



ARDMS Topic:
Ultrasound Physical Principles

Unit 21: Acoustic Artifacts

**Sononerds Ultrasound Physics
Workbook & Lectures**

Unit 21: Acoustic Artifacts

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Unit 21: Acoustic Artifacts

Entire Unit 21 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 21: Acoustic Artifacts

In ultrasound, an artifact is anything in the image that doesn't represent the **true** anatomy.

Some artifacts cause fake "anatomy" to appear or real anatomy to "disappear." Sometimes the real anatomy is the wrong shape, size, location or brightness.

There are multiple mechanisms by which artifacts can arise. Most artifacts appear because the machine has made an assumption and the way the sound is interacting with the tissue causes that assumption to be invalid.

→ **An assumption that the machine makes is that sound travels at 1540 m/s.**

We know this to be the propagation speed for soft tissue. In reality though, the beam travels through many different types of tissue and if the average speed for the area we're imaging varies from 1540 m/s then artifacts will appear.

Other assumptions that the machine makes that can result in artifacts include:

- **Sound travels directly to a reflector and back**
- **Reflections only come from anatomy in the main beam path**
- **Sound does not change direction**
- **The beam is narrow in all dimensions**

The machine cannot tell when the returning echoes are invalid, so it displays the data that returns and in doing so, artifacts are created.

Other ways in which artifacts are created are mechanical errors and operator errors. A broken crystal causes dropout, which doesn't represent true anatomy in the area. This is artifact. Same is true if the operator decreases the gain too much, causing anatomy to disappear. This results in artifact as well. Outside sources of energy like medical equipment can also cause distortion of anatomy in the image.

Artifacts can be categorized based on invalid assumptions and what they do to the image/anatomy.

- **Resolution Artifacts**
- **Position Artifacts**
- **Attenuation Artifacts**

When studying artifacts focus on what the artifact looks like first. You should be able to name an artifact based on its appearance in the image.

Next, try to understand what assumption(s) is invalid, and why the artifact occurs. As a sonographer, it is also going to be important for diagnostic clinical imaging to know how to correct for an artifact, when to leave it because it adds to a diagnosis or know that it is what it is, because, well physics!

Section 21.1 Resolution Artifacts

Resolution artifacts occur when the detail in the image does not represent true anatomy. These artifacts typically occur because the beam is not as narrow as it needs to be in **all** planes.

Resolution artifacts are associated with:

- **Poor axial resolution**
- **Poor lateral resolution**
- **Poor elevational resolution (slice thickness)**

The physics behind these artifacts was previously covered in detail in our resolution units, but let's review them briefly.

21.1.1 Axial Resolution

$$\text{Axial Resolution} = \frac{SPL}{2}$$

Recall that axial resolution is related to the spatial pulse length.

When 2 objects that are parallel to the sound beam sit less than $\frac{1}{2}$ the SPL from one another, the machine will display them as one object.

Reality

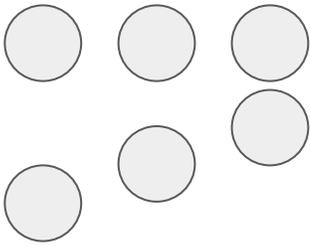
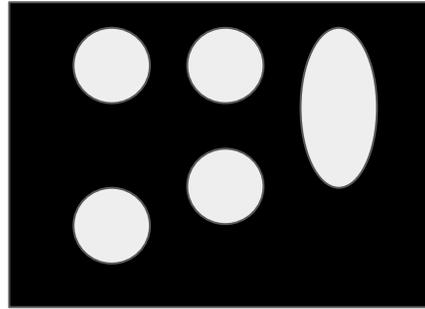


Image with Artifact



The resulting image does not accurately represent the anatomy as 2 reflectors, therefore this is artifact.

Poor axial resolution is typically seen with **low frequency** transducers.

To reduce the chances of this artifact, the sonographer should use the highest frequency possible that allows the sound to reach the depth of the anatomy.

21.1.2 Lateral Resolution

Lateral resolution is equal to the sound beam width. When 2 objects that are perpendicular to the sound beam sit less than the beam width from one another, the machine will display them as one object.

Reality

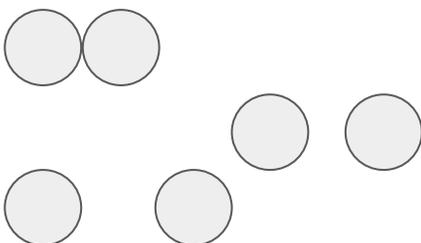
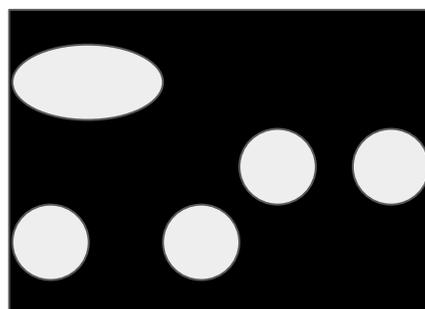


Image with Artifact



The resulting image does not accurately represent the anatomy as 2 reflectors, therefore this is artifact. **This is also known as point spread artifact.**

To improve lateral resolution, the area of interest should sit within the focal zone of the beam. The sonographer typically places the focal point at the area of interest for the best lateral resolution.

21.1.3 Elevation Resolution

Elevational resolution is related to how thick the beam is. If the beam is too thick, echo information from above or below the slice can be detected in the image.

Reality

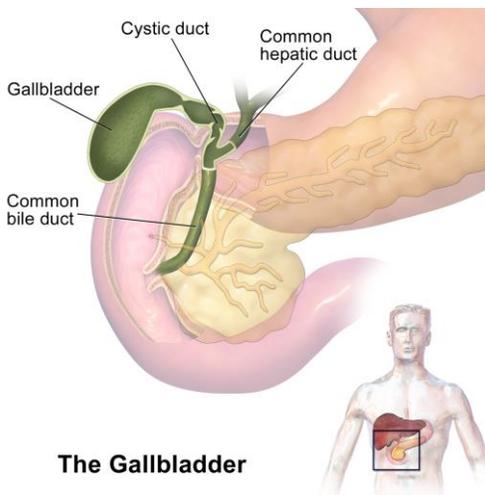
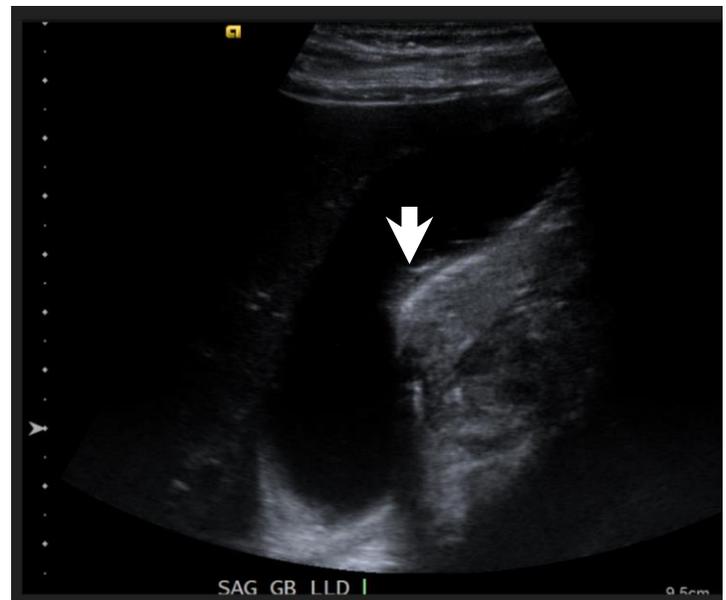


Image with Artifact



When elevation resolution is poor, the artifact is known as **slice thickness artifact, partial volume artifact or section thickness artifact.**

In this image, we can see part of the duodenum being recorded as if it was in the gallbladder lumen. Elevational resolution partially overlaps with position artifacts because it causes reflections to be in the wrong locations. Slice thickness artifact will be most apparent in structures that should not have echoes within. They will appear as low level echoes.

To correct this, the sonographer should try a 1 ½ D array transducer, annular transducer or use harmonics.

Section 21. 2 Position Artifacts

Position artifacts are artifacts in which anatomy appears in the **wrong location**.

Anatomy can be displayed in the wrong location because:

- **Sound changed direction**
 - Refraction
 - Mirror Artifact
 - Multipath Artifact
- **All sound didn't return directly to the transducer**
 - Reverberation
 - Ring Down/ Comet Tail Artifact
 - Mirror Artifact
 - Multipath Artifact
- **Sound energy from outside of the main beam interacted with reflectors**
 - Grating/Side Lobes
 - Slice Thickness
- **Propagation speed issues**
 - Speed Error
 - Range Ambiguity

Remember the machine is like a big stopwatch. The machine times how long it takes for pulses to be sent and reflections returned. This is how it knows what depth to place those echoes. It also expects that echoes returning come from the direction the beam was steered and places returning echoes along that path.

A lot of the artifacts that we see are positional. For some, a change in transducer angulation resolves the artifact, for many of them though, the artifact is result of acoustic physics.

21.2.1 Refraction

Refraction occurs when sound enters the body and the “bends” or changes directions from the original path of the beam.

The beam expects that any reflections that are coming back are from the original path. When other reflections come back, they are mapped to that path.

→ **Refraction artifact causes an exact replica of anatomy to be placed to the side of true anatomy**

The side by side or lateral placement of the false anatomy also degrades **lateral** resolution as it obscures the anatomy that should be there.

Reality

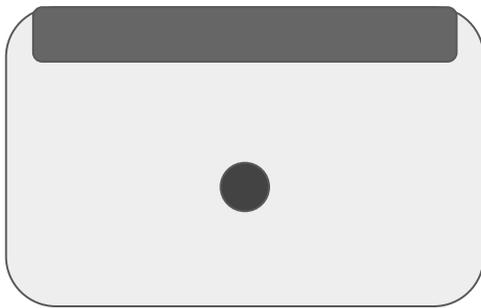
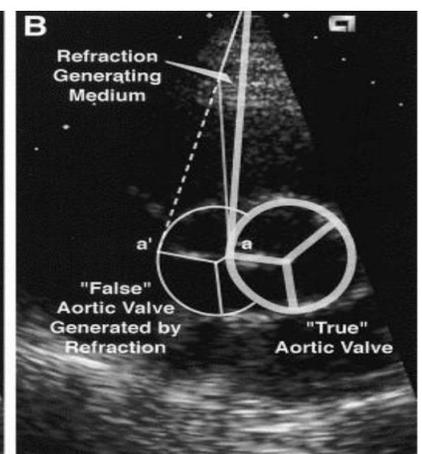
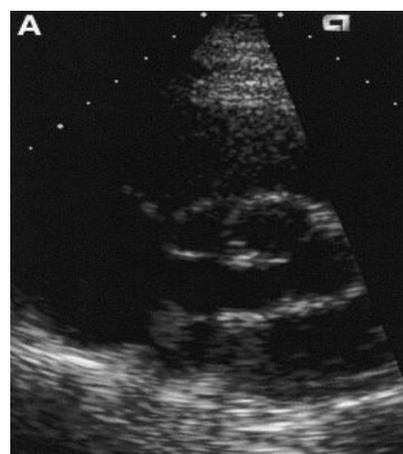
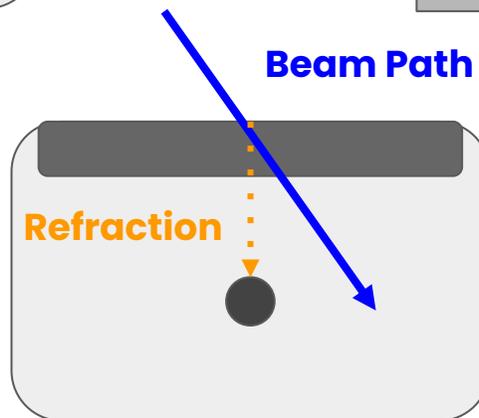
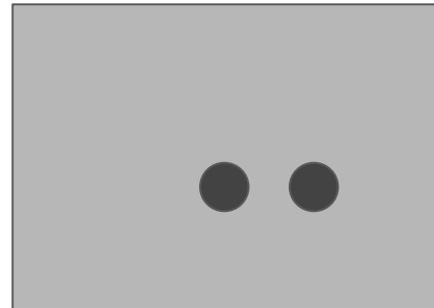


Image with Artifact



21.2.2 Mirror Artifact

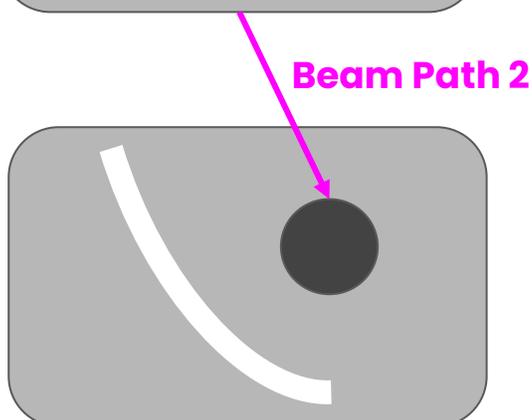
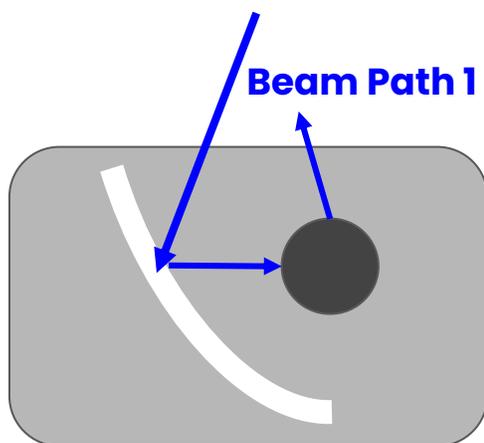
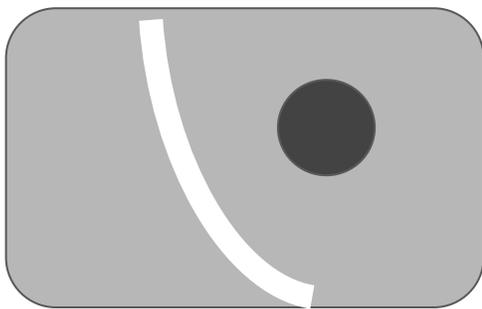
Mirror artifacts occur when sound interacts with a strong, specular reflector at an oblique incidence. The beam is reflected towards another structure causing sound to travel in another direction before heading back to the transducer.

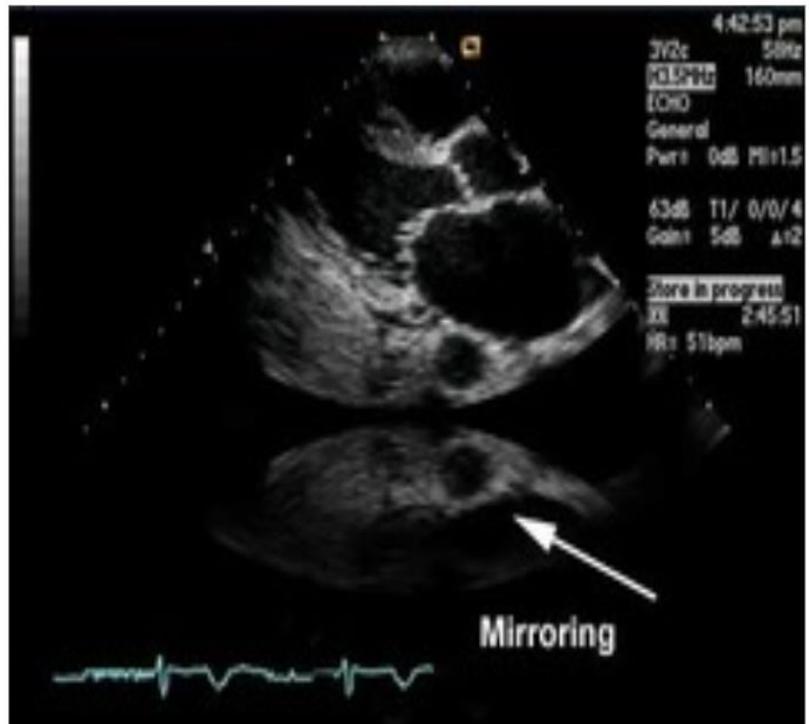
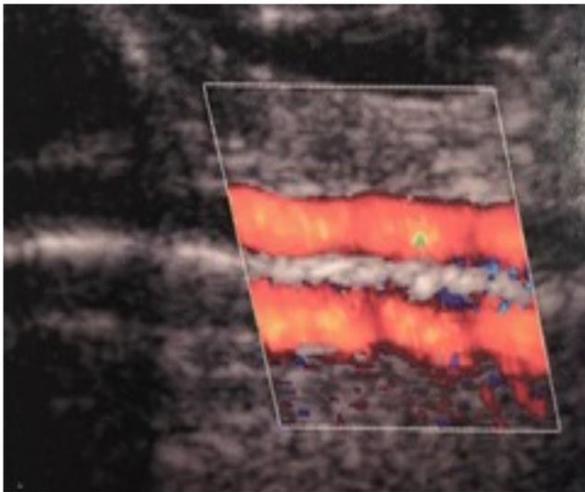
Mirror artifacts are more likely to occur near **air filled structures like the lungs**. The **diaphragm** is commonly involved as the specular reflector causing the mirror artifact. Vessel walls and chamber walls are also strong enough reflectors to create mirror artifact.

→ **Mirror artifacts create an exact replica of anatomy that is deep to the true anatomy.**

Reality

Image with Artifact





Examples of mirror artifact, all taking place near the lungs. The deep "anatomy" is the artifact. Changing the angle of insonation will help with mirror artifact. As will reducing the gain.

21.2.3 Multipath Artifact

Multipath artifact is another example of sound changing direction before returning to the transducer. This is similar to mirror artifact, but this time it is the specular reflector that is placed deeper artifactually.

The beam path interacts with the specular reflector at an oblique angle, and the sound is redirected to another off axis strong reflector. It will bounce off of this reflector and return to the transducer. This lengthens the path of the specular reflection echoes, meaning they will be placed deeper in the image.

→ **Multipath artifacts create similar appearing anatomy that is deep to the true anatomy.**

Reality

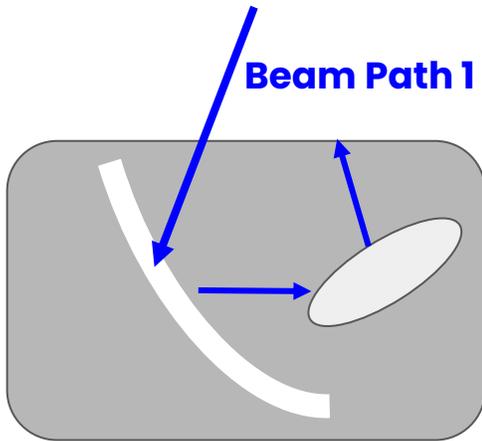
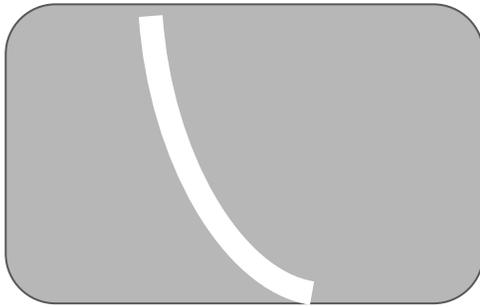
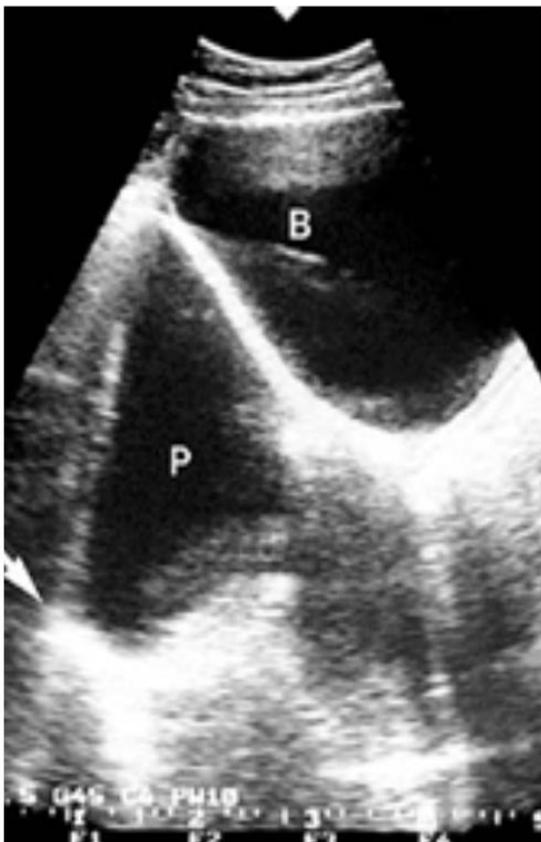
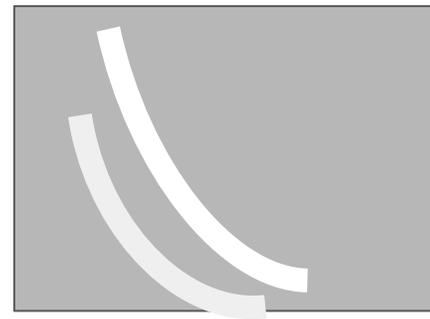
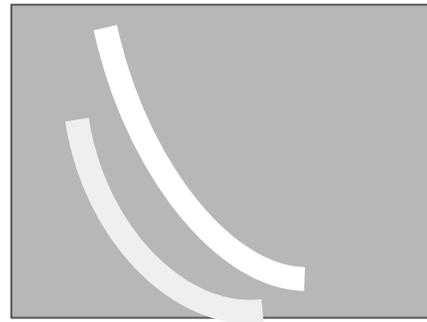


Image with Artifact



Example of multipath artifact. The bladder (B) walls are strong reflectors, the sound bounces around a little bit and because of the gas in the bowel, the multipath artifact is created. A similar structure to the bladder appears deeper to the true anatomy. Changing the angle of insonation will help with multipath artifact.

21.2.4 Reverberation

Reverberation artifact occurs when sound bounces between two reflectors. With each “bounce” a lot of sound energy is redirected to the other reflector and some returns to the transducer.

The transducer reads each “bounce” as returning echoes that each take a little longer to return so the machine places them each a little deeper into the image. Reverberation occurs at many interfaces in the body. The stronger the reflectors are, the more apparent the reverberation artifact appears.

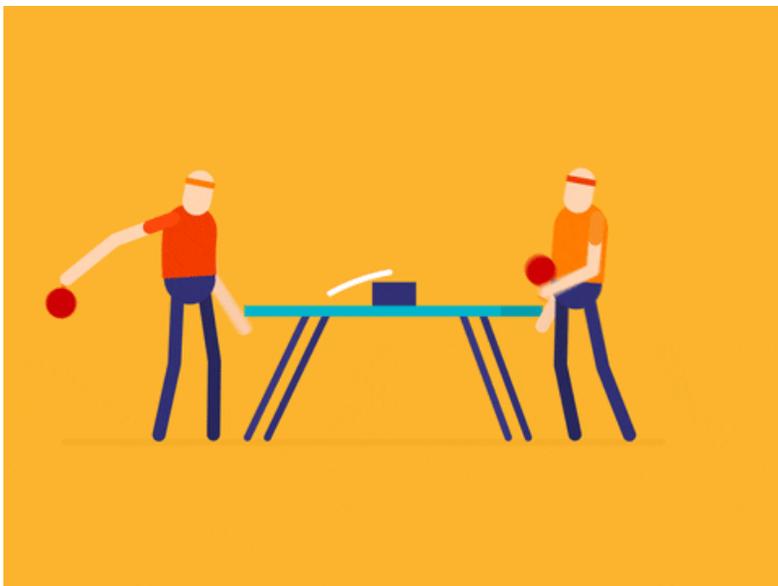
The transducer and specular reflectors can cause reverberation. So can two specular reflectors in the body. It is also commonly seen with devices such as needles or mechanical valves.

→ **Reverberation artifact causes equally spaced reflectors to be displayed deep in the image.**

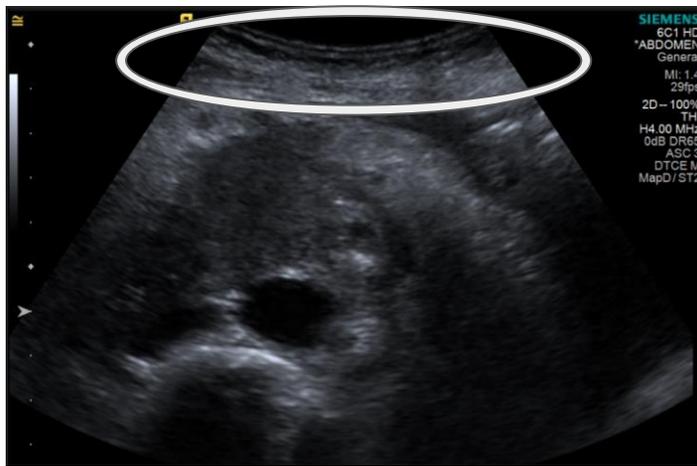
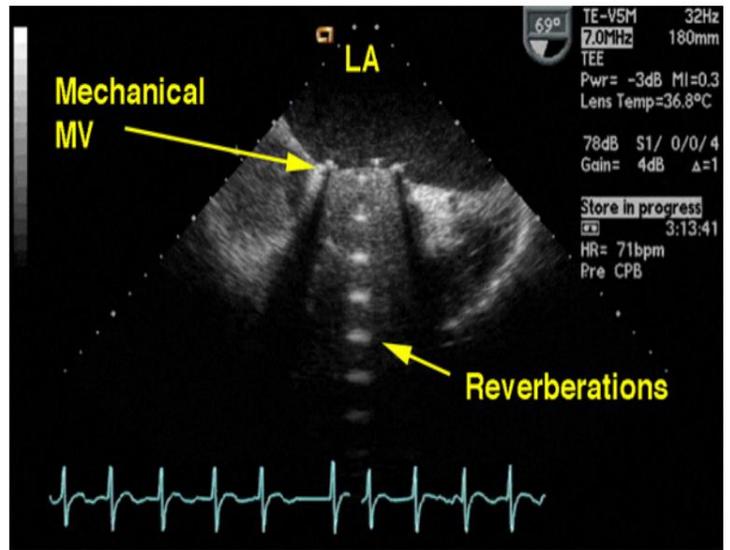
Reality



Image with Artifact



The sound “ping-pongs” between reflectors. Each creating a deeper reflector.



Reverberation is more apparent behind strong reflectors, but often occurs throughout many interfaces in the body.

21.2.5 Ring Down Artifact

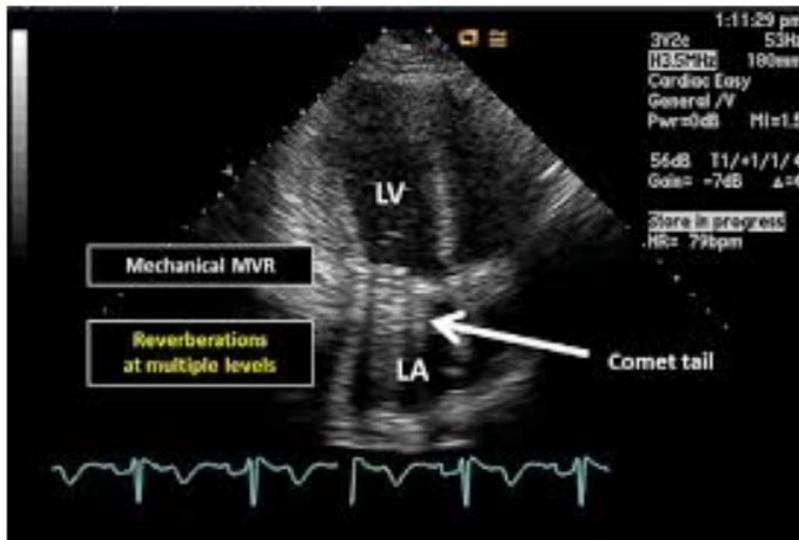
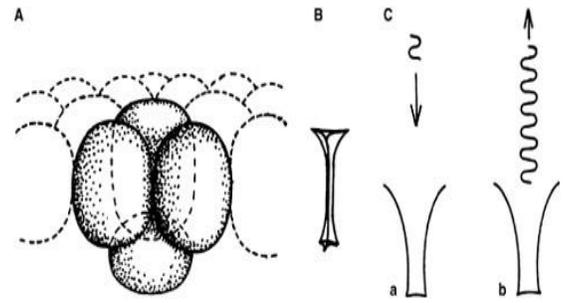
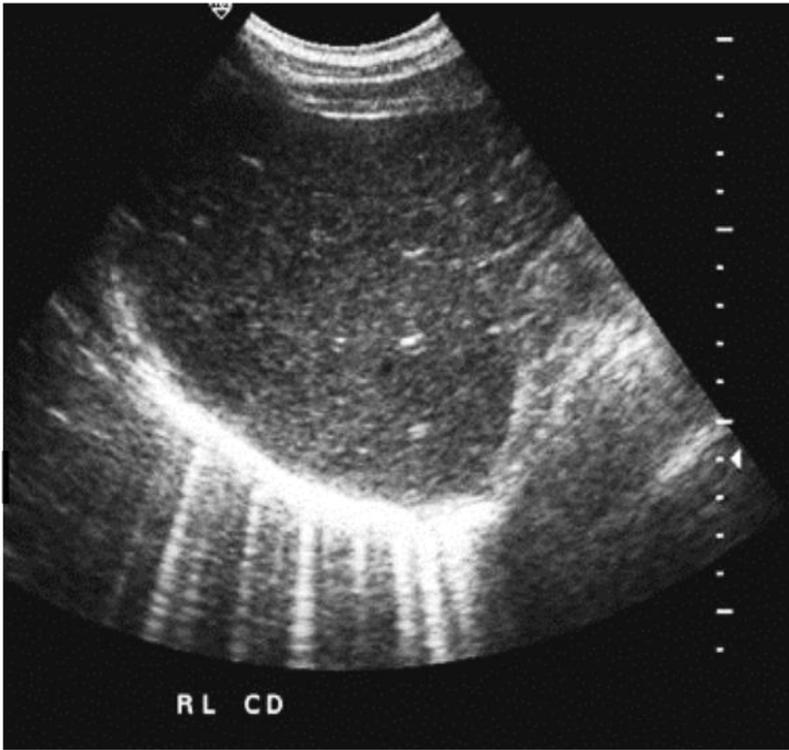
Ring down artifact occurs under the same conditions as reverberation, but arise from structures that are MUCH closer together. The spaces appear almost “squeezed” out and a more dense line appears.

Ring down artifact is also known as comet tail artifact.

→ **Ring down artifact causes a bright line parallel with the sound beam path due to sound bouncing between small structures.**

Ring down artifact can aid in the diagnosis of some diseases. For example, comet tail artifact is often seen behind small air bubbles. Air in the biliary tree would exhibit ring down. It is also seen with adenomyomatosis of the gallbladder or with small surgical clips.

The lungs are common place to see ring down artifact because of the interaction of sound and the air bubbles.



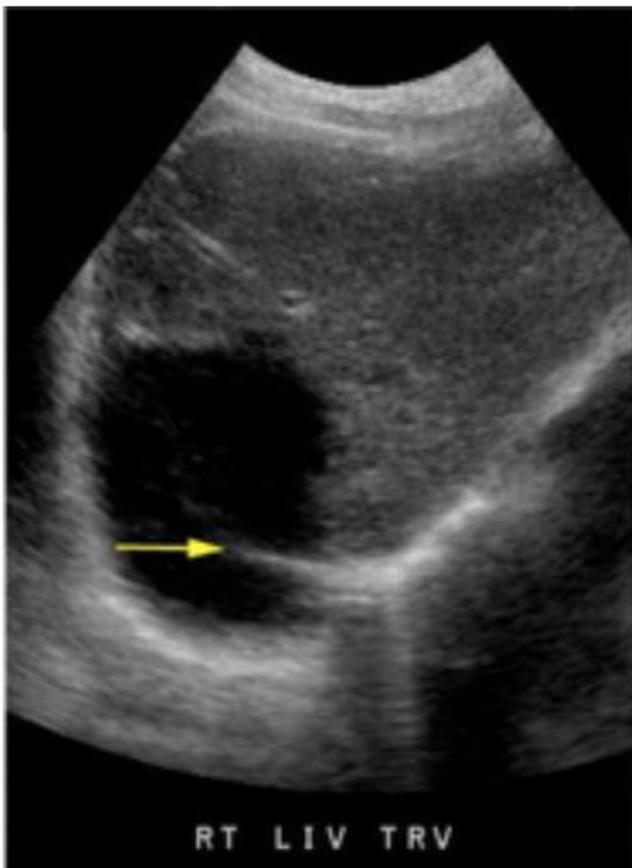
21.2.6 Lobe Artifact

Lobe artifact occurs when sound energy escapes the main beam and interacts with strong reflectors. The system believes these echoes are returning from the main beam and displays those echoes in the image.

→ **Lobe artifact incorrectly displays echoes from anatomy that is lateral to the main beam.**

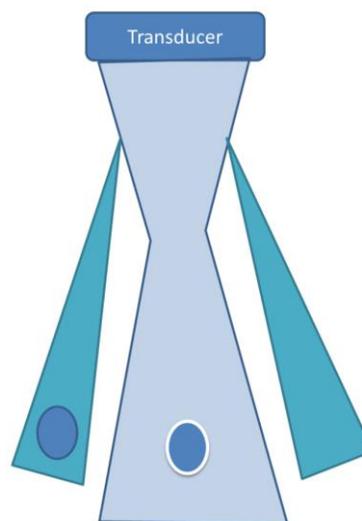
These are usually low level echoes that are more apparent over areas that should be free of echoes. If strong enough, they can produce a replica of the off axis strong reflector.

Side lobes are the result of single element transducers, where grating lobes are the result of array transducers. Array transducers can use **apodization** to reduce grating lobes. **Subdicing** can be used on single or array elements to reduce lobe artifact.



Lobe artifact is similar to slice thickness, but recall that slice thickness is above and below the anatomy, where lobe artifact is side to side. Because it is side to side, **lobe artifact degrades lateral resolution.**

When artifacts appear over anechoic areas, they can mimic pathology. Make sure to always try different angles and different planes to determine real pathology/anatomy from artifact.



21.2.7 Speed Error

Speed error occurs when the medium sound is traveling through is different than 1540 m/s. Faster propagation speeds result in a shallower placement of echoes, where slower propagation speed result in a deeper placement of echoes.

→ **Speed error artifact makes anatomy appear “broken” or displaced due to propagation speeds other than 1540 m/s.**

Fat has a propagation speed of about 1450 m/s. Structures under fat tend to be placed deeper.

Reality

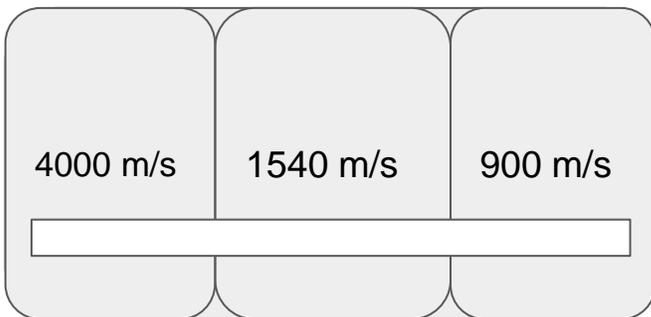
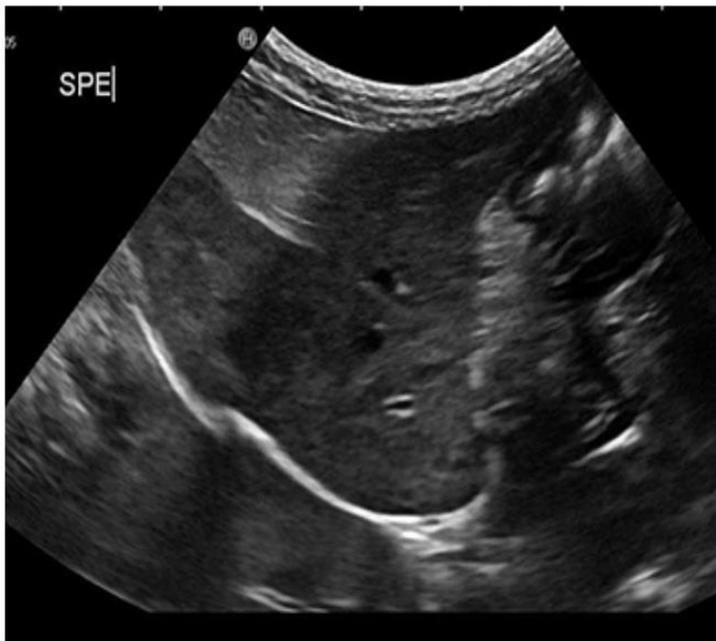


Image with Artifact



21.2.8 Range Ambiguity

Range ambiguity is very similar to aliasing in Doppler, but in the 2D image. The machine isn't supposed to send another pulse until all echoes return. However, some echoes come back after the next pulse is sent. These echoes appear in the next pulse's image.

Range ambiguity artifact is more prevalent when the image depth is very shallow. The sound will still continue to propagate and interact with reflectors. Once those reflections come back, they will be displayed in the shallow the frame.

Reality

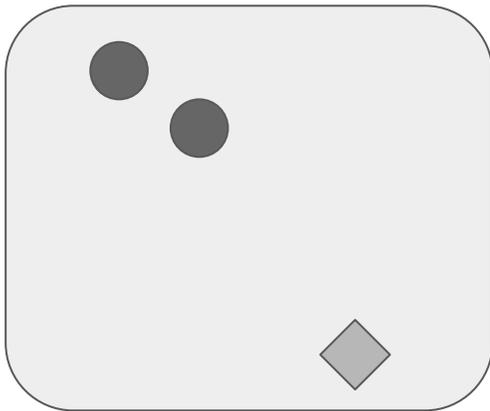


Image with Artifact



Increasing the depth will solve the issue of range ambiguity to reduce the PRF and include anatomy that was causing the artifact.

Section 21.3 Attenuation Artifacts

Attenuation artifacts occur when sound interacts with a reflector and the attenuation of sound is either greatly affected or minimally affected.

In ultrasound, we rely on the echogenicity of tissue to help tell us more about it. If the attenuation over a section of anatomy causes it to appear overly dark or overly bright, then the resulting image has artifact in it.

Attenuation artifacts also help to tell us more about the reflector causing the change in attenuation. Sometime we leave attenuation artifacts because they aid in a diagnosis.

Attenuation artifacts include:

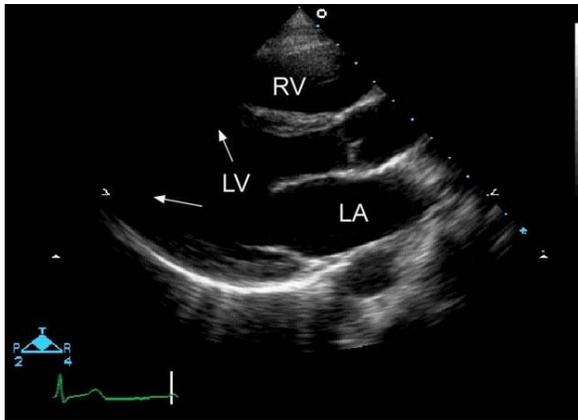
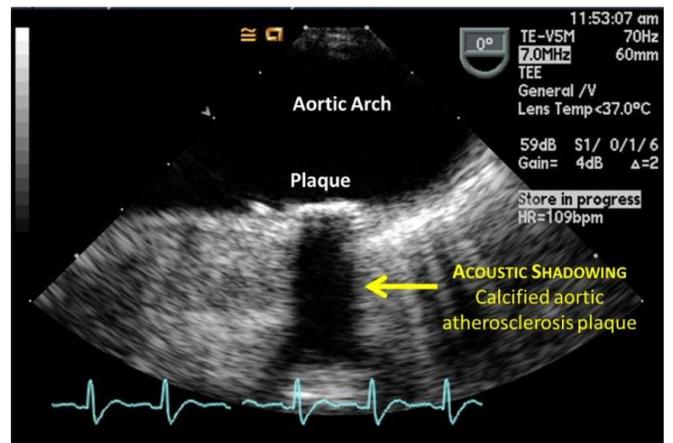
- Shadowing
- Edge Shadow (overlaps with beam direction change)
- Enhancement
- Focal Enhancement

21.3.1 Shadowing

Shadowing occurs when the sound energy is attenuated greatly by a structure. The result is that there is not enough sound energy behind the structure to continue producing echoes, so the machine sees this area as having no echoes and it is coded as an anechoic area.

- **Shadowing is the result of sound interacting with highly attenuating structures**
 - ◆ **The result is an anechoic (no echoes) area on the image OR**
 - ◆ **Hypoechoic (darker than expected) area on the image**

Shadowing is very helpful for diagnosing calcified anatomy and pathology like plaque, gallstones, kidney stones, etc. The sonographer needs to decide if the shadows should be “worked around” or if they should stay in the image.

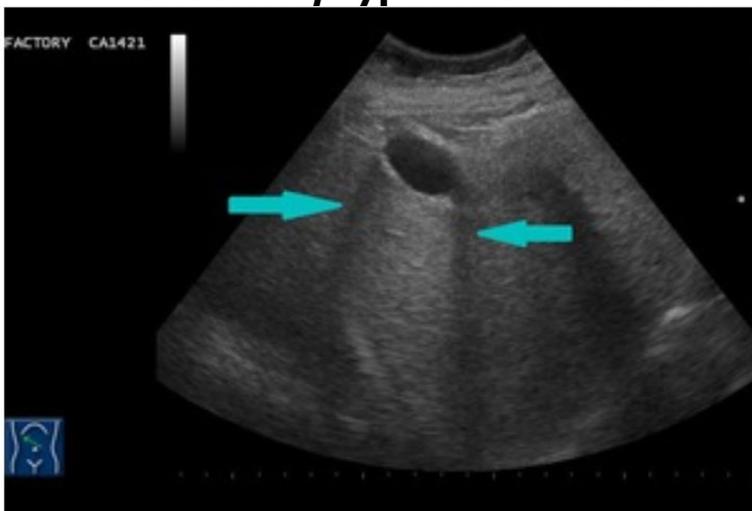


Sonographers should work around shadows that obscure the anatomy.

21.3.2 Edge Shadow

Edge shadow appears similar on the image to regular shadowing, but instead of attenuation due to a structure, the sound beam refracts & diverges due to a rounded interface. The refraction sends the sound energy in another direction and the divergence weakens the beam, leaving no sound energy for what is directly behind the curve. Spatial compound can help get rid of edge shadows.

→ **Edge shadow is seen with curved structures, creating an anechoic/hypoechoic line behind the curve due to refraction &**

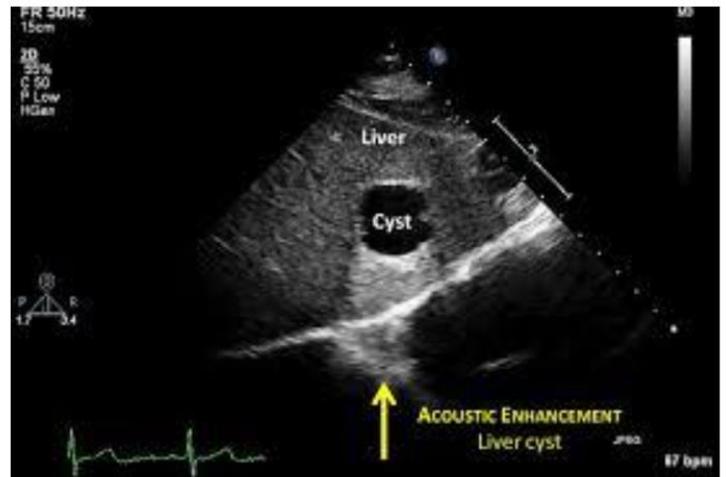
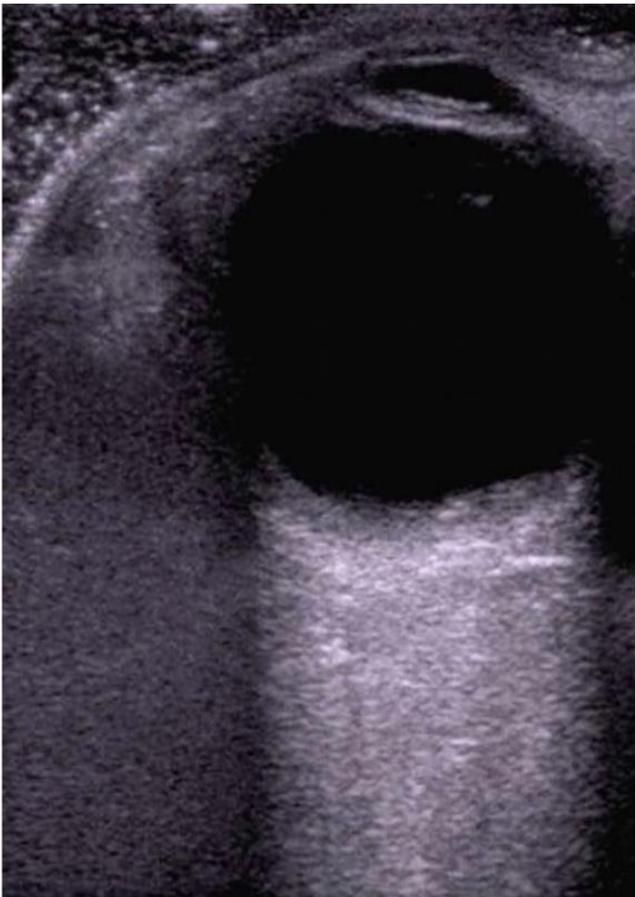


21.3.3 Enhancement

Enhancement occurs when the sound energy is minimally attenuated by a structure. The result is that there is a lot more sound energy behind this structure, making these structures reflect more sound, which the machine codes as brighter echoes.

- **Enhancement is the result of sound interacting with low attenuation structures**
 - ◆ **The result is hyperechoic (brighter echoes) anatomy behind the area on the image**

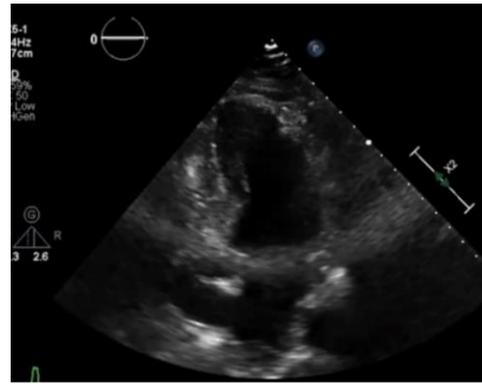
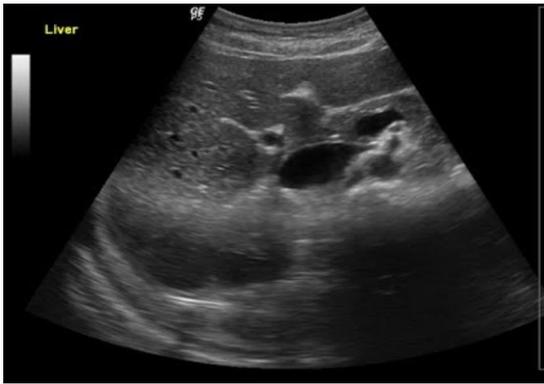
Enhancement is helpful in distinguishing cysts or other water-like fluid filled structured. Solid pathology will not typically enhance, where benign fluid filled pathology will.



21.3.4 Focal Enhancement

Focal enhancement operates under the same principle of regular enhancement that there is more sound energy in an area. With focal enhancement the sound energy is increased at the focal point and a band of increased echogenicity arises from this area. Using TGCs can easily correct for focal enhancement.

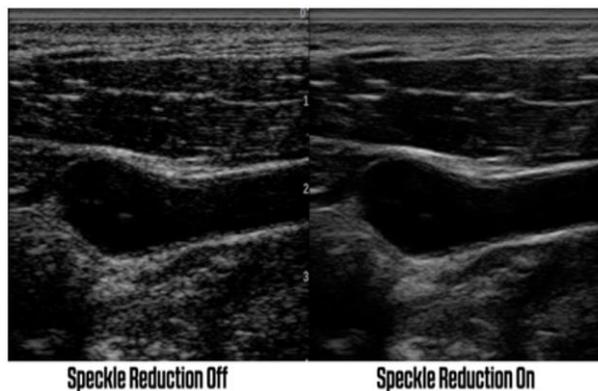
- **Focal enhancement causes a horizontal band of hyperechoic tissue due to the increased intensity of sound energy at the focus.**



Section 2.4 Other Artifacts

At the top of the unit I mentioned that artifact is anything that doesn't really represent anatomy. One of the key features of ultrasound that allows us to see anatomy is the idea that echoes will interfere with one another creating tissue texture. This is called speckle and is technically an artifact. Speckle adds a grainy appearance to the entire image, especially prevalent in the near field. Modern ultrasound machines do have techniques in which speckle can be reduced, but one of the biggest ones is using a high frequency transducer.

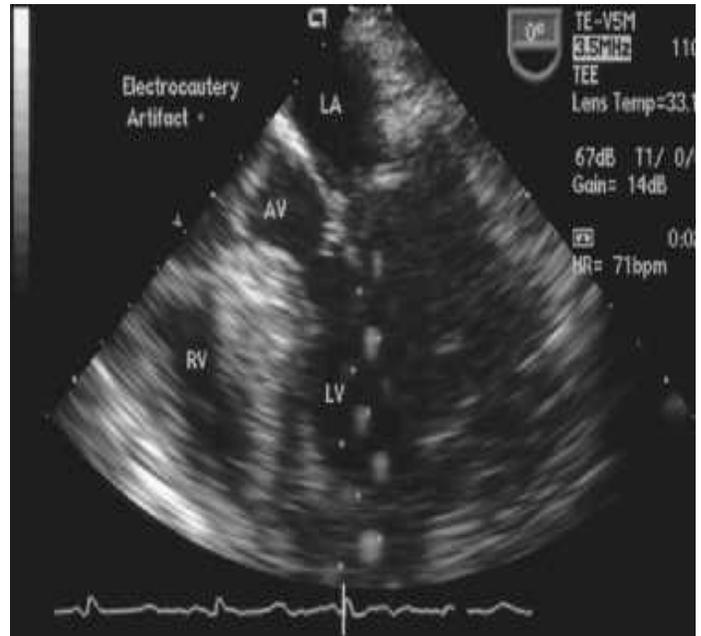
Another method is using **speckle reduction**. This helps to smooth the tissue out which improves sensitivity and appearance.



Other things can cause interference in the image from outside the body and the ultrasound system.

These include:

- Electronic interference
- Other machines, surgery cautery
- Biological interference
- Talking, external noise



Remember there are many techniques that are used to reduce the appearance of noise, speckle, enhancement and shadowing that we learned about in Unit 15a.

These included:

Spatial Compounding - combined images from 3 differently steered beams

Frequency Compounding - combined images from different frequencies

Coded Excitation- Complex pulses that are "uncoded" upon reception

Never set your image and forget it - make adjustments when necessary to the gain, depth and focus to make sure always getting the best image possible.

[Section 21.5 Activities](#) ← [Link to Answers](#)

Drag the name of the artifact to the image.



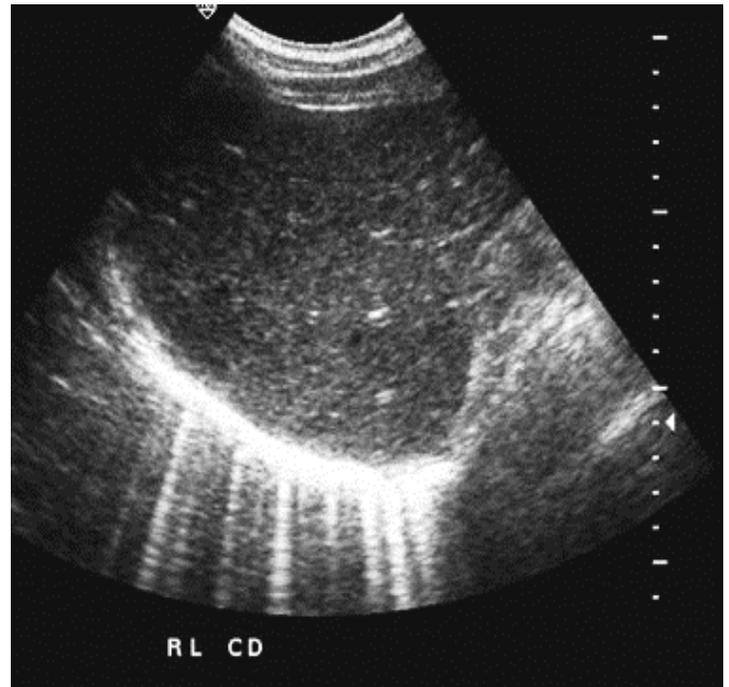
What kind of artifacts are these? What are 2 key things about each?

Positional

- Due to sound changing direction
- Exact replica side by side
- Degrades lateral resolution

Positional

- Due to sound changing directions
- Sound obliquely strikes a strong reflector
- Exact replica deep



What kind of artifacts are these? What are 2 key things about each?

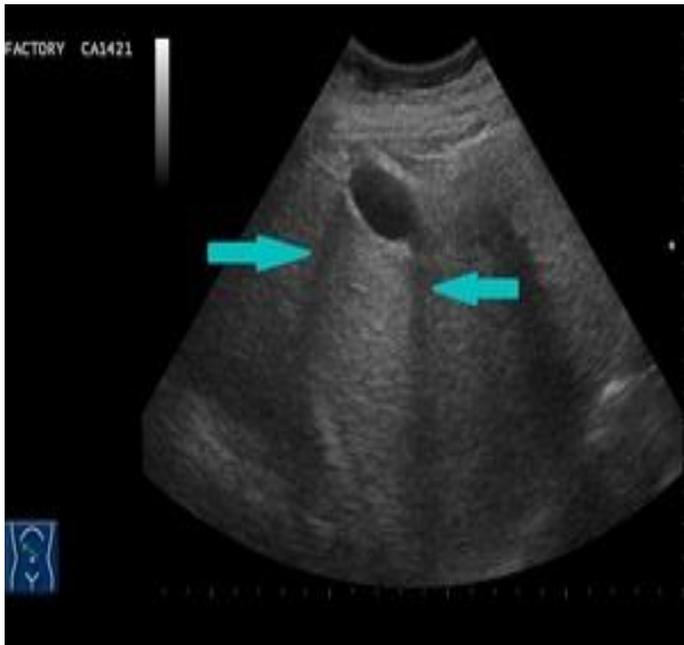
Positional

- Due to sound bouncing in between two reflectors
- Equally spaced reflectors deeper into the image

Positional

- Due to small air bubble or small structures
- Parallel with the sound beam
- Hypoechoic line with spaces squeezed out
- Special type of reverberation

Drag the name of the artifact to the image.



What kind of artifacts are these? What are 2 key things about each?

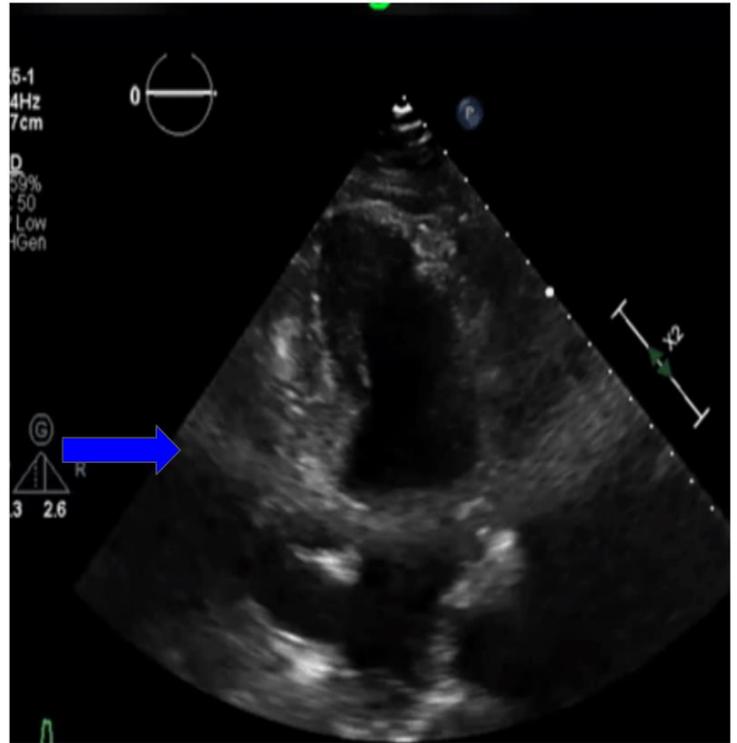
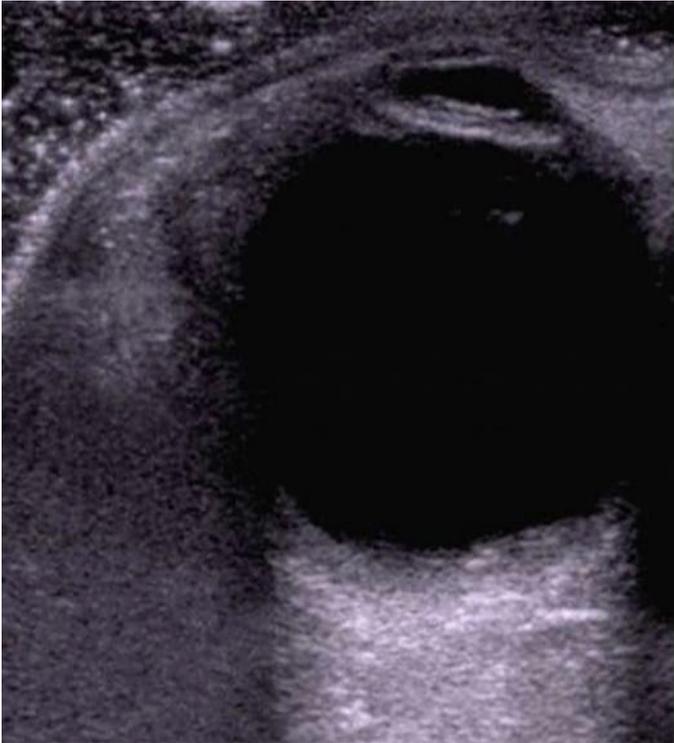
Attenuation

- Found with curved edges
- Beam diverges
- Dropout parallel with sound beam

Attenuation

- Found behind highly attenuating structures
- Can help to diagnose
- No sound energy left to image behind

Drag the name of the artifact to the image.



What kind of artifacts are these? What are 2 key things about each?

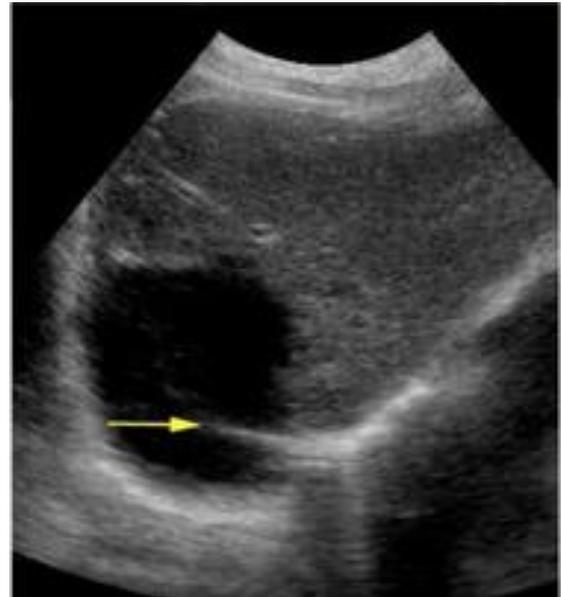
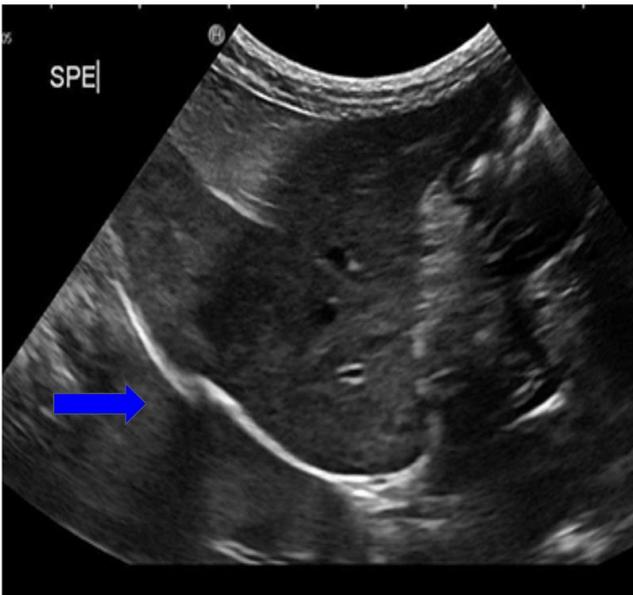
Attenuation

- Found behind low attenuation structures
- Cause the tissue to be brighter
- Fluid filled structures

Attenuation

- Found at the focus
- Greatest intensity increases brightness
- Fix with TGCs

Drag the name of the artifact to the image.



What kind of artifacts are these? What are 2 key things about each?

Position

- Anatomy appears broken
- Different propagation speeds
- Faster = shallower
- Slower = deeper

Position

- Grating lobes from array transducers
- Degrades lateral resolution
- Anatomy from side comes in
- Apodization can fix

Section 2.6 Nerd Check!

1. What is an artifact in ultrasound?
2. What are the assumptions a machine makes?
3. Why do these lead to artifacts?
4. What are some other things that can cause artifact unrelated to machine assumptions?
5. What are the 3 general categories of artifacts?
6. What are the resolution artifacts?
7. What assumption do they mainly invalidate?
8. What is axial resolution?
9. How can axial resolution be improved?
10. How does poor axial resolution with artifact appear in the image?
11. What is lateral resolution?
12. How does poor axial resolution with artifact appear in the image?
13. What determines lateral resolution?
14. What is another name for unresolved reflections?
15. What is elevational resolution?
16. What is another name for elevational artifact?
17. What can be done to remove elevational artifact?
18. What are position artifacts?
19. How are they, in general, created?
20. Why is the machine keeping track of time from pulse to echo important?
21. For these artifacts list: What is it? How does it look on the screen? What causes it? Can it be fixed?

Refraction, Mirror, Multipath, Reverberation, Ring down / comet tail, Lobe, Speed error & Range ambiguity

1. What are attenuation artifacts?
2. For these artifacts list: What is it? How does it look on the screen? What causes it? Can it be fixed?

Shadow, Edge Shadow, Enhancement, Focal Enhancement

1. What does anechoic mean?
2. What does hyper and hypoechoic mean?
3. What is speckle?
4. What are some outside sources of artifacts?