Sononerds
in the classroom

ARDMS Topic:
Clinical Safety, Patient Care, and Quality Assurance

Unit 5:
That Sounds Intense

Sononerds Ultrasound Physics Workbook & Lectures

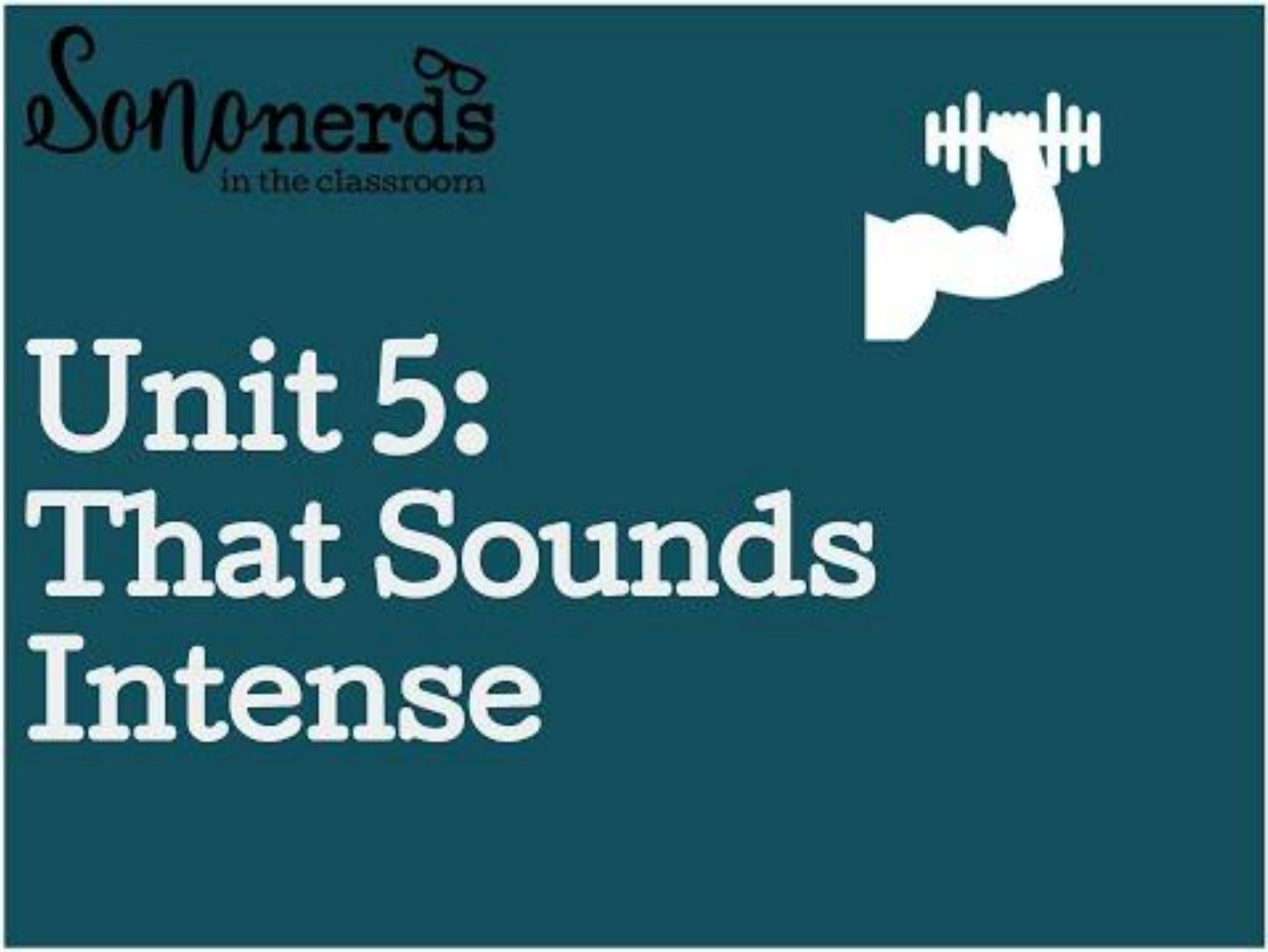
Unit 5: That Sounds Intense

Table of Contents:

- Unit 5 Lecture
- Section 5.1 Intensity (Again)
- Section 5.2 Intensity & Area
    - 5.2.1 Beam Uniformity Ratio
- Section 5.3 Intensity & Time
- Section 5.4 Measuring Intensity
    - 5.4.1 Bioeffects
- Section 5.5 Activities
- Section 5.6 Nerd Check!

Unit 5: That Sounds Intense

Entire Unit 5 Lecture



Section 5.1 Intensity (Again)

In unit 3, we learned that intensity:

- Is one of the ways we can describe a continuous or pulse wave's strength
- Is proportional to power and amplitude squared
- Is directly related to power and inversely related to area, based on this formula:

$$I\ (W/cm^2) = \frac{P\ (W)}{Area\ (cm^2)}$$

- Has units of W/cm^2
- Ranges from 0.01 to 100 mW/cm^2 in diagnostic ultrasound

The ultrasound beam, much like a flashlight's beam, is strongest in the center and weakens towards the edges.

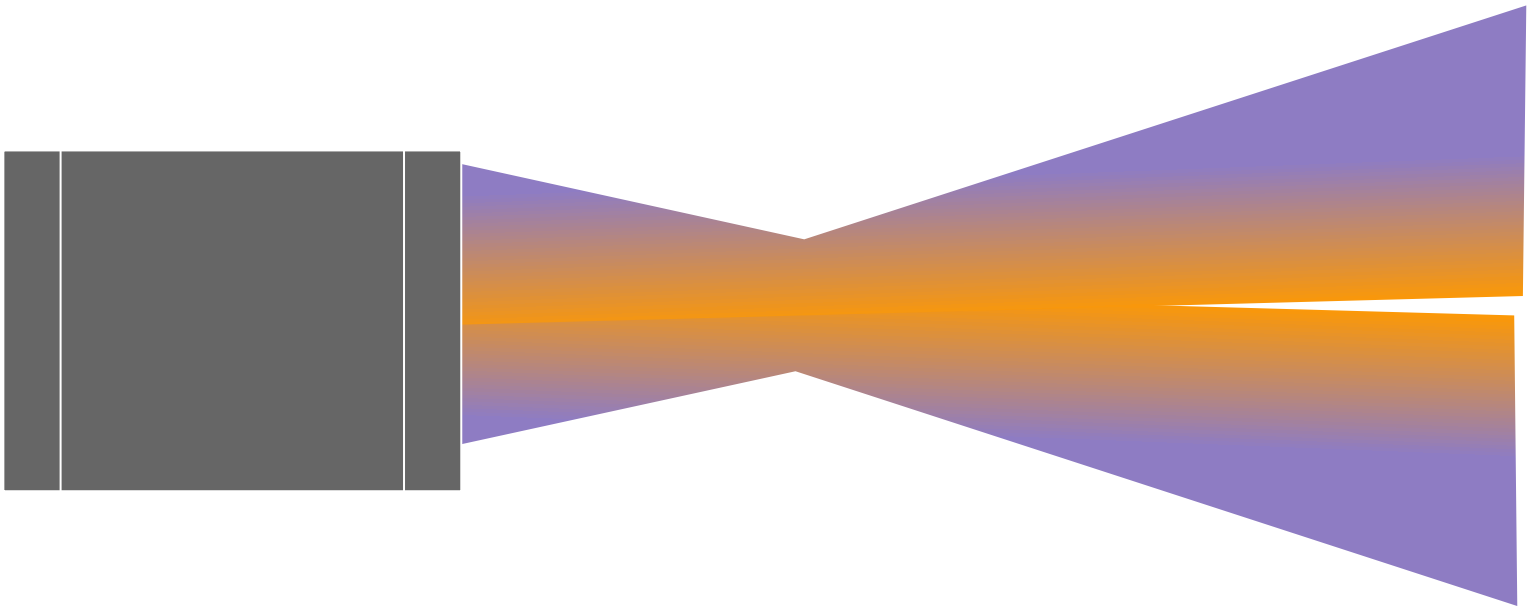
Continuing the flashlight analogy, if the beam is on constantly, we would be correct in thinking that over time, that beam would carry higher intensity, versus a beam that is on and off...or pulsed.

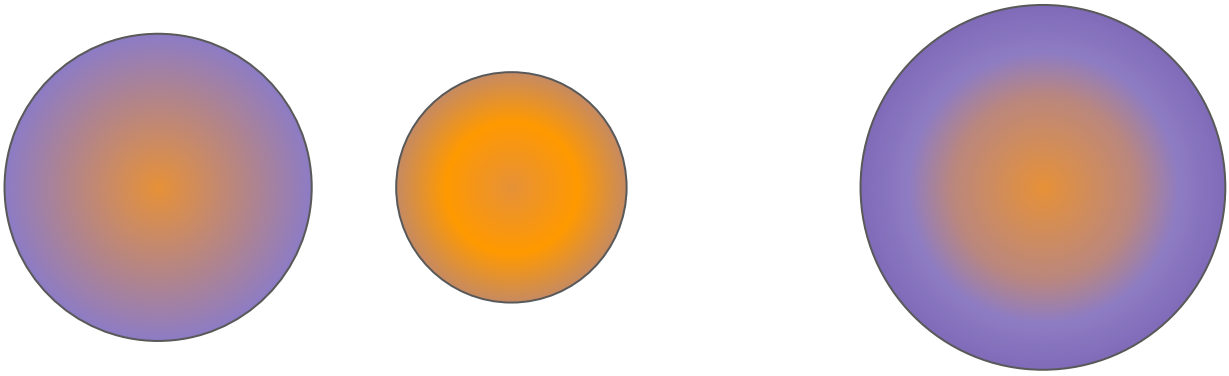
Section 5.2 Intensity & Area

Intensity is inversely related to area. If the beam is concentrated to a small area, the intensity increases. If it is spread out over a larger area, the intensity will decrease.

Think about the heat from a campfire. If you are too far away from it, you can feel very little, if any heat. Moving a little closer, you may start to feel warmth as the heat is directed to less area and is comfortable- it isn't *too intense.* However, if you bring your hand very close to the flames, the heat is much stronger and more concentrated on your hand. It becomes too intense very quickly and you pull away.

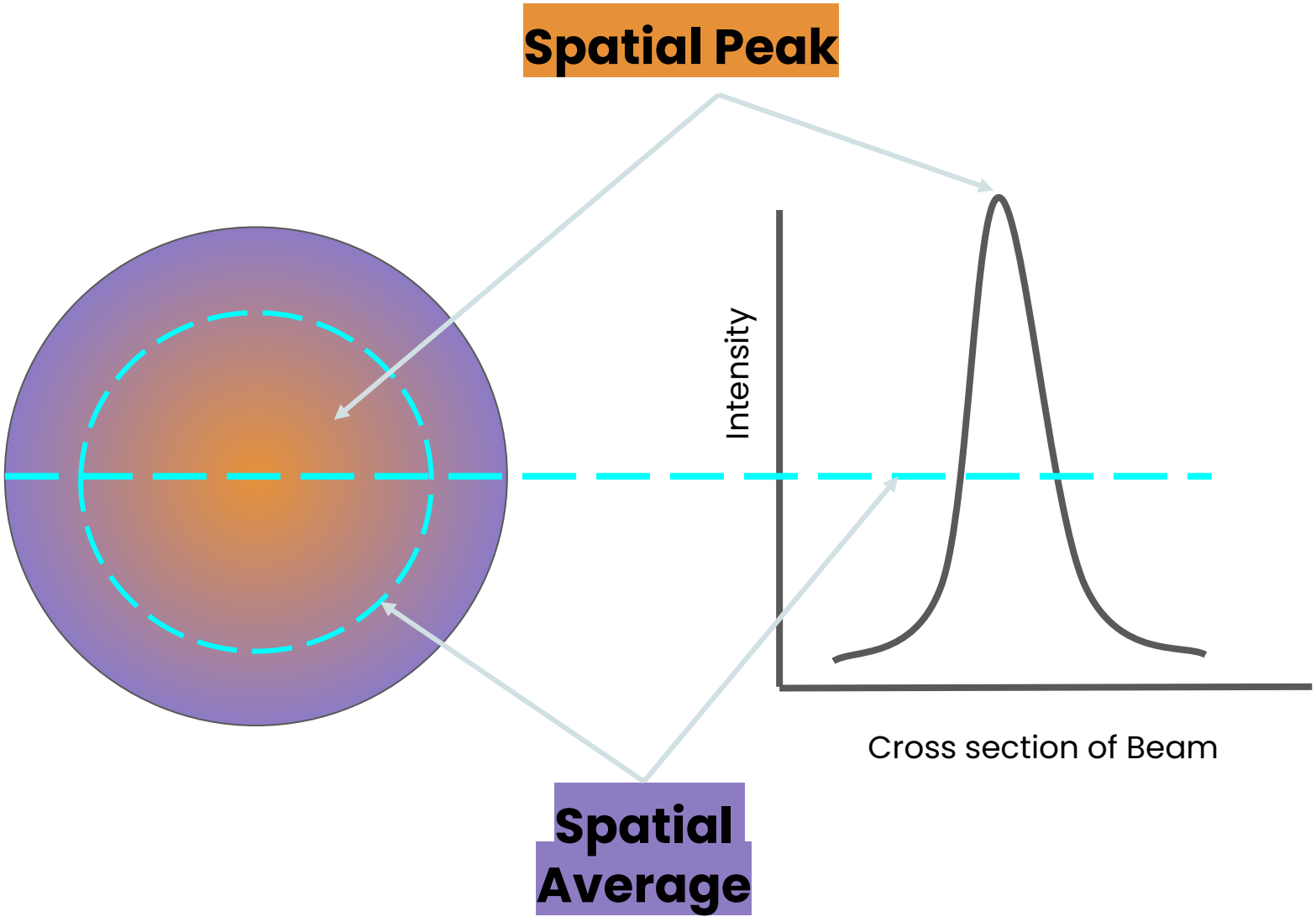
- ➔ **The energy in a sound beam is strongest and most intense at its center.**
- ➔ **As the energy dissipates away from the center, the intensity lessens because the energy spreads out over more area.**
- ➔ **The sound beam is most intense at the focus because the area is reduced the most here.**





When we consider how a beam's intensity "looks" in space, we need to acknowledge that the beam's intensity varies in space and because of this, three things are true:

- ➔ **The beam's Spatial Peak Intensity is at the center of the beam**
- ➔ **The beam's Spatial Peak Average is the mathematical center of the intensities of the beam**
- ➔ **The Spatial Peak Intensity is stronger than the Spatial Average Intensity.**
- ➔ **The beam has the most intensity at the focus.**



Section 5.2.1 Beam Uniformity Ratio

The beam uniformity ratio is a comparison of the Spatial Peak Intensity to the Spatial Average Intensity. It is a **unitless** value and describes how the beam is consistent (or inconsistent) in intensities across the beam.

$$BUR = \frac{SP}{SA}$$

- ➔ **Also known as the SP/SA Factor, BUC or BUF**
- ➔ **Value is usually over 1 (SP is stronger than SA)**

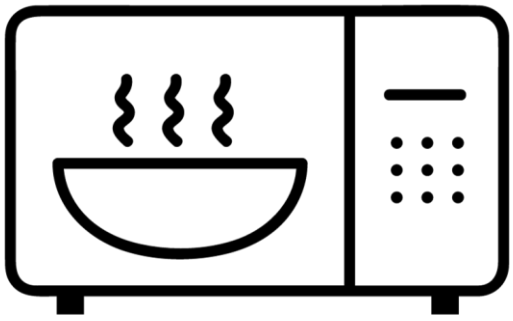
When the number is closer to 1, the beam is more consistent across.

As the BUR value increases, this suggests that the SP is very intense, compared to a much less intense SA.

Think about microwaving a frozen meal.

If you microwave your meal and it is lava in the center, but frozen on the edges still, you have inconsistent heating. If you compared the hottest center to the average temperature of the meal, you would have a bigger disparity because of the frozen edges.

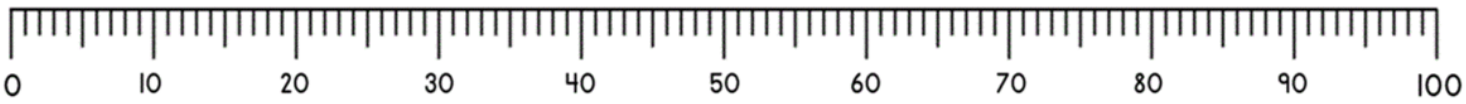
But if you microwave your meal and it's hot in the middle and hot-ish on the edges, you have more consistent heating throughout and your hottest temperature would be closer to your average.



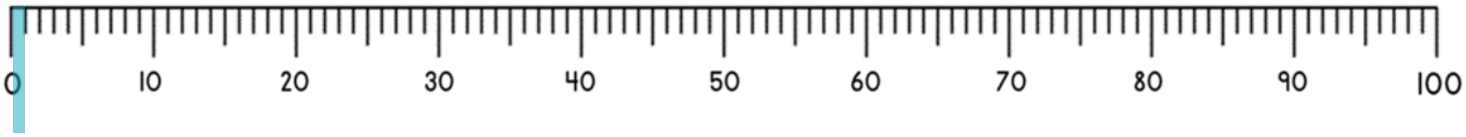
Section 5.3 Intensity & Time

Pulsed ultrasound typically has a VERY short burst of sound energy followed by a much longer off period. The amount of time that the sound energy is present, compared to the off time is described by the Duty Factor. Duty Factor can range from 0 - 1 or 0% to 100%

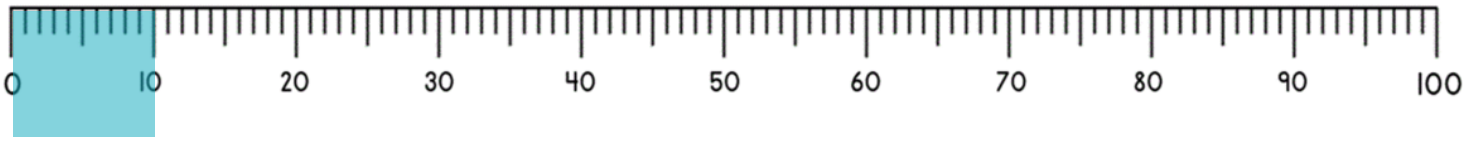
When the machine is off, the Duty Factor is 0%



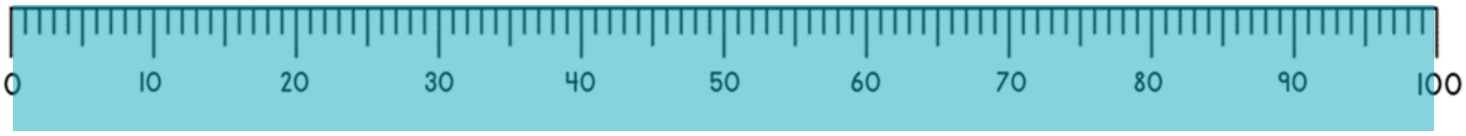
When the machine is imaging in grayscale, the DF is usually < 1%



When the machine is using Doppler, the DF is usually 1-10%



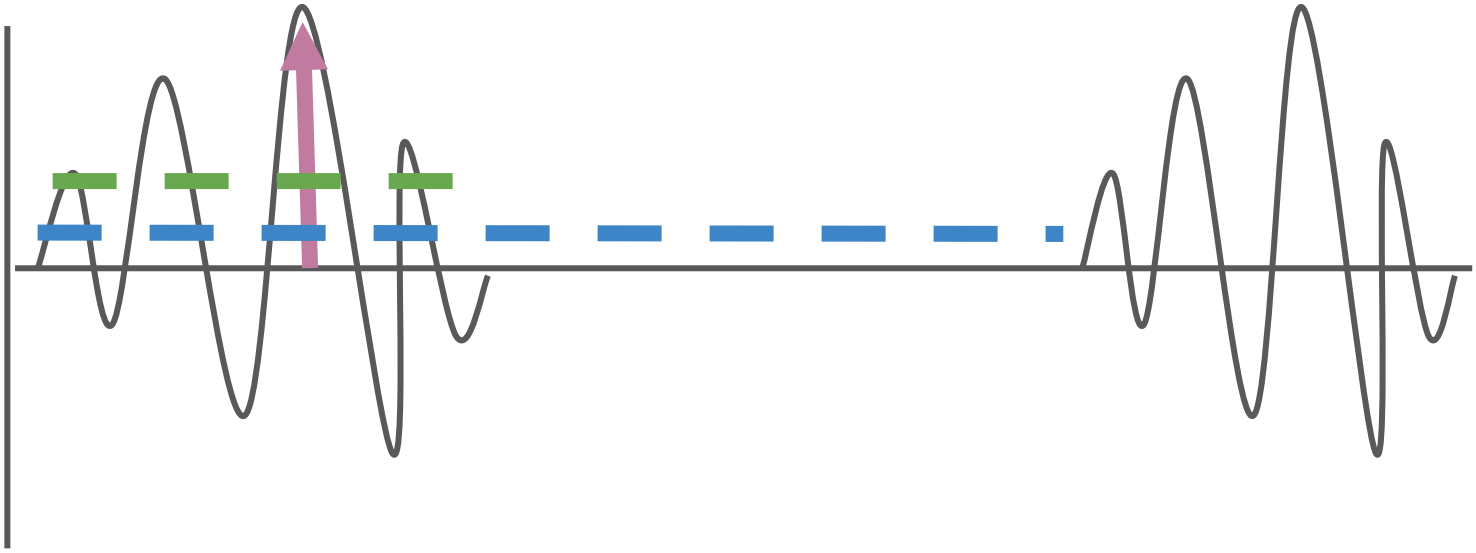
When the machine is using Continuous Wave, the DF is 100%



We need to consider the intensity of the ultrasound beam over time. Looking at the Temporal Peak Intensity, Pulse Average Intensity and Temporal Average Intensity.

When considering how a beam's intensity "looks" over time, we know this to be true:

- ➔ **Temporal Peak is the strongest intensity**
- ➔ **Temporal Average is the weakest intensity**
- ➔ **Pulse Average is weaker than TP, but stronger than TA**
- ➔ **When the machine is listening or off, the intensity is 0 W/cm^2**



The ultrasound pulse is not typically consistent in its amplitude, power and intensity through all cycles, but there is a stronger portion of the pulse.

Temporal Peak is the strongest intensity in a pulse.

Pulse Average is the mathematical center of the intensities found in a pulse.

Temporal Average is the mathematical center of the intensities found in the pulse and listening time. It is typically VERY low due to the off-time intensity being 0. The formula for Temporal Average is:

$$TA = PA \times DF$$

Continuous wave ultrasound PA is equal to TA because there is no listening time (Duty factor is 1 or 100%)

Section 5.4 Measuring Intensity

A hydrophone, also known as a microprobe is a tool that can measure the output intensity of a beam produced by a transducer.

There are two variants of the hydrophone, a needle shaped probe and a disc. The hydrophone can measure the pulse repetition period, pulse duration and period. From these parameters, many others (as you know!) can be calculated.

The hydrophone is capable of measuring amplitude, power and intensity as well. The strength of the beam has a large effect on how the beam will interact with human tissue. This is known as bioeffects and needs to be considered when using ultrasound equipment for patient safety.

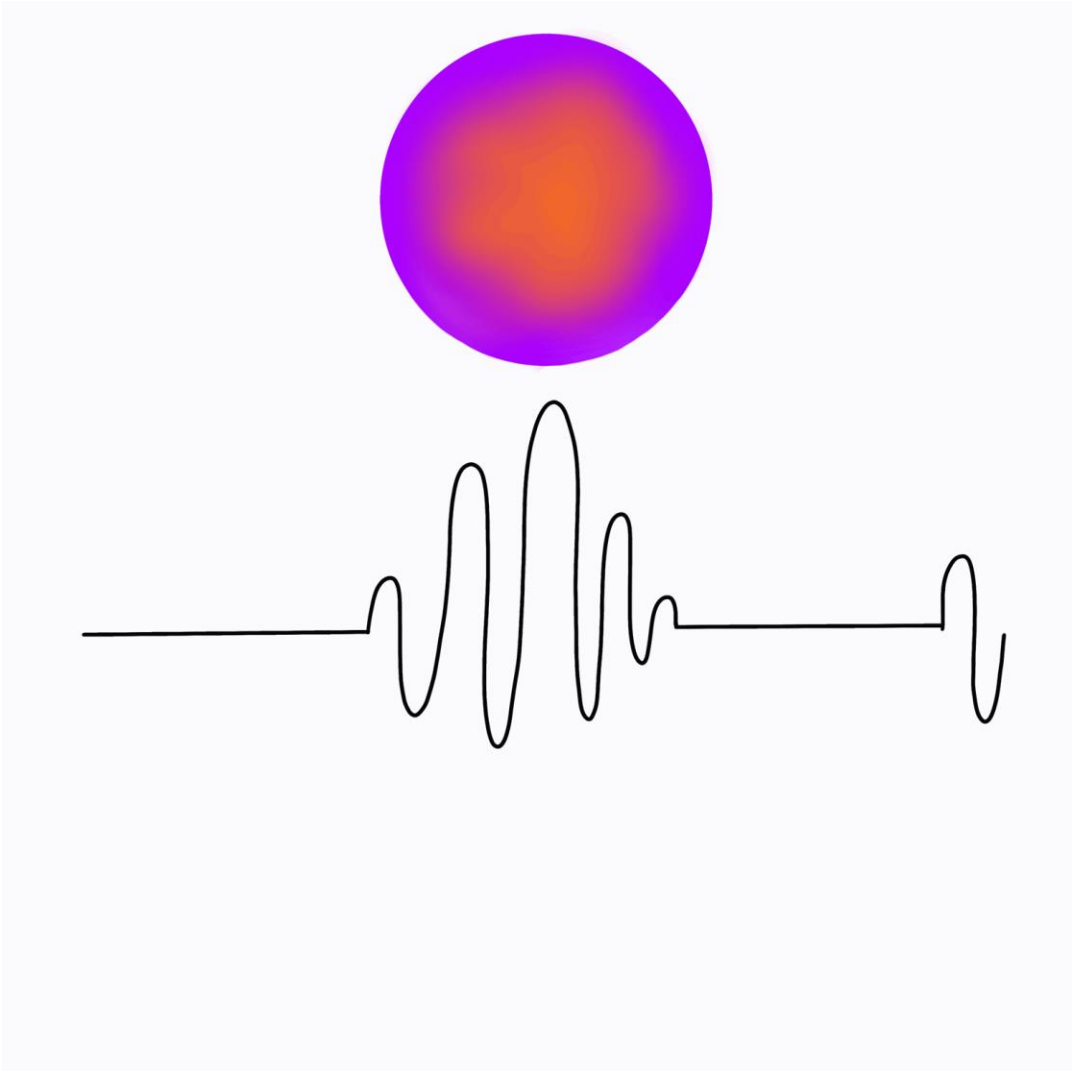
The hydrophone can be moved to different spots of the ultrasound beam. What is measures for intensity will mainly depend on:

- **Where was the beam measured?**
  - At the spatial peak or spatial average?
- **When was the beam measured?**
  - At the temporal peak, temporal average or pulse average?

When combined, we can say specifically where and when an intensity was measured:

- **SPTP -Spatial Peak, Temporal Average ***
- **SATP - Spatial Average, Temporal Peak**
- **SPPA - Spatial Peak, Pulse Average**
- **SAPA - Spatial Average, Pulse Average**
- **SPTA - Spatial Peak, Temporal Average***
- **SATA - Spatial Average, Temporal Average***

- ***SPTP is the strongest intensity**
- ***SATA is the weakest**
- ***SPTA is the used to describe thermal bioeffects**



5.4.1 Bioeffects

Ultrasound has not shown any severe adverse side effects in the application of diagnostic medical sonography. However, computer studies suggest that very strong pulses and very long durations may affect the body.

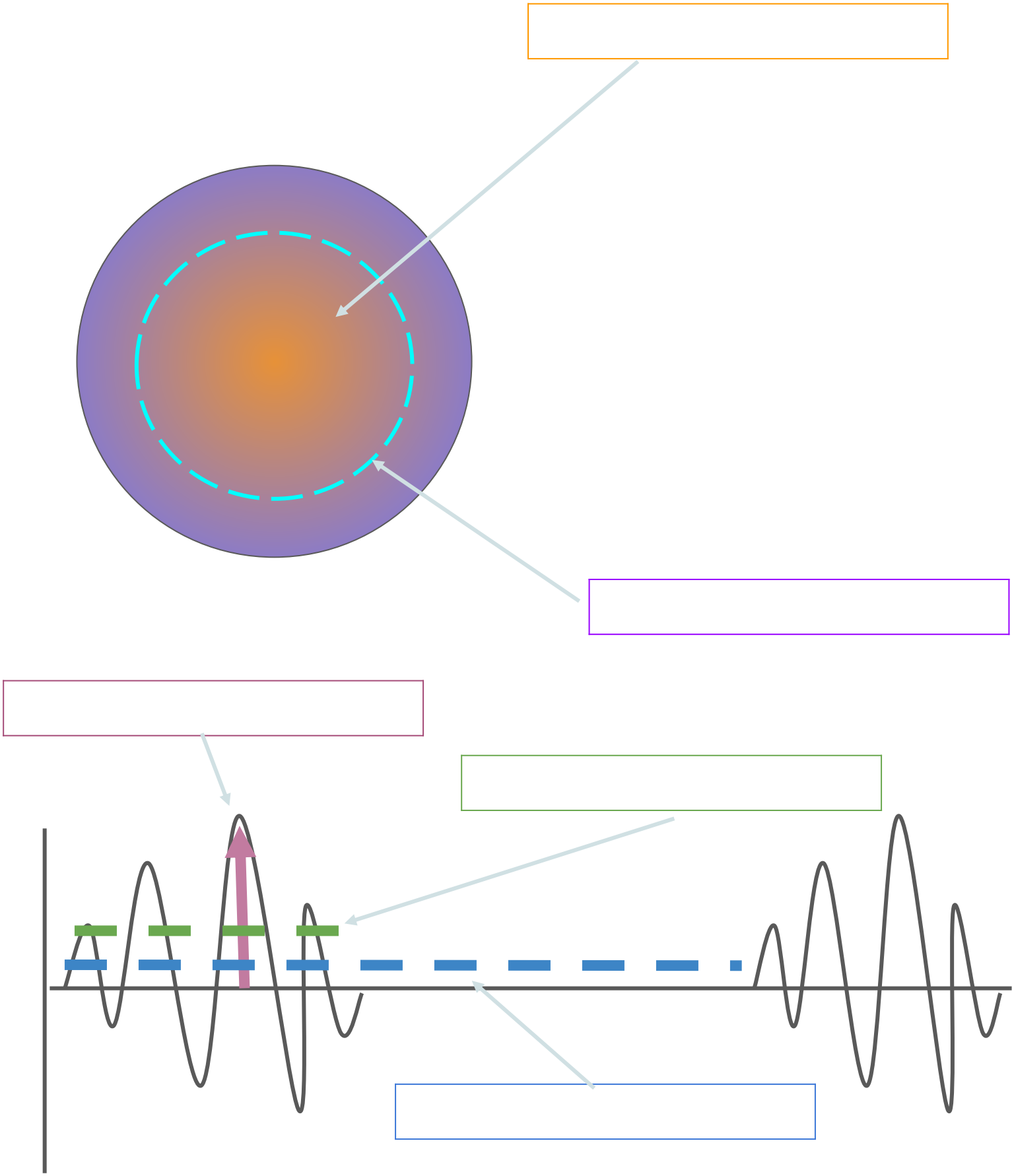
Mechanical concerns arise when the pulse is very strong. It can cause liquid to form small bubbles. This is called **cavitation**. Those bubbles then can rupture, causing cell damage. 2D imaging has more risk for creating cavitation. SPPA is monitored for cavitation levels.

Thermal concerns arise from the duration a pulse interacts with the body. When a beam is held is one spot for long periods, there is a greater chance of the tissue heating up since sound energy is partially transferred into heat energy. Doppler is more likely to cause heating as the sample area has longer pulses and repeatedly samples the same area. An increase in 2℃ has shown to be harmful. SPTA is monitored for thermal bioeffects as it accounts for all the time a patient is exposed to the transducer and pulses.

The FDA regulates ultrasound machines and their intensity output. The SPTA cannot exceed 720 mW/cm^2 .

Section 5.5 Activities ← Answer Link

1. Label the Spatial & Temporal Considerations:



2. List the combined intensity measurements:

Move the stars to indicate:

STRONGEST

WEAKEST

BIG EFFECTS

Section 5.6 Nerd Check!

1. What does intensity describe?
2. What is intensity proportional to?
3. How is intensity related to power and area?
4. What are the units of intensity?
5. In an ultrasound beam, where is intensity the greatest?
6. Why does intensity get weaker as the area gets larger?
7. Where is the spatial peak intensity?
8. Where is the spatial average intensity?
9. Which is bigger, SP or SA?
10. What is the beam uniformity ratio?
11. What are other names for BUR?
12. What unit is used for BUR?
13. What value is BUR usually greater than?
14. What is duty factor?
15. What is the range of duty factor?
16. Of TP, PA and TA, which is the strongest? Weakest?
17. What is the intensity of the beam when the machine is off/listening?
18. Why are TA and PA equal in a continuous wave?
19. What is a hydrophone?
20. How can spatial and temporal measurements be combined?
21. What measurement combo is the strongest?
22. What measurement combo is the weakest?
23. What measurement combo is monitored for bioeffects?
24. What is cavitation?
25. What temperature increase can cause damage to cells?