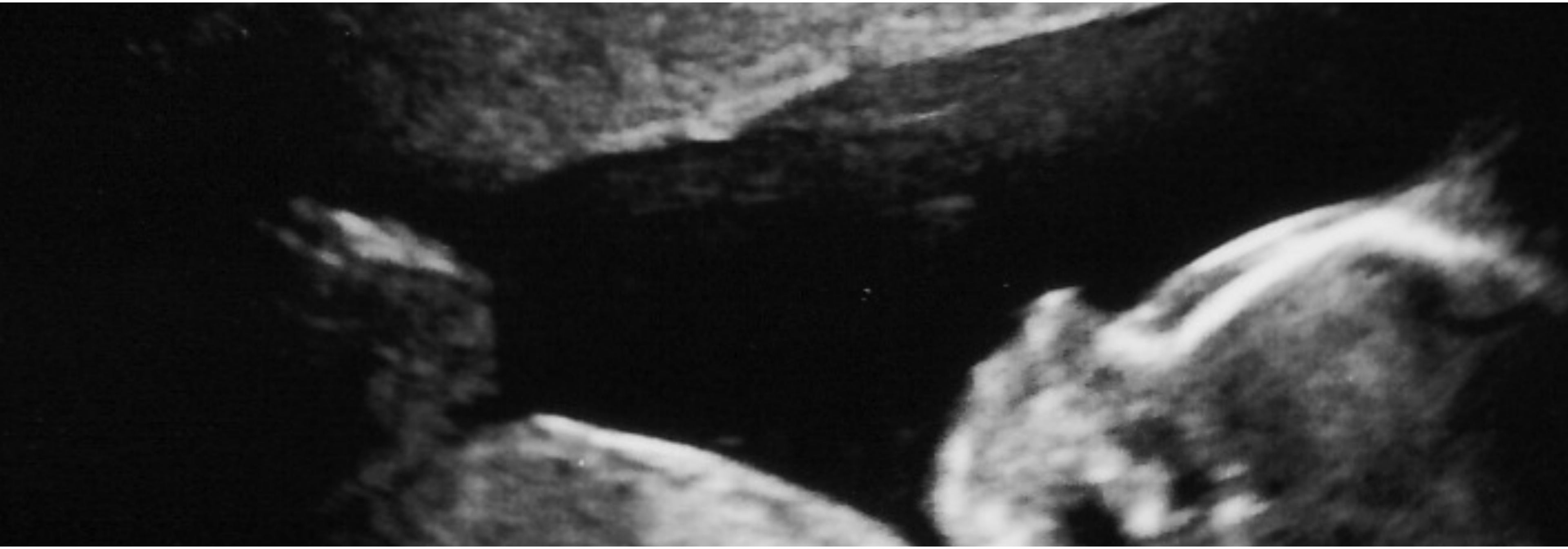
# Ultrasound Physics (BWHRR.US)

## 3. Ultrasound Imaging and Artifacts



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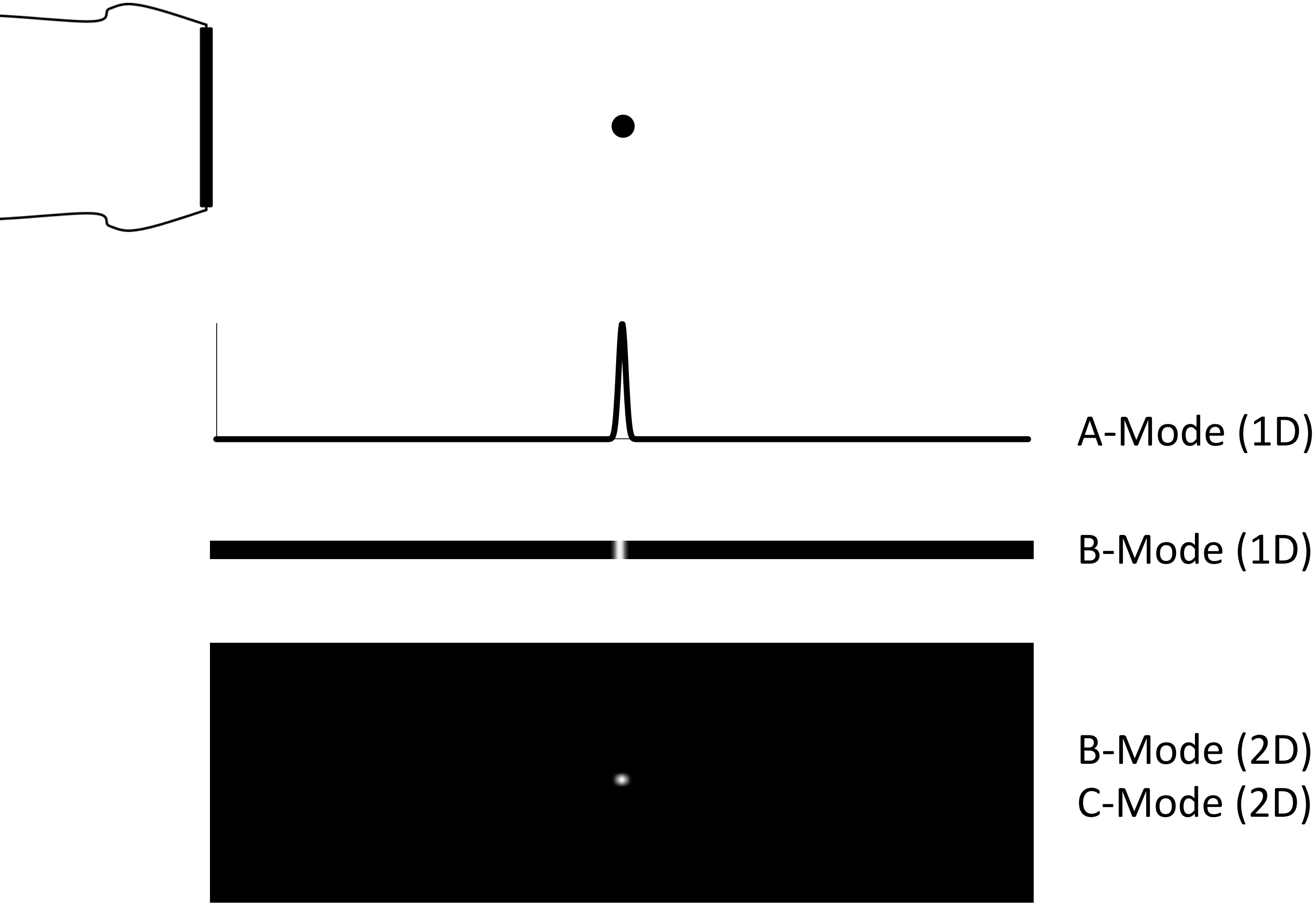
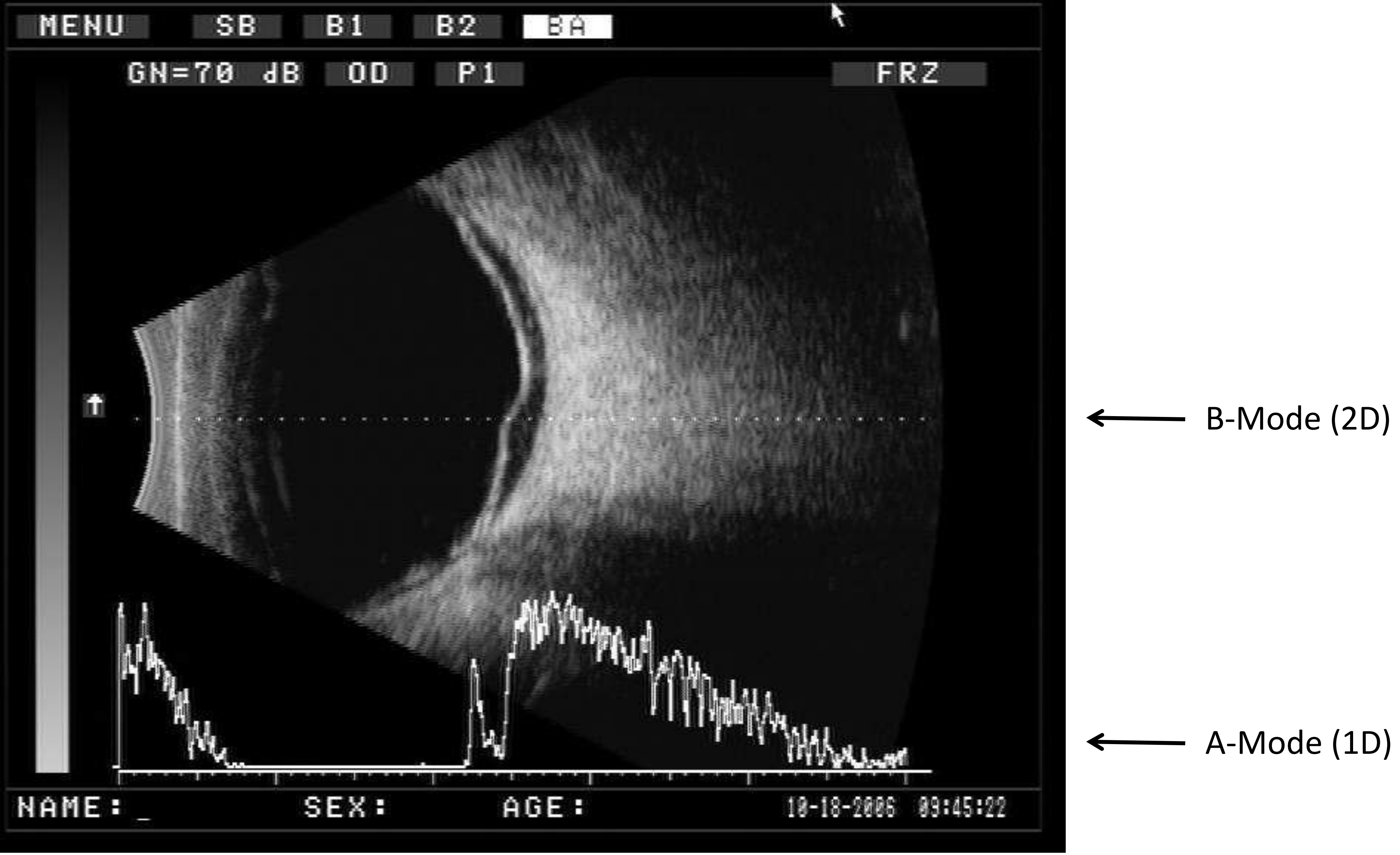
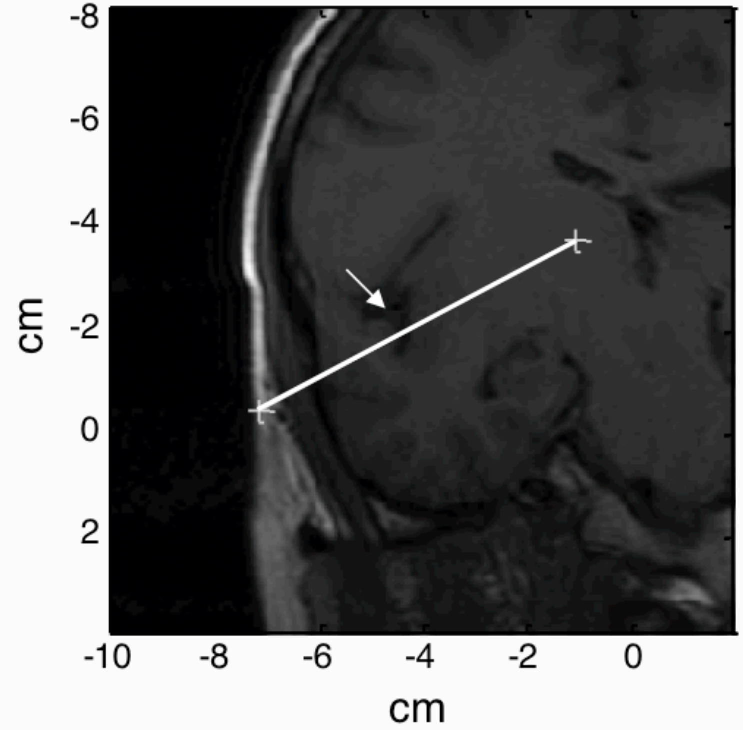
Contact: (617) 525-7465, white@bwh.harvard.edu

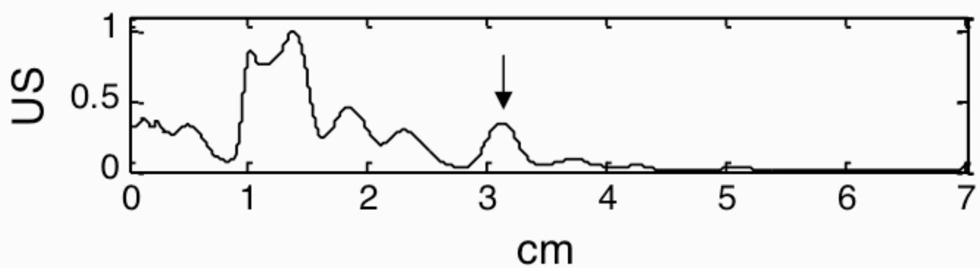



# Pulse-Echo Modes




# A-Mode Ultrasound

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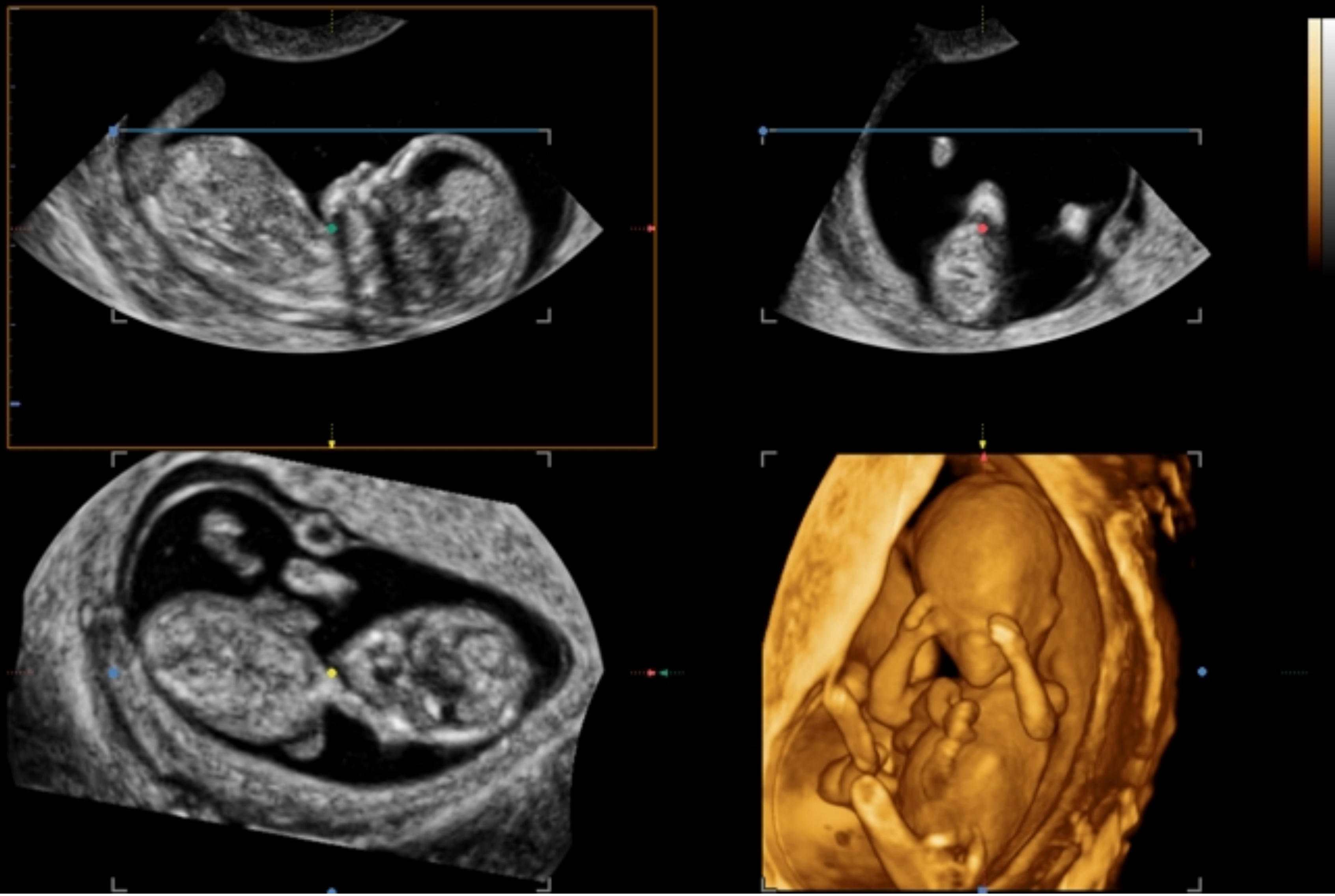
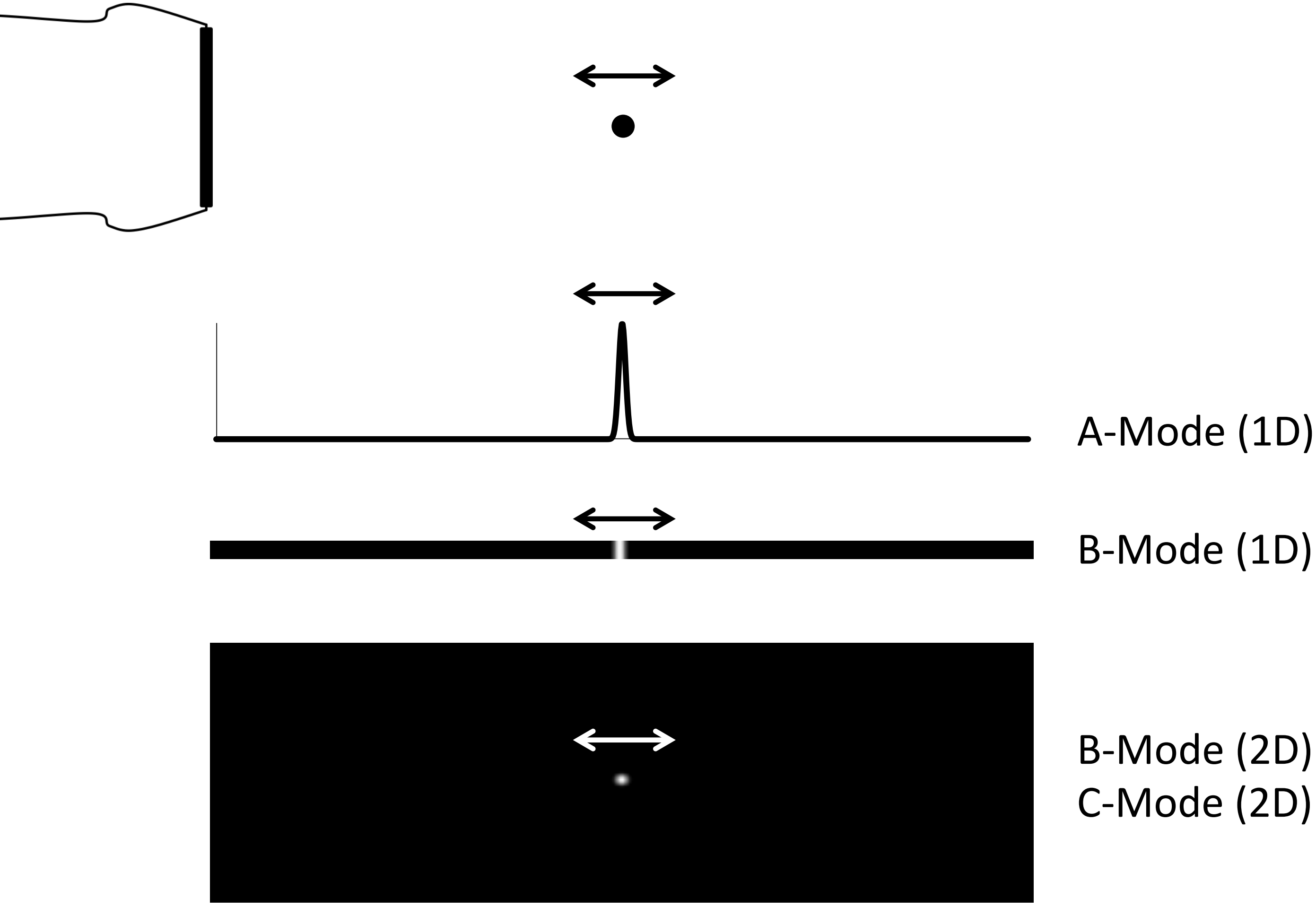


B-Mode and C-Mode Ultrasound

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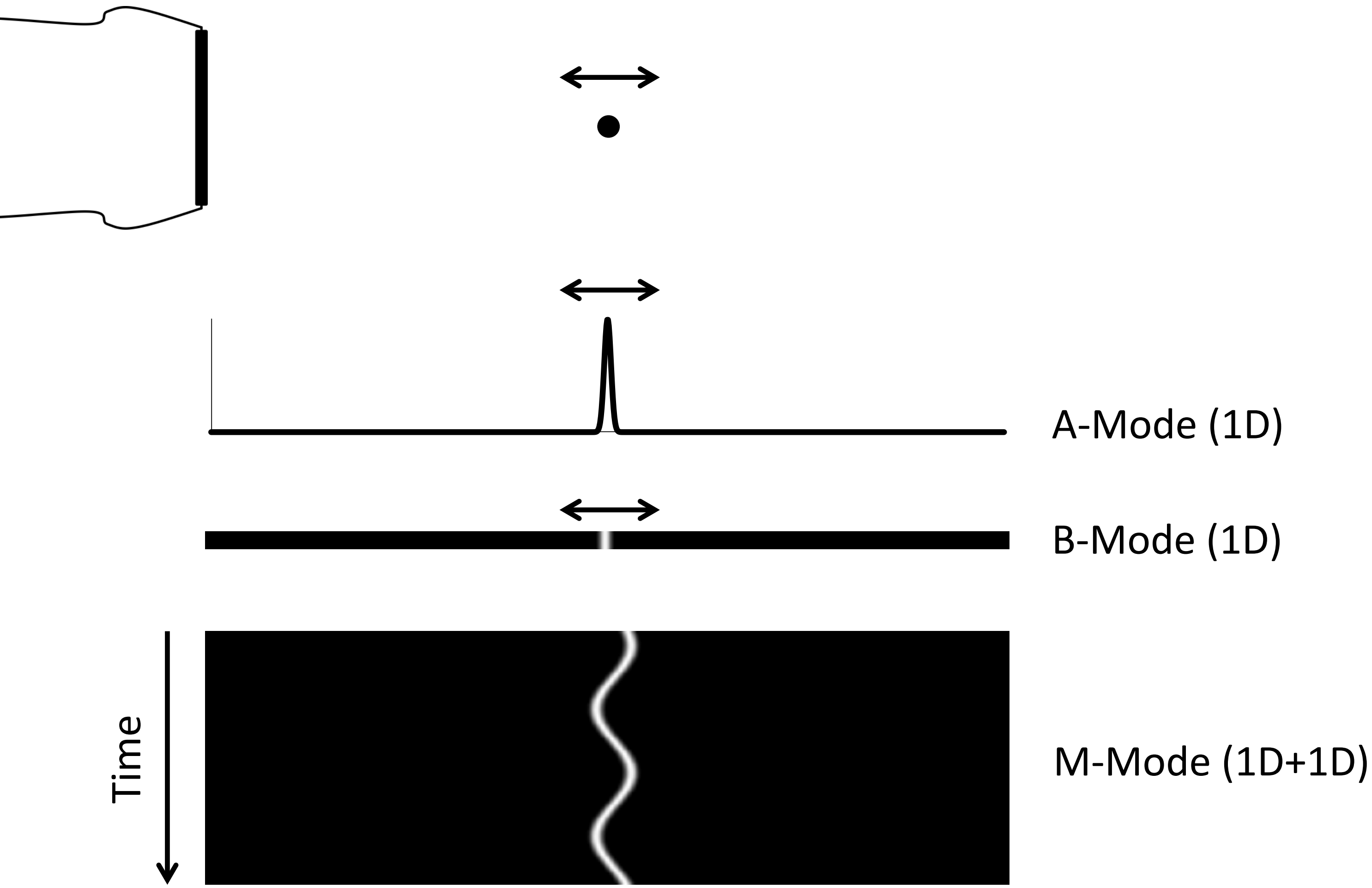
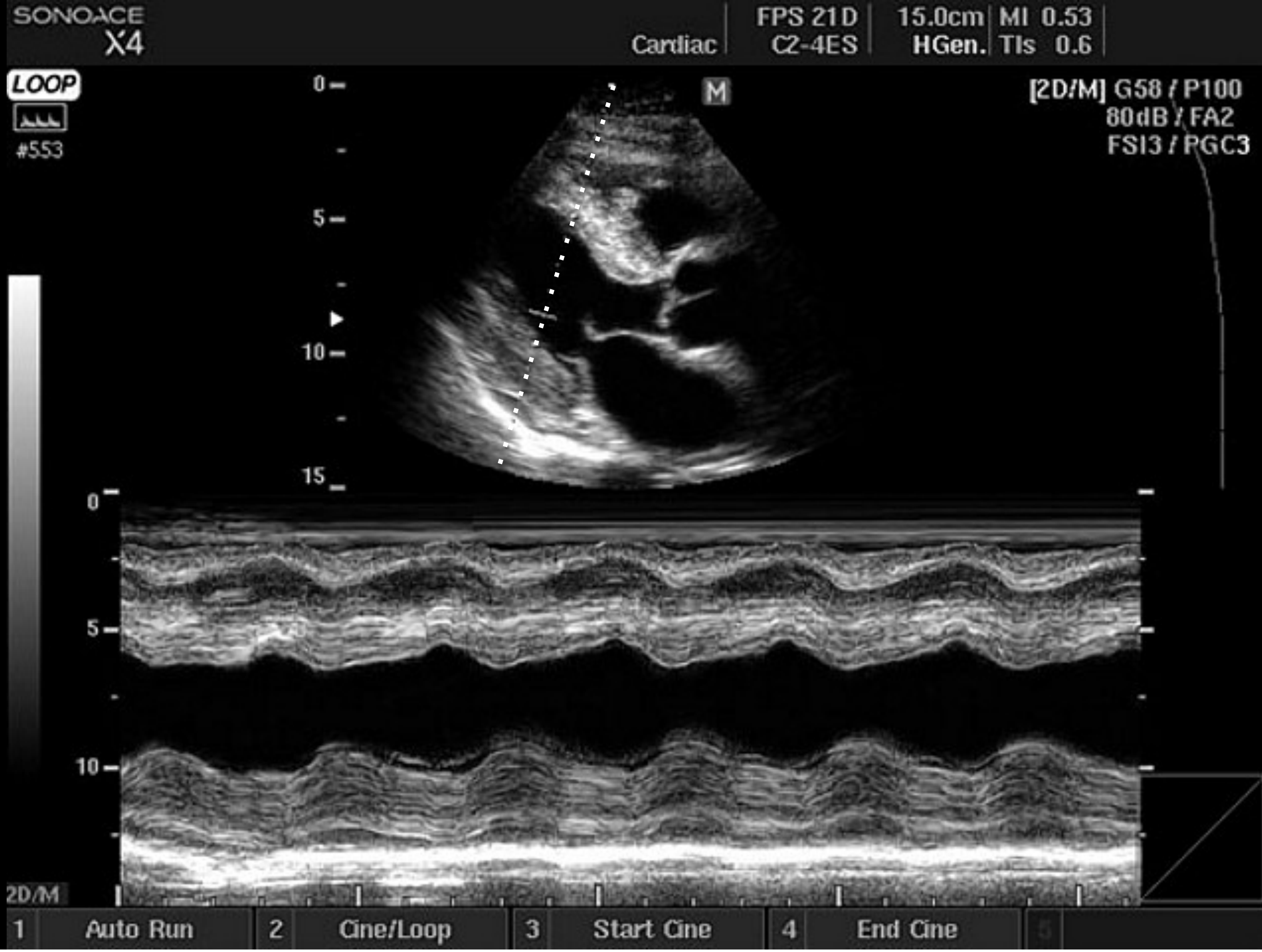
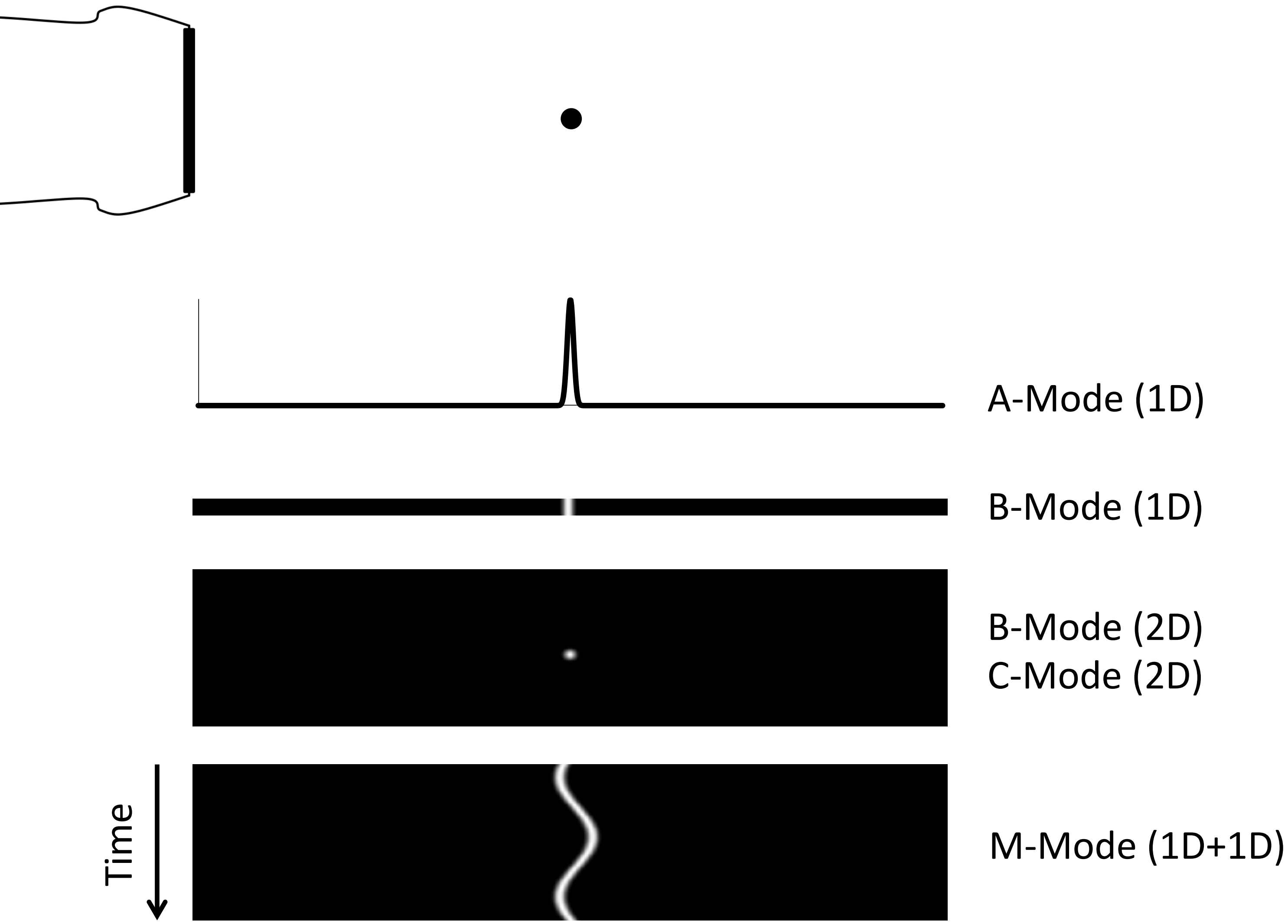


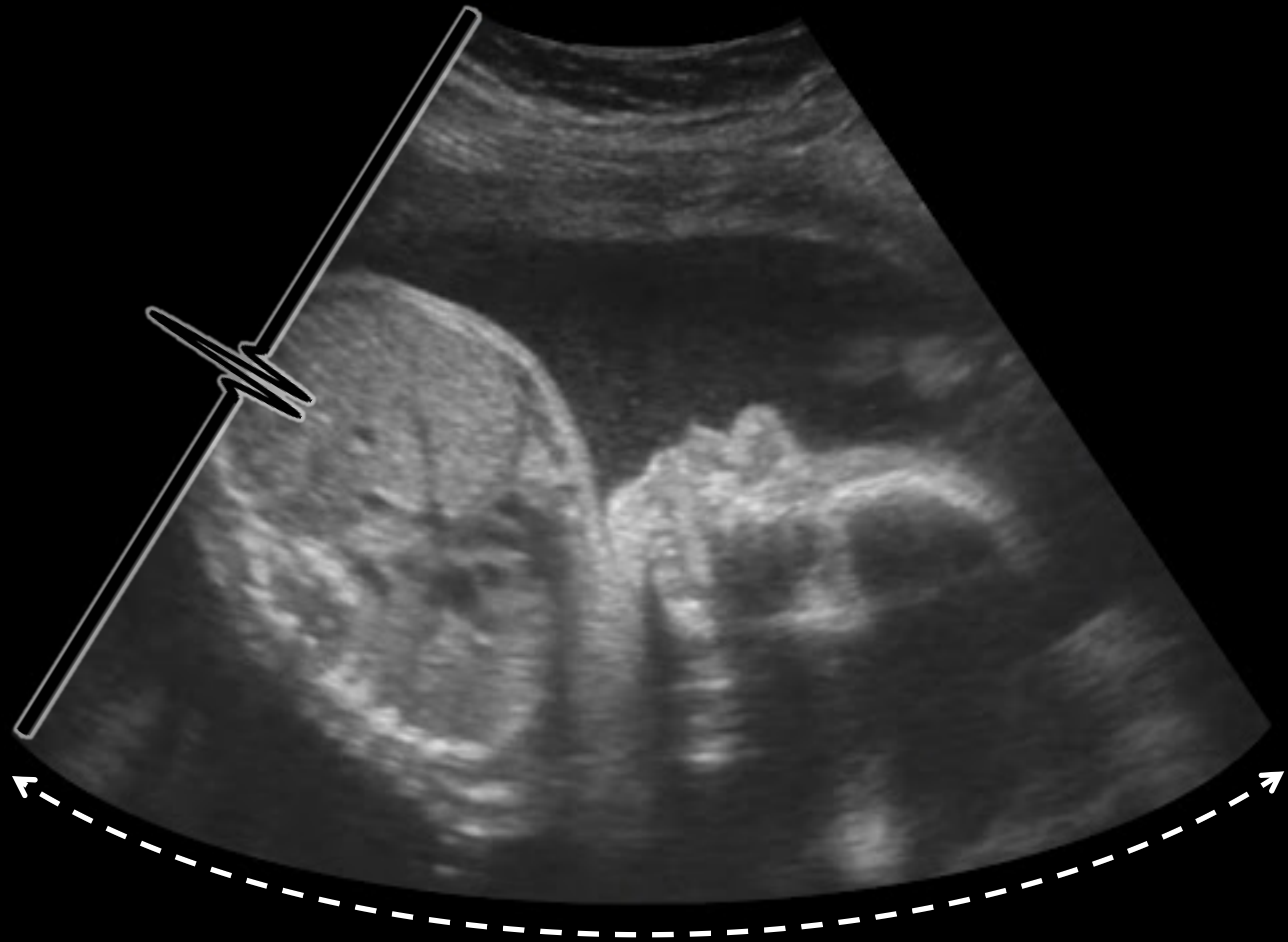

# Pulse-Echo Modes



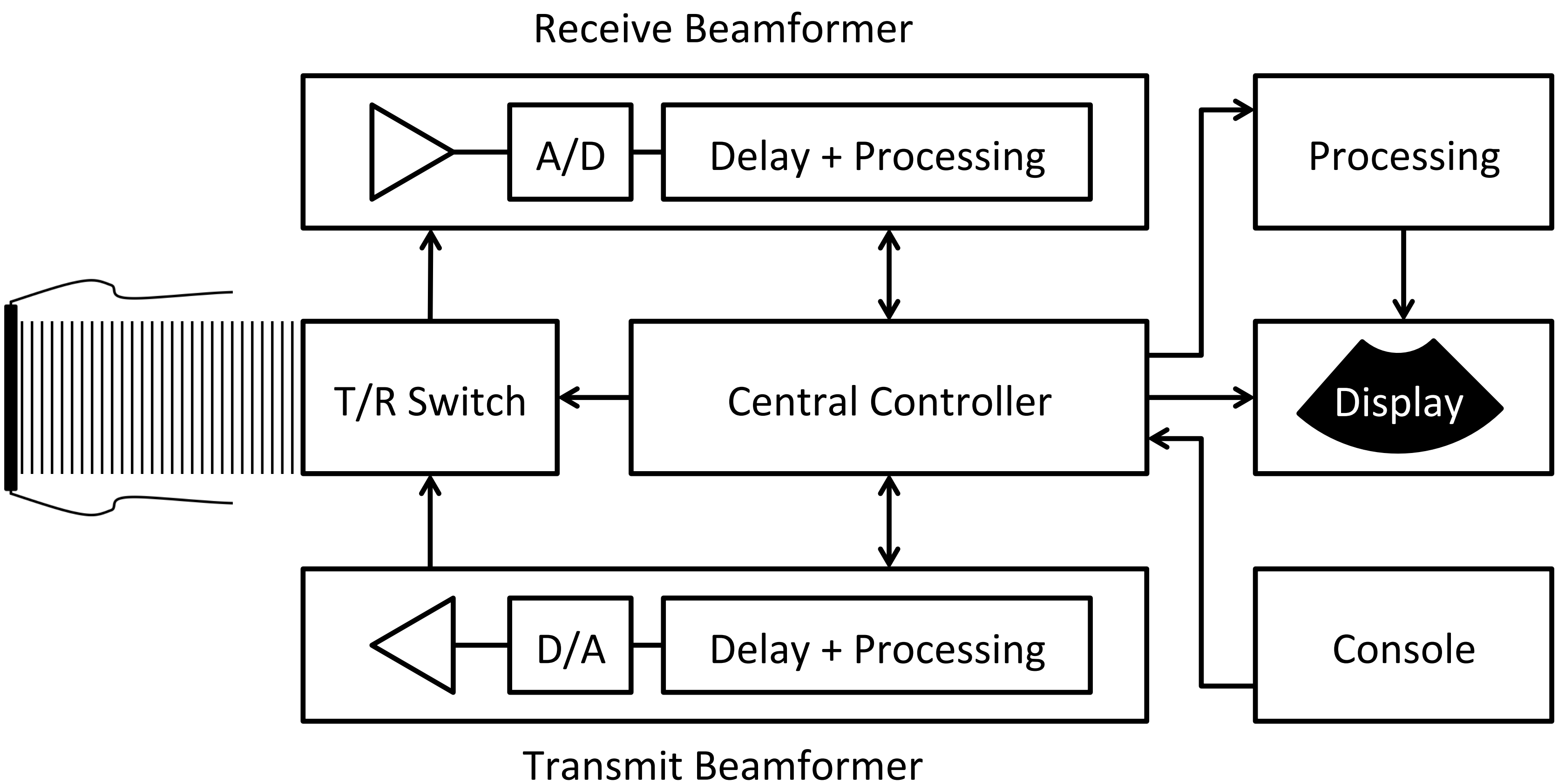

M-Mode Ultrasound




# Pulse-Echo Modes

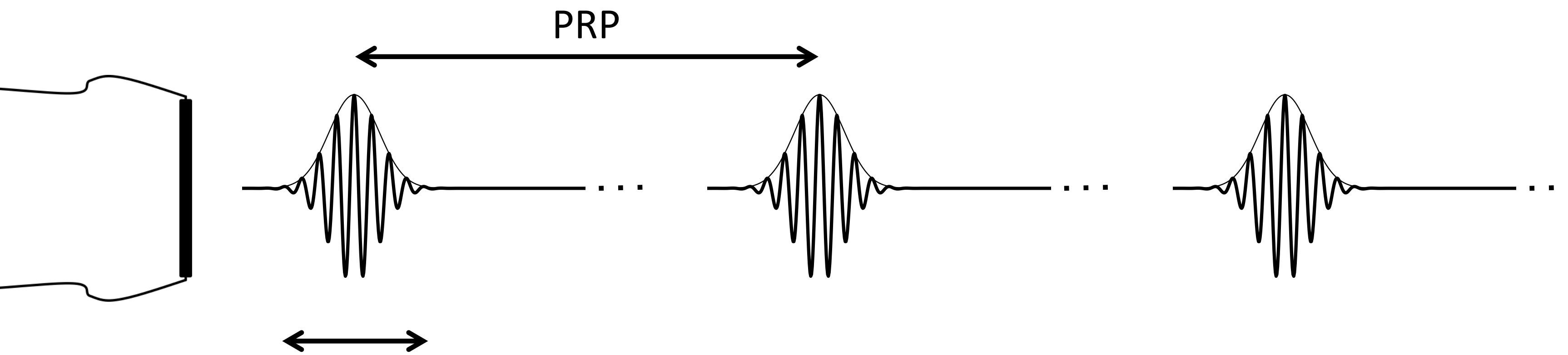


Ultrasound Imaging




# Transmit and Receive Beamformers

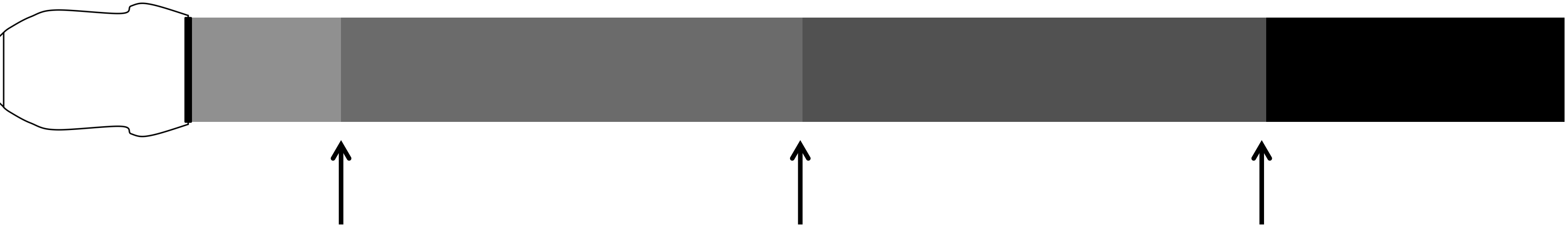
# Transmit Processing



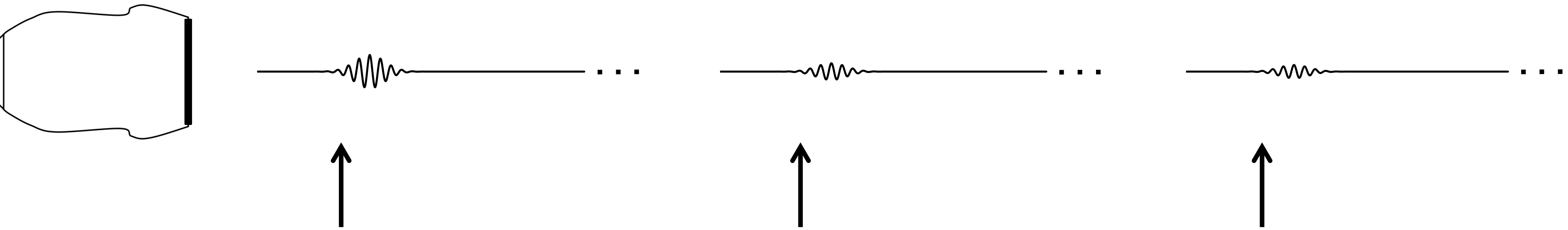

Duty Cycle = 0.2-2%

$$D_{\max} = \left(\frac{\text{PRP}}{2}\right)c$$

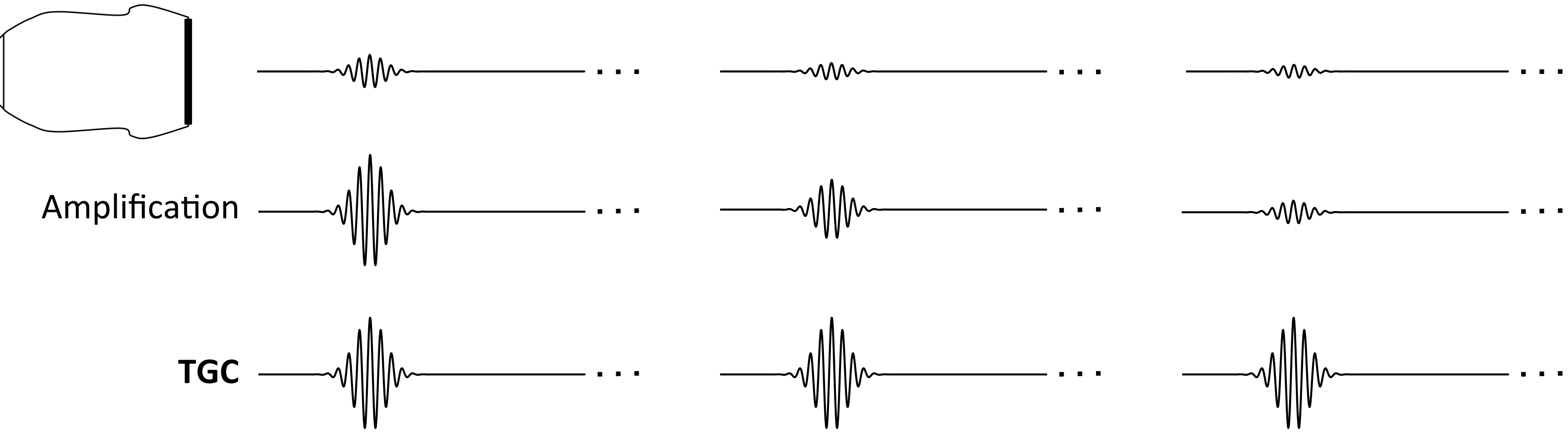
| PRP (μs) | PRF (kHz) | Range (cm) |
|---|---|---|
| 100 | 10 | 7.7 |
| 150 | 6.7 | 11.6 |
| 250 | 4 | 19.3 |
| 500 | 2 | 38.5 |



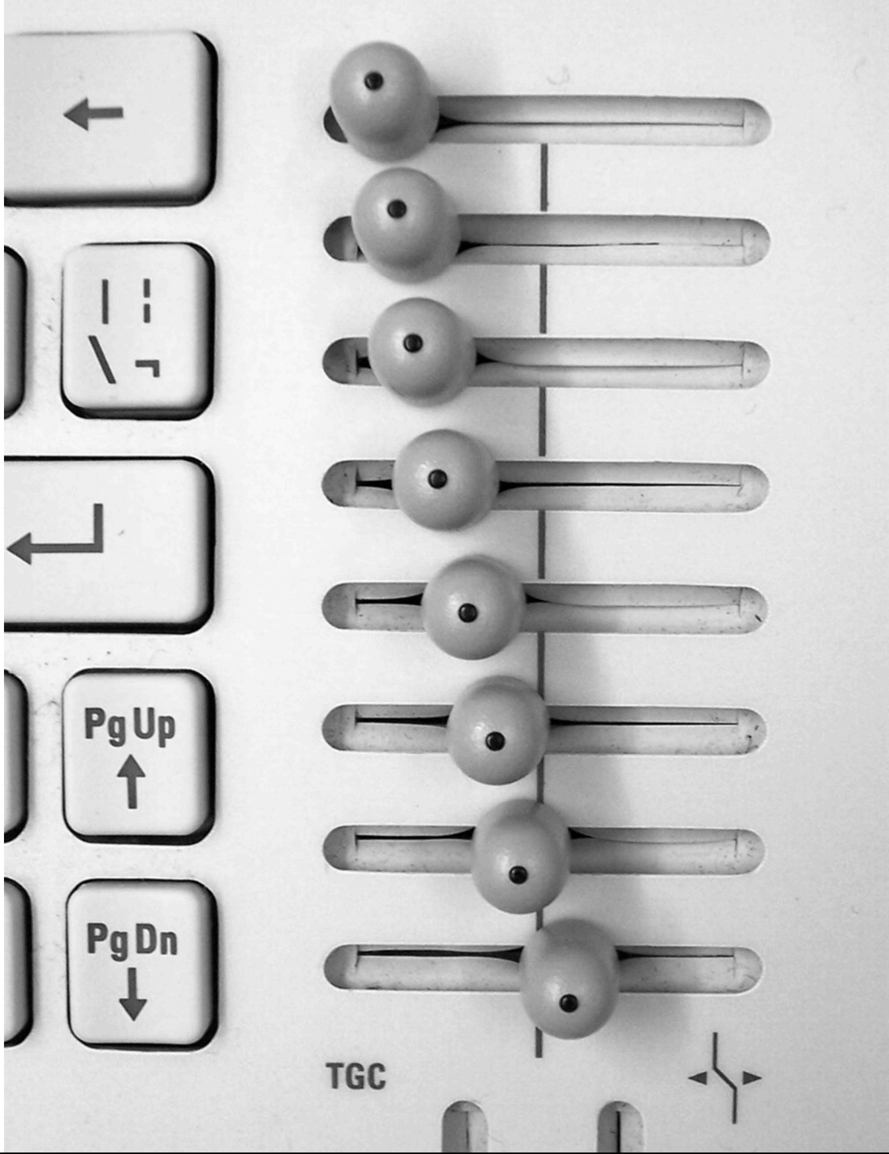
Receive Processing



Receive Processing

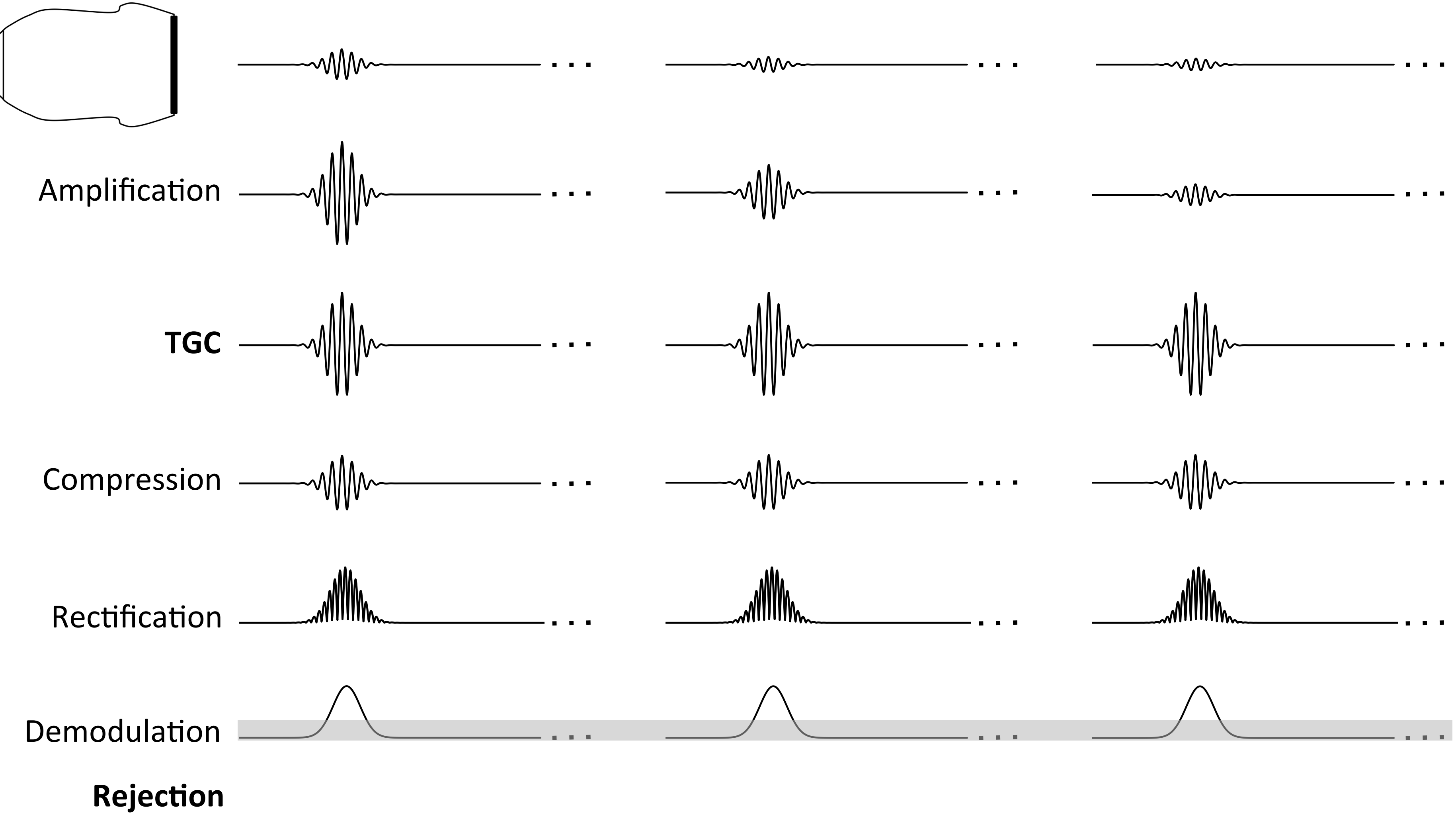



Receive Processing

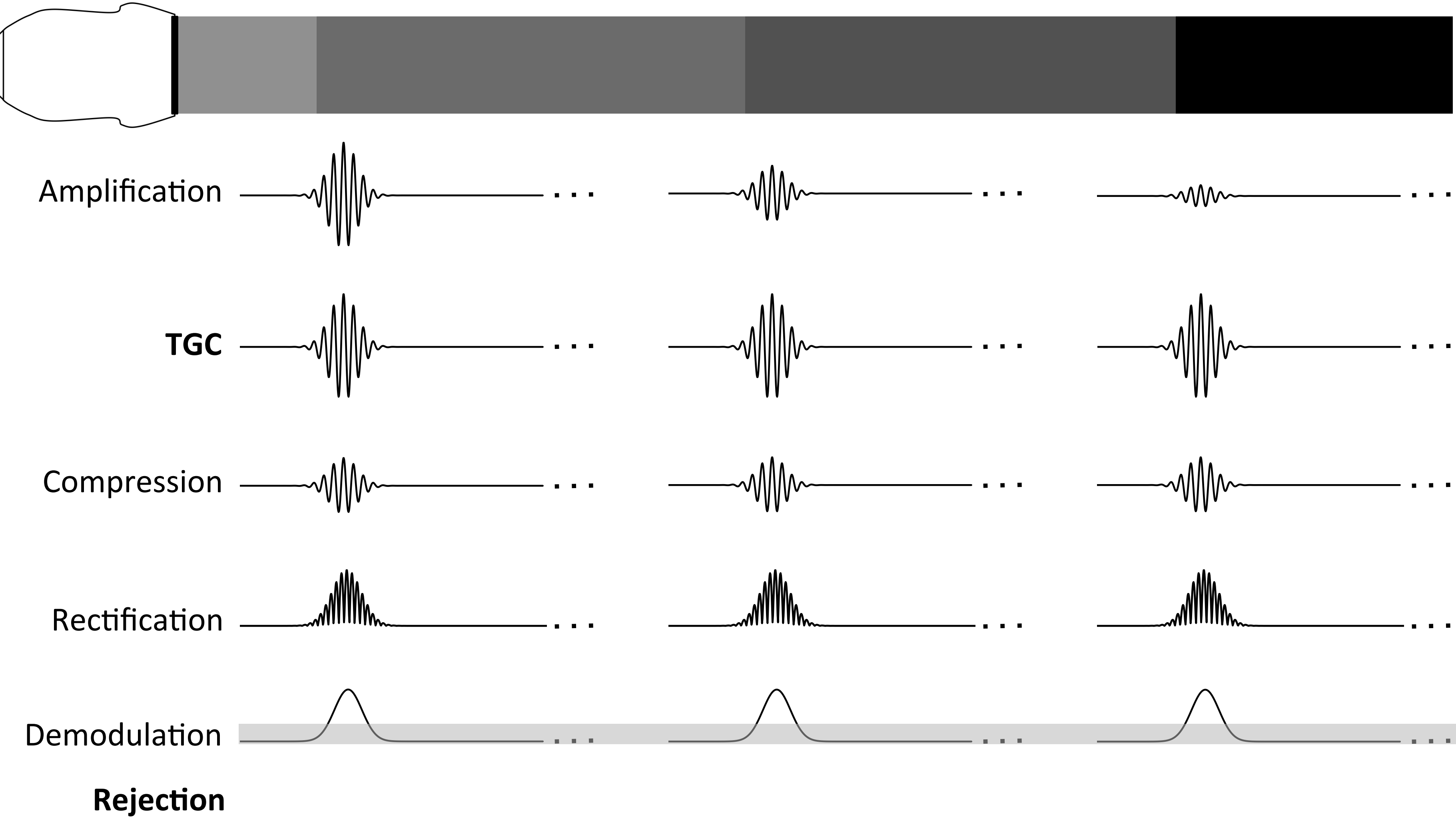



Time-Gain Compensation (TGC)

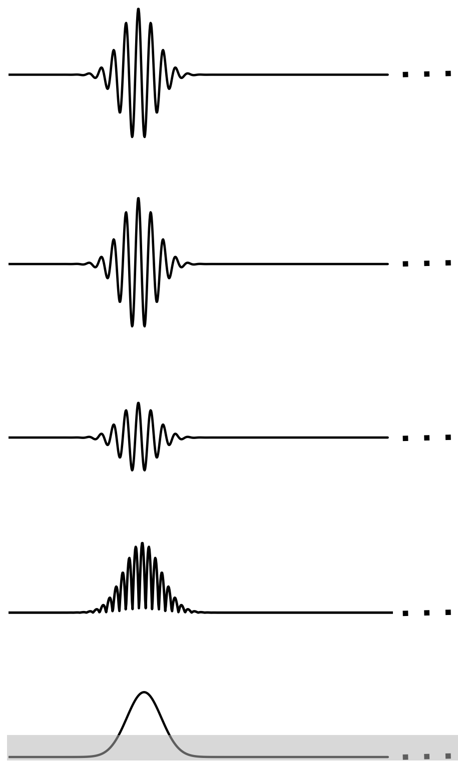

Time-Gain Compensation (TGC)




# Receive Processing

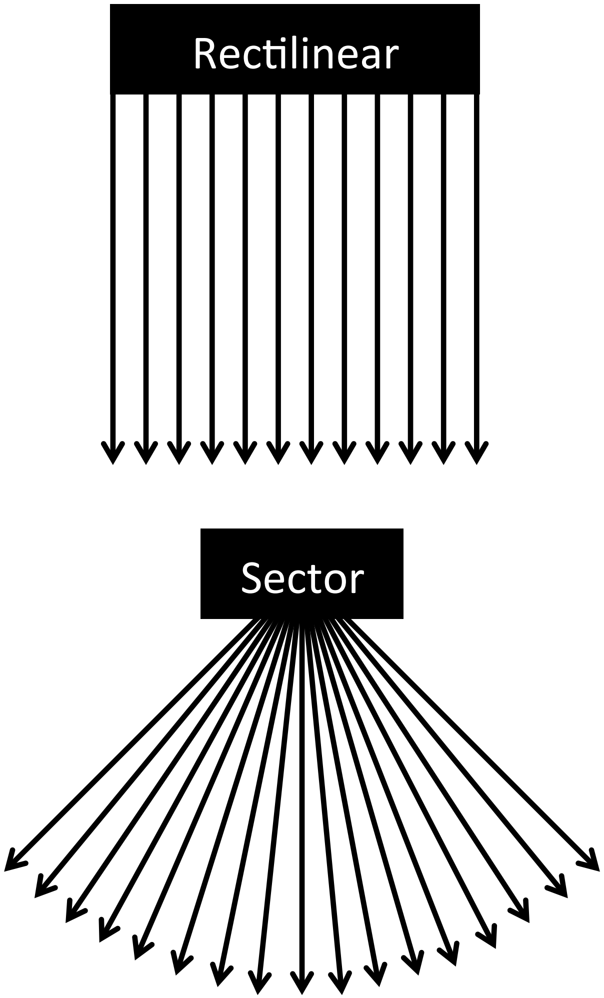



# Receive Processing



| Stage | Also known as |
|---|---|
| Amplification | Pre-amplification |
| **TGC** | **Depth Gain Compensation, Swept Gain, Time Varied Gain** |
| Compression | Dynamic Compression, Logarithmic Amplification |
| Rectification | |
| Demodulation | Envelope Detection, Analytic Signal |
| **Rejection** | **Noise Rejection, Threshold Filtering, Decluttering** |

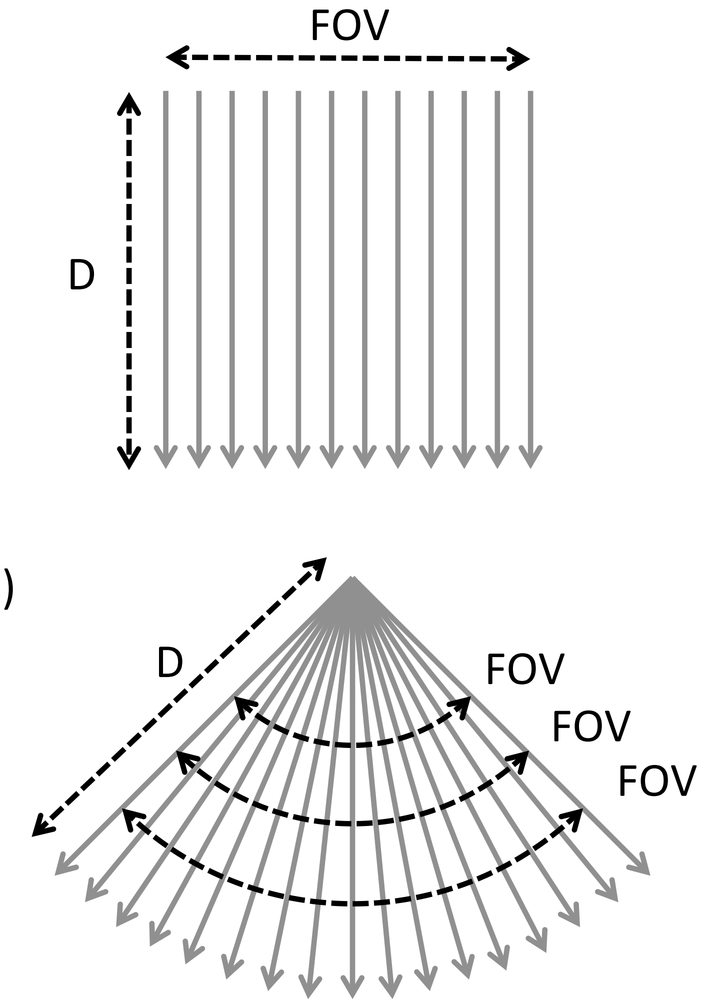
# Receive Processing



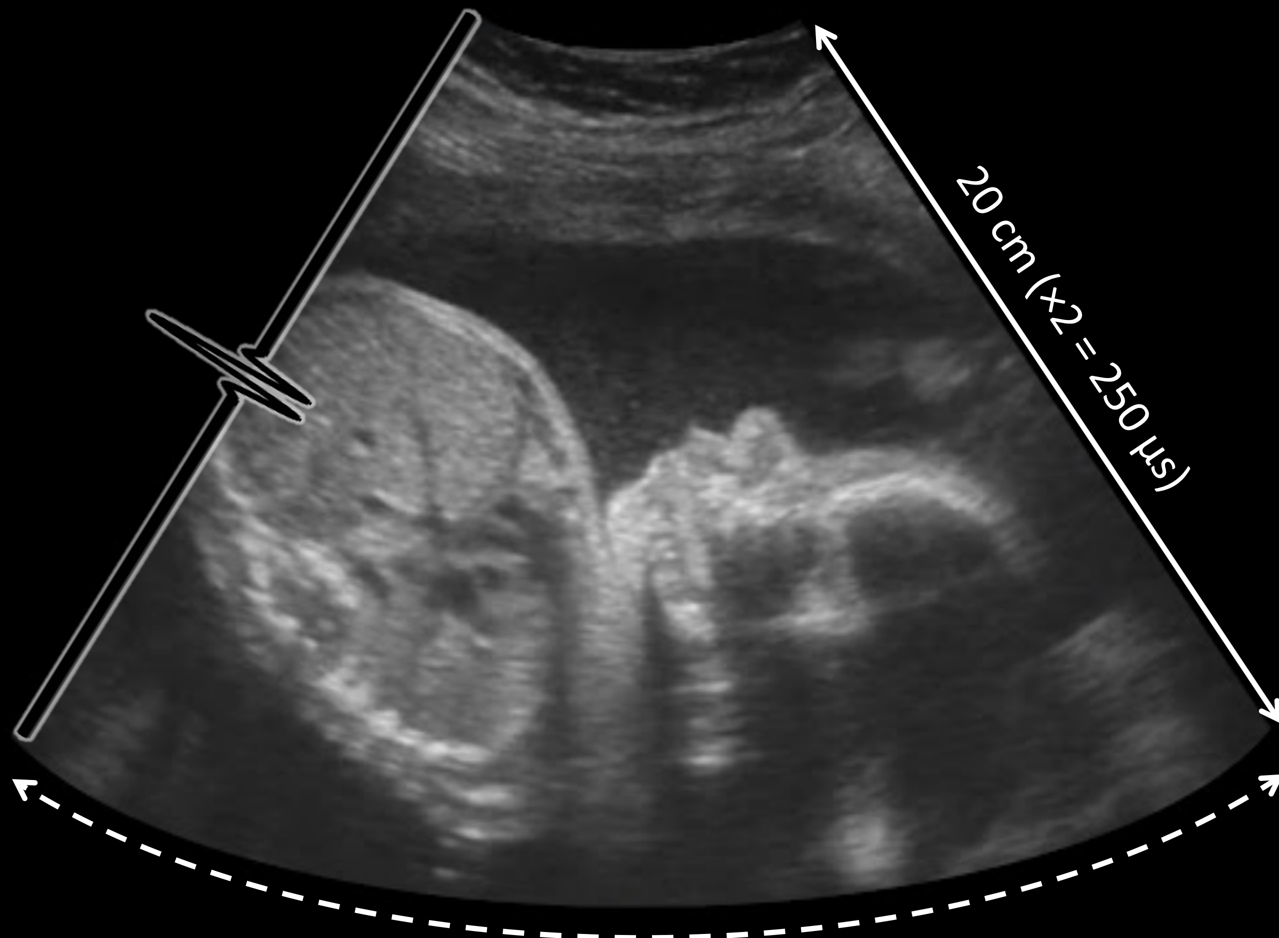

# Imaging Performance

LD = Line Density
= N/FOV

D = Depth (Range)
FOV = Field of View
N = Number of Lines
FR = Frame Rate (PRF/N)



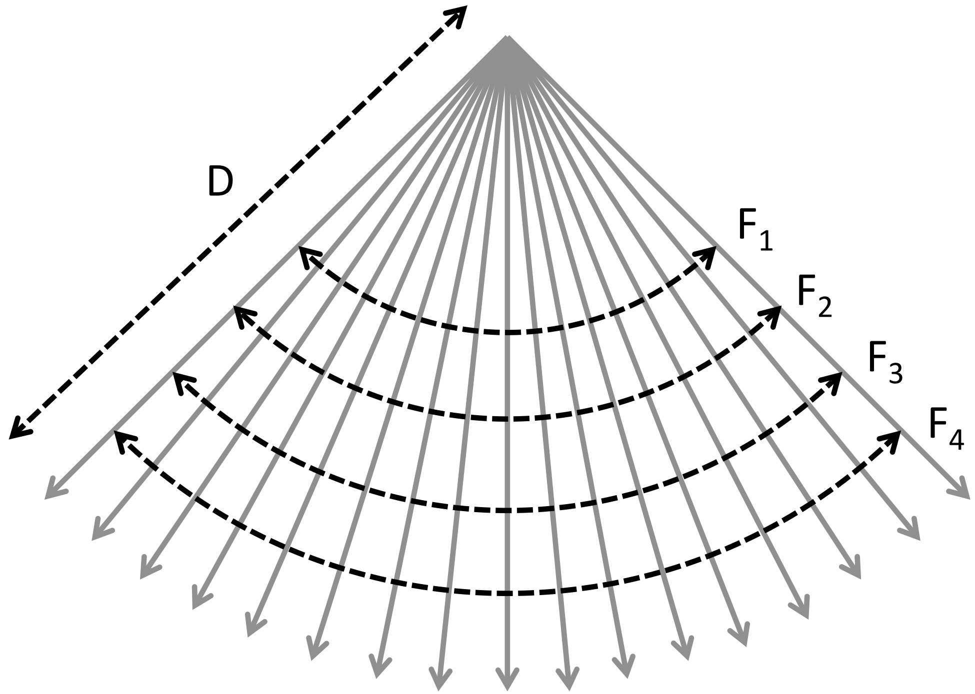

# Imaging Performance




# Imaging Performance

| Range (cm) | Number of Lines (N) | Max Frame Rate ($s^{-1}$) |
|---|---|---|
| 20 | 50 | 80 |
| | 100 | 40 |
| | 200 | 20 |
| 13 | 50 | 120 |
| | 100 | 60 |
| | 200 | 30 |
| 10 | 50 | 160 |
| | 100 | 80 |
| | 200 | 40 |
| 8 | 50 | 200 |
| | 100 | 100 |
| | 200 | 50 |

# Imaging Performance




Dynamic Focus

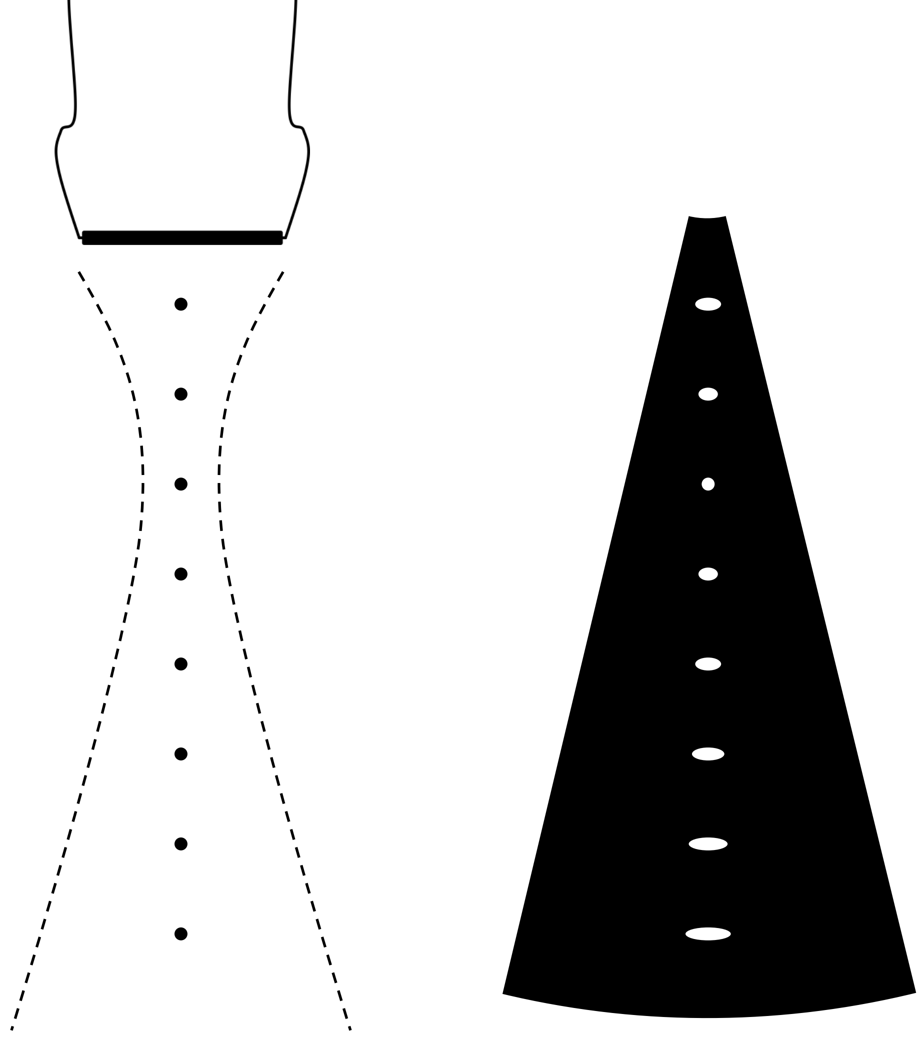
1. **Beamforming**
    a. Beam width
    b. Slice thickness
    c. Side lobes
    d. Grating lobes

2. **Velocity Discrepancies**
    a. Refraction
    b. Displacement
    c. Edge

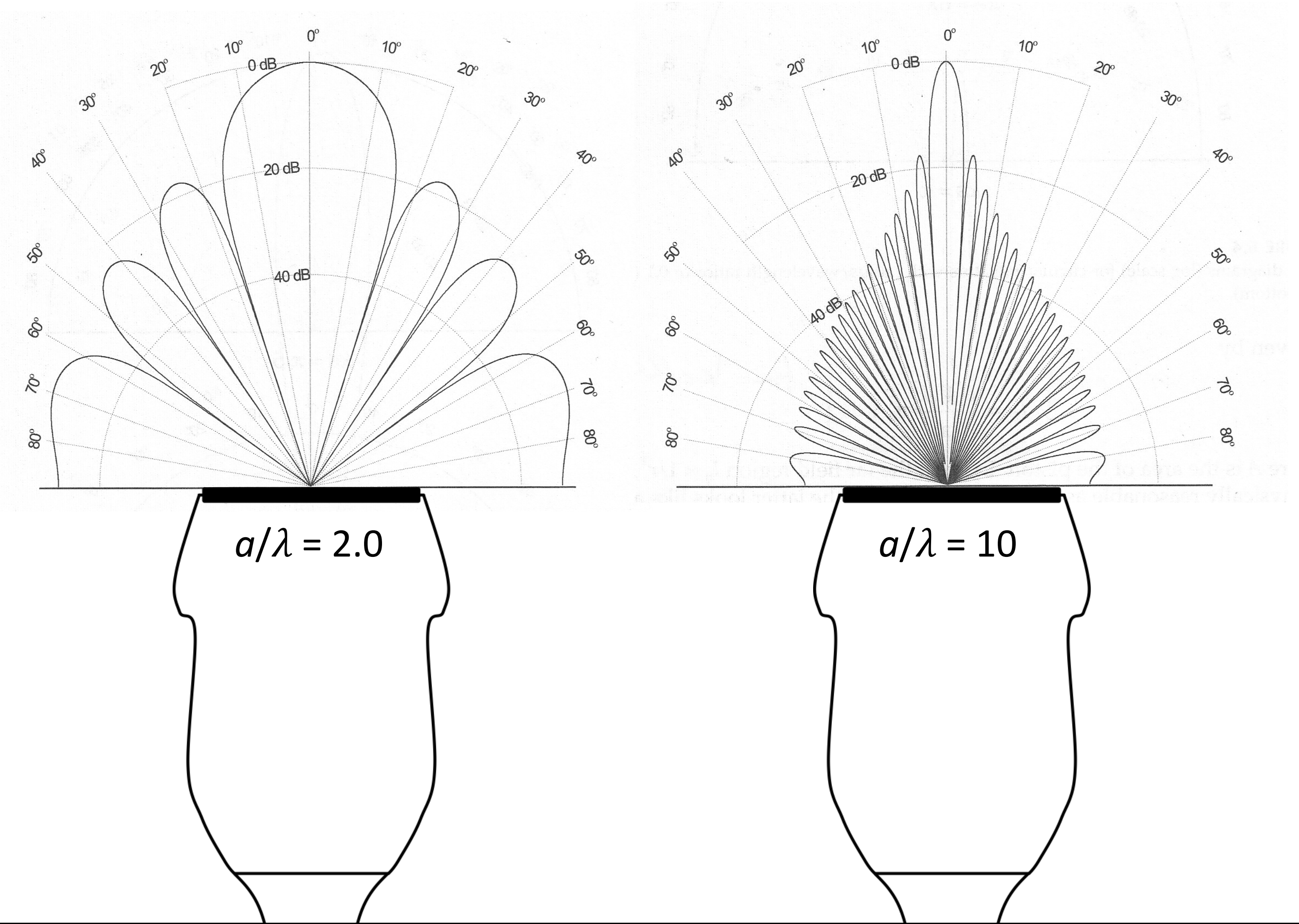
3. **Multiple Reflections**
    a. Reverberation
    b. Mirror
    c. Speckle

4. **Attenuation**
    a. Shadowing
    b. Enhancement

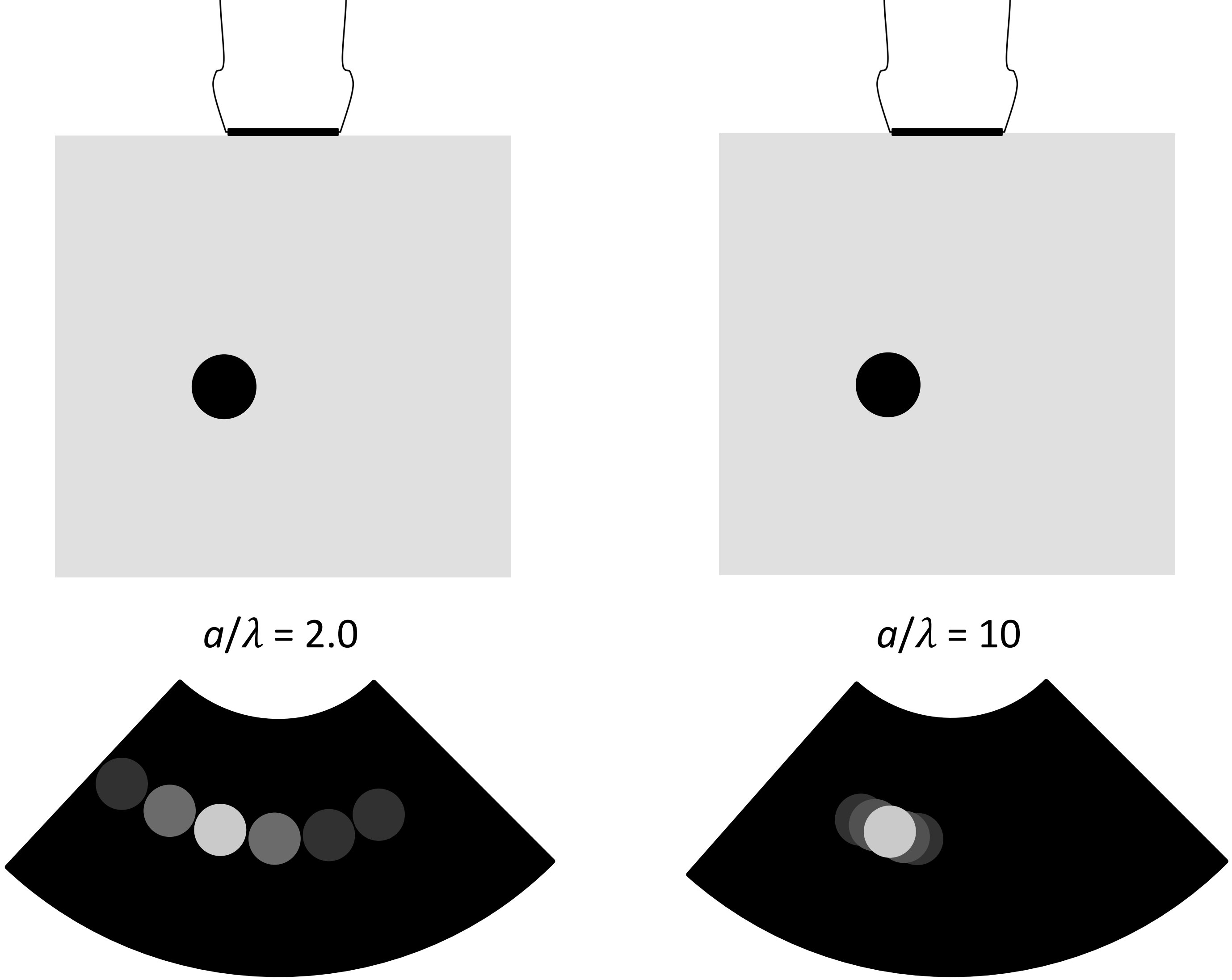
# Artifacts



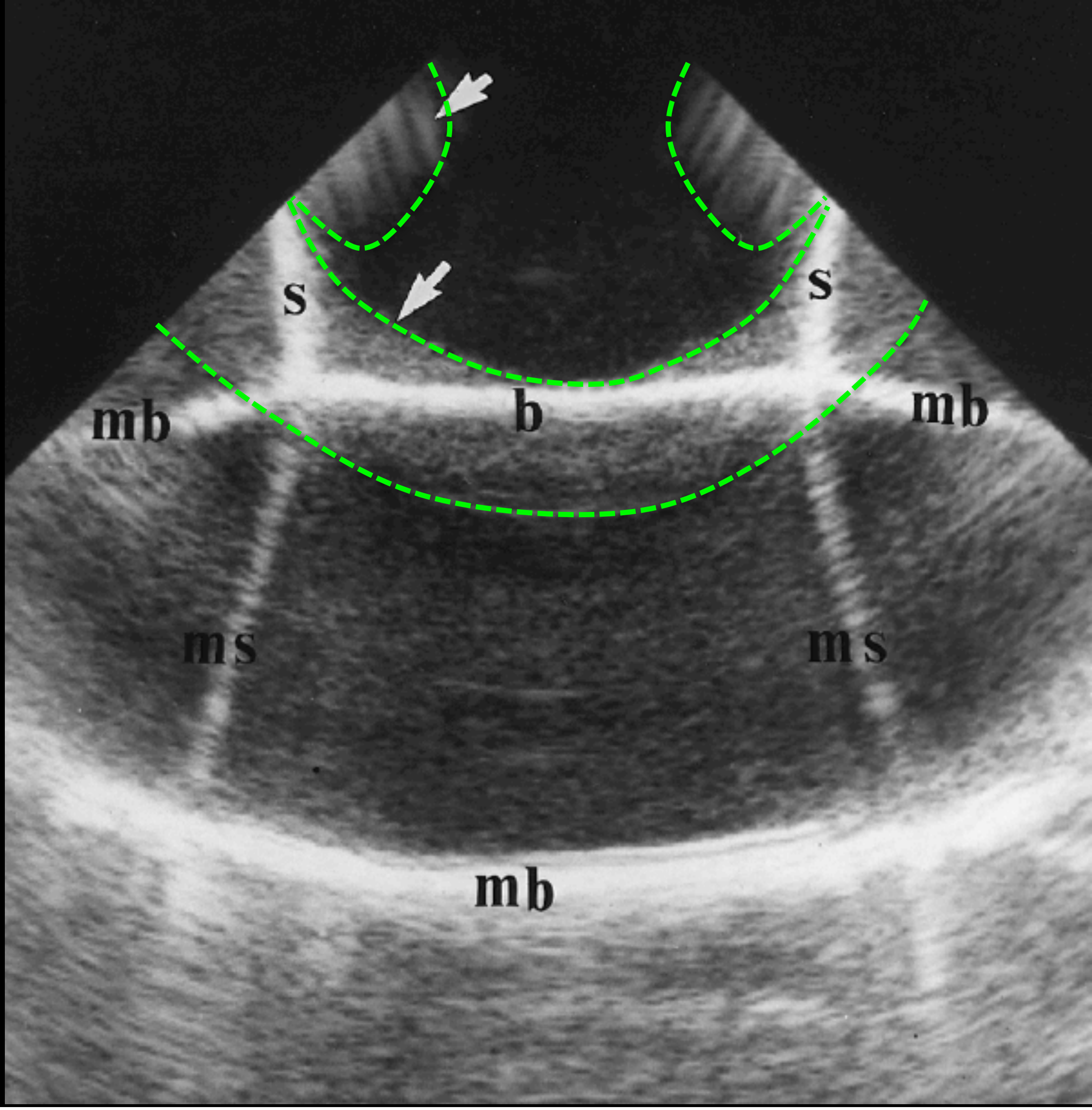
# Beamwidth and Slice Thickness Artifacts



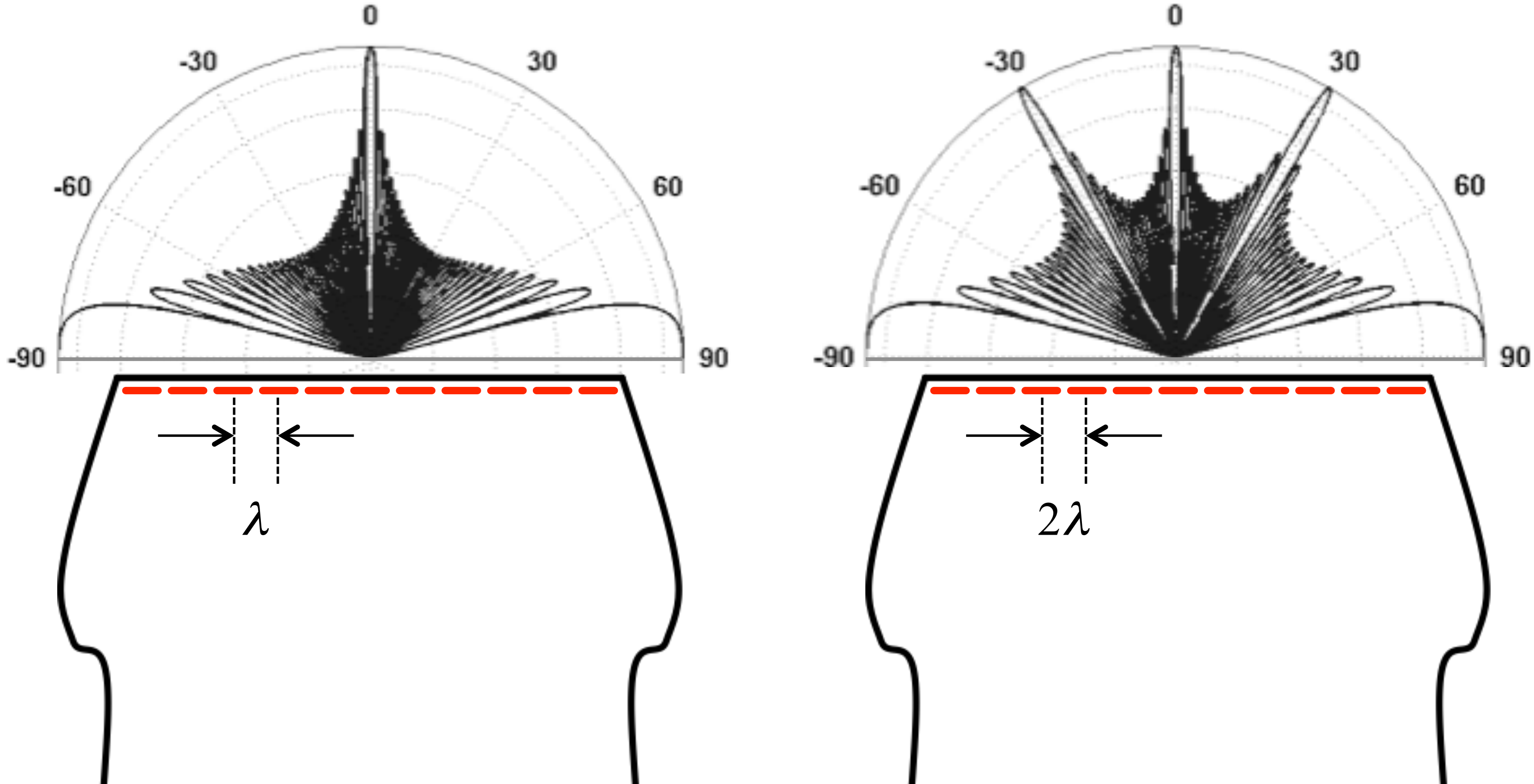

Side Lobe Artifacts



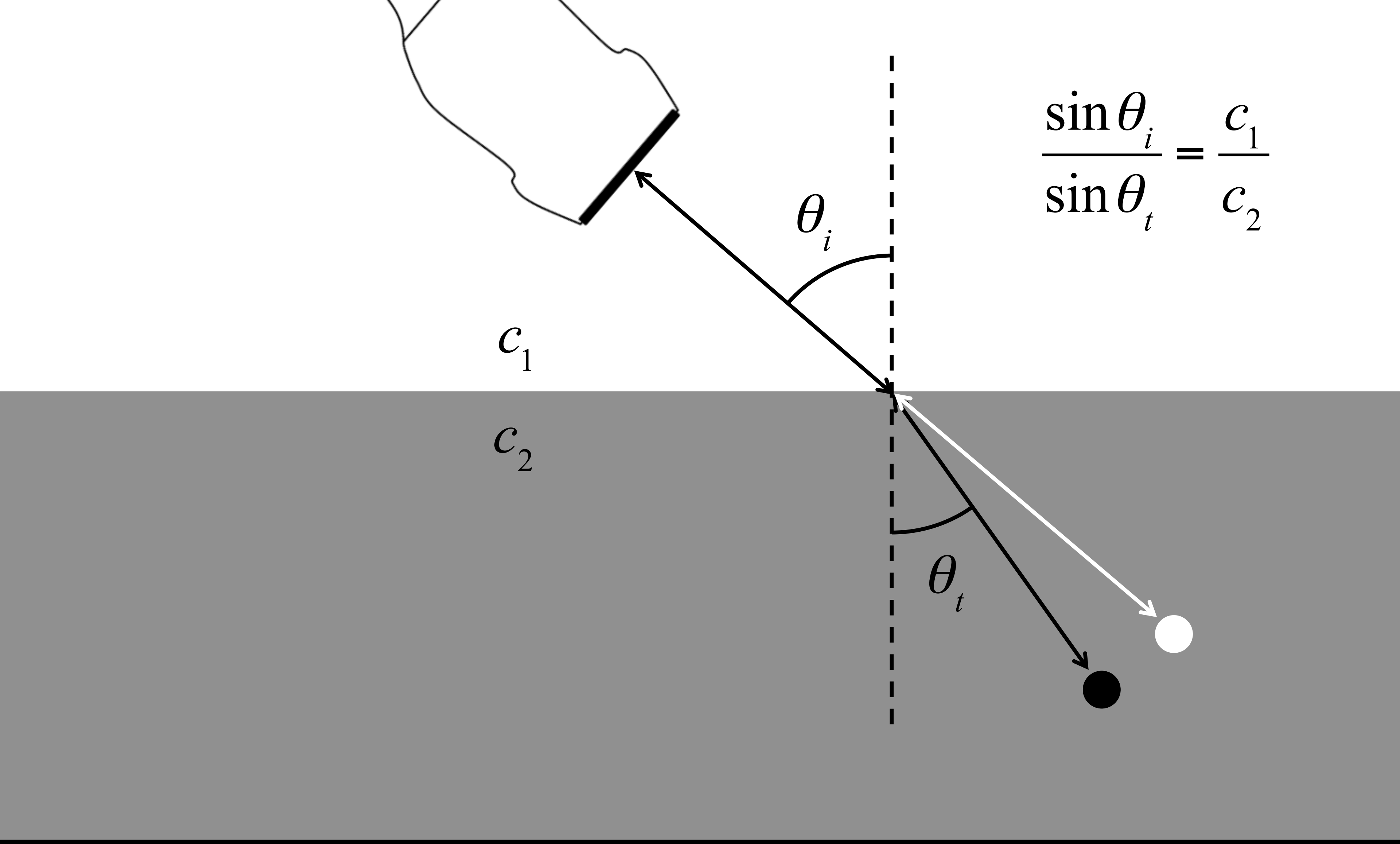

# Side Lobe Artifacts



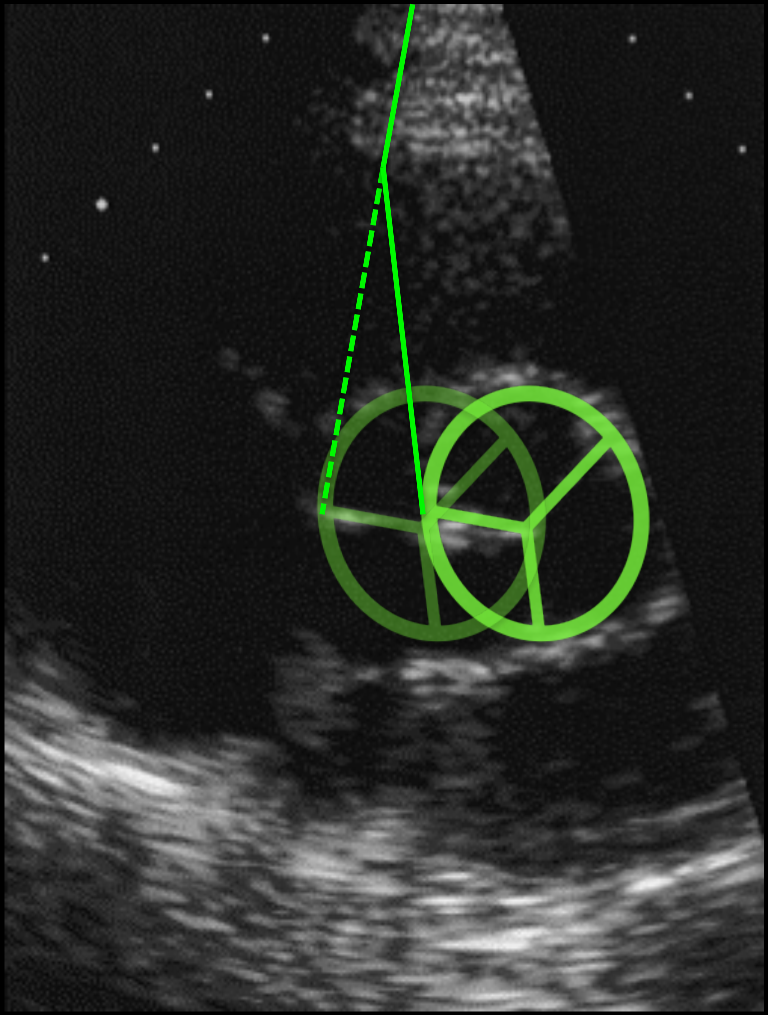

Side Lobe Artifacts



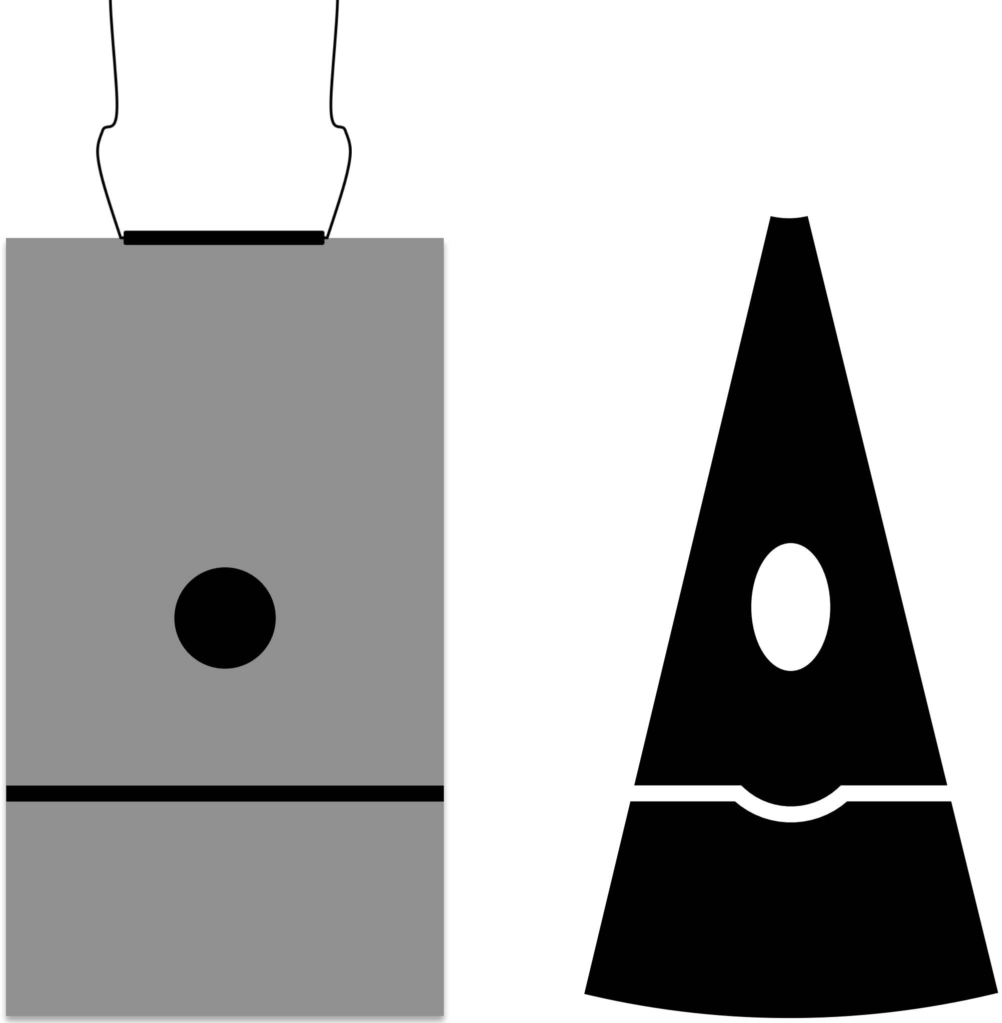

Grating Lobes



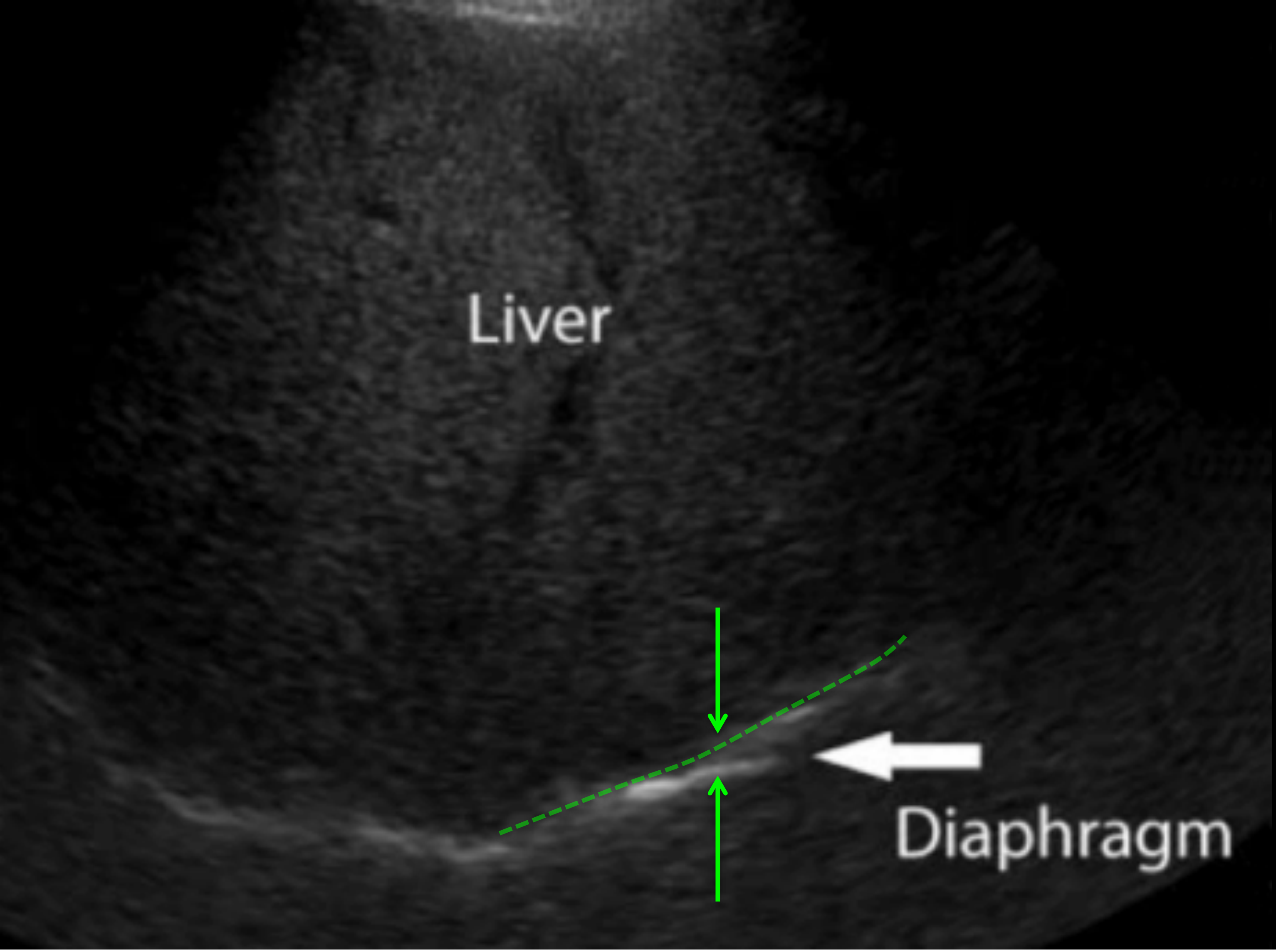

Refraction Artifacts



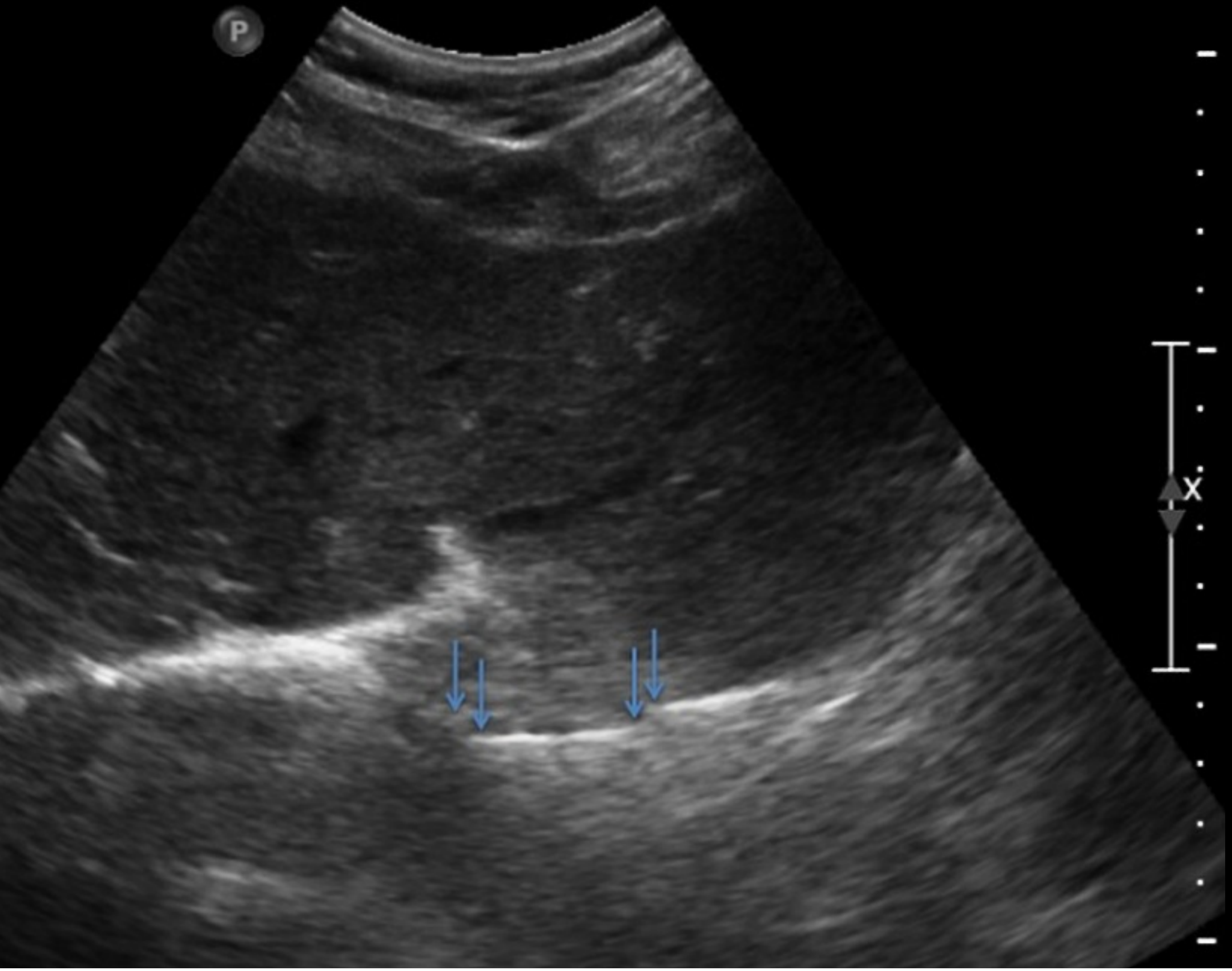
Refraction Artifacts



Displacement Artifact



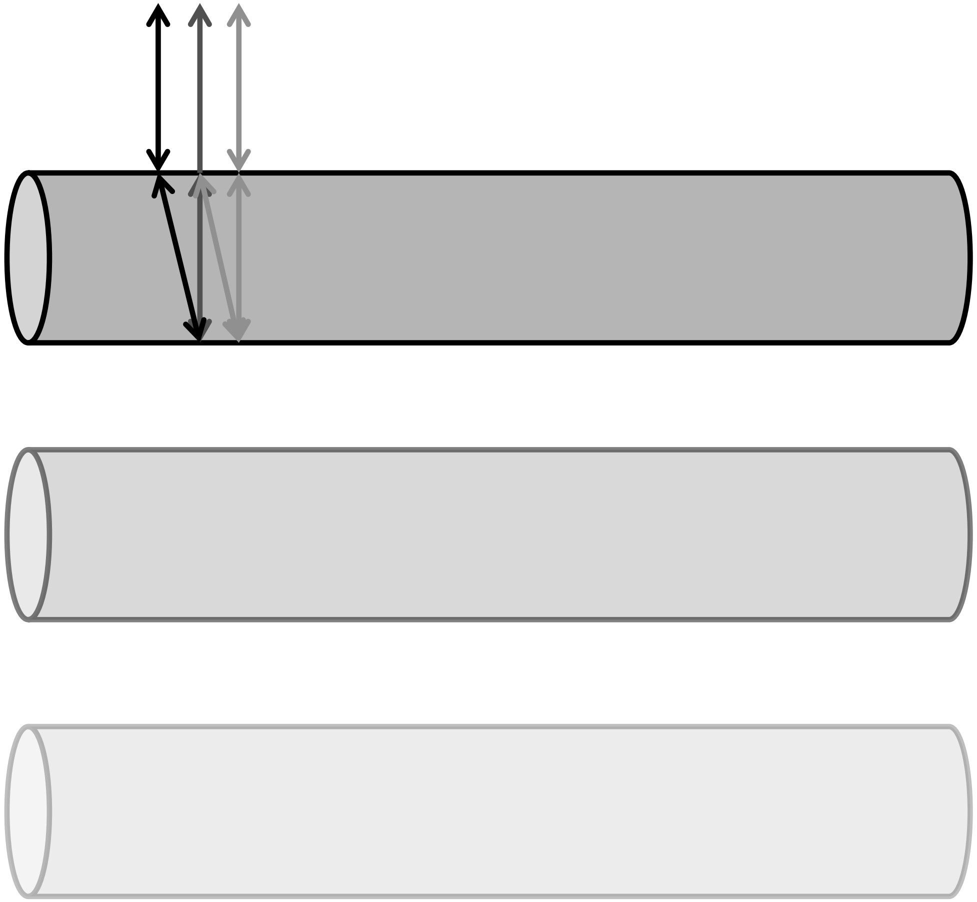

Displacement Artifact



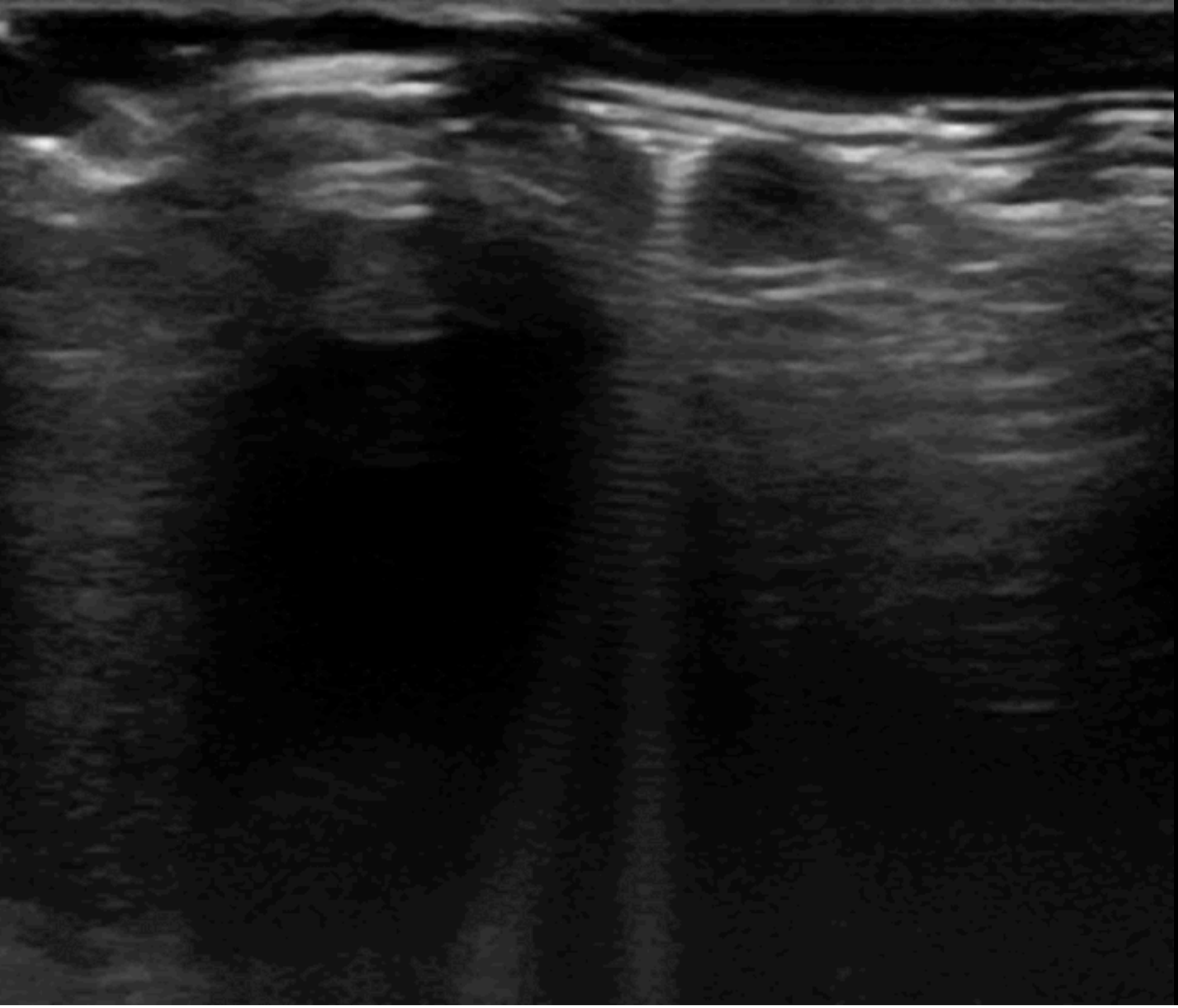

Displacement Artifact

Displacement Artifact

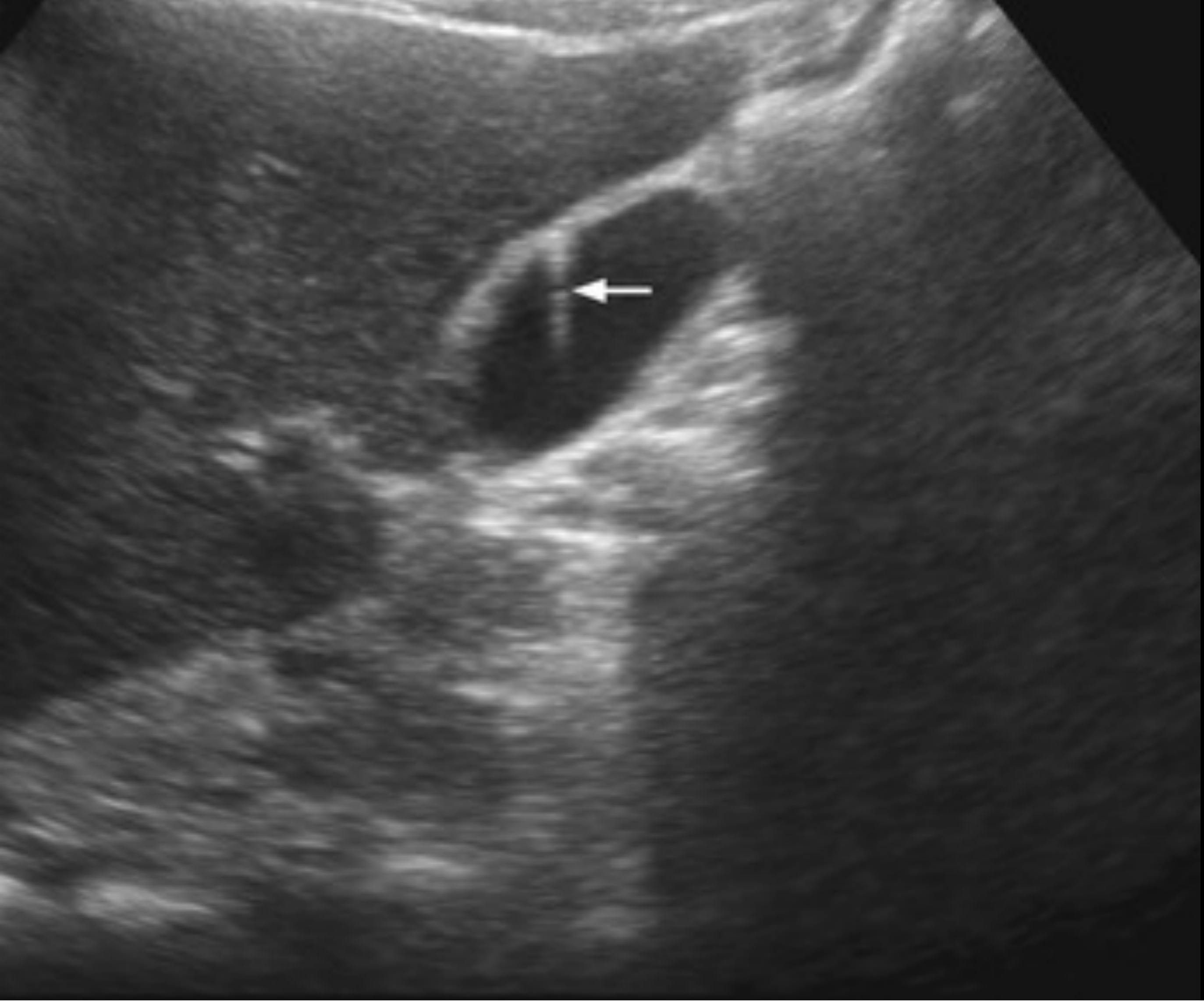
Edge Artifacts



Reverberation Artifacts



Reverberation Artifacts



Reverberation Artifacts

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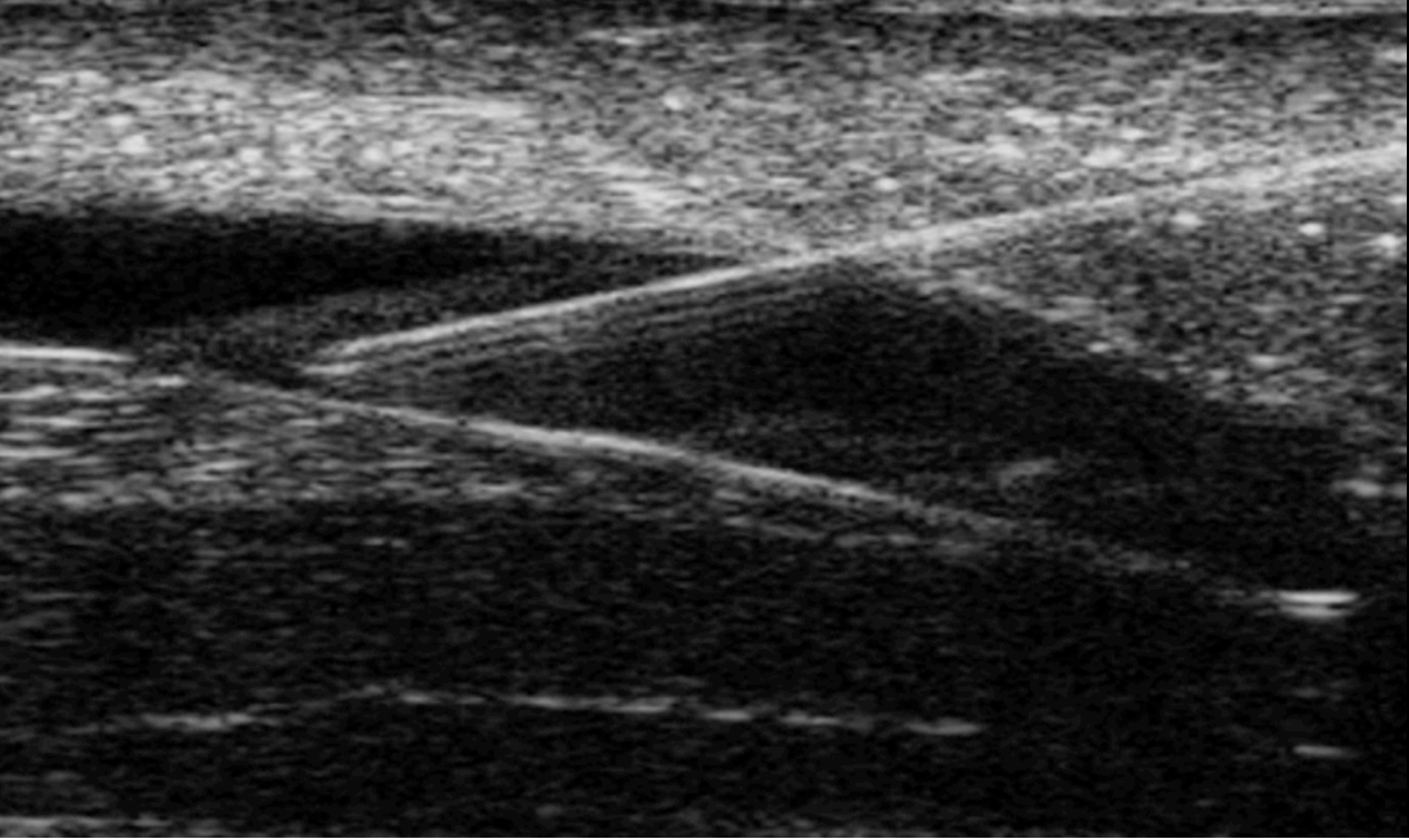
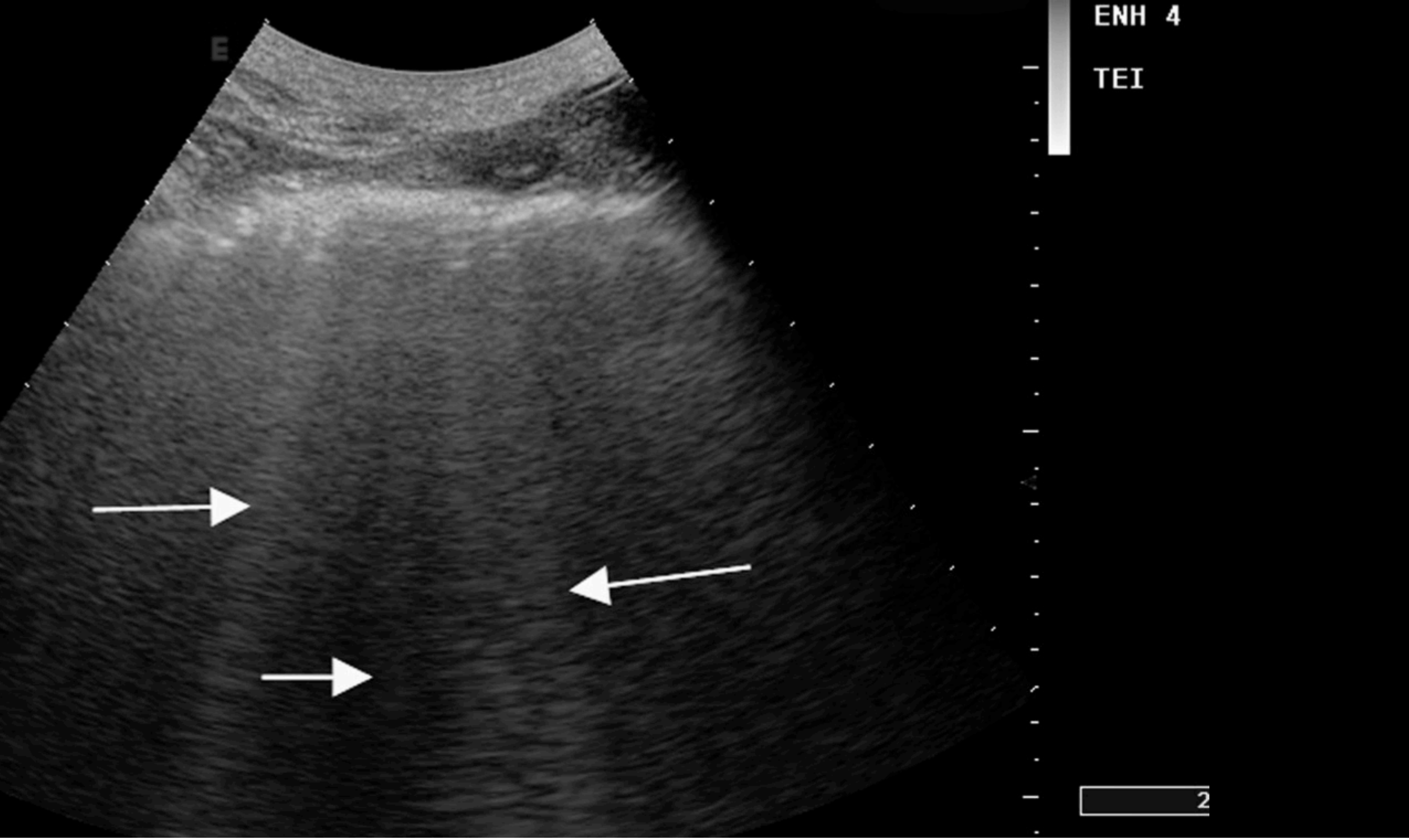
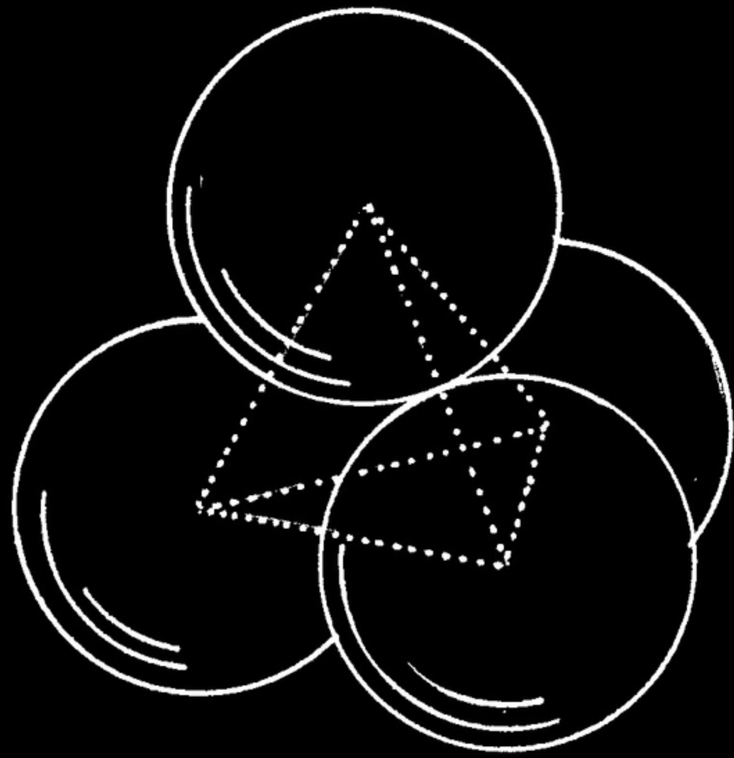


Reverberation Artifacts




Ring-Down Artifact



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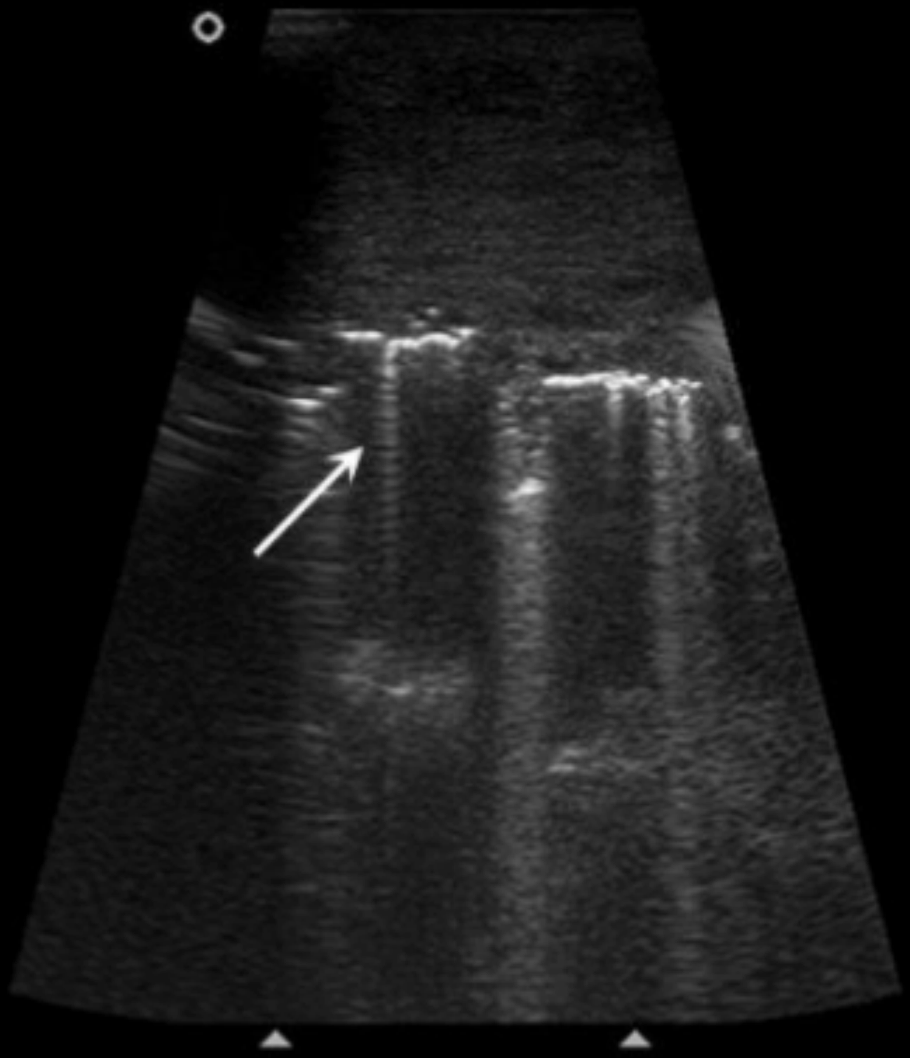

Ring-Down Artifact

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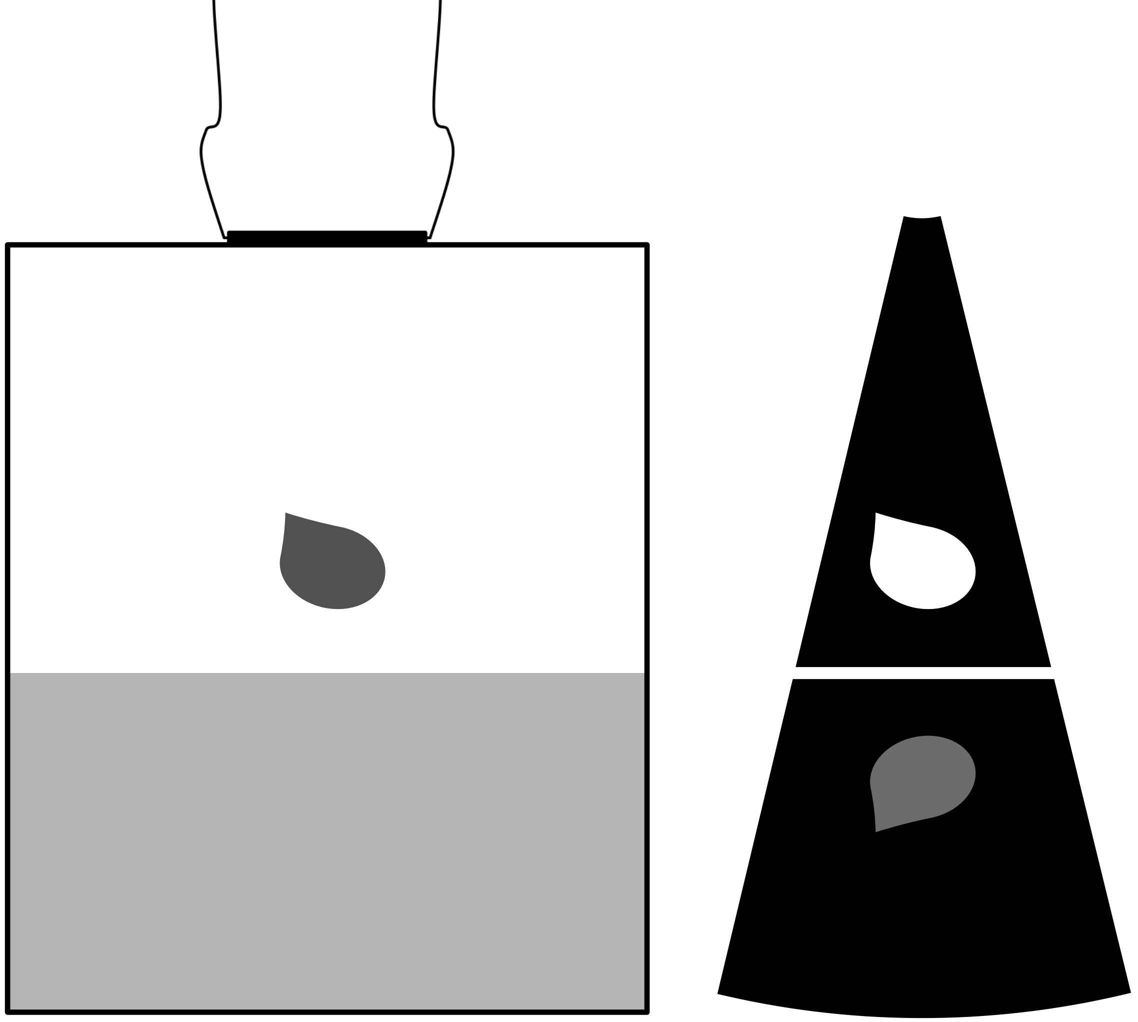
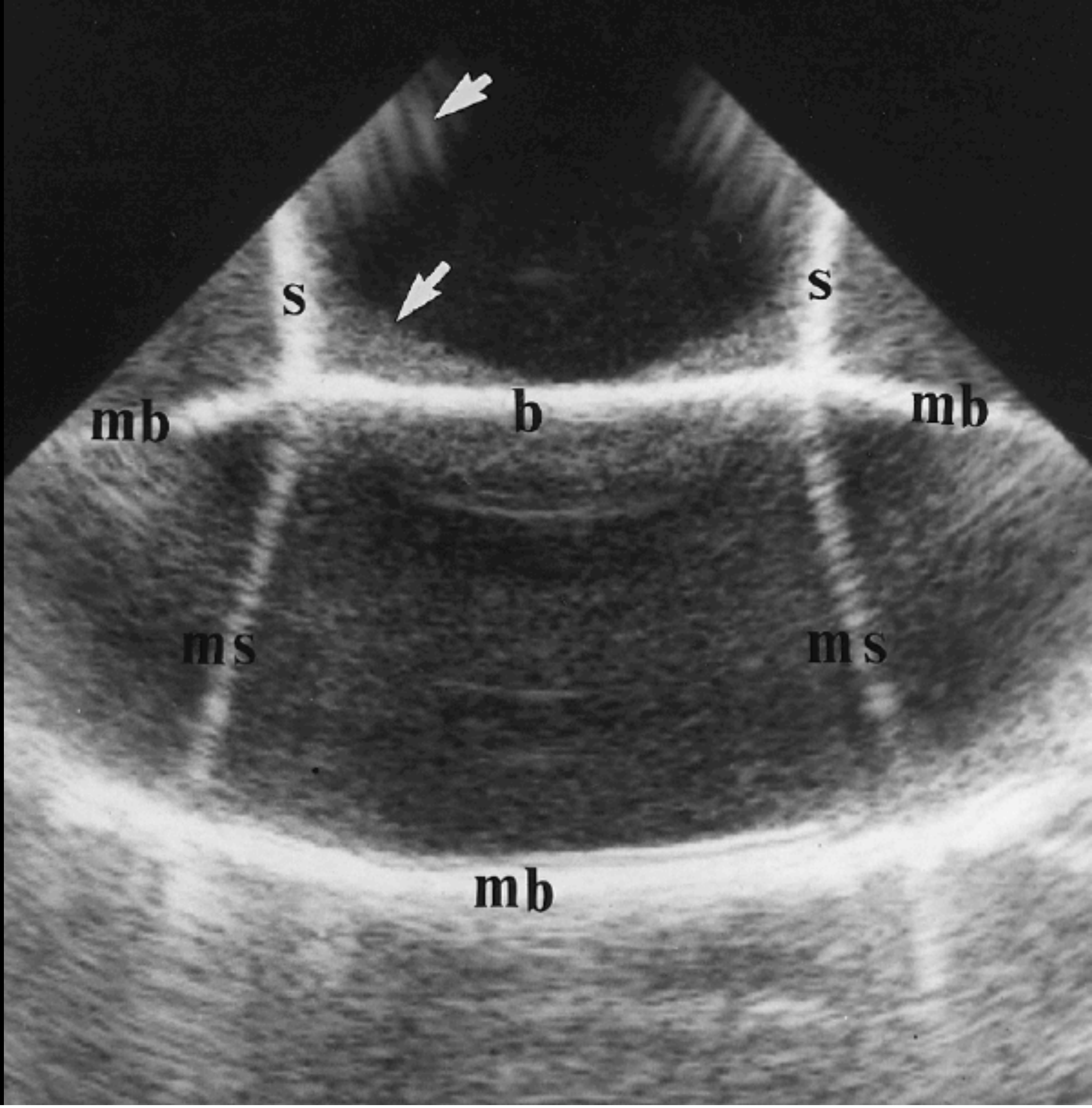


Mirror Image Artifact

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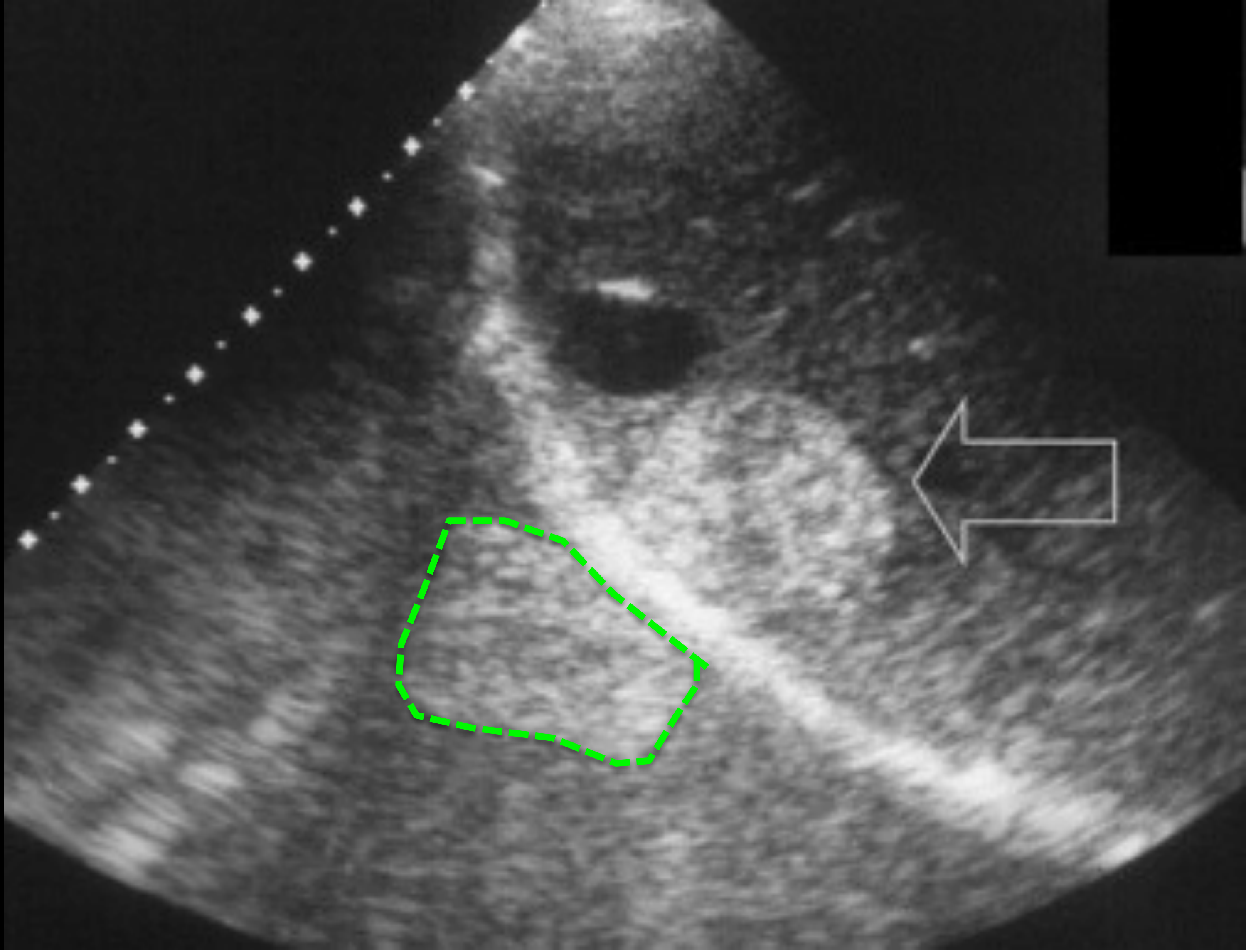

Mirror Image Artifact

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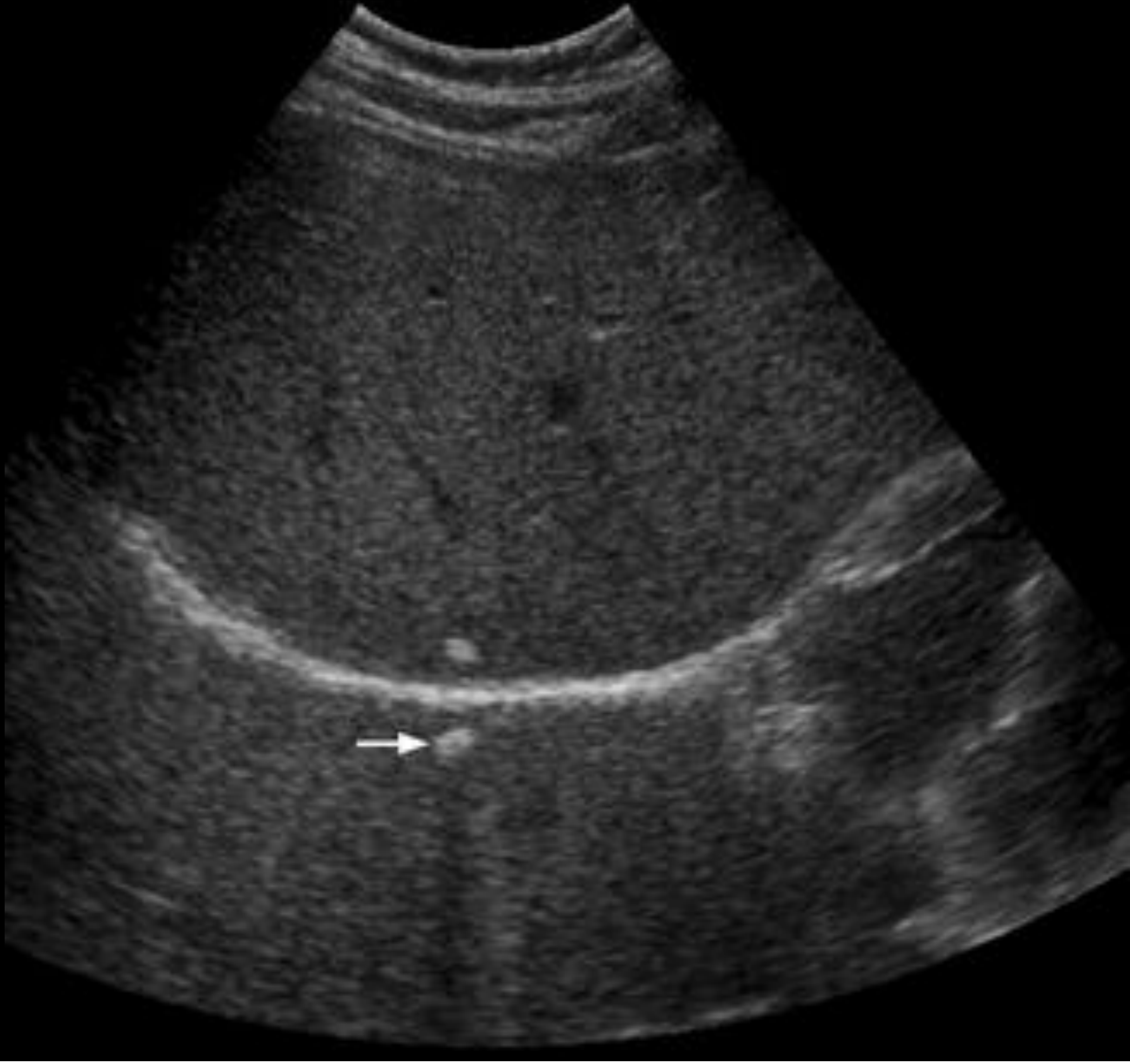
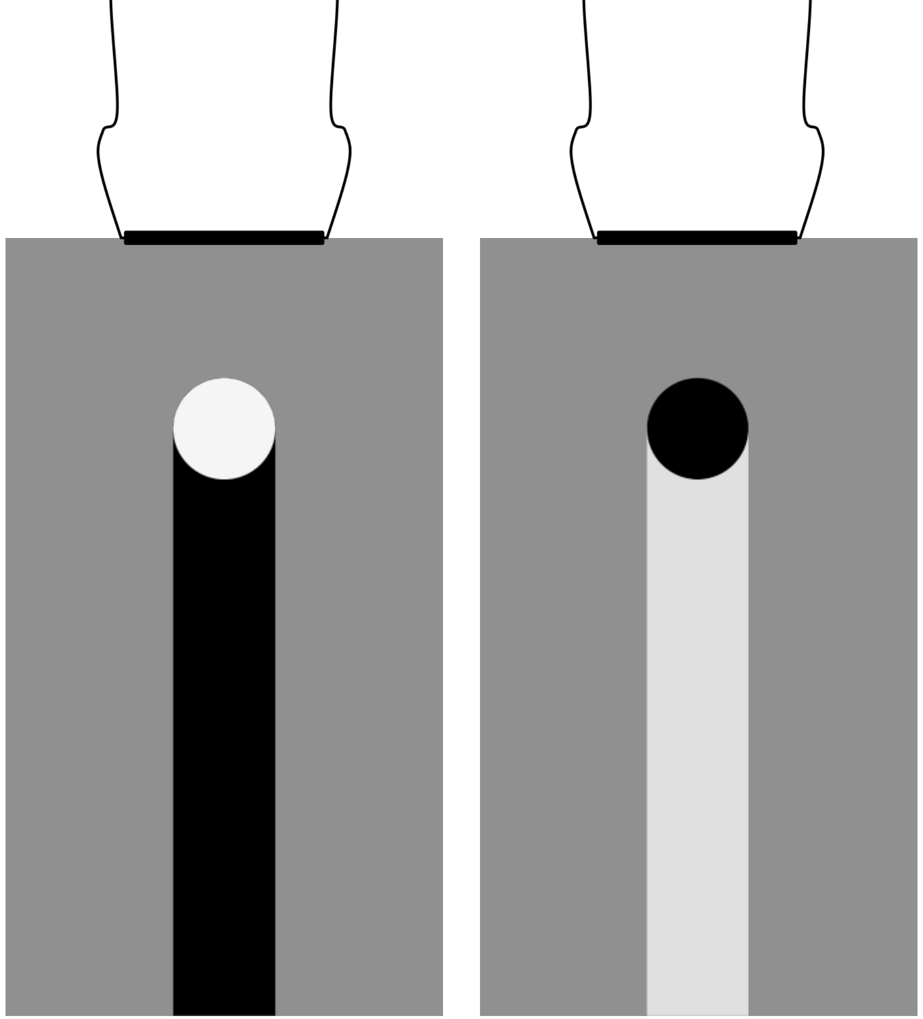
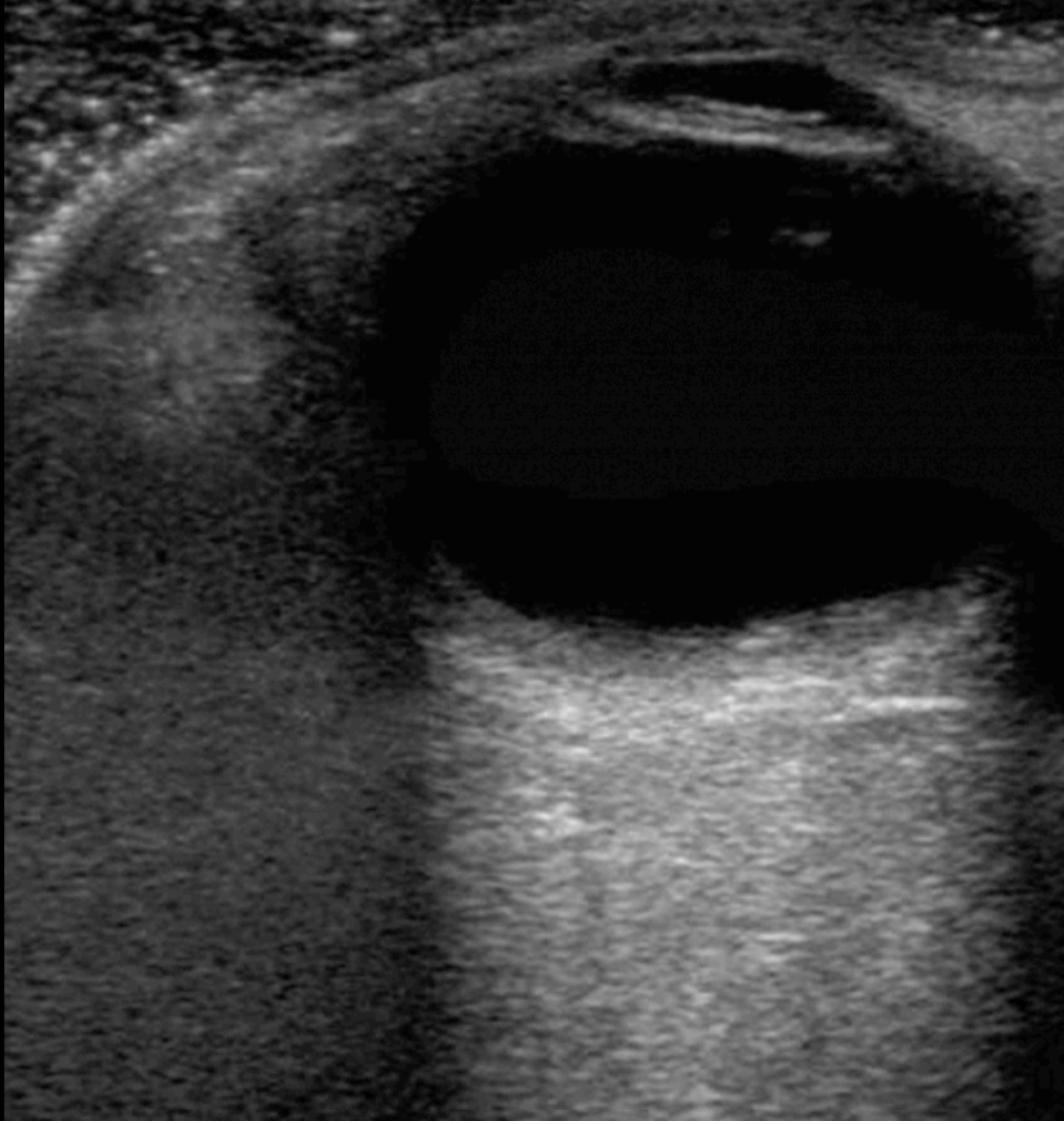


Mirror Image Artifact

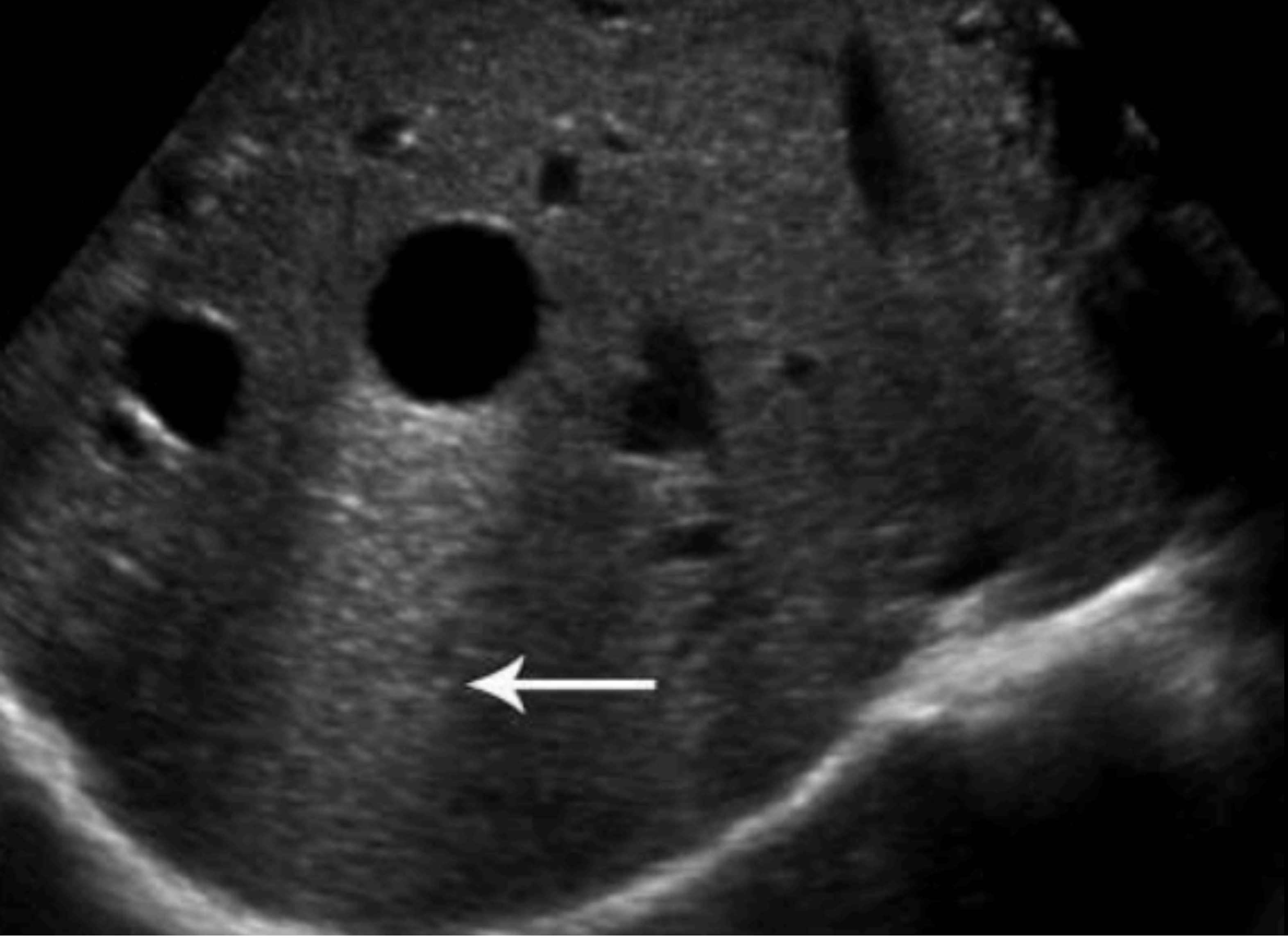
Speckle



Shadowing and Enhancement Artifacts



Shadowing and Enhancement Artifacts



Shadowing and Enhancement Artifacts

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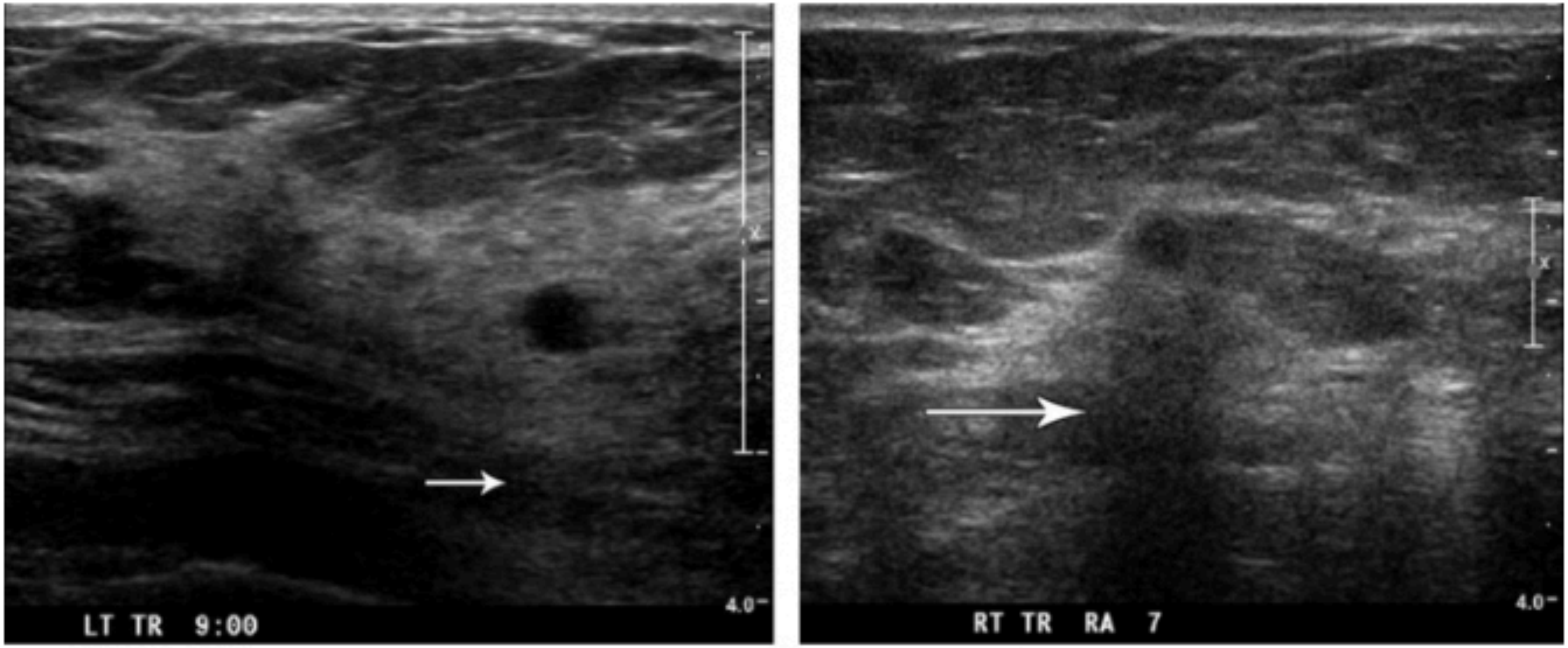


a.　　b.

**Figure 11.** Use of attenuation artifacts to analyze the composition of tissue. **(a)** Transverse US image of the breast shows a small hypoechoic nodule with increased through transmission (arrow). The nodule was stable over a 2-year period in a patient with multiple cystic breast lesions. **(b)** Transverse US image of the breast shows a small hypoechoic nodule with posterior shadowing (arrow). The lesion was a pathologically proved breast cancer.

Shadowing and Enhancement Artifacts

# Summary

Pulse-Echo A-Mode

Pulse-Echo B-Mode

Pulse-Echo C-Mode

Pulse-Echo M-Mode

Transmit Processing

Receive Processing

Imaging Performance

Transmit Focus

Beamforming Artifacts

Velocity Discrepancy Artifacts

Multiple Reflection Artifacts

Attenuation Artifacts