Sononerds
in the classroom

ARDMS Topic:
Ultrasound Physical Principles

Unit 6a:
Attenuation

Sononerds Ultrasound Physics
Workbook & Lectures

Unit 6a: Attenuation

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Unit 6a: Attenuation

Unit 6a and 6b are going to have the overarching theme of what happens to sound when it travels through a medium.

6a is going to focus on attenuation, or sound weakening as it travels into the body. Understanding attenuation will help the sonographer to understand some of the physical limitations of creating a diagnostic image.

6b is going to focus on the creation of echoes. The whole reason diagnostic medical sonography exists is because sound and the medium, that is a soft tissue body, will interact in a way that returns echoes to the machine for processing and display. Understand how echoes are created will also help us to better understand some of the physical limitations on creating a diagnostic image.

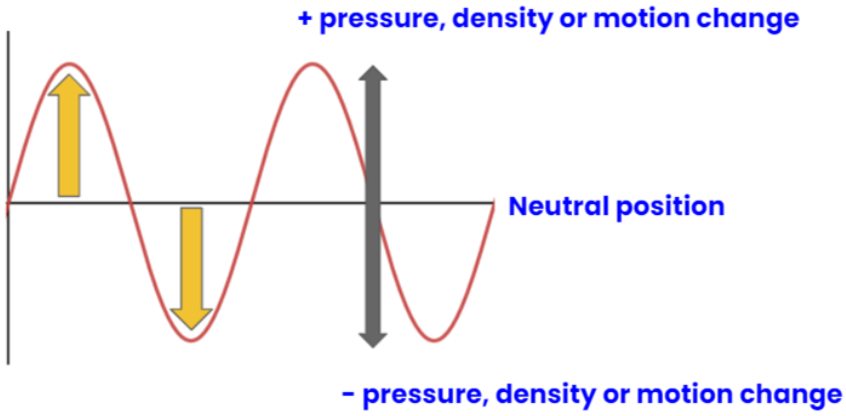
Remember we're not learning ultrasound physics to build a machine or repair one, we are learning the physics of ultrasound because it will impact the decisions you make as a sonographer for every image you take. From transducer selection to image optimization, physics is there (even when it becomes second nature to you - which it will, I promise!).

Section 6a.1 Strength Parameters (Again)

When we were discussing the 7 parameters of a sound wave, there was a subset of parameters that describe the strength or bigness of the wave:

- Amplitude
- Power
- Intensity

Amplitude described the maximum variation of an acoustic variable (max or minimum density, pressure or movement). When amplitude is high, the wave is really strong, it is causing larger fluctuations in the variable from their resting place.



Power is the rate at which work can be performed or the rate that energy is transmitted. In the ultrasound setting, the machine uses a voltage to initiate the sound pulse. This voltage is the driving force behind the power of the wave and will translate into sound power / energy.

Intensity describes how the power is distributed over an area. When a certain power is used over a large area, the intensity is weak. However, when the same power is used in a small area, the intensity increases.

All three of these parameters are determined by the machine and can be adjusted by the sonographer if they change the output power. But, all three of the parameters also:

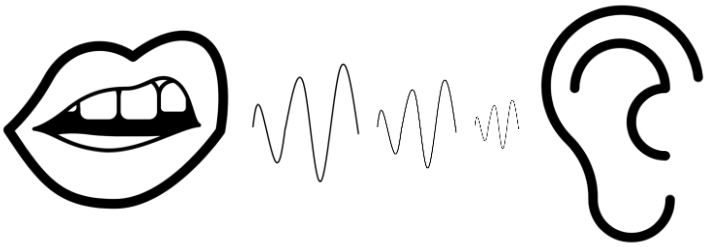
weaken with propagation.

Section 6a.2 Attenuation

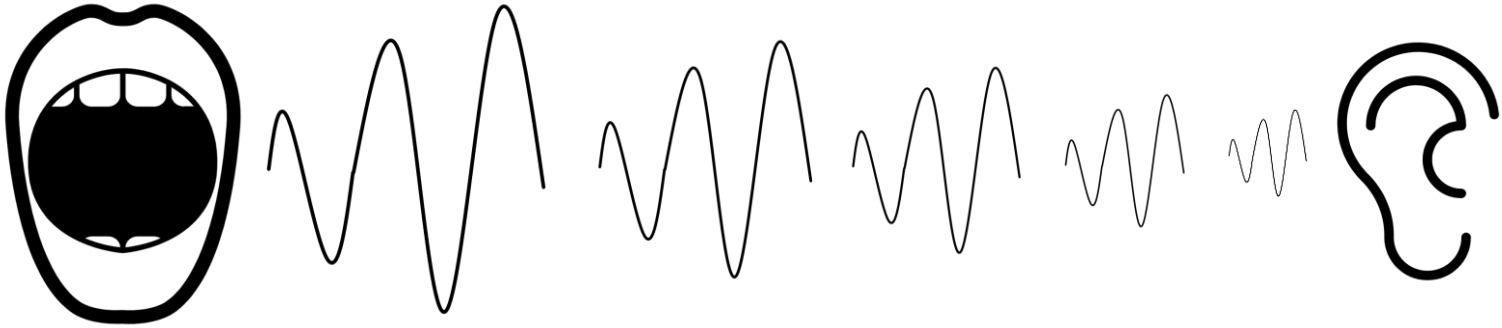
- **Attenuation causes a decrease in the amplitude & intensity of a sound beam as the beam travels through a medium**

Imagine you are talking to a friend. Remember that your friend can hear you because the sound you are creating with your voice travels through air (a medium!) and into their ears.

If you were to whisper, the amplitude of your voice is very small. Unless your friend was very close, the sound would attenuate before they could hear you.



If you shout to your friend, there would be a much higher amplitude. That sound will still attenuate, but it would take longer for it to do so. Your friend could be further away from you and still hear you.



The sound created by an ultrasound machine will attenuate in the body as well. The amount of attenuation will depend on a few factors like the power/amplitude/intensity of the initial beam, the frequency of the beam and the medium it is traveling through.

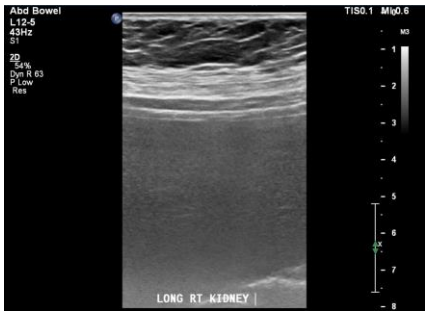
- ➔ **Attenuation limits the depth to which an image can be created by a sound beam**

- ➔ **Attenuation needs to be compensated for by our machines**

Attenuation of the sound beam is highly applicable to the sonographer and the decisions that make about every exam and every image. As we work through this course, you will start to see how your knowledge of physics will help you to create better images.

For example, in regards to attenuation:

High frequencies attenuate faster. Therefore they are not good for imaging deep into the body. Signals can't be processed from deeper depths because they are too weak.



Some "soft tissues," like fluid, barely cause attenuation. Therefore a lot of sound energy continues forward. More energy means brighter reflectors.

Some "soft tissues," like bone, cause sound to attenuate very quickly. Therefore, the sound energy is gone or very weak and nothing can be seen behind the structure.

Let's explore how we measure & calculate attenuation and what causes it.

Section 6a.3 Decibels

When we refer to attenuation (and as we'll learn later, amplification), we are referring to the change in amplitude, power or intensity, which can be measured in decibels (dB).

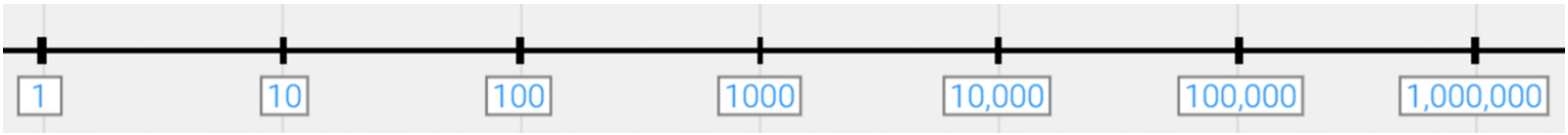
- ➔ **Decibels are used to define a change in two values.**
- ➔ **By using decibels, there is an understanding that there is a comparison of an initial value and a final value.**
- ➔ **Decibels are logarithmic**

Section 6a.3.1 Logarithmic Scales

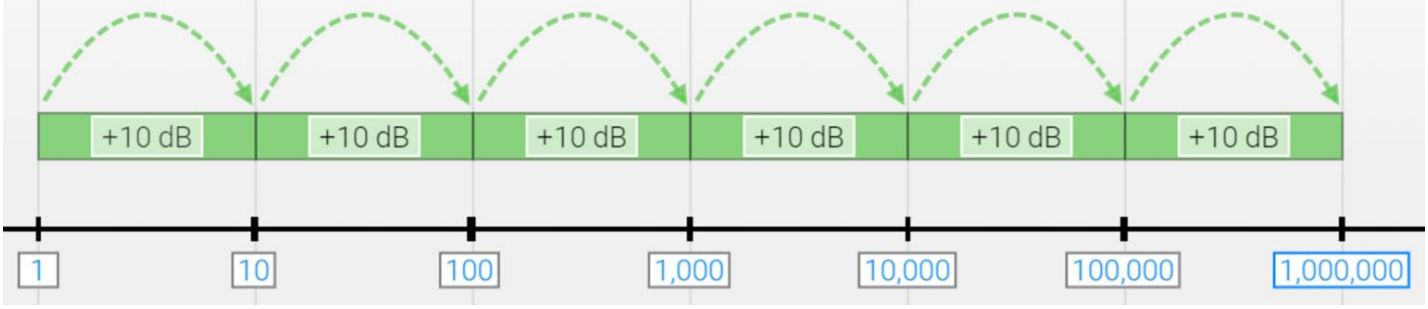
A logarithmic scale is a nonlinear scale that is typically used to show a range of large quantities. Instead of increasing by equal increments, the scale increases by a factor of the base of the logarithm. Decibels uses a base of 10.

In a linear scale like this one, the values increase by +1. To move from the first tick mark to the third tick mark indicates a change of 3.

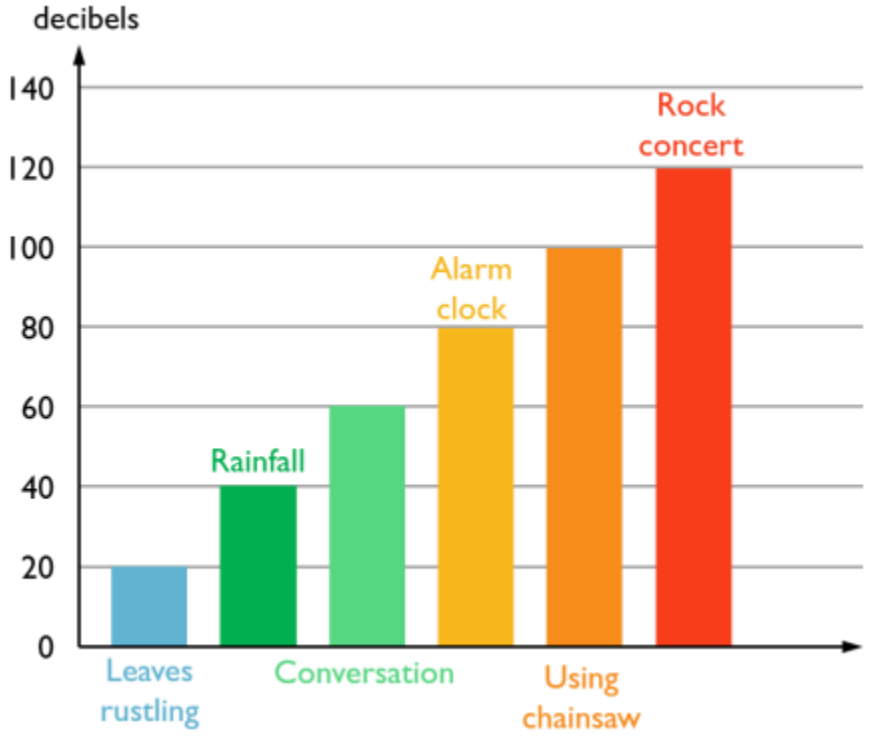
In a logarithmic scale, the values increase by a factor of 10 (x 10). Moving from the first tick mark to the third tick mark on this scale indicates an increase of 1000.



The decibels of a sound wave also use a logarithmic scale. A change of 20 dB is not an increase of 20, but an increase of 100.



To further show how this concept applies to decibels look at this chart:



Our threshold of hearing is 0 dB. Leaves rustling is not 20 more than our threshold of hearing, but rather 100 x louder than our threshold. Where the concert isn't 120 more than our threshold, but 1,000,000,000 x our threshold of hearing.

Decibels uses a logarithmic scale. By increasing (or decreasing) in units of 10 dB, the compared loudness doesn't change by the same increment of +10, it changes by a factor of 10 (x10).

Using this knowledge of logarithmic scales and applying it to decibels, we can calculate the relative change in power and intensity of a wave.

6a.3.2 Positive Decibels

When decibels increase, the power and intensity of the wave also increase. Normal restaurant sound is about 60 dB, where a rock concert is about 120 dB. The rock concert sound is louder - more powerful and more intense. We see positive decibels when sound is amplified.

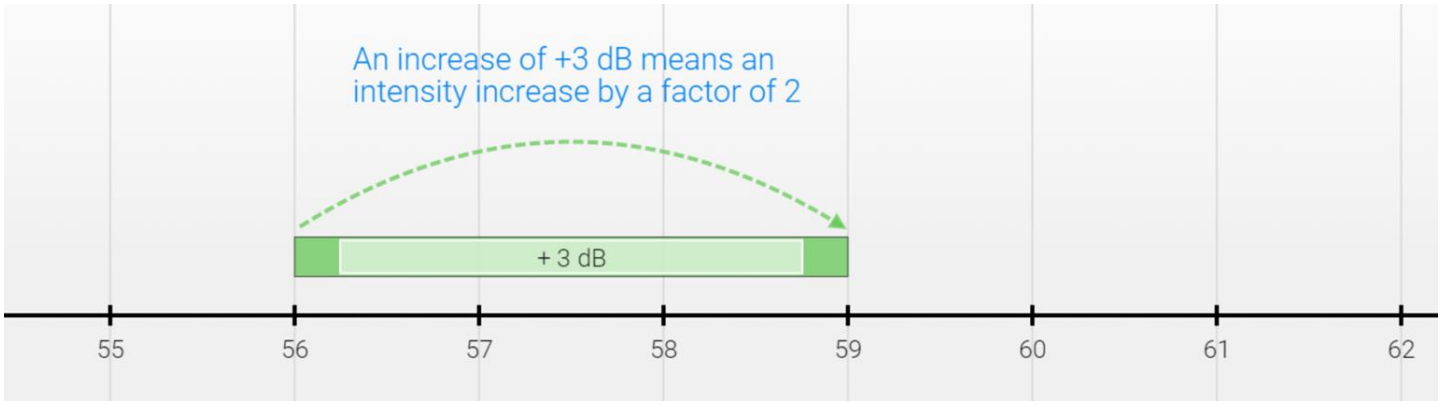
There are two rules when increasing or using positive decibels that you need to know for ultrasound physics:

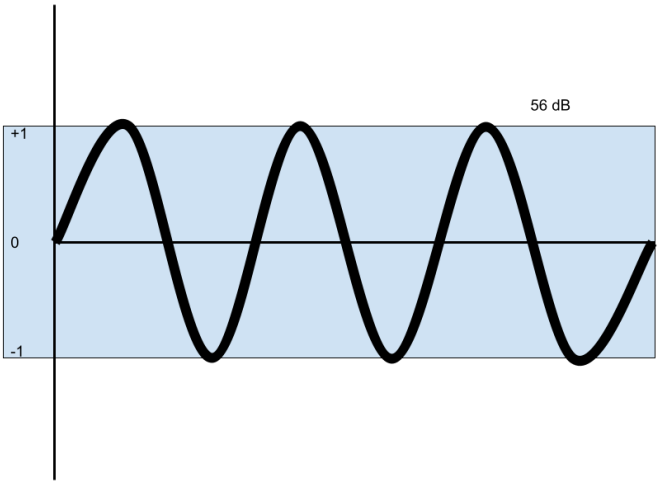
- ➔ **When decibels increase +3 dB, the intensity increases by a factor of 2**
- ➔ **When decibels increase +10 dB, the intensity increases by a factor of 10**

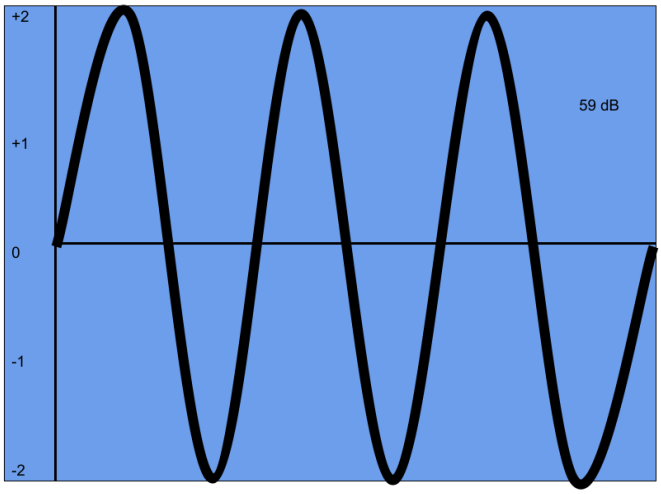
Because of the logarithmic scale and using our rules:

The intensity is twice as strong when an increase of 3 dB has occurred.

56 dB → 59 dB is a change of +3 dB, the wave at 59 dB is twice as intense as the wave at 56 dB.

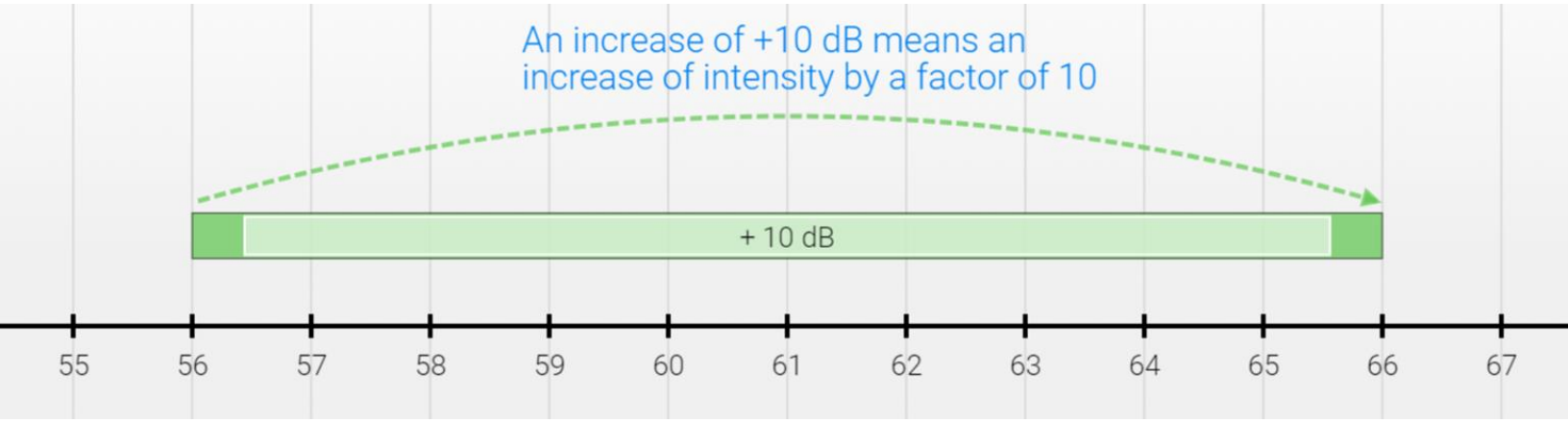


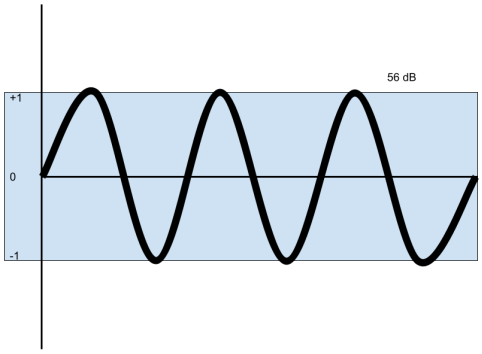


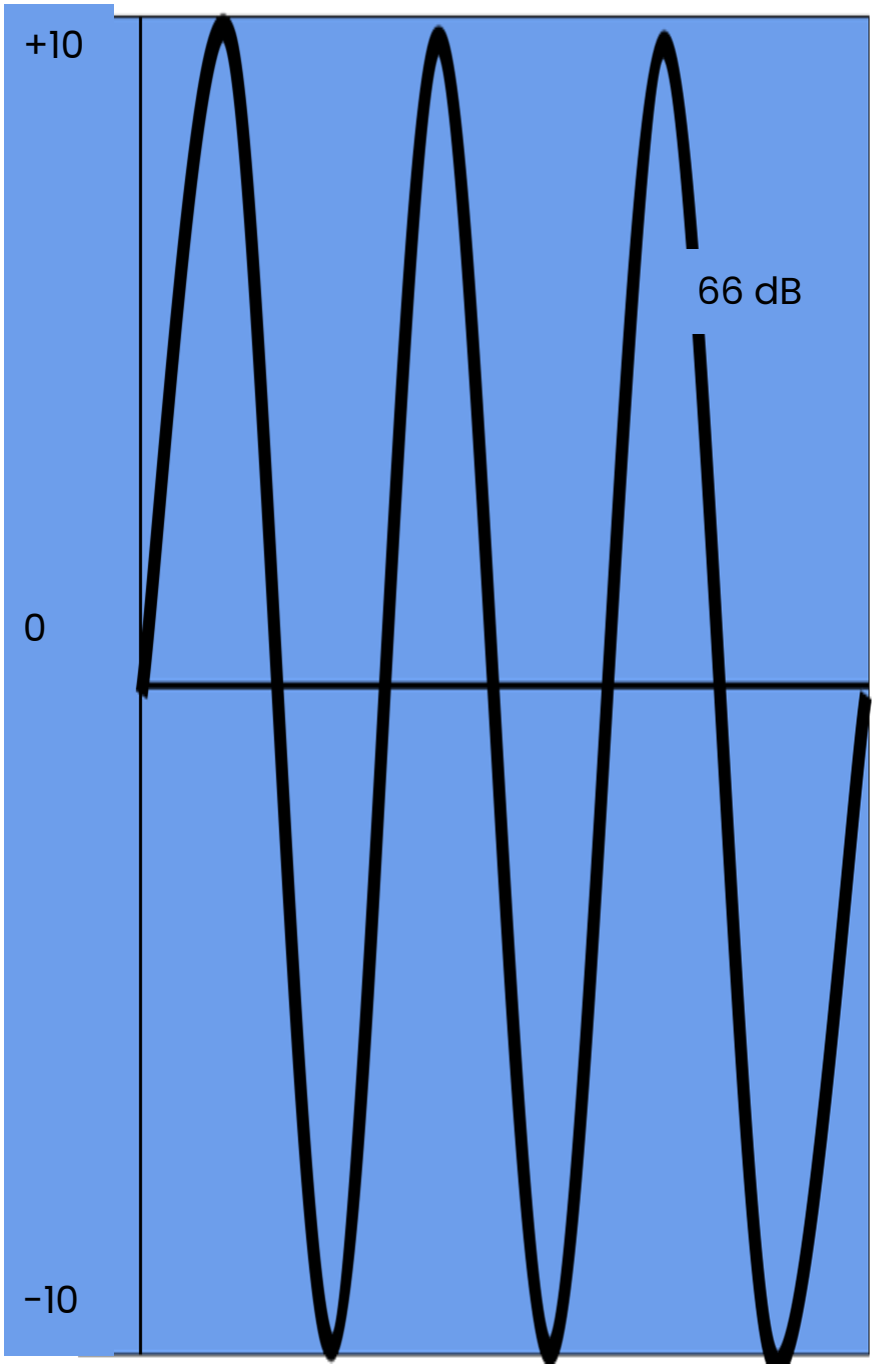


The intensity is 10 x as strong when an increase of 10 dB has occurred.

56 dB → 66 dB is a change of +10 dB, the wave at 66 dB is ten times more intense than the wave at 56 dB.

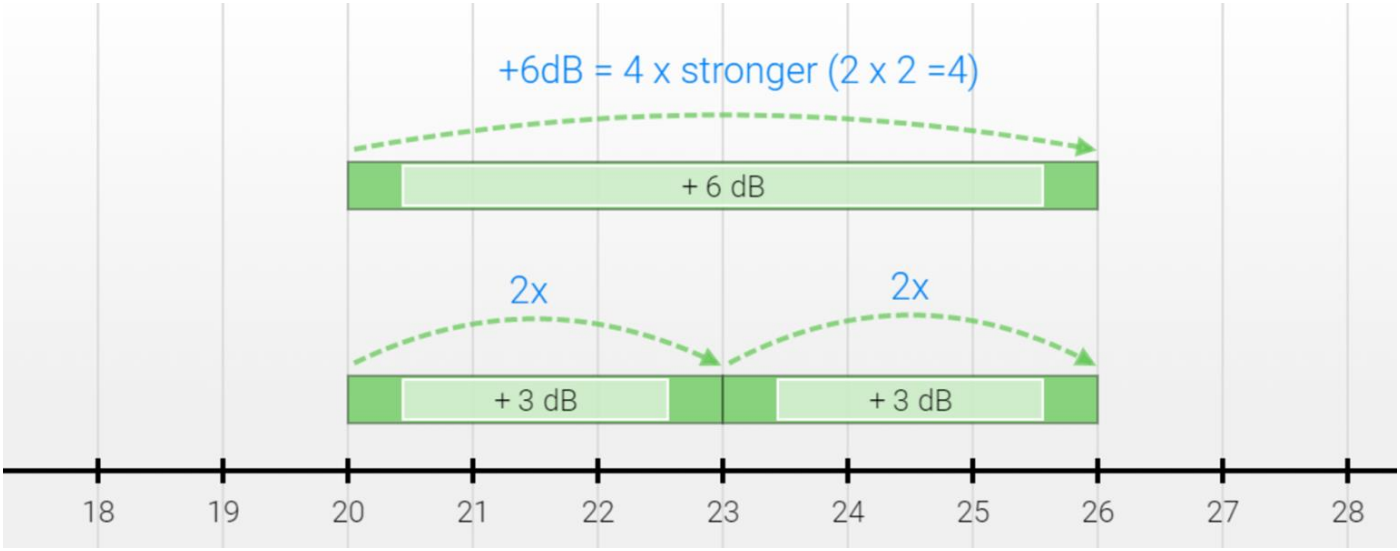




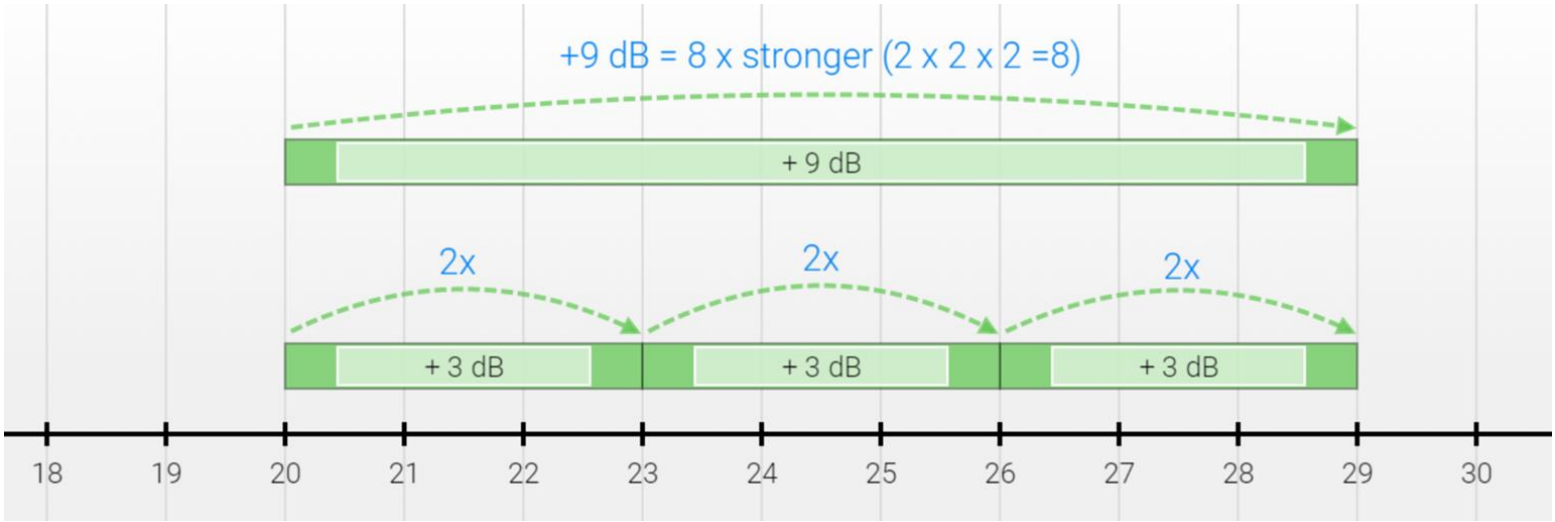


Using the +10 and +3 dB changes, we can then combine dB changes to understand other changes.

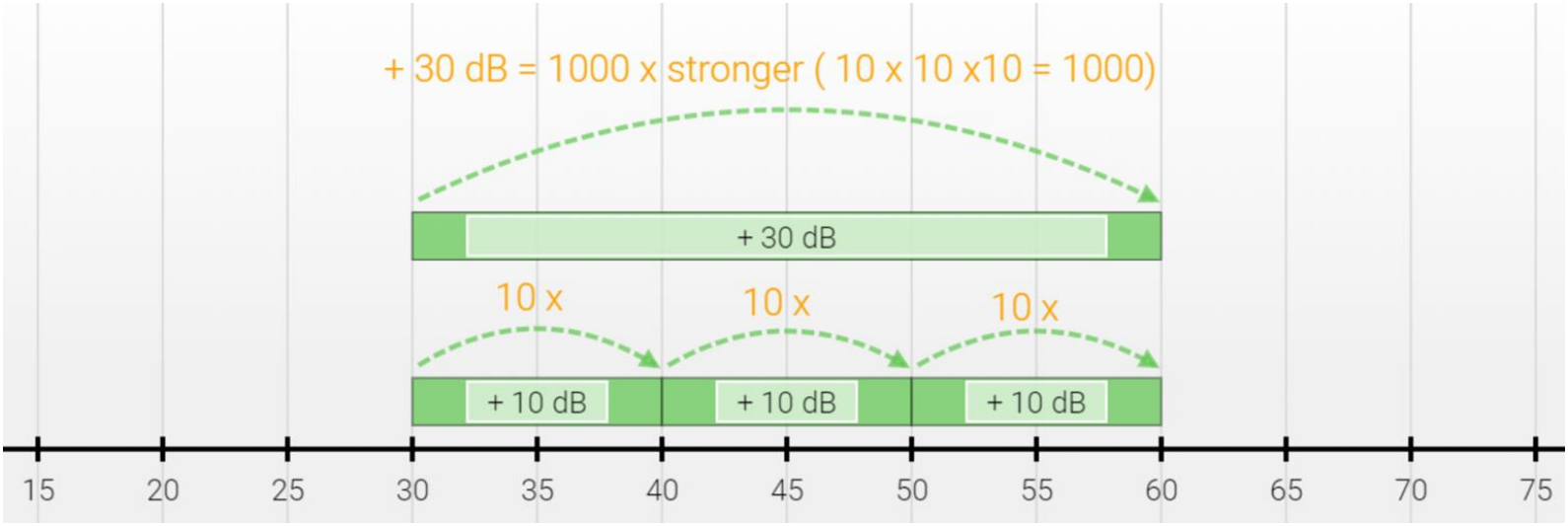
20 dB → 26 dB is a change of +6 db. The 26dB wave is 4 x stronger than the 20 dB wave.



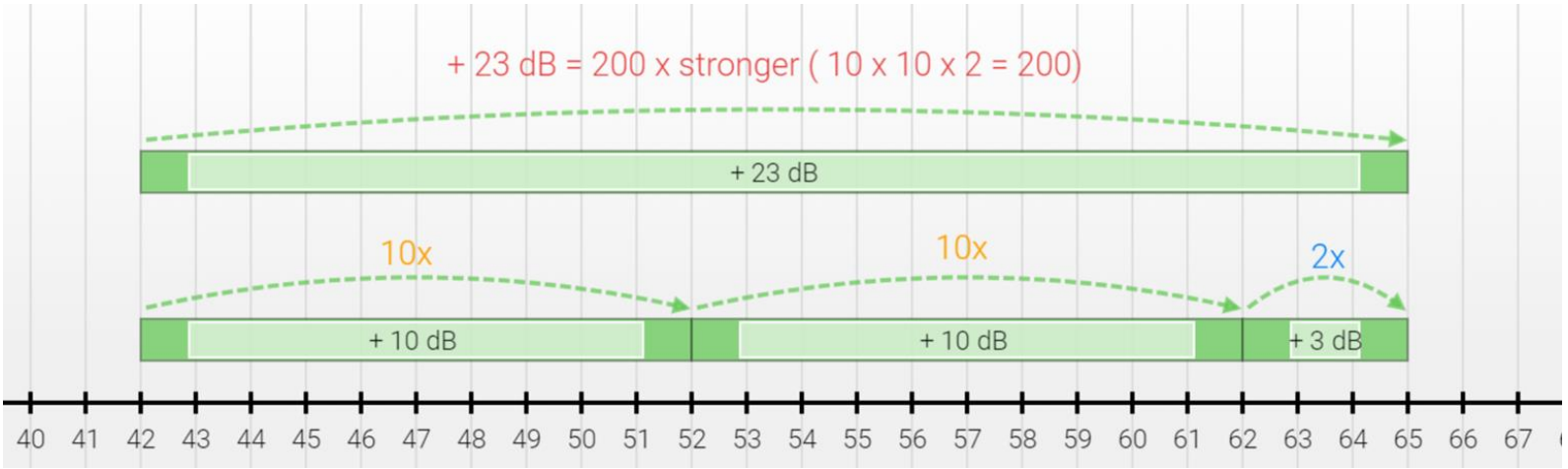
20 dB → 29 dB is a change of +9 db. The 29dB wave is 8 x stronger than the 20 dB wave.



30 dB → 60 dB is a +30 dB change. The 60 dB wave is 1000 x stronger than the 30 dB wave.



42 dB → 65 dB is a +23 dB change. The 65 dB wave is 200 x stronger than the 42 dB wave.



6a.3.3 Negative Decibels

When decibels decrease, the power and intensity of the wave also decrease. Talking in a normal voice is about 60 dB, but when we whisper the decibels decrease to about 30 dB. The whisper is quieter, meaning it has less power and less intensity than the normal talking voice.

- ➔ **Attenuation implies a decrease in decibels.**

There are two rules when decreasing decibels that you need to know for ultrasound physics:

- ➔ **When decibels decrease -3 dB, the intensity:**
  - ◆ **decreases by a factor of 2 OR**
  - ◆ **is ½ as strong as the original wave OR**
  - ◆ **is 2 x weaker than the original wave.**

- ➔ **When decibels decrease -10 dB, the intensity:**
  - ◆ **decreases by a factor of 10 OR**
  - ◆ **is 1/10 as strong as the original wave OR**
  - ◆ **is 10 x weaker than the original wave**

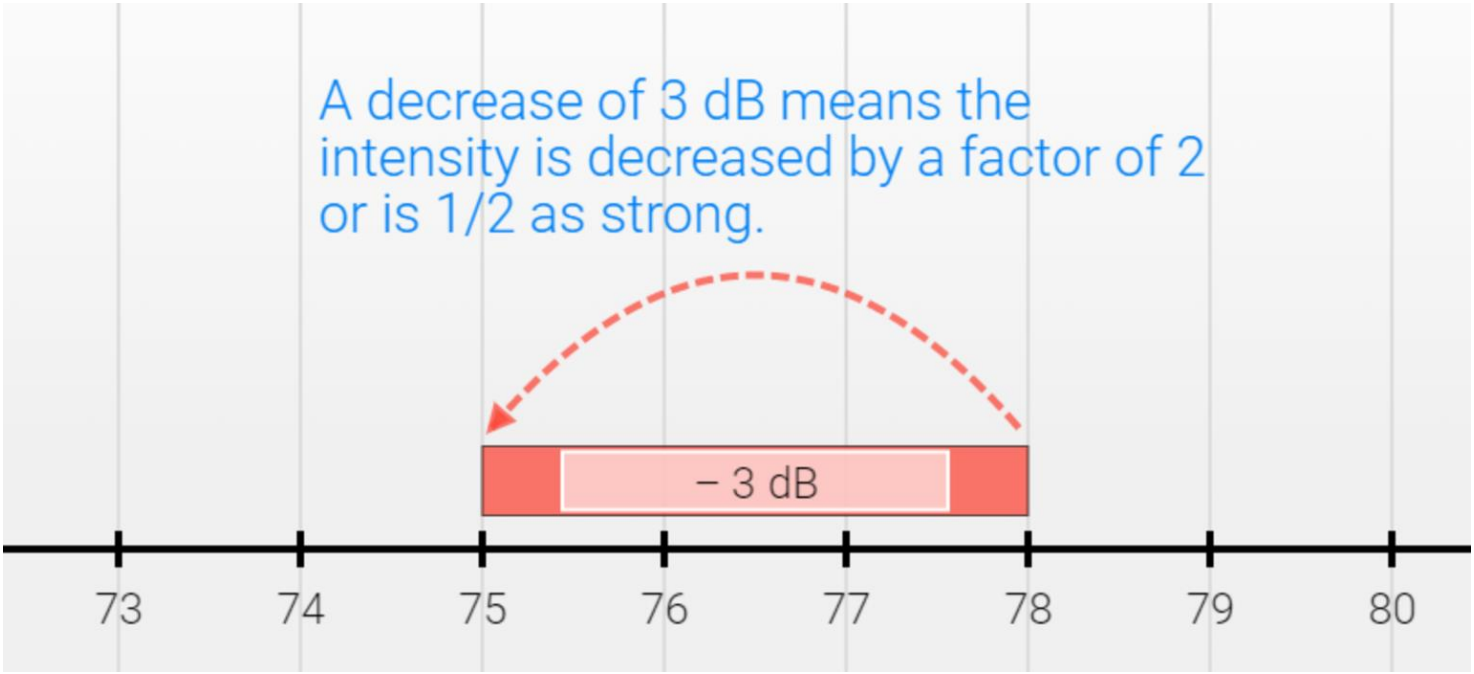
Note that all the options mean the same thing. It depends on how you phrase the change, which is not as intuitive as saying something is a certain amount of times stronger.

It might be helpful to know too, that dividing by 2 is the same a multiplying by ½. And dividing by 10 is the same as multiplying by 1/10. When you multiple a number by a value less than 1, it makes the number smaller.

Because of the logarithmic scale and using our rules:

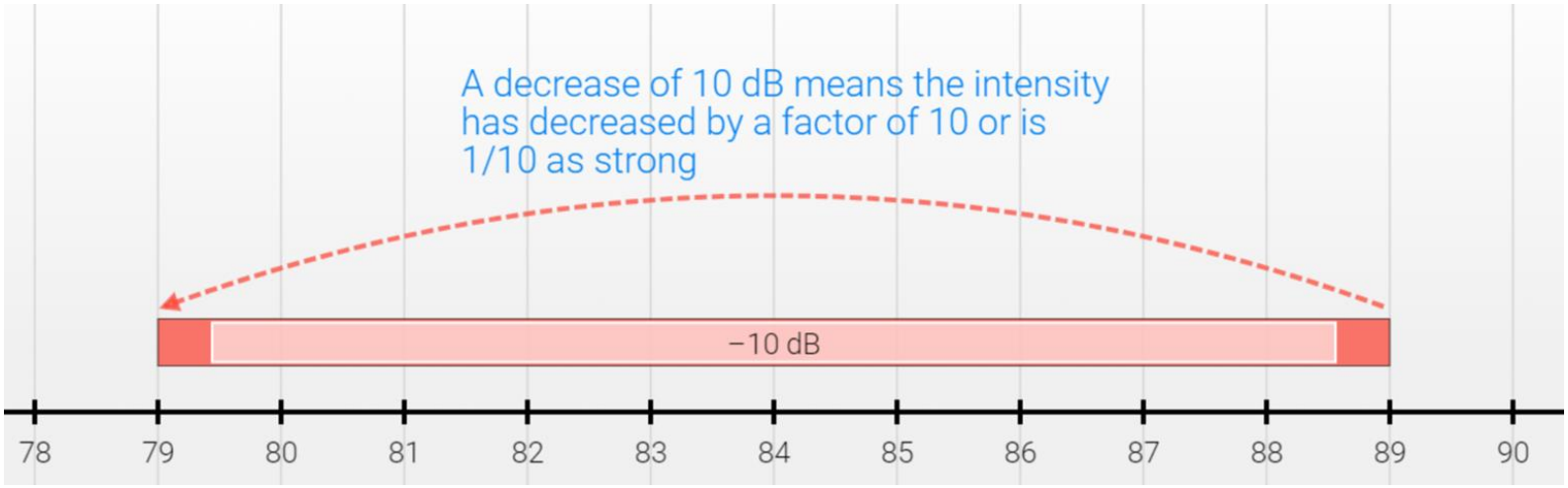
The intensity is ½ as strong when a decrease of 3 dB has occurred.

78 dB → 75 dB is a change of -3 dB. The 75 dB is ½ as strong as the 78 dB wave.



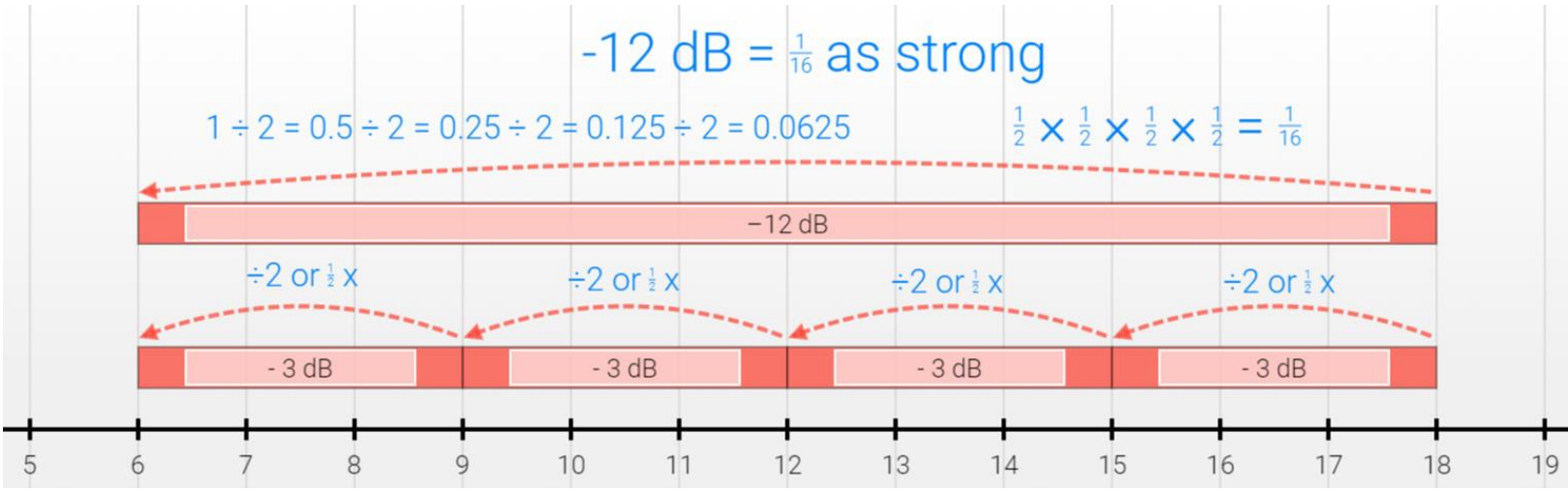
The intensity is 1/10 as strong when a decrease of 10 dB has occurred.

89 dB → 79 dB is a change of -10 dB. The 89 dB is 1/10 as strong as the 79 dB wave.

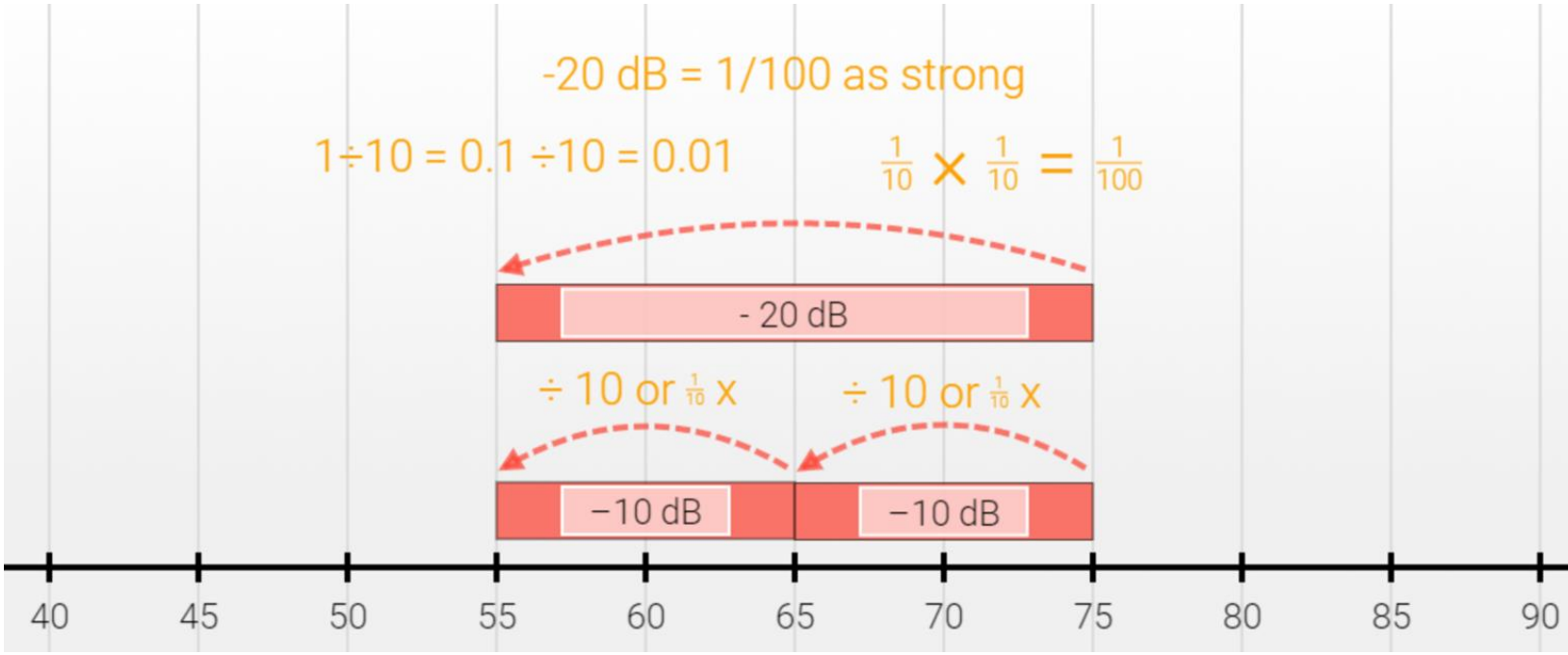


Just like positive decibels, we can combine these values as well.

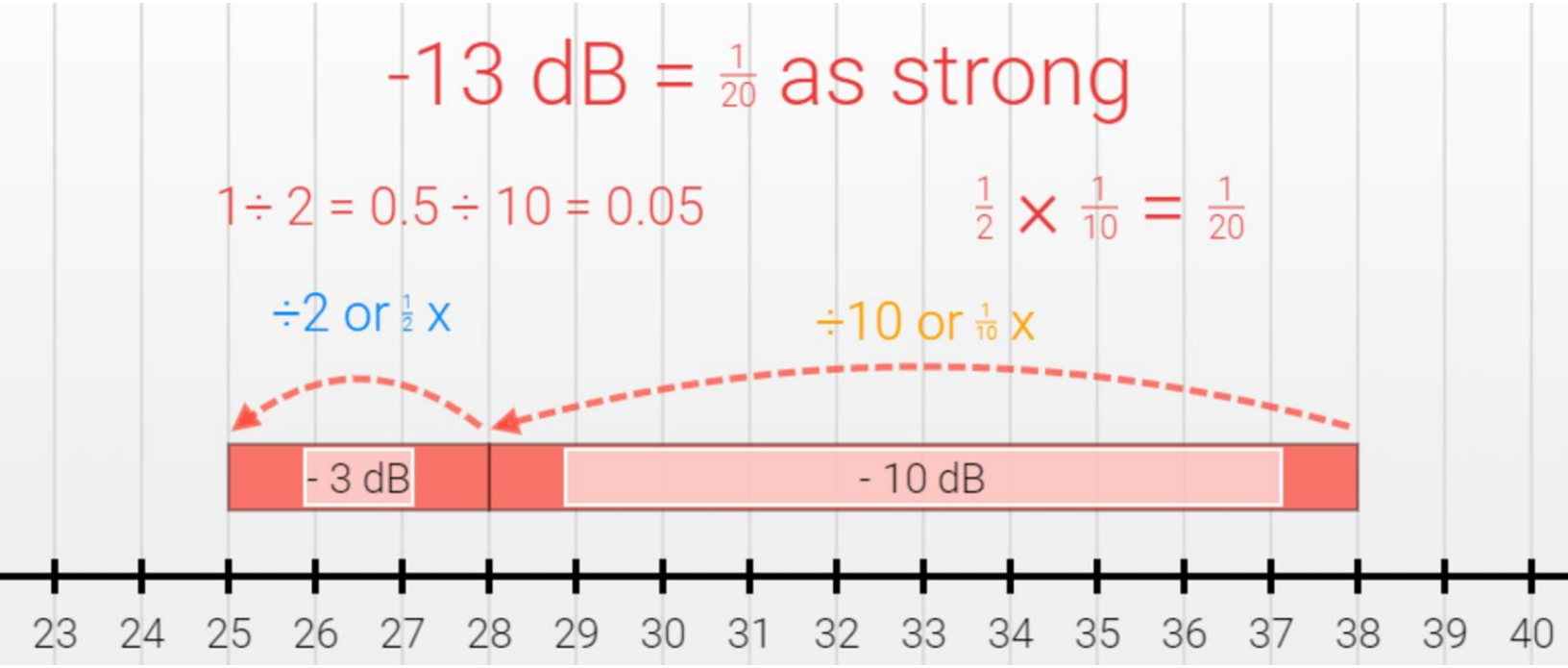
18 dB → 6 dB is a change of -12 dB. The 6 dB wave is 1/16 the strength of the of 18 dB wave.



75 dB → 55 dB is a change of -20 dB. The 55 dB wave is 1/100 the strength of the 75 dB wave.



38 dB → 25 dB is a change of -13 dB. The 25 dB wave is 1/20 the strength of the 38 dB wave.



6a.3.4 Equating Intensity Changes to dB Changes

If you are given two intensities, you can use their ratio to calculate the dB change.

Example 1:

Intensity 1= 30 mW/cm^2 increases to Intensity 2 = 60 mW /cm^2

Intensity 2 is doubled or 2 times stronger than Intensity 1.

Knowing that +3 dB would cause a doubling or increase by a factor of 2, then we know the wave has undergone a change of + 3 dB.

Example 2:

Intensity 1 = 5 mW/cm^2 and increases to Intensity 2 = 100 mW/cm^2

Intensity 2 is 20 x greater than intensity 1.

Knowing that a + 10 dB will increase 10x and a + 3 dB will increase another 2x, (10 x 2 = 20) we can figure out that wave has undergone a 13 dB increase.

Same idea, but using decreasing intensity examples:

Example 3:

Intensity 1= 30 mW/cm^2 increases to Intensity 2 = 15 mW /cm^2

Intensity 2 is half or 2 times weaker than Intensity 1.

Knowing that -3 dB would cause a halving or a decrease by a factor of 2, then we know the wave has undergone a change of - 3 dB.

Example 4:

Intensity 1 = 10 mW/cm^2 decreases to Intensity 2 = 0.01 mW/cm^2

Intensity 2 is 1000 x weaker than intensity 1. To see a change of 1 / 1000, we would need a change of 1/ 10 x 1/10 x 1/10. Each 1/10 is created by a -10 dB change.

The wave would undergo a dB change of -30 dB to see a change in intensity from 10 mW/cm^2 to 0.01 mW/cm^2 .

6a.3.5 Decibel Review

Decibels and logarithms are kind of hard mathematical concept. For this section focus on:

- Decibels compare 2 values
- Increasing decibels is amplification and causes positive decibel changes
- Decreasing decibels is attenuation and causes negative decibel changes
- 4 rules regarding positive and negative decibels

Increasing Intensity & Power		Decreasing Intensity & Power	
+ 0 dB	No Change	- 0	No change
+ 3 dB	Double	- 3 dB	½
+ 6 dB	Quadruple	- 6 dB	¼
+ 10 dB	10 x	- 10 dB	1/10
+ 20 dB	100 x	-20 dB	1/100

6a.3.5 Practice

The boards will mostly focus on your knowledge of 3 and 10 dB changes. But for more practice on understanding the magnitude of changes try filling out this chart:

Original Signal	New Signal	Change in strength (original to new)
100 dB		2 x stronger
100 dB		4 x stronger
100 dB		8 x stronger
100 dB	91 dB	
100 dB	94 dB	
100 dB	97 dB	
3 dB	6 dB	
20 dB		10x stronger
50 dB	47 dB	
	60 dB	1/10 as strong
25 dB		100 x stronger
	80 dB	100000x stronger
100		1/10 as strong
60 dB	80 dB	

Section 6a.4 Causes of Attenuation

When a pulse is emitted from the transducer, it will travel through the acoustic gel and into the body. As sound propagates through a medium it will attenuate.

There are three physical phenomena that *cause attenuation*:

- ➔ **Absorption**
- ➔ **Scattering**
- ➔ **Reflection**

There are two factors that determine *the amount of attenuation*:

- ➔ **Frequency**
- ➔ **Propagation distance**

All sound waves will encounter absorption, scattering and reflection, but it will depend on the sound wave frequency and how far it travels to determine the total amount of attenuation that will occur.

6a.4. 1 Absorption, Reflection & Scattering

When a sound wave comes to an interface of two media, sound can be absorbed, reflected, scattered, refracted or transmitted.

- ➔ **Absorption is the main cause of attenuation.**

Absorption is the conversion of sound energy into another form of energy - mainly heat.

With absorption being the main cause of attenuation due to the conversion of heat, absorption is also the main driver of thermal bioeffects. As sound is absorbed by the tissue of the body, it will heat up. High energy sound beams provide more energy that can be absorbed. More absorption leads to an increase in temperatures and this can cause cellular damage.

Bone is considered a highly attenuating tissue due to its likelihood to absorb sound energy.

➔ **Scattering allows us to see the parenchyma of the organs.**

As sound interacts with interfaces that are small (less than one wavelength) they send some of the sound energy into multiple directions. Scattering removes some of the sound energy from the main beam, causing it to weaken.

Scattering of the sound beam allows us to see more of the organ tissue when it is useful. If the tissue is very dense, it will take more energy to move the particles. Scattering and absorption will weaken the beam quickly.

➔ **Reflection allows us to see borders.**

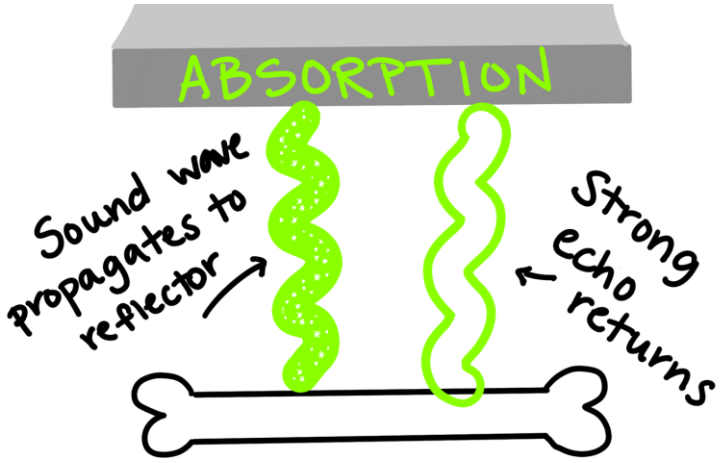
Reflections occur at large interfaces (more than a wavelength) and also causes some sound energy to be sent back the way it came from. A tiny fraction of the sound energy “escapes” the transmitting wave and weakens it. Reflection has a very small impact on attenuation, but is also the reason we can see the borders of organs in the body.

There are two types of reflections that can occur in the body:

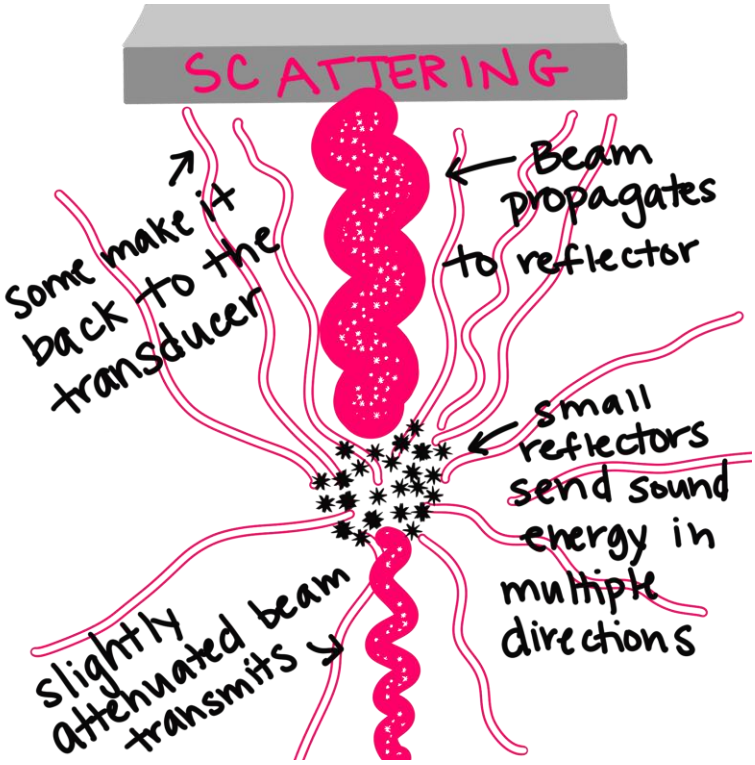
- Specular (mirror like)
- Diffuse (combination of specular and scattering)

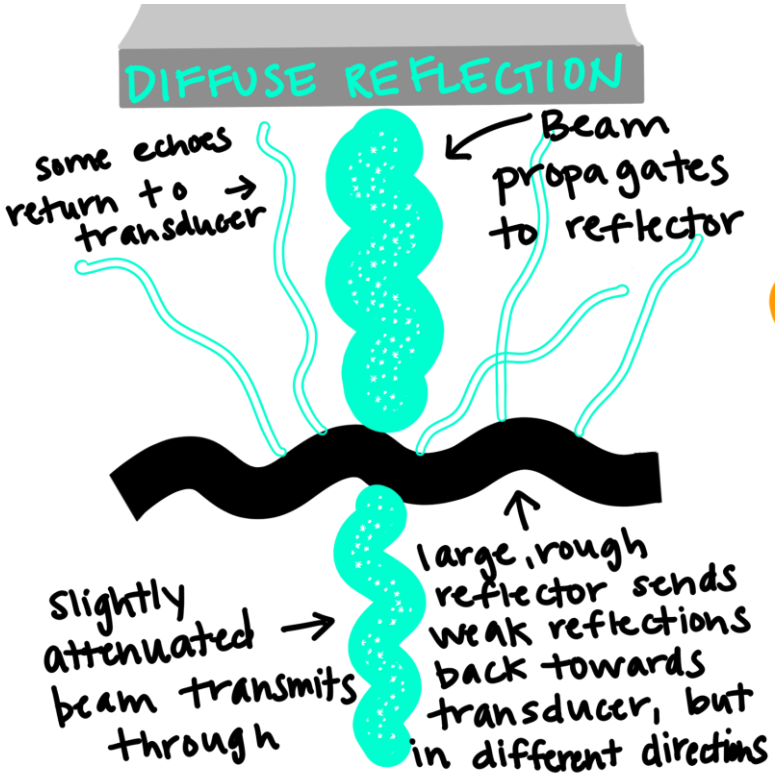
Scattering and reflection overlap the attenuation and echo components of how sound interacts with the body. Since they have more to do with the creation of echoes, both will be discussed in more detail in Unit 6b.

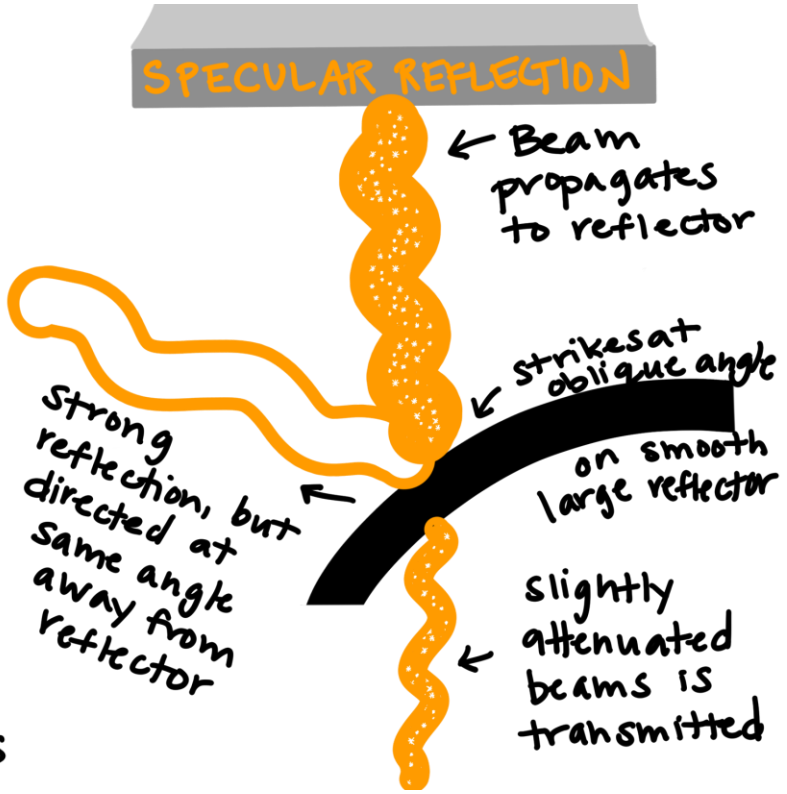
Note - that to get more image behind a reflector, there must be sound transmitted through. If all of the sound is reflected or absorbed, there would be no sound energy left to get more of the image



But reflector absorbs most of the sound energy, leaving none to be transmitted.







6a.4.2 Frequency & Distance

Absorption, scattering and reflecting were all interactions that sound could have with a medium that would cause it to weaken. However, the amount that the sound weakens is more dependent on the frequency of the sound beam and the distance it travels.

- ➔ **The higher the frequency, the more attenuation will occur.**

This makes attenuation and frequency directly related. Most of us have probably experienced this too. If you've ever lived in an apartment building, dorm or other close quarters, when a neighbor is playing music you typically can only hear the bass notes because the higher frequency melody notes attenuate quickly. The low frequency bass notes continue transmitting through the walls.

- ➔ **High frequencies are absorbed more.**

Higher frequencies will cause the particles in a medium to move more. With more motion, more energy is transferred into heat. The more sound that is absorbed, the less sound can be transmitted.

- ➔ **High frequencies cause more scattering.**

When a high frequency transducer interacts with small reflectors, the scattered echoes are more intense, thus drawing more energy out of the beam. The more energy that is scattered means there is less energy that can be transmitted.

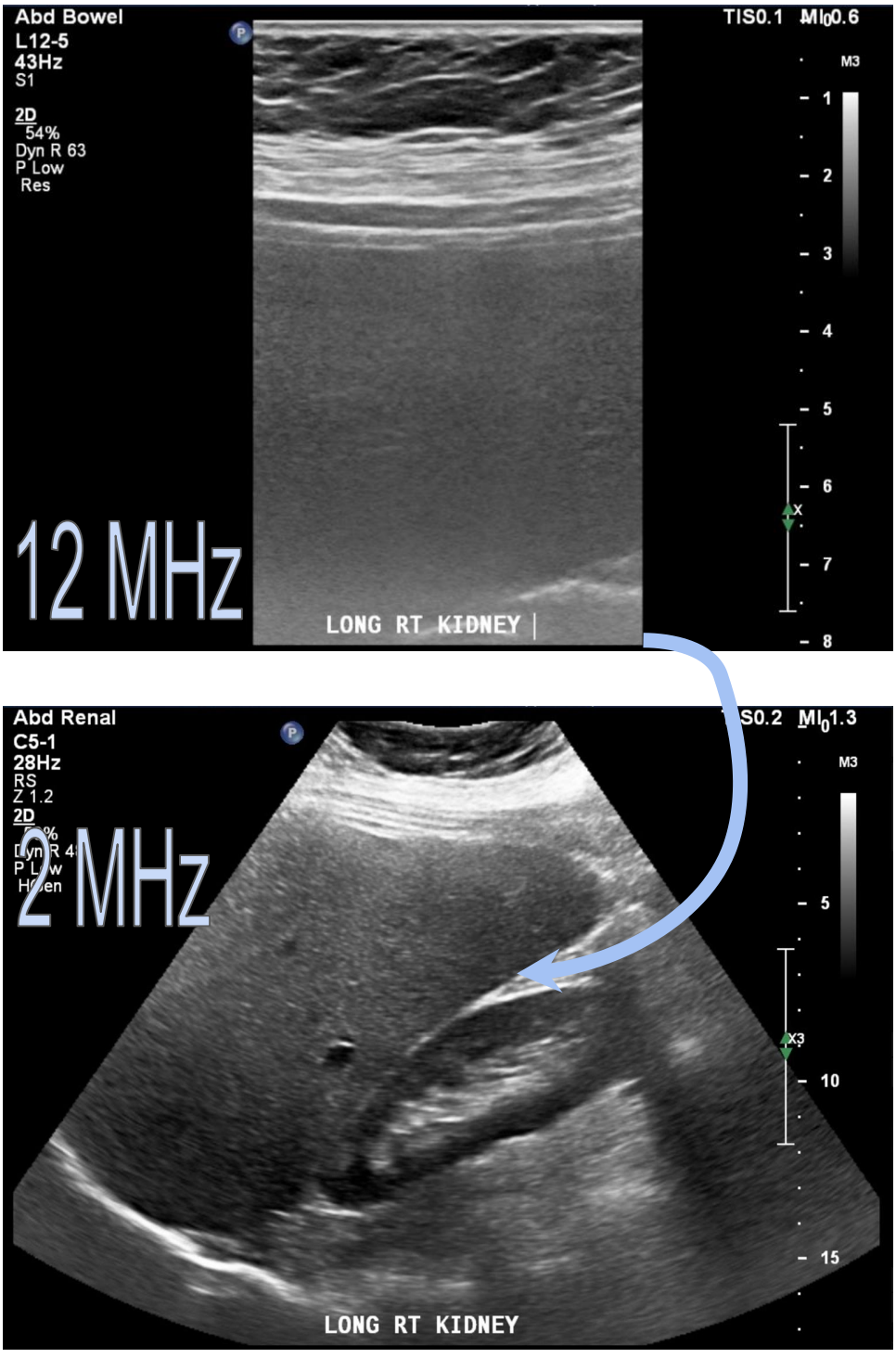
- ➔ **Longer distances cause more attenuation.**

The further a beam travels, the more it will attenuate. This makes attenuation and distance directly related. If a beam travels further, it interacts with more interfaces which gives the beam more opportunity to be absorbed, scattered or reflected.

These pictures were used early, but it shows nicely the difference between using a low frequency transducer and a high frequency transducer.

Note that the low frequency transducer can penetrate further than the high frequency transducer. The arrow from the bottom of the high frequency transducer is pointing to its depth on the low frequency image.

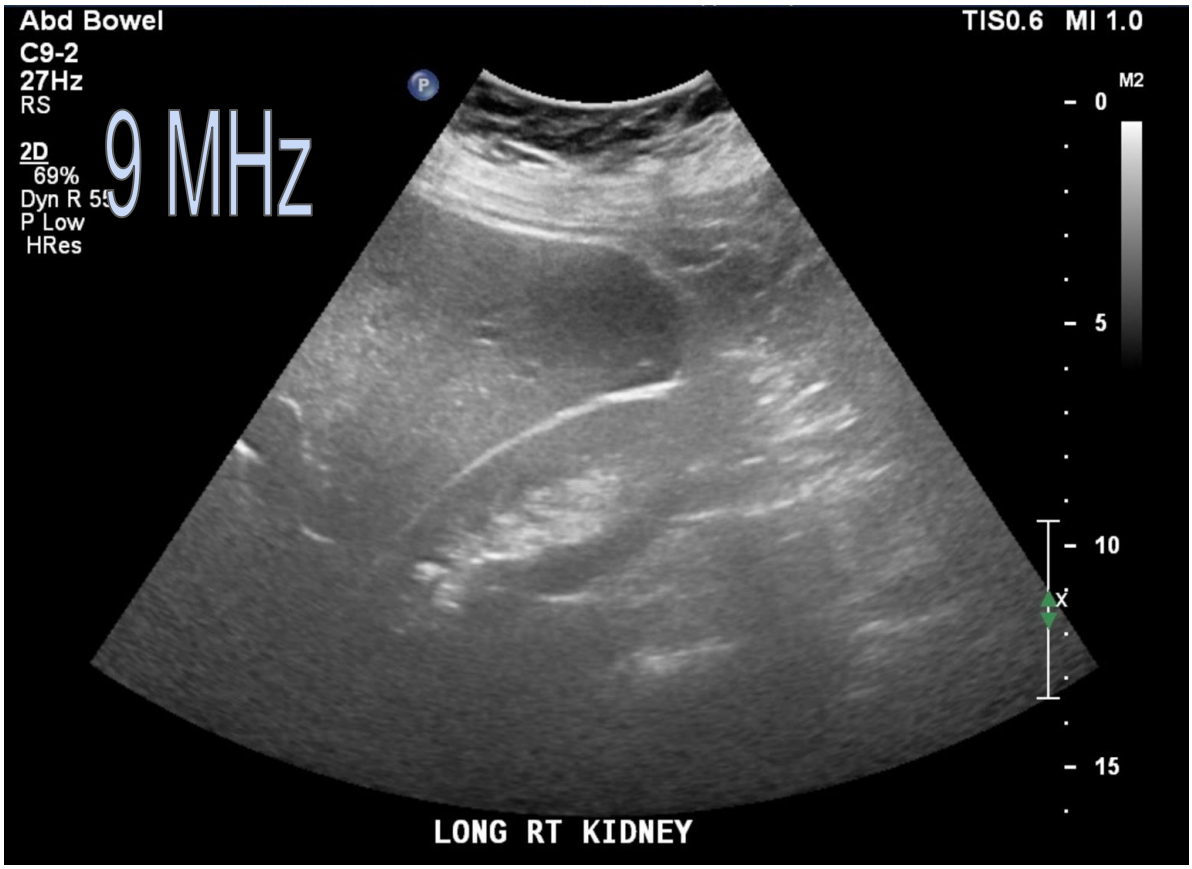
Contrary through, look at how much detail is visible in the first few centimeters of the high frequency transducer compared to the low frequency.

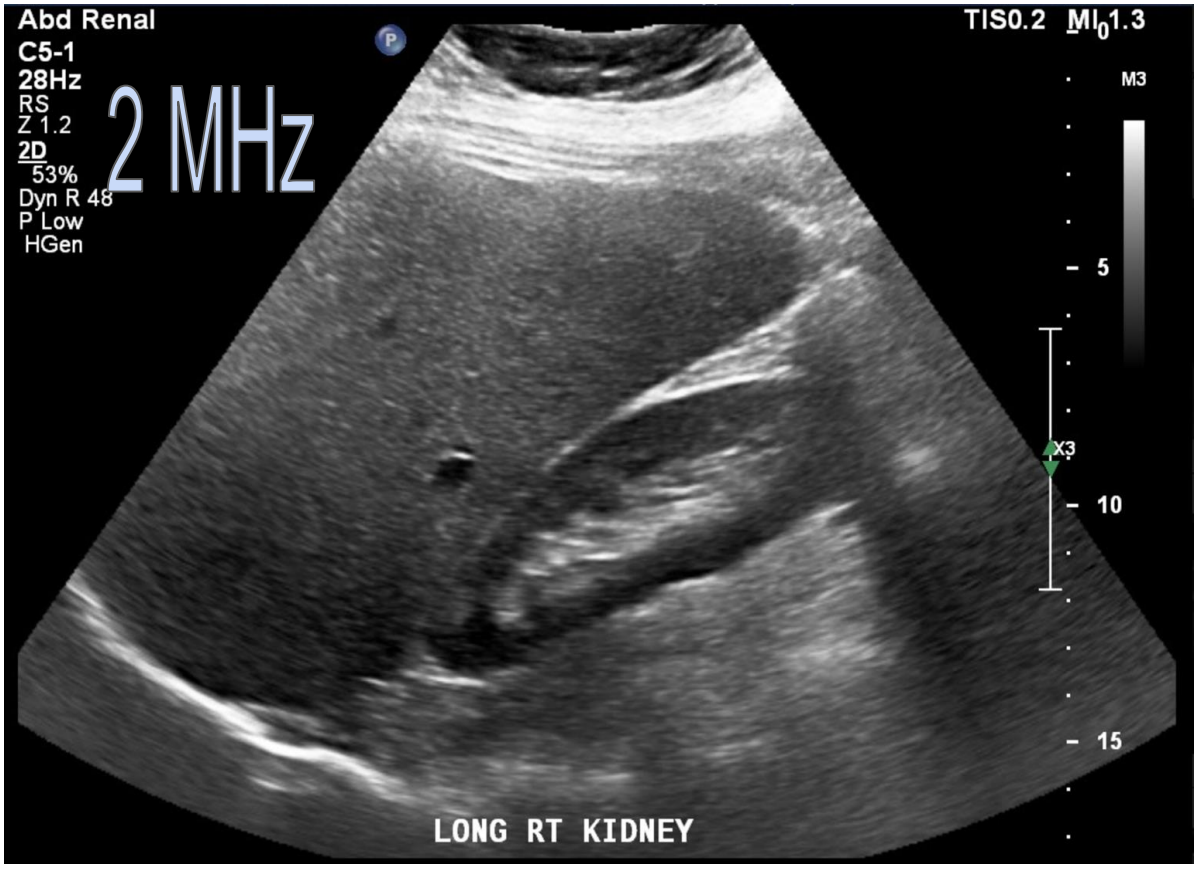


Sonographers need to balance detail and depth when selecting a transducer's frequency for their exams.

Here is another example of a higher frequency, attenuating too quickly and not being able to image to the max image depth set by the sonographer.

Both images are set to about 16 cm depth.

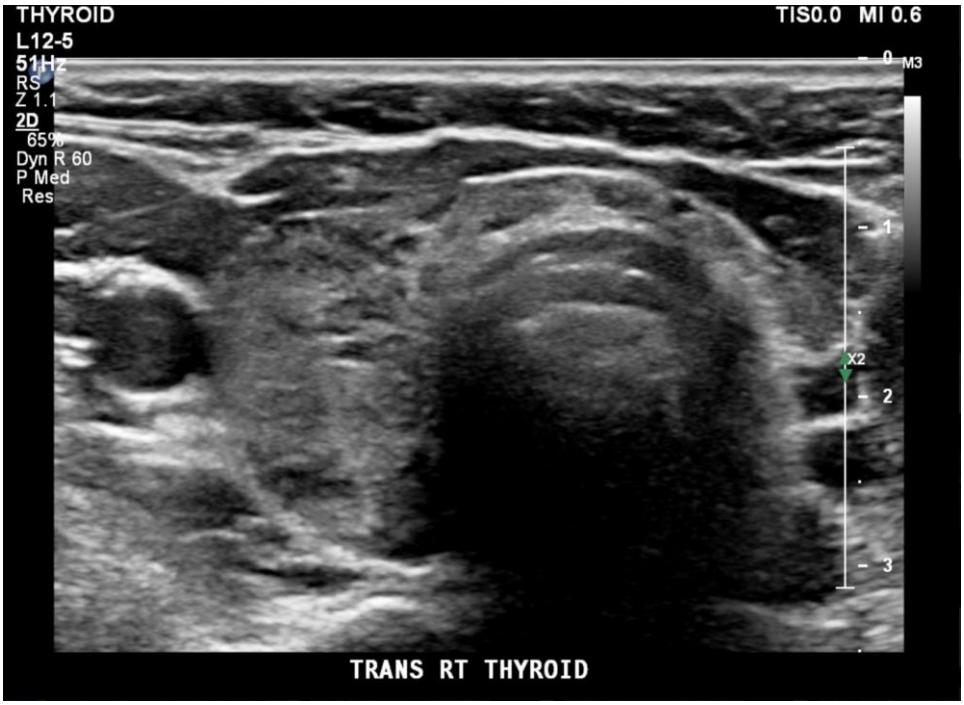




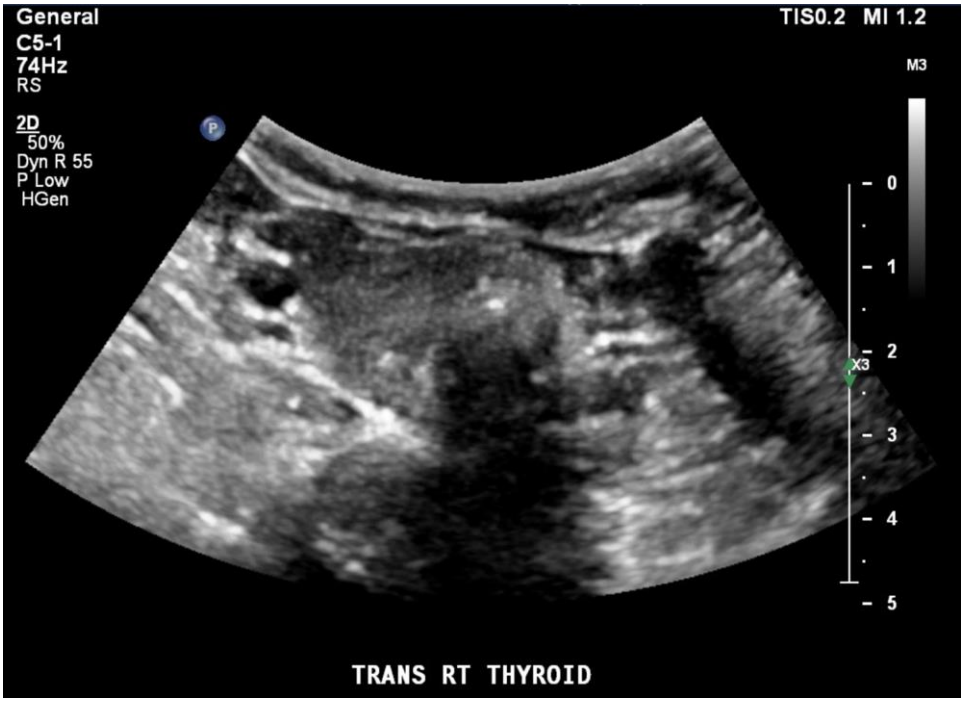
This example shows how the right frequency for the job can provide better detail. The 12 MHz transducer provides enough detail and sound penetration for 3.5 centimeters into the neck. The 3 MHz transducer also provides enough penetration, but severely lacks detail.

Notice how both transducers attenuate in the midline of the image at the trachea, a structure filled with air. Air causes a lot of scattering, therefore more attenuation.

12 MHz



3 MHz



Section 6a.5 Reporting Total Attenuation

Attenuation is reported in decibels and implies a negative decibel change. We know the sound beam is getting weaker, which means the power and intensity are decreasing.

We also know that there are a lot of factors that go into how much the beam will attenuate...did it cross any high attenuators that will absorb the sound? What is the frequency? How far did it travel? What reflectors did it come in contact with and how many?

Thanks to science, we have a term and an equation that will help us to define how much a beam attenuates based on the frequency, path length and type of medium.

- ➔ **Attenuation coefficient is the decrease in decibels a beam will experience for every one centimeter of travel.**
- ➔ **Total Attenuation can be determined by the attenuation coefficient and the the distance.**

6a.5.1 Attenuation Coefficient in Soft Tissue

The attenuation coefficient is the number of decibels sound attenuates for every centimeter of travel. This value, once calculated in **consistent** at every depth, so it is helpful for calculating the total attenuation.

There are two formulas that will help us to determine the attenuation coefficient of ultrasound in **soft tissue.**

$$Attenuation\ Coefficient\ (dB\ /\ cm) = \frac{f\ (MHz)}{2}$$

$$Attenuation\ Coeffecient = 0.5\ dB/cm/MHz$$

These two formulas make it easy to explain how much energy is lost as the beam travels through soft tissue. To draw relationships from the formulas, we see that frequency is directly related to the attenuation coefficient. If frequency increases, then the attenuation coefficient will also increase. (Proving that higher frequencies have increased attenuation!)

6a.5.2 Total Attenuation

Once we know the attenuation coefficient, we can calculate how much attenuation has occurred over the path of a beam.

The formula for total attenuation is:

$$Total\ Attenuation\ (dB) = \text{Attenuation Coefficient}\left(\frac{\text{dB}}{\text{cm}}\right) \times distance\ (cm)$$

A relationship that we can pull from this formula tells us that distance and total attenuation are also directly related. It's great when we can prove things with math!

The total attenuation will use the attenuation coefficient to calculate how much attenuation has happened at any depth.

Remember that the attenuation coefficient presented only applies to a soundbeam travelling in **soft tissue.**

6a.5.3 Half Value Layer Thickness

- ➔ **Half Value Layer (HVLT) Thickness is also known as Half-Intensity Depth (HID), penetration depth, depth of penetration, half-boundary layer**

HVLT is another term that can describe the rate of attenuation. The half-value layer thickness is the depth at which the intensity is ½ of the original intensity. Knowing that decreasing by 3 dB is also the equivalent to intensity being ½ as strong, another way to define the HVLT is at what depth -3dB change occurs.

Since this is a distance, the units for HVLT is centimeters, with the clinical average being 0.25 cm to 1 cm. If you calculate the attenuation coefficient in soft tissue, you will know how many centimeters it takes to get to 3 dB of attenuation. Or to make it even easier, for soft tissue, divide 6 by the frequency.

$$HVLT\ (cm) = \frac{3\ dB}{Attenuation\ Coefficeint\left(\frac{dB}{cm}\right)} \qquad HVLT\ (cm) = \frac{6}{f\ (MHz)}$$

The HVLT will change based on the the medium. We have been discussing mostly soft tissue up until this point. The next section will discuss some other type of media and their effect on attenuation.

However, in general, the HVLT will depend on two things:

- ➔ **Frequency**
- ➔ **Medium**

Frequency is inversely related to HVLT. WHen the frequency increases, the HVLT will decrease. If the Frequency decreases, the HVLT will increase.

The medium's attenuation rate is also inversely related to HVLT. If a medium will attenuate sound quickly, it has a thin HVLT. If the medium will attenuate sound slowly, it'll have a thick HVLT.

6a.5 Practice

The math is pretty straight forward for these equations. Fill in the chart using the attenuation coefficient, total attenuation and HVLT formulas, assuming soft tissue.

Frequency	Attenuation Coefficient	Total Attenuation at:		HVLT
2 MHz		4 cm		
		16 cm		
5 MHz		2 cm		
		10 cm		
12 MHz		3 cm		
		12 cm		
15 MHz	7.5 dB/cm	6 cm	45 dB	0.4 cm

Section 6a.6 Attenuation in Other Tissue

Ultrasound machines assume a soft tissue average for propagation speed and we can calculate the attenuation based on this assumption as well. However, the sound beam will interact with other types of tissue.

Some tissue causes sound to attenuate faster than the soft tissue average:

- **Air**
  - Attenuates quickly due to absorption (anything over 1 MHz can't even propagate through air)
  - Lungs attenuate sound quickly due to absorption and scatter
- **Bone**
  - Attenuates quickly due to absorption
- Muscle
  - Attenuates faster when sound crosses muscle fibers vs. parallel to them

And some tissue will barely cause any attenuation at all:

- **Water**
  - Causes essentially zero attenuation in frequencies under 10 MHz
- **Fluids (blood, urine, bile)**
  - Very slight attenuation compared to soft tissue
- Fat

To revisit HVLT for other tissues, the lungs attenuate sound quickly. This means that the HVLT will be thin.

Contrary to this Water hardly attenuates sound at all. Therefore, it will take a lot of distance to attenuate 3 dB. The slow attenuation means a thick HVLT.

Section 6a.7 Activities ← Link to Answers

1. What are the three factors that cause attenuation? Place the star next to the factor that has the biggest impact on attenuation.

1.	
2.	
3.	

1. What are the two factors that determine how much attenuation occurs?

1.	
2.	

1. Define:

Attenuation Coefficient	
Total Attenuation	
Half Value Layer Thickness	

4. Match these terms to the statements. Some will be used more than once and some statements have more than one correct answer.

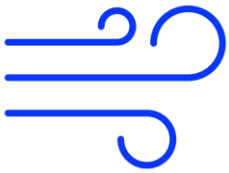
A. Specular Reflection
B. Diffuse Reflection
C. Scattering
D. HVLT
E. Heat
F. Attenuation Coefficient

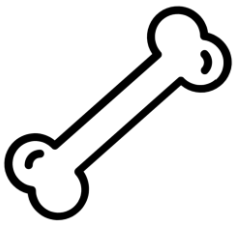
	Requires interface to be larger than the wavelength.
	Requires interface to be smaller than a wavelength
	Type of energy sound is transferred into during absorption
	Causes sound to go in multiple directions
	Causes an organized reflection based on angle
	Helps with seeing the parenchyma of an organ.
	Helps with seeing the borders of an organ.
	Number of decibels of attenuation per centimeter
	Depth at which intensity is half the original
	Occurs with a smooth reflector
	Occurs with an irregular reflector
	Allows for transmission of a beam after interaction

5. Place these body tissues in order from the MOST attenuator to the LEAST attenuator

MOST

LEAST





6. Fill in the chart given the information:

Assuming the media is soft tissue, calculate the following using a 10 MHz Transducer, with an original output of 70 dB.

What is the attenuation coefficient?	
At 1 cm, what is the signal's new dB?	
At 2 cm?	
At 3 cm?	
At 2 cm, what is the strength of the signal compared to the original?	

7. Fill in the chart given the information:

Assuming the media is soft tissue, calculate the following using a 20 MHz Transducer, with an original output of 70 dB.

What is the attenuation coefficient?	
At 1 cm, what is the signal's new dB?	
At 2 cm?	
At 3 cm?	
At what depth has the sound attenuated to 1/10th of the original sound?	

8. Fill in the chart given the information:

Assuming the media is soft tissue, calculate the following using a 6 MHz Transducer, with an original output of 30 dB.

What is the attenuation coefficient?	
At 1 cm, what is the signal's new dB?	
At 2 cm?	
At 3 cm?	
What is the half-value layer thickness?	

9. Fill in the chart given the information:

Assuming the media is soft tissue, calculate the following using a 3 MHz Transducer, with an original output of 30 dB.

What is the attenuation coefficient?	
At 1 cm, what is the signal's new dB?	
At 2 cm?	
At 3 cm?	
What is the half-value layer thickness?	

Section 6a.8 Nerd Check!

1. What are the three parameters that describe the strength of a wave?
2. What happens to these parameters as they travel through tissue?
3. What is attenuation?
4. Why do sonographers need to be aware of attenuation?
5. What is a decibel?
6. What is a linear scale?
7. What is a logarithmic scale?
8. What number base goes with decibel?
9. How would you describe the loudness of a rock concert compared to the threshold of hearing?
10. What does a positive decibel change mean?
11. How much does the intensity increase with a +3 dB?
12. How much does the intensity increase with a +10 dB?
13. What does a negative decibel change mean?
14. How much does intensity change with a -3 dB?
15. How much does the intensity change with a -10 dB?
16. If intensity doubles, what was the dB change?
17. If intensity halves, what was the dB change?
18. If intensity is 10 x stronger, what was the dB change?
19. If intensity is 1/10 the original, what was the dB change?
20. What are the three causes of attenuation?
21. What determines the amount of attenuation?
22. What type of energy is sound transferred to?
23. What are some structures in the body that cause a lot of absorption of sound?
24. Why is the transfer of sound energy to heat important for bioeffects?
25. How are we able to see the parenchyma of organs?
26. What direction does scattering send sound waves?
27. What size reflectors are scattering interfaces?
28. What allows us to see borders?
29. What size are reflective interfaces?
30. What types of reflective interfaces are there?
31. What does it mean to transmit sound?

32. How are frequency and attenuation related?
33. How are depth and attenuation related?
34. What type of frequency will attenuate more?
35. What type of frequency will be absorbed more?
36. What type of frequency will scatter more?
37. Why do longer distances cause more attenuation?
38. How can attenuation affect the image?
39. Why are high frequencies good?
40. Why are low frequencies good?
41. What is the attenuation coefficient?
42. Why is the attenuation coefficient helpful?
43. What two formulas help to calculate the attenuation coefficient?
44. What is total attenuation?
45. What is the formula for total attenuation?
46. What is the half value layer thickness?
47. What are other names for half value layer thickness?
48. What are two formulas that can help to calculate HVLT?
49. What two factors is HVLT dependent on?
50. If a medium attenuates quickly, how is the HVLT affected?
51. If a medium attenuates slowly, how is the HVLT affected?
52. If a transducer has a high frequency, how is the HVLT affected?
53. If a transducer has a low frequency, how is the HVLT affected?
54. What body tissues attenuate slower than soft tissue?
55. What body tissues attenuate higher than soft tissue?
56. What is the main attenuation cause in air?
57. What is the main attenuation cause in lungs?
58. What is the main attenuation cause in bone?
59. How is attenuation affected by muscle?
60. How does water affect sound attenuation?
61. Do bodily fluids cause attenuation?