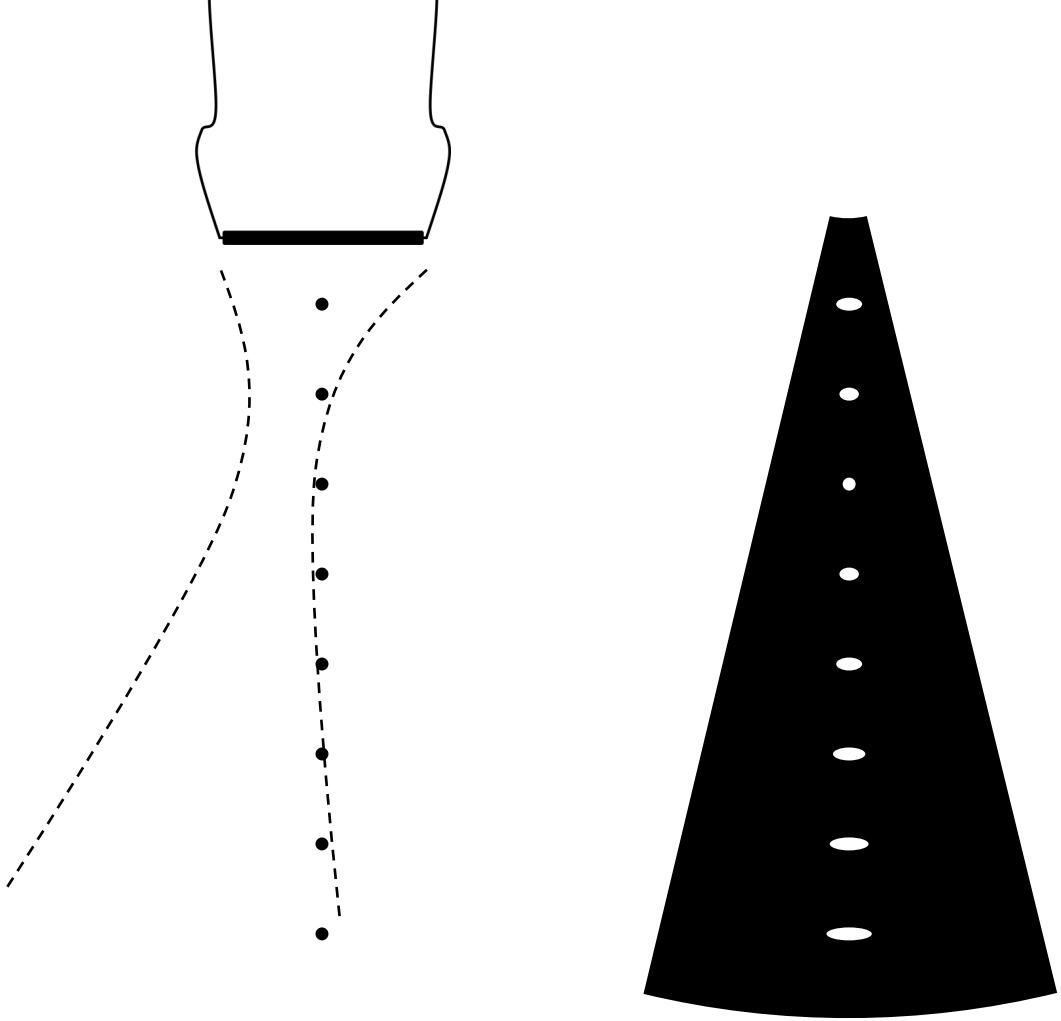
Lateral (Azimuthal) Resolution



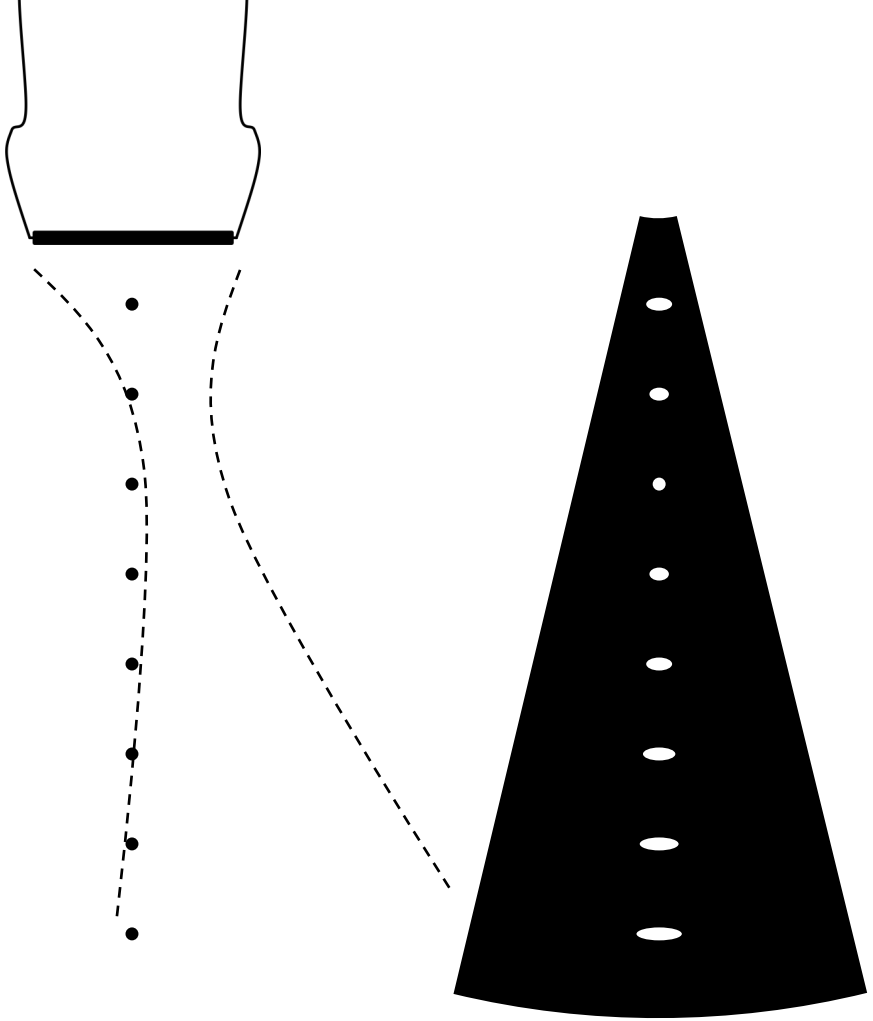
Lateral (Azimuthal) Resolution



Lateral (Azimuthal) Resolution

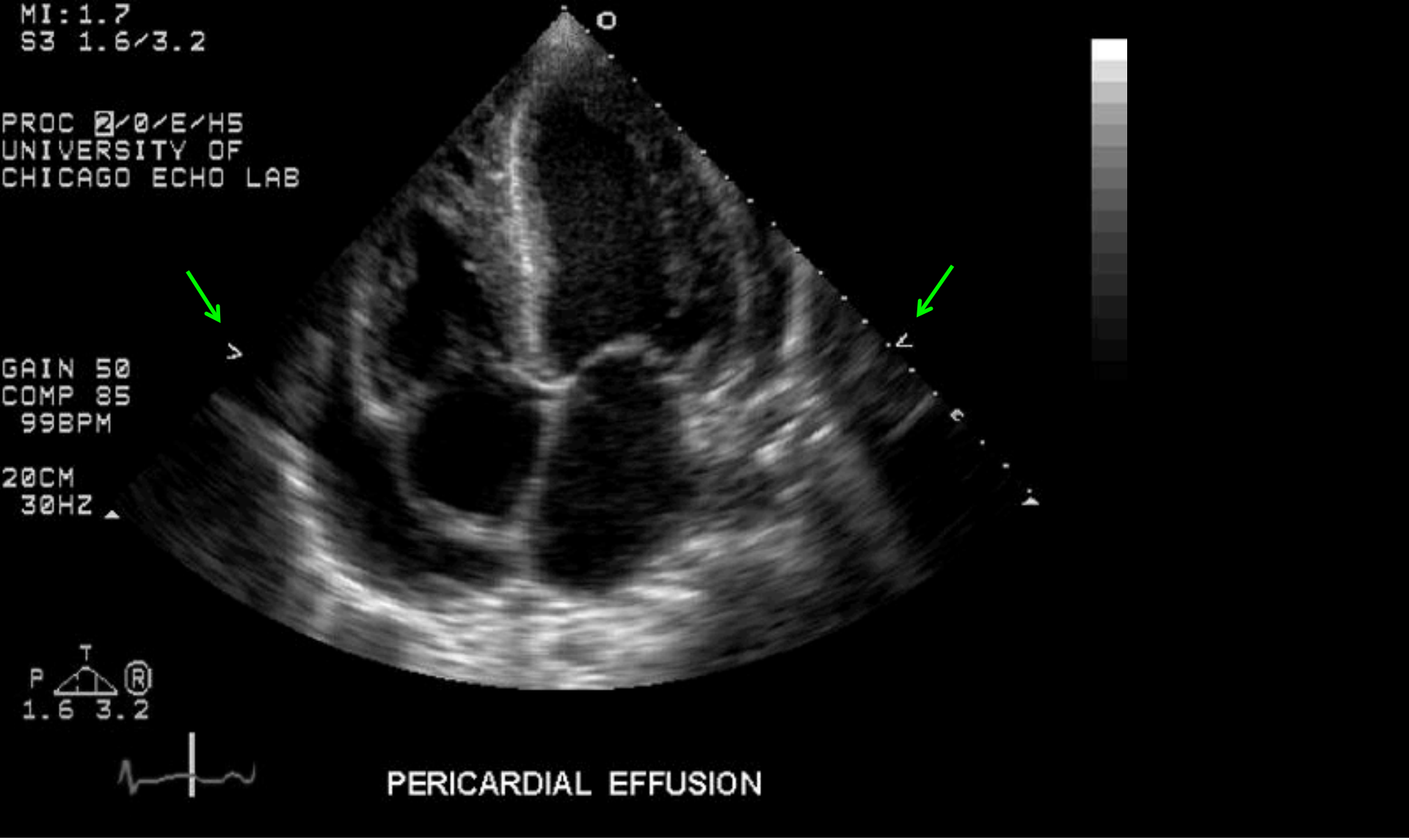


Lateral (Azimuthal) Resolution

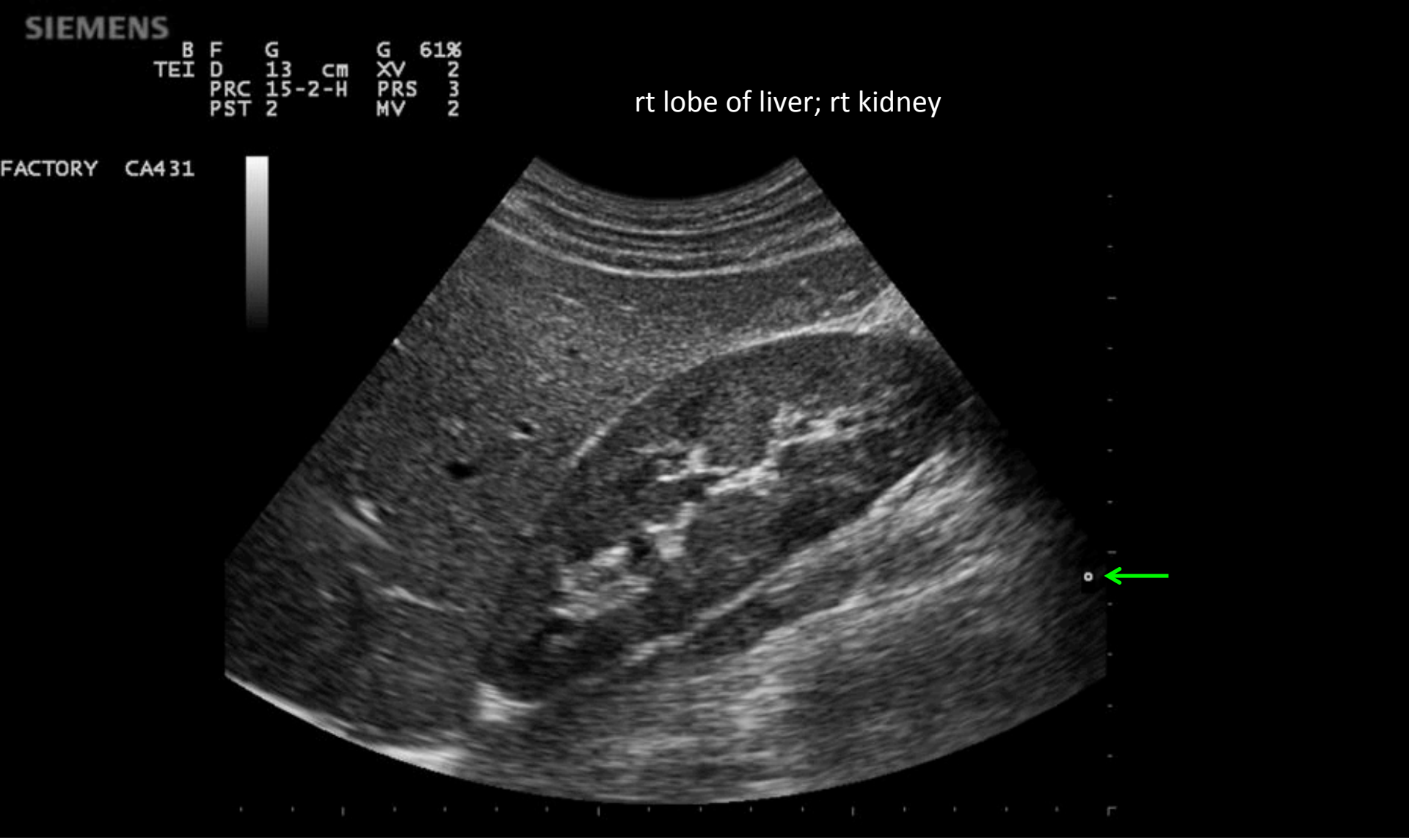


Lateral (Azimuthal) Resolution

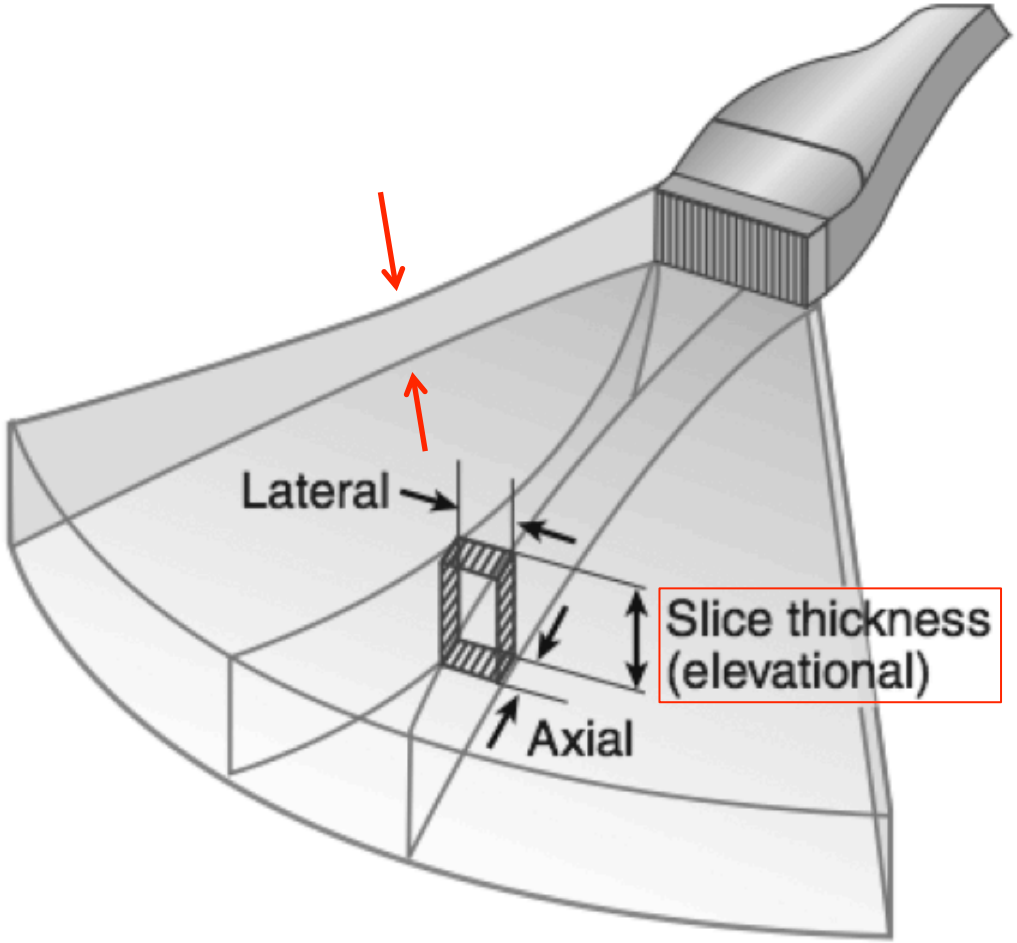
Lateral (Azimuthal) Resolution



Lateral (Azimuthal) Resolution

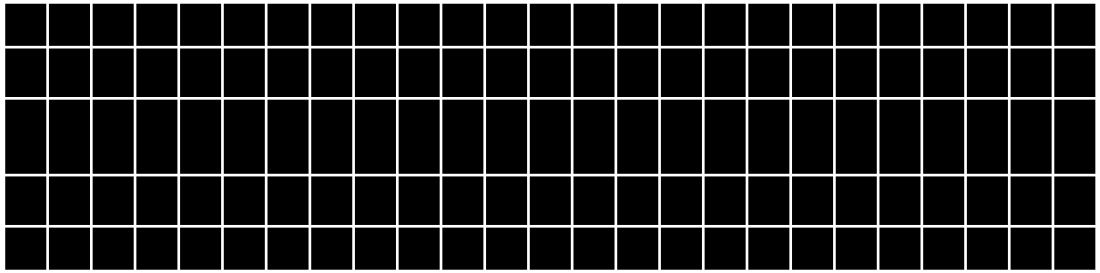


Lateral (Azimuthal) Resolution

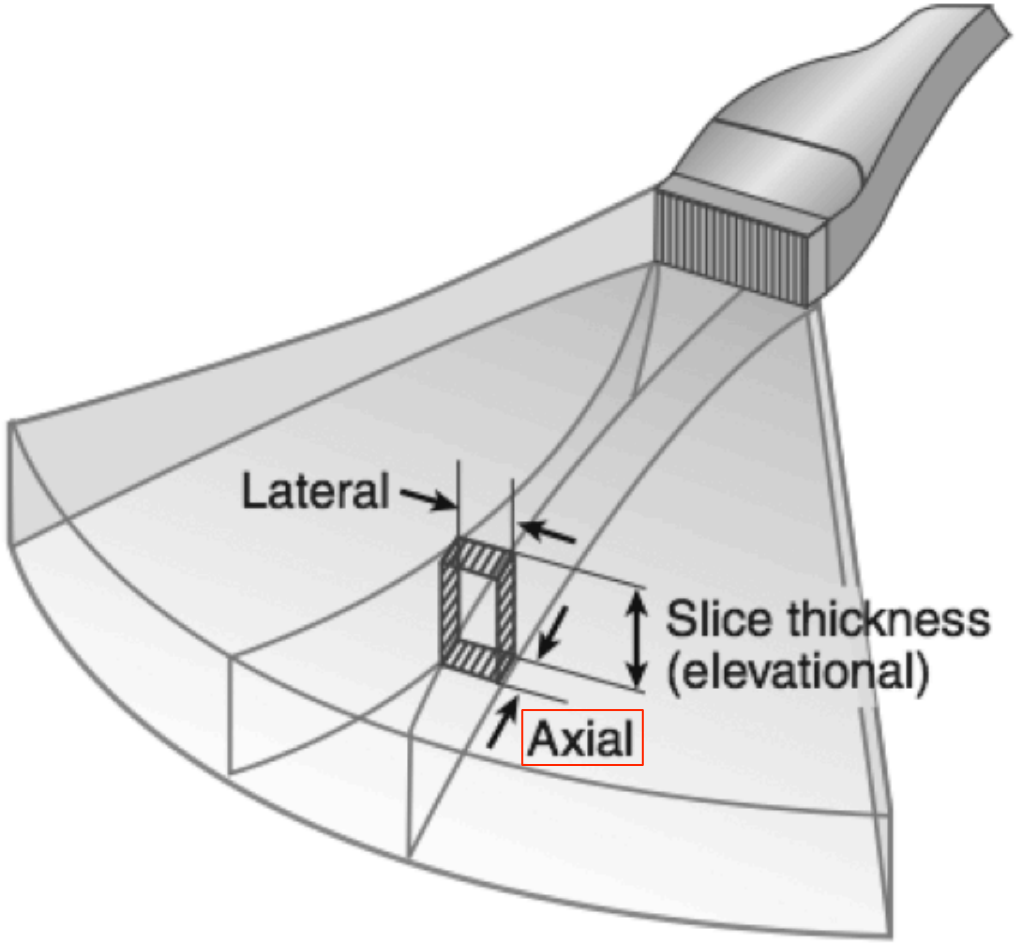


Elevational Resolution (Slice Thickness)

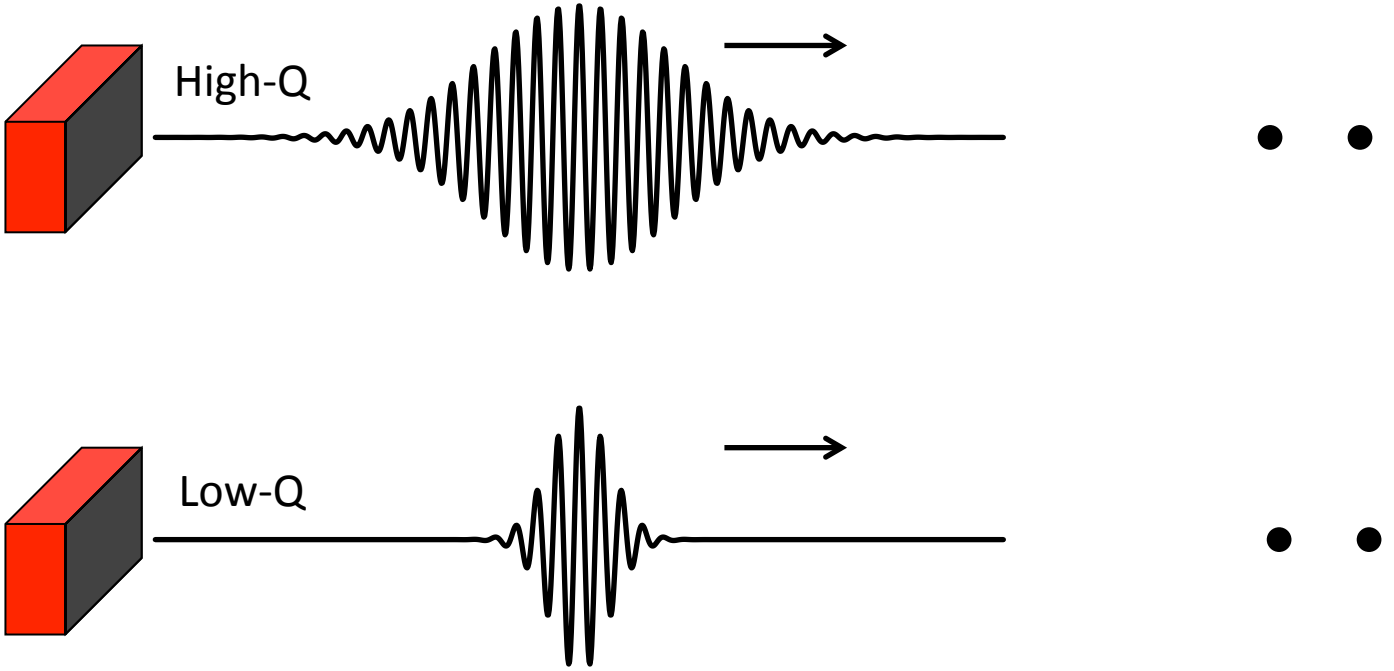
1.5-D Array
1.75-D Array



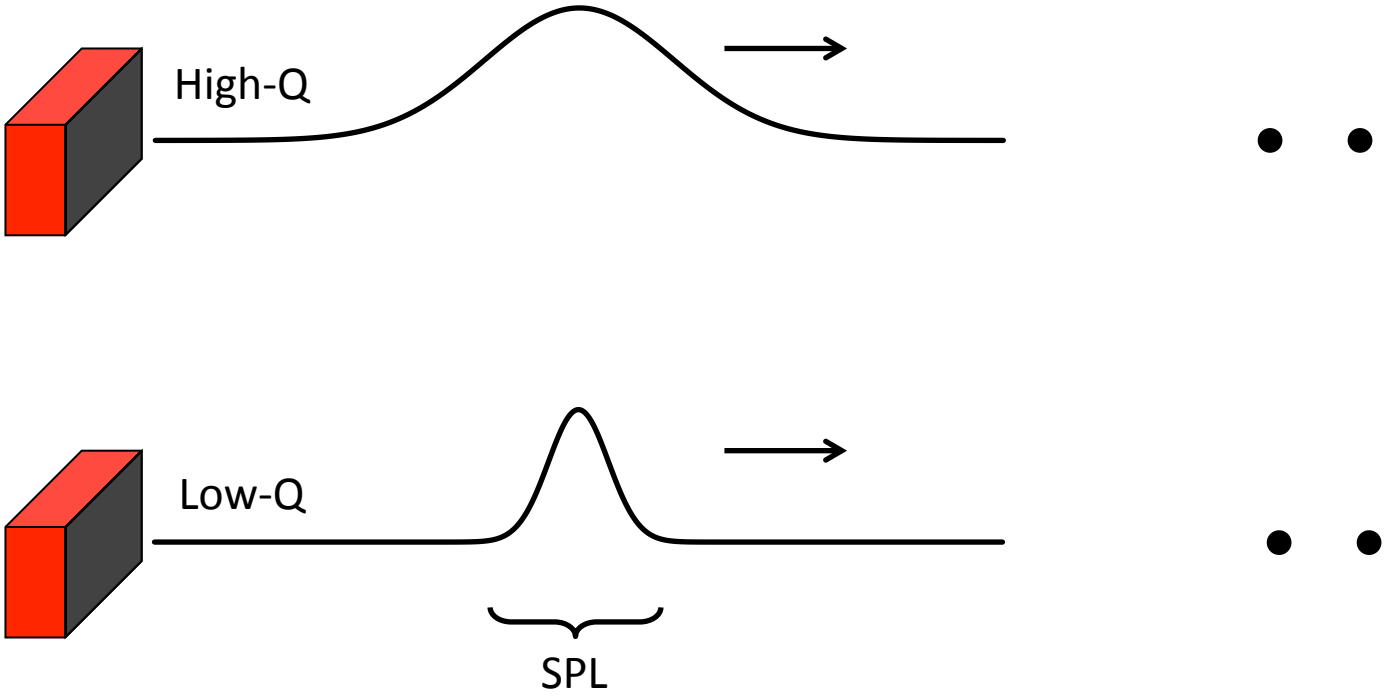
Elevational Resolution (Slice Thickness)



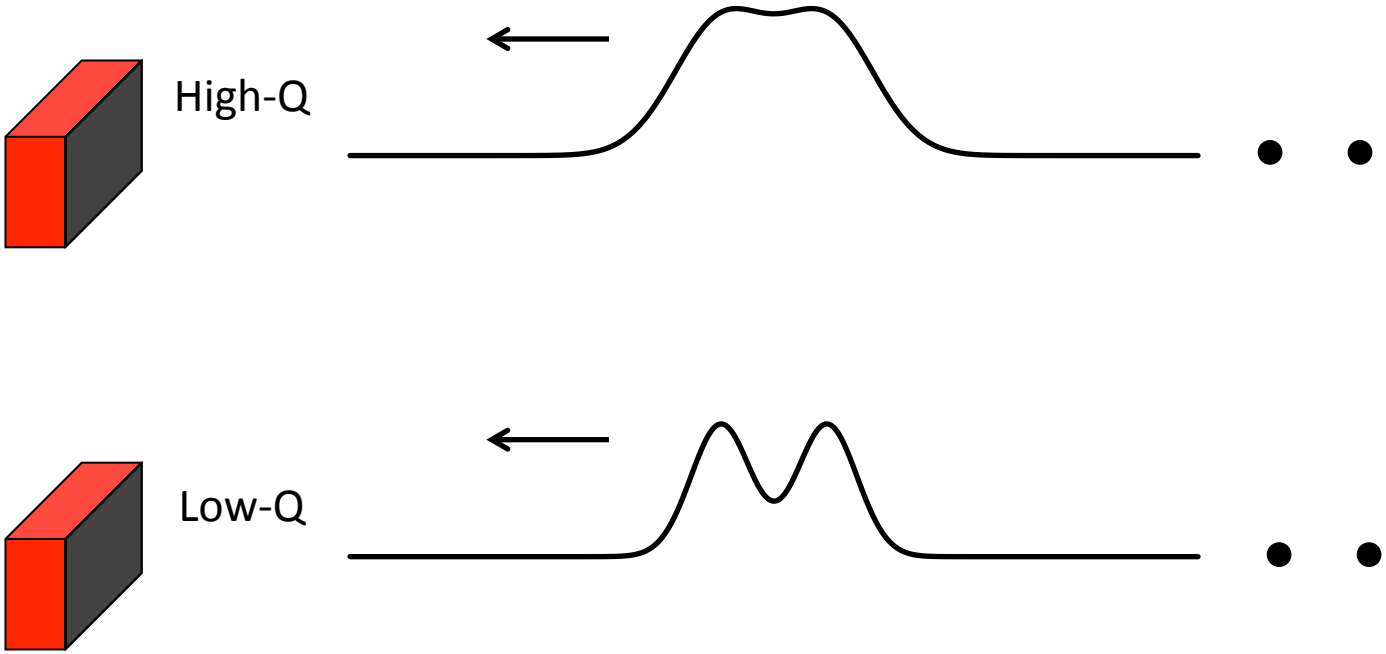
Axial (Linear, Depth, Range, Longitudinal) Resolution



Axial (Linear, Depth, Range, Longitudinal) Resolution



Axial (Linear, Depth, Range, Longitudinal) Resolution



Axial (Linear, Depth, Range, Longitudinal) Resolution

The Piezoelectric Effect

Transduction

Transducer Backing

¼λ Matching Layer

Transducer Array Design

Beamforming

Side Lobes

Grating Lobes

Spatial Resolution

Summary