

IMAGING PRINCIPLES AND INSTRUMENTATION

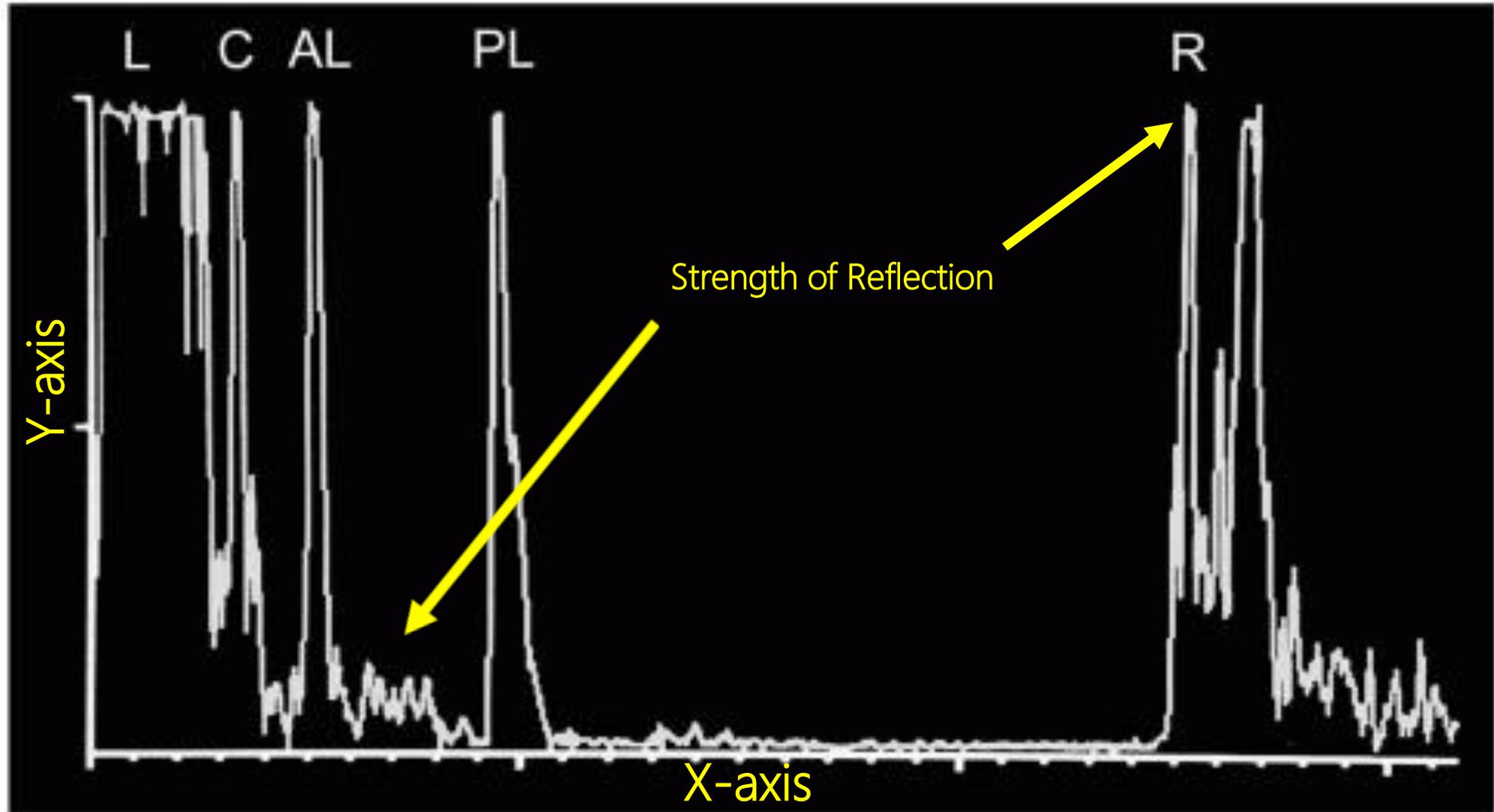
CHAPTER 3



A-MODE

- Amplitude
- Appears as a series of upward spikes
- When pulse is emitted
 - Dot moves at a constant speed across the display
- When pulse returns
 - It is processed and the moving dot is deflected upward on the screen
 - Stronger the reflection, the higher the "spike"

A-MODE



A-MODE

- Y-axis
 - Height of upward deflection
 - Amplitude of returning echo
 - Strong echoes create tall spikes
 - Weak echoes create short spikes
- X-axis
 - Represents depth of reflector
 - Derived from time-of-flight
 - Accurate in determining depth of reflectors

NORMAL IMMERSION 00 10:18 MAY 19

MAN 74db

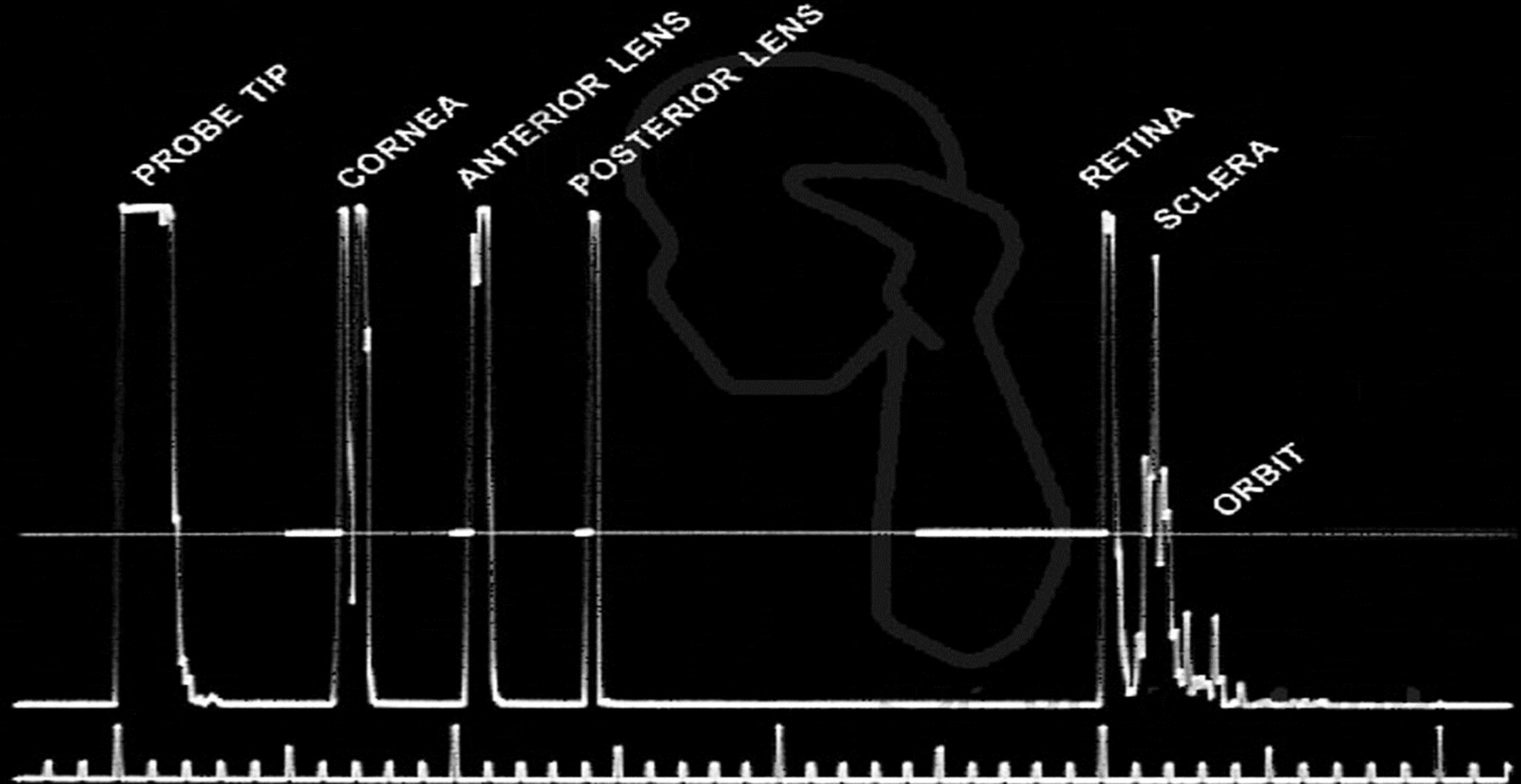
PHAKIC-1 1532/1641/1532

00 00

AXL = 23.99mm

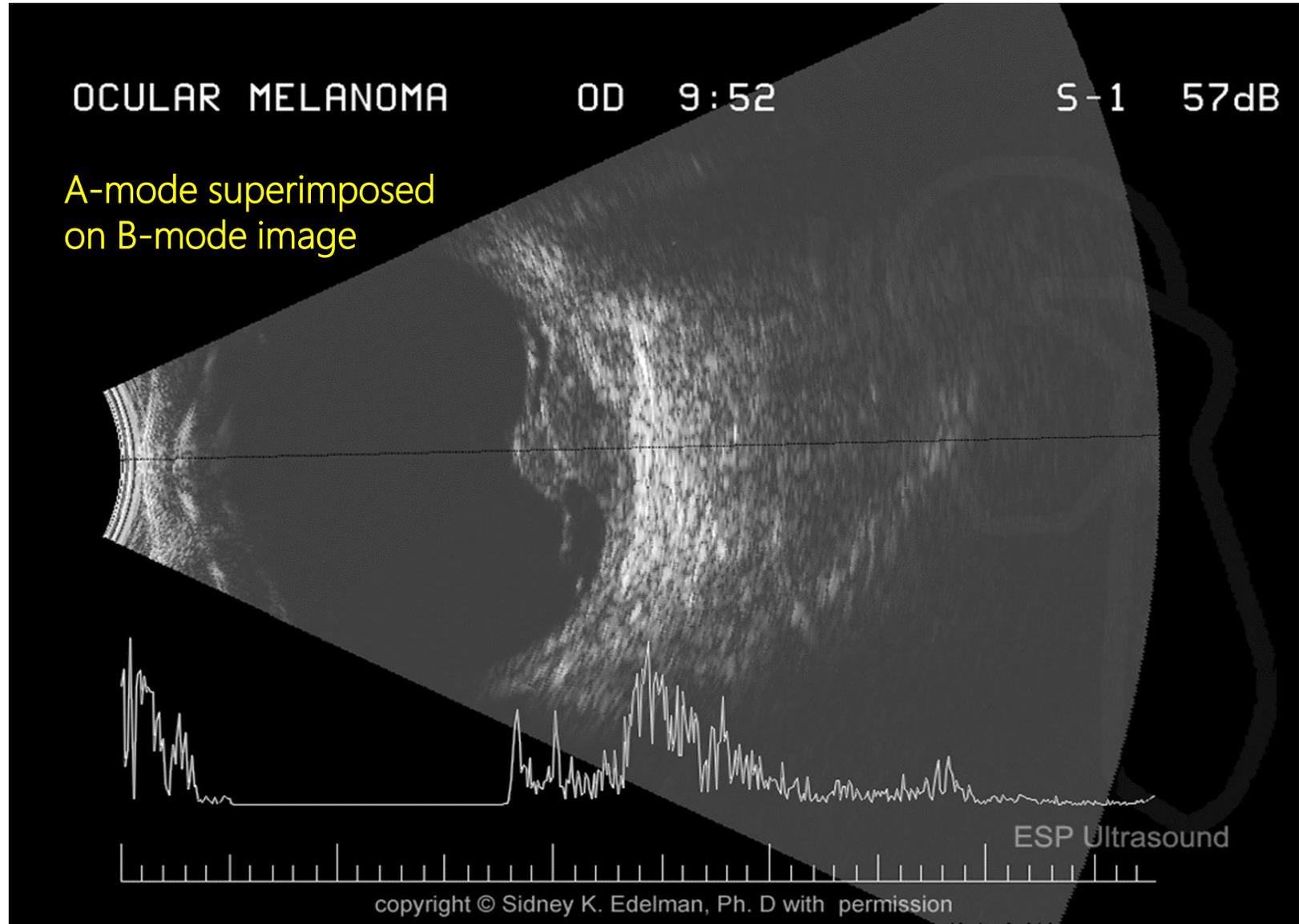
LENS = 3.99mm

ACD = 3.97mm



A-MODE

- Used in ophthalmology
 - Accurate measurements of depth or structure thickness are important
- One scan line is created from one pulse
 - No image is created



B-MODE

- Brightness
- Appears as a line of dots of varying brightness
- When pulse is emitted
 - An invisible dot moves at a constant speed across the display
- When reflection returns
 - It is process and the invisible dot is turned on

B-MODE

- Brightness of the dot indicates the strength of the reflection
 - Weaker reflections appear as darker gray dots
 - Stronger reflections appear as brighter white dots
- Modern equipment uses a white dot on a black background
 - Very strong reflectors will be hyperechoic
 - Weak reflectors will be hypoechoic
 - No return echoes appear as anechoic

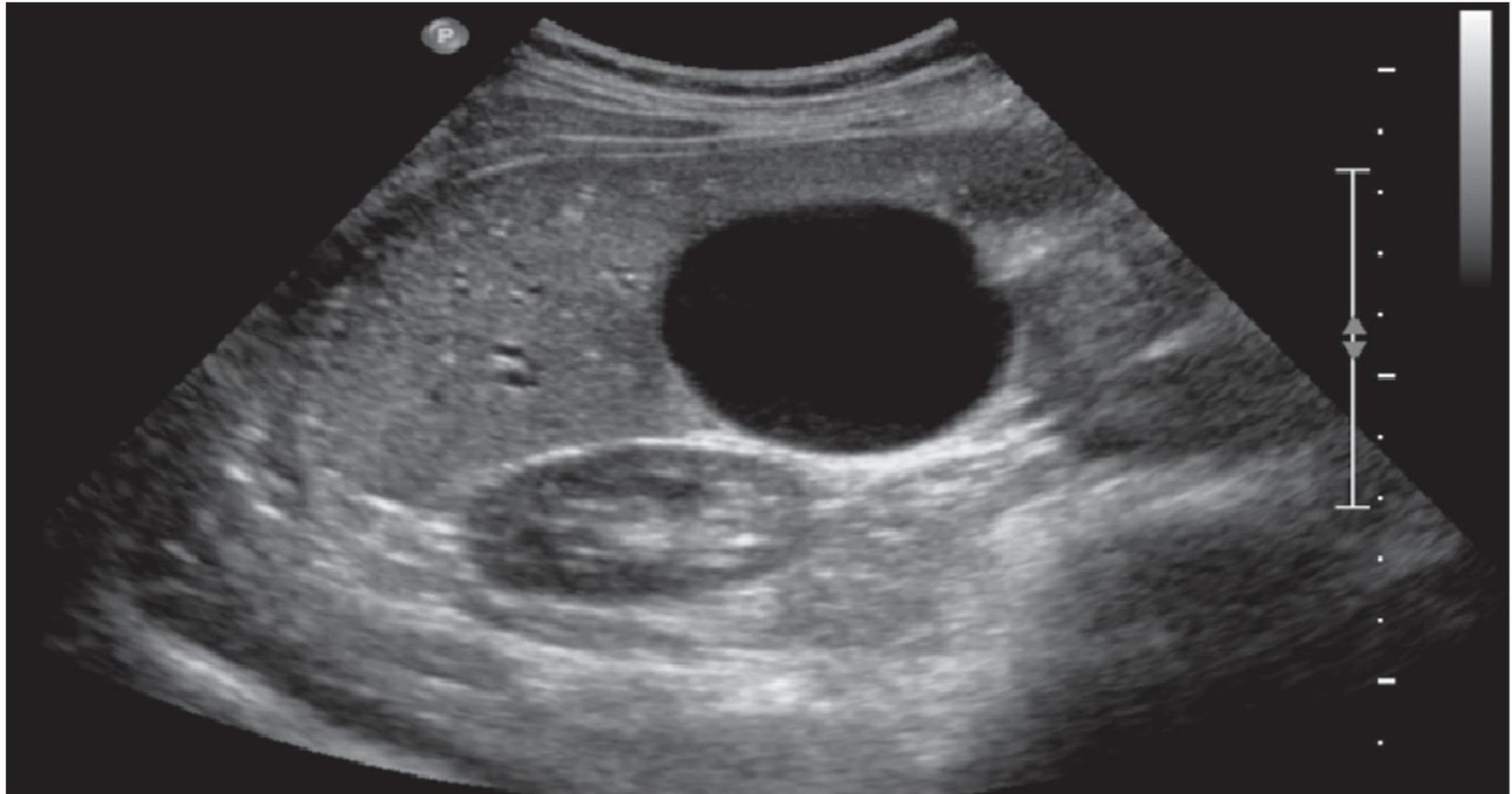
B-MODE

- X-axis
 - Reflector depth; derived from time-of-flight
- Z-axis
 - Brightness of dot
 - Measured by reflection amplitude
 - Amplitude information is routed into the Z-axis instead of the Y-axis

STATIC SCAN IMAGE



B-MODE



B-MODE

- First form of grayscale imaging
 - Basis for all other types of grayscale including real-time imaging
- Some authors use B-mode or B-scan to describe any form of grayscale image
- B-mode images are made up of many scan lines stacked together
 - Each scan line is made up of one or more pulses of sound

B-MODE

- For the dots to be placed correctly on the screen, the system needs to know where the echoes came from
 - The time it takes for the sound to reach the reflector and return must be known
 - *Range Equation*
- Distance to the reflector (d) is equal to the propagation speed (c) multiplied by the round-trip time (t) [or time to the reflector and back], divided by 2
- Range Equation:
$$d = \frac{c \times t}{2}$$

RANGE EQUATION

- To create an anatomic image, a sound pulse must travel to a reflector located in the body and return to the transducer
 - This travel time allows us to accurately position the reflector
- "Time-of-Flight" or "Go-Return Time"
 - Time elapsed from pulse creation to pulse reception
 - Superficial reflectors have a very short "time-of-flight" whereas deeper reflectors have a longer "time-of-flight"

$$\text{Depth (mm)} = \frac{1.54 \text{ mm}/\mu\text{s} \times \text{go-return time } (\mu\text{s})}{2}$$

2

RANGE EQUATION

- Simplified:

$$d = 0.77t$$

- Follow the 13 μs rule to identify "t" in the equation

13-MICROSECOND RULE

- Always applies when sound travels through soft tissue
- For every 13 μs of go-return time, the object creating the reflection is 1 centimeter deep in the body
 - i.e. it takes 6.5 μs for the pulse to travel 1 cm to the reflector and 6.5 μs for the pulse to travel back to the transducer ["go-return time"]
- Pulse travels to the reflector and back to the transducer, the total distance that a pulse travels is twice the reflector depth

Time of Flight	Reflector Depth	Total Distance Traveled
13 μs	1 cm	2 cm
26 μs	2 cm	4 cm
39 μs	3 cm	6 cm

13-MICROSECOND RULE

- Pay close attention to board questions that ask you about reflector depth versus total distance traveled
- Example 1: A sound wave travels 13 μs and impinges on a reflector. How far away is the reflector?
- Example 2: A reflector is 25 mm away from the transducer. How long does it take to get back to the transducer?

PRP AND IMAGING DEPTH

- When a sonographer adjusts the imaging depth, they also change the PRP of the system
- PRP is the time from the start of one pulse to the start of the next
 - PRP is the go-return time!
 - If your depth of view is set at 10 cm, following the 13 μs rule, your PRP would be 130 μs

$$\text{PRP } (\mu\text{s}) = \text{imaging depth (cm)} \times 13 \mu\text{s}$$



QUESTIONS

A SOUND WAVE IS CREATED BY A TRANSDUCER, REFLECTS OFF AN OBJECT, AND RETURNS TO THE TRANSDUCER. THE DEPTH OF THE REFLECTOR IS 10 CM IN SOFT TISSUE. WHAT IS THE GO-RETURN TIME?

A. 13 μs

B. 1.3 μs

C. 65 μs

D. 130 μs

A SOUND WAVE IS CREATED BY A TRANSDUCER, REFLECTS OFF AN OBJECT, AND RETURNS TO THE TRANSDUCER. THE GO-RETURN TIME IS 26 MICROSECONDS. WHAT IS THE DEPTH OF THE REFLECTOR?

- A. 1 cm
- B. 2 cm
- C. 3 cm
- D. 4 cm

A SOUND WAVE IS CREATED BY A TRANSDUCER, REFLECTS OFF AN OBJECT, AND RETURNS TO THE TRANSDUCER. THE GO-RETURN TIME IS 26 MICROSECONDS. WHAT IS THE TOTAL DISTANCE THAT THE PULSE TRAVELED?

A. 1 cm

B. 2 cm

C. 3 cm

D. 4 cm

THE MAXIMUM IMAGING DEPTH DURING AN
ULTRASOUND EXAM IS 10 CM. THE
SONOGRAPHER ADJUSTS THE IMAGING
DEPTH TO 20 CM. WHAT HAPPENS TO THE
PULSE REPETITION PERIOD?

- A. It is unchanged
- B. It is halved
- C. It is doubled
- D. It is 20 times longer

THE MAXIMUM IMAGING DEPTH DURING AN
ULTRASOUND EXAM IS 10 CM. THE
SONOGRAPHER ADJUSTS THE IMAGING
DEPTH TO 20 CM. WHAT HAPPENS TO THE
PULSE REPETITION FREQUENCY?

- A. It is unchanged
- B. It is halved
- C. It is doubled
- D. It is 20 times longer

M-MODE

- Motion
- With B-mode imaging, we are usually interested in the anatomy on the image
- M-mode is interested in the movement of the reflectors and not the anatomy
 - Motion of heart valve, myocardial wall thickness during systole/diastole
 - Used in cardiac and obstetrics

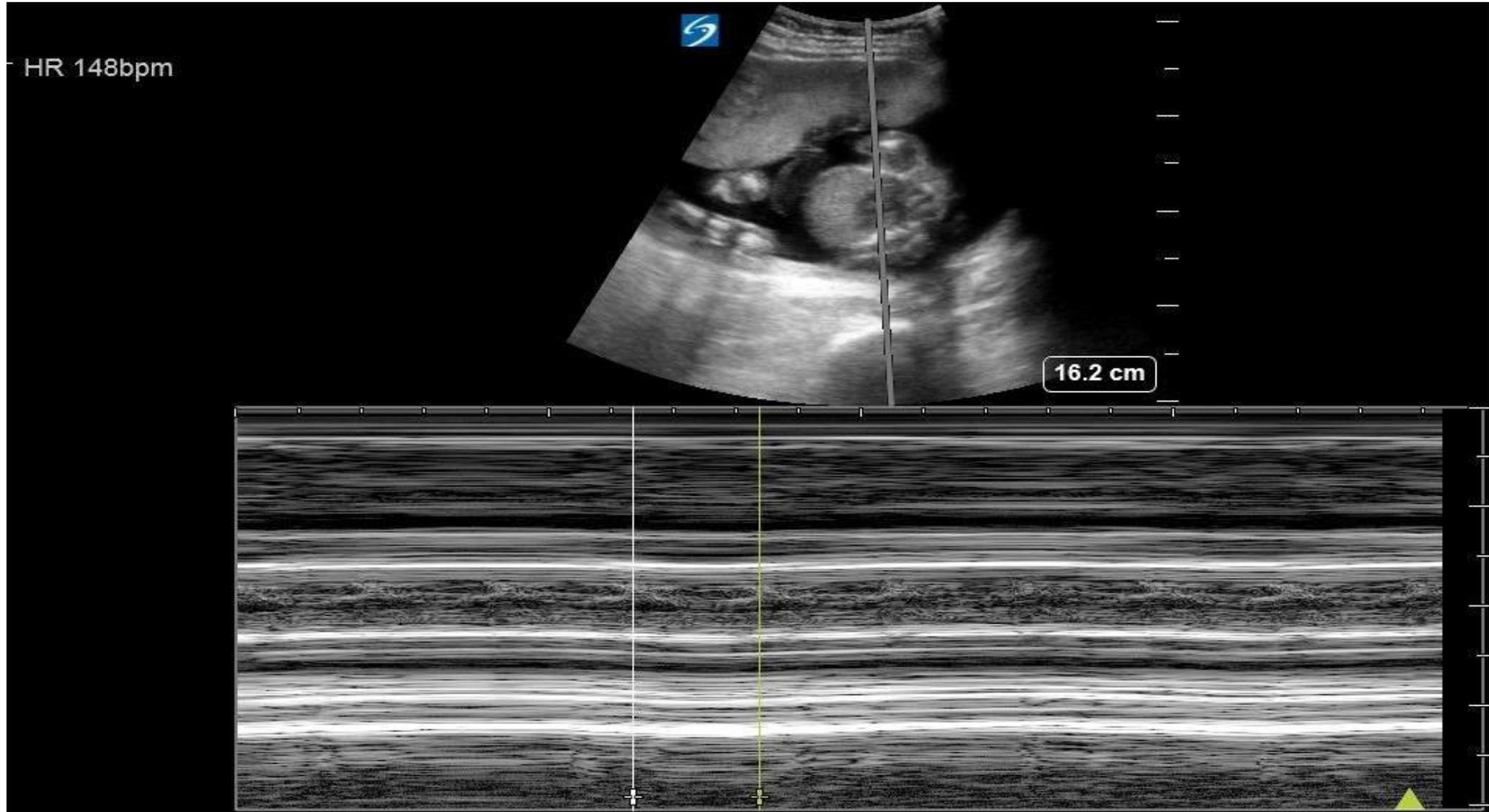
M-MODE

- Motion of the reflectors along a single scan line is analyzed
- Appears as a group of horizontal wavy lines
- When pulse is emitted
 - Scan line is moved at a constant speed across a B-mode display
- When reflections return
 - Various squiggly lines represent changing depth of the reflecting surfaces

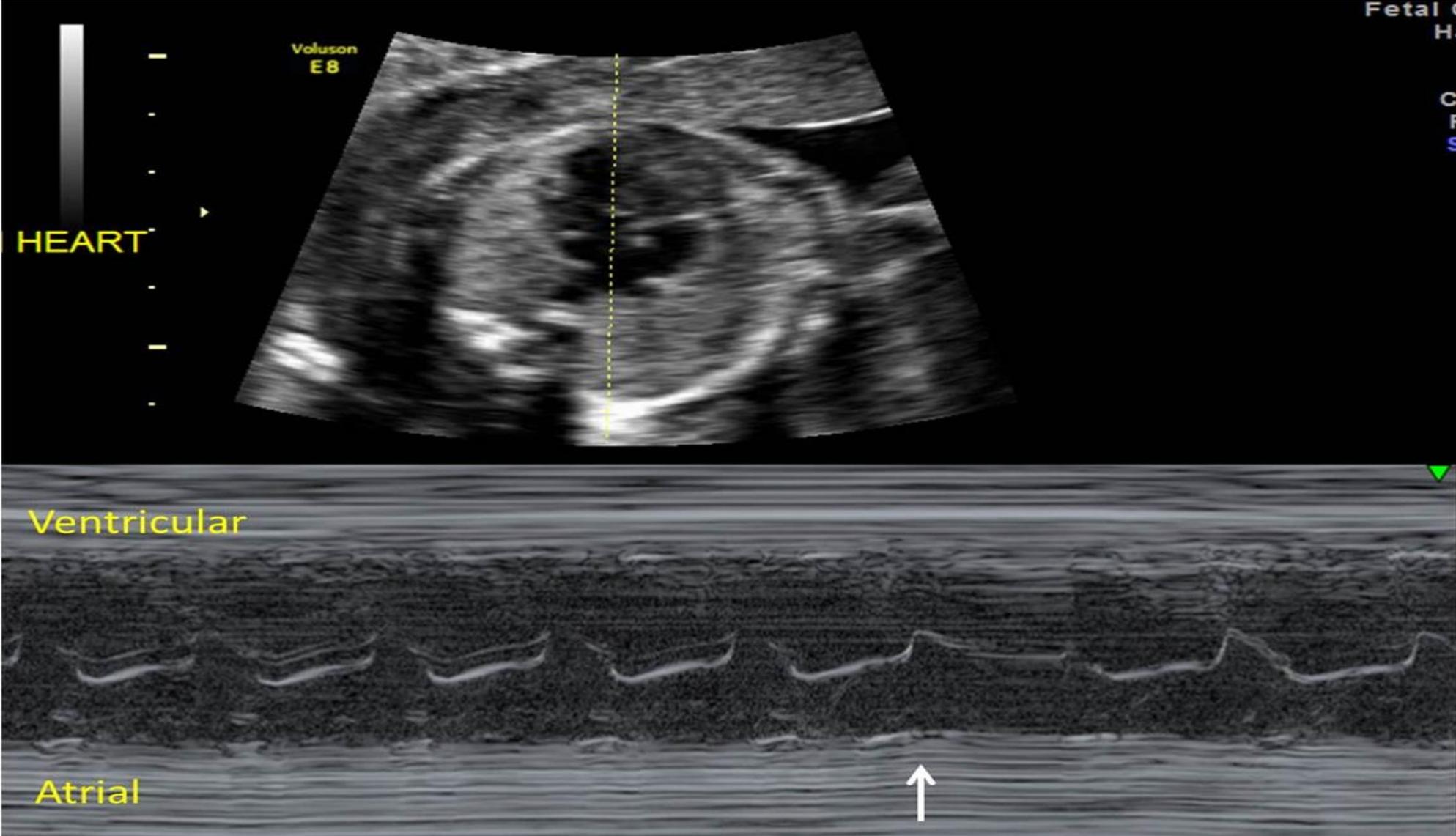
M-MODE

- If the “squiggly” line moves up and down on a display
 - Indicates the reflector is moving closer to and further away from the transducer
- If the “squiggly” line is a straight horizontal line
 - Indicates a stationary reflector
- X-axis
 - Represents time
- Y-axis
 - Reflector depth; derived from time-of-flight

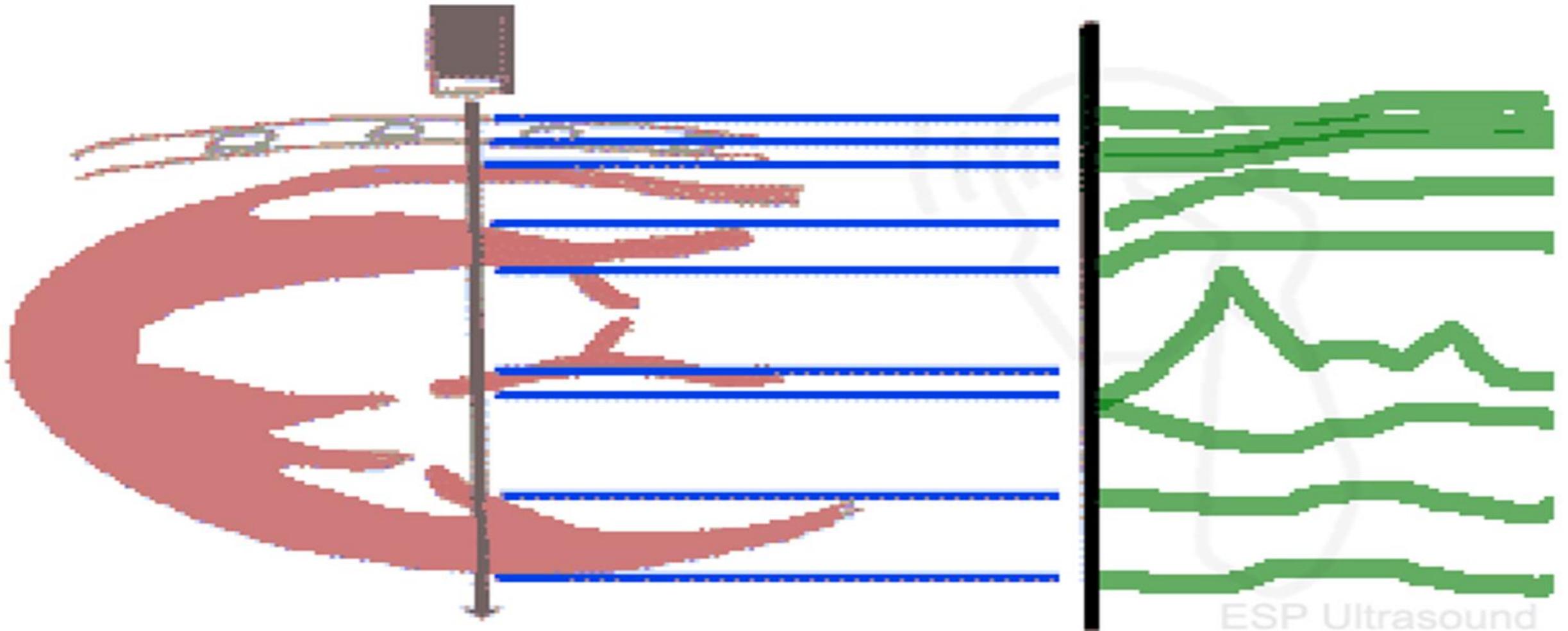
M-MODE



M-MODE



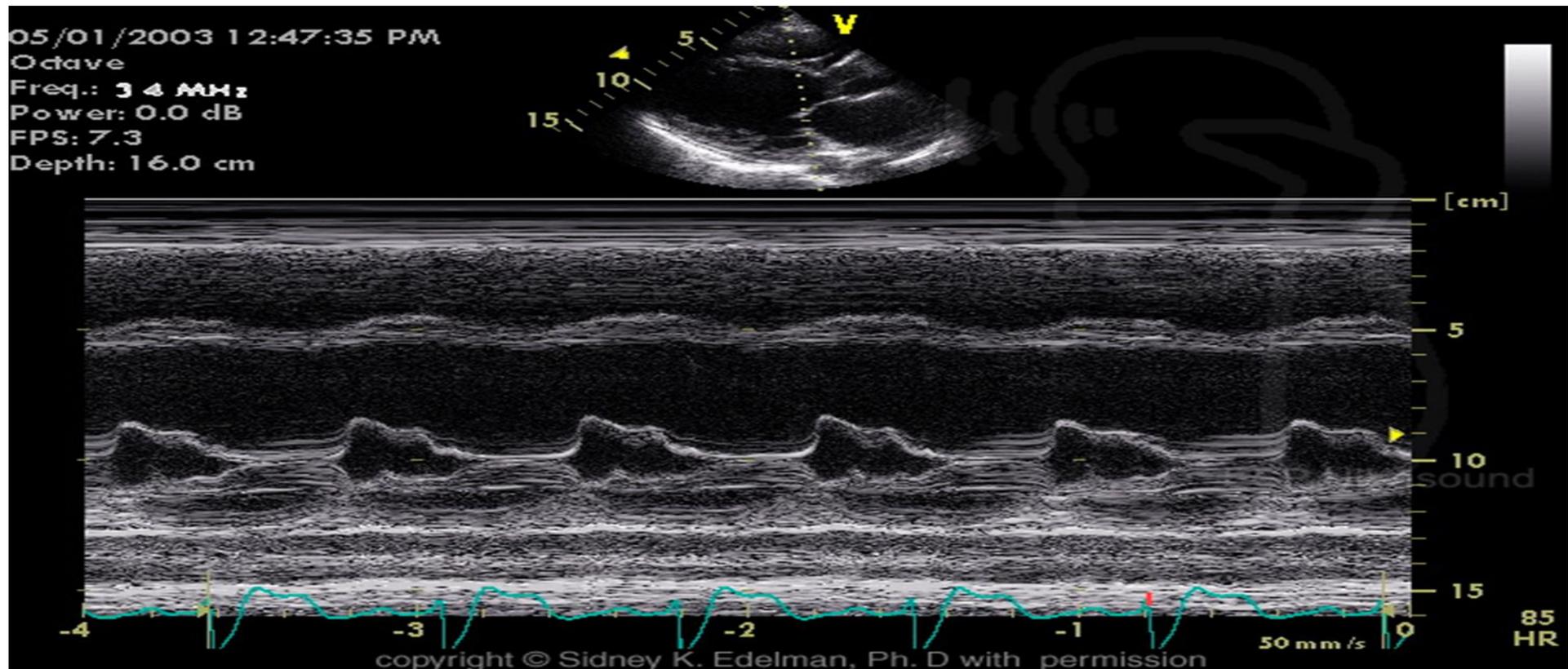
M-MODE



ESP Ultrasound

M-MODE

- Only mode that displays the changing position of reflectors with respect to time



DISPLAY MODE AXES

Mode	X-axis	Y-axis	Z-axis
A-mode	Depth	Amplitude	None
B-mode	Depth	None	Amplitude
M-mode	Time	Depth	None



QUESTIONS

WITH A-MODE, WHAT DOES THE Y-
AXIS DISPLAY?

- A. Depth of reflector
- B. Amplitude
- C. Brightness
- D. Time

WITH B-MODE, WHICH AXIS IS
RELATED TO THE STRENGTH
OF THE REFLECTION?

- A. X-axis
- B. Y-axis
- C. Z-axis

WHAT IS THE ONLY DISPLAY MODE THAT PROVIDES INFORMATION REGARDING REFLECTOR MOTION WITH RESPECT TO TIME?

- A. A-mode
- B. B-mode
- C. C-mode
- D. M-mode

WITH A-MODE, WHAT DOES
THE X-AXIS DISPLAY?

- A. Depth of reflector
- B. Amplitude
- C. Brightness
- D. Time

TRANSMISSION OF ULTRASOUND

- Ultrasound systems are highly sophisticated and have two major functions:
 1. Preparation and transmission of electrical signals to the transducer, which creates the sound beam
 2. Reception of electrical signals from the transducer, with subsequent processing into meaningful images and sounds

TRANSMISSION OF ULTRASOUND

- Major Components:
 - Transducer
 - Pulser and Beam Former
 - Receiver
 - Display
 - Storage
 - Master Synchronizer

BEAM FORMER

- Controls the timing of firing delay patterns for phased array systems
 - Beam former determines the sequence of the voltage pulses sent to the individual elements
 - This allows sonographers to steer and focus the sound beam
- Controls apodization to reduce grating lobes
 - Apodization decreases strength of the voltage pulse sent to the outermost elements

PULSER

- Part of the beam former that determines:
 - Amplitude
 - Pulse Repetition Period (PRP)
 - Pulse Repetition Frequency (PRF)
- The strength of the sound wave entering the medium is directly proportional to the strength of the signal (voltage) exciting the elements
 - The stronger the output power, the stronger the sound beam (i.e., higher the amplitude) entering the medium, and therefore the proportionally stronger the signal that returns from the reflectors in the medium

PULSER

- Note that frequency and amplitude are unrelated
 - Increasing/decreasing the strength of the pulse sent out of the transducer in no way changes the operating frequency of the transducer
- Pulser controls the amount of power entering the patient
 - If the word “output” or “power” is used in a term, it is a pulser function (i.e. output gain, output power, acoustic power, etc)
- Changes in the voltage modify the brightness of the entire image
 - Active element will vibrate with a magnitude related to pulser voltage

PULSER

- Lower voltage applied – PZT vibrates gently
- Weaker sound beam is transmitted and reflected echoes are weaker



PULSER

- Higher voltage applied – PZT vibrates forcefully
- Stronger sound beam is transmitted and reflected echoes are stronger



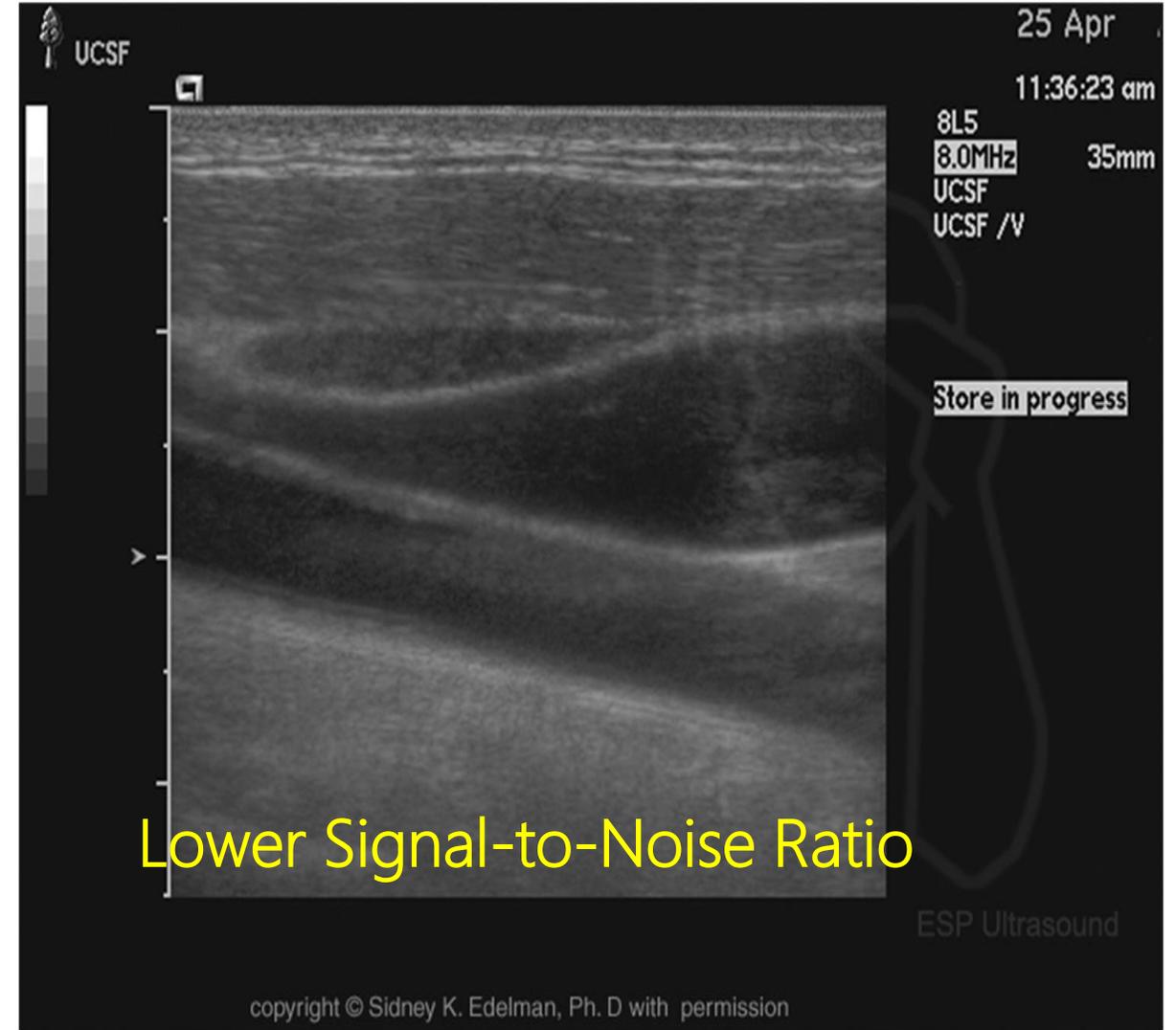
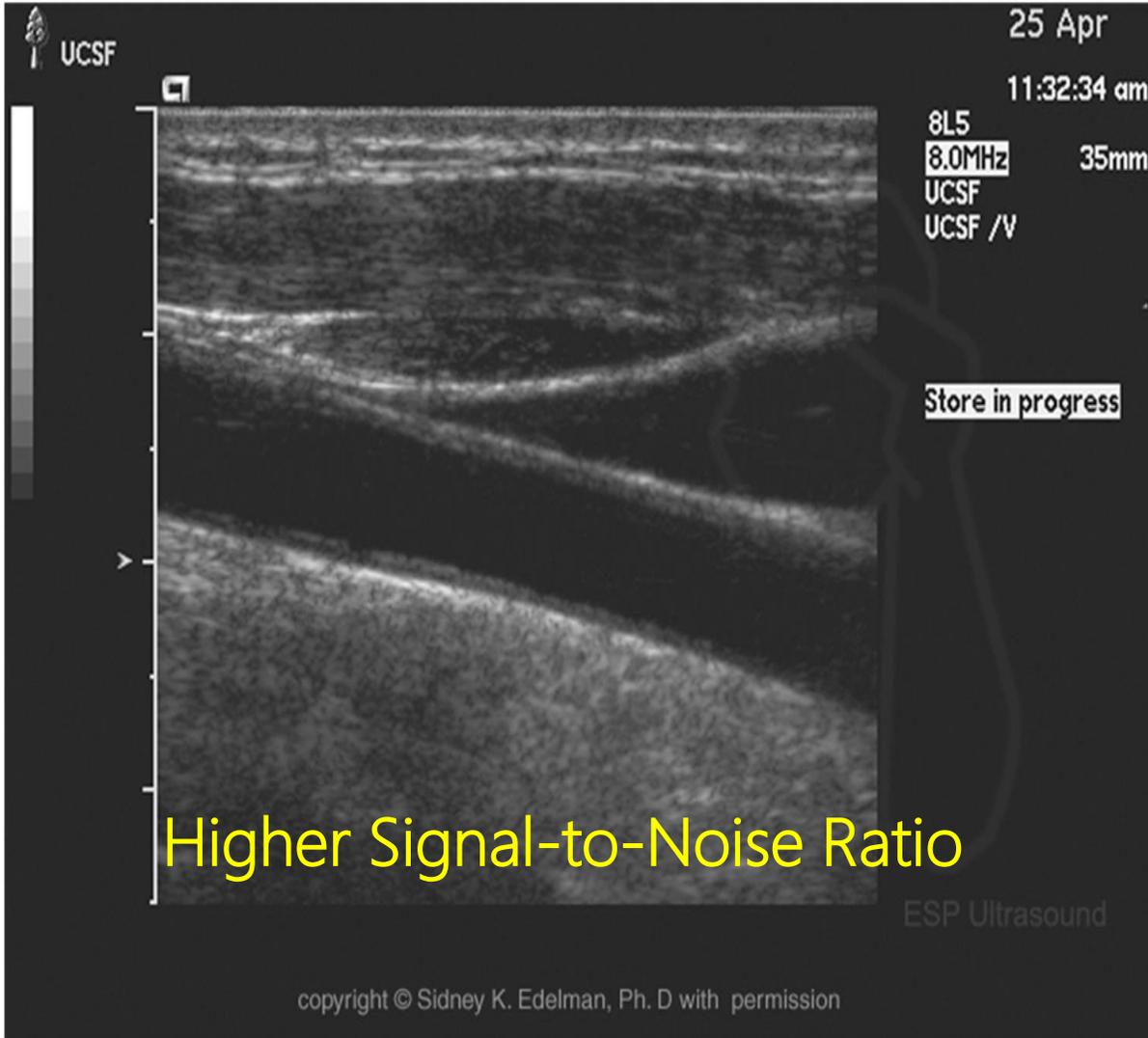
PULSER

- Voltage changes described by many ways:
 - Output gain
 - Acoustic power
 - Pulser power
 - Energy output
 - Transmitter output
 - Power
 - Gain
 - Vague – should be avoided

PULSER

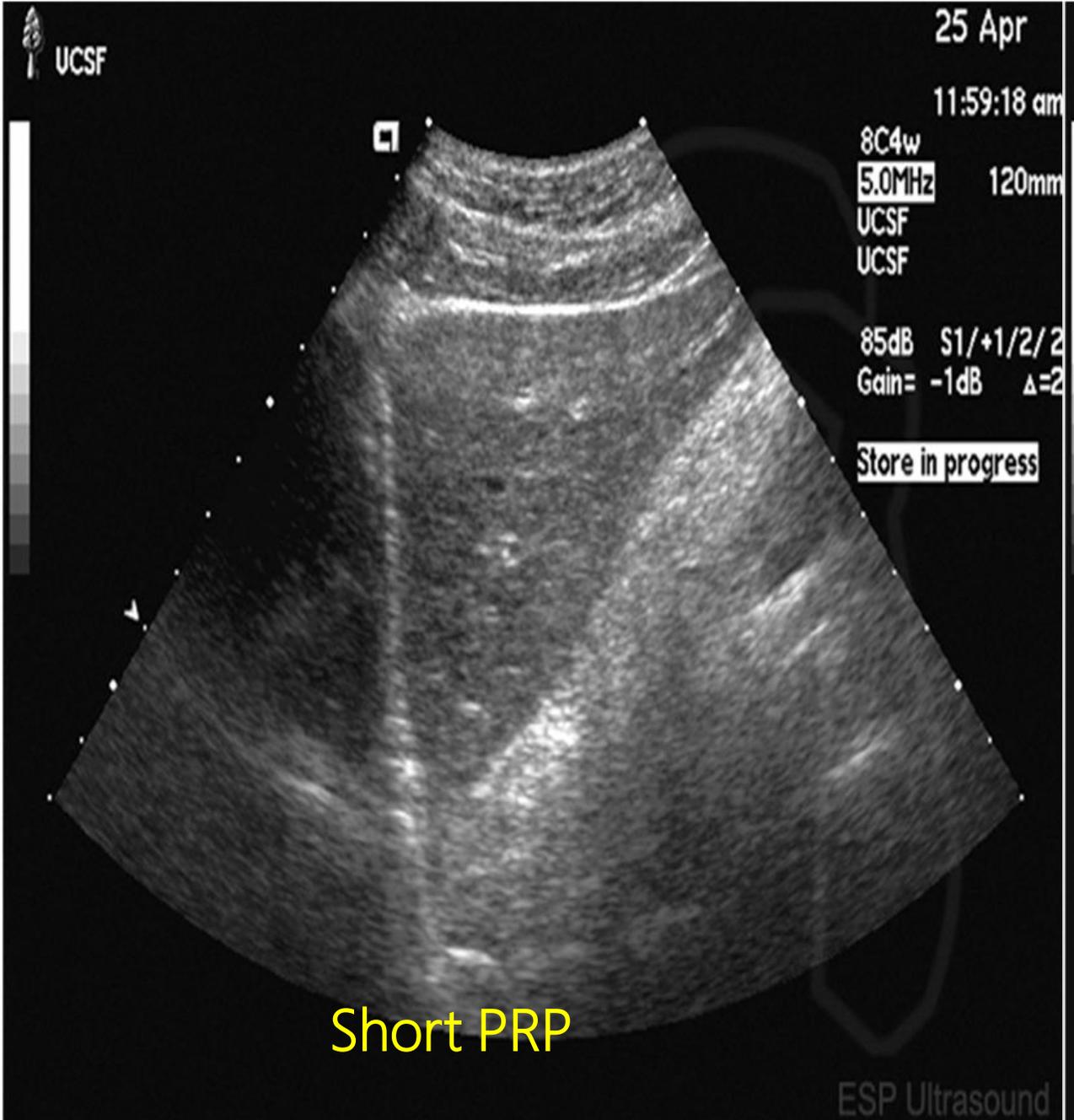
- Advantages to increased output power:
 1. Higher amplitude return echoes for a better signal-to-noise ratio (creates an image with less noise interference)
 2. Improved depth penetration
- Disadvantages to increased output power:
 1. Increases exposure to the patient and therefore carries increased risk for potential bioeffects
 - Always follow the principle of **ALARA**; use the lowest power and shortest scanning time to reduce risk of bioeffects
 - If image is too dark, use receiver gain instead of output power

PULSER



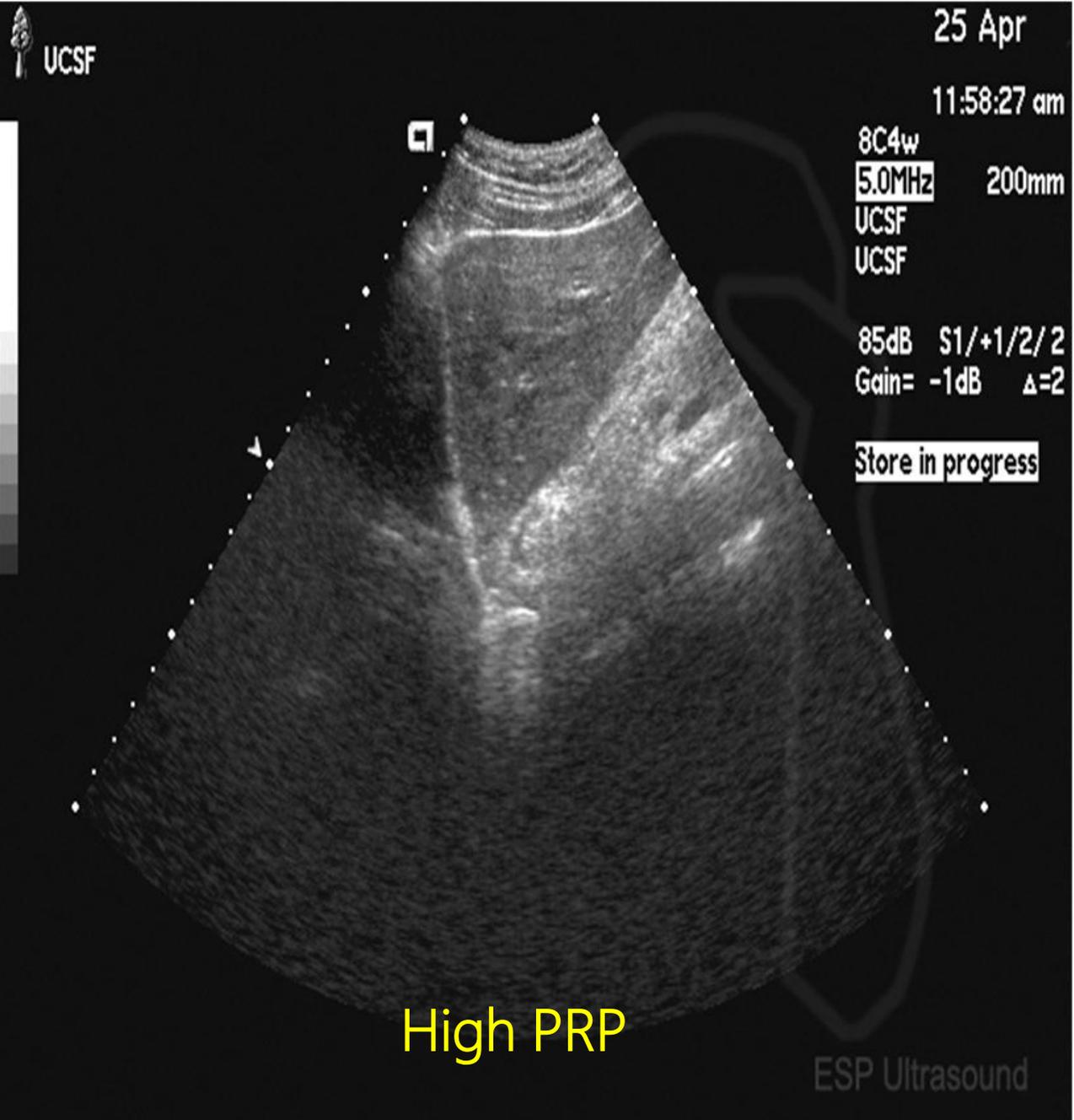
PULSER

- Pulser determines not only the strength of the sound wave but also the time between voltage spikes (PRP)
 - PRF and PRP are reciprocals; pulser also determines PRF
- Short PRP
 - PRF is high
 - Less listening time; superficial imaging
- High PRP
 - PRF is low
 - More listening time; deeper imaging



Short PRP

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High PRP

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PULSER

- Coded excitation uses a series of pulses to form one scan line instead of the “one-pulse-per-scan-line” method
 - Allows for multiple focal zones, improved penetration, speckle reduction, B-flow imaging, improved contrast resolution
- Frequency compounding allows for averaging of all frequencies in a wide bandwidth transducer
 - Improves contrast resolution, reduces noise and acoustic speckle

MASTER SYNCHRONIZER

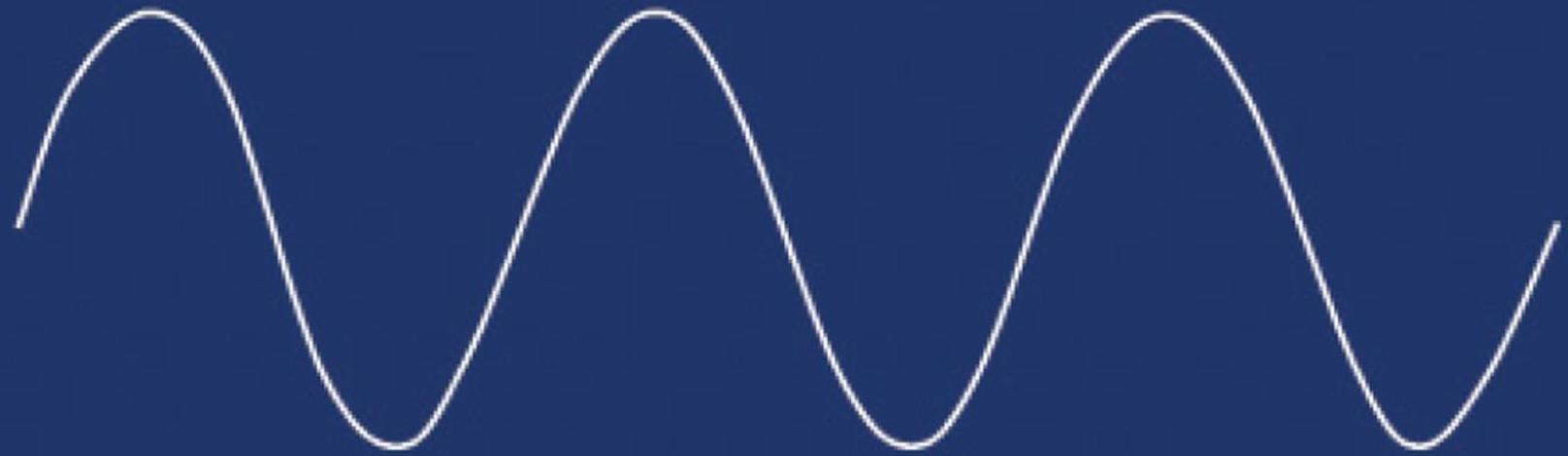
- Maintains/organizes proper timing and interaction of components
- Times functions so everything operates as a single integrated system
- Ensures that a new pulse is not sent out until the previous pulse has returned



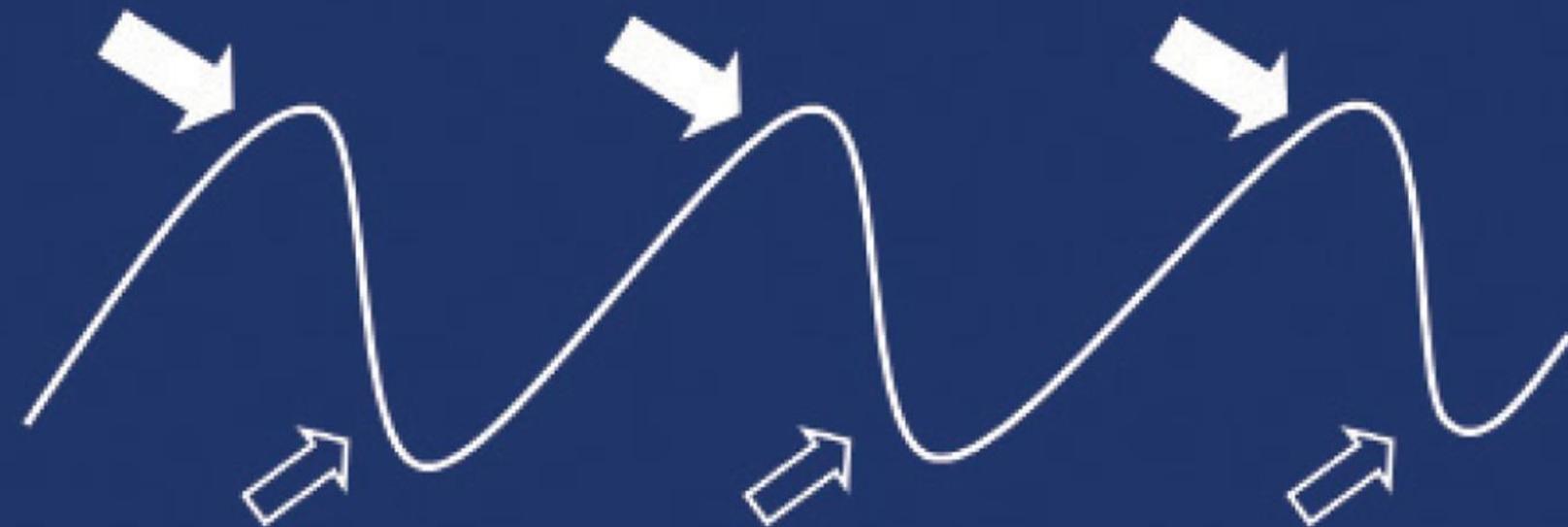
TISSUE HARMONIC IMAGING

- As a pressure wave travels through tissue, its shape is deformed so that the high-pressure peak of the wave starts traveling faster than its low-pressure trough
- The deeper the wave travels, the more deformed, or **non-sinusoidal**, it becomes
- Because of the deformed wave, sound waves are generated by the patient's own tissue, called **harmonics**

2a

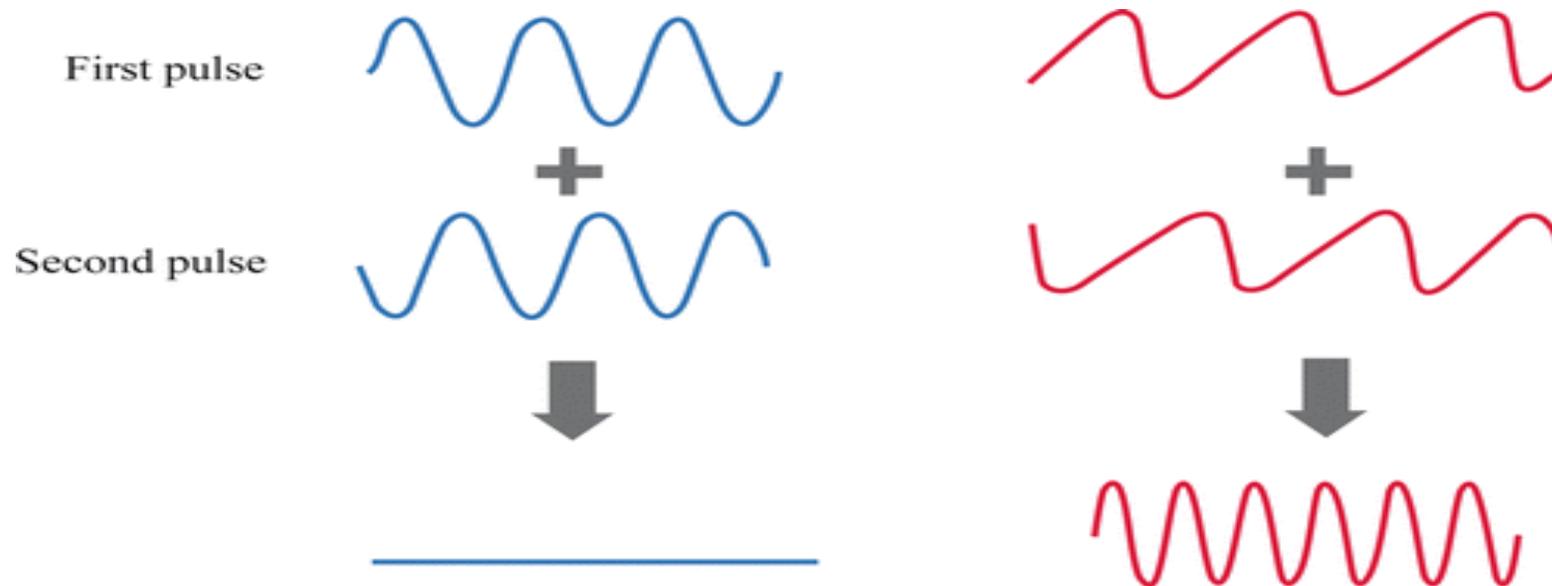


2b



TISSUE HARMONIC IMAGING

- At the surface, no harmonics are generated; they are only generated as the beam travels deeper
- The original frequency, called the **fundamental frequency**, is filtered out of the received beam and only the harmonic signal is processed

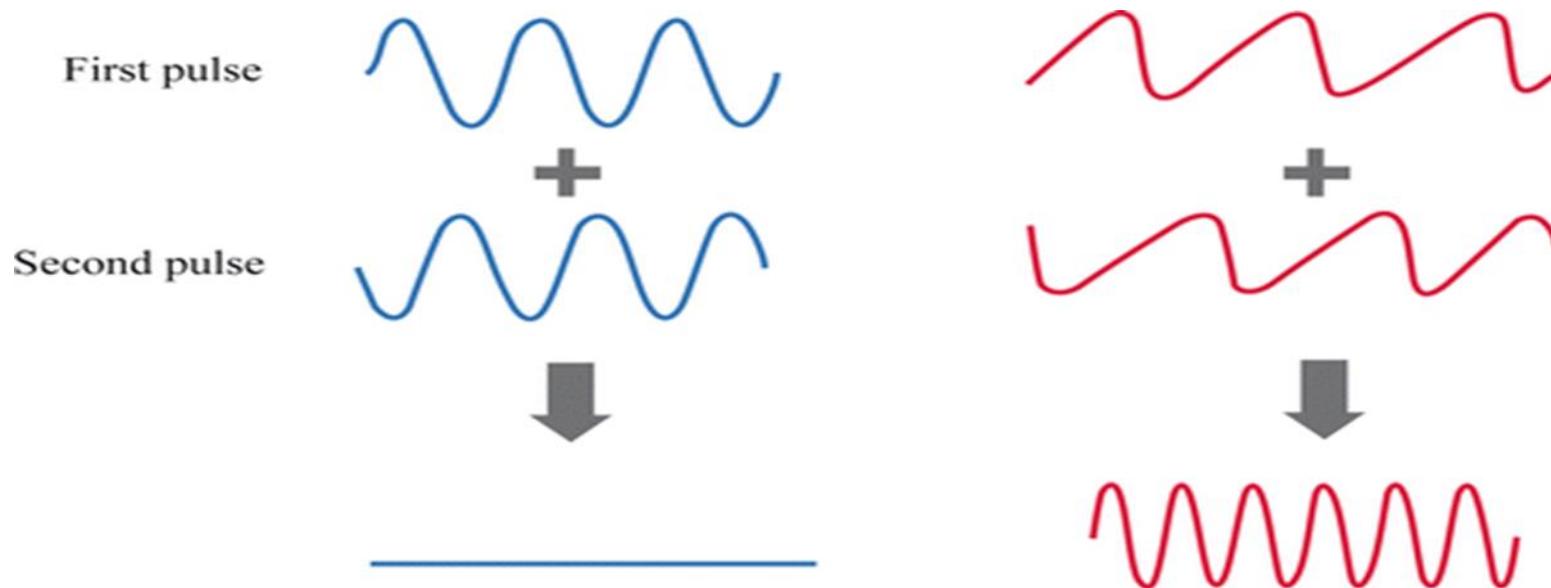


TISSUE HARMONIC IMAGING

- These harmonic signals are multiples of the fundamental frequency
 - Harmonics operate at twice the fundamental frequency
 - Therefore, if a 2-MHz beam is sent into the patient, the 4-MHz harmonic signal is what is displayed
- This harmonic signal is very narrow and offers excellent lateral resolution
- As a result of harmonic signals being generated deep to the surface, most superficial **artifacts**, such as reverberation, are reduced or eliminated

TISSUE HARMONIC IMAGING

- The fundamental frequency may be eliminated using **pulse inversion technology**
- With pulse inversion, the fundamental frequency is flipped 180° and transmitted, which cancels out the fundamental via destructive interference, leaving only the harmonic signal



RECEIVER

- The return signal is first processed by the receiver, aka the signal processor
- Changing any of the receiver functions will not alter the amount of power entering the patient
- Signals returning from the transducer are very weak
 - Receiver “boosts” the strength of the signals, processes them accordingly, and prepares the signals for display

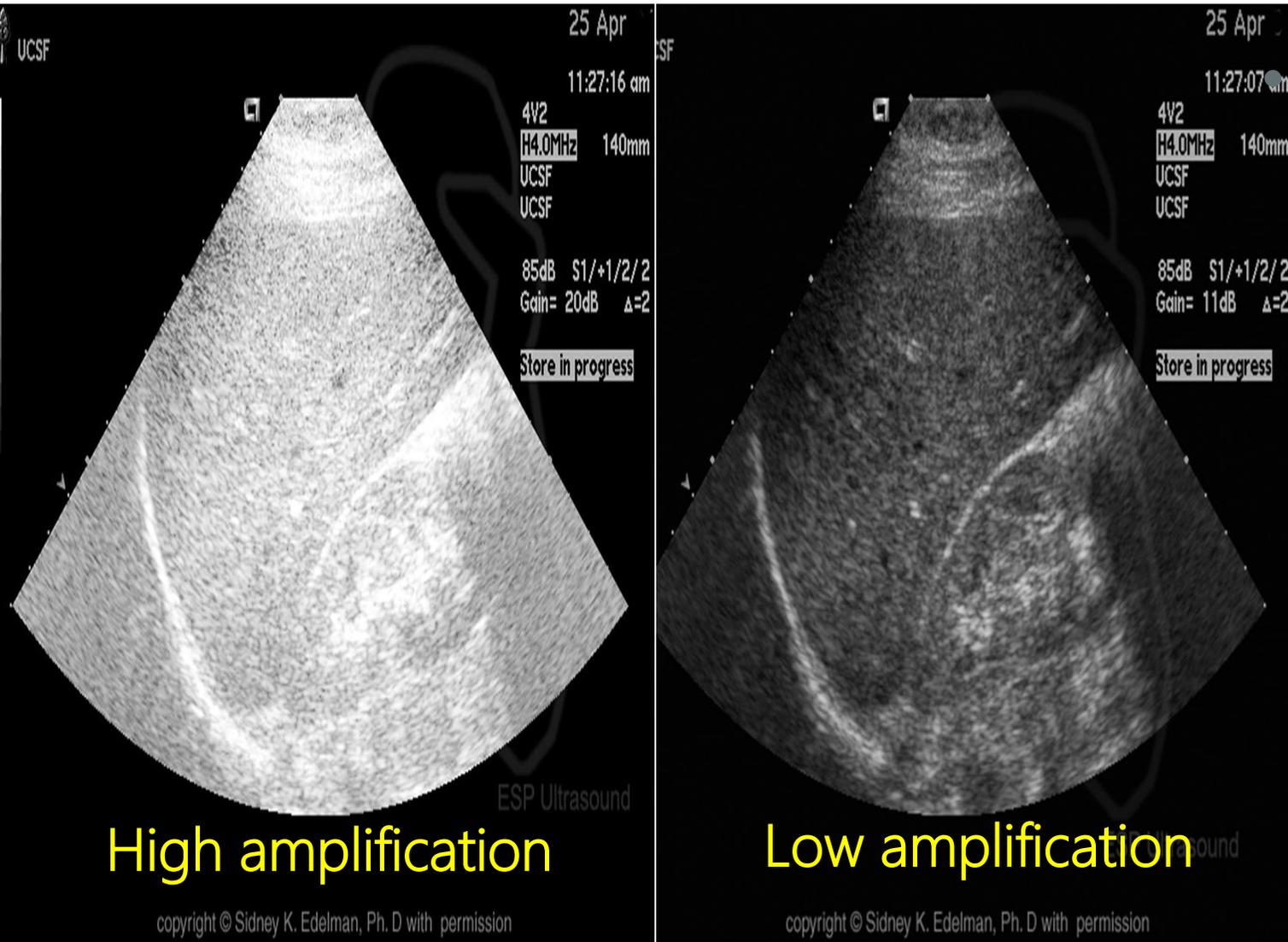
RECEIVER

- Includes several functions:
 - Preamplification
 - Amplification
 - Compensation
 - Compression
 - Demodulation
 - Rejection

RECEIVER

- Preamplification – process of improving the quality of the signal before it's amplified
 - Occurs within the transducer
 - Prevents electronic noise from contaminating tiny signals
- Amplification – each signal returning is made larger and all signals are treated identically; entire image is made brighter or darker
 - "Overall gain"

RECEIVER



Amplification:

- Increases the strength of an electrical signal in the receiver prior to further processing
- Every signal is treated identically
 - Amplification changes brightness of entire image

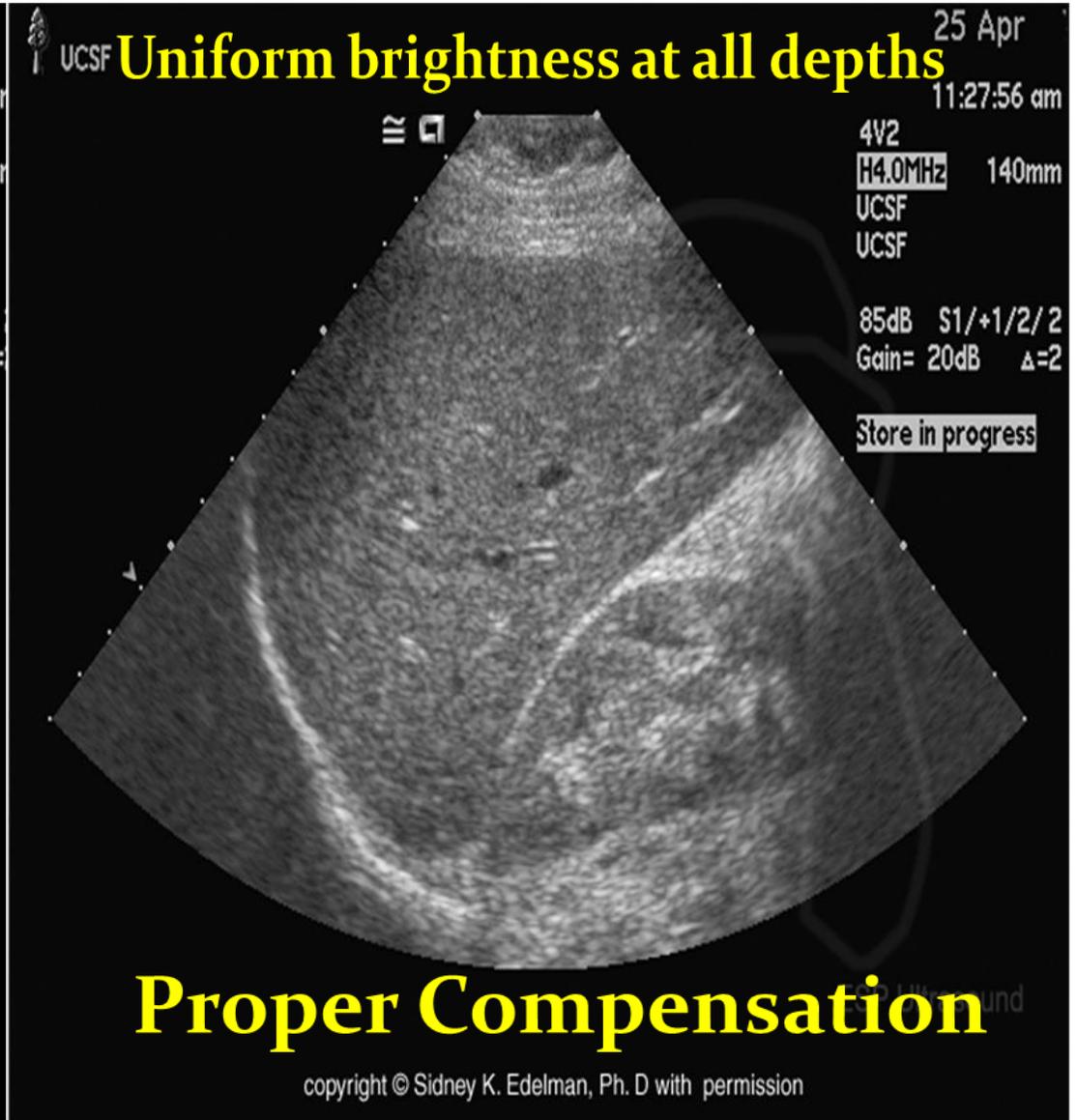
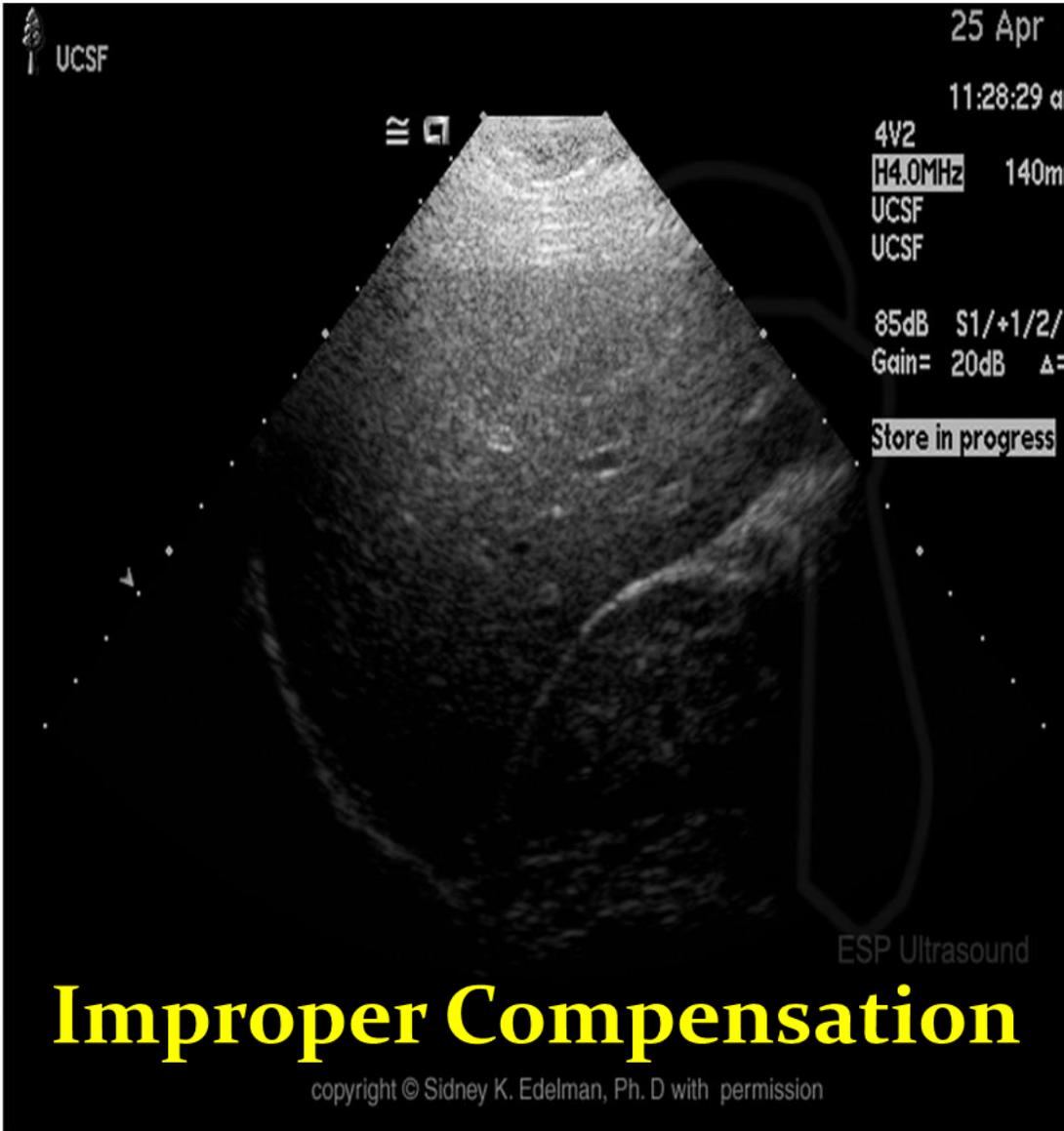
RECEIVER

- Amplification:
 - Cannot distinguish between signal and noise
 - Amplification cannot improve the signal-to-noise ratio
 - Both are amplified equally
 - Adjusting amplification cannot make an image of uniform brightness from top to bottom
- Units: decibels (dB)
- Also known as "receiver gain"

RECEIVER

- Compensation:
 - Corrects for attenuation
 - Used to create image of uniform brightness from top to bottom
 - Makes all echoes from similar reflectors appear identical regardless of their depth
- Units
 - dB

RECEIVER



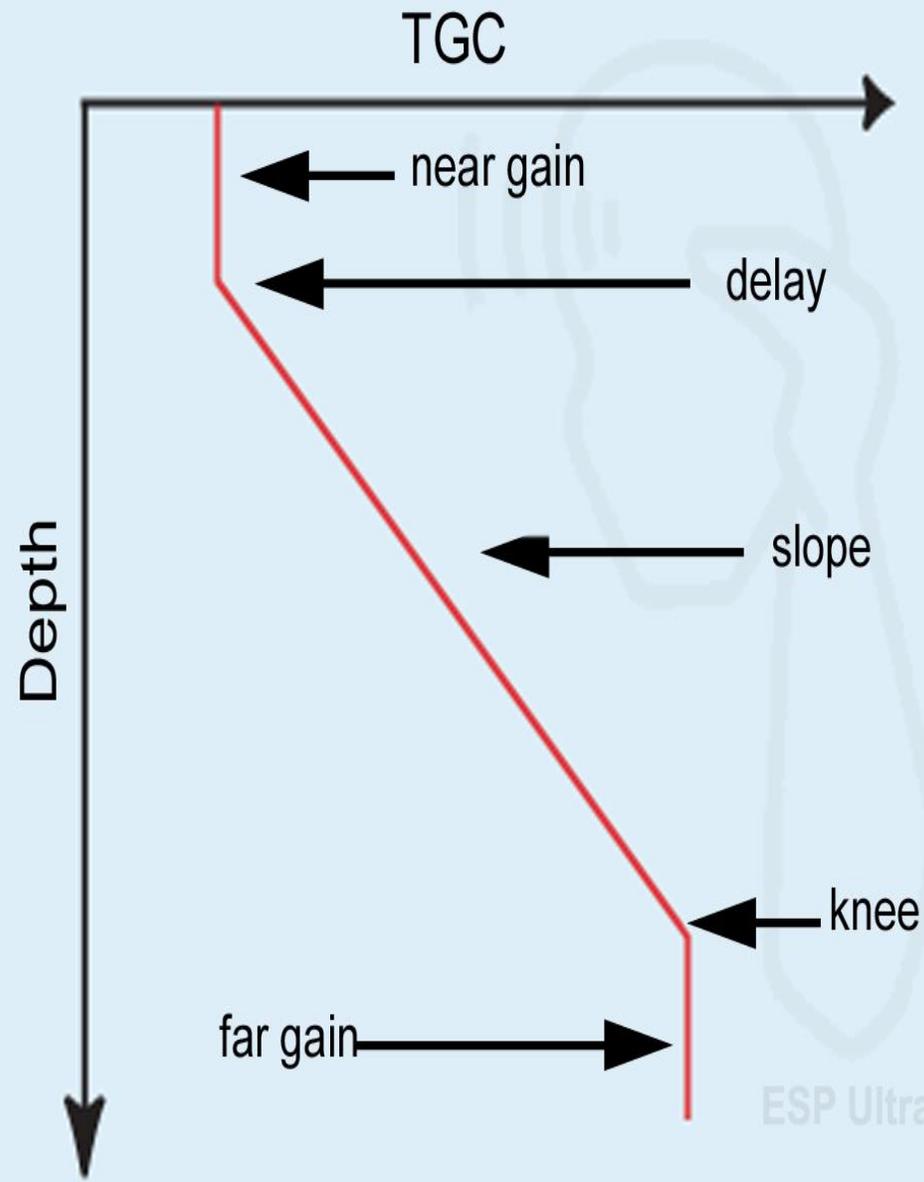
RECEIVER

- Compensation:
 - Treats echoes differently depending upon depth
 - Function is to produce a final image of uniform brightness from top to bottom

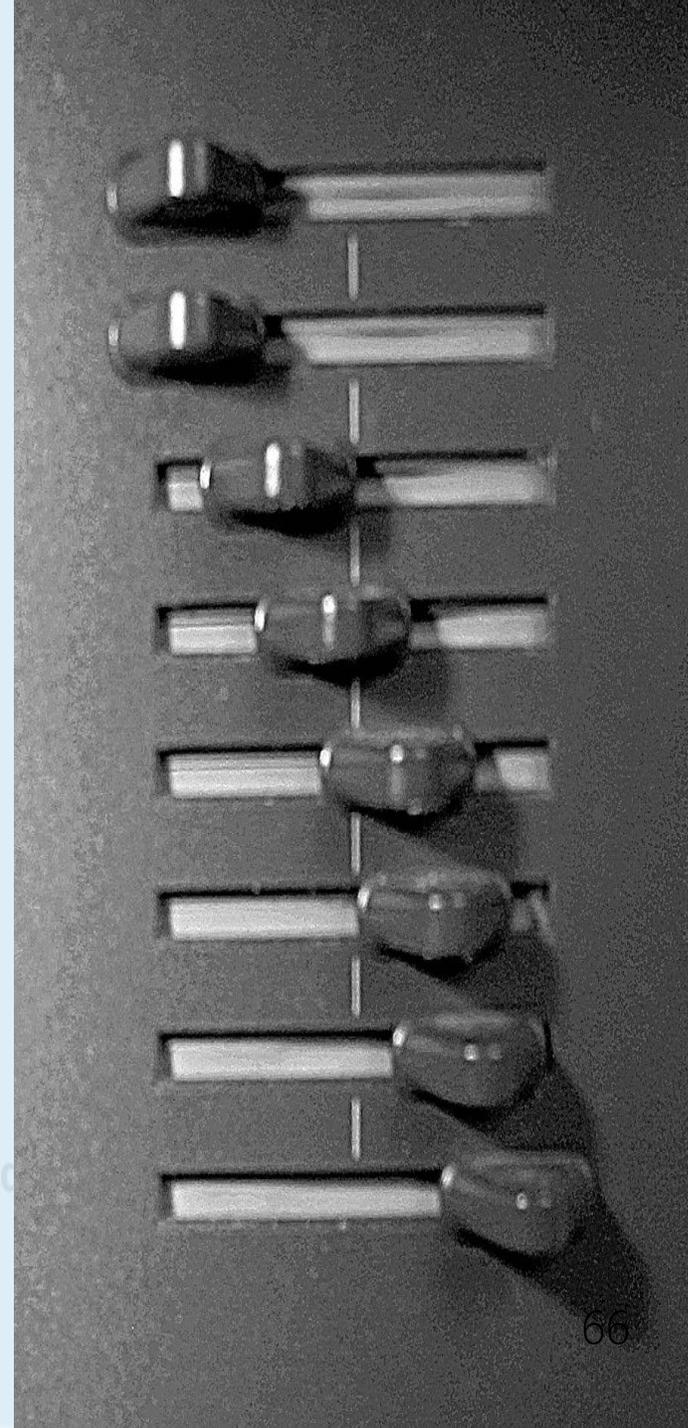
also known as: “time-gain compensation”
 “depth gain compensation”
 “swept gain”

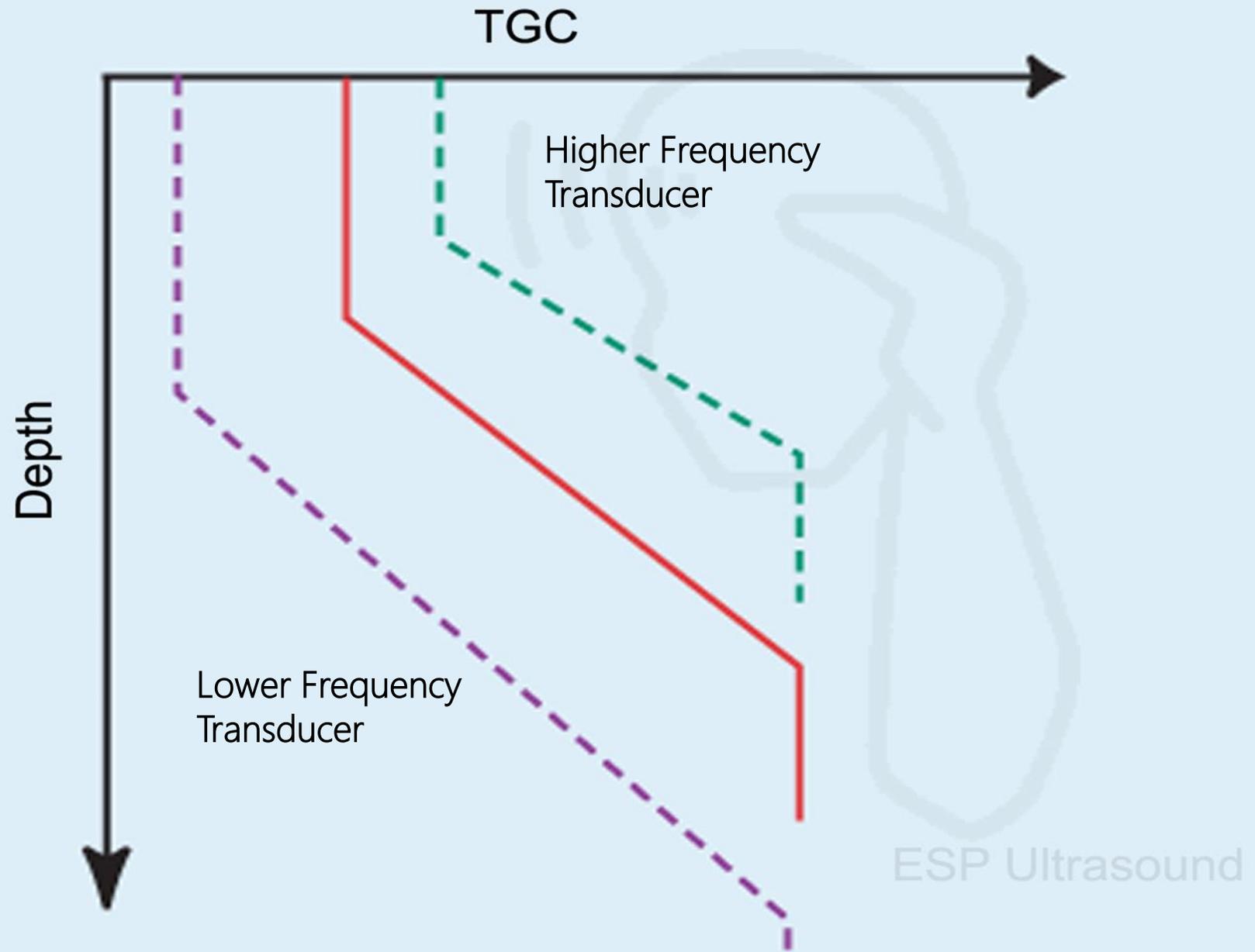
TGC CURVE

- Near gain
 - At superficial depths reflections undergo a small constant amount of compensation
- Delay
 - Depth at which variable compensation begins
- Slope
 - Compensation corrects for attenuation
- Knee
 - Reflections are maximally compensated
- Far gain
 - Maximum amount of compensation receiver can provide



ESP Ultrasound





RECEIVER

- Compression:
 - Keeps image's grayscale within range of detection of human eye
 - Humans can distinguish approx. 20 shades of gray
 - Allows visualization of all gray shades
 - Keeps electrical signal levels within accuracy range
- Reduces the total range of signals from smallest to largest
- Decreases the dynamic range of signals

RECEIVER

- Compression:
 - Adjustable
 - Alters grayscale mapping
 - Units
 - dB

also known as

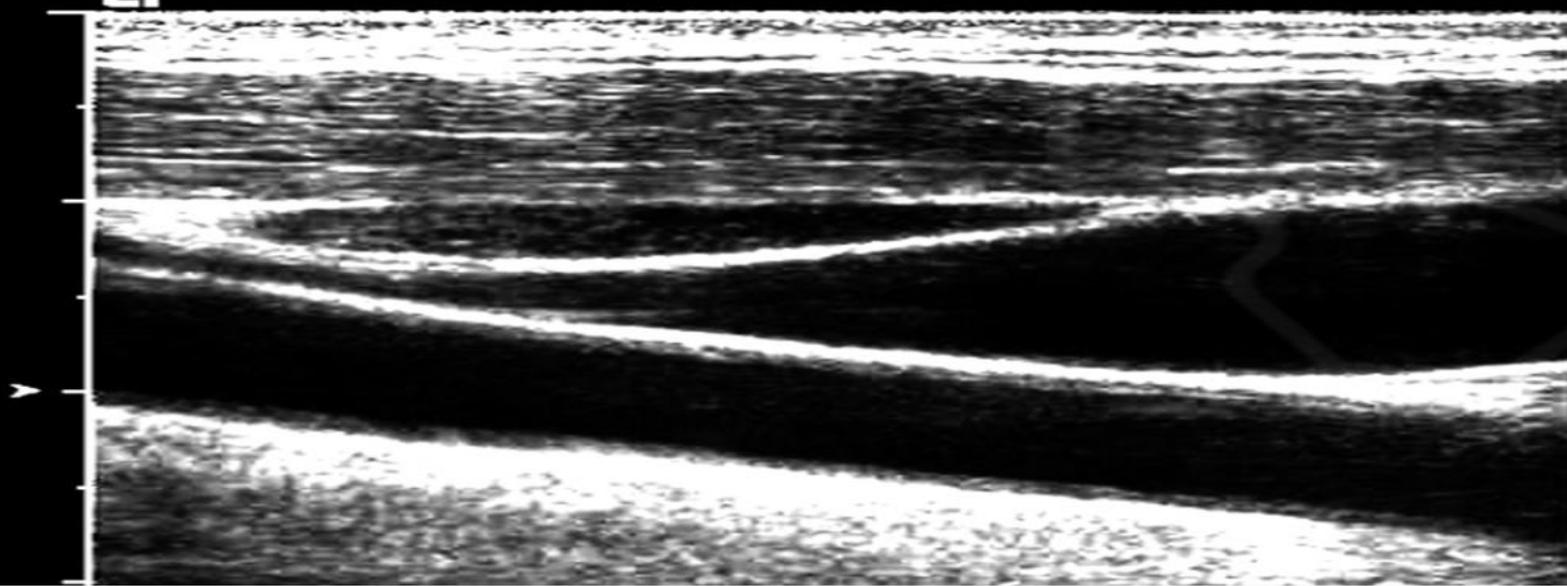
“log compression”

“dynamic range”



UCSF

CI



25 Apr

11:36:17 am

8L5

13Hz

3.0MHz

35mm

UCSF

UCSF /V

100dB S2/+1/5/2

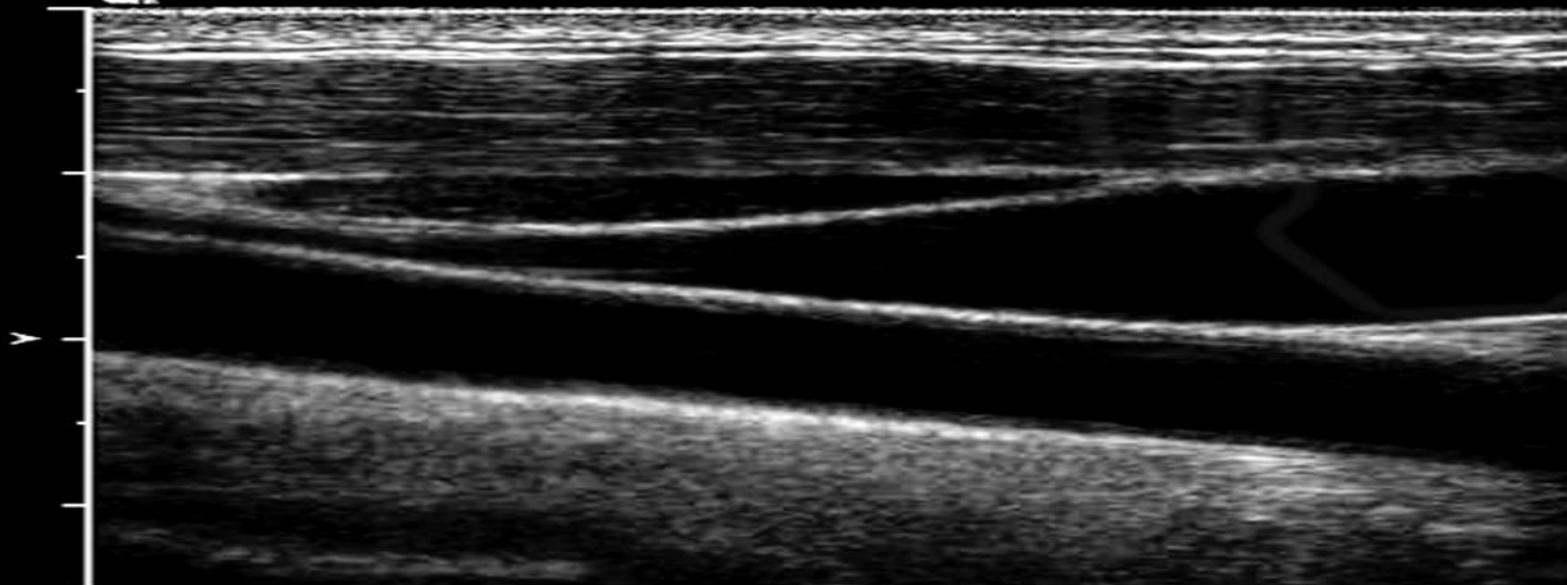
Gain= 14dB $\Delta=1$

Store in progress



UCSF

CI



25 Apr

11:36:19 am

8L5

13Hz

3.0MHz

35mm

UCSF

UCSF /V

100dB S2/+1/5/2

Gain= 14dB $\Delta=1$

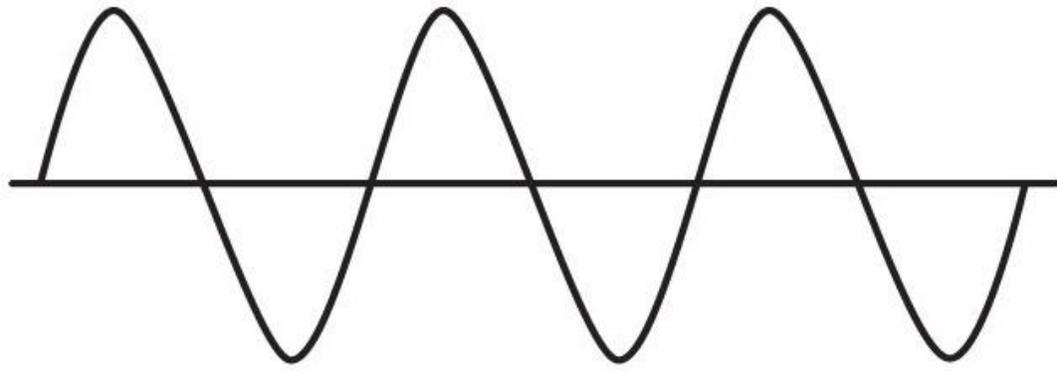
Store in progress

ESP Ultrasound

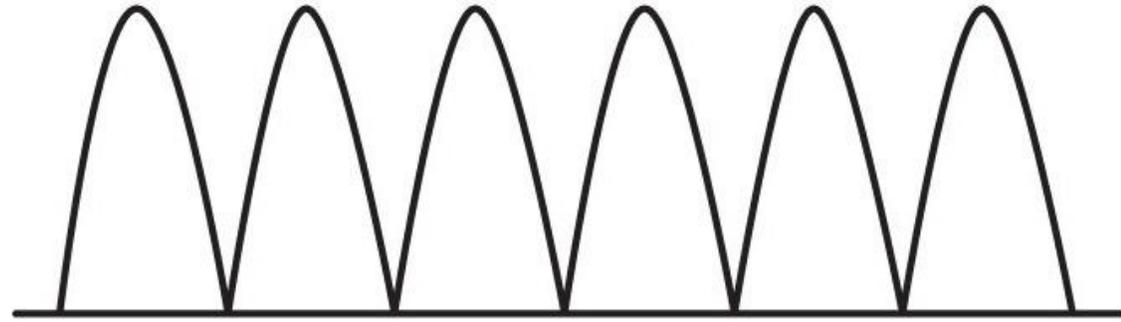
RECEIVER

- Demodulation:
 - Two-part process that changes electrical signals within receiver into a form more suitable for display
 1. Rectification
 - Converts all negative voltages into positive
 - Corrects or eliminates negative voltages
 2. Smoothing or "enveloping"
 - Places a smooth line around the "bumps and evens them out

Normal Signal

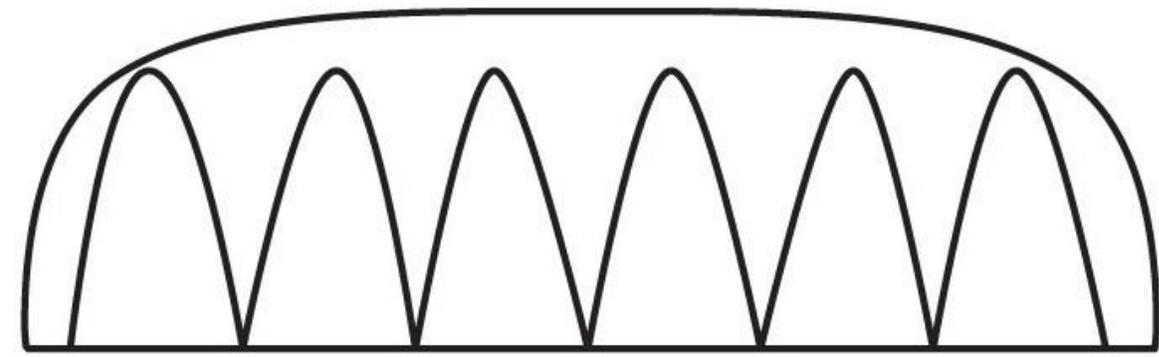


Rectification



A

B



Enveloping

C

RECEIVER

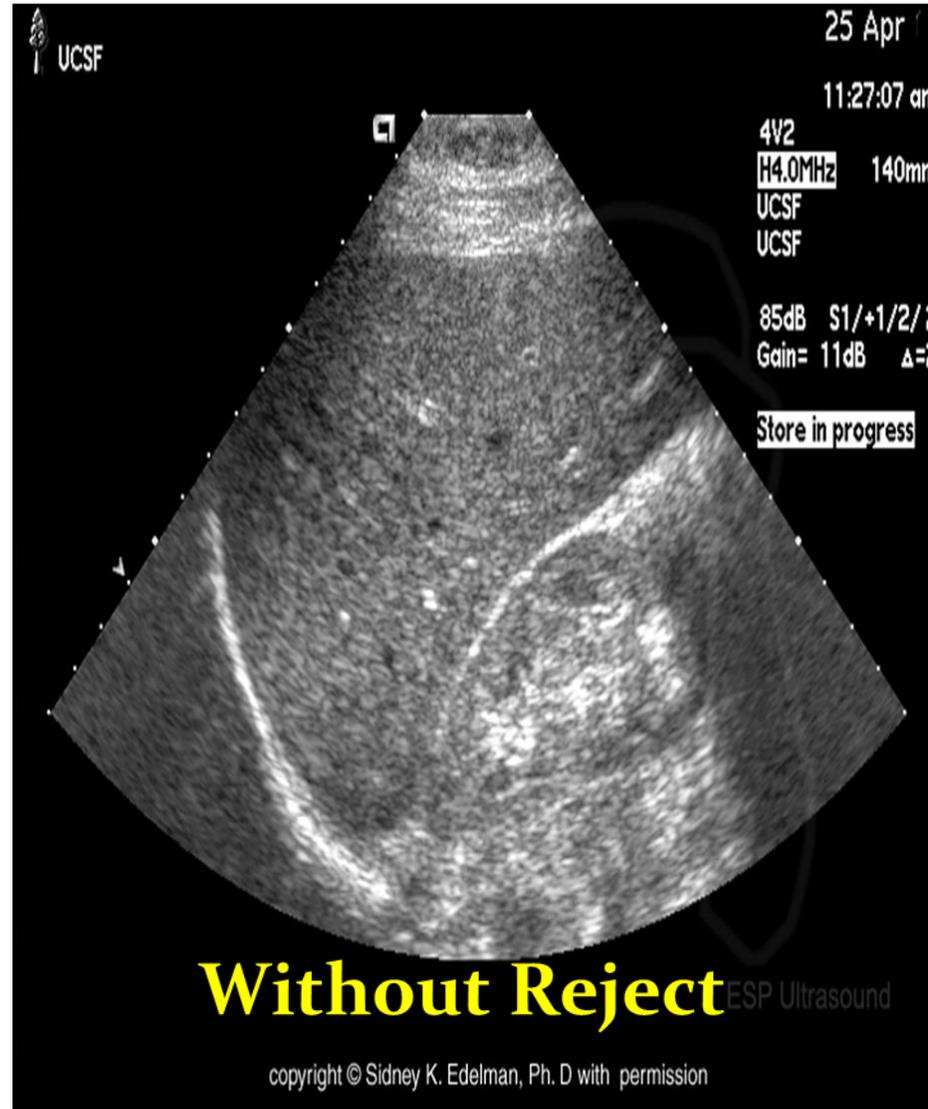
- Demodulation:
 - Not adjustable
 - No visible effect on image
- Purpose
 - Changes signal's form to one more suitable for TV display

RECEIVER

- Rejection:
 - Allows control of whether low-level grayscale information will appear on image
 - Very low-level signals may be associated with meaningful or meaningless information
 - Adjustable; affects all low-level signals on image regardless of location
 - Does not affect strong (bright) echoes
- Also known as “threshold”
“suppression”

RECEIVER

- Rejection:
 - Very low-level echoes may or may not be important
 - Reject eliminates low-level noise



RECEIVER FUNCTIONS

Function	Adjustable	Signal Processed	Effect on Image
Amplification	YES	All signals treated identically	Entire image gets brighter or darker
Compensation	YES	Signals treated differently based on reflector depth	Image will be uniformly bright from top to bottom
Compression	YES	Signals treated differently depending on strength	Changes grayscale mapping
Demodulation	NO	Prepares electrical signals to be suitable for display	None
Reject	YES	Only weak signals affected; strong signals unchanged	Weak echoes are present or eliminated from image

TRANSMIT/RECEIVE SWITCH

- Protects receiver components from power signals that are created for transmission
- Directs electrical signals from transducer to appropriate electronic processing components

SCAN CONVERTER

- Makes grayscale imaging possible and is responsible for storage of the image data
- Two different types of scan converters:
 1. Analog
 2. Digital (more modern)

SCAN CONVERTER

- Analog numbers are “real world” numbers that contain a continuum of values
 - Actual weight of an individual
 - True length of a putt
 - i.e. 8.2 inches, 12.3579 inches, 132.999034 lbs, etc.
 - Dimmer switch
- Digital numbers are “computer world”
 - Discrete values that are limited in their numbers
 - i.e. 130.23 lbs would be reported as 130 lbs
 - Light switch

SCAN CONVERTER

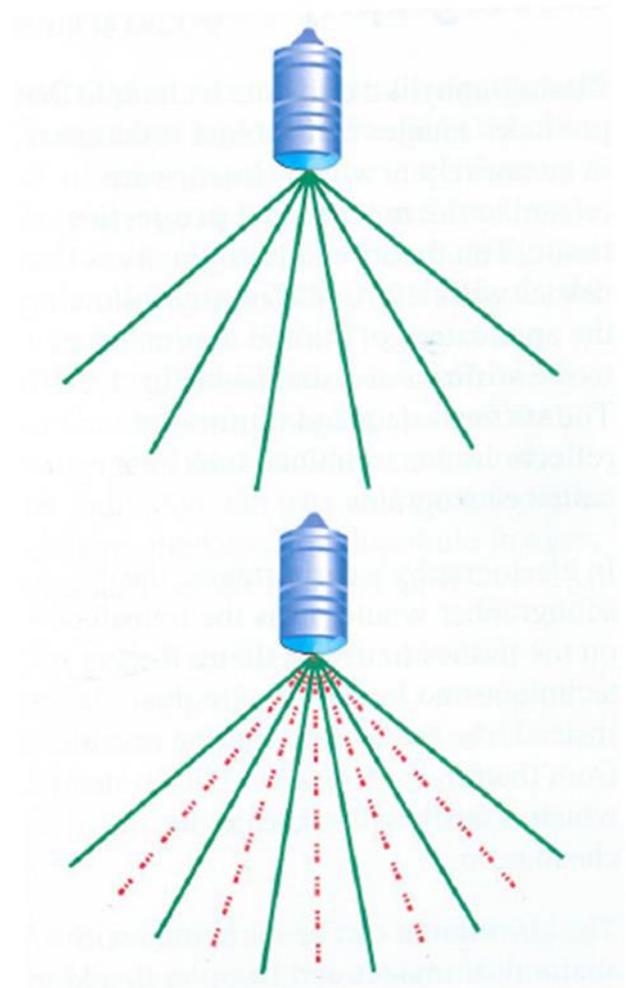
- Digital devices such as computers use the binary system, which utilizes only zeroes and ones instead of the numbers zero through nine
 - Computers only communicate and process signals in binary, so any signal coming into the computer has to be converted into zeroes and ones
- In ultrasound machines, signals are represented by black-and-white dots, or echoes; zero (0) represents "off," or a black echo, while one (1) represents "on," or a white echo
- Before scan converters made gray-scale imaging possible, images were purely black and white, or **bistable**

SCAN CONVERTER

- Signals travel from the receiver to the scan converter, which consists of the **analog-to-digital (A-to-D) converter**, computer memory, and the **digital-to-analog (D-to-A) converter**
- **Preprocessing** of the signal occurs in the A-to-D converter, where incoming signals are assigned shades of gray based on their amplitudes
- At this point the image is still "live"
- Any changes to the image that need to be made while the image is live (i.e., not frozen) occur in the preprocessing phase

SCAN CONVERTER

- There are occasions where gaps exist between the scan lines, such as the diverging scan lines of sector scans
- In these cases, the machine guesses what pixel should be placed there based on the surrounding shades of gray, a process called **fill-in interpolation (pixel interpolation)**



SCAN CONVERTER

- After the signal is converted to a digital form, it can be processed by the computer. The computer is where the image is stored so it can be displayed
 - Computers use the **binary system**, where the image information is made up of zeroes and ones
 - A bit is the smallest amount of computer memory possible.
 - Eight bits equal 1 byte

SCAN CONVERTER

- Groups of "bits" are assigned to each pixel to store gray shades in that pixel
 - More bits per pixel:
 - More shades of gray
 - Better contrast resolution
 - The formula to determine the number of shades of gray is 2^n , where n is the number of bits
 - Two bits of memory = four shades of gray ($2^2 = 2 \times 2$)
 - Eight bits of memory = 256 shades of gray (most ultrasound units 8-bit memory) ($2^8 = 2 \times 2$)

SCAN CONVERTER

- The digital computer has a location in its memory for every pixel on display
 - Pixel = short for “picture element”; smallest part of any picture
 - More pixels on a display, the better the spatial resolution of the display
- Therefore, an image matrix with 512 x 512 pixels is better than 256 x 256 pixels
 - Generally, its better to have more pixels than it is to have more shades of gray
- For 3D imaging, the term used is **voxel**, which is short for volume element

PIXELS



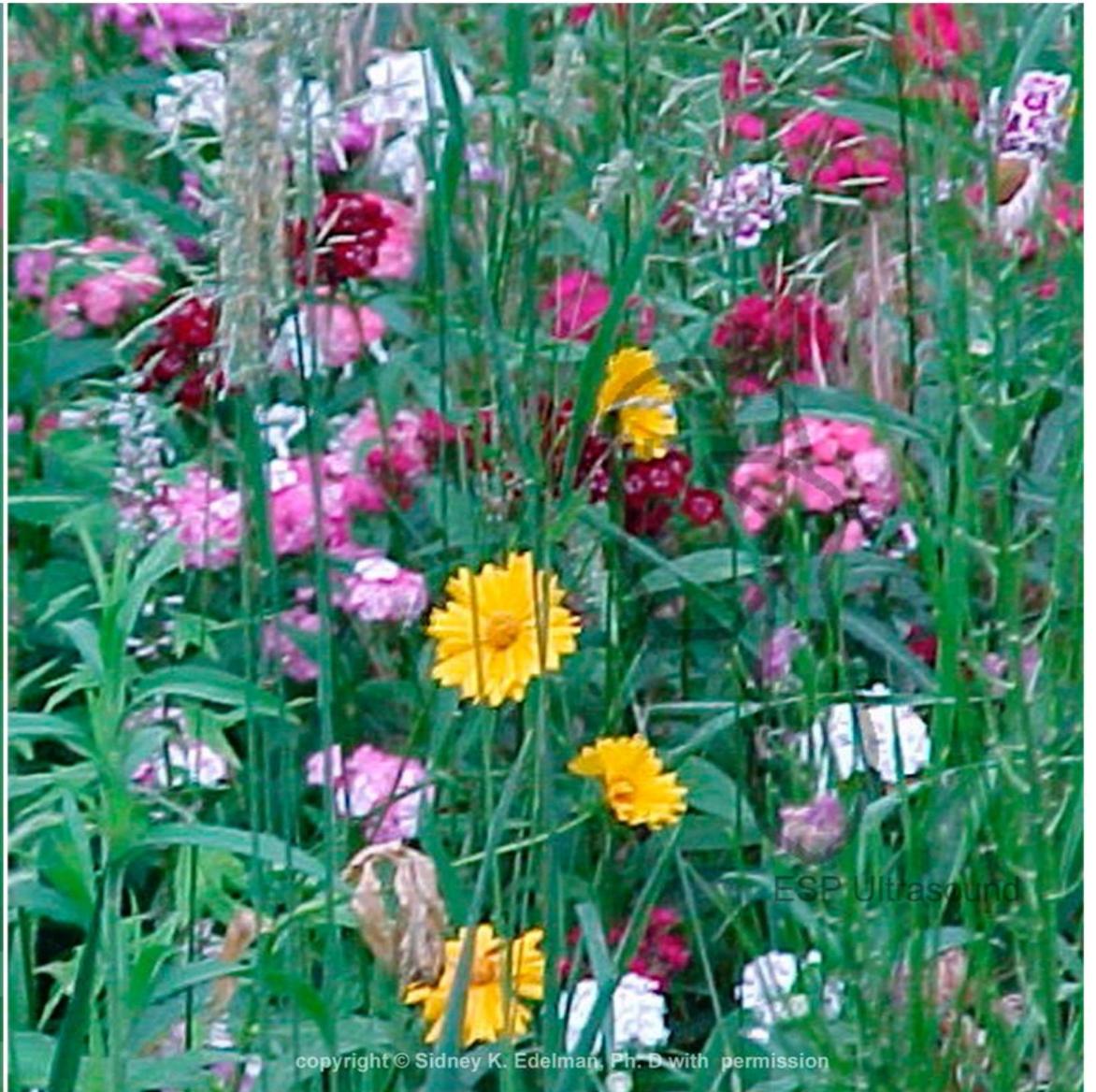
- Each box is a pixel
- At any instant in time, entire pixel can only be a single shade of gray

Binary conversion is explained in detail on page 89 & 90 in your book!!! May have a one or two board questions on how to convert to/identifying binary numbers!

PIXEL DENSITY

- Number of picture elements per inch
- Higher density
 - Achieved with smaller pixels
 - More pixels are required to create image
 - Spatial resolution improves
 - Greater detail image
- *More pixels per inch, greater detail (spatial/detail resolution)
- Lower density
 - Just the opposite

PIXEL DENSITY



SCAN CONVERTER

- Once the signal is stored in memory, it is sent to the **D-to-A converter**
 - Signal is converted back to analog form so it can be displayed and sent to PACS, film, video, etc
- This is a component of the **postprocessing** part of the digital scan converter
- Most modern machines offer a postprocessing image setting that can be changed after the image is frozen, including gain and some Doppler settings

SCAN CONVERTER

- 5 step process:
 - 1. Analog signals converted to digital
 - By analog-to-digital (A to D) converter
 - 2. Preprocessing (digital information is stored)
 - Processing of signals before storage
 - 3. Postprocessing (digital information is stored)
 - Processing of signals after storage
 - 4. Digital signals converted to analog
 - (D to A) converter
 - 5. Analog form presented on display

SCAN CONVERTER

- There are two different ways of magnifying the ultrasound image: **write zoom** and **read zoom**
- Write zoom, a preprocessing function, enlarges the image by redrawing it. As the image has not been stored in memory yet, it is possible to enlarge the image while maintaining the pixel density.
- This offers a high-quality zoomed image
- Write zoom is a preprocessing function, therefore the image must be live

SCAN CONVERTER

- Read zoom, a postprocessing function, enlarges the image by magnifying the pixels
- The image has already been stored in memory, so it is not possible to maintain the pixel density
- This type of zoom offers a courser, less optimal type of zoom
- With read zoom, the image is frozen
- To remember which is which, remember: Write zoom is the “write” way to do it

WRITE VS READ ZOOM



A



B



C

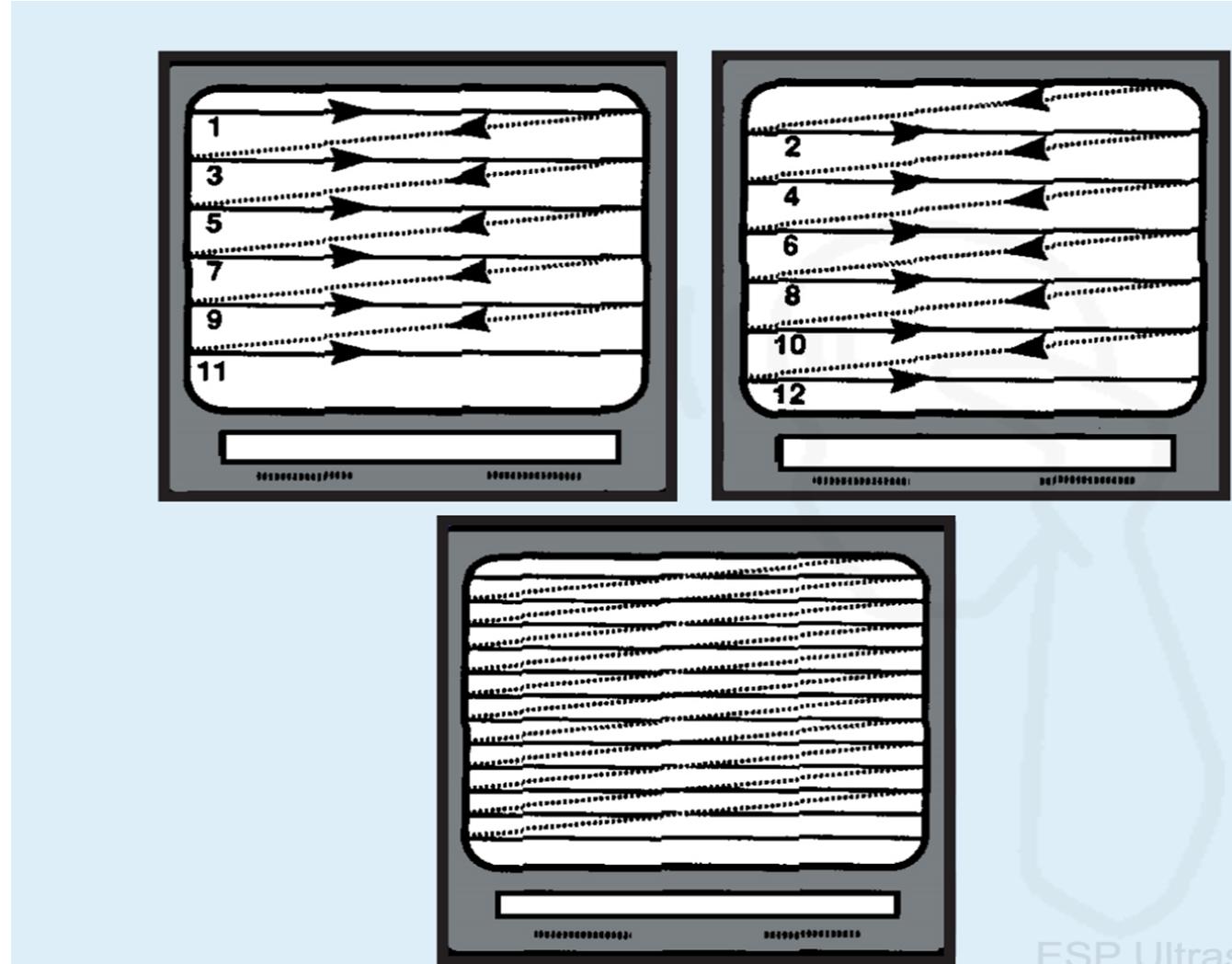
Preprocessing	Postprocessing
Time Gain Compensation	Any change after freeze frame
Log Compression	Black/White Inversion
Write Magnification	Read Magnification
Persistence	Contrast Variation
Spatial Compounding	3D Rendering
Edge Enhancement	
Fill-in Interpolation	

DISPLAY

- There are two displays used as ultrasound monitors: **cathode ray tubes (CRTs)** or **liquid crystal displays (LCDs)**
- The CRT is like a vintage television and it is no longer readily used in clinical practice
 - It works by using an electron gun to send a stream of electrons toward a phosphor-coated screen
 - The image is *interlaced*; that is, a single 525-line **frame** (image) is made up of two **fields**, even and odd
 - Interlaced displays helped to eliminate flicker

DISPLAY

- The odd field (line 1, 3, 5, . . . , 525) is placed on the screen first with the electron beam, and then the even field (2, 4, 6, , 524)
- It takes 1/60th of a second to produce each field.
- Therefore, since two fields make one frame, it takes 1/30th of a second to display one frame, or one ultrasound image, on a CRT



DISPLAY

- The LCD, or flat-panel display, works with a light source positioned behind two polarized filters with liquid crystals sandwiched between them
- The twisting or untwisting of the crystals determines if light shines through to the face of the display



RECORDING AND STORAGE DEVICES

- Recording and Storage Devices
 - PACS is the most recent display and storage medium
 - *Picture Archiving and Communication System*
 - Other storage devices include all the following: film, video recording such as VHS, which uses a magnetic tape, CD/DVD, which are optical storage devices, and magneto-optical (MO) storage
 - Images can also be sent to paper or thermal printers
 - PACS systems use a RAID (redundant array of independent disks) to store large quantities of data

RECORDING AND STORAGE DEVICES

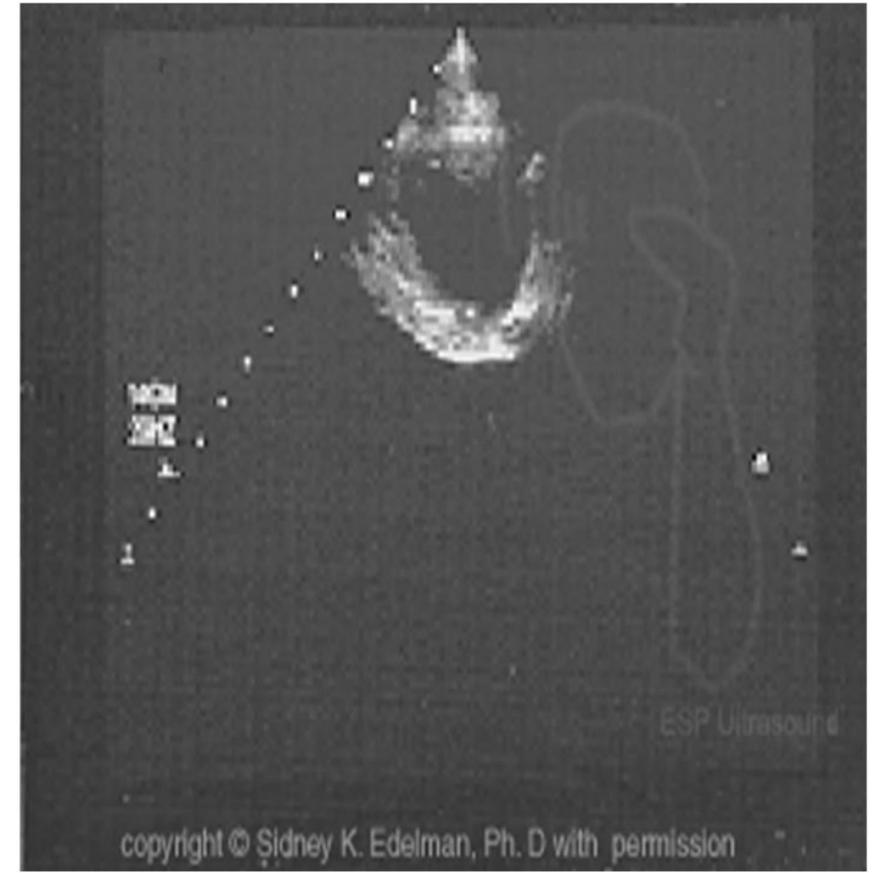
- Recording and Storage Devices
 - Imaging computers use a standardized format called DICOM (Digital Imaging in Communications and Medicine) to communicate with each other and exchange data
 - DICOM is used in sonography, CT, MRI, and other medical imaging systems



QUESTIONS

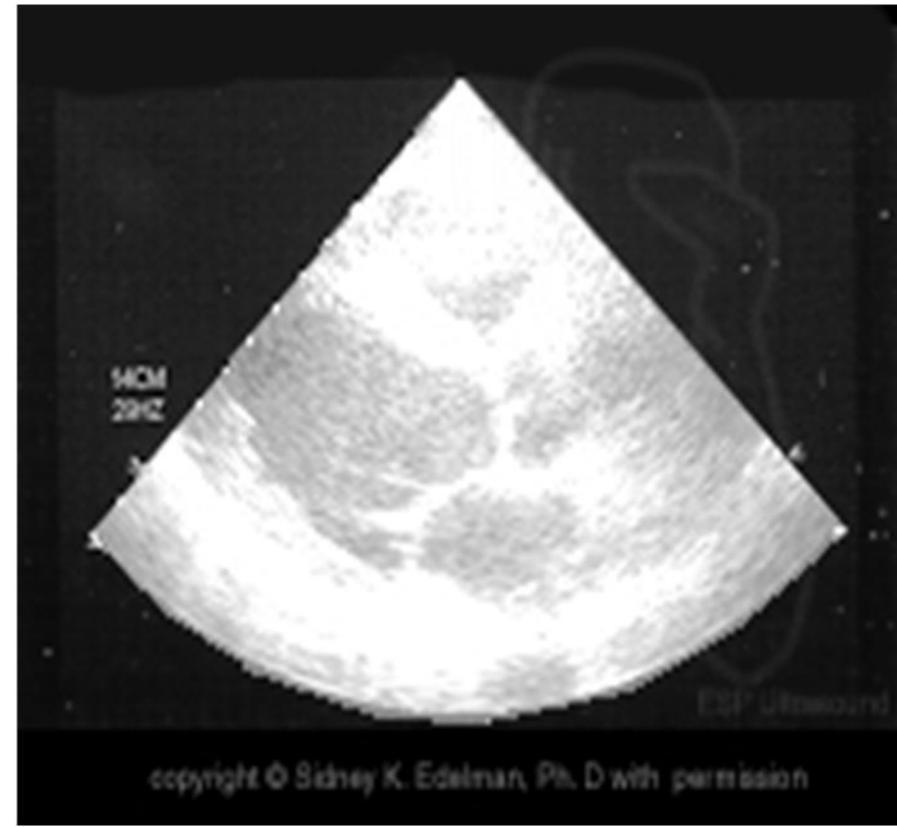
WHICH OF THE FOLLOWING CHOICES IS BEST WHEN THE IMAGE ON YOUR ULTRASOUND SYSTEM DISPLAYS ONLY REFLECTORS IN A REGION CLOSE TO THE TRANSDUCER BUT NO REFLECTORS DEEP?

- A. Adjust system's compensation
- B. Use higher frequency transducer
- C. Increase output power
- D. Adjust reject level



WHICH OF THE FOLLOWING CHOICES IS
BEST WHEN THE IMAGE ON YOUR
ULTRASOUND SYSTEM IS TOO BRIGHT TOP
TO BOTTOM?

- A. Decrease compensation
- B. Use higher frequency transducer
- C. Decrease output power
- D. Adjust reject level



ALL OF THE FOLLOWING ARE FUNCTIONS OF
THE RECEIVER EXCEPT:

- A. Attenuation
- B. Amplification
- C. Demodulation
- D. Suppression

COMPENSATION PROCESSES ALL REFLECTED
SIGNALS IN A SIMILAR MANNER:

A. True

B. False

ALL OF THE FOLLOWING ARE COMPONENTS
OF AN ULTRASOUND SYSTEM EXCEPT:

- A. Transducer
- B. Alternator
- C. Display
- D. Synchronizer

THIS TYPE OF PULSER GENERATES A
CONSTANT ELECTRICAL SIGNAL IN THE
FORM OF A SINE WAVE:

- A. Pulsed wave, phased array
- B. Continuous wave
- C. Pulsed wave, single crystal

IMAGING ARTIFACTS

- Artifacts are reflections that are:
 - Not real
 - Not seen on image
 - Not of correct shape or size
 - Not in correct position
 - Not of correct brightness

IMAGING ARTIFACTS

- Results from:
 - Violations of assumptions
 - Equipment malfunction or poor design
 - Physics of ultrasound
 - Operator error
- Artifacts may also occur from electrical interference

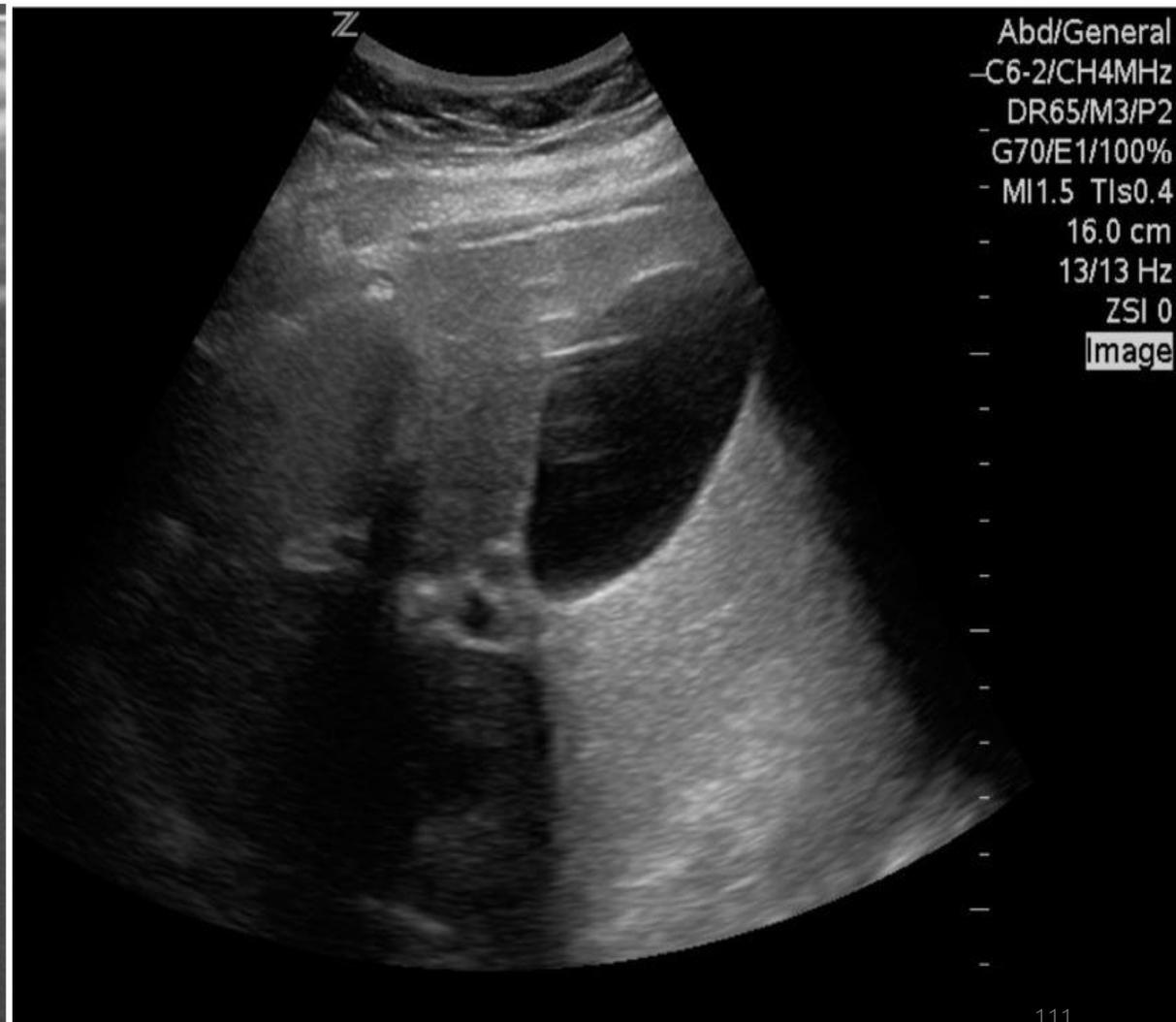
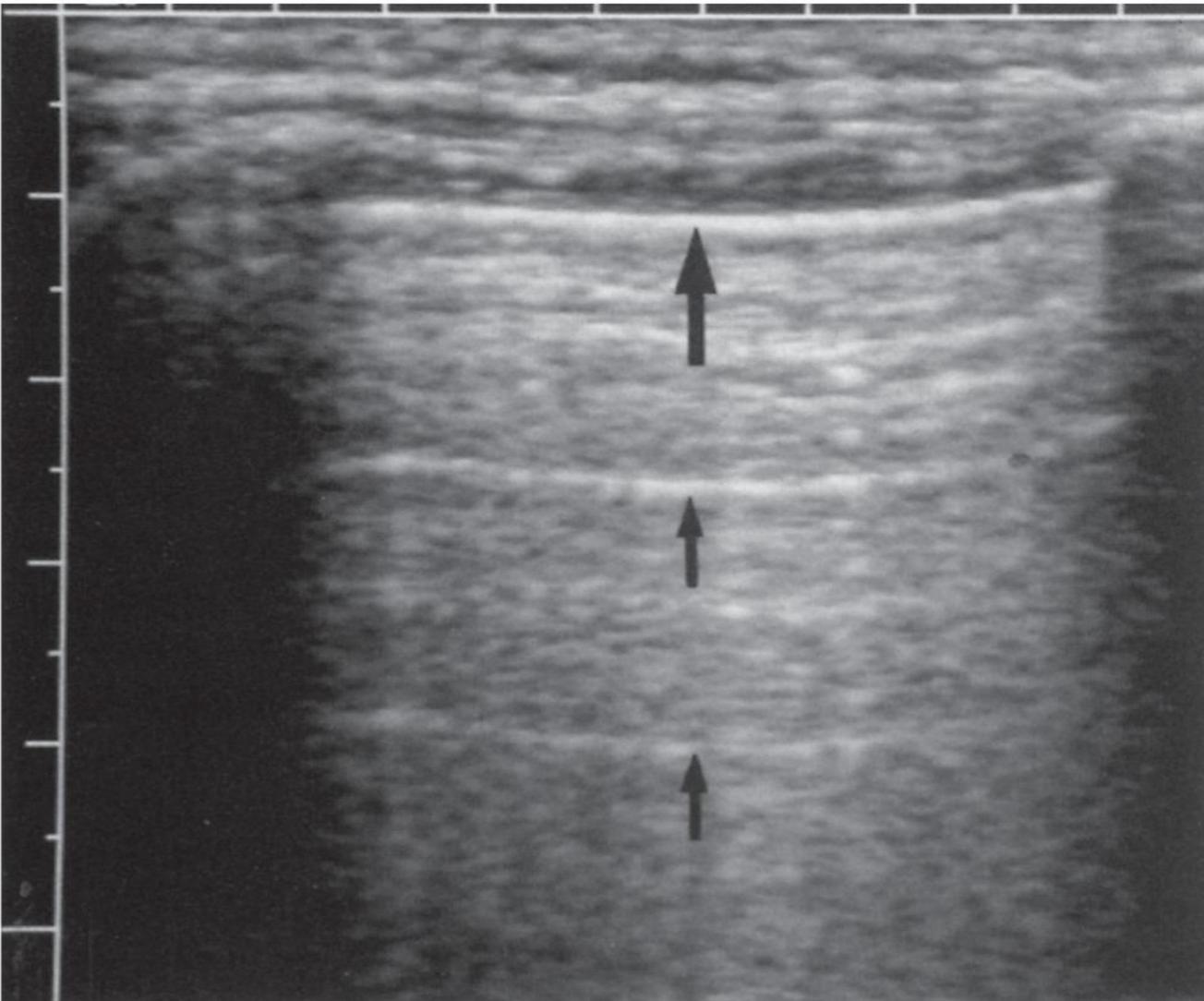
IMAGING ARTIFACTS

- Six main assumptions that create artifacts:
 1. Sound travels in a straight line
 2. Sound travels directly to a reflector and back
 3. Sound travels in soft tissue at exactly 1,540 m/s
 4. Reflections arise only from structures positioned in the beam's main axis
 5. Imaging plane is very thin
 6. Strength of a reflection is related to characteristics of tissue creating reflection

IMAGING ARTIFACTS

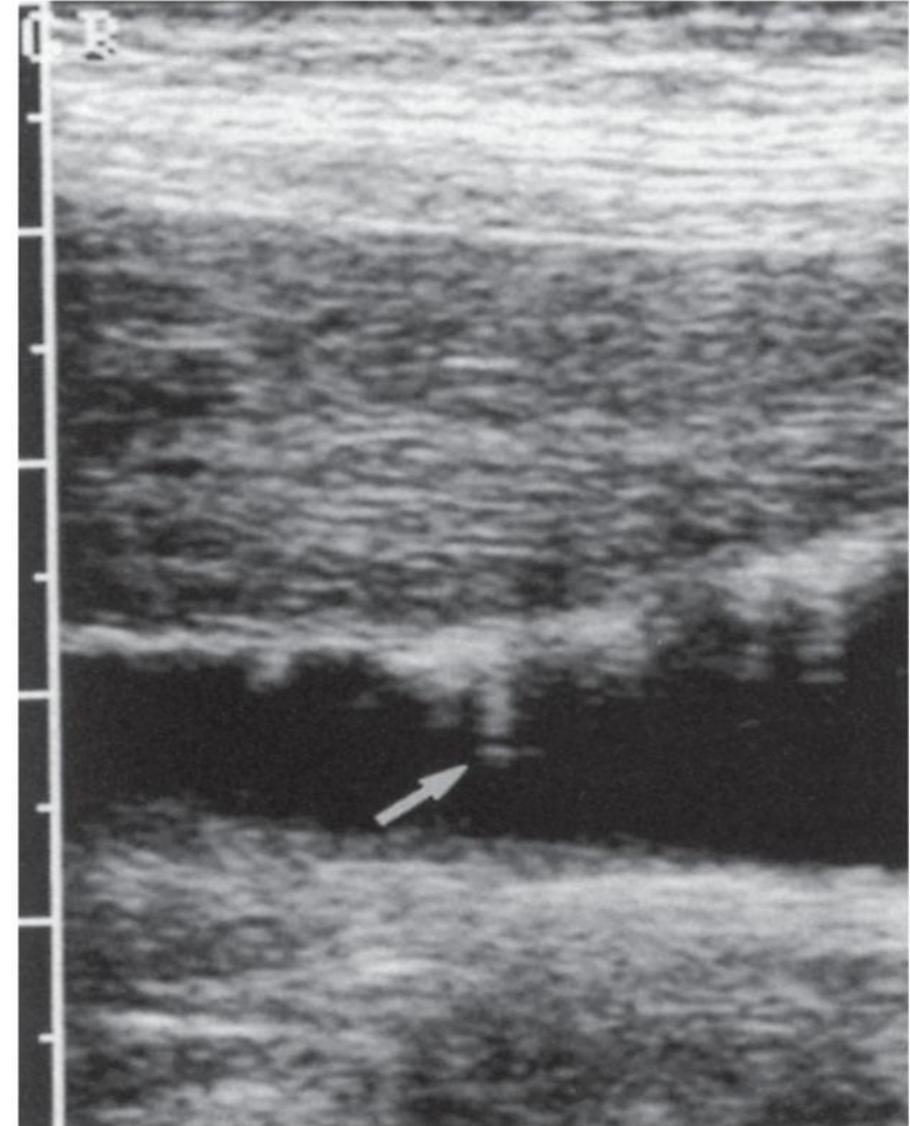
- **Reverberation:**
 - Multiple equally spaced echoes
 - Caused by sound wave bouncing between two strong reflectors positioned parallel to beam
 - Characteristics
 - Appears in multiples
 - Appears as equally spaced
 - Located parallel to beam's main axis
 - Located at ever-increasing depths
 - Resembles ladder or Venetian blind

REVERBERATION



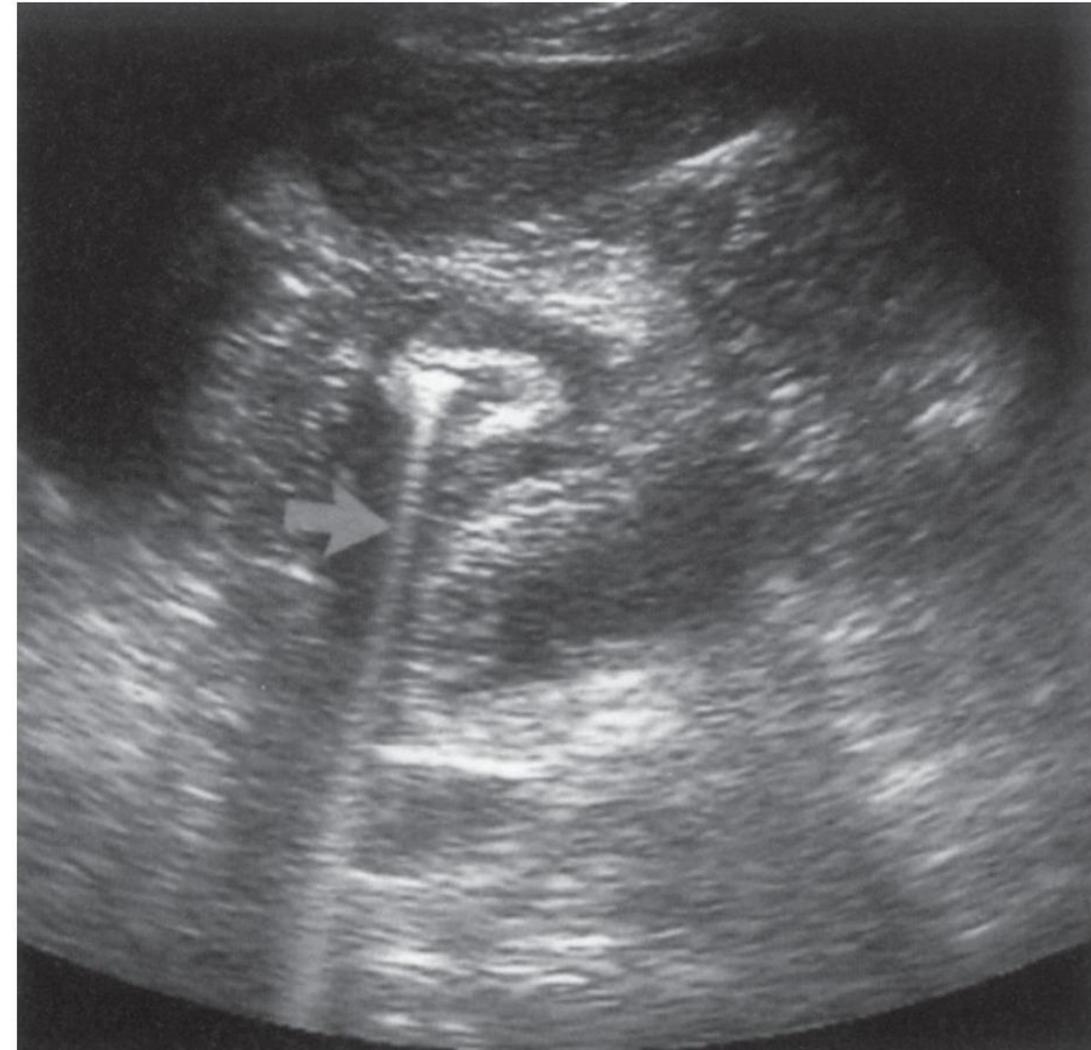
IMAGING ARTIFACTS

- **Comet Tail:**
 - Subtype of reverberation
 - Reverberation with the spaces squeezed out
 - Appears a solid hyperechoic line that tapers quickly
 - Often caused by small structures (surgical clips, adenomyomatosis)



IMAGING ARTIFACTS

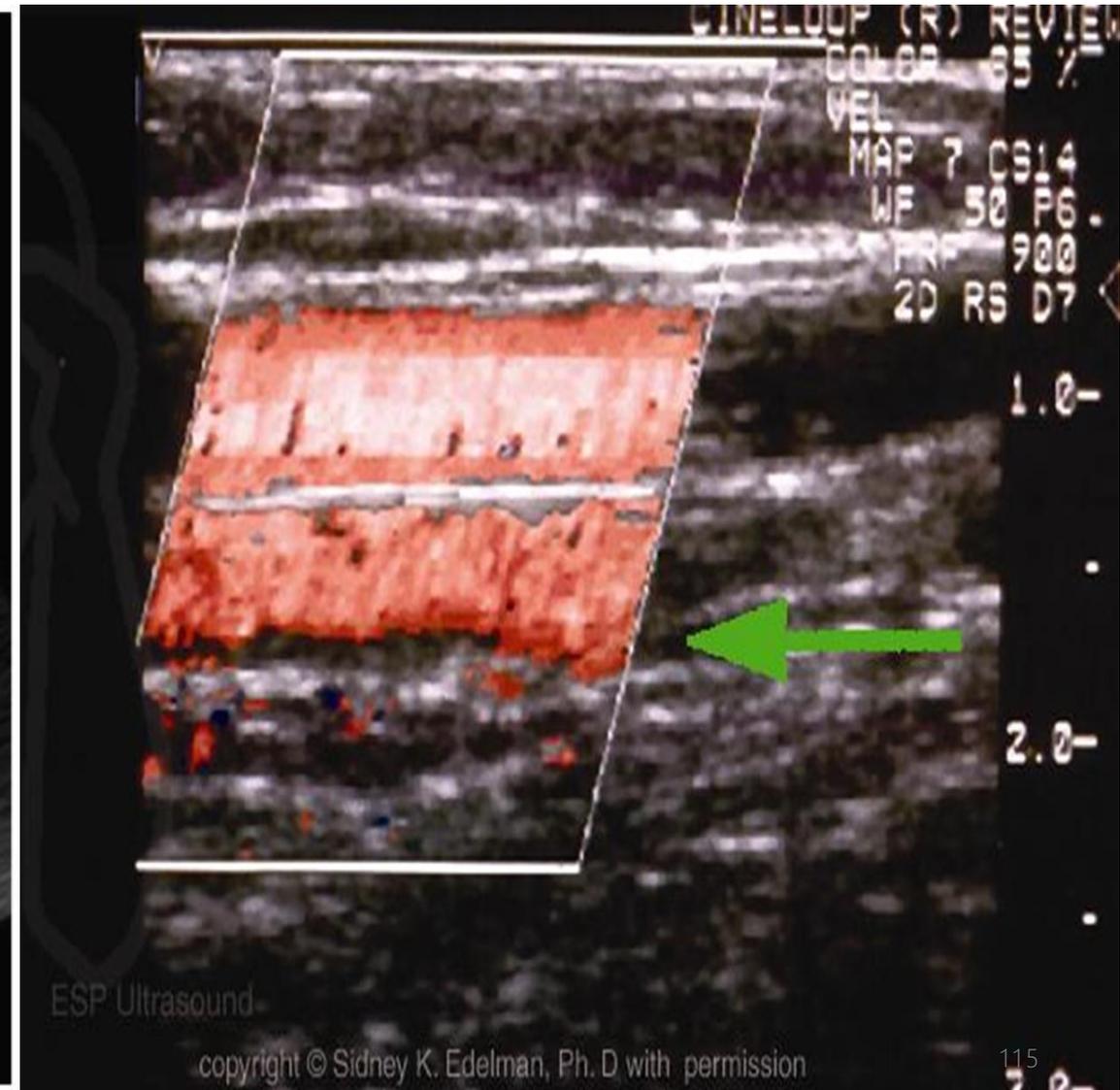
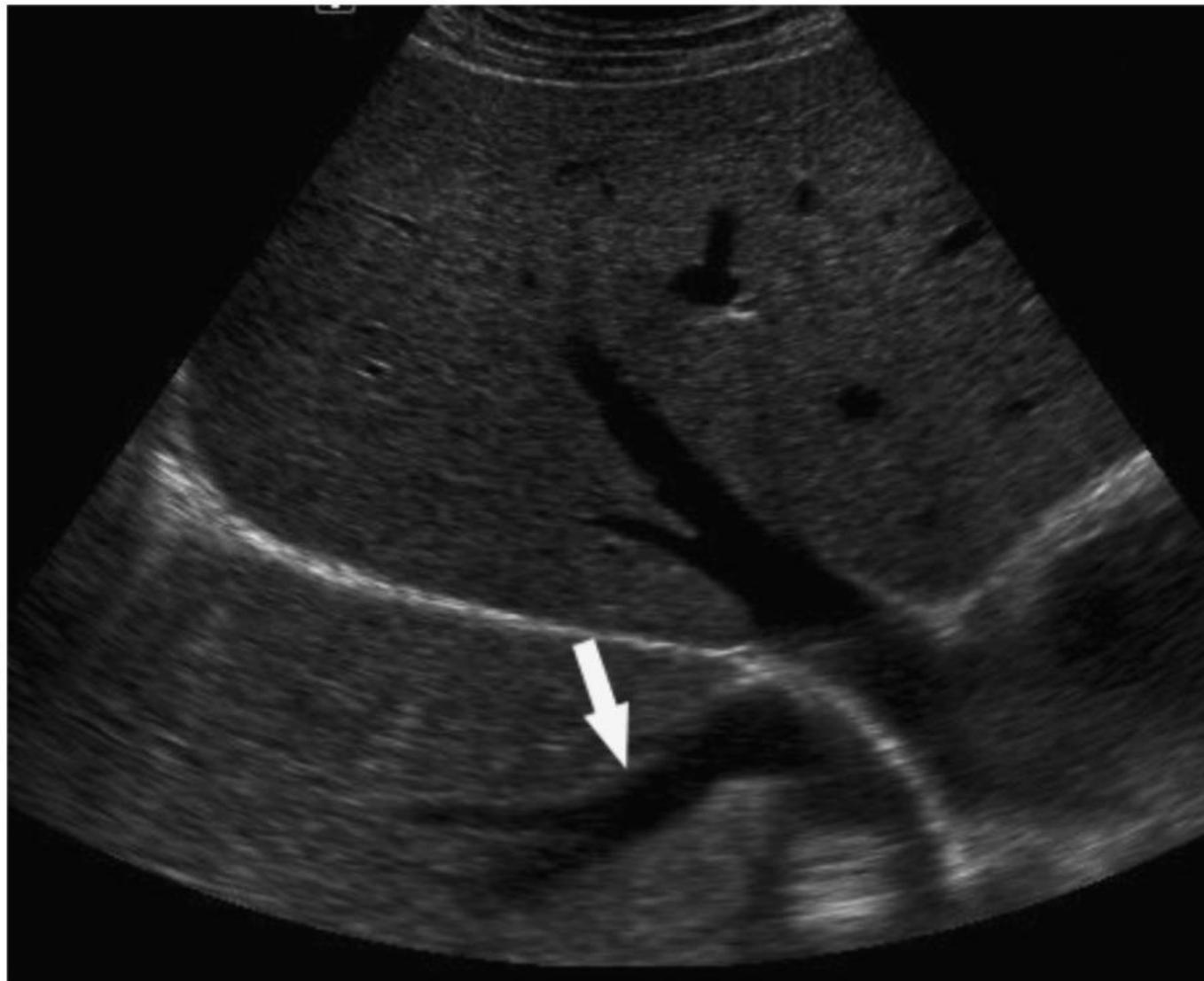
- **Ring-down:**
 - Another subtype of reverberation
 - Appears similar to comet tail but underlying cause is different
 - Sound interacts with trapped air bubbles which causes the bubbles to vibrate
 - Creates a single, long, hyperechoic echo that extends from the air bubble (reflector) to the bottom of the screen



IMAGING ARTIFACTS

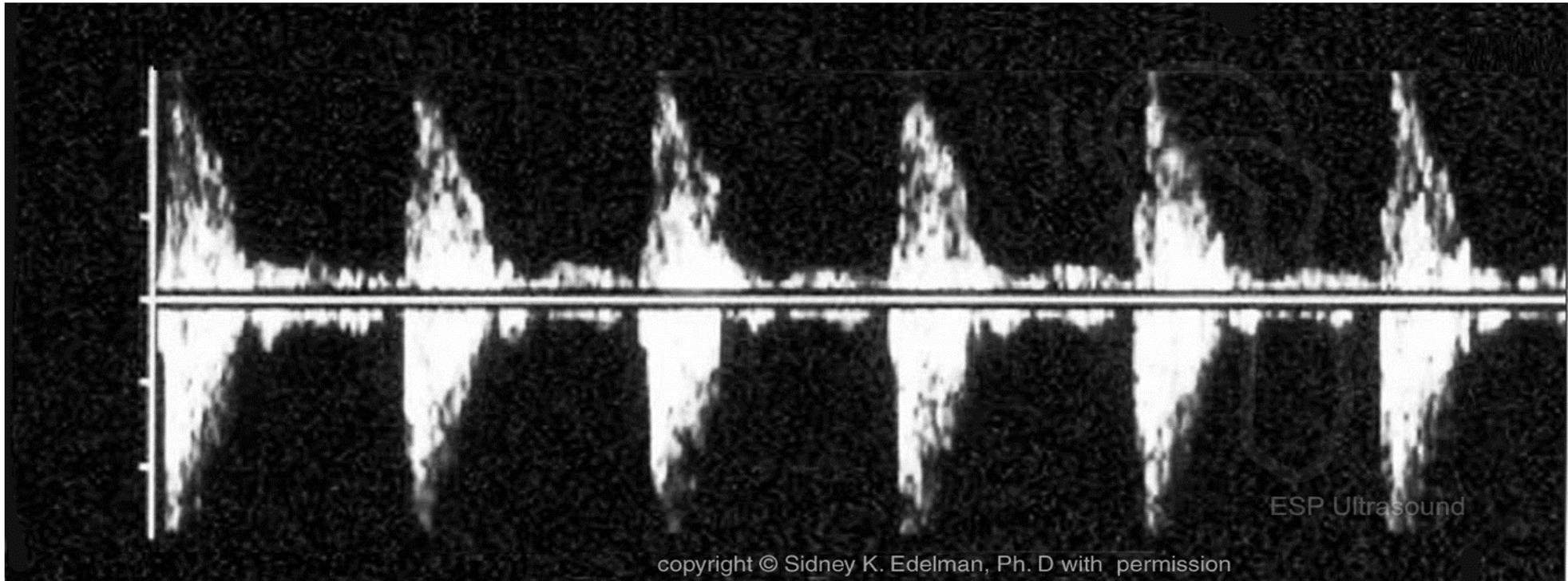
- **Mirror image:**
 - Sound strikes a large specular reflector that acts like a mirror, some of the sound is directed away from the transducer
 - Creates a replica of the reflector but is located deeper than the actual structure being duplicated
 - Second copy of a true reflector
 - Can occur with 2D imaging, color Doppler, spectral Doppler
 - Spectral Doppler mirror imaging is called *crosstalk*

MIRROR IMAGING



MIRROR IMAGING/CROSSTALK

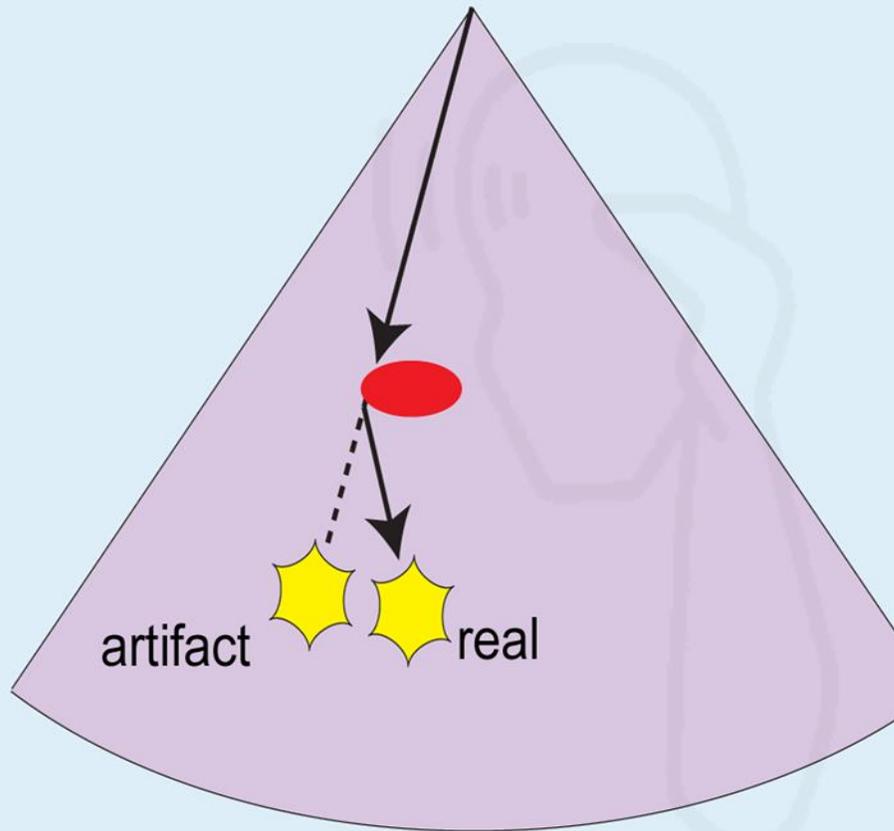
- Crosstalk occurs either because the Doppler gains are set too high, or your incident angle is too close to 90-degrees
- True blood flow should be unidirectional; however, crosstalk appears bidirectional



IMAGING ARTIFACTS

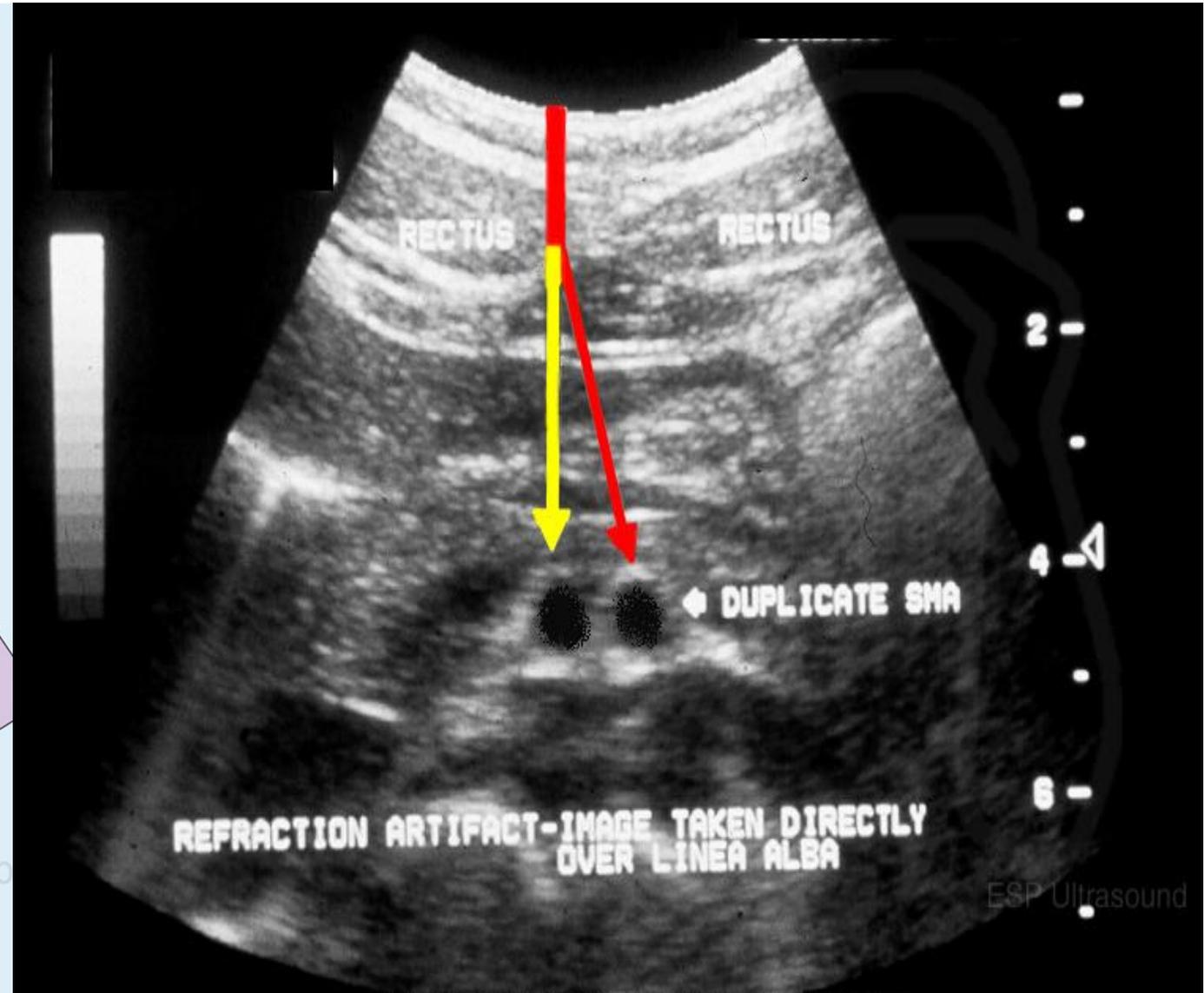
- **Refraction ("Transmission with a Bend")**
 - Creates artifacts as the beam is directed away from the path in which it was originally intended to go
 - Strikes boundary obliquely and medium on either side have different propagation speed
 - Creates a second copy of the true reflector and places it at the same depth
 - Difficult to identify which is real from a single image

REFRACTION



ESP Ultrason

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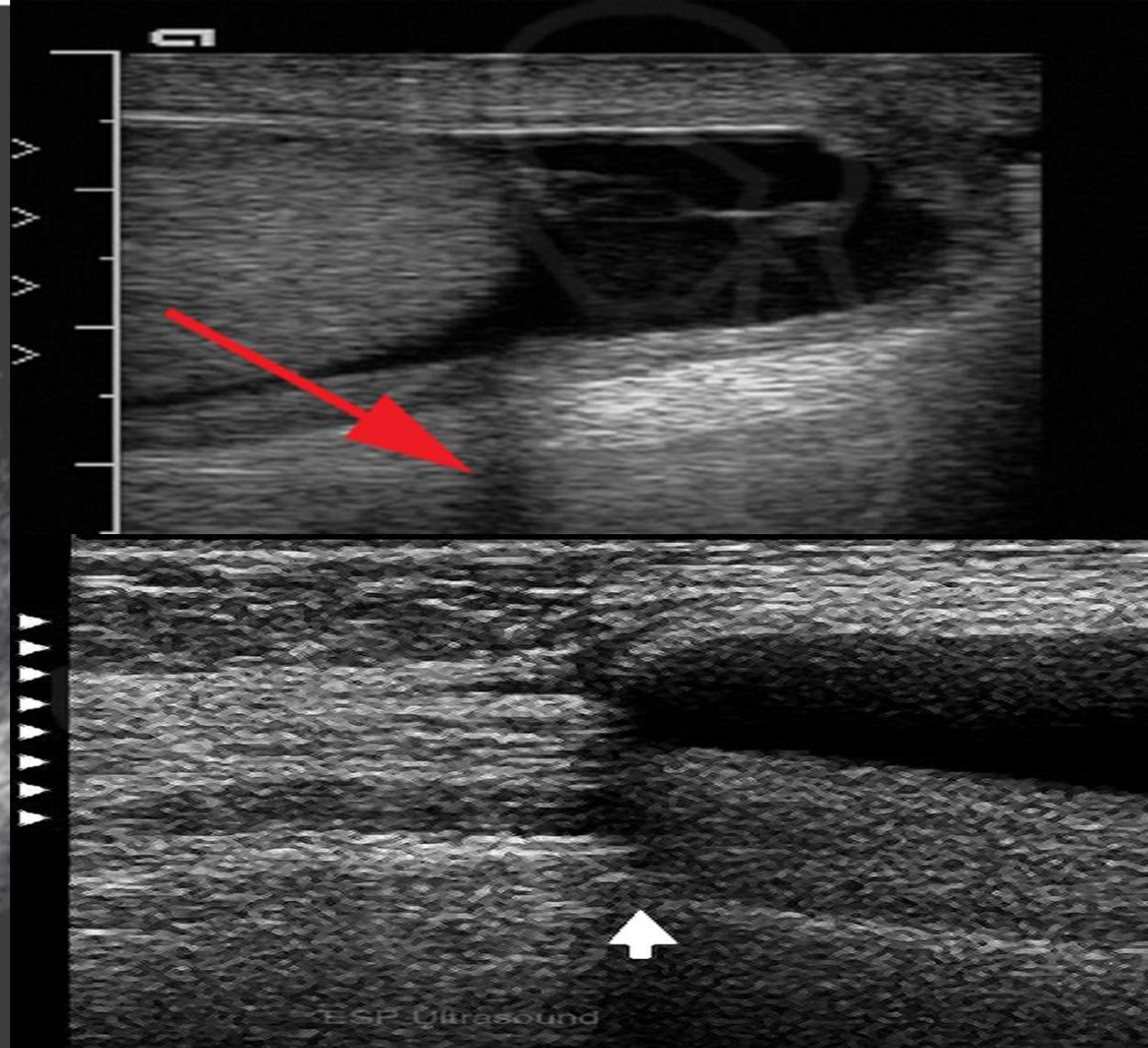
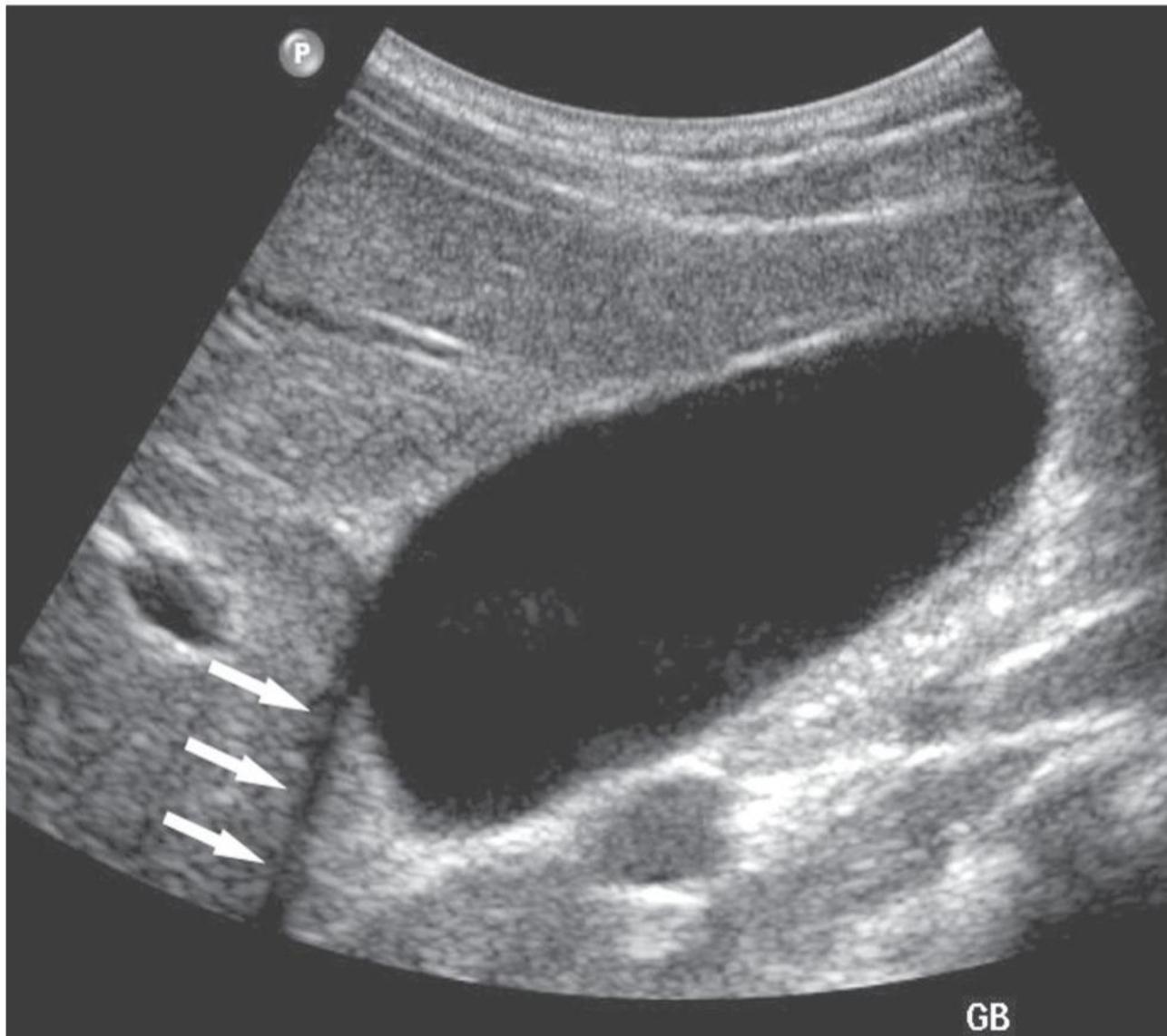
ESP Ultrasound

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IMAGING ARTIFACTS

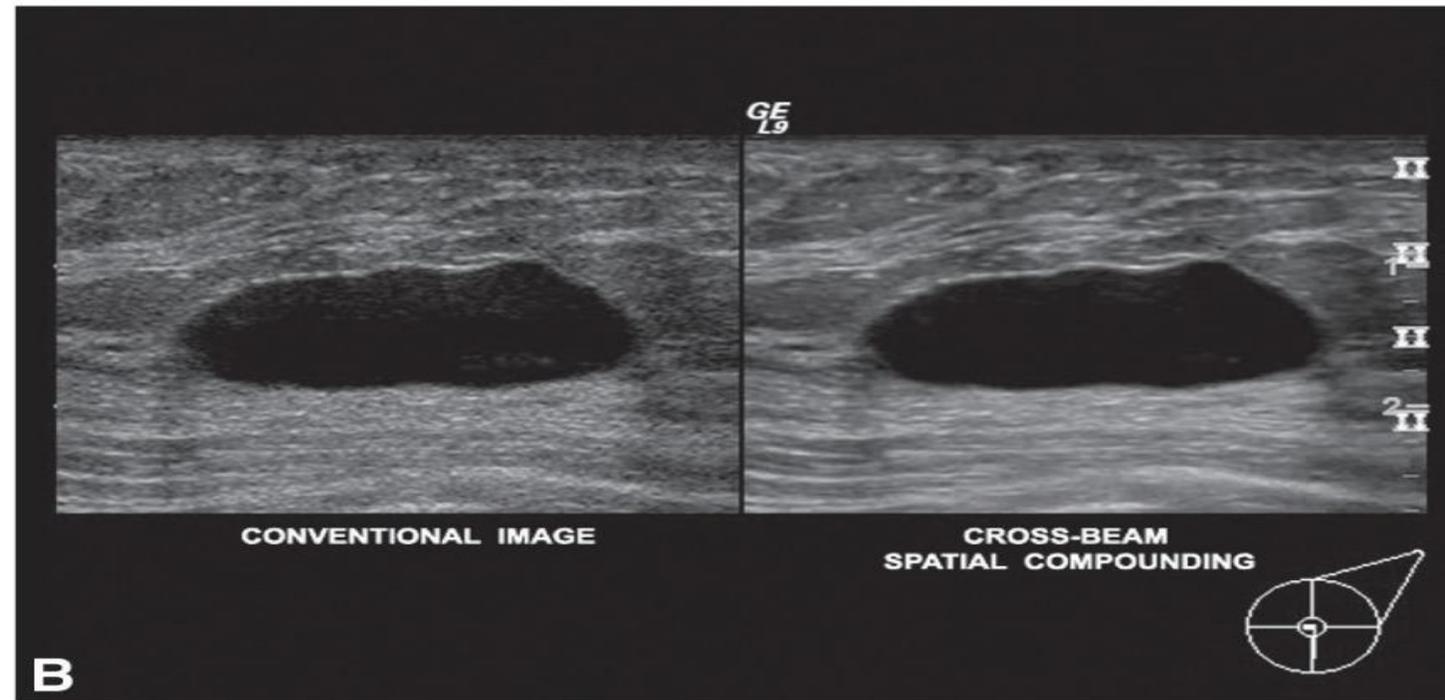
- **Edge Shadowing**
 - Also called “shadowing by refraction”
 - Sound strikes a curved reflector and creates a shadow extending from the sides of the curved structure (i.e. gallbladder or bladder in Transverse)
 - Beam intensity decreases suddenly due to the refraction, and this is what creates the shadowing

EDGE SHADOWING



IMAGING ARTIFACTS

- **Edge Shadowing (cont.):**
 - Spatial compounding eliminates edge artifact because the sound beam hits the structures at different angles

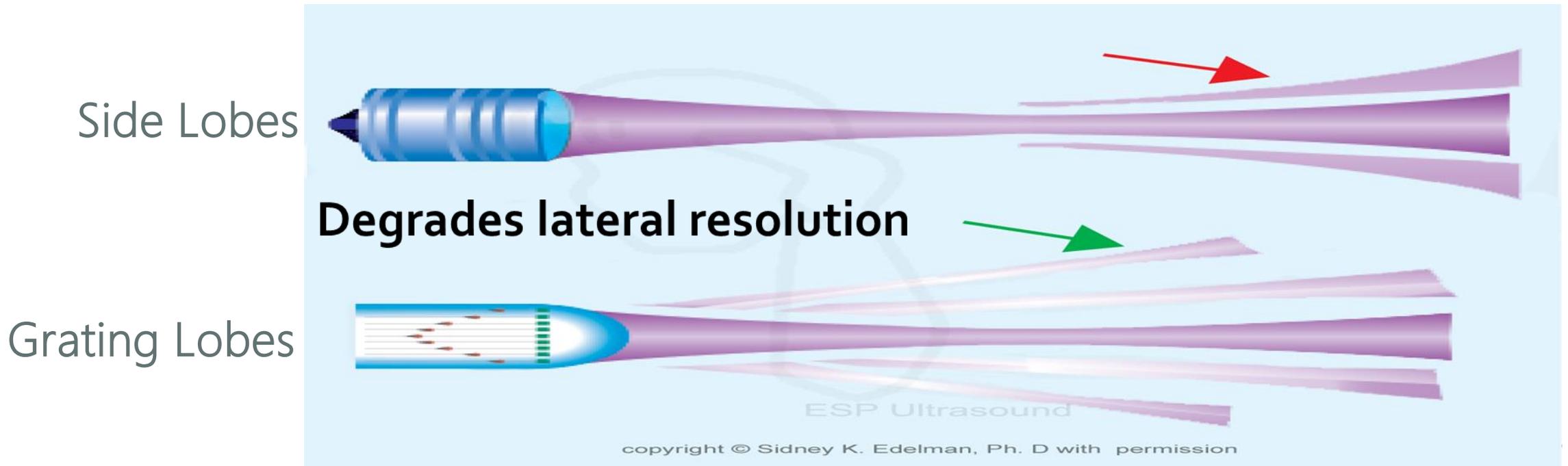


IMAGING ARTIFACTS

- It is expected that sound energy travels along the main axis of the beam
- If there is extraneous sound energy not along the main axis, the possibility exists that this sound will cause reflections back to the transducer
- As the machine assumes that all reflectors lie along the path of the beam, the artifacts produced are called side lobes or grating lobes
 - Lobes are weaker than primary beam and typically do not create reflections
 - May cause a second copy of true reflector at the same depth

IMAGING ARTIFACTS

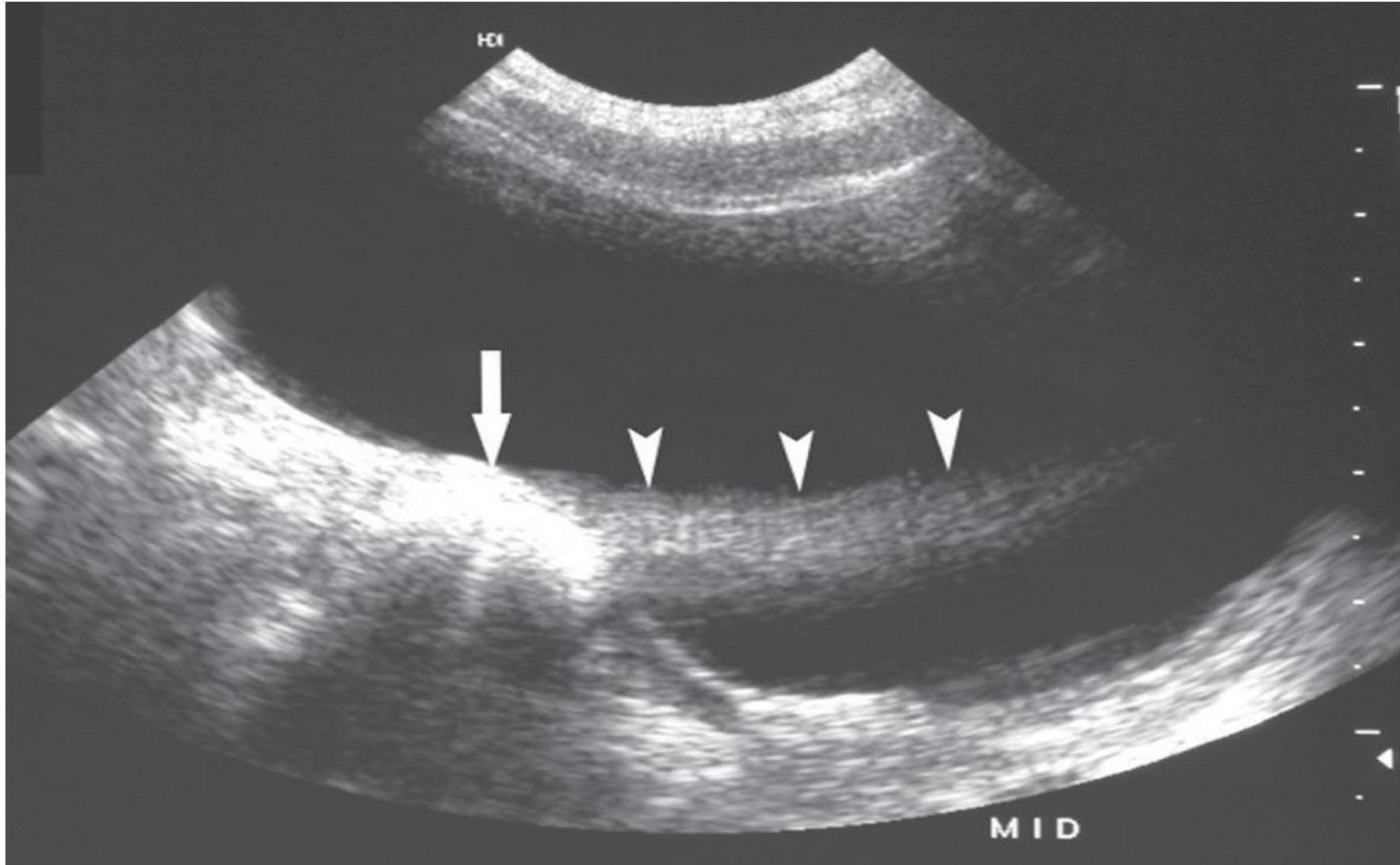
- Side lobes occur with single-element transducers and grating lobes occur with array transducers
- Tissue harmonics, apodization, and **subdicing** (slicing the crystals into even smaller sections) have largely reduced or eliminated grating lobes



IMAGING ARTIFACTS

- **Side Lobes/Grating Lobes:**
 - Reduction of lobes can occur with harmonics, subdicing, apodization
 - Subdicing:
 - Divides each crystal element into small pieces
 - Apodization:
 - Further reduced by exciting subdiced elements with different voltages
 - Center crystals have higher voltages
 - Outer crystals have lower voltages

GRATING LOBE



IMAGING ARTIFACTS

- **Propagation speed errors** can occur as well because the machine assumes that the sound travels through all tissues at 1540 m/s
 - In the body, the different tissues have different propagation speeds, but the machine uses 1540 m/s regardless of which type of tissue the beam is traveling through
 - The number of reflectors shown on the image is correct, but they appear at the wrong depth on the image
 - Appears as a "step off," "split," or "cut"

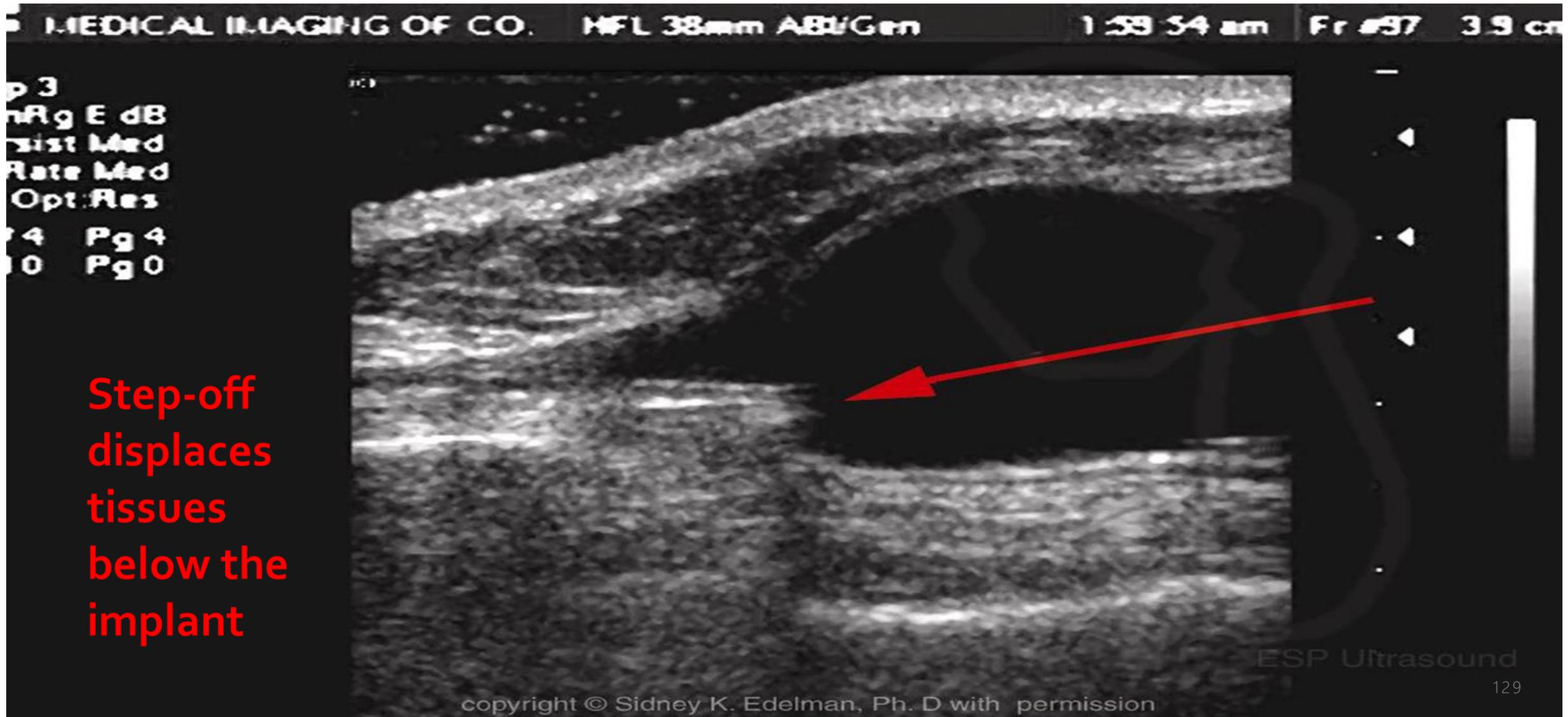
IMAGING ARTIFACTS

- **Propagation Speed Error:**
 - If the medium is faster than soft tissue (1540 m/s):
 - Sound travels faster than the system expects
 - Pulses return FAST
 - Go-return time is too short
 - System assumes the reflectors are close to the transducer and misplaces the reflectors too shallow on the image
 - Underestimated the distance of where reflectors are located in the body

IMAGING ARTIFACTS

- **Propagation Speed Error:**
 - If the medium is slower than soft tissue (1540 m/s):
 - Sound travels slower than the system expects
 - Pulses return SLOW
 - Go-return time is too long
 - System assumes the reflectors are far away from the transducer and misplaces the reflectors too deep on the image
 - Overestimated the distance of where reflectors are located in the body

PROPAGATION SPEED ERROR



IMAGING ARTIFACTS

- **Propagation Speed Errors**
 - Also called:
 - Speed Errors
 - Range Error Artifact
 - Range Ambiguity Artifact

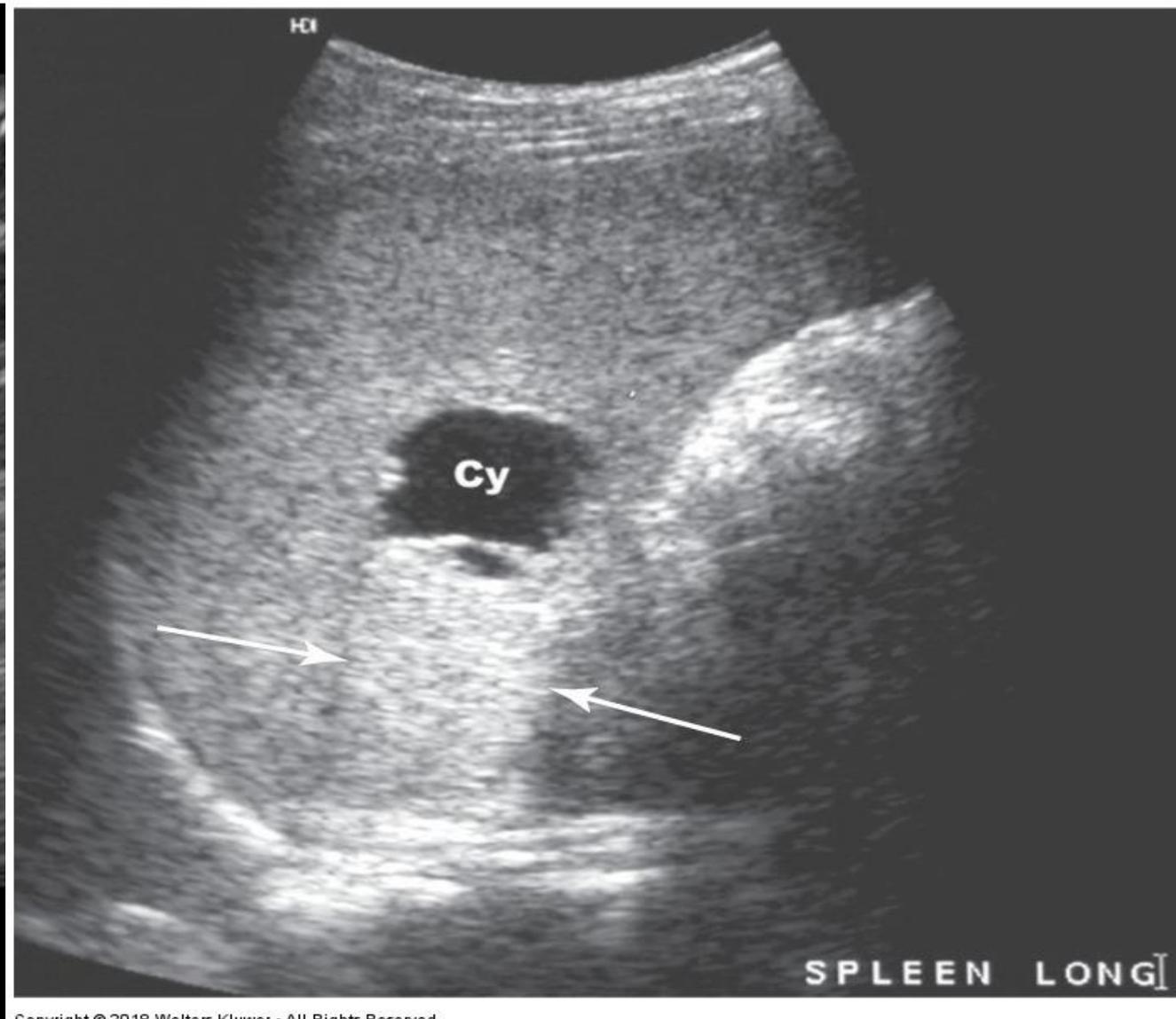
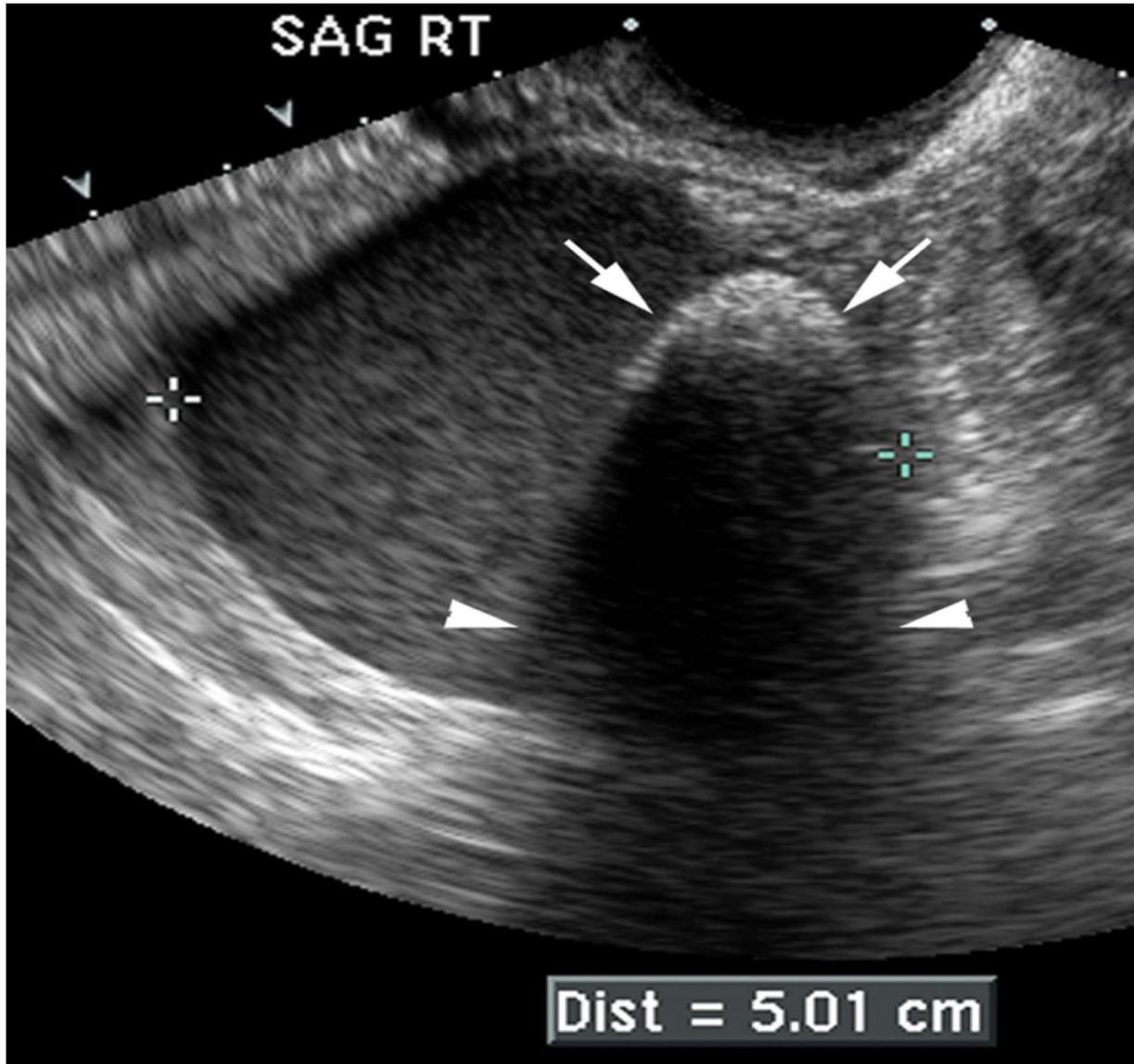
IMAGING ARTIFACTS

- Two particularly useful artifacts are **shadowing** and **acoustic enhancement**
- **Shadowing** occurs when the sound travels through an area of higher attenuation (such as a rib or other calcified/bony structure) compared with the surrounding tissue
- This artifact is useful because it helps with the identification of stones

IMAGING ARTIFACTS

- **Acoustic enhancement** (formerly known as through transmission) occurs from sound traveling through areas of lower attenuation, such as fluid
- Because less of the sound is attenuated when traveling through this region (e.g., a cyst), there is more signal strength distal to the object
- This makes the tissue deep to the weak attenuator appear brighter

SHADOWING/ENHANCEMENT

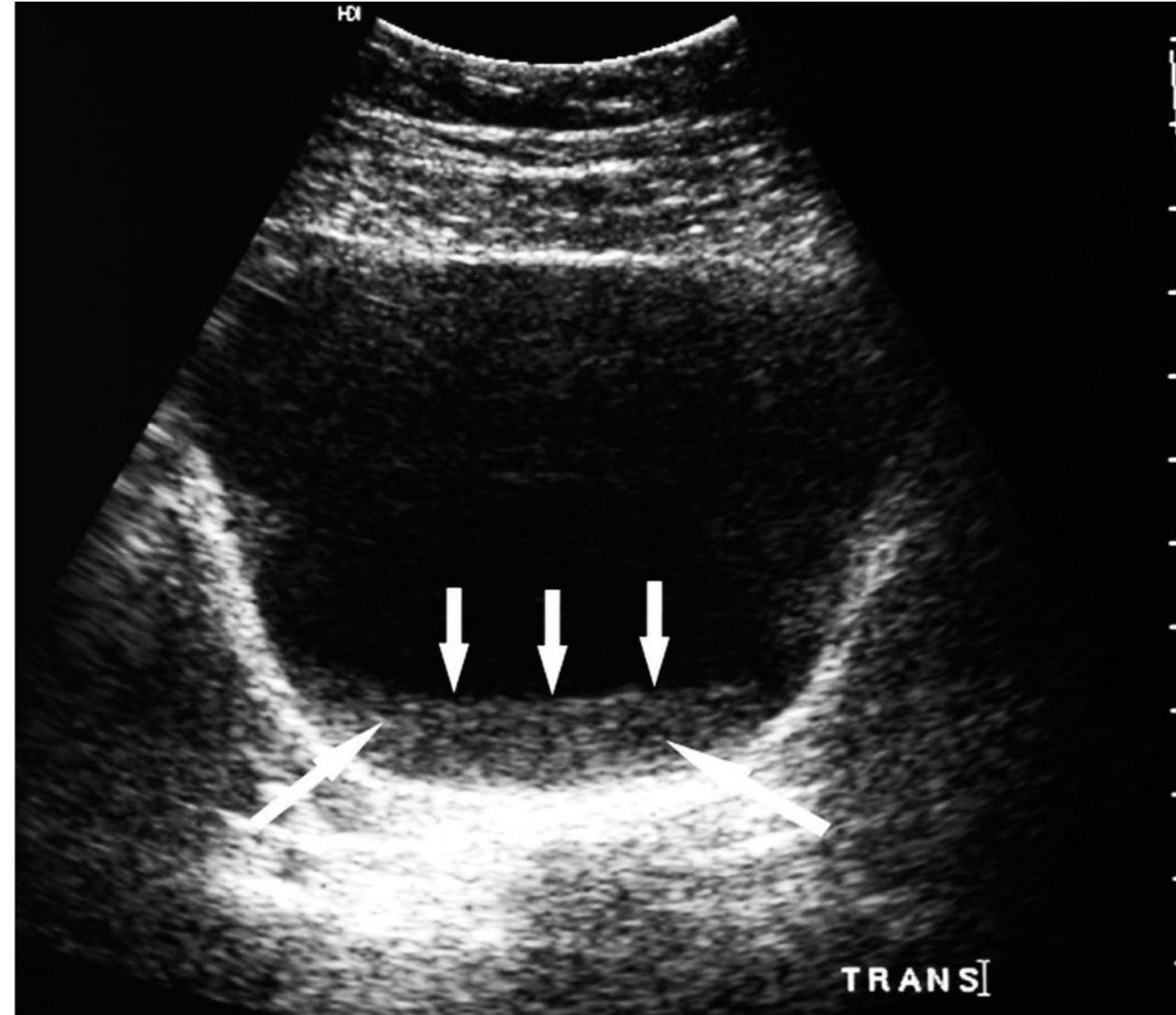


IMAGING ARTIFACTS

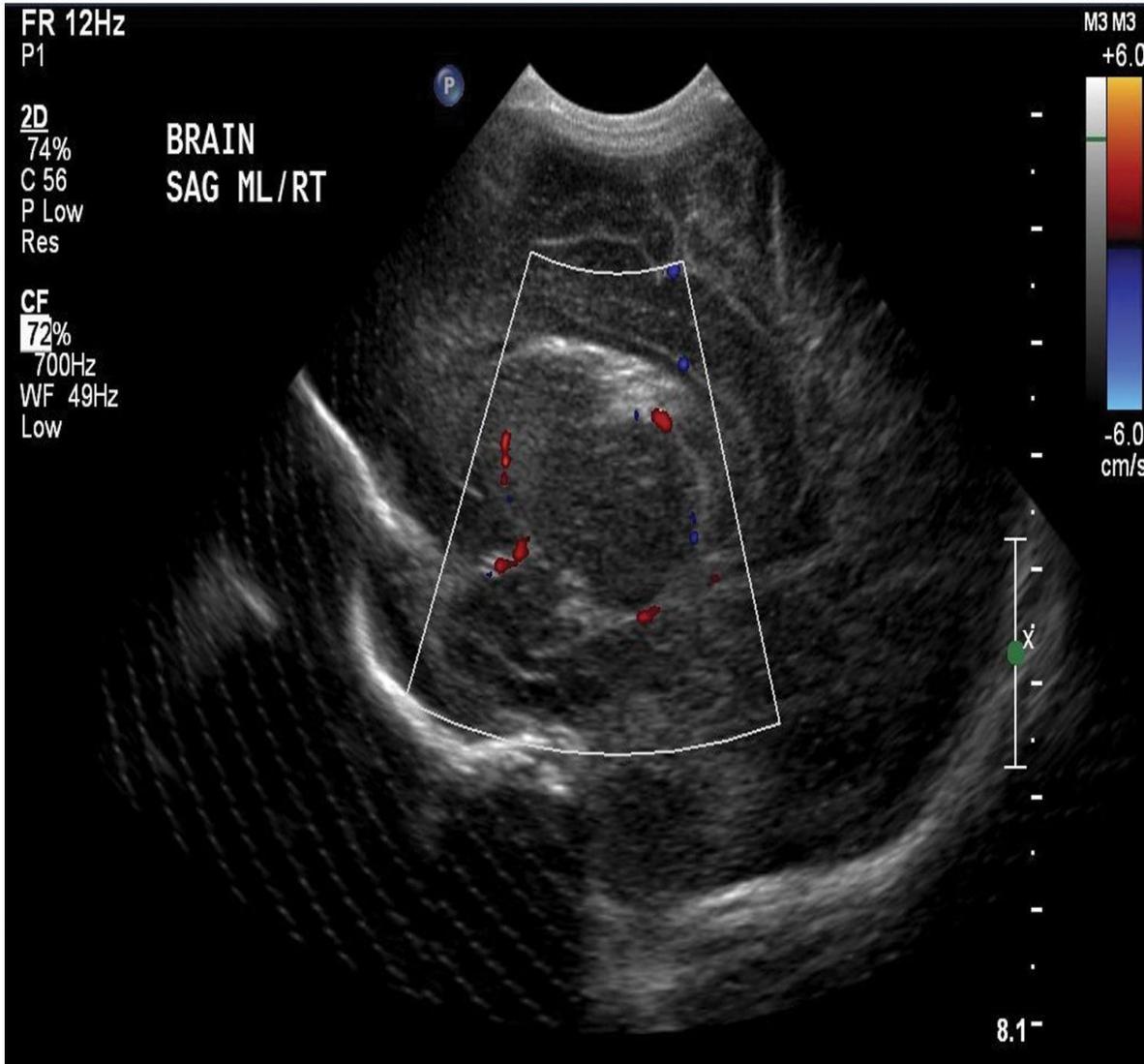
- The ultrasound beam is not razor thin; it has a definite thickness in what is called the slice thickness, or elevational plane
 - Any reflectors appearing in this plane will appear in the image, even if you were looking at something else
 - An often-seen example of this is scanning through an ovarian cyst and seeing what appears to be echoes within it
 - After the transducer is turned 90° , the echoes disappear, indicating they are not really within the cyst

IMAGING ARTIFACTS

- **Slice thickness artifact:**
 - Occurs because the beam scanned through both the cyst and the soft tissue adjacent to the cyst, causing both to appear on the image
 - Can be corrected by obtaining better focusing in the elevational plane, such as with 1.5D transducers



IMAGING ARTIFACTS



- The presence of electrical equipment near the ultrasound machine (e.g., unshielded ventilators) may cause an artifact related to **electrical interference**
- This causes arc-like bands that move across the screen as long as the machine is in the proximity of the unshielded equipment



QUESTIONS

TWO REFLECTIONS, ONE TRUE AND ONE ARTIFACT, ARE DISPLAYED ON AN IMAGE. IN THE BODY, ONLY ONE ANATOMIC STRUCTURE IS PRESENT. THE CORRECT REFLECTION AND THE ARTIFACT ARE FOUND SIDE BY SIDE. WHAT IS THE MOST LIKELY CAUSE OF THIS ARTIFACT?

- A. Mirror image
- B. Grating lobe
- C. Enhancement
- D. Multi-beam array

WHICH ARTIFACT PRODUCES AN IMAGE
WITH AN INCORRECT NUMBER OF
REFLECTOR?

- A. Propagation speed error
- B. Shadowing
- C. Enhancement
- D. Side lobes

MIRROR IMAGE ARTIFACTS ALWAYS APPEAR
DEEPER THAN THE TRUE ANATOMY.

A. True

B. False

ALL OF THE FOLLOWING ARTIFACTS RESULT
IN THE PLACEMENT OF TOO MANY ECHOES
ON THE IMAGES EXCEPT:

- A. Shadowing
- B. Reverberation
- C. Mirror image
- D. Grating lobe

WHICH ONE OF THESE ARTIFACTS DOES NOT
RESULT FROM MULTIPLE REFLECTORS?

- A. Comet tail
- B. Reverberation
- C. Ring down
- D. Enhancement