

ARDMS Topic:
Ultrasound Instrumentation

Unit 15a: Image Processing & Contemporary Features

Sononerds Ultrasound Physics
Workbook & Lectures

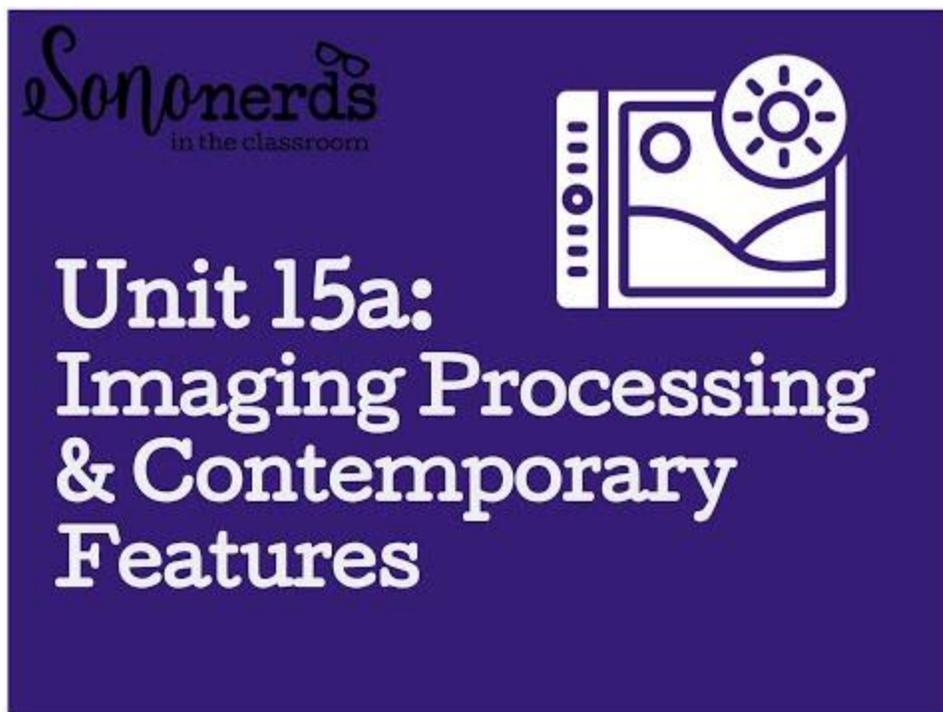
Unit 15a: Image Processing & Contemporary Features

Table of Contents:

- [Unit 15a Lecture](#)
- [Unit 15a: Image Processing & Contemporary Features](#)
- [Section 15a.1 Image Processor](#)
- [Section 15a.2 Magnification](#)
 - [15a.2.1 Write Zoom](#)
 - [15a.2.2 Read Zoom](#)
- [Section 15a.3 Fill-in Interpolation](#)
- [Section 15a. 4 B-Color](#)
- [Section 15a. 5 Panoramic Imaging](#)
- [Section 15a.6 Compounding Techniques](#)
 - [15a.6.1 Spatial Compounding](#)
 - [15a.6.2 Temporal Compounding](#)
 - [15a.6.3 Frequency Compounding](#)
- [Section 15a.7 Frequency Tuning](#)
- [Section 15a.8 Coded Excitation](#)
- [Section 15a. 9 Edge Enhancement](#)
- [Section 15a. 10 Elastography](#)
- [Section 15a. 11 Cardiac Strain Imaging](#)
- [Section 15a. 12 3D Rendering](#)
- [Section 15a. 13 Final Thoughts](#)
- [Section 15a. 14 Activities](#)
- [Section 15a.15 Nerd Check!](#)

Unit 15a: Image Processing & Contemporary Features

[Entire Unit 15 Lecture:](#)

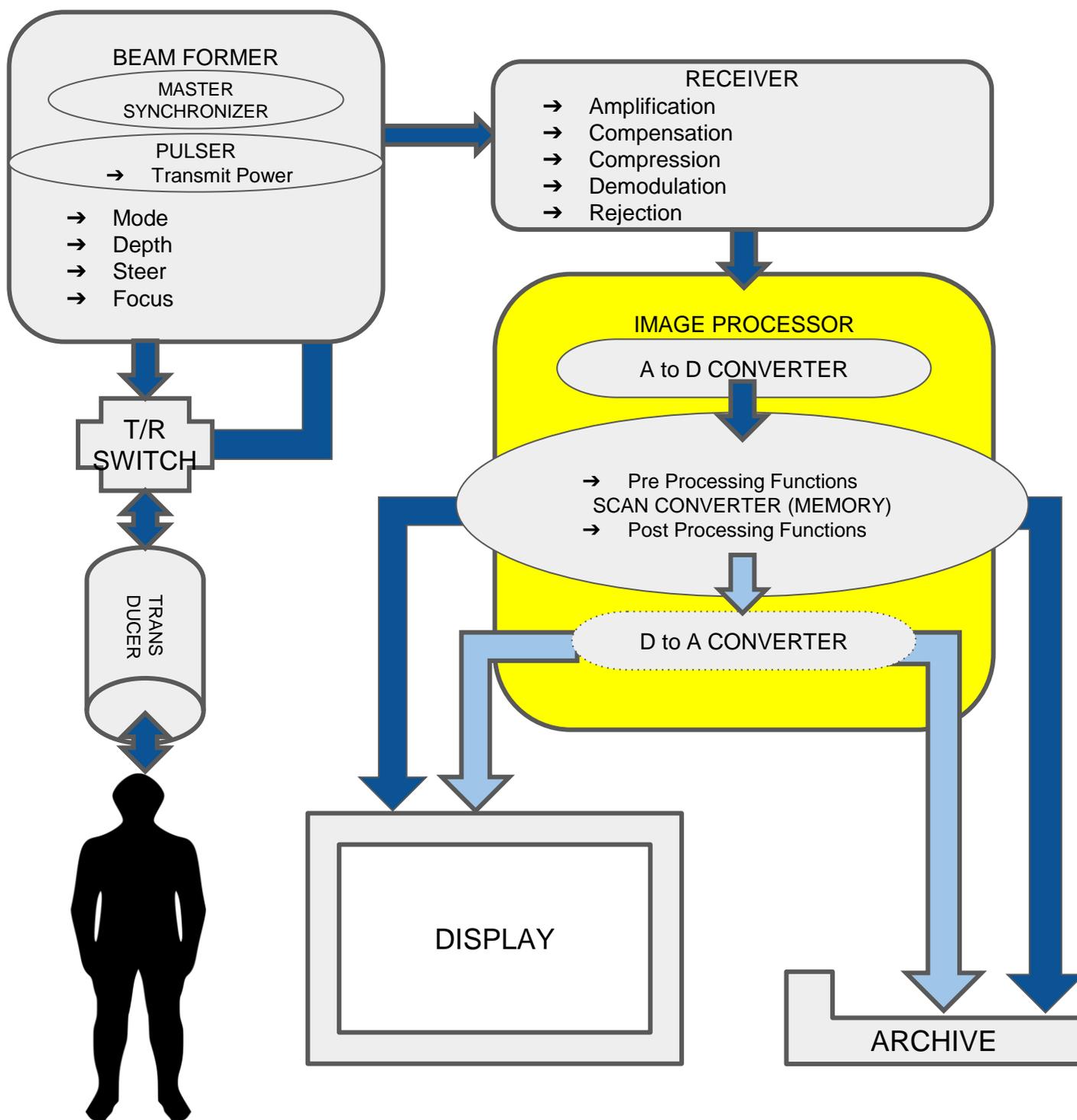


Did you know you can time jump to each section by using the “chapters” in the YouTube video playbar OR timestamps in the video description?

Unit 15a: Image Processing & Contemporary Features

In unit 14 we learned that the image processor is home to the AD and DA converters and the scan converter. We also briefly covered the idea of pre and post processing.

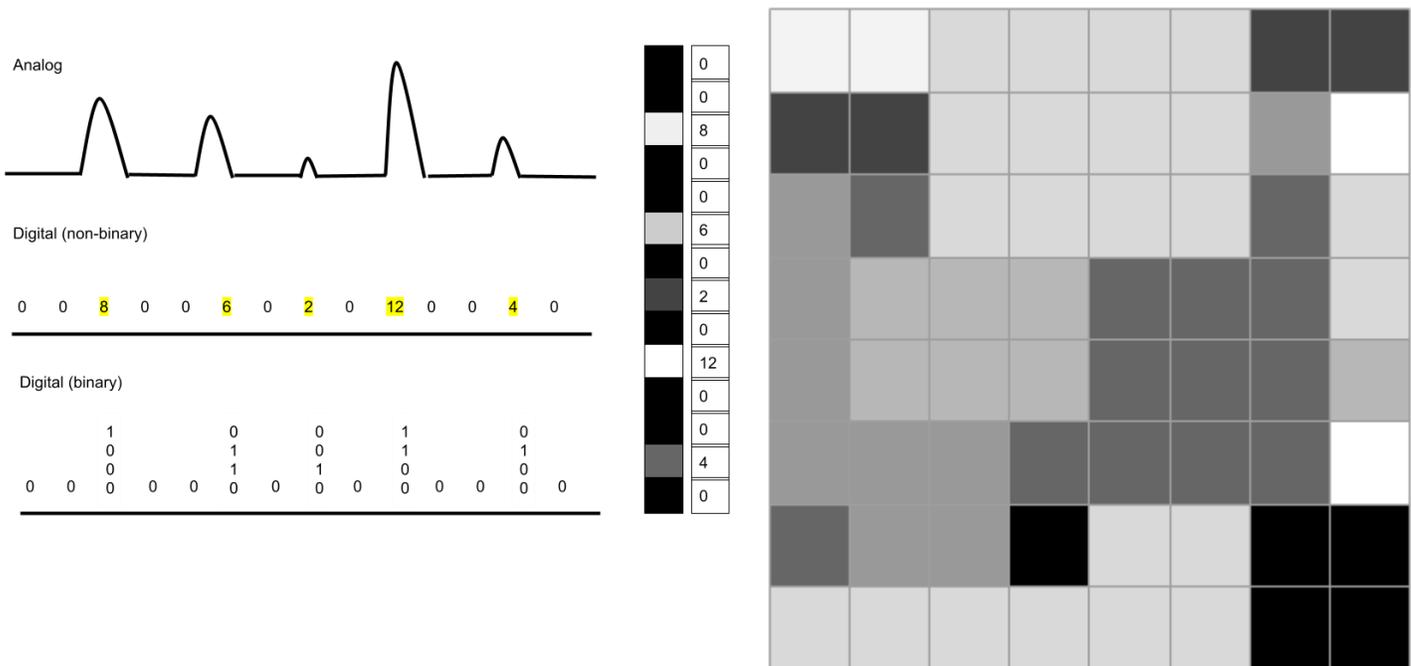
Unit 15 has been split into 15a, where we will learn about different image processing features and 15b in which we will learn about how image processing features affect the spatial, contrast and temporal resolution for our fourth discussion on resolution.



Section 15a.1 Image Processor

The image processor receives scanline information from the signal processor. No image is created at this point, as all the information is still just a long string of data representing the single scanlines. In the image processor, the information becomes digitized, saved into the scan converter and switched from its vertical format to its horizontal format that the system display needs.

When the scan converter fills its matrix of pixels with the information a frame has been created and is displayed. The idea is that this happen at least 30 times per second to create what we perceive as real time imaging.

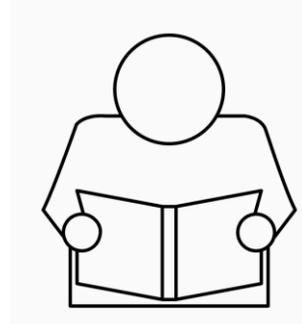


When the scan converter is filling the matrix with data, the machine is **writing**. The scan line data is continuously written over when we are live scanning to refresh the image that we see on the display. During the writing process we are changing the image using various tools and machine knobs. Anything that occurs while the machine is writing is a **pre-process function**.

When we freeze the image the scan converter switches to **read**. This means that the image can no longer be altered with pre-processing tools. The data displayed is what it is and anything we alter at this point is a **post-process function**.

A helpful way to think about the pre-process & write mode vs. the post-process & read mode is to think about an author.

When an author is writing a book they can change it all they want. They can rewrite the story, change the character names, create a new setting. Once the book is published, it can now be read.



The machine is doing a similar thing in its memory. Rewriting in the memory to create new frames that can be altered with one of many pre-processing features, we are changing the story. Once we hit freeze, the memory is no longer accepting new data and is only available for reading.

The data that is saved in the memory at this point can undergo post-processing changes, but we can always revert back to the original saved data by reading what's in the memory. During the writing process, we can never really get back to that data once it's written over.

As you learn about image processing features, take note if it is a pre-processing or post-processing feature. Image processing features include:

- **Magnification**
- **Fill-in Interpolation**
- **B-Color**
- **Panoramic Imaging**
- **Spatial Compounding**
- **Persistence (Temporal Compounding)**
- **Frequency Compounding**
- **Frequency Tuning**
- **Coded Excitation**
- **Edge Enhancement**
- **Elastography**
- **Cardiac Strain Imaging**
- **3D Rendering**
- **Harmonics (has its own unit)**
- **Dynamic Range (has its own unit)**

Focus on the definition of the feature, what it looks like and how it improves/creates an image.

Section 15a.2 Magnification

Magnification, also known as **zoom**, allows the sonographer to create a larger, close-up view of the region of interest (ROI). Zoom is controlled by a knob/button on the machine.

There are two types of magnification:

- **Write Magnification**
- **Read Magnification**

15a.2.1 Write Magnification

Write magnification (aka write zoom) happens while the image is still live. So this makes it a **pre-processing function**. Follow these steps to understand how write magnification works:

1. A **live** image is being acquired by the machine.
2. Sonographer selects the zoom button (usually need to push it).
3. A region of interest box appears.
4. Sonographer resizes and moves the box to the area of interest.
5. Activate zoom button again.
6. Machine **rescans** the ROI using **ALL scan lines**.

When the machine uses all the scanlines to rescan the ROI, the same amount of pixels and scan lines are used to image a smaller area.

- **Write magnification improves spatial (detail) resolution.**

When the region of interest box is placed more shallow than the max depth, the rescan will only image down to the depth of the zoom box, so this means the pulses take less time to travel to the “new” max depth than the unzoomed image.

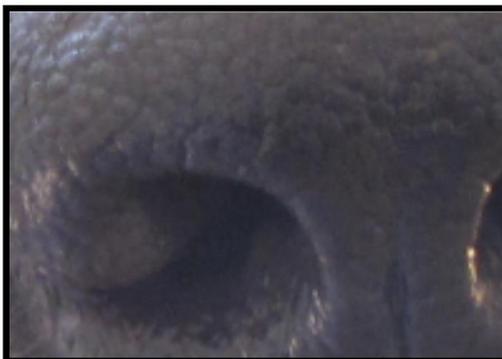
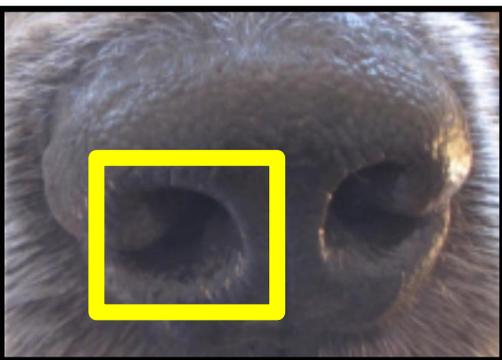
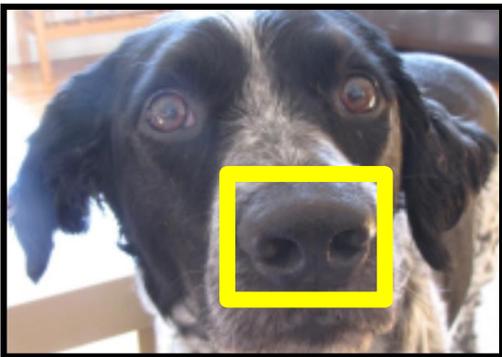
- **Write magnification *can* improve temporal resolution.**

15a.2.2 Read Magnification

Read magnification (aka read zoom) happens once an image is frozen.. So this makes it a **post-processing function**. Follow these steps to understand how read magnification works:

1. The sonographer **freezes** the image
2. Sonographer turns the zoom knob.
3. Pixels in the image becomes larger.
4. Sonographer can “pan” around image to find ROI if it wasn’t already centered in view.

When read zoom is used, the pixels get bigger. The computer is reading the image information from the scan converter and changing the size of the pixel. No rescanning occurs during read zoom.



Section 15a.4 B-Color

Different “maps” are used for displaying the digital data on the screen. Often times, the machine is set at a default gray map, but you can change the gray map to suit your preference. Or, you can add a color. The sonographer chooses the setting by adjusting a knob/button.

B-Color is a **post-processing function**. It simply takes a color of choice and exchanges it for the gray scale. The human eye is better at distinguishing color tints over gray tints, so using B-Color can be exceptionally helpful when trying to see the borders on a very subtle finding.

→ **B-Color improves contrast resolution.**



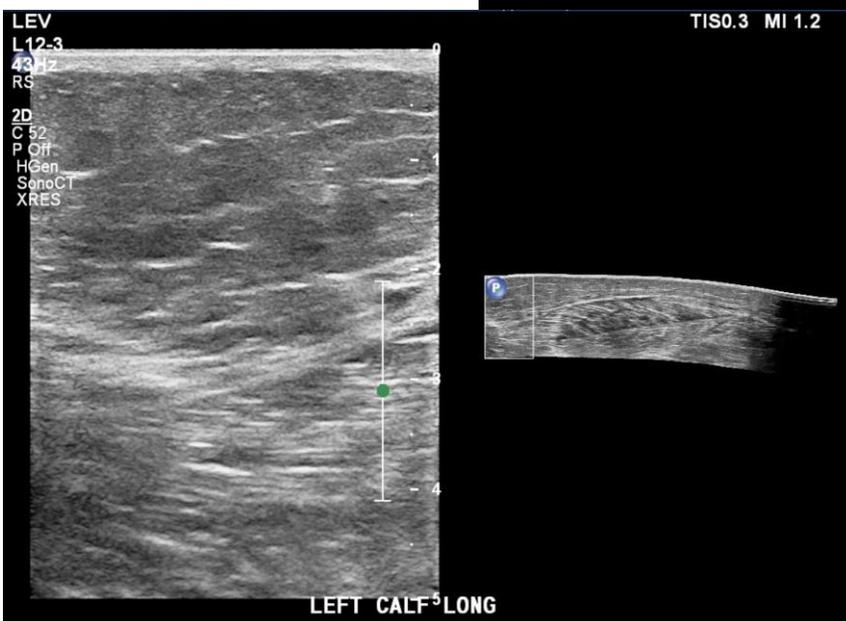
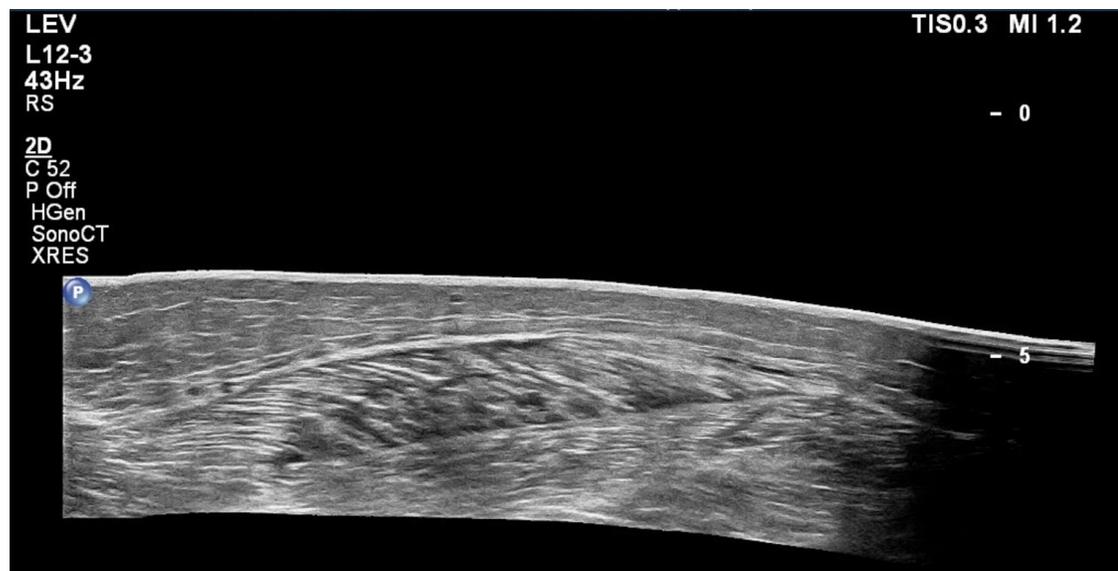
Section 15a.5 Panoramic Imaging

The footprint of the transducer is about as wide as the image can be for linear transducers. If the machine has the option, a wide scan can be used to steer the edges out slightly and increase the visible anatomy slightly.

A newer technology called panoramic imaging allows the sonographer to drag the transducer in one plane, creating a really long image. This is especially helpful for vessels and large lumps or area surface to be imaged.

As the sonographer slides the transducer, the machine looks for matching scanlines. As long as the scan lines match up, the machine can track where the the end of the already scanned portion starts and where to start acquiring new information.

Essentially, frames are aligned side by side to make a wider field of view.



LEFT CALF LONG

LEFT CALF³ LONG

Section 15a. 6 Compounding Techniques

Compounding images refers to adding or averaging images together. There are three distinct compounding features that can be utilized by the machine:

- Spatial Compounding - images from different angles
- Temporal Compounding - images from different times
- Frequency Compounding - images from different frequencies

15a.6.1 Spatial Compounding

Spatial compounding is a **pre-processing function**.

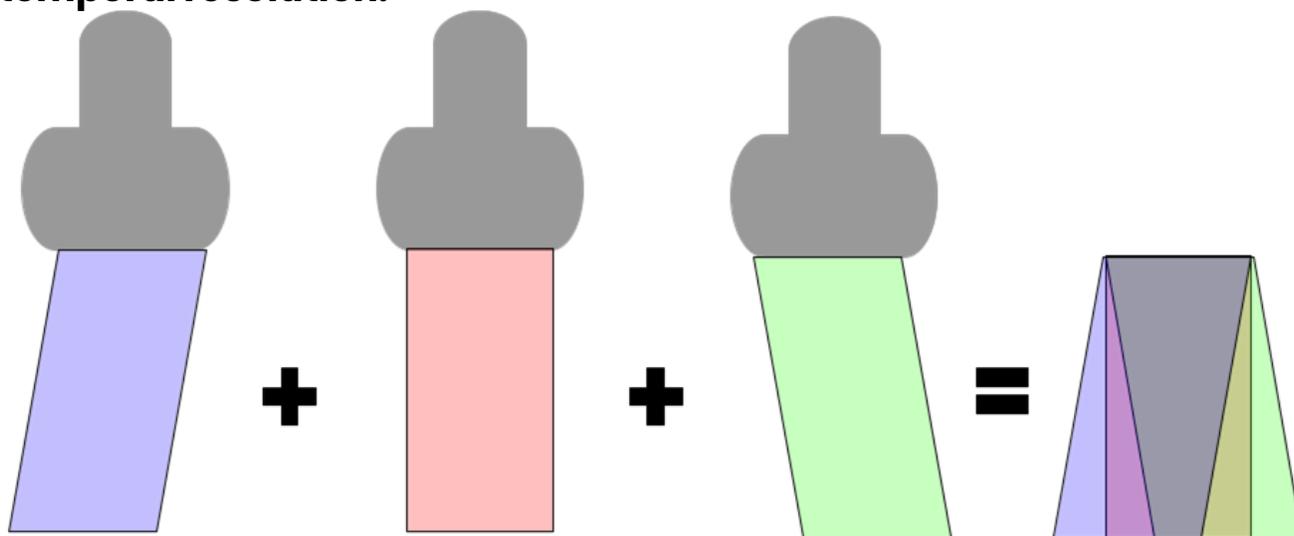
We know that transducers are capable of phasing to steer the beam and we think of it mostly as a “fanning” to make the sector shape. Newer machines use this technique as a default, but it can be turned on or off by the sonographer.

However, the beam can be steered in multiple directions, getting A LOT of scan data. The machine can take all of the scanned lines and compound or add them together to make a final image.

→ **Spatial Compounding averages multiple frames taken from multiple angles.**

Most noticeably, the image becomes smoother, angle dependent reflectors are more apparent, artifacts are less obvious and overall signal is improved. This does however require multiple pulses for one frame, which will decrease frame rate.

→ **Spatial compounding improves spatial resolution, but degrades temporal resolution.**





15a.6.2 Temporal Compounding

→ **Temporal compounding is also known as persistence or temporal averaging.**

Temporal compounding is achieved by superimposing frames upon one another, or layering images **over time** on one another. The sonographer can increase or decrease the persistence using a knob/button.

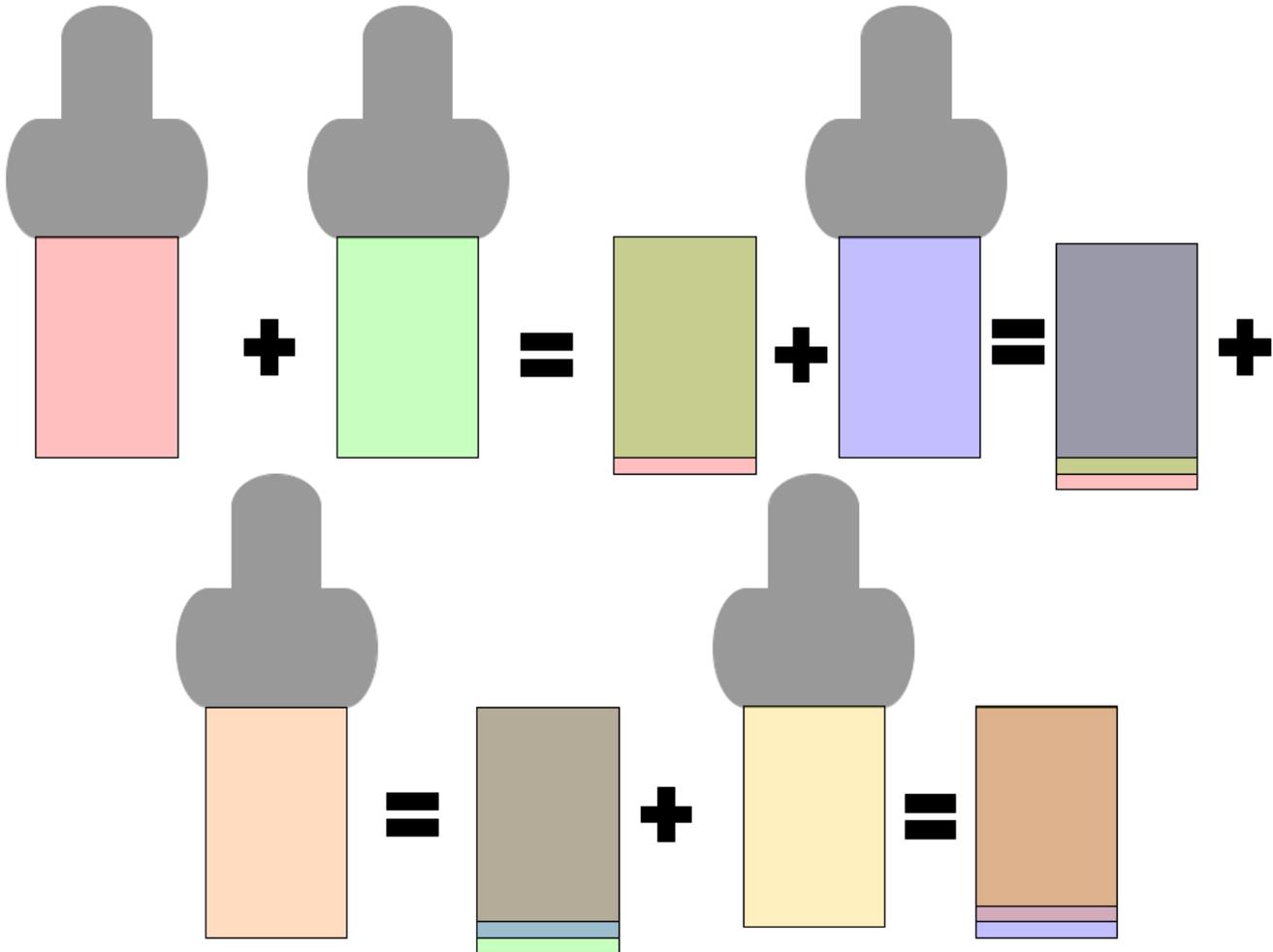
Temporal compounding creates a smoother and higher quality image by reducing noise and increasing the SNR. By layering color images together, it can improve the color fill in vessels as well.

→ **Temporal compounding improves spatial & contrast resolution.**

Spatial compounding averages images from different angles. Temporal compounding uses images taken from the same angle to improve the image. But, it still requires the frames to be created and then averaged, so the time to get one frame now is essentially the time it takes to get more frames.

→ **Temporal compounding reduces temporal resolution.**

Each color represent **one frame**. Over time, the frames are added to one another. As more time passes by, the oldest frames are “forgotten” and new frames are layered on top.



15a.6.3 Frequency Compounding

The last compounding technique is frequency compounding which works a little differently than the other two types of compounding, but results are similar in that it reduces noise and improves the signal.

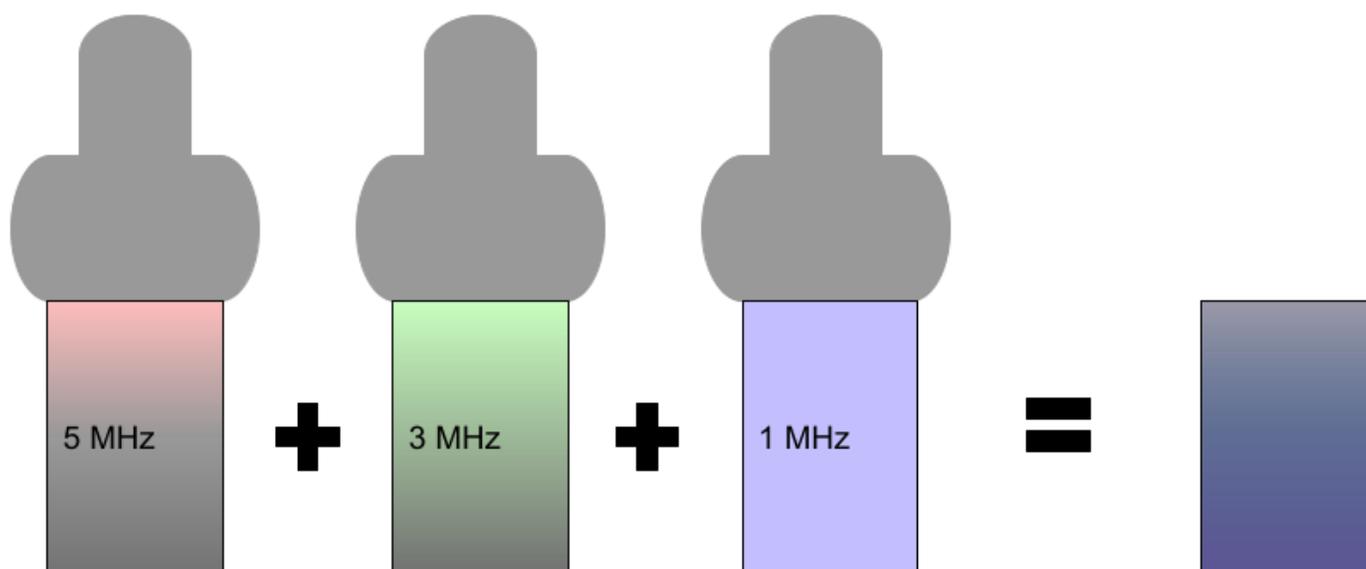
Frequency compounding is also known as **frequency fusion**. Spatial and Temporal compounding acquires separate frames and averages them together. Frequency compounding processes different frequencies **all at once**, instead of sequentially.

Essentially, the machine sends out its bandwidth worth of frequencies through its normal pulse creation. It then listens for echoes from different frequencies and processes them all at once, creating one frame.

If a machine has a bandwidth of 1- 5 MHz and the frequency map is set to listen for 1, 3, and 5 MHz returning echoes, it will process 3 frames of the **same anatomy at the same time**.

This feature creates images with better resolution throughout the image and allows for improved penetration of sound.

- **Frequency compounding improves spatial and contrast resolution.**
- **Frequency compounding does NOT degrade temporal resolution.**

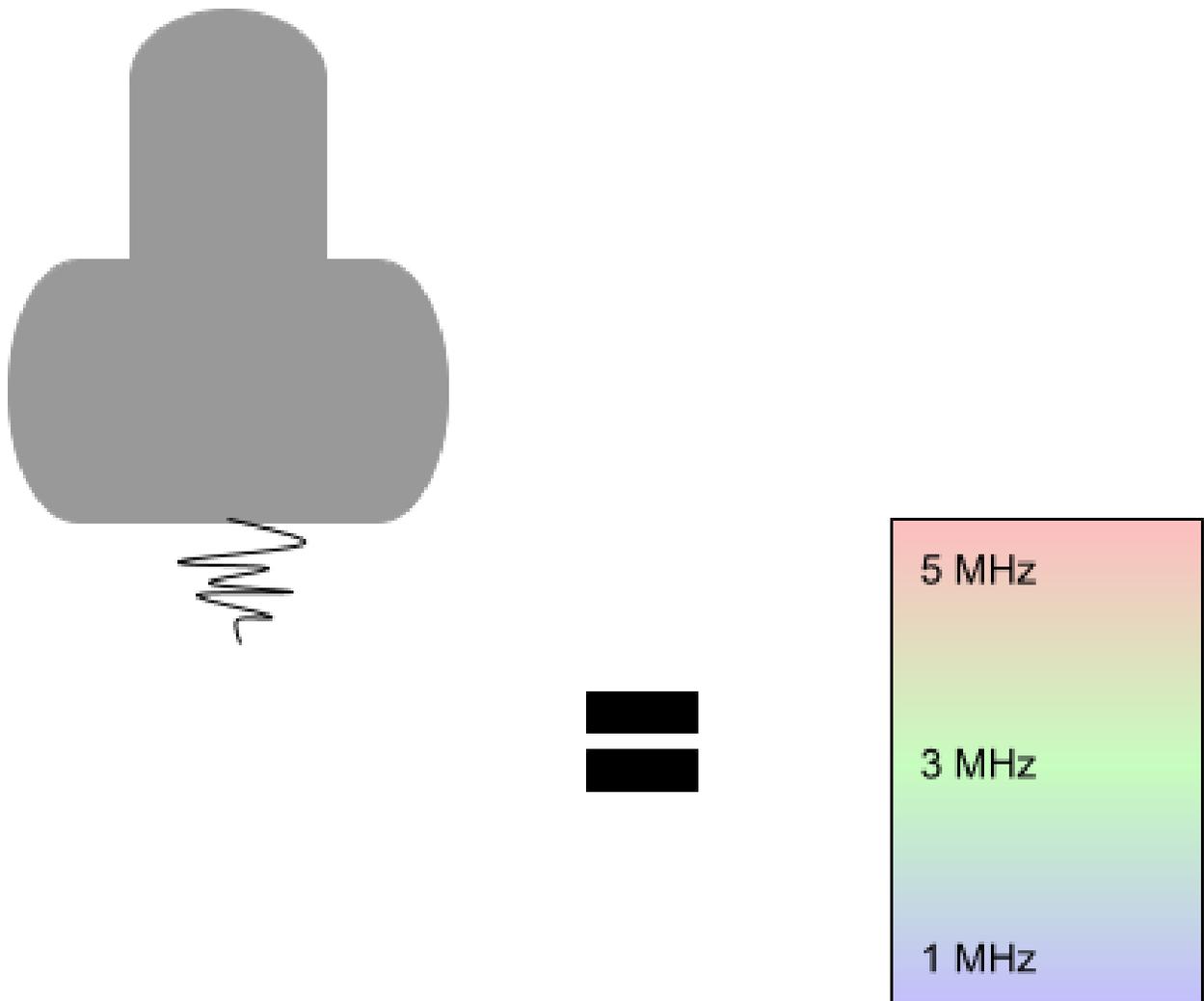


Section 15a.7 Frequency Tuning

Another image processing technique that should not be confused with frequency compounding is frequency tuning. Frequency tuning uses different frequencies from the bandwidth to create different layers of the image.

High frequencies are only used to create the upper portion of the field of view where low frequencies are used to create the deep portion of the field of view. This is not a layering technique, so the SNR is not improved, but the lateral and axial resolutions are improved in the near and mid fields as they are created using higher frequencies.

→ Frequency tuning takes place in the beamformer



Section 15a.8 Coded Excitation

When we talked about axial resolution, we learned that a short pulse is best (because axial resolution is $SPL/2$). Coded excitation changes that premise up a bit.

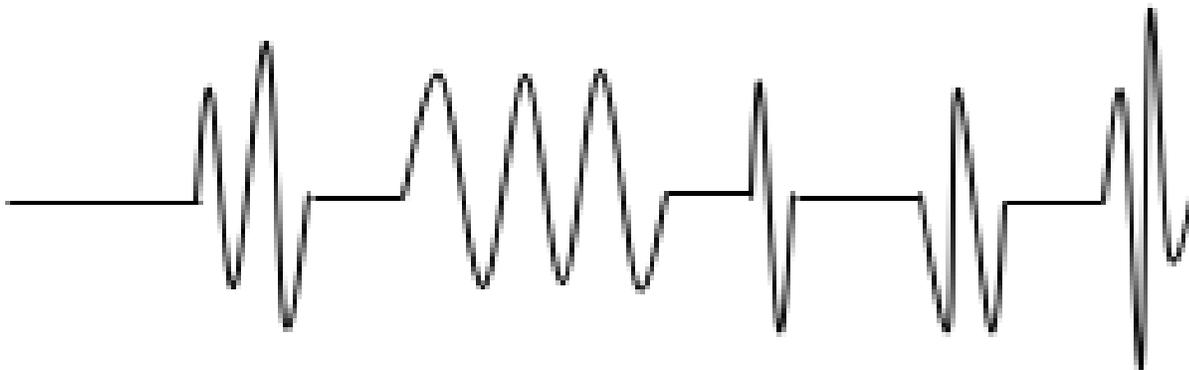
Coded excitation involves sending out a long pulse that has a “code” within it. Each “coded” part is a short pulse and as echoes come back, the machine matches them up with patterns from the code.

Even though the pulse itself is long, it is made up of short coded pieces that improve the image without having to send out multiple pulses.

→ Coded excitation occurs in the beam former (pulser)

There are 5 improvements to the image that are a result of coded excitation:

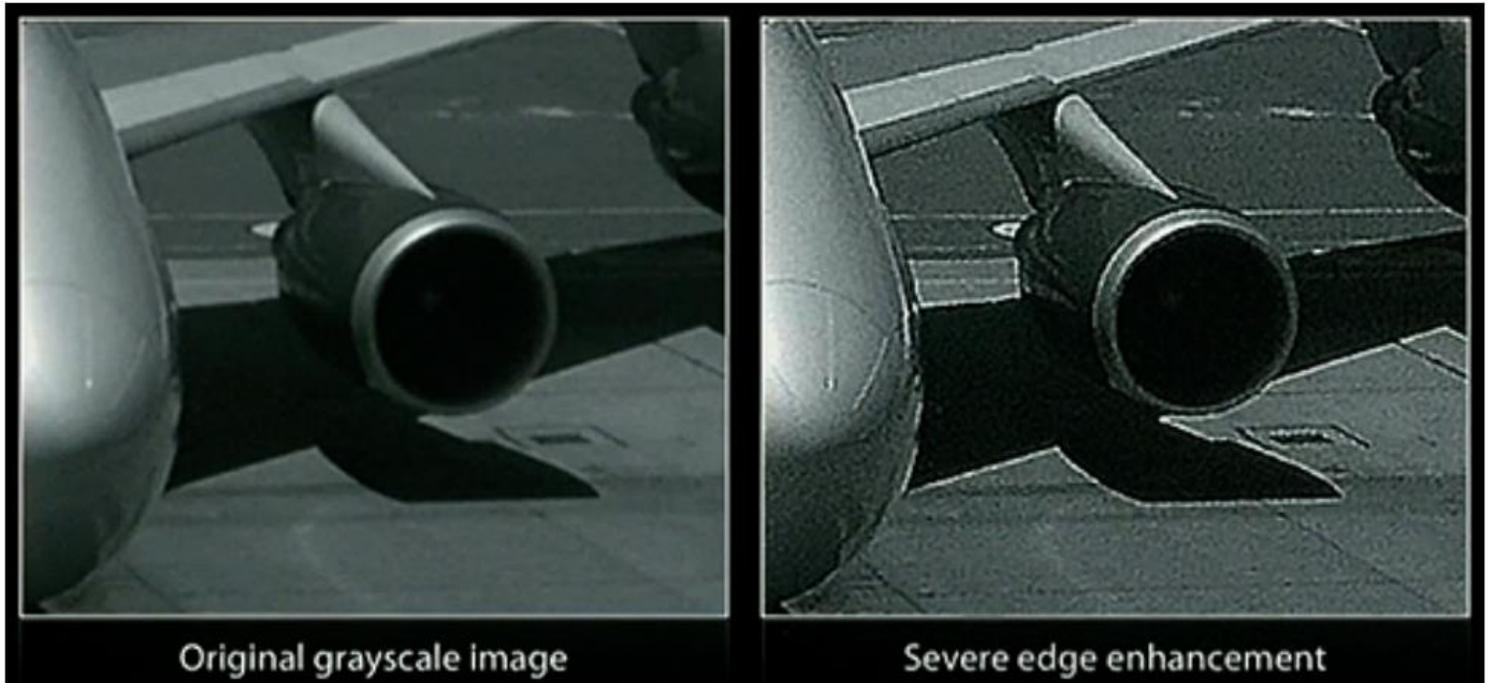
- **Improved axial resolution**
- **Higher S to N Ratio**
- **Improved spatial resolution**
- **Improved contrast resolution**
- **Deeper penetration**



Section 15a.9 Edge Enhancement

Edge enhancement makes the picture look sharper. It is also a **pre-processing function**. The machine recognizes reflective areas between two media and locally improves contrast by creating a subtle bright and dark highlight on either side of boundary.

→ **Edge enhancement improves contrast resolution**



Section 15a. 10 Elastography

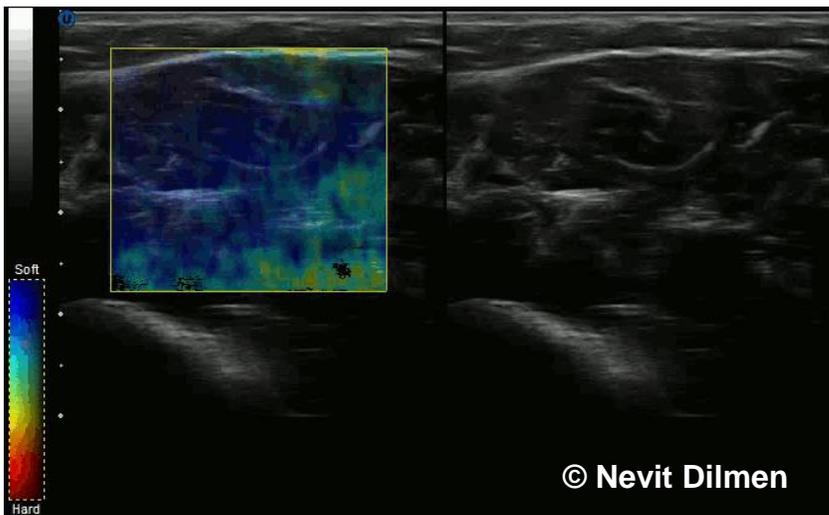
Elastography is a helpful method of imaging to assess the **stiffness** of tissue.

For many practitioners, touching the patient to assess for masses or firm areas is important to the diagnostic process. This is often the case in breast or thyroid cases as benign masses tend to be squishy and mobile, where cancers are more likely to be firm and fixed. Elastography can also be helpful in determining the extent of fibrosis in the liver.

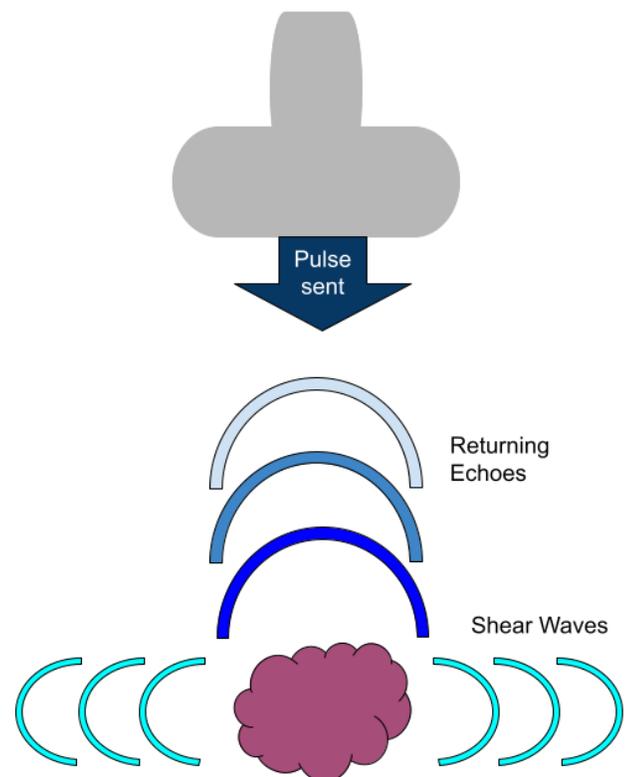
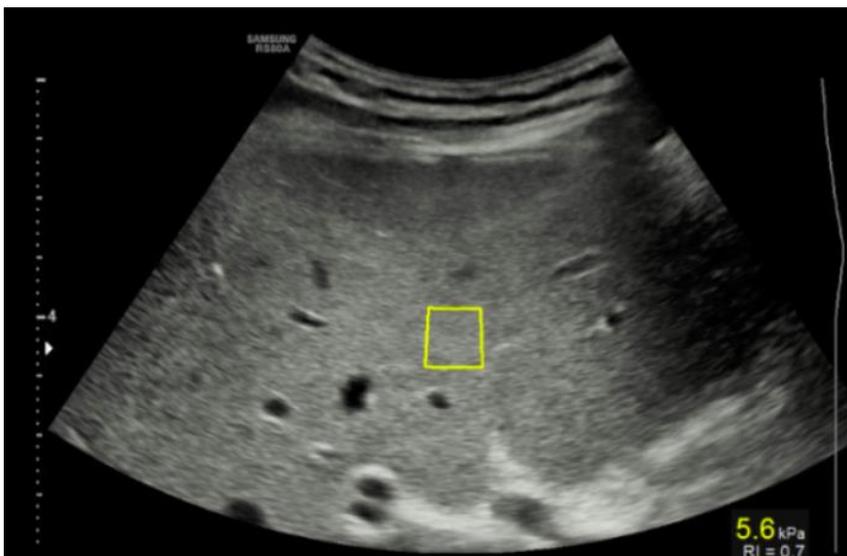
Elastography can provide more information about the true stiffness of the tissue through **ultrasound palpation**.

There are two types of elastography. The first type is **strain elastography**. This needs the sonographer to physically apply pressure to the area and then the machine could calculate the changes. This resulted in qualitative results that were suspect to operator variability.

Newer elastography uses **shear wave elastography**. Shear waves are the echoes that move off to the sides in the tissue. The speed of the shear waves is measured and a quantitative value is measured, giving a number in kPa. Remember that propagation speed increases with stiffness, so shear waves that propagate faster are in tissue that is stiffer.



Strain method uses manual compression and assigns colors to identify the tissue stiffness.

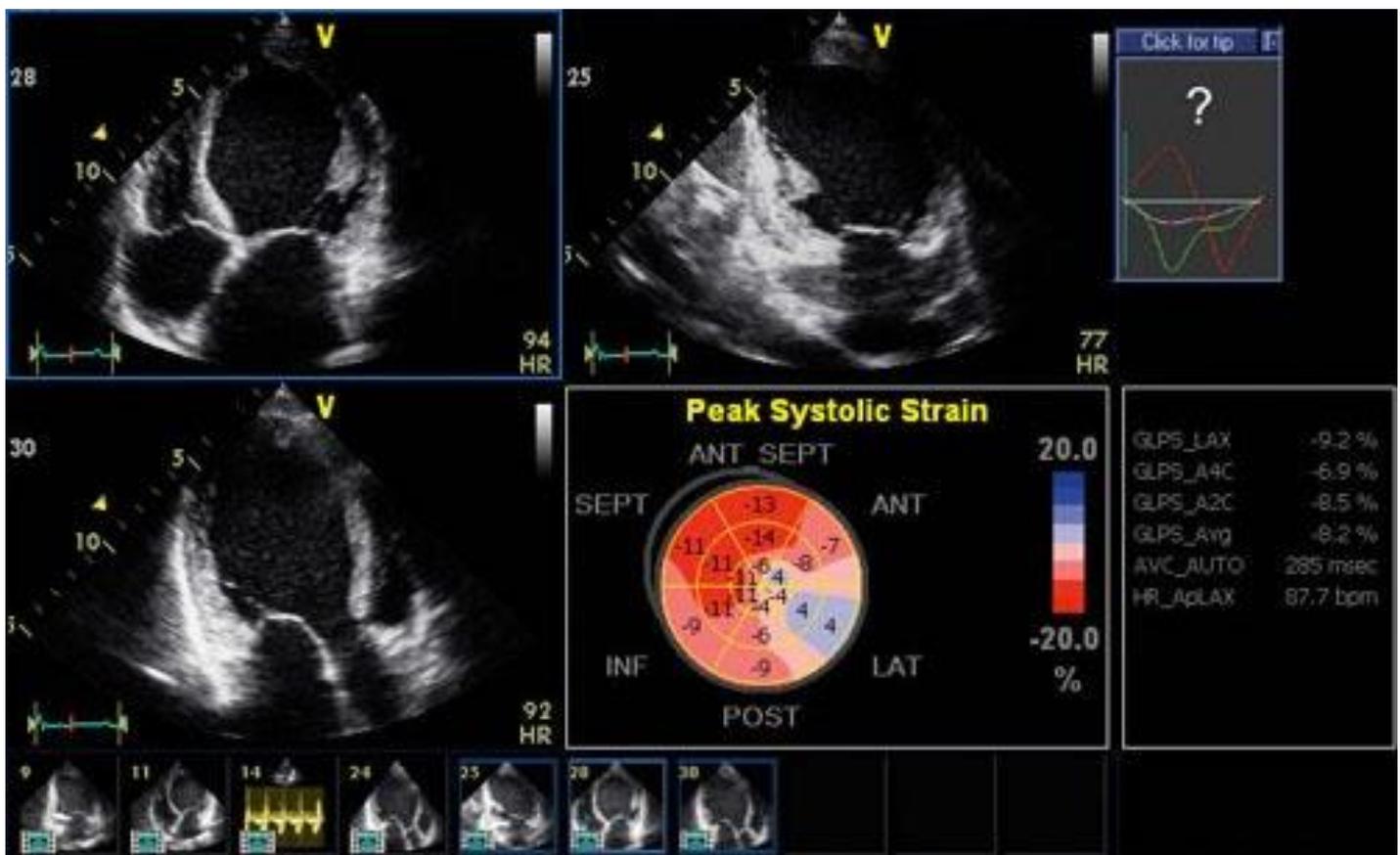


Section 15a.11 Cardiac Strain Imaging

Cardiac strain imaging is very similar to elastography. Elastography required outside force (pushing or shear waves) to qualify the stiffness of the tissue.

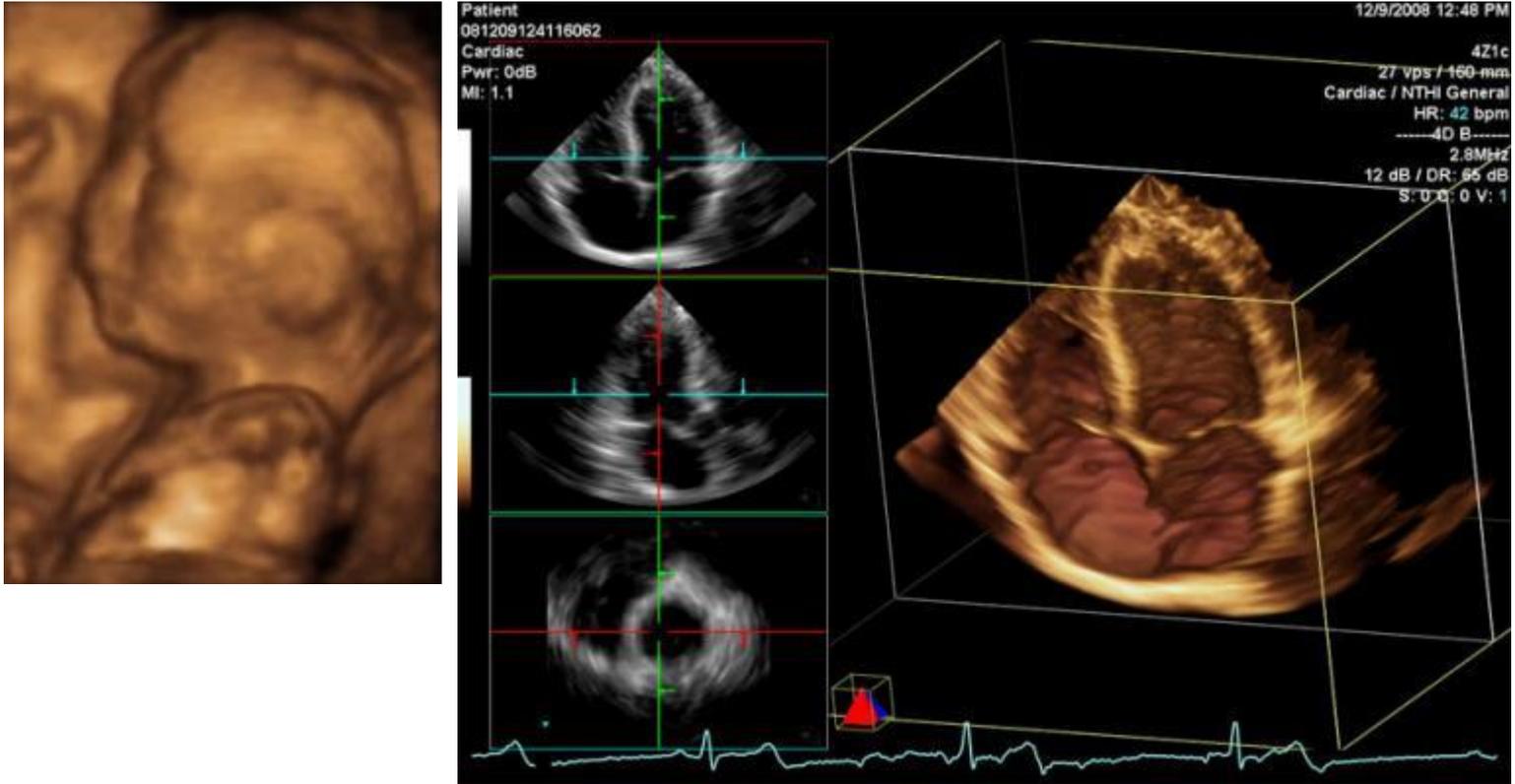
Since the heart is its own strain creator, the machine can measure the stiffness of the heart muscles as they contract. The **strain rate** shows how effective the myocardium is at contracting.

There are two methods that cardiac strain imaging can be achieved - through **speckle tracing** in which specific areas of the myocardium are tracked for movement or through **tissue Doppler**. The two methods essentially describe the deformation of the cardiac wall or chamber from a relaxed to a contracted state.



Section 15a. 12 3D Rendering

3D imaging requires the machine to acquire ultrasound information in 3 different planes. After the acquisition, the information is saved and can be manipulated to create the 3D image. Since the rendering is done after the image is frozen, rendering is a **post-processing function**.



Section 15a. 13 Final Thoughts

Harmonic imaging, contrast imaging and dynamic range are some other image processing techniques that are used frequently in ultrasound. Due to their prevalence, they warrant their own units and will be discussed later.

Note that most of the techniques discussed in the unit either have the express purpose of improving resolution(s) or to create more information for diagnostic purposes.

Section 15a.14 Activities ← [Link to Answers](#)

1. Use an **R** if the statement is true for **read magnification** and **W** if the statement is true for **write magnification**.

	Pre-processing function		Selects portion of frozen image
	Selects portion of live image		Machine rescans entire selection
	Makes all the pixels bigger		Better spatial resolution
	Post processing function		Can improve temporal resolution
	Detailed dog nose 		Blurry dog nose 

2. Match the modern functions with their definition:

- A. Coded Excitation
- B. Spatial Compounding
- C. Frequency Compounding
- D. Edge Enhancement
- E. Temporal Compounding
- F. Fill-in Interpolation
- G. Elastography
- H. Cardiac Strain
- I. Frequency Tuning
- J. 3D Rendering
- K. Panoramic
- L. B-mode color

	Tests the stiffness of tissue using shearing force of sound
	Predicts the gray value of gaps between scan lines
	Used to show wall motion of the heart
	Changes grayscale pixels to other colors.
	Uses long complex pulses to improve the SNR and resolution
	Makes borders sharper with bright and dark highlights
	Creates an images with optimized layers
	Scans the image from different angles and combines the pictures
	Superimposes older pictures under the current picture
	Connects frames side by side to create a wide field of view
	Averages whole images together that were made from different wave characteristics
	Combines 3 planes of imaging

Section 15a.15 Nerd Check!

1. Where does the information for the image processor come from?
2. When the machine is still acquiring data this is _____?
3. When the machine saves its data, this is _____?
4. When a tool is used on a live image it is a _____ function.
5. When a tool is used on a frozen image, it is a _____ function.
6. What is another name for magnification?
7. What are the two types of magnification?
8. What are the steps for write magnification?
9. How many scan lines does the machine use to create an image during write magnification?
10. What resolutions does write magnification improve?
11. Write magnification is a _____ processing function.
12. What happens to the pixels in read mag?
13. What are the steps to read mag?
14. Read zoom is a _____ - processing function.
15. What is fill-in interpolation?
16. What is another name for fill-in interpolation?
17. fill-in interpolation is a _____ - processing function.
18. What is B-color?
19. Why would B-color be helpful?
20. What resolution does B-color improve?
21. What is panoramic imaging?
22. What is spatial compounding?
23. Spatial compounding is a _____ - processing function.
24. What resolution(s) does spatial compounding improve?
25. What resolution(s) does spatial compounding reduce?
26. What is temporal compounding?
27. What other names does temporal compounding go by?
28. What resolution(s) does temporal compounding improve?
29. What resolution(s) does temporal compounding reduce?
30. What is frequency compounding?
31. What other names does frequency compounding go by?
32. What resolution(s) does frequency compounding improve?
33. Does frequency compounding have an effect on temporal resolution?
34. What is frequency tuning?
35. Where does frequency tuning take place?

36. What is coded excitation?
37. Where does coded excitation occur?
38. What are the 5 benefits to coded excitation?
39. What is edge enhancement?
40. What resolutions does edge enhancement improve?
41. What is elastography?
42. What does elastography test for?
43. What are the two types of elastography and how do they each work?
44. What is cardiac strain imaging?
45. What can value shows how effective the heart walls contract?
46. What are the two methods that cardiac strain imaging is performed under?
47. 3D rendering is a _____-processing function.
48. What is 3D rendering?