

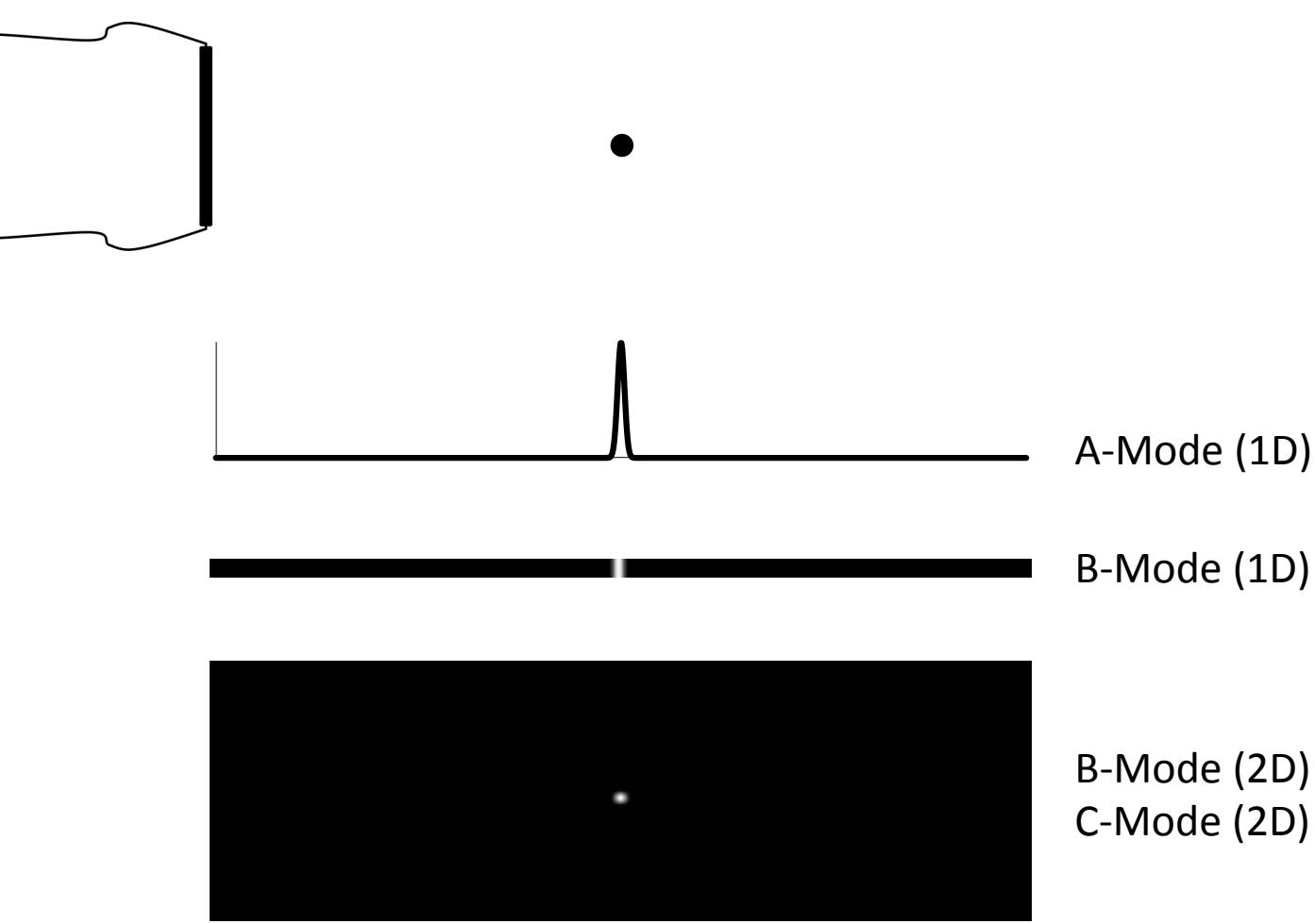
# Ultrasound Physics (BWHRR.US)

## 3. Ultrasound Imaging and Artifacts

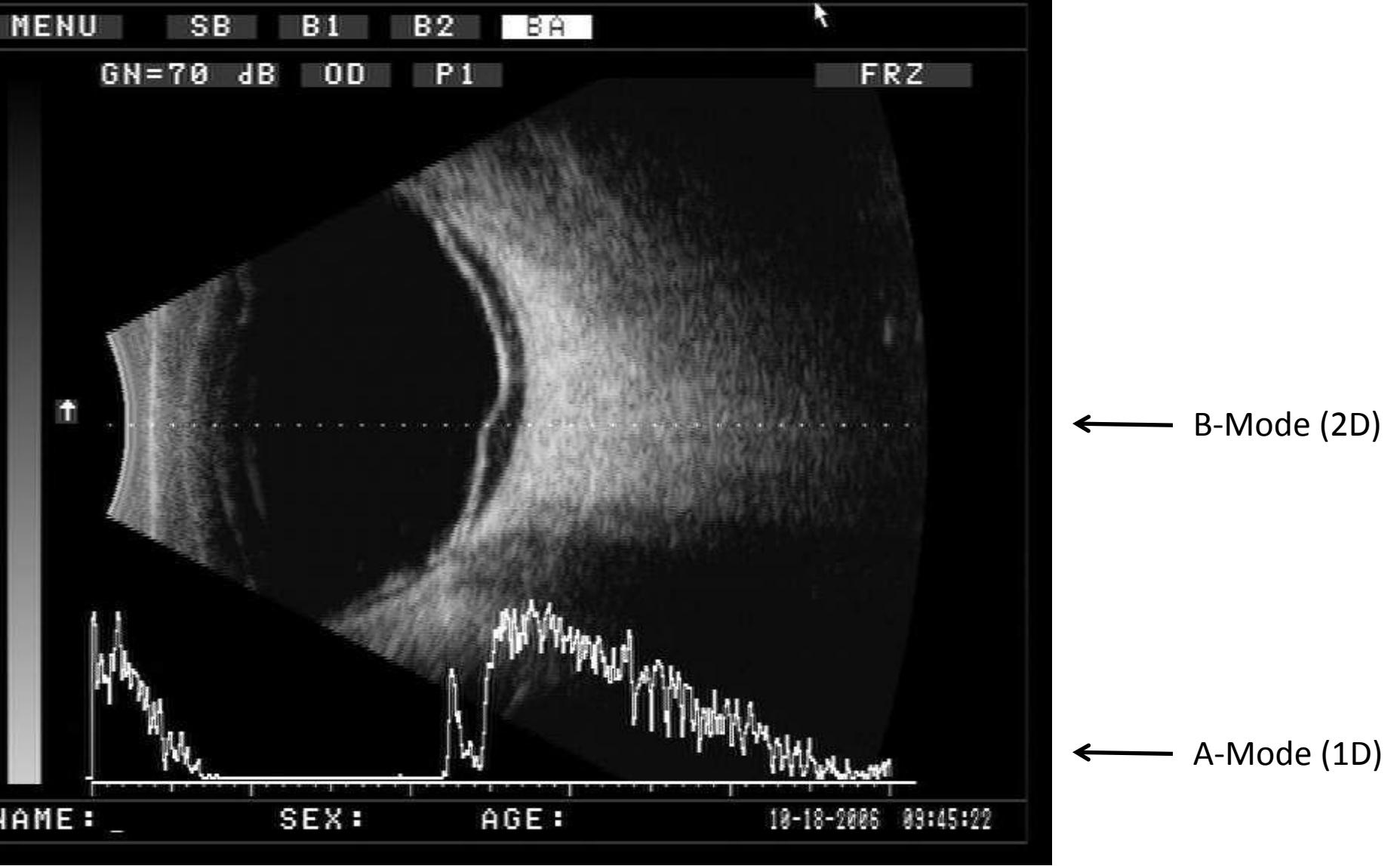


Phillip Jason White, Ph.D.  
Department of Radiology  
Brigham and Women's Hospital | Harvard Medical School  
221 Longwood Avenue | EBRC 521  
Boston, MA 02115

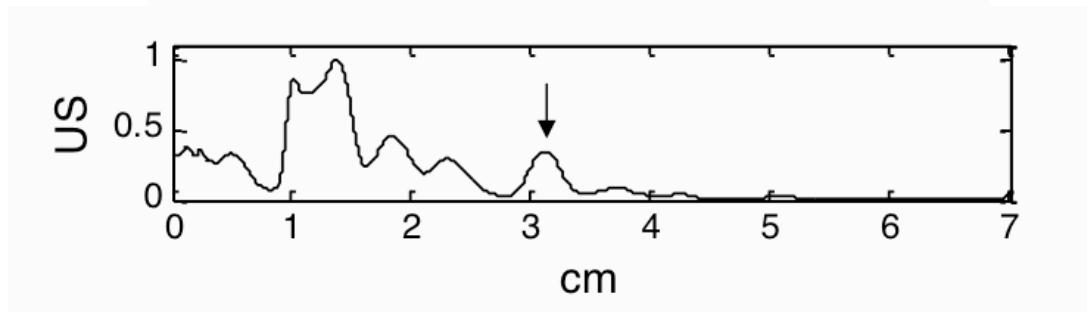
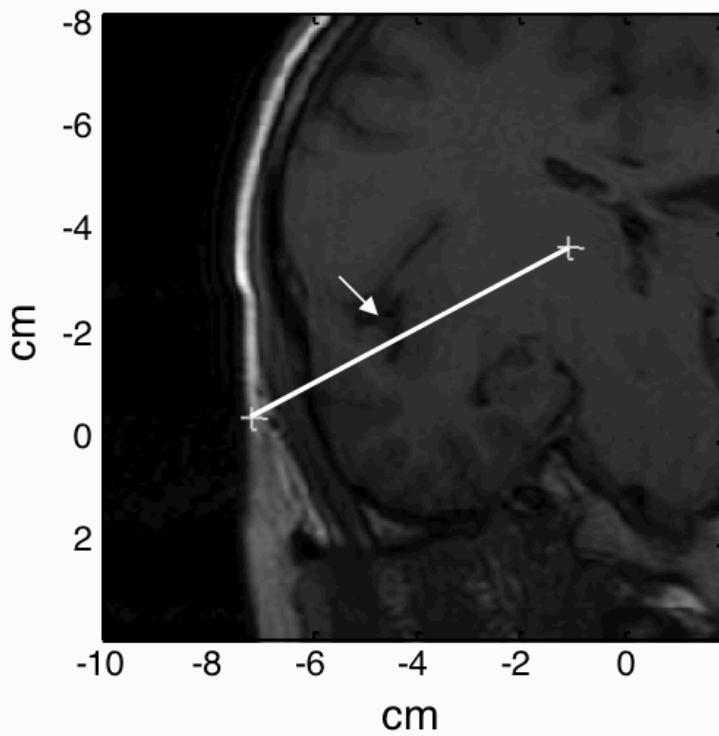
Contact: (617) 525-7465, white@bwh.harvard.edu



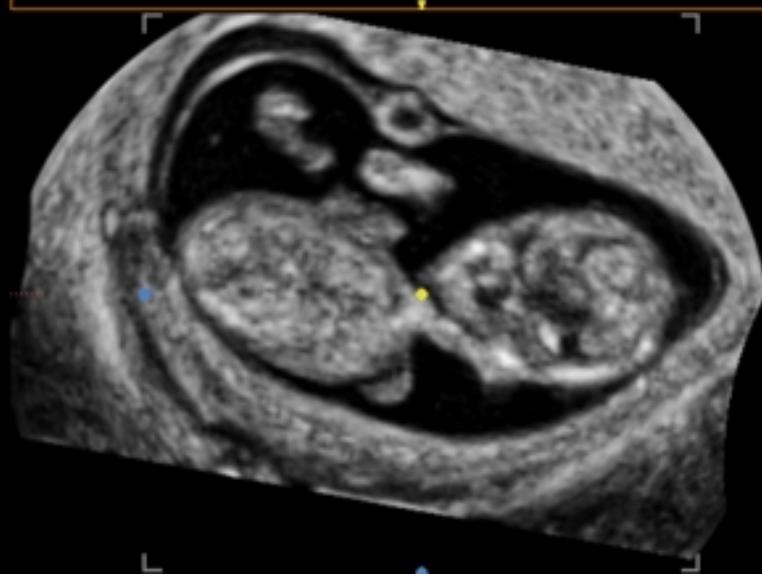
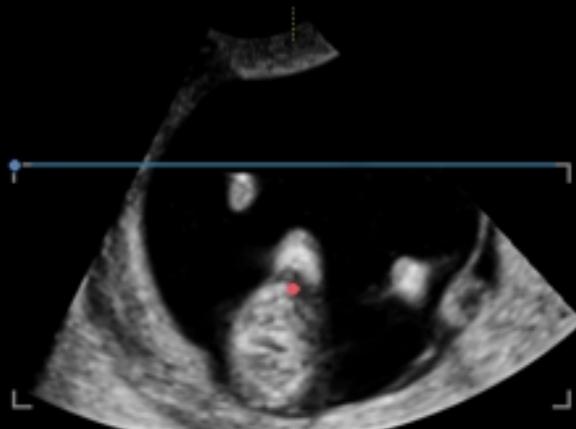
Pulse-Echo Modes



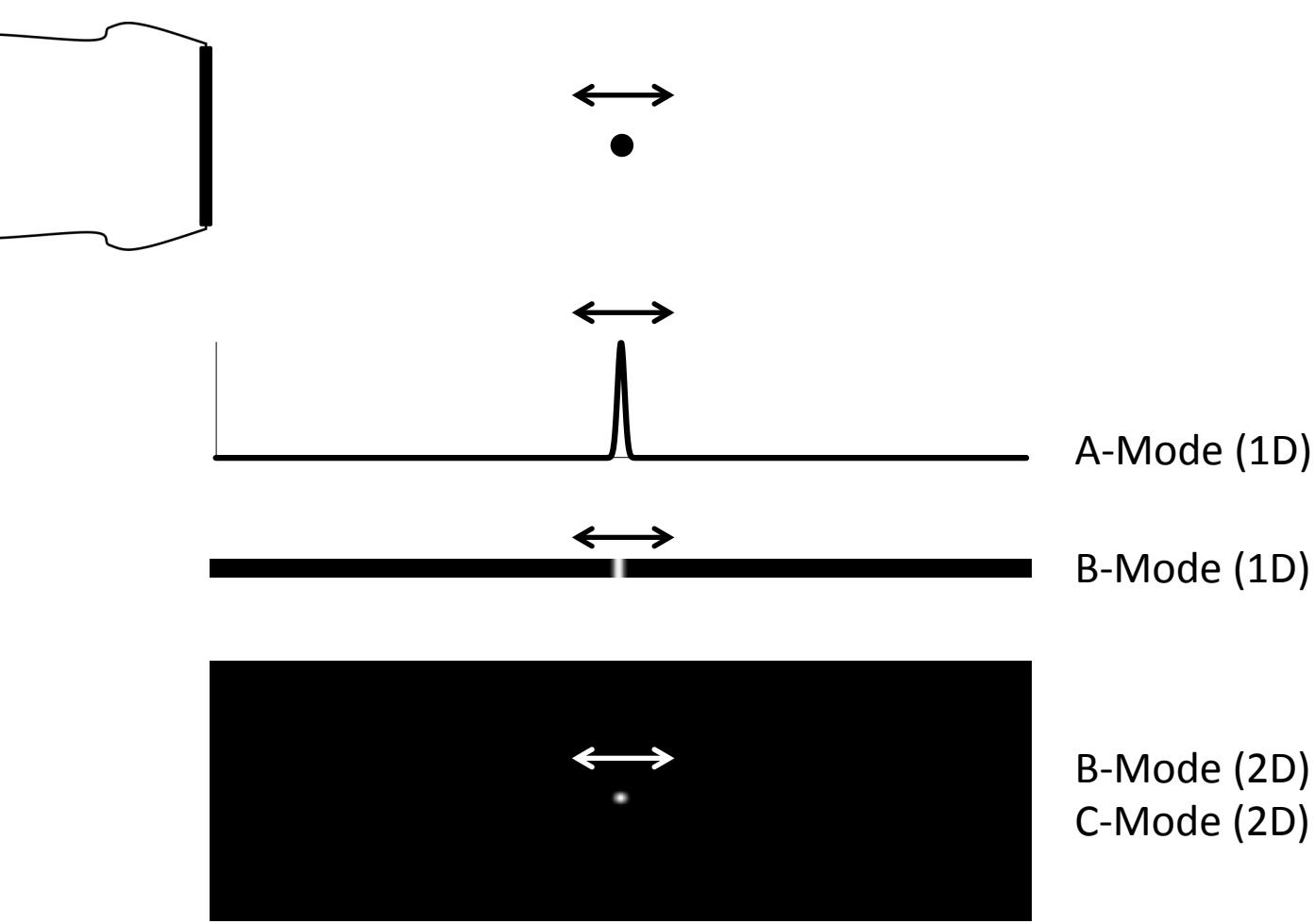
A-Mode Ultrasound



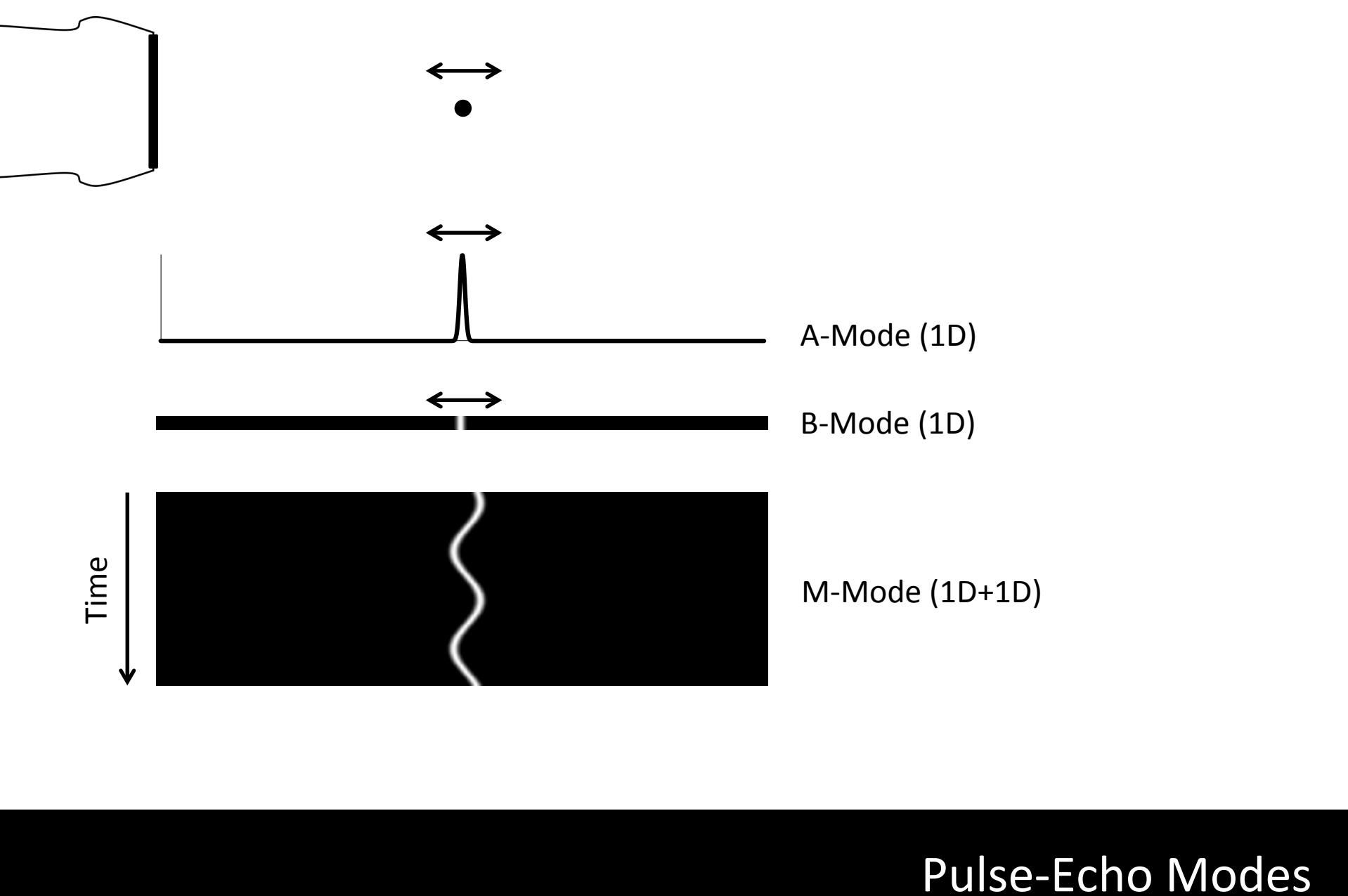
A-Mode Ultrasound



B-Mode and C-Mode Ultrasound



Pulse-Echo Modes



SONOACE  
X4

Cardiac

FPS 21D | 15.0cm | MI 0.53  
C2-4ES | HGen. TIs 0.6

LOOP



#553

0 -

5 -

-

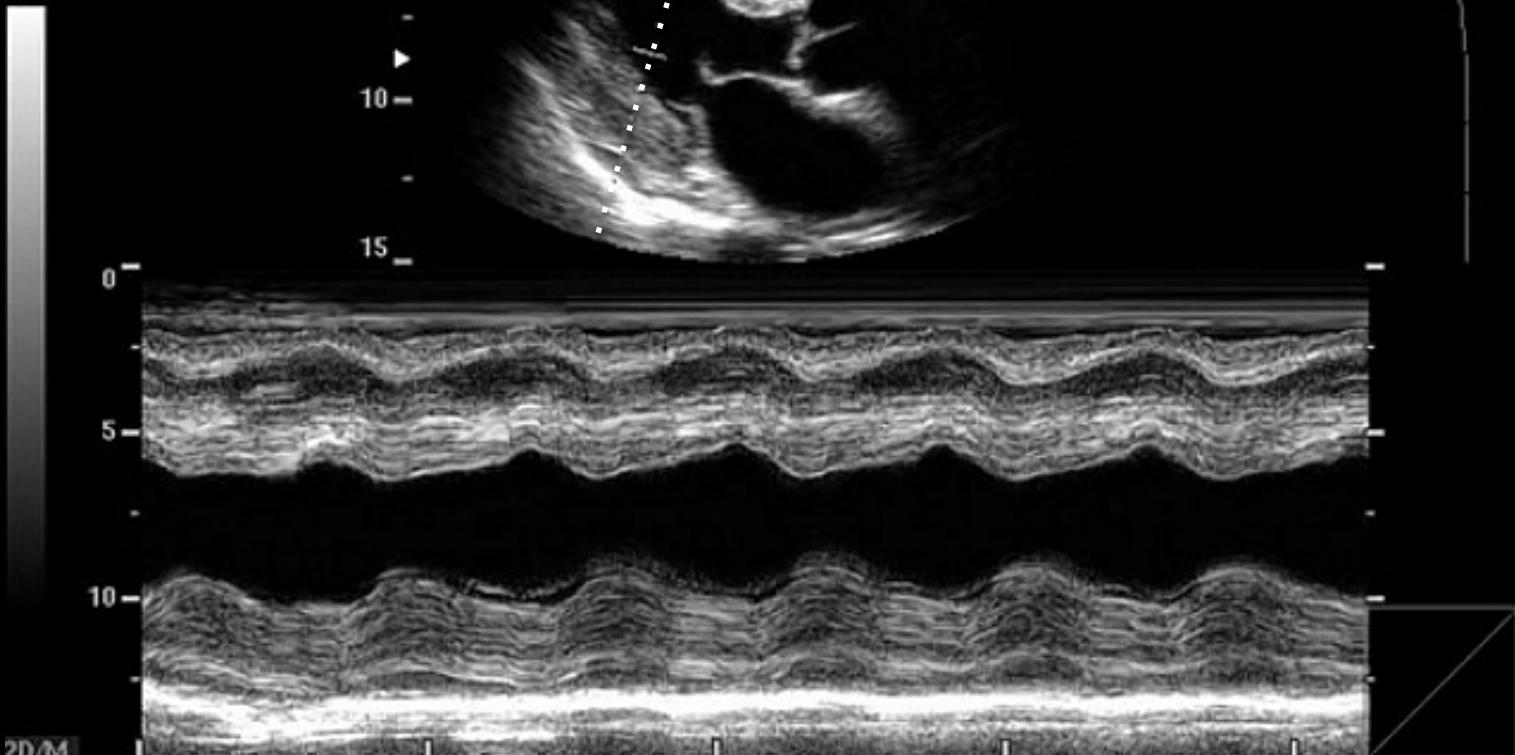
10 -

-

15 -

M

[2D/M] G58 / P100  
80dB / FA2  
FSI3 / PGC3



2D/M

1

Auto Run

2

Cine/Loop

3

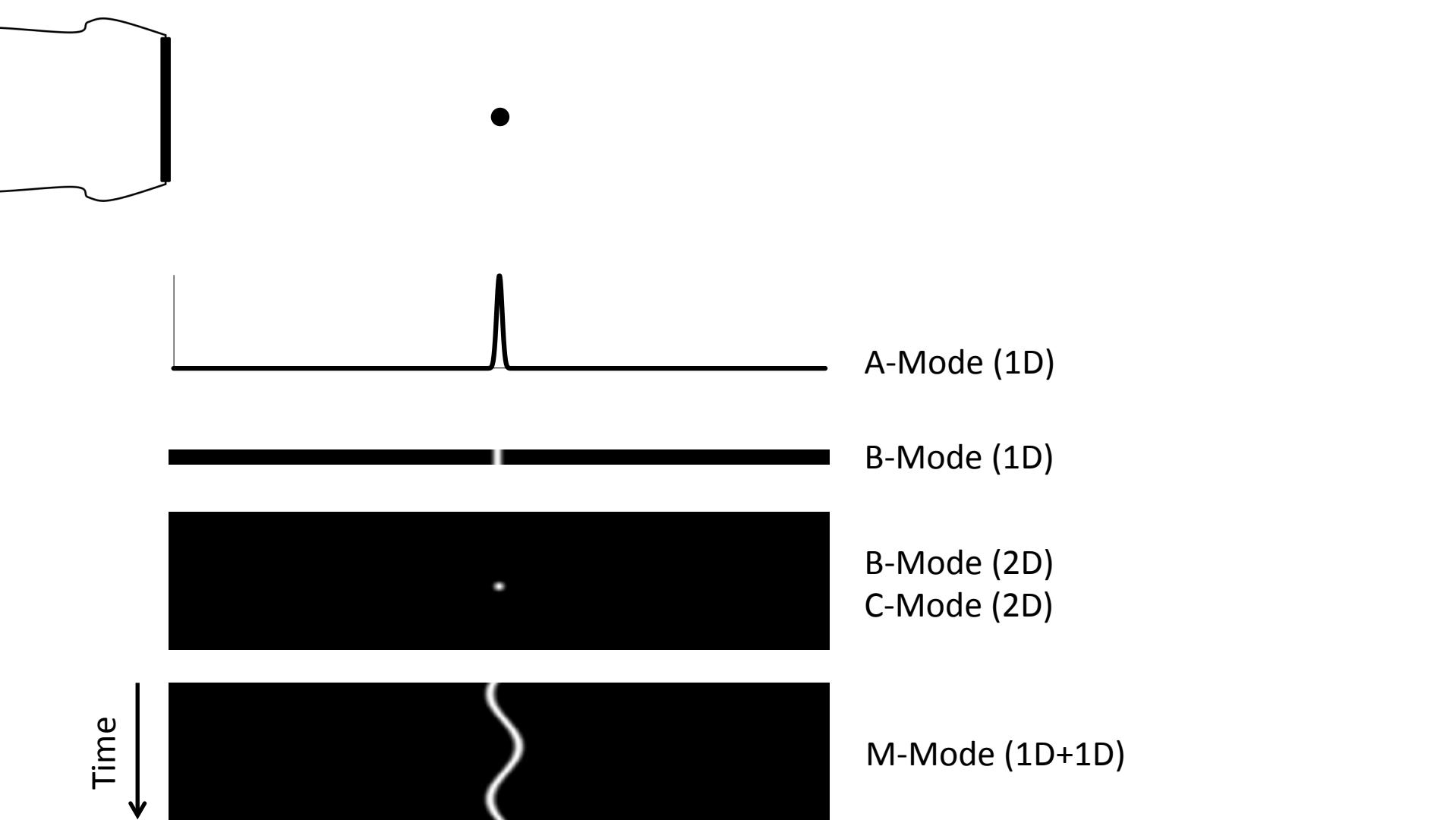
Start Cine

4

End Cine

5

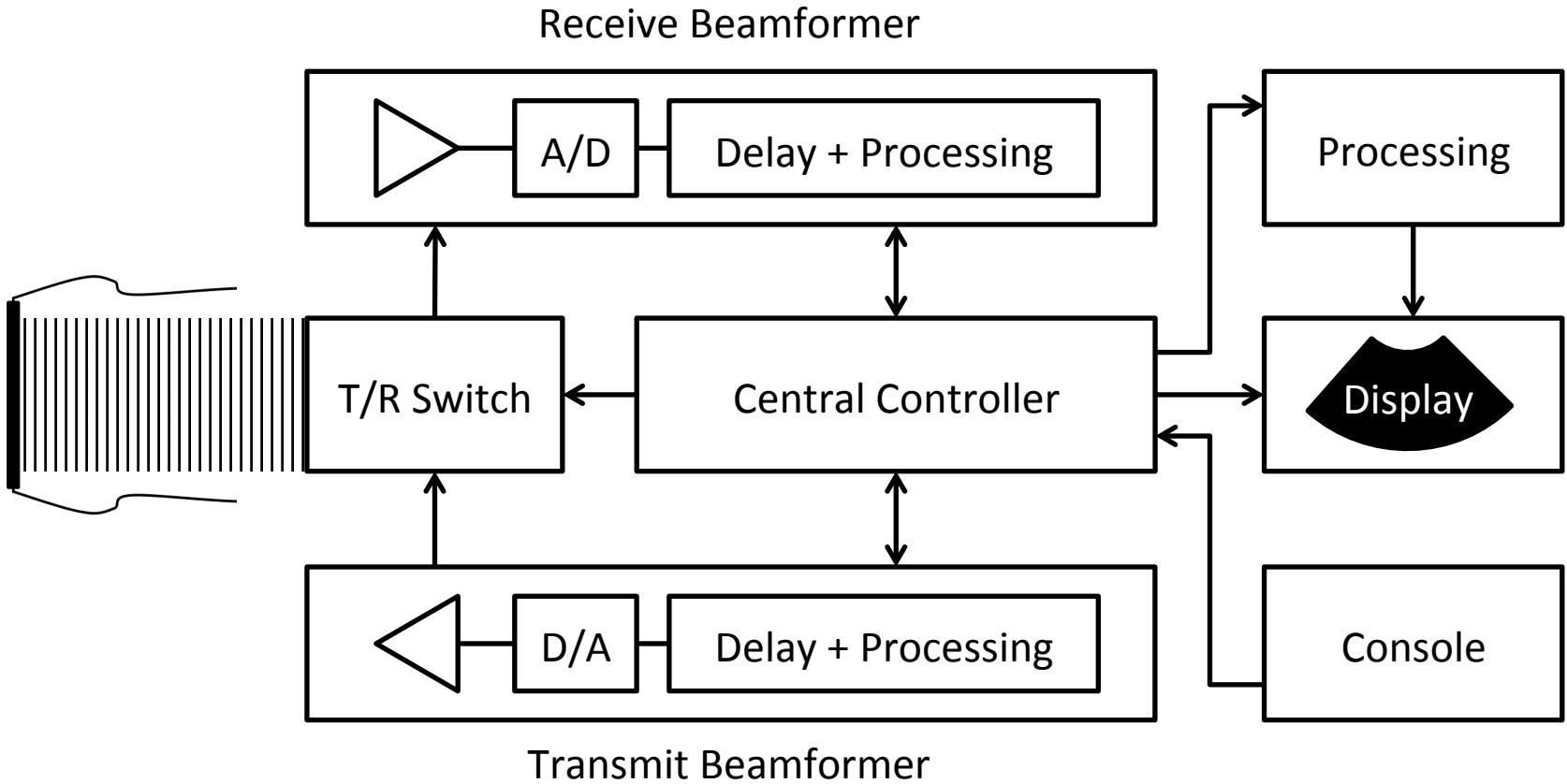
# M-Mode Ultrasound



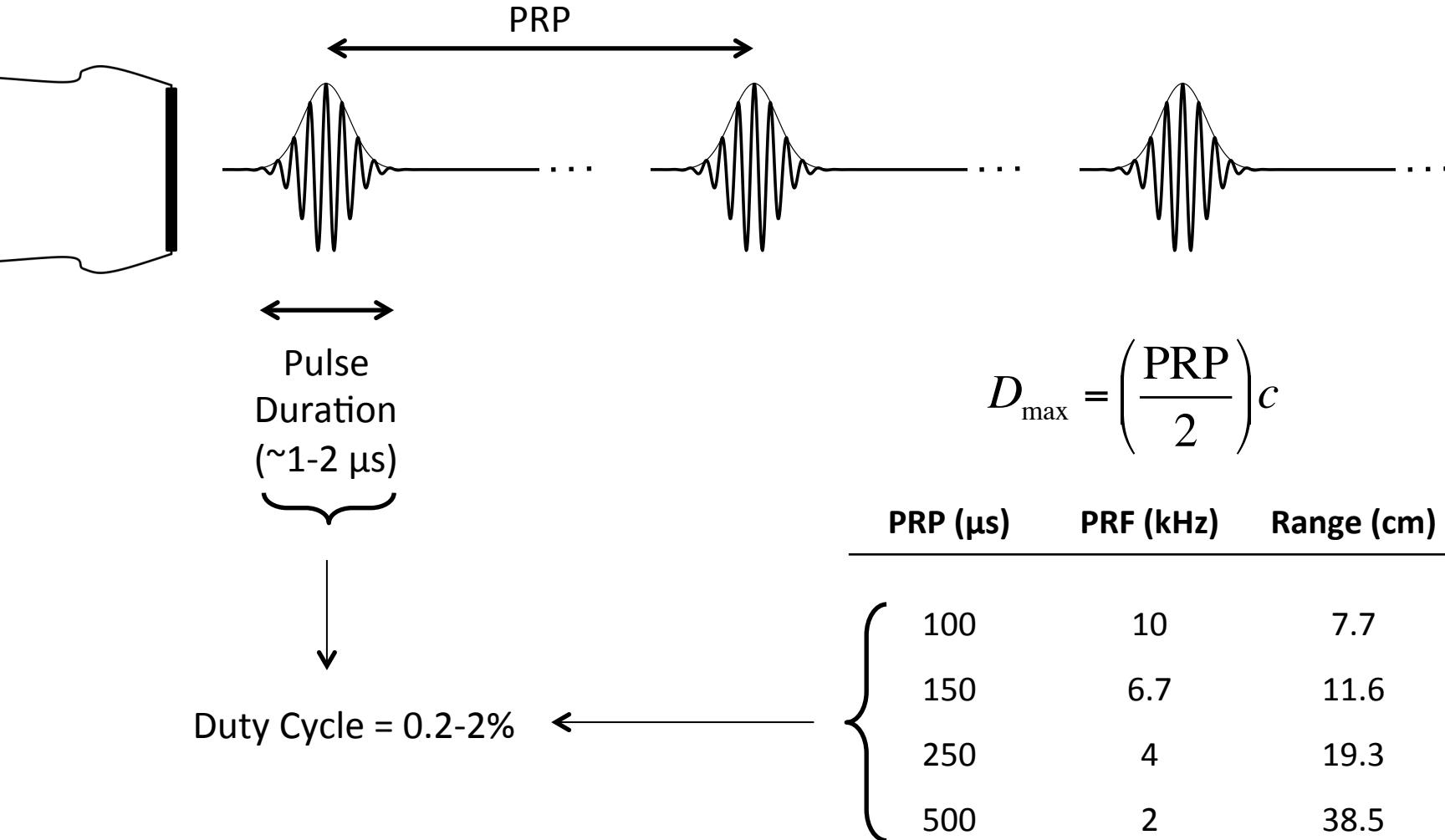
Pulse-Echo Modes



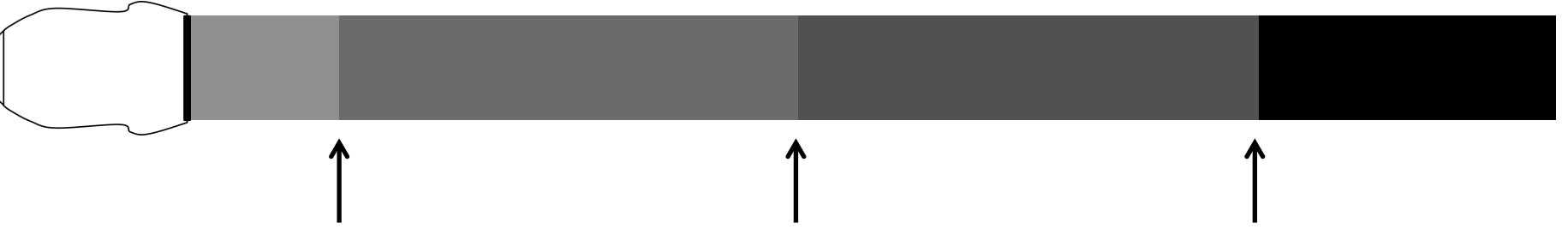
Ultrasound Imaging



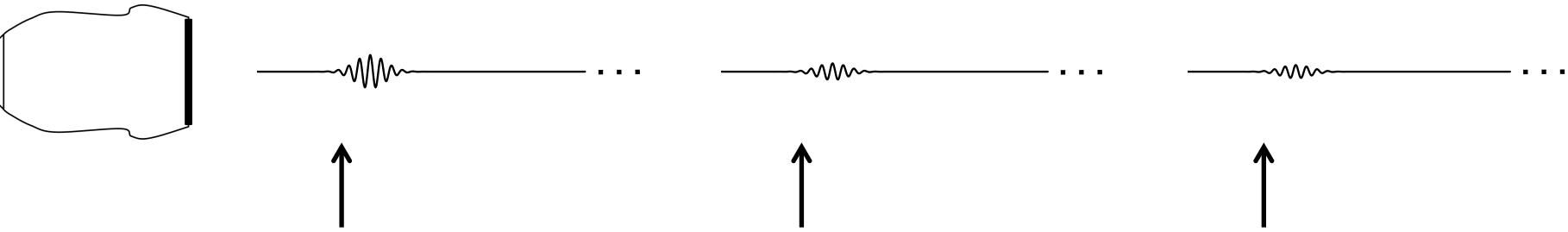
Transmit and Receive Beamformers



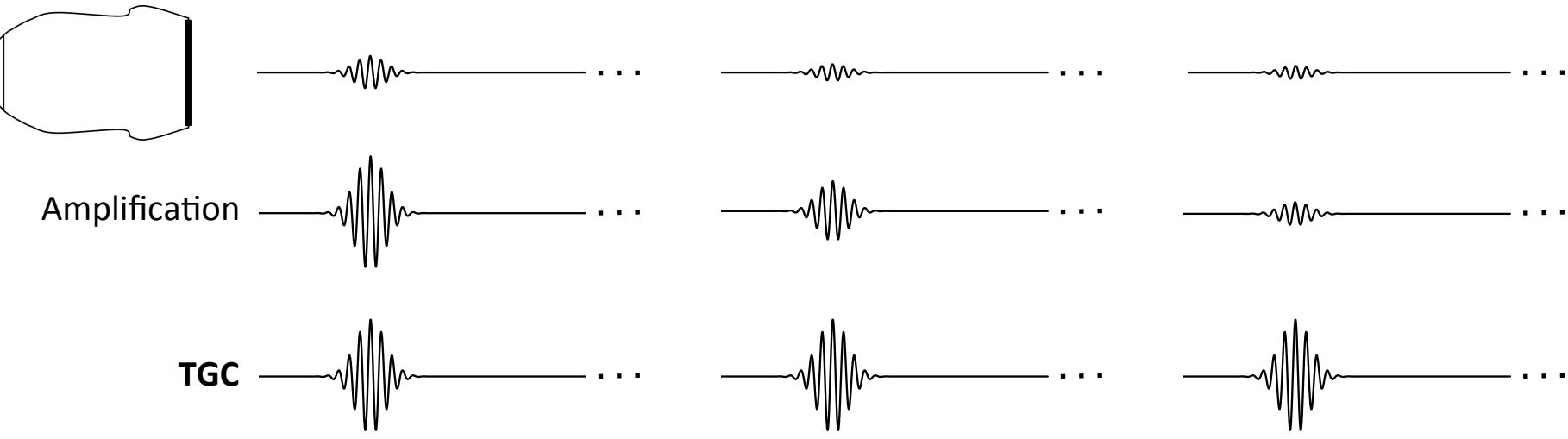
## Transmit Processing



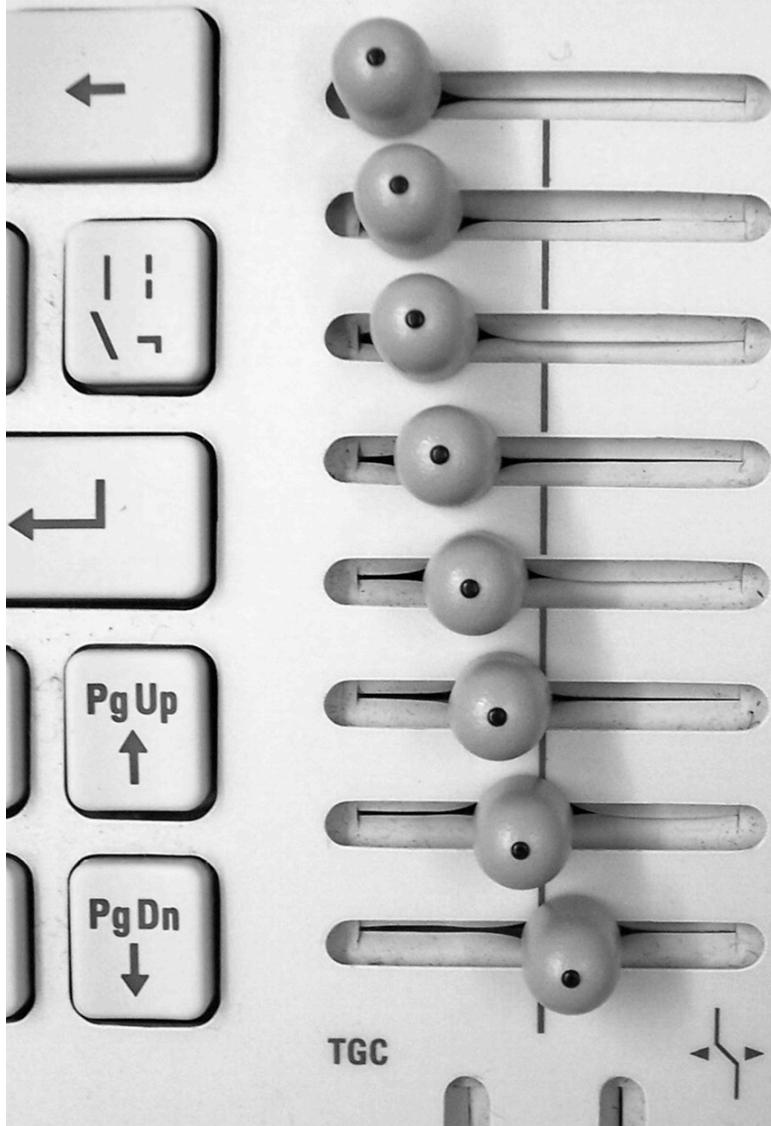
Receive Processing



Receive Processing



Receive Processing



# Time-Gain Compensation (TGC)

HDI AYLMER  
ECHO 308201689 ULTRASOUND

11/04/20:082547  
C5-2 OB/Gen

20 Apr 14 AYLMER F1b02 M12  
08:26:47 Fr #227A12.MER

Map 161  
170dB/C 4  
Persist Off  
2000pt MSCT  
Fr Rate:Surv  
SonoCT®

ATL

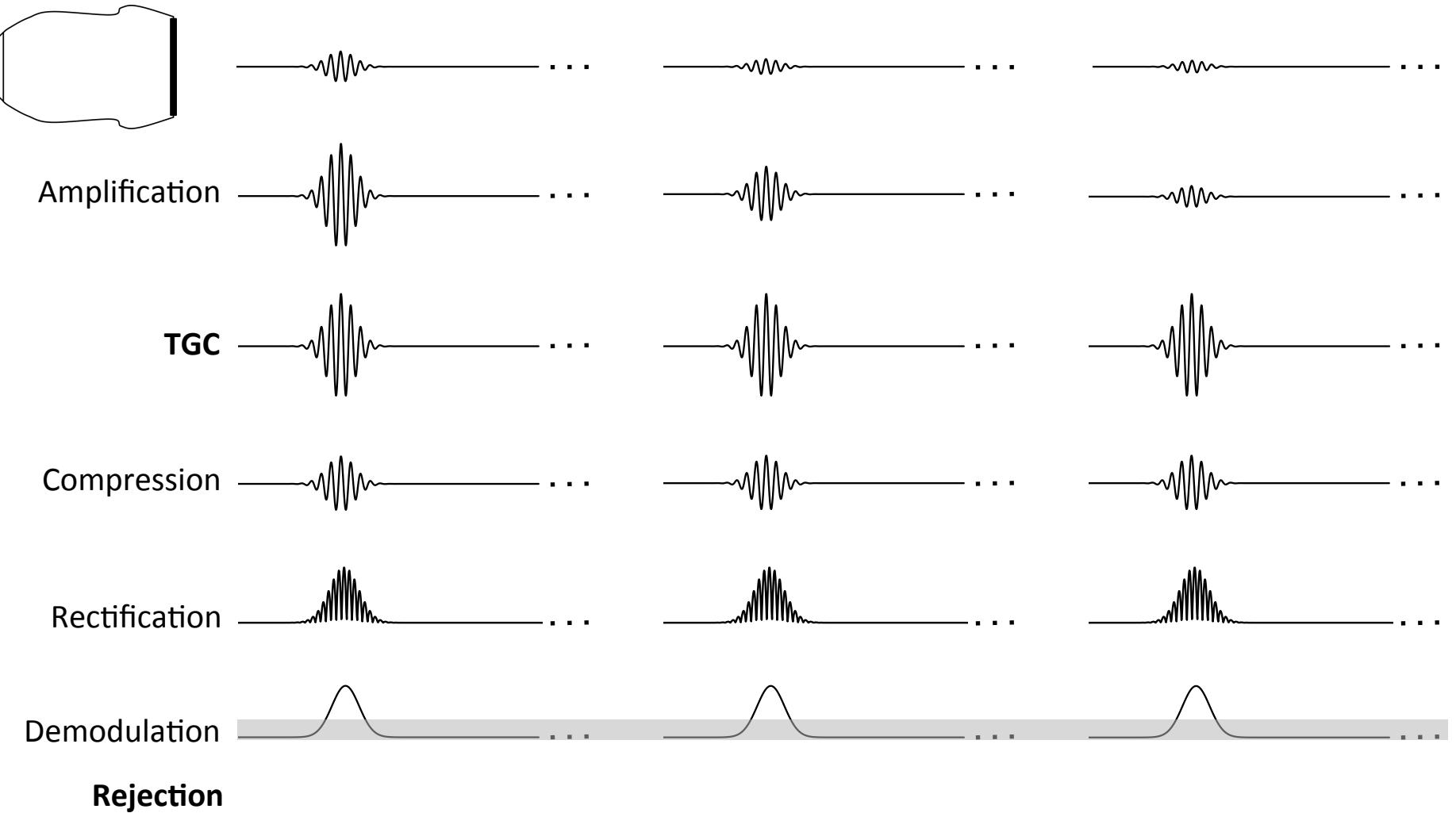
0000 1254/20:082547

32 Acc:  
40 -20 11 Apr 20  
48 08:26:47  
55 -  
57 -  
58 -  
60 -

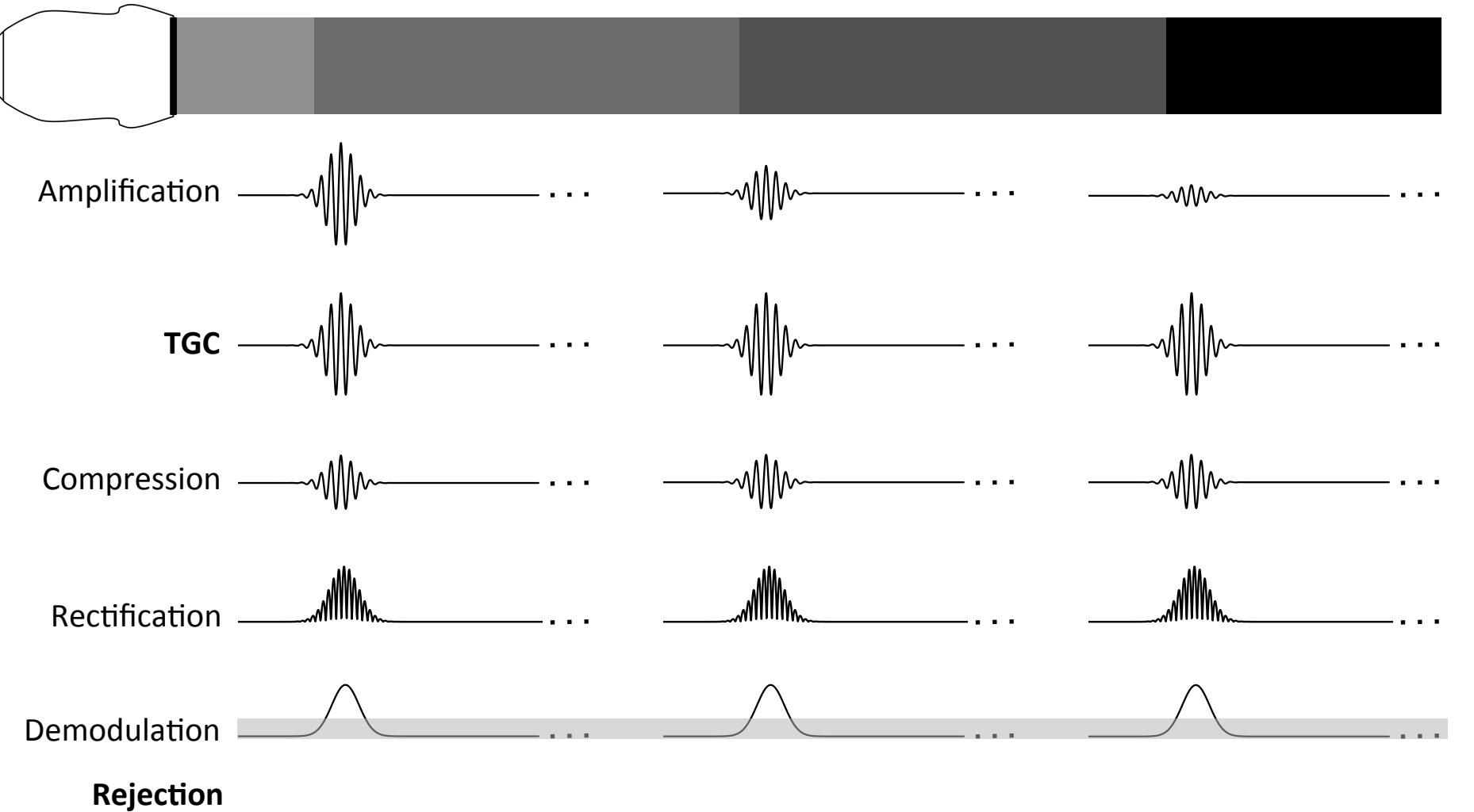
-5  
-10



Time-Gain Compensation (TGC)



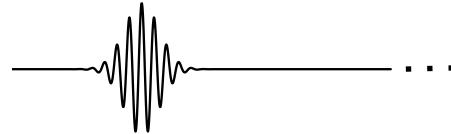
Receive Processing



Receive Processing

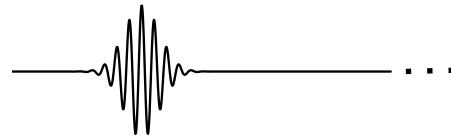


Amplification



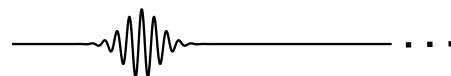
... Pre-amplification

TGC



**Depth Gain Compensation, Swept Gain, Time Varied Gain**

Compression



... Dynamic Compression, Logarithmic Amplification

Rectification



Demodulation

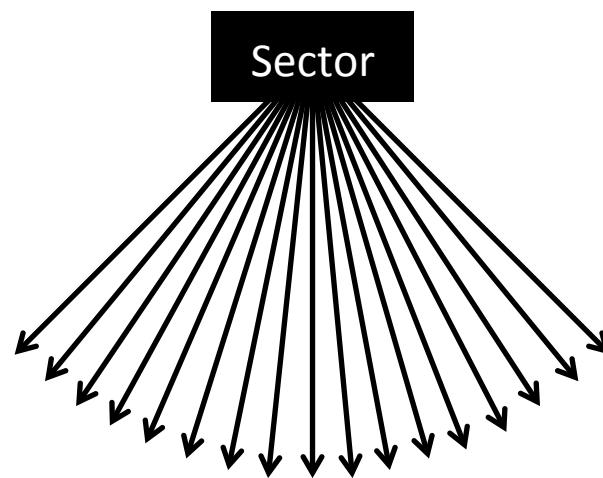
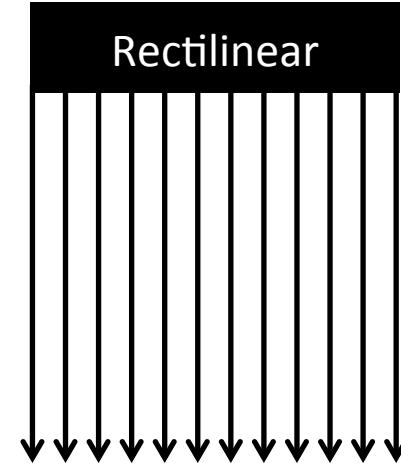


... Envelope Detection, Analytic Signal

Rejection

**Noise Rejection, Threshold Filtering, Decluttering**

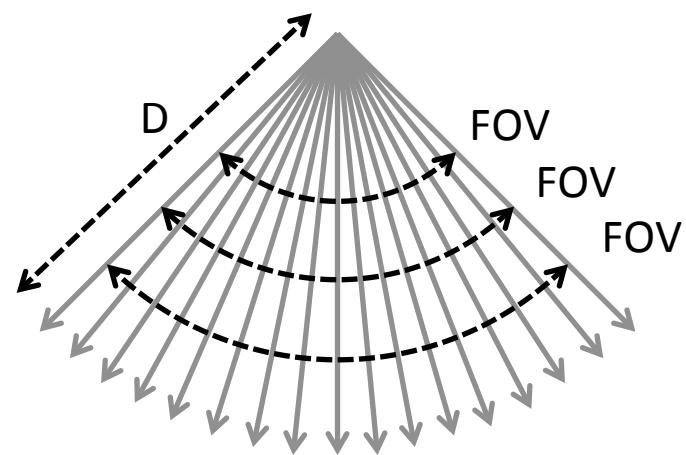
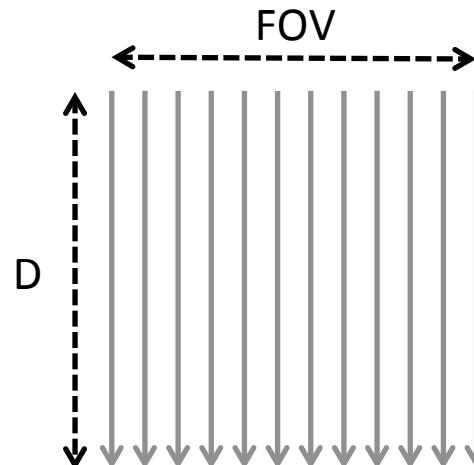
Receive Processing



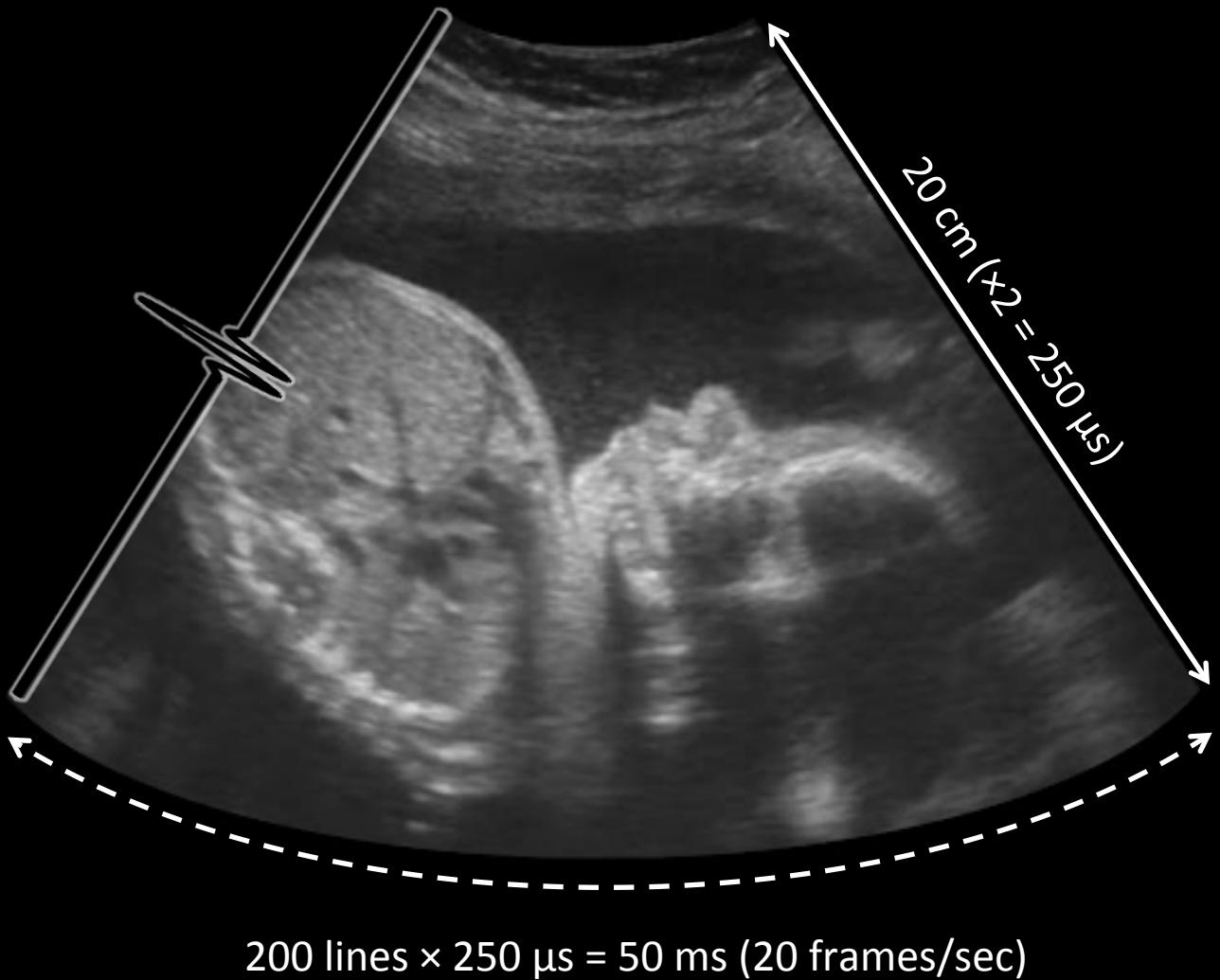
# Imaging Performance

$$\text{LD} = \text{Line Density} \\ = N/\text{FOV}$$

$\left. \begin{array}{l} D = \text{Depth (Range)} \\ \text{FOV} = \text{Field of View} \\ N = \text{Number of Lines} \\ \text{FR} = \text{Frame Rate (PRF/N)} \end{array} \right\}$



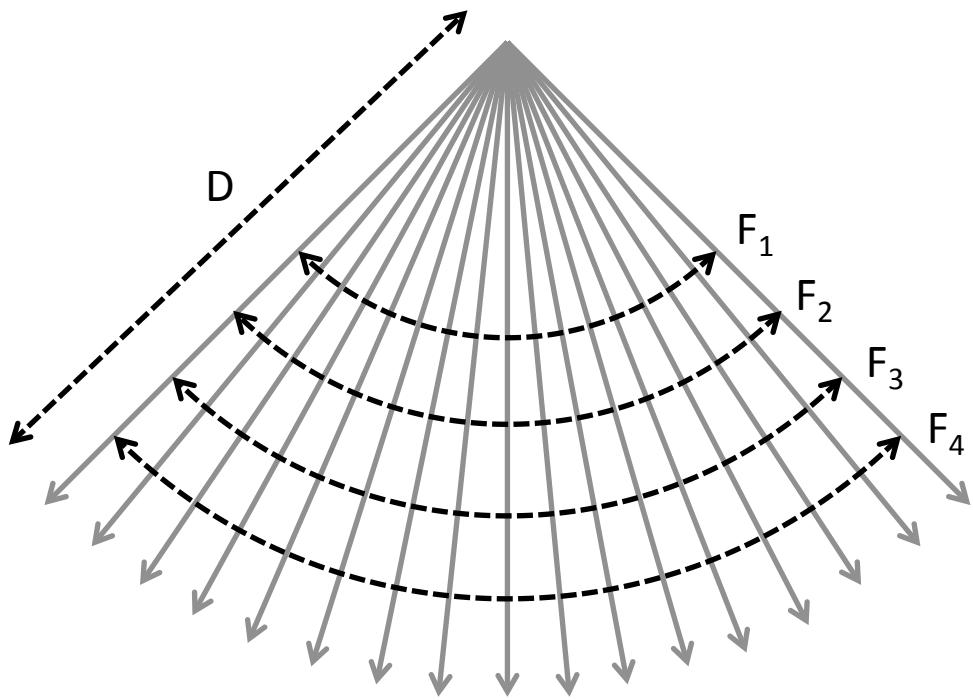
## Imaging Performance



## Imaging Performance

Range (cm)	Number of Lines (N)	Max Frame Rate (s <sup>-1</sup> )
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

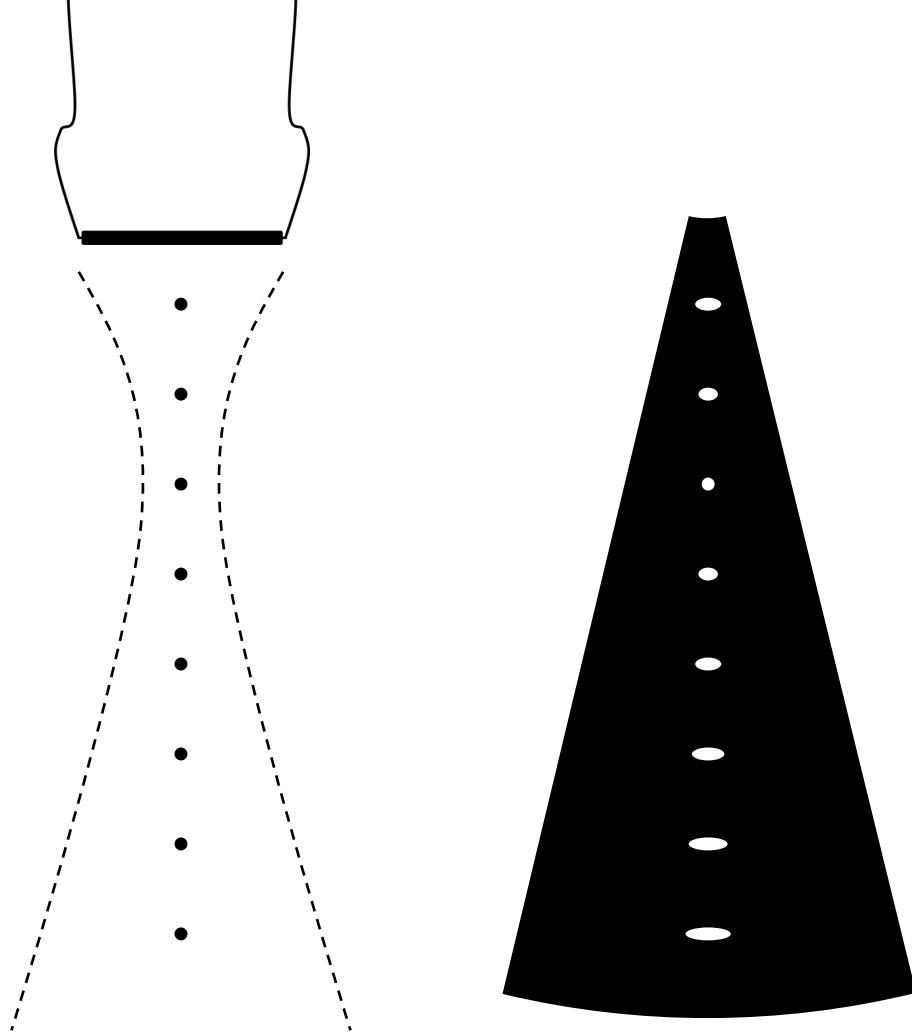
## **3. Multiple Reflections**

- a. Reverberation
- b. Mirror
- c. Speckle

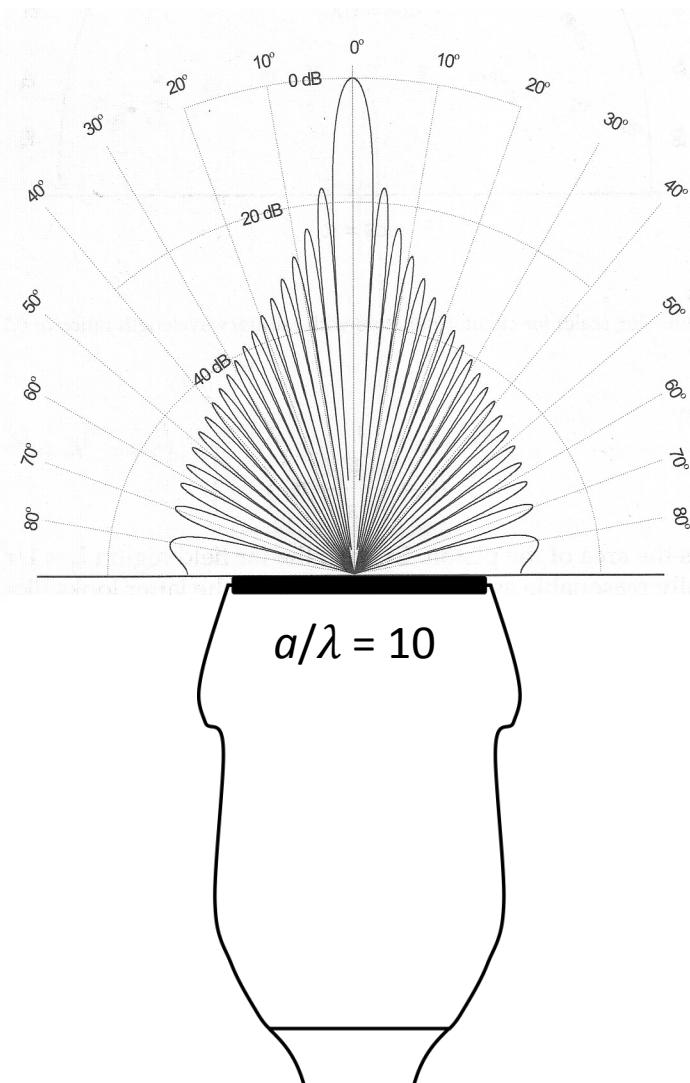
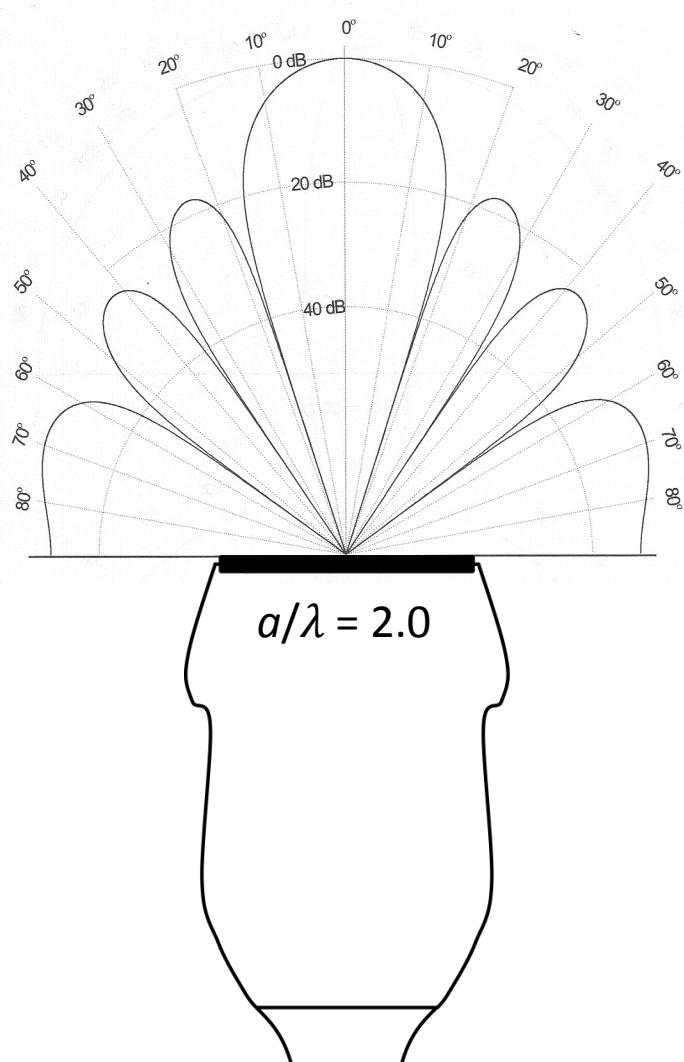
## **4. Attenuation**

- a. Shadowing
- b. Enhancement

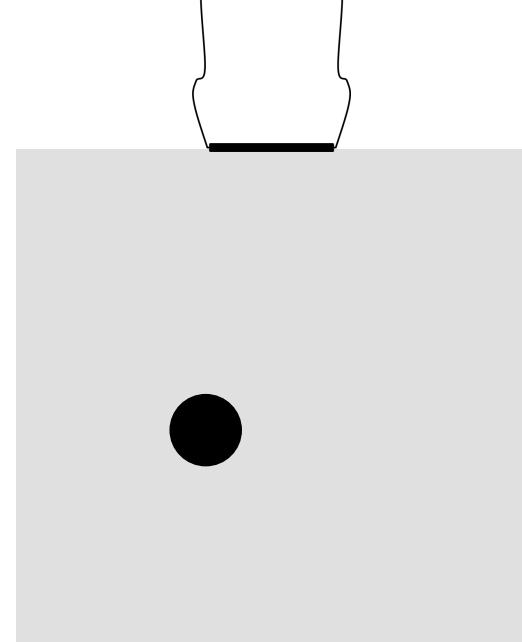
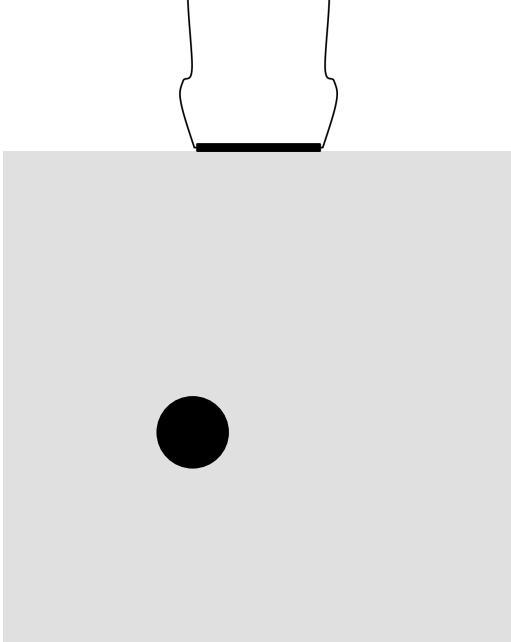
# **Artifacts**



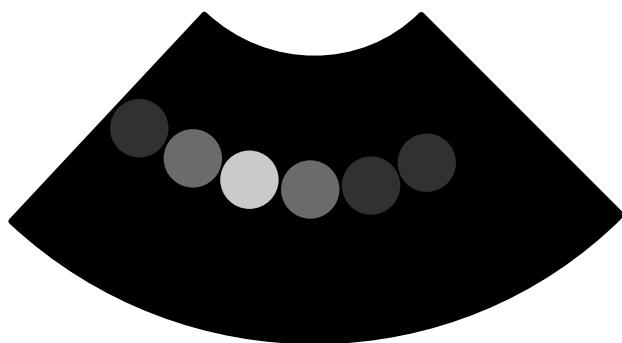
Beamwidth and Slice Thickness Artifacts



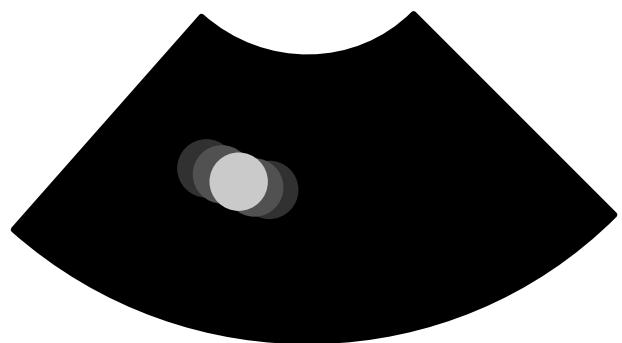
## Side Lobe Artifacts



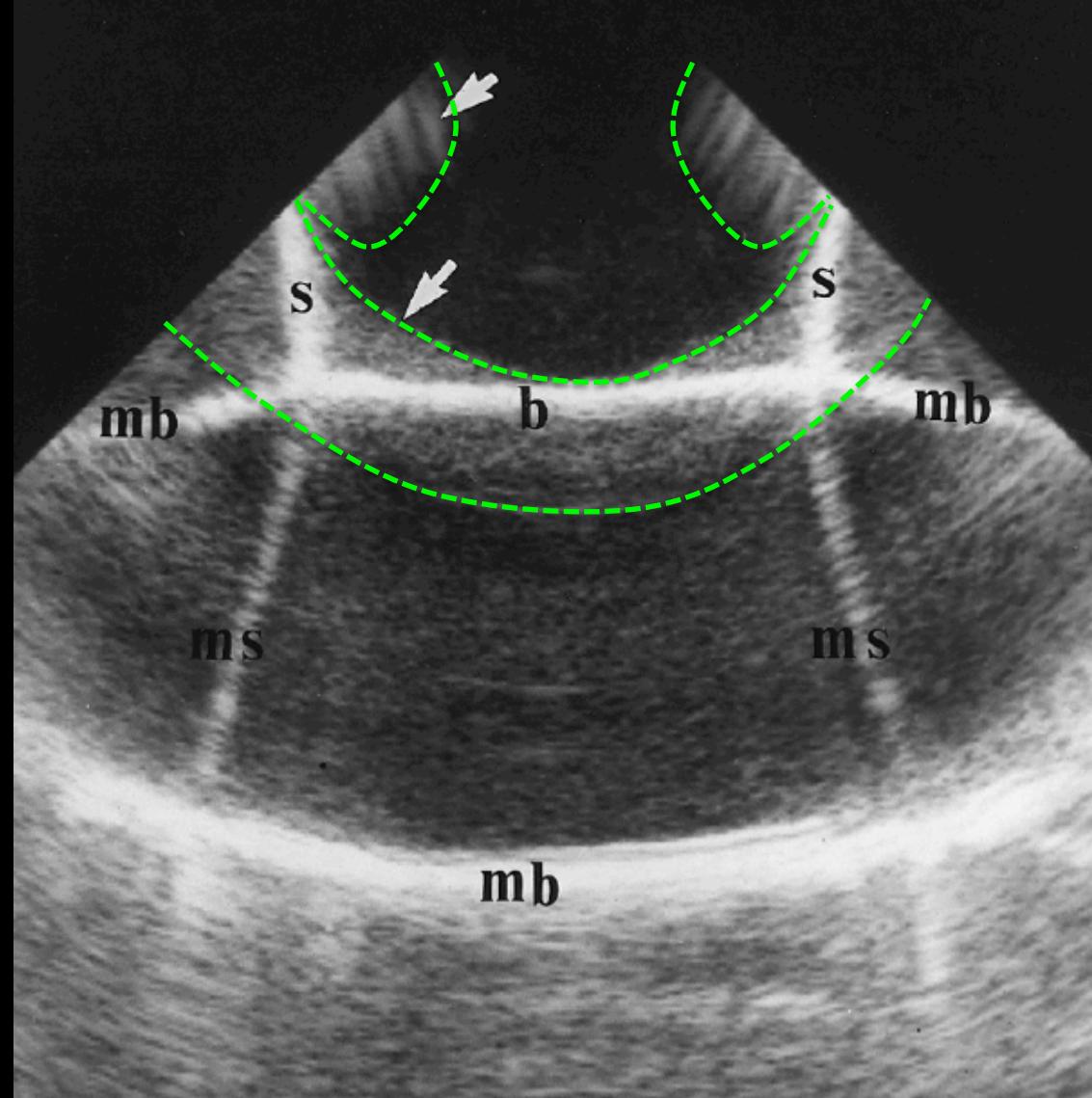
$a/\lambda = 2.0$



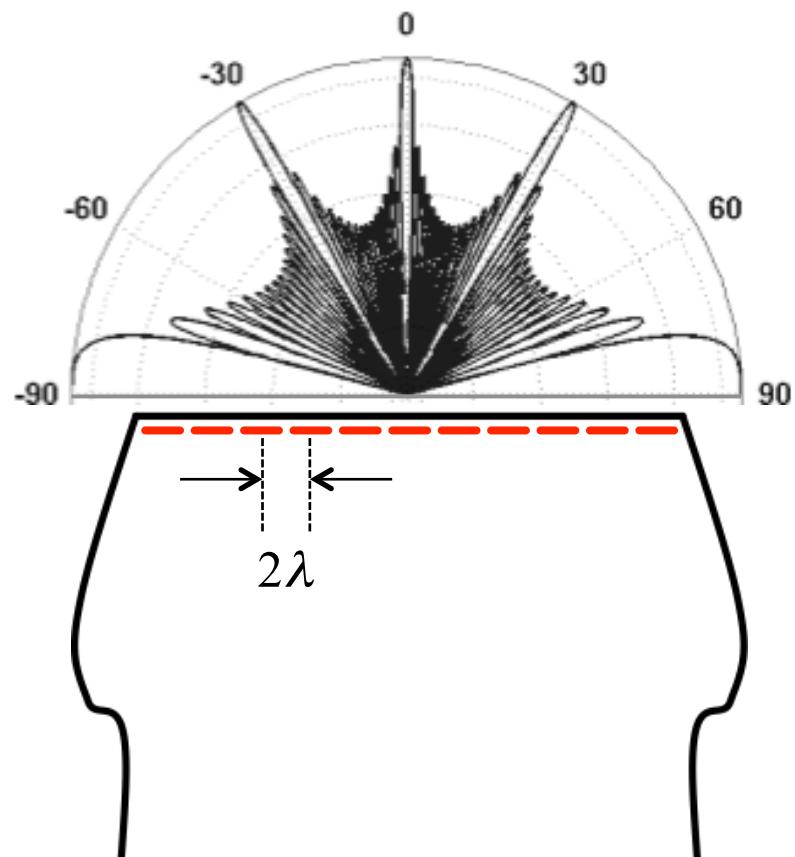
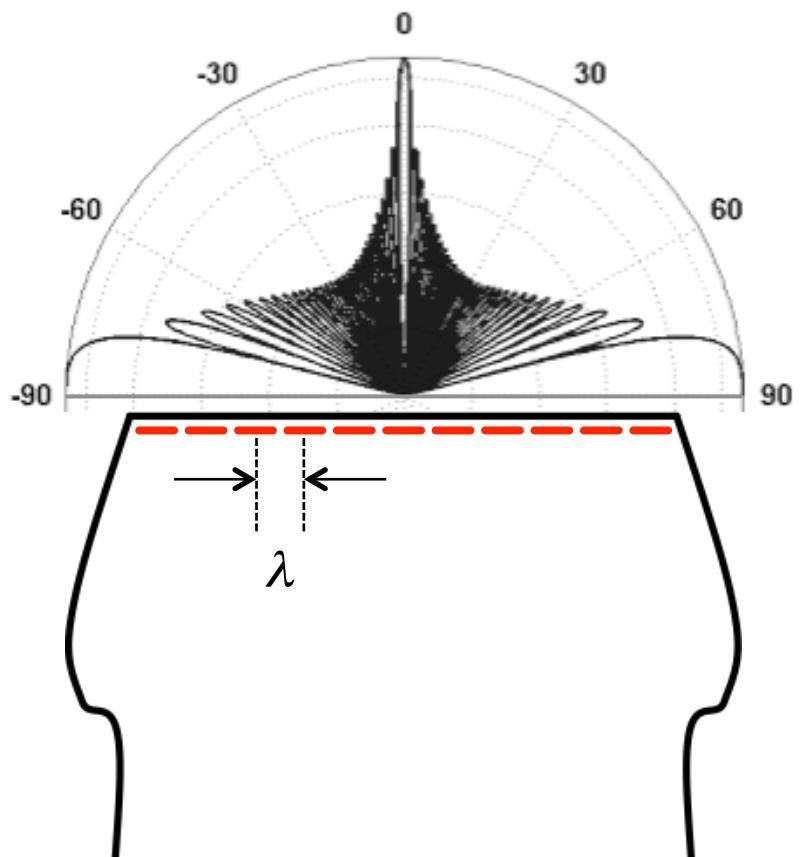
$a/\lambda = 10$



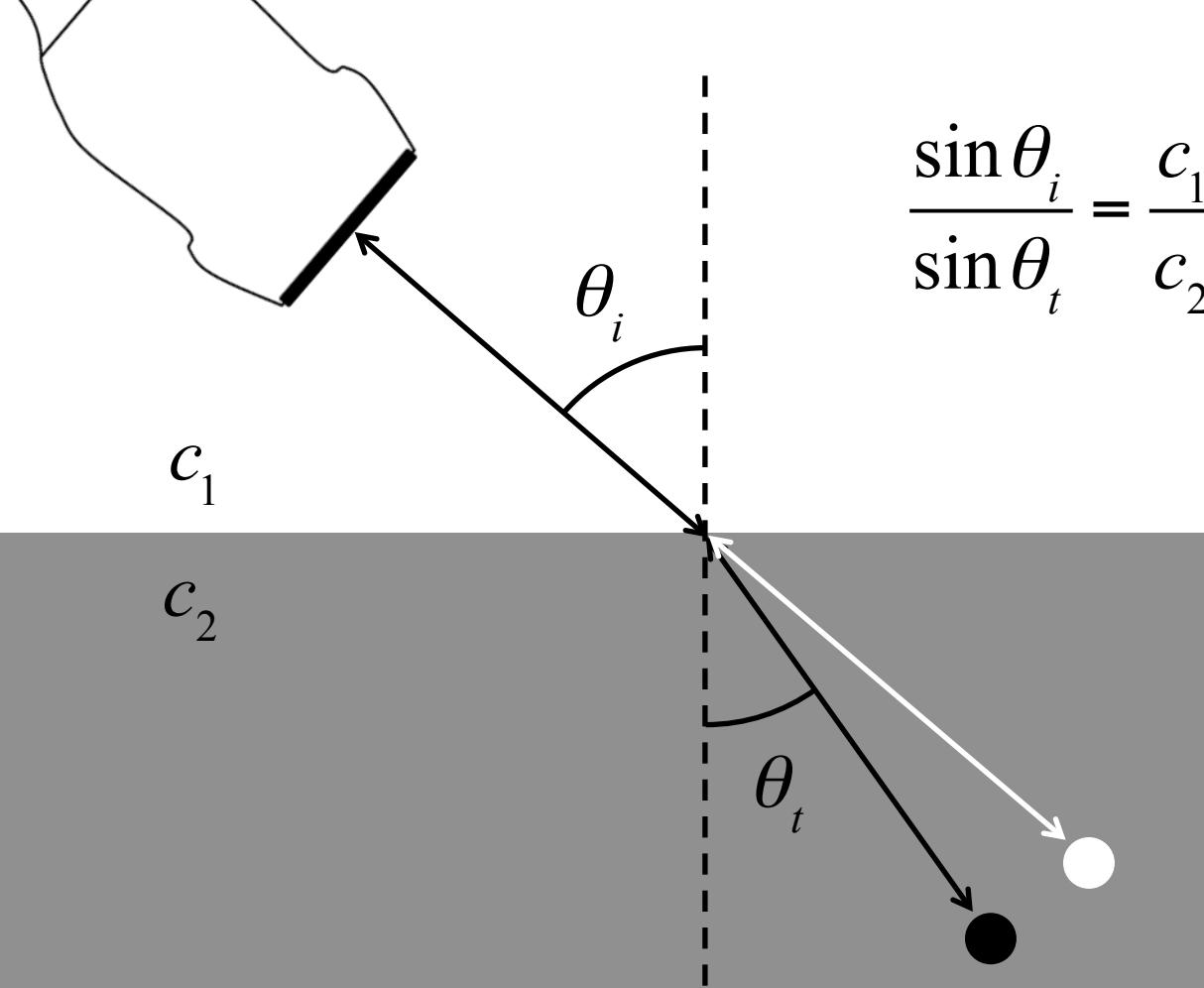
Side Lobe Artifacts



Side Lobe Artifacts

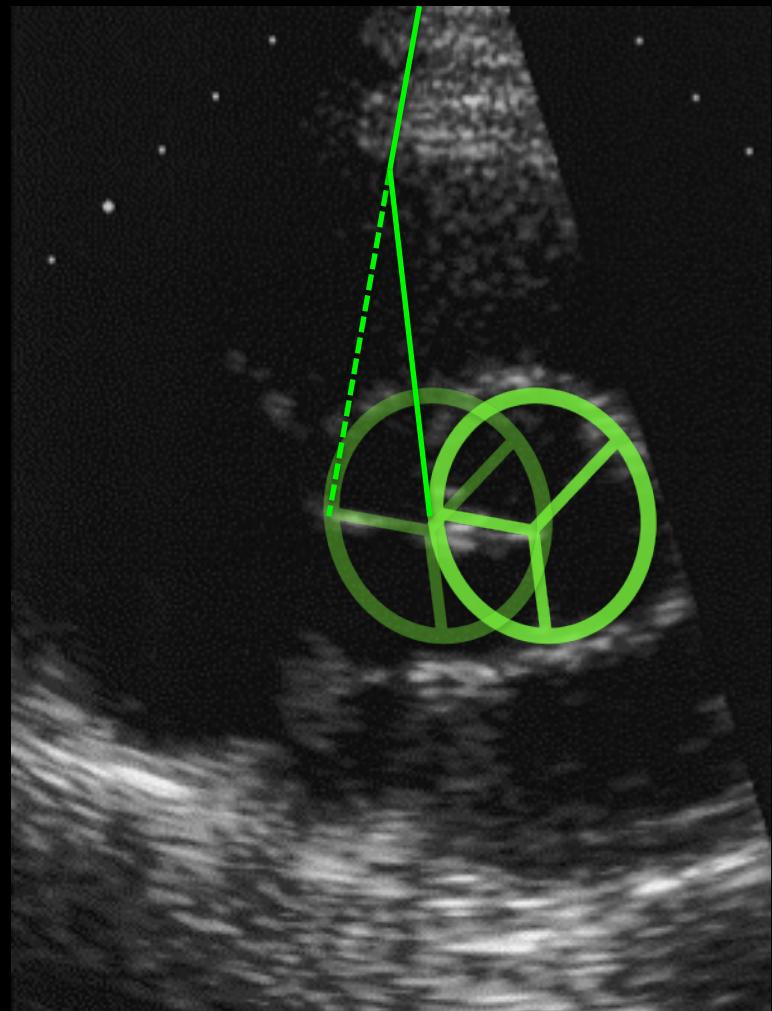


Grating Lobes

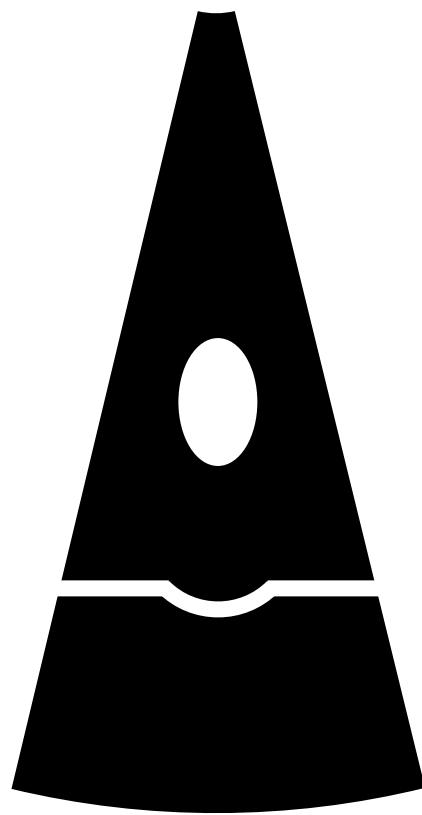
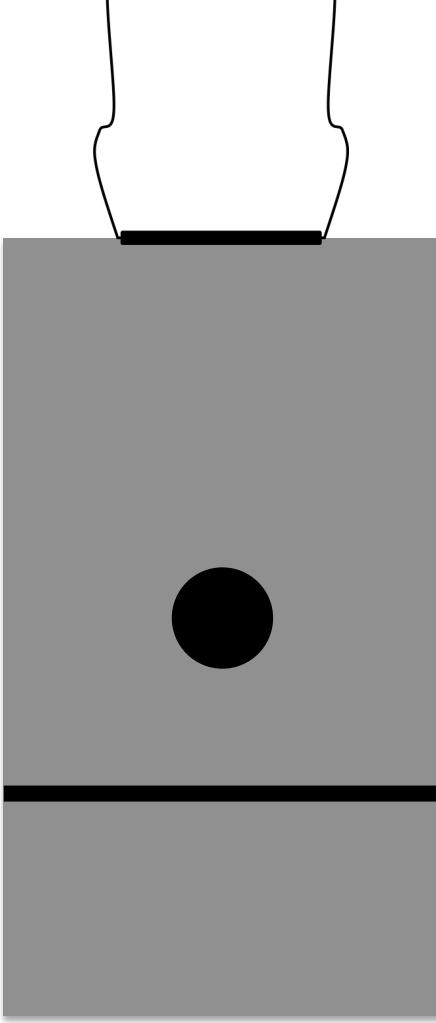


$$\frac{\sin \theta_i}{\sin \theta_t} = \frac{c_1}{c_2}$$

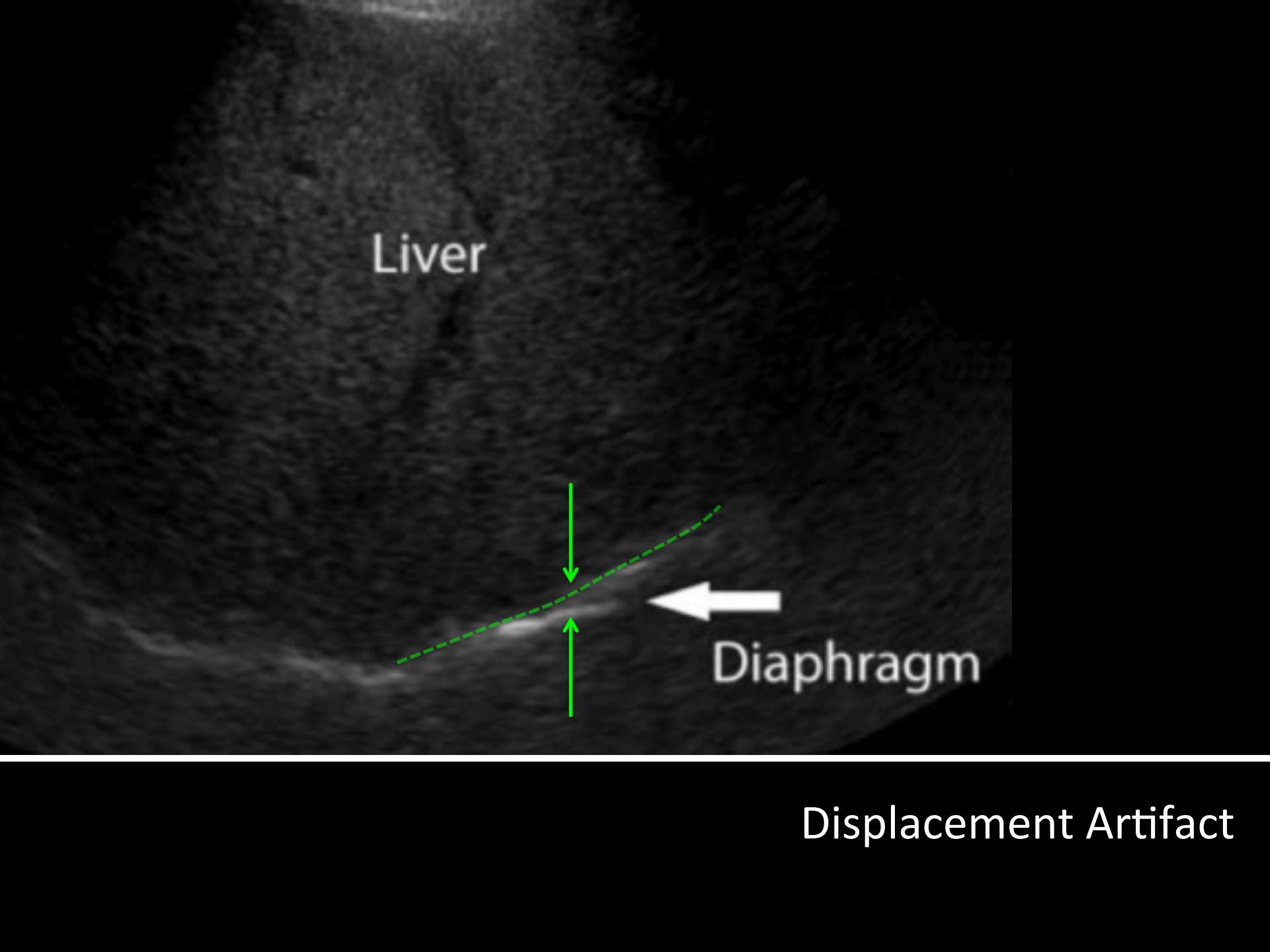
Refraction Artifacts



## Refraction Artifacts



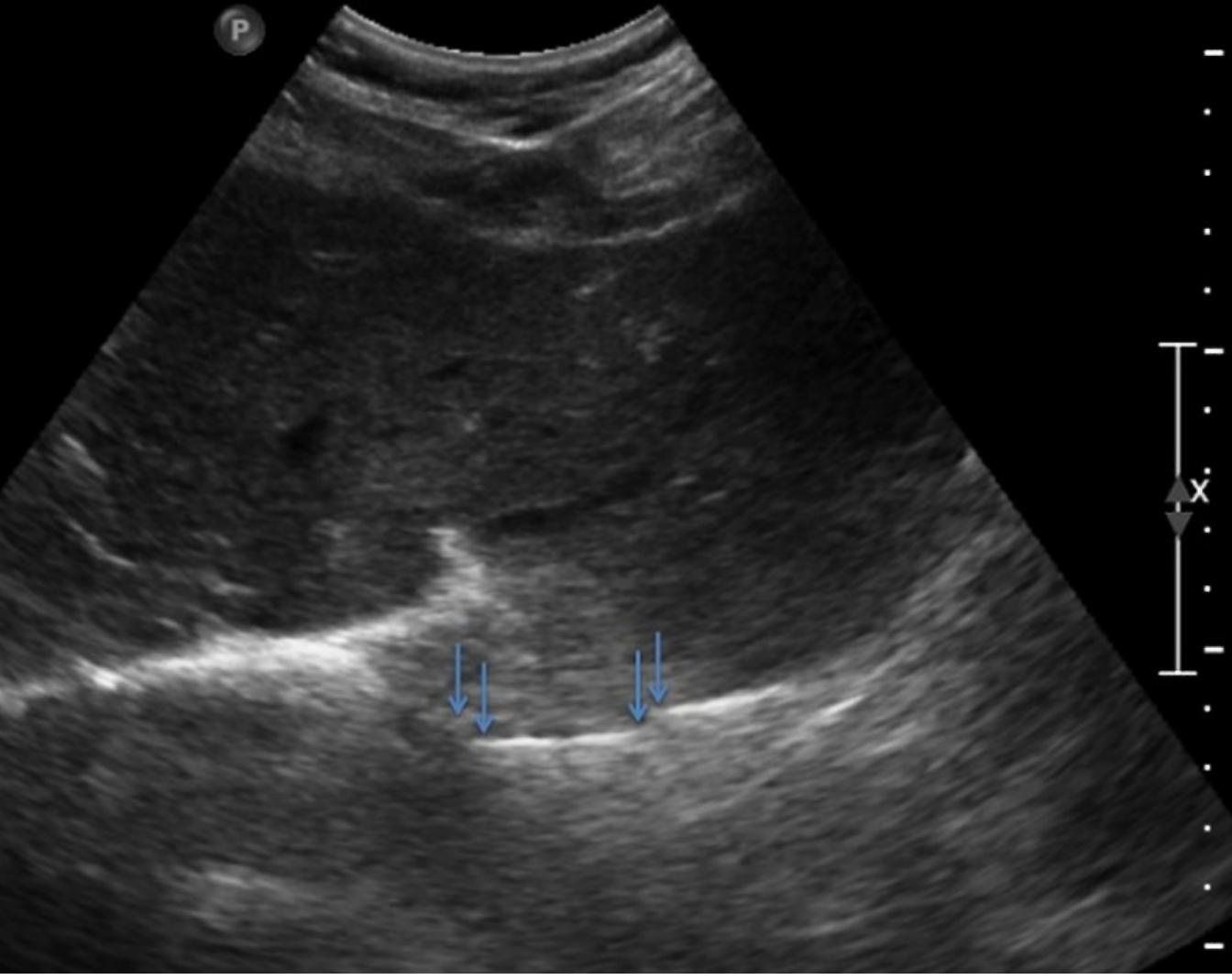
Displacement Artifact

An ultrasound image showing a cross-section of the liver (labeled "Liver") and the diaphragm (labeled "Diaphragm"). A dashed green line indicates the interface between the liver and the diaphragm. A vertical green arrow points downwards from the top of the dashed line, and a horizontal white arrow points to the left from the same point, indicating the direction of the displacement artifact.

Liver

Diaphragm

Displacement Artifact



Displacement Artifact



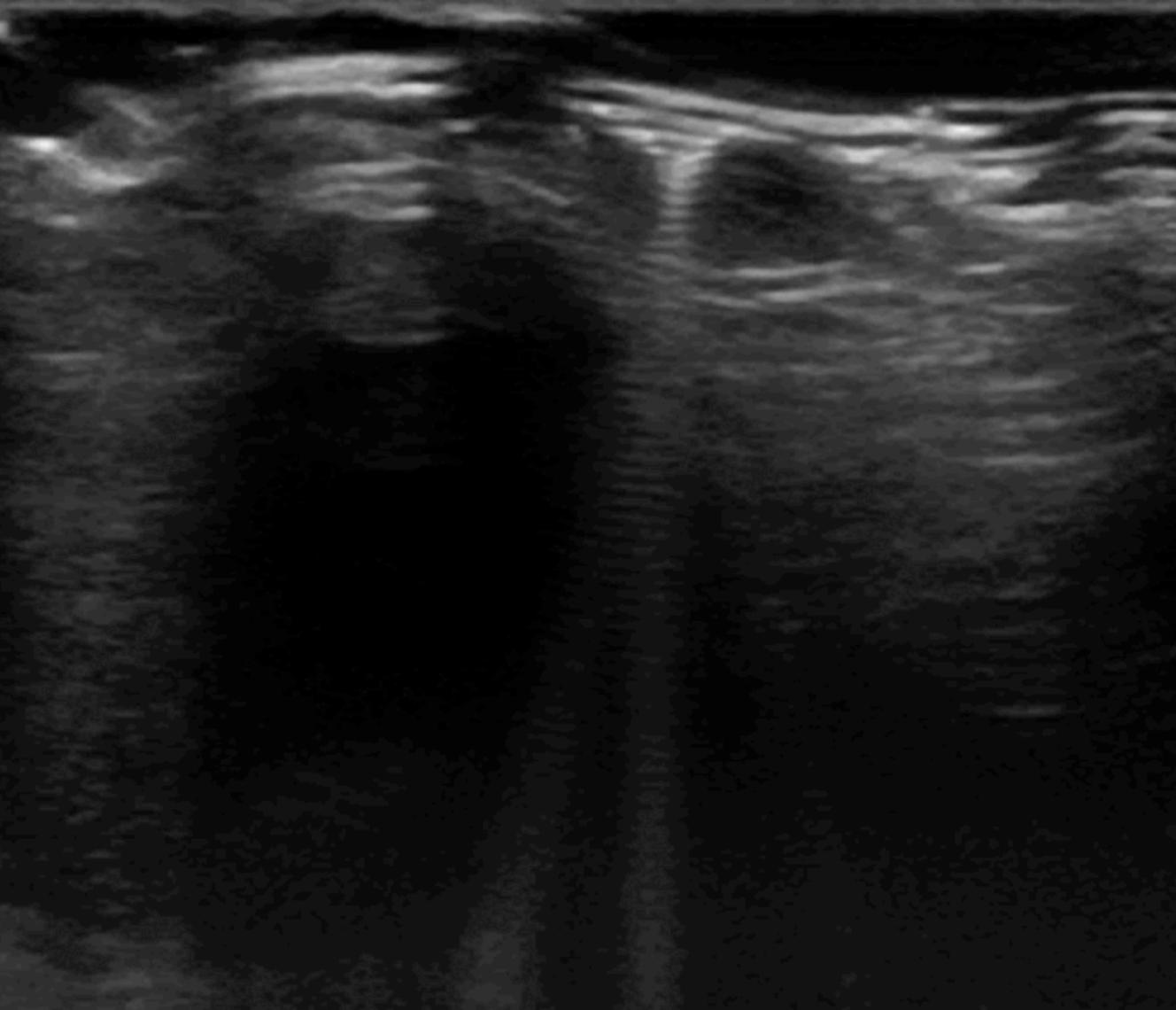
Displacement Artifact



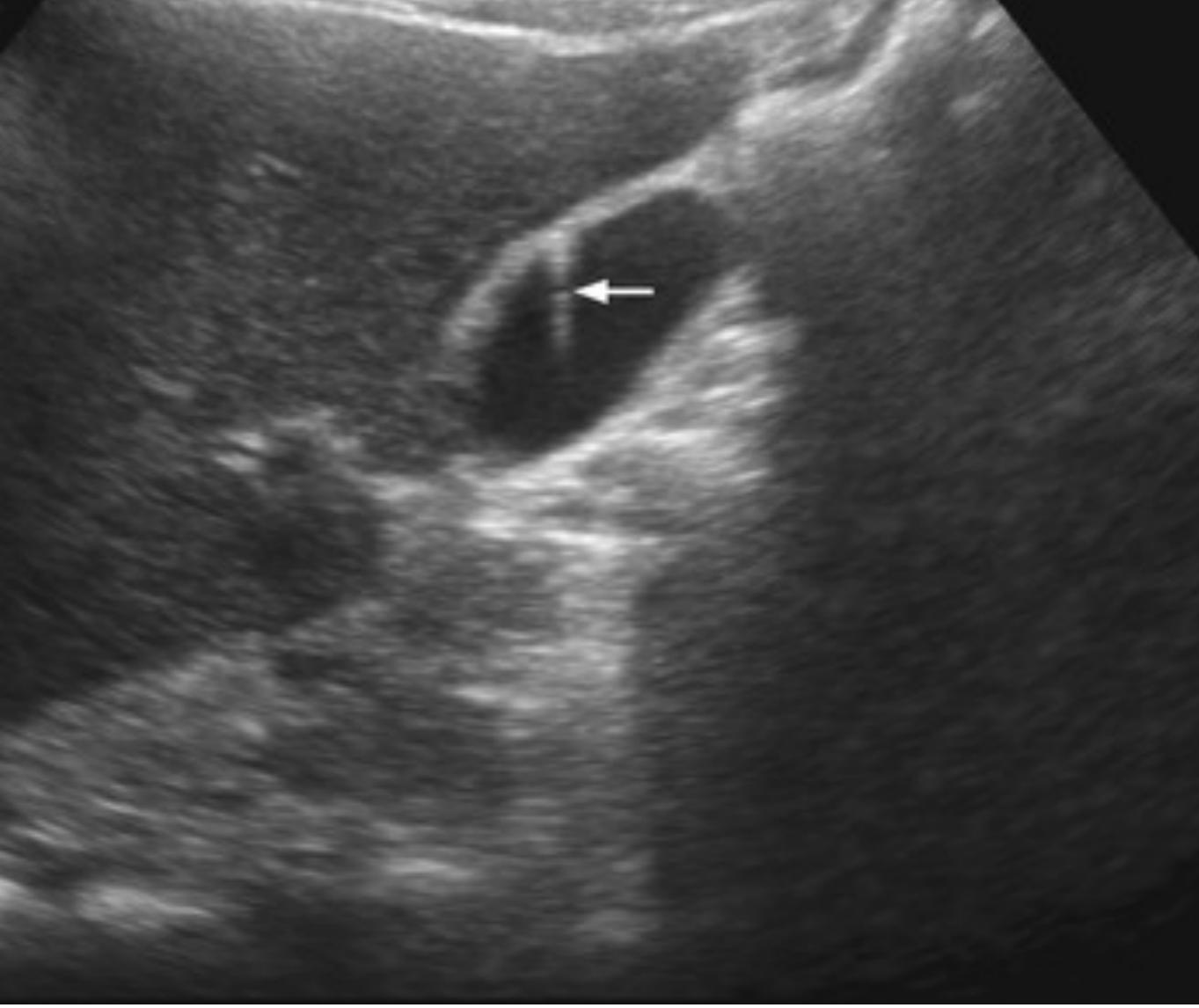
Edge Artifacts



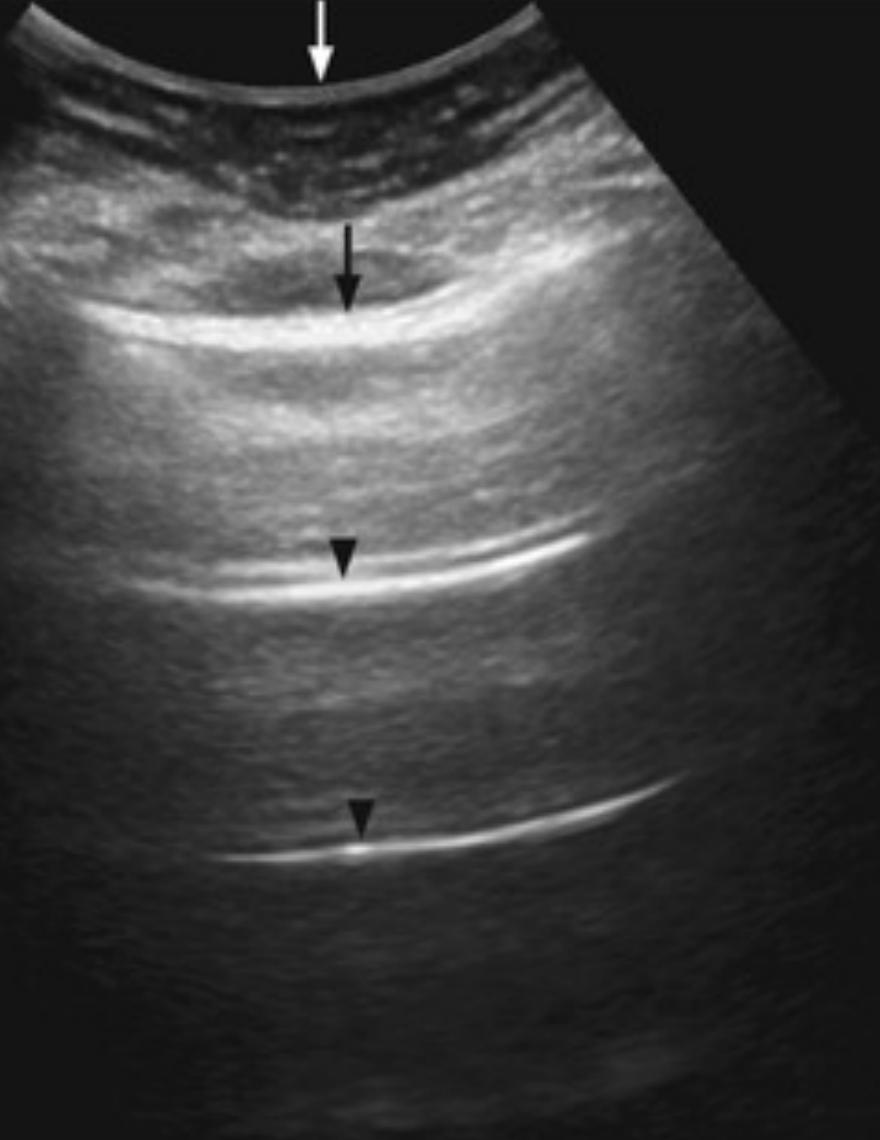
Reverberation Artifacts



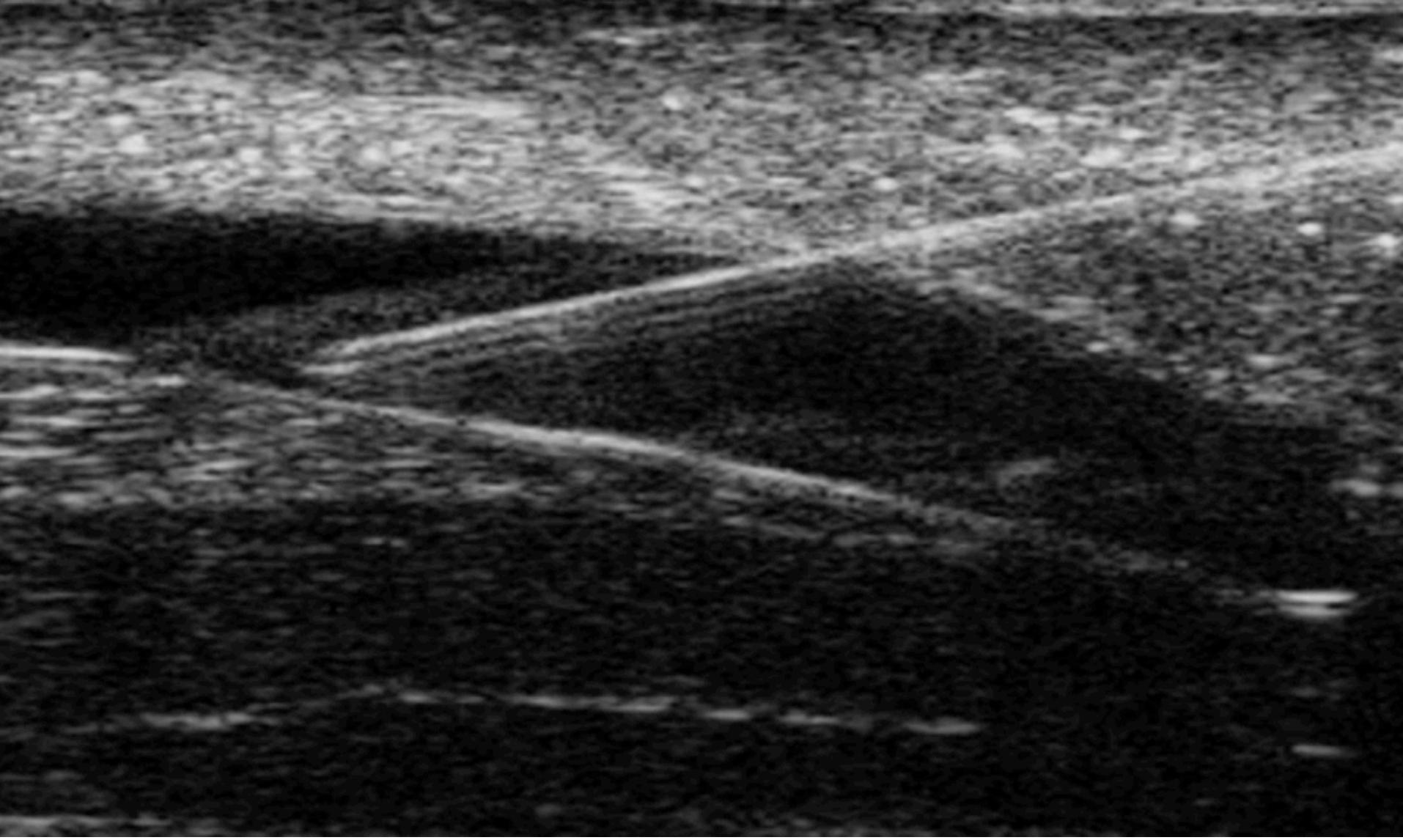
Reverberation Artifacts



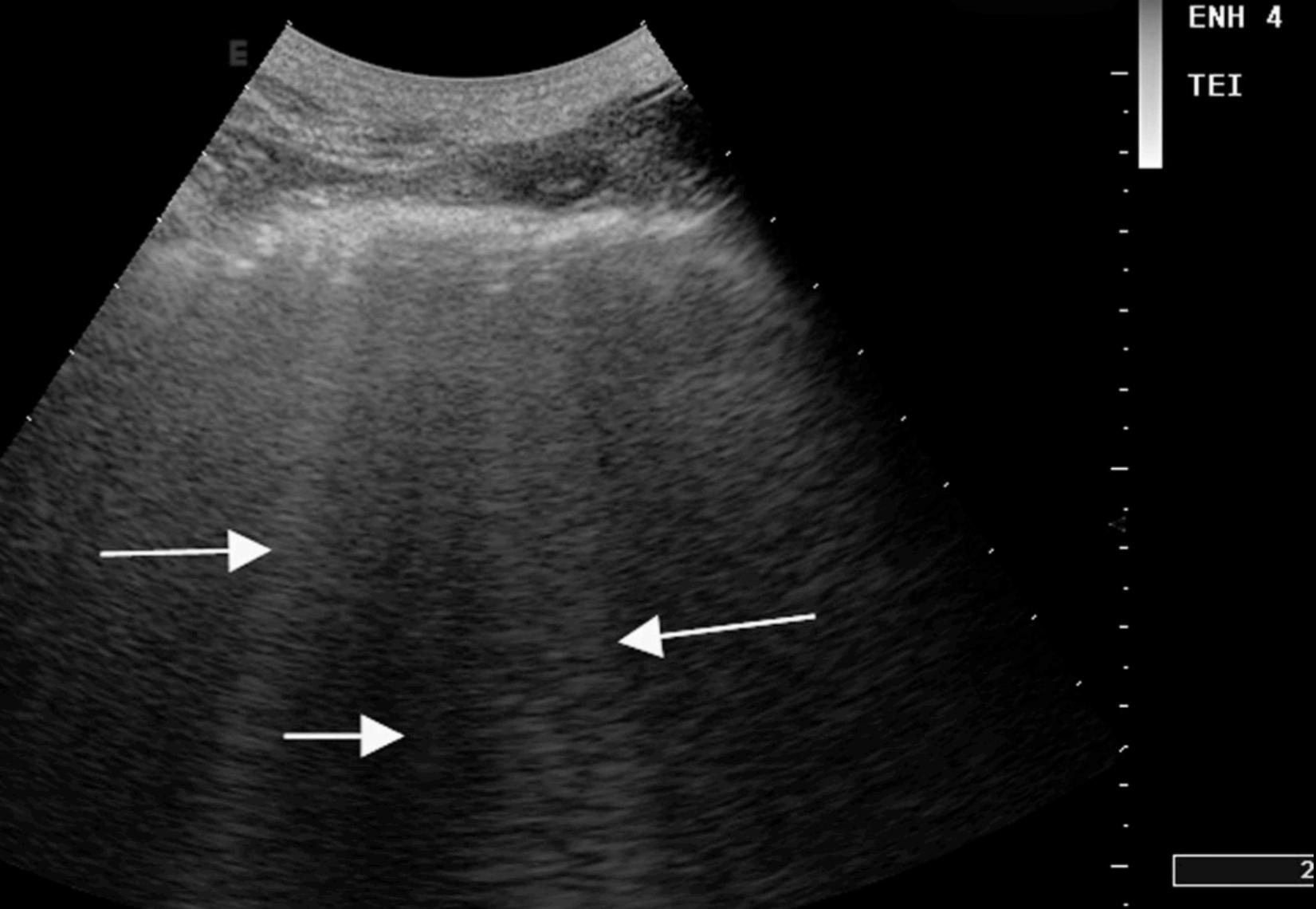
Reverberation Artifacts



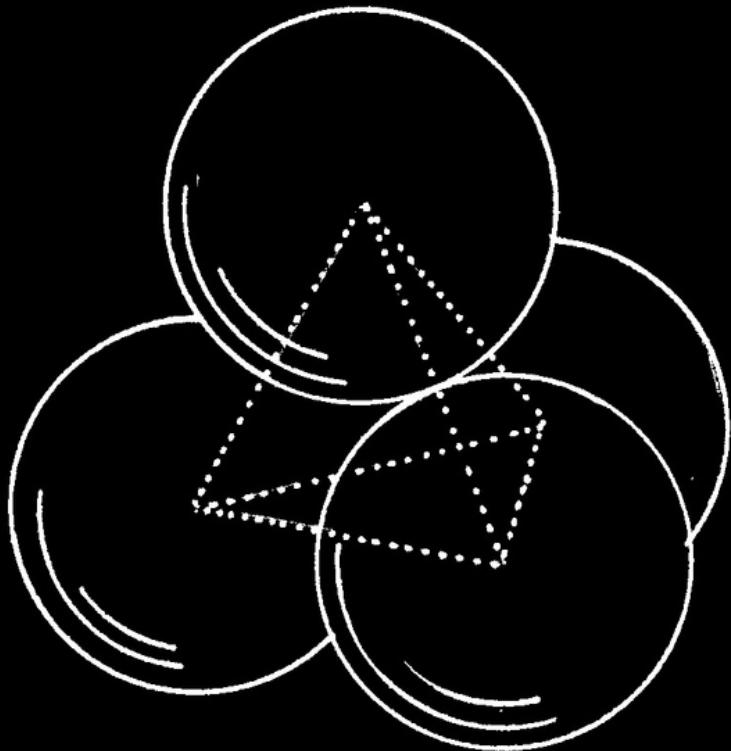
Reverberation Artifacts



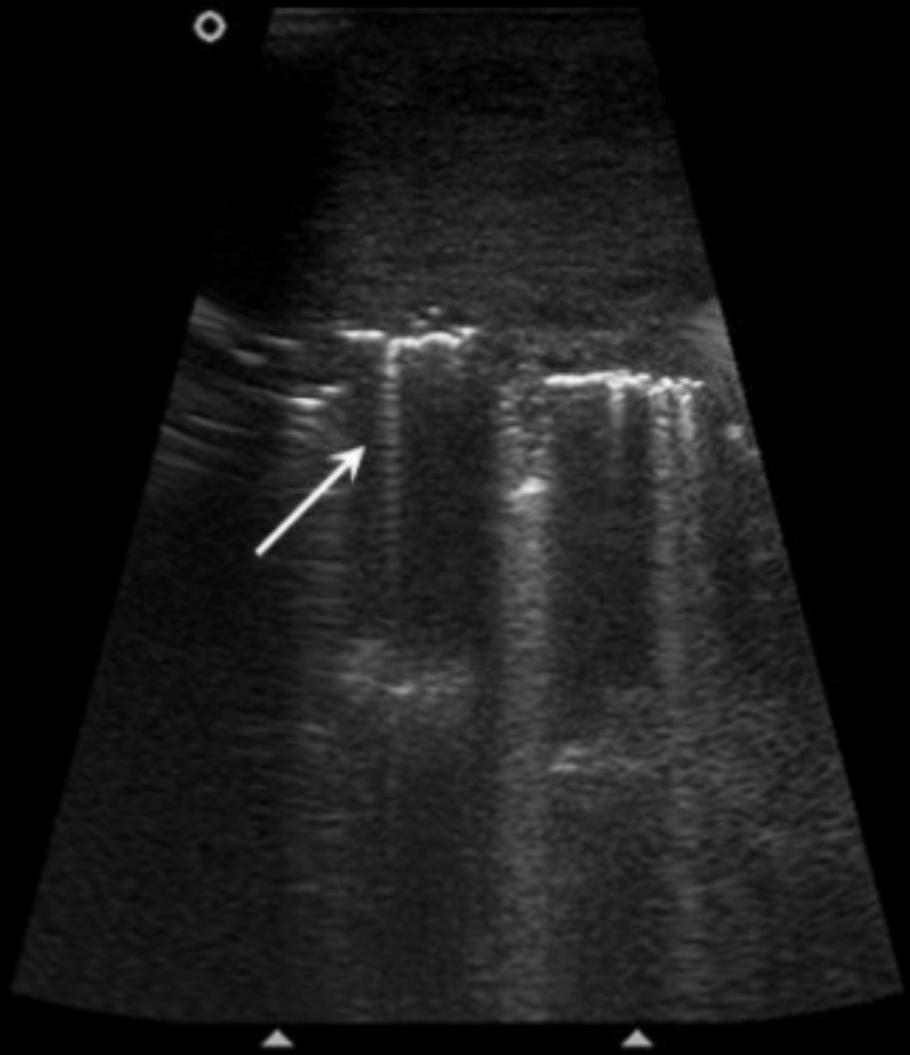
Reverberation Artifacts



Ring-Down Artifact



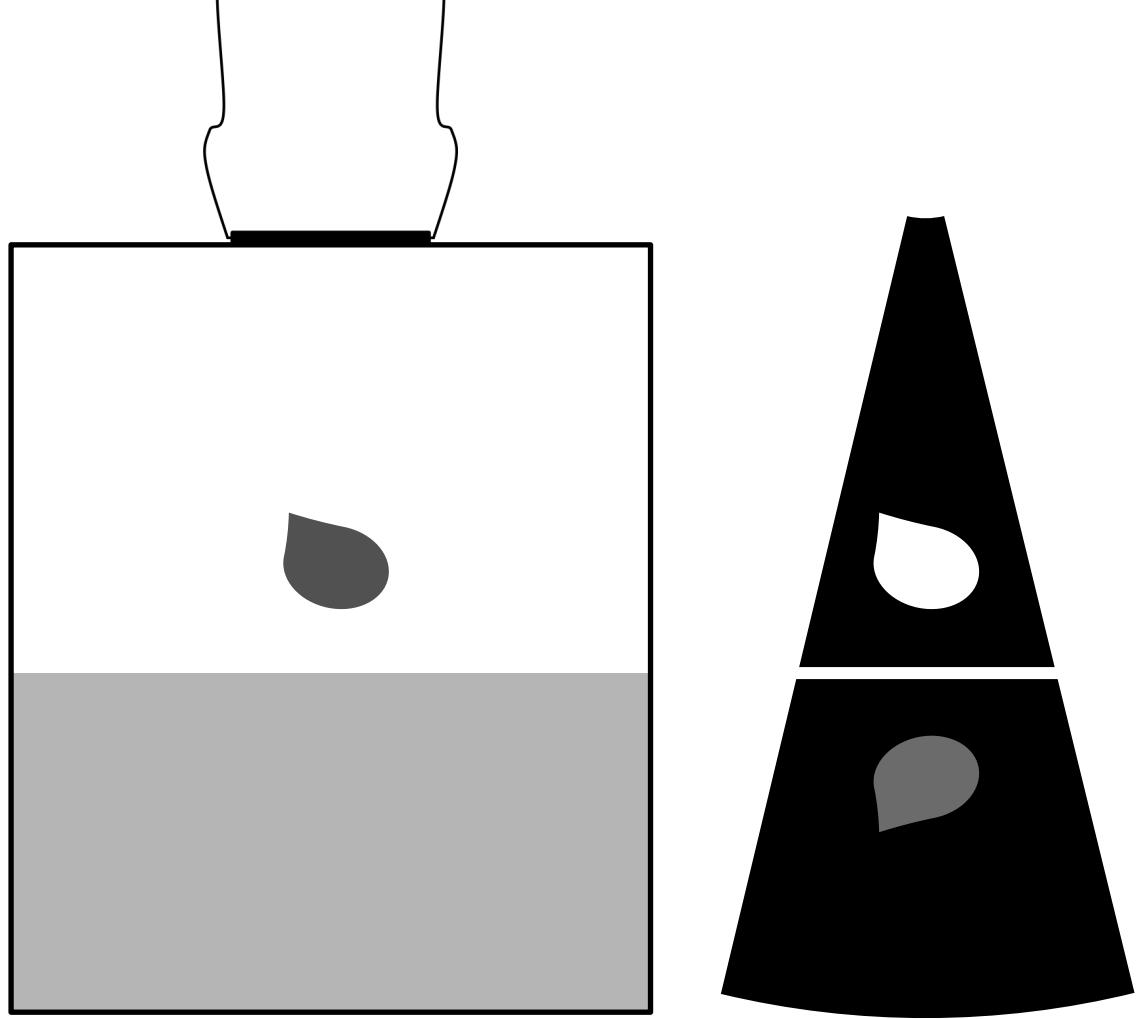
Ring-Down Artifact



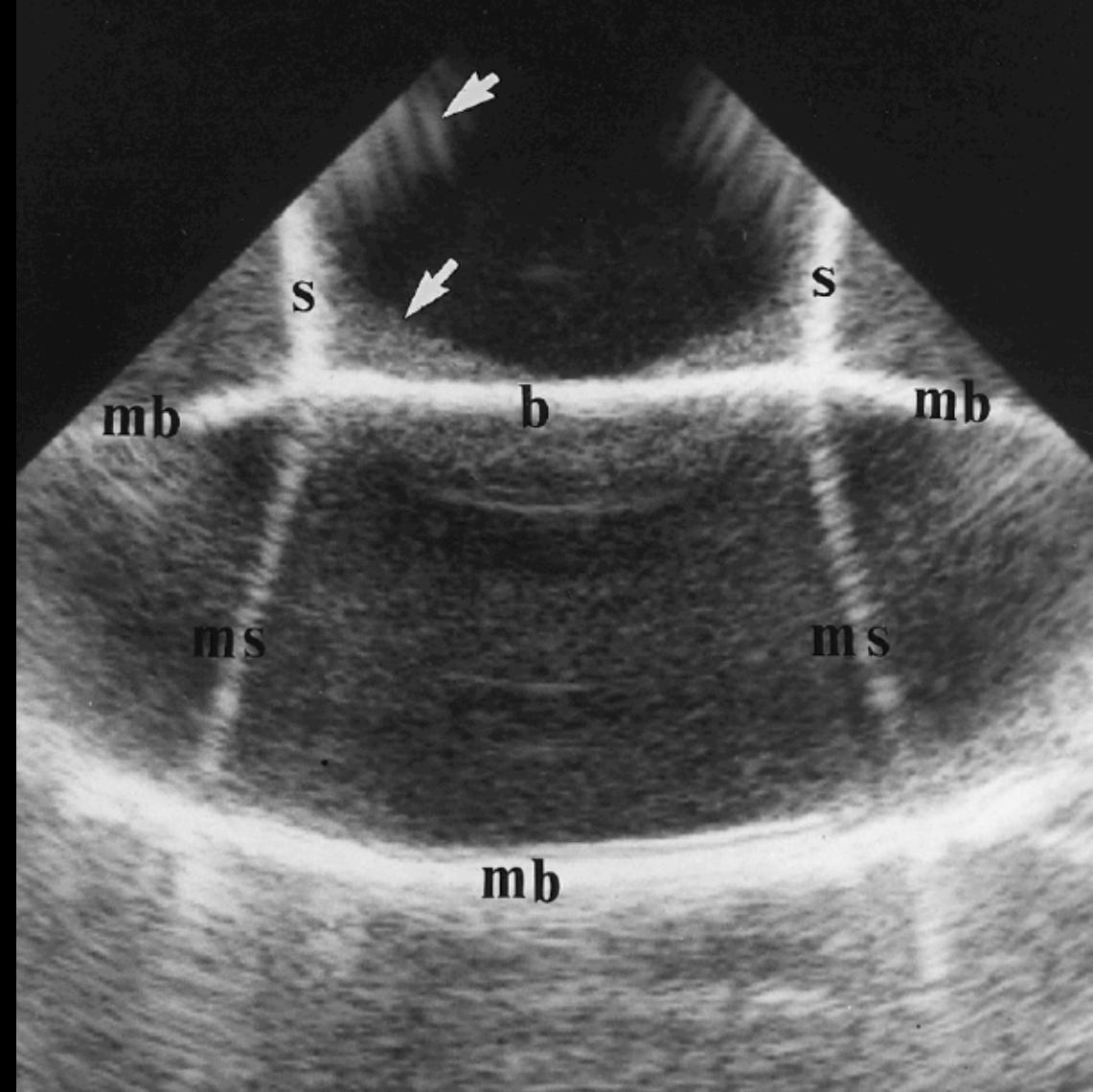
Ring-Down Artifact



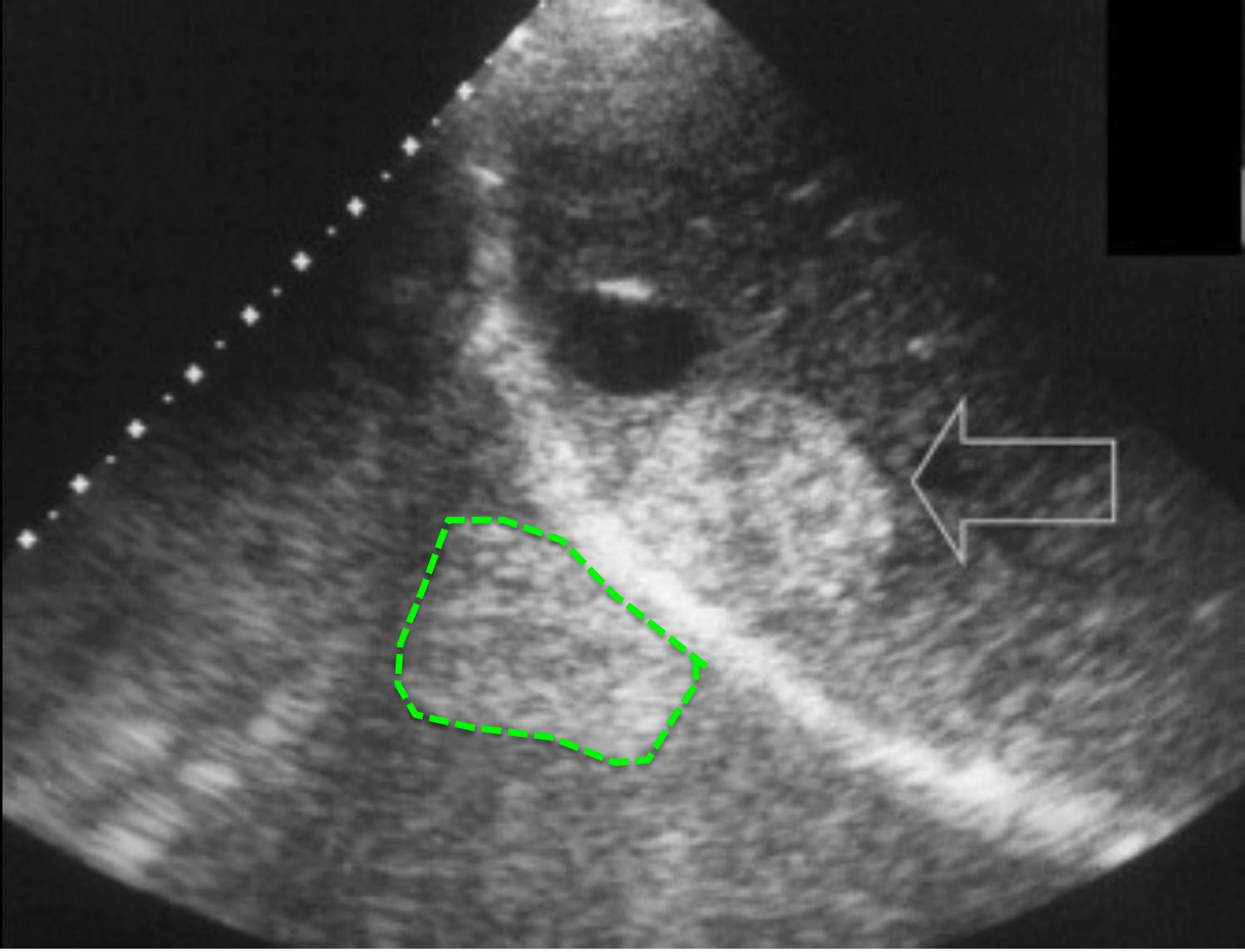
Ring-Down Artifact



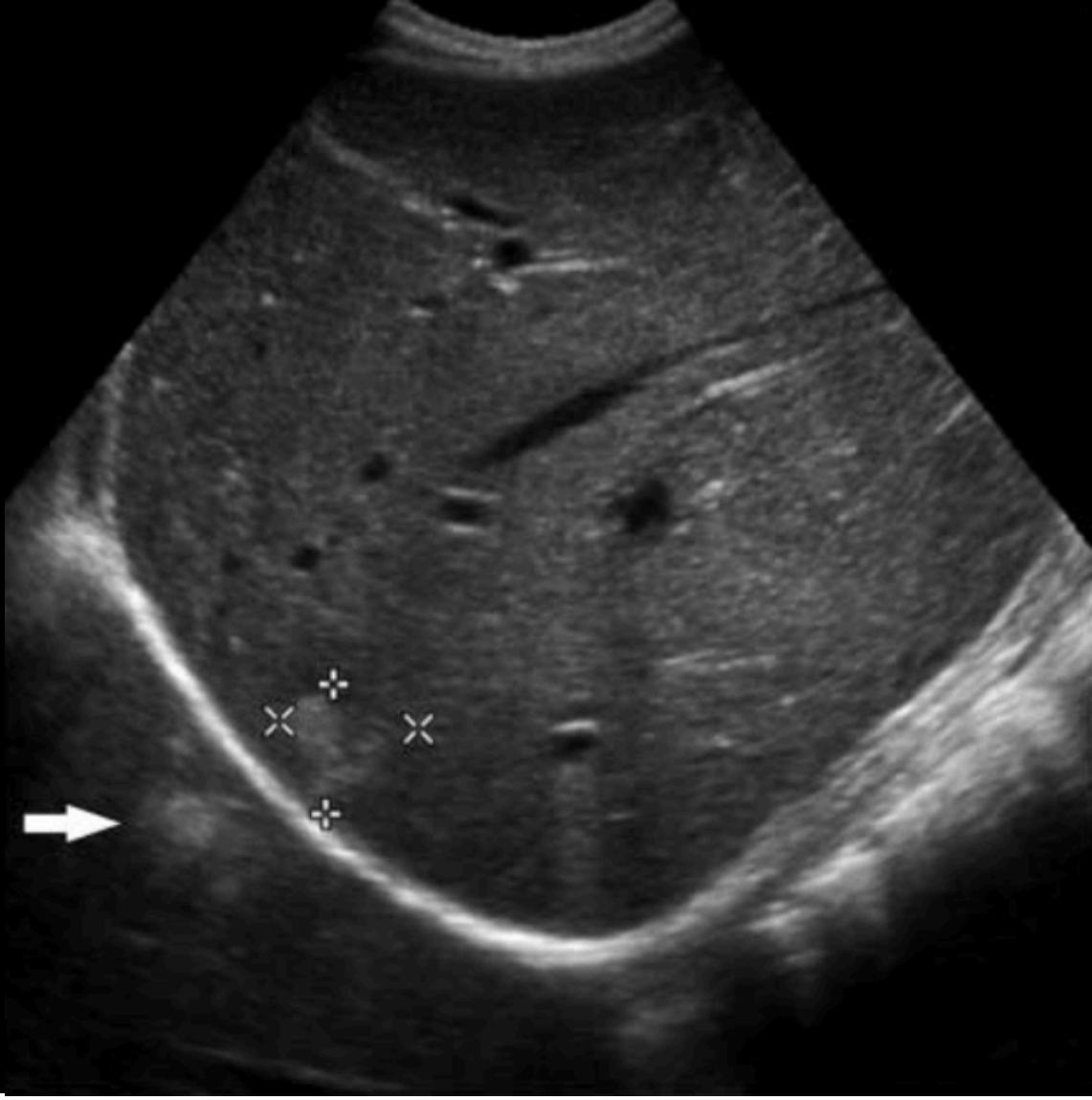
Mirror Image Artifact



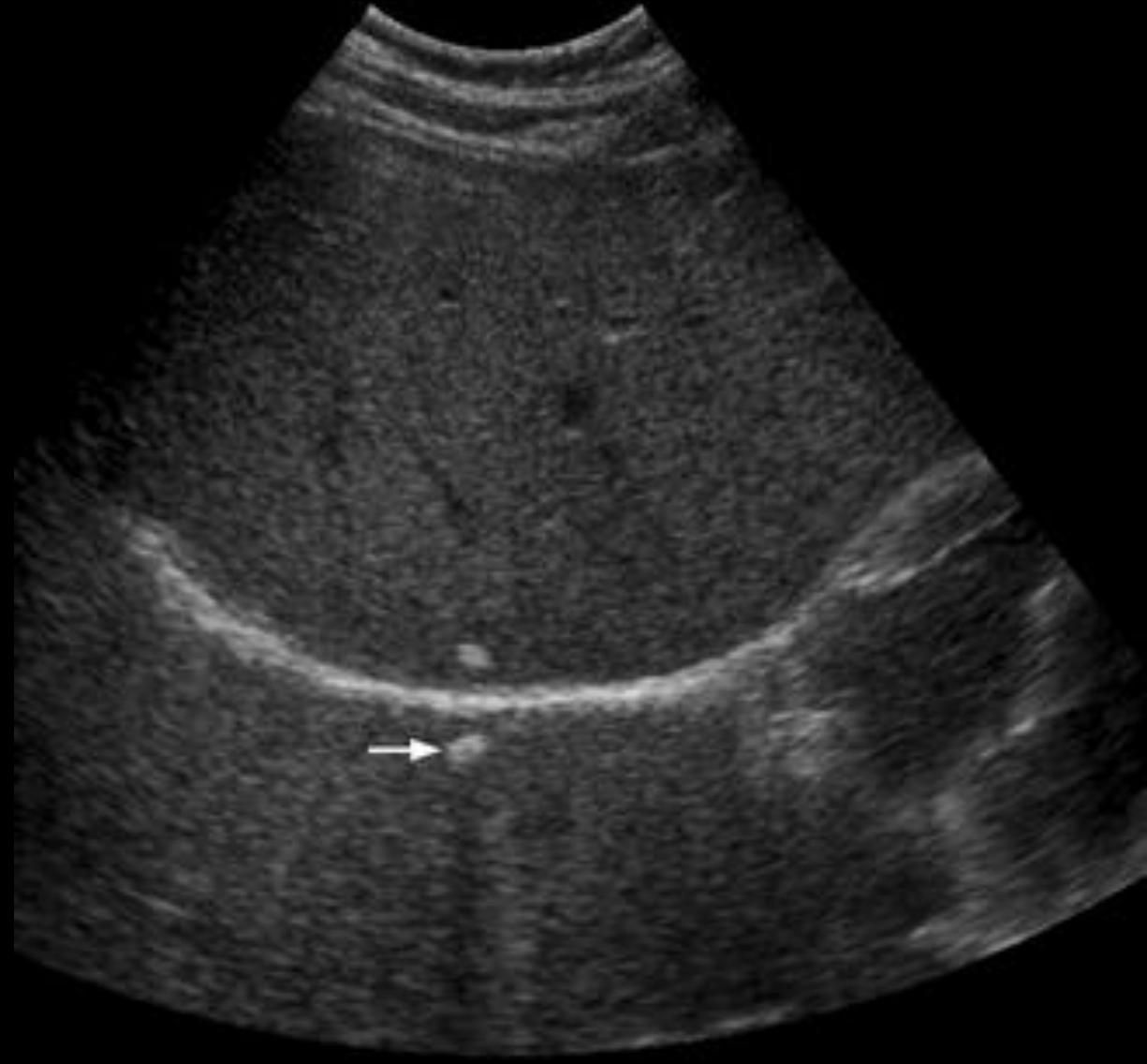
Mirror Image Artifact



Mirror Image Artifact



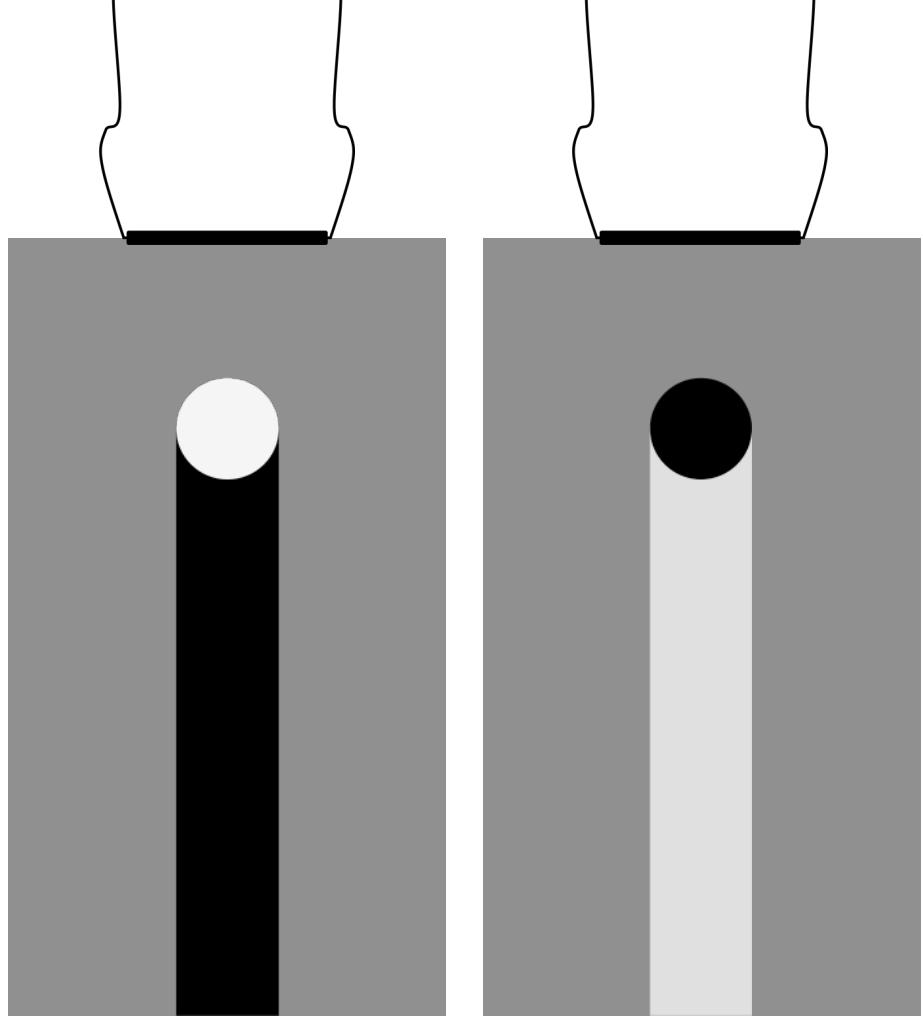
Mirror Image Artifact



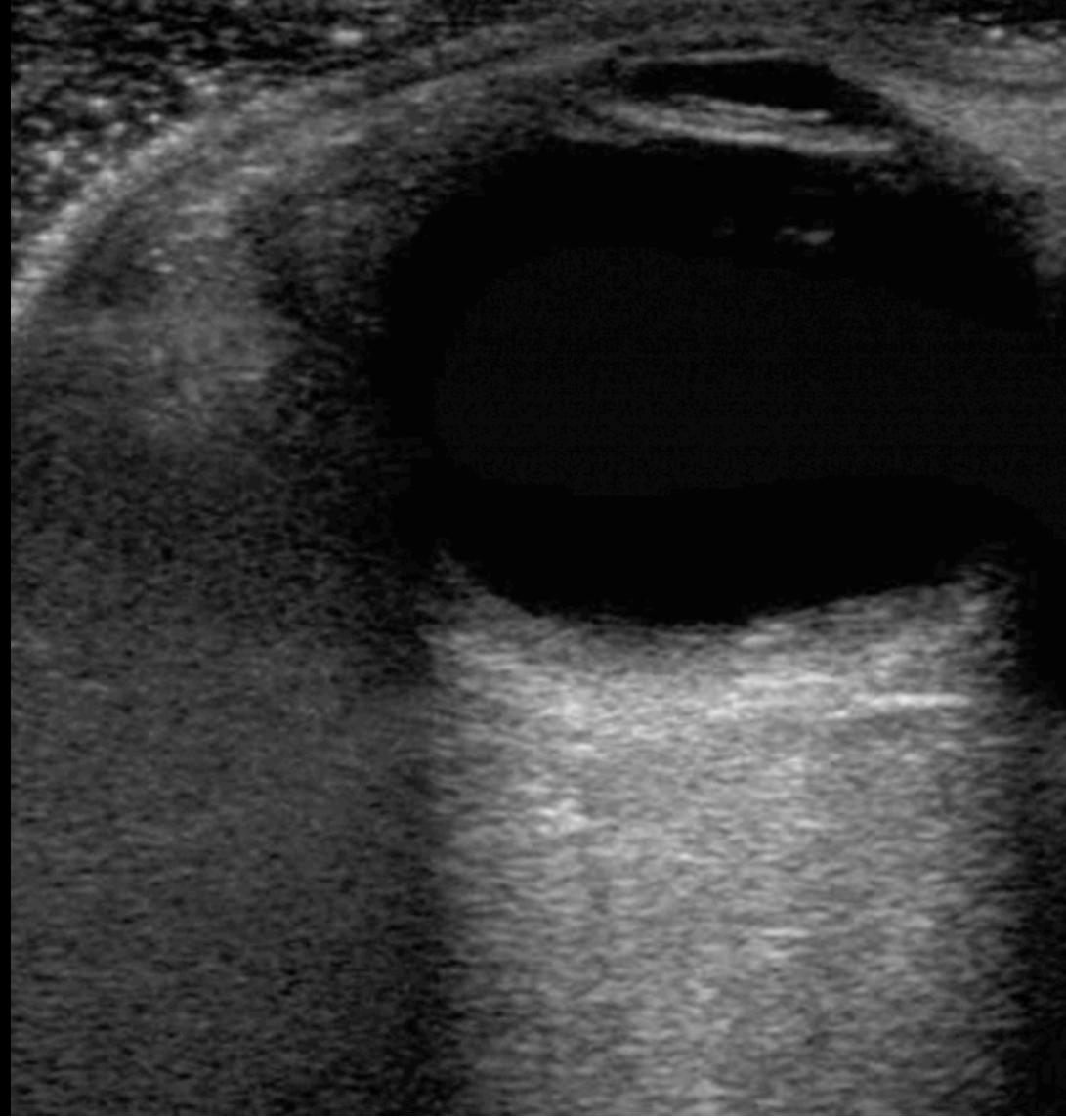
Mirror Image Artifact



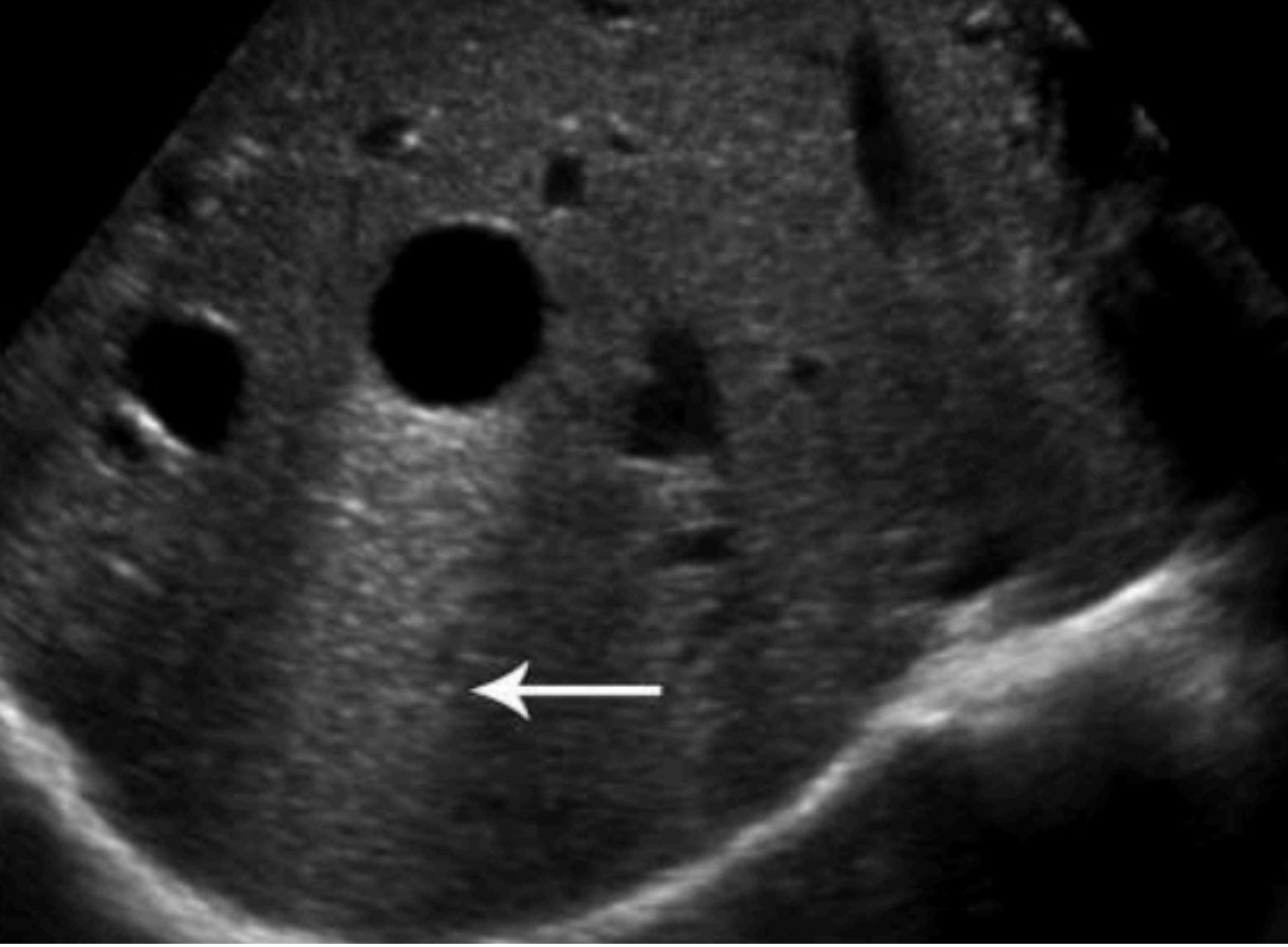
Speckle



## Shadowing and Enhancement Artifacts



Shadowing and Enhancement Artifacts



Shadowing and Enhancement Artifacts



Shadowing and Enhancement Artifacts



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

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

# Summary