Sononerds
in the classroom

ARDMS Topic:
Ultrasound Physical Principles

Unit 12b: Resolution #3 (Elevational & Lateral)

Sononerds Ultrasound Physics
Workbook & Lectures

Unit 12b: Resolution #3 (Elevational & Lateral)

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Unit 12b: Resolution #3 (Elevational & Lateral)

Entire Unit 12b 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 12b: Resolution #3 (Elevational & Lateral)

Unit 12 has been divided into 12 a and 12b.

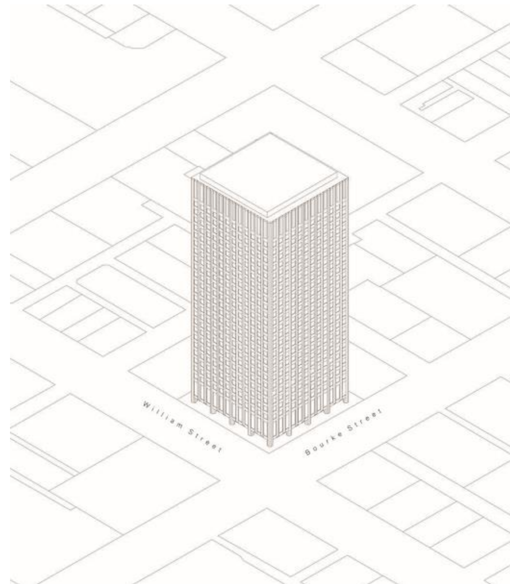
Unit 12a discussed the characteristics of transducers and covered how they each create an image.

Unit 12b will continue the discussion surrounding resolution. In this third resolution discussion, we'll explore what elevational resolution is and how the transducer construction effects it. We will also retouch on lateral resolution and some other things that can improve it.

Section 12b.1 Elevational Resolution

➔ **Elevational resolution is the system's ability to create a thin imaging plane.**

If we think of our transducer beam as a building:



Axial resolution would be walking down the street that comes directly away from the transducer (parallel to the beam) and lateral resolution would be walking down the street that is side to side (perpendicular to beam).

Elevational resolution would be the amount of floors in the building or the height of the beam.

For ultrasound, a beam with "one floor" is MUCH preferred than a beam with "50 floors."

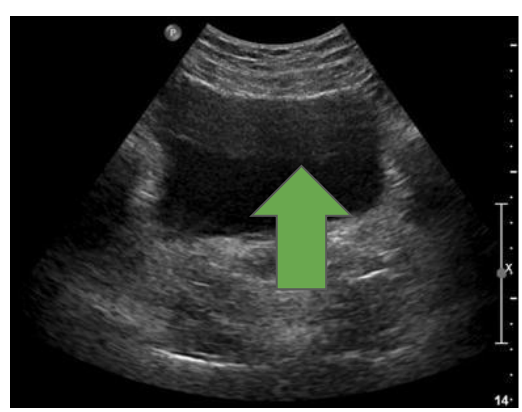
Elevation is the Z-axis.

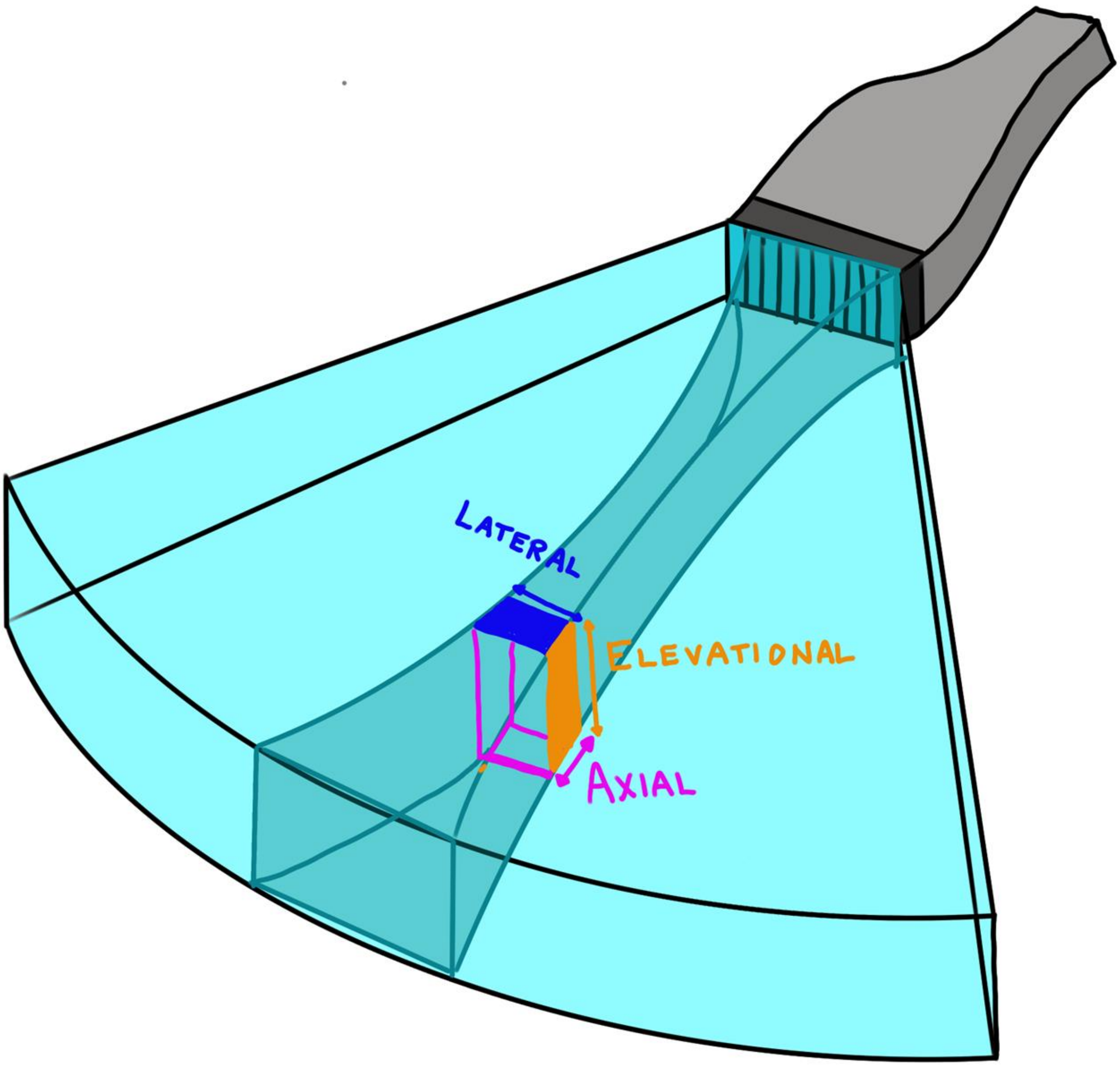
➔ **Improved elevational resolution occurs when the ultrasound beam is thin.**

The thickness of the beam improves (or degrades) image quality. When the beam is thin, then the reflectors displayed are the most accurate representation of the anatomy. When the beam is thick, the reflectors displayed not only represent reflectors in the center of the beam, but we start to see some reflectors from different heights of the beam too.

The unwanted reflections are not always apparent in our images, sometimes they just blend in as extra "noise" in the image. However, when you are imaging structures you expect to be anechoic or echo free, sometime you will see artifact within. This is often reflections occurring because of the thickness of the beam.

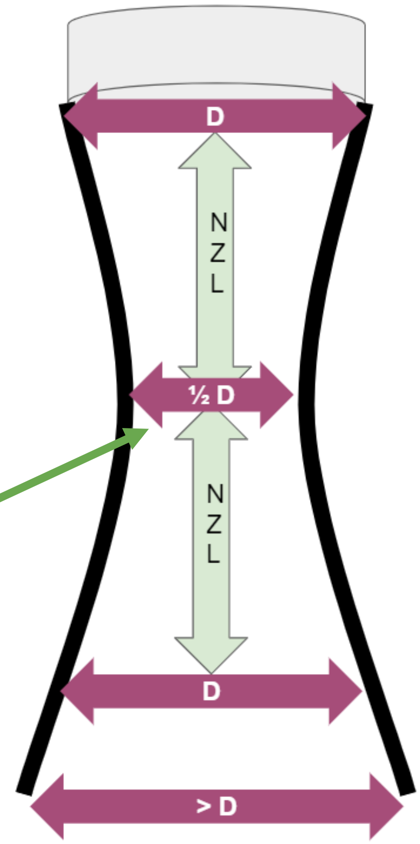
➔ **Elevational resolution is also known as SLICE THICKNESS resolution.**




LATERAL
ELEVATIONAL
AXIAL

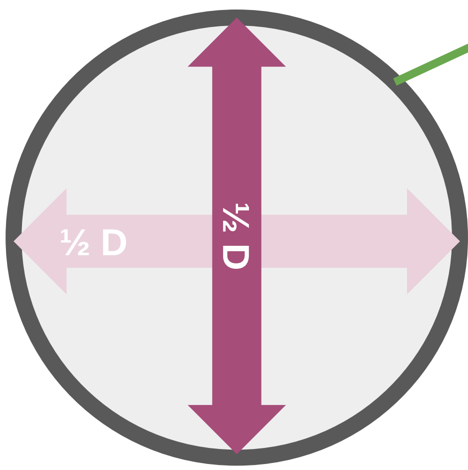
12b.1.1 Disc Shaped Elements

The slice thickness of a beam is dependent on the transducer. Recall that we learned about two transducers that have disc shaped elements - the mechanical transducer and the annular transducer.



We also learned with single element transducers that the diameter of the crystal will determine the diameter of the beam at the focus.

If we were to look at the cross section of the beam so we could see the height or elevation of it, we would see that the beam is circular.

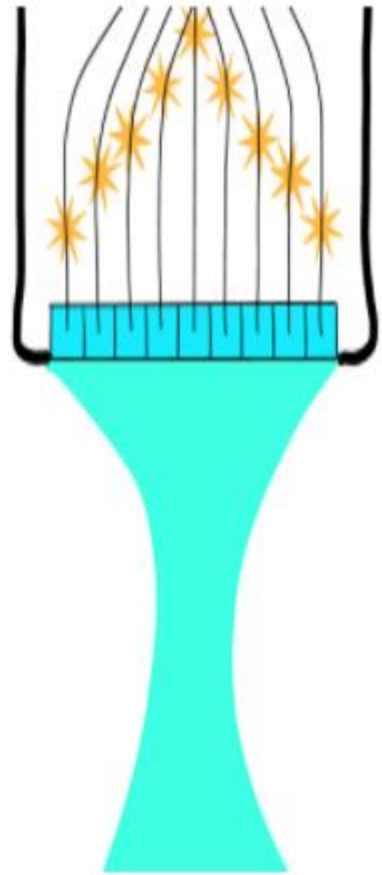


And it turns out the the width of the beam is the same as the height of the beam.

- ➔ **Elements that are disc shaped create the best elevational resolution.**

But we don't use these type of transducers anymore...

12b.1.2 1D Element Arrays



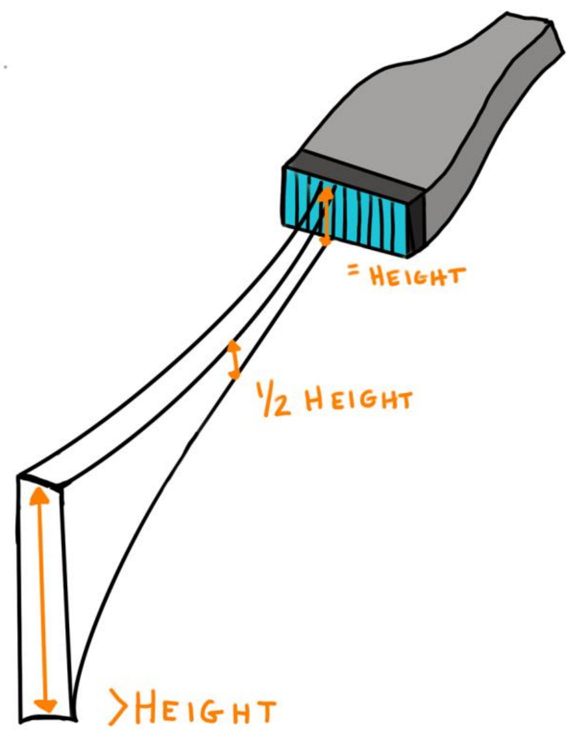
Our modern transducers use multiple, rectangular shaped elements to create an array. We learned that with this type of transducer, focusing can be achieved in the lateral plane by phasing the electrical pulses in a curved pattern.

The phasing helps the beam to be thinner in the lateral plane, but does not change the elevational thickness.

For **1D element arrays**, to improve elevational thickness, these types of transducers usually employ an **acoustic lens** to focus the beam in the elevation plane, creating a **fixed** thickness to the beam.

With the fixed focusing in the elevational plane, we see the beam thickness:

- Same height as the element at the beginning
- ½ the element height at the focus
- Diverging in the far field



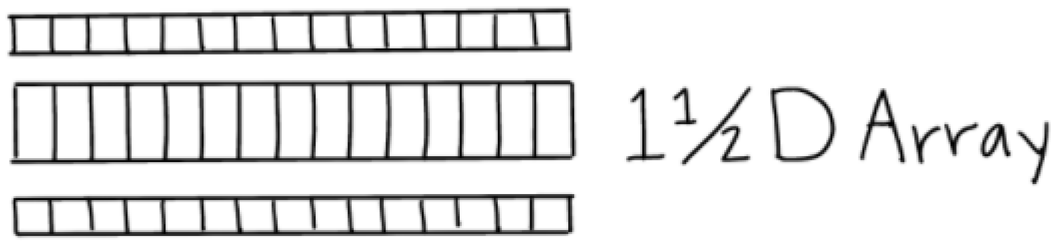
When a lens is used for the slice thickness, we see the quality of the resolutions, from best to worst is:

Axial → lateral → elevational

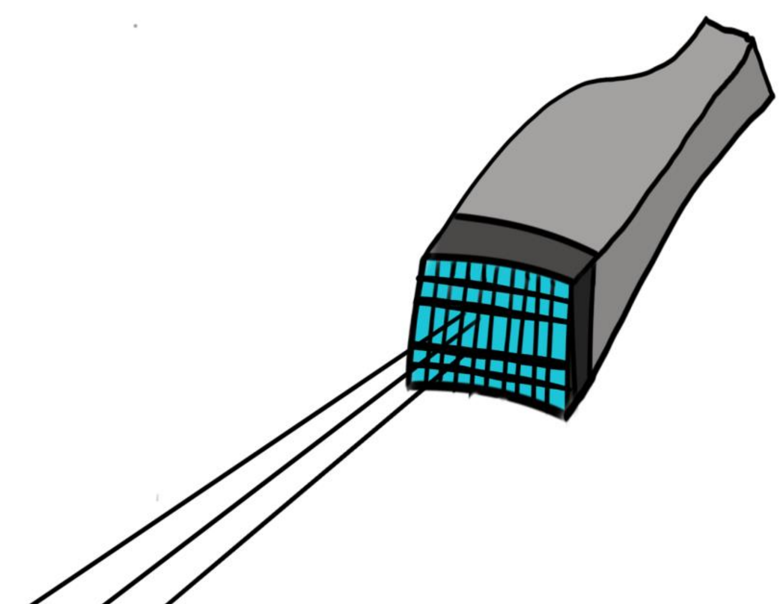
12b.1.3 1 ½ D Element Arrays

Instead of just one row of elements, manufactures started to develop transducer that have multiple rows of elements. If the number of elements across the face of the transducer does NOT equal the number of elements up the face of the transducer, it is considered a 1 ½ D array transducer.

For example, a transducer might contain 300 elements: 3 rows, of 100 each. This would be a 1 ½ D array. (If it was 100 rows x 100 elements that would be a 2D array.)



When there are multiple elements along the height of the transducer, **phasing** can be used, just like it is is for focusing the beam laterally to focus the beam elevationally. When the sonographer moves the focus, the machine will change the curve pattern for both the lateral and elevational voltages to optimize the beam width and thickness at the focal point.



→ 1 ½ D array transducers improve elevational resolution

Section 12b. 2 More Lateral Resolution

Now that we know more about transducers, there are a few new concepts about lateral resolution that we can explore. First, how the sound beam's energy affects lateral resolution and how the array transducer can improve lateral resolution at deeper depths.

12b.2.1 Lobes

Up until this point, we have discussed a transducer beam that has sound energy moving out of the transducer with a very definitive border. In reality, sound sound escape the central sound beam. This sound is known as **lobes** and comes in two types:

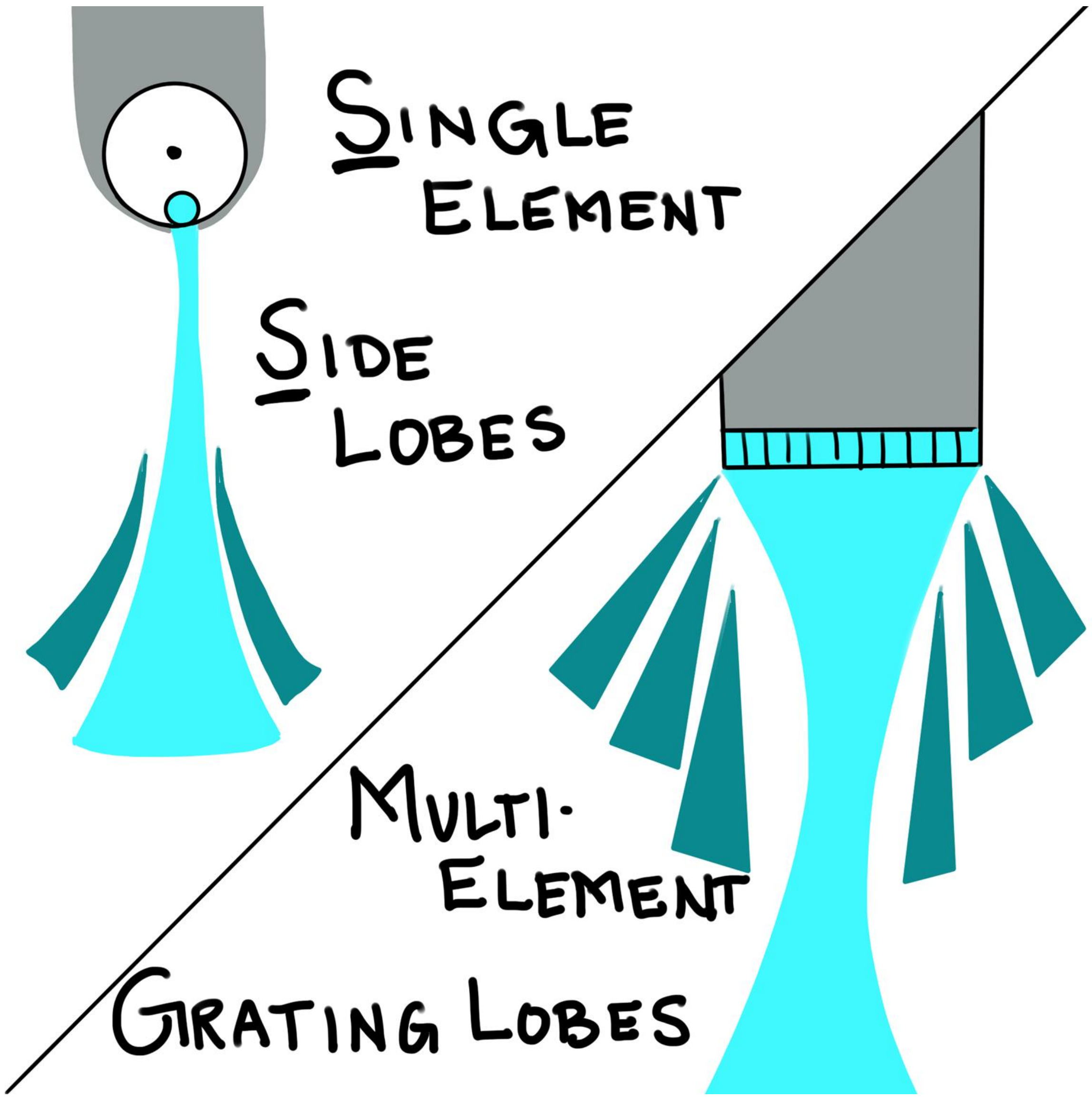
- ➔ **Single element transducers produce side lobes.**
- ➔ **Multi-element transducers produce grating lobes.**

- ➔ **Both types of lobes degrade lateral resolution.**

When lobes are present, the sound energy from them can be strong enough to interact with tissue in a way that meaningful echoes will return to the transducer. Since the lobes essentially widen the beam, the lateral resolution worsens and more artifacts are seen in our image.

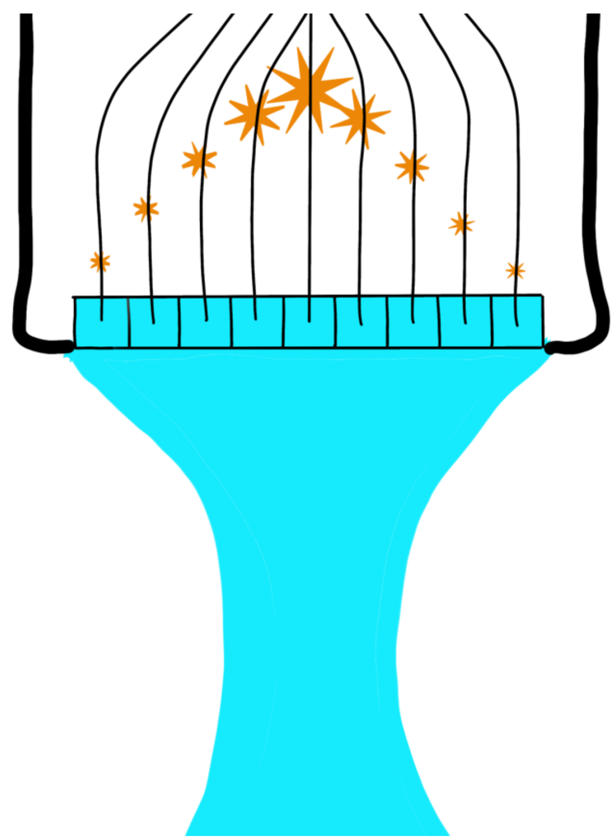
Side lobes are inherent to the single element transducer. However, there are two techniques that can help with reducing grating lobes in the array transducer:

- ➔ **Apodization**
- ➔ **Subdicing**



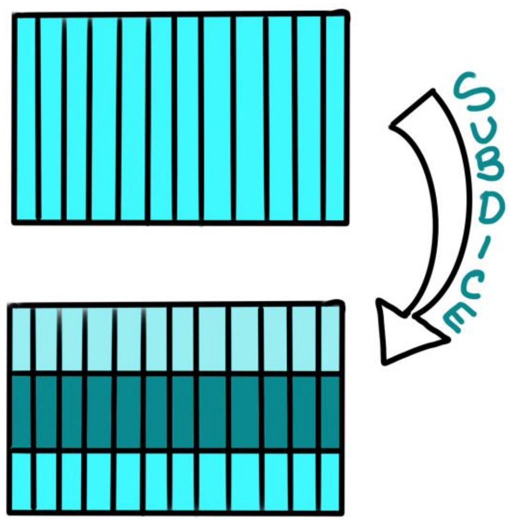
If the sound beam is created by voltages that are the same on the edges as they are in the middle, the edge of the beam still has a lot of energy. This is how grating lobes are created. The edge energy escapes the main beam. To avoid this, the machine can reduce the strength of the edge of the beam through apodization.

→ **Apodization uses stronger voltages for the center elements and weaker voltages for the outer elements.**



Another technique to reduce grating lobes is subdicing.

- **Subdicing breaks elements into sub-elements.**
- **The sub-elements all work together as one element.**



12b.2.2 Dynamic Aperture

Another concept that we learned with single element transducers is that the focal depth is deeper when the diameter is wider. However, when we are using multiple elements the machine can control how many elements to make a beam with AND how many elements to "listen" for echoes with.

- **Fewer elements will improve lateral resolution in the near field**

- **More elements will improve lateral resolution in the far field.**

Section 12b.3 Activities ← Link to Answers

1. Determine if the statements below are true or false.

	Elevational resolution is improved with a 1.5 D array transducer.
	Slice thickness is improved through apodization.
	Grating lobes are found on single element transducers.
	The machine can use dynamic aperture to improve lateral resolution at multiple depths.
	1D array transducers use a lens to create an adjustable slice thickness.
	In single element transducers, the elevational width is the same as the beam width.
	Single element transducer have the best elevational resolution.
	When a sonographer is using a 1.5 D array transducer and adjusts the focal point, the machine uses phasing to adjust the lateral and elevational thickness.
	Subdiced elements work as individual elements to reduce grating lobes.
	More elements used to make a beam will improve the lateral resolution in the near field.

Section 12b.4 Nerd Check!

1. How are axial, lateral and elevational resolution related to the scanning plane?
2. What is elevational resolution?
3. What makes for “better” elevational resolution?
4. What is another name for elevational resolution?
5. What type of element makes for the best elevational resolution?
6. In a single element, what is the elevational thickness equal to?
7. What shape is the cross-section of a beam created by a single element?
8. What is a 1D array?
9. How do 1D arrays create thinner elevational planes?
10. Can the elevational thickness be adjusted for a 1D transducer?
11. What resolution type is best in a 1D transducer? Which is the worse?
12. What is a 1 ½ D Array transducer?
13. Give an example of element figuration of a 1.5D transducer.
14. What does 1.5 D transducers improve?
15. How does it improve ?
16. What are lobes?
17. What type of transducer produces what types of lobes?
18. What type of resolution do lobes degrade?
19. What are two methods the lobes can be corrected with?
20. What is apodization?
21. What is subdicing?
22. What is dynamic aperture?
23. How many elements are better for shallow imaging? For deep?