

**ARDMS Topic:
Ultrasound Instrumentation**

Unit 17a: Tissue Harmonics

**Sononerds Ultrasound Physics
Workbook & Lectures**

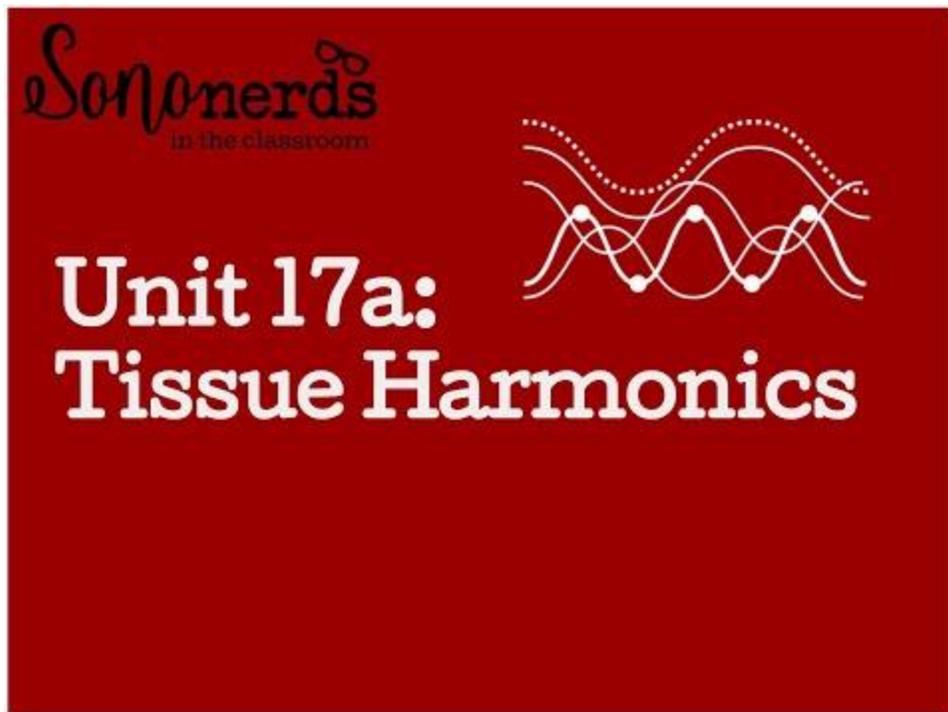
Unit 17a: Tissue Harmonics

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Unit 17a: Tissue Harmonics

[Entire Unit 17a 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 17a: Tissue Harmonics

Tissue harmonics and contrast agents both rely on the ideas of “non-linear” behavior. When the non-linear behavior is the result of the sound beam interacting with the soft tissue, tissue harmonics are created. When the non-linear behavior is the result of the sound beam interacting with a bubble, contrast harmonics are created.

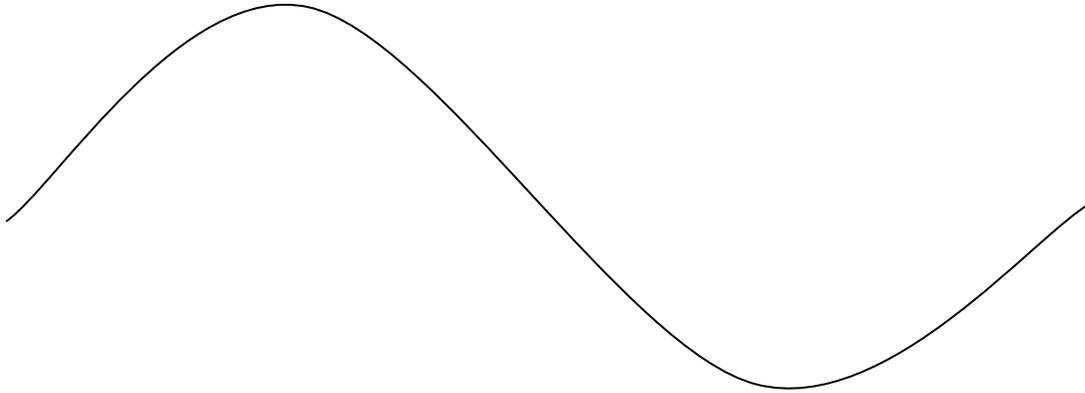
Even though these two ultrasound advancements have similar concepts and are integral to superior diagnostic imaging, their physics discussions look a little different, so unit 17 has been split into:

17a: Tissue Harmonics & 17b: Contrast Harmonics

Section 17a. 1

Fundamental & Harmonic Frequencies

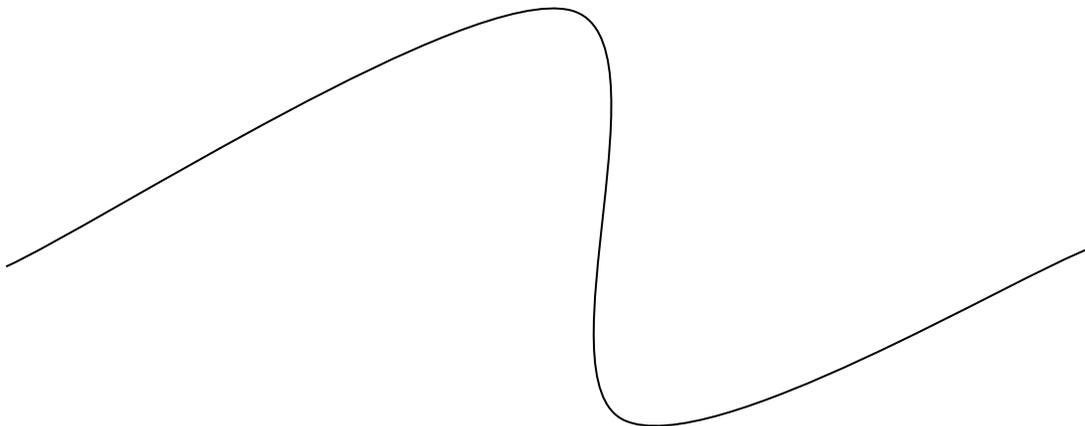
When sound waves are created, the waves propagate in a smooth, predictable manner and we represent it with a sinusoidal wave like this:



However, as sound interacts with the media that it is propagating through we see the wave start to transform. Due to the pressure changes, we begin to see

→ **Compressions travel faster & rarefactions travel slower.**

This creates a non-sinusoidal waveform like this:

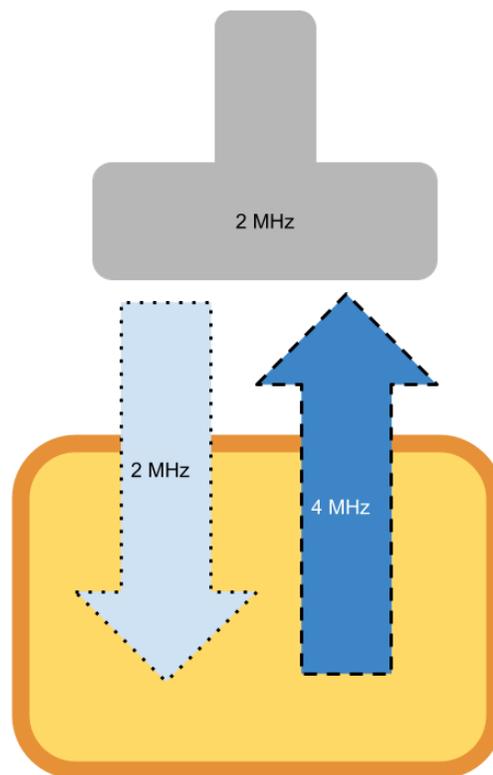


When the waveform is predictable (linear) a **fundamental frequency** is created. The fundamental frequency is what we expect, it is the frequency being produced by the transducer.

When the waveform becomes unpredictable (non-linear) a **harmonic frequency** is created. The harmonic frequencies are derived from the fundamental frequency. **Harmonic frequencies are multiples of the fundamental frequency.** They come in odd and even harmonics.

For example, a fundamental frequency may be 2 MHz, the 2nd harmonics would be 4 MHz, 3rd harmonics would be 6 MHz and so on.

Harmonic frequencies are not created until sound is in the tissue. This is why they are referred to as tissue harmonics.



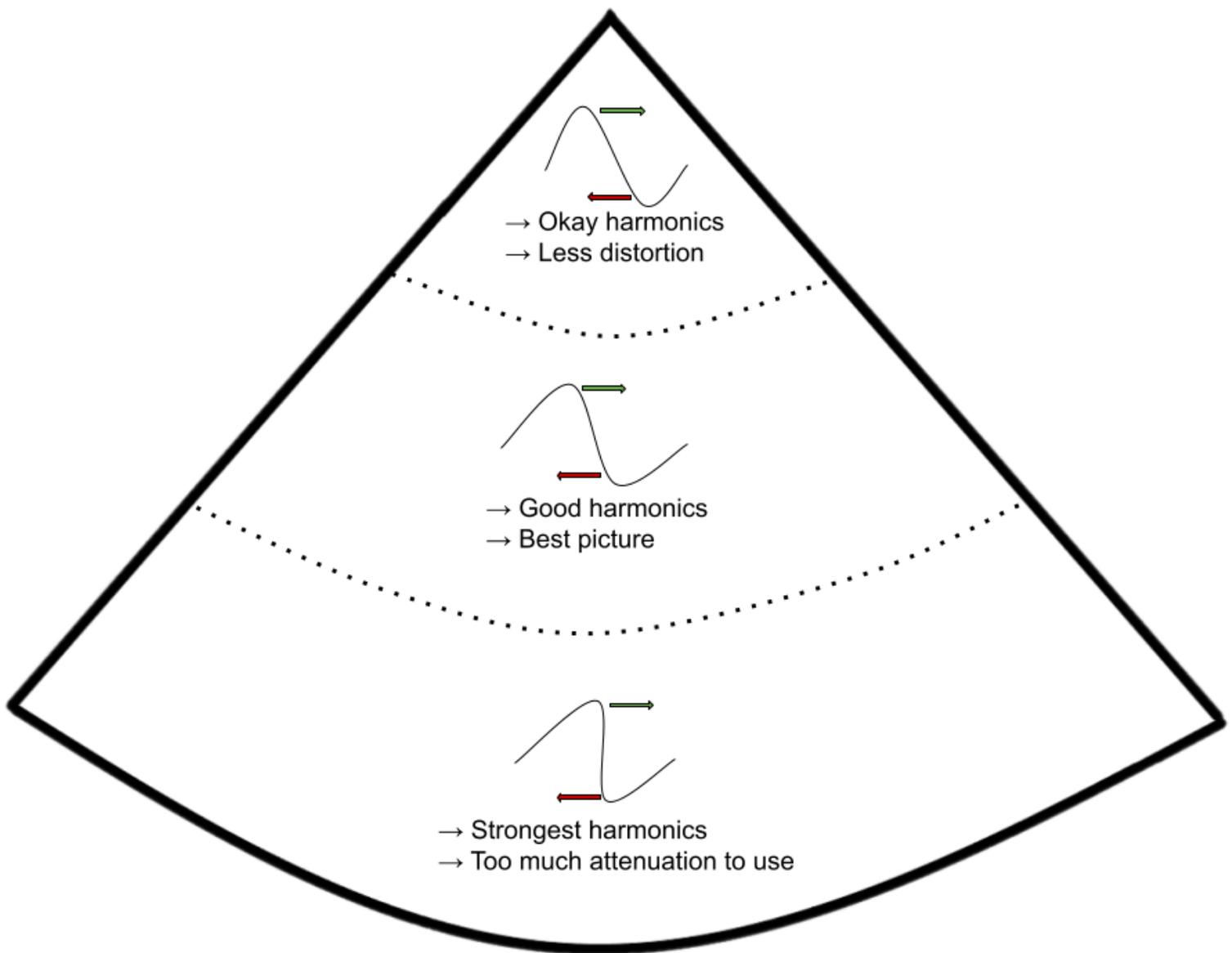
Key things to remember about harmonic frequencies:

- **Harmonics are created in the media.**
- **Harmonics are non-linear (unpredictable) behavior of the sound**
- **Harmonics are multiples of the fundamental**
- **The less sinusoidal the wave becomes, the stronger the harmonics**

Section 17a.2 Tissue Harmonics

When the sound wave enters the body, it will start to change shapes. As the sound wave continues to propagate through the body, the harmonics (deforming of the waveform) becomes stronger.

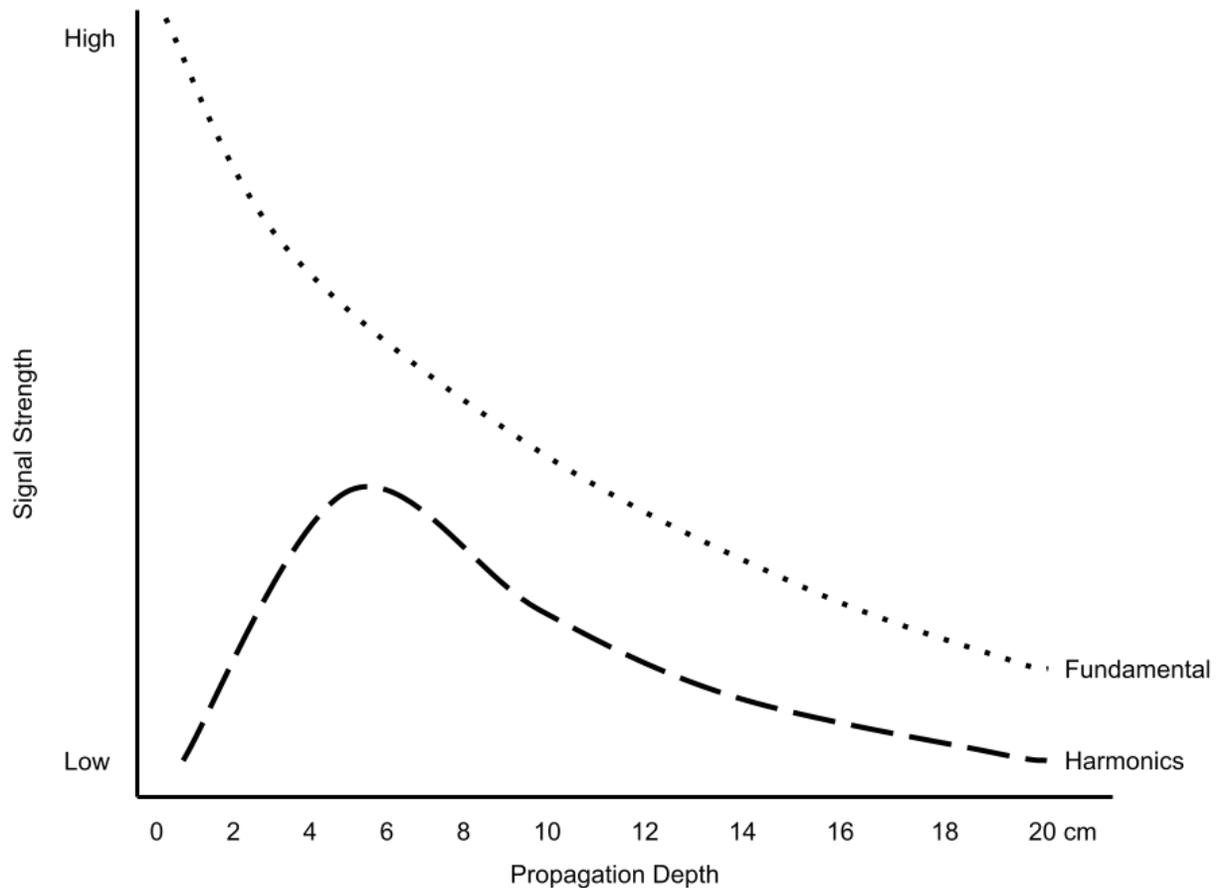
We see in the near field, very little change as the sound has not had much of a chance to interact with the tissue. In the mid-field, harmonics are at their best and in the far field, harmonics are at their strongest, but **strong harmonics attenuate faster**, so we don't get a lot of benefit from those harmonics.



Fundamental frequencies are created by the transducer. They are very strong waves, but due to the multiple thin layers at the surface of the body, they tend to attenuate quickly. This means the sound wave gets weaker as it travels in the body.

Harmonics are not created right away as the media needs to alter the propagation of the wave. Harmonics improve with depth to a certain point and then begin to attenuate before they can be used.

→ **Harmonics improves the SNR in the near and mid field of the image.**



→ **Strong beams are required for harmonics**

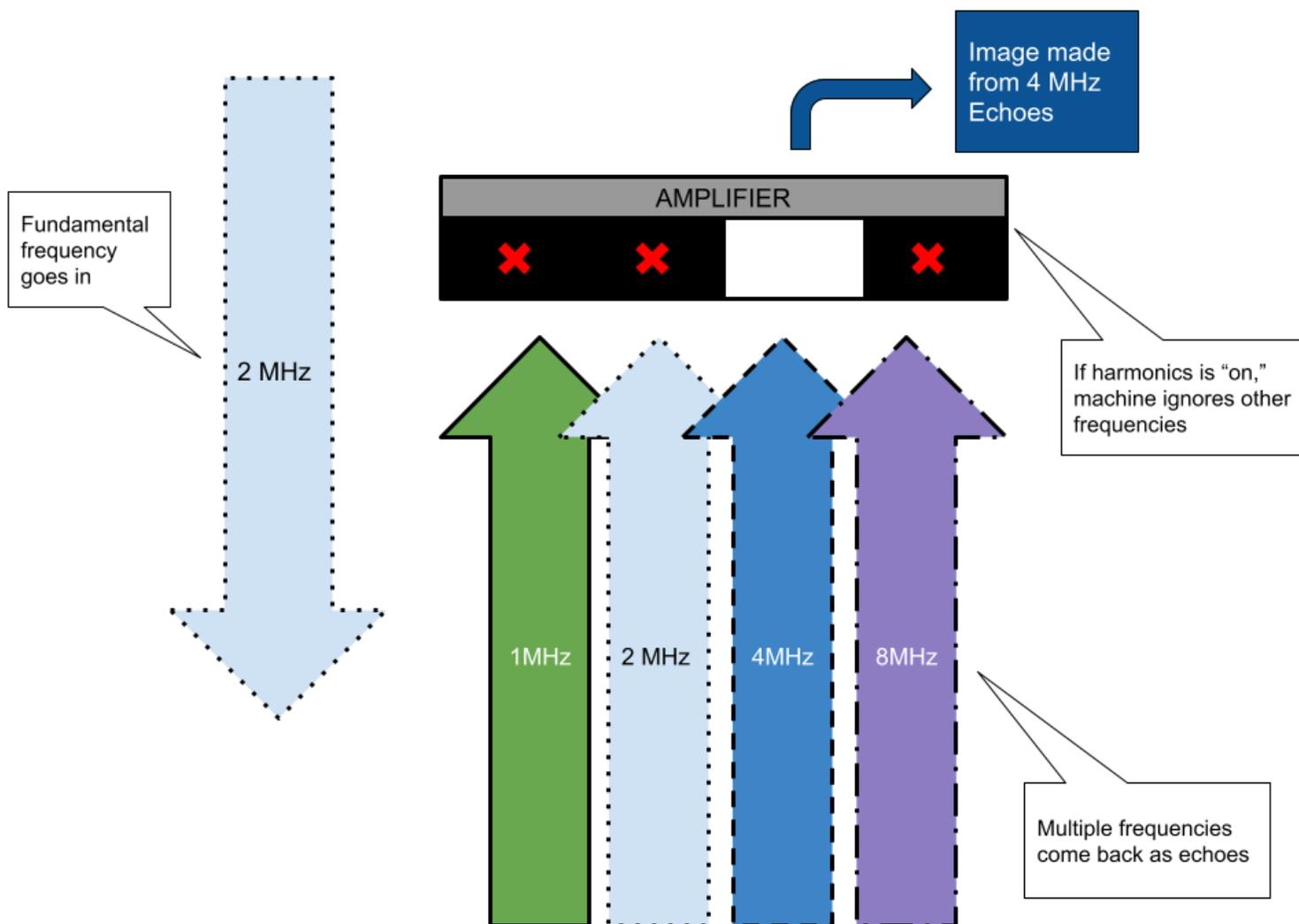
With this in mind, it makes it very important where the focus is placed when using harmonics because the beam gets stronger near the focus, making harmonics stronger too.

Section 17a.3 Harmonics Imaging

In the receiver, one of the functions we talked about was amplification. The amplifiers are **tuned** to listen for specific frequencies in the bandwidth created by the transducer. They can then **filter** signals coming back from other frequencies and either amplify them (because they are wanted) or ignore them (because they are unwanted - noise, electrical interference or not being used for a certain operation).

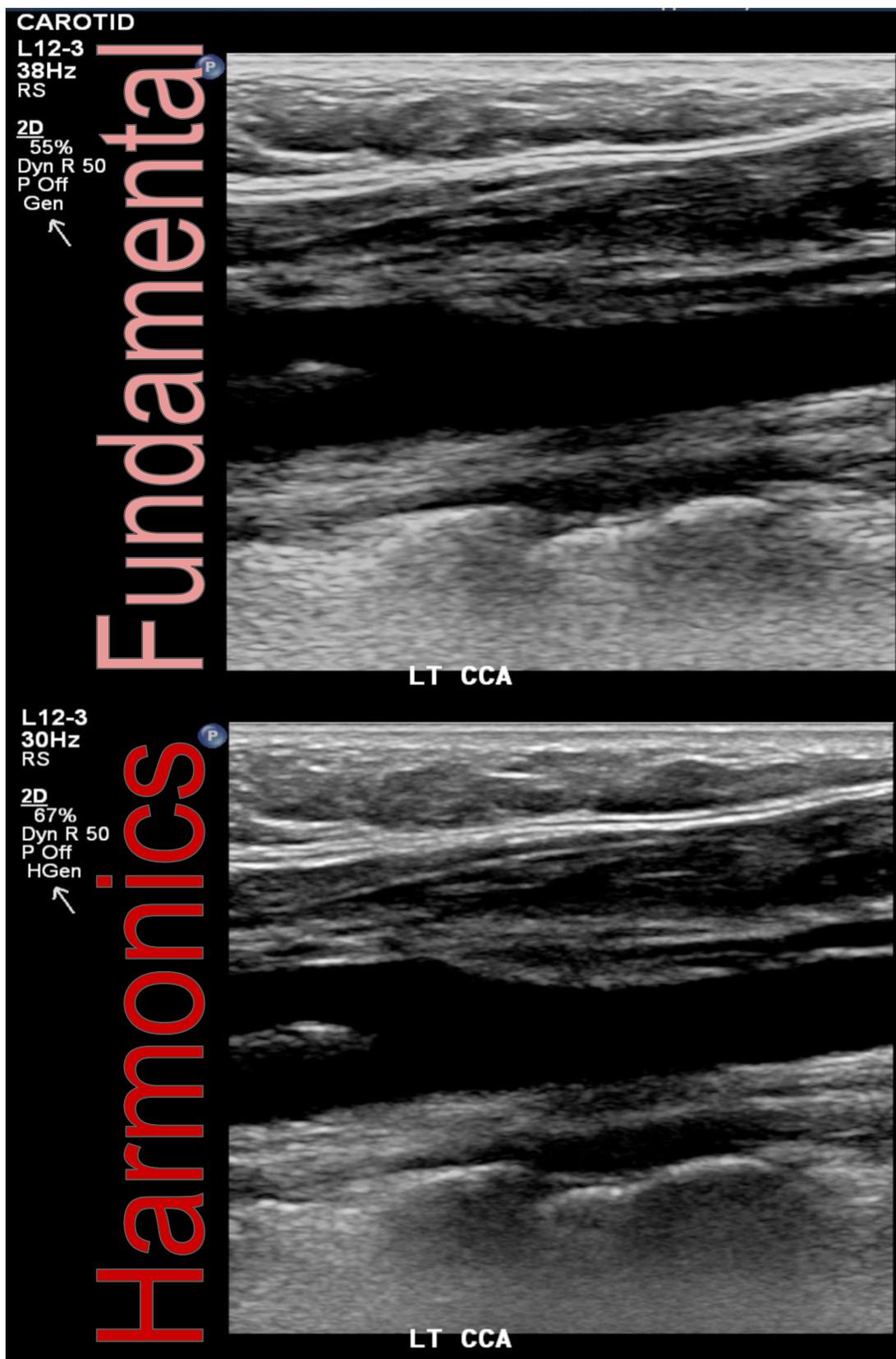
Turning harmonics on tells the machine to amplify the harmonic signals and “ignore” the fundamental signals returning to the machine.

The harmonics the machine listens for is usually **2nd harmonics** because the the returning echoes still need to fit within the bandwidth of the transducer.



The use of the harmonics signal improves the image in three ways:

- **Harmonic beam is narrow, therefore improving lateral resolution**
- **Grating lobes (and their artifacts) are eliminated because only strong beams can create harmonics**
- **Near field artifacts and sound distortion cannot occur**



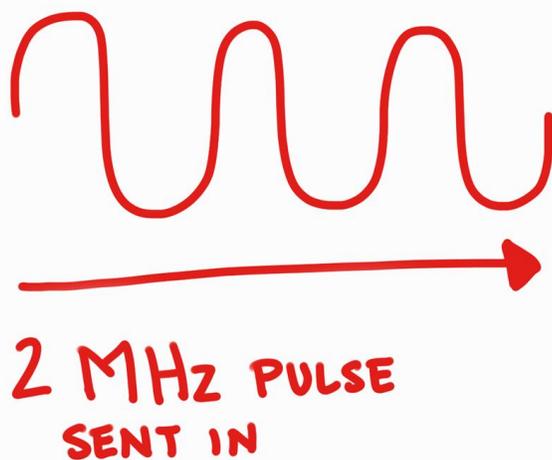
17a.3.1 Pulse Inversion Harmonics

When filtering is used to “pick out” the harmonics frequency, the **axial resolution degrades**. This is because the machine needs a narrow bandwidth to identify the second harmonics. Narrow bandwidths are created by waves that are allowed to “ring” longer, which increases the spatial pulse length.

To combat this, machines employ something called **pulse inversion harmonics** so there is no loss in axial resolution.

The process of pulse inversion harmonics is as follows:

1. Machine sends **2 pulses** down each scan line
 - a. They are fundamental frequency
 - b. They are 180 degrees out of phase
2. The fundamental waves create harmonics in the tissue
3. The echoes returning from the fundamental waves **100% destruct**
4. The harmonics are 100% in phase and construct, thus **doubling their size**.



The pitfall to pulse inversion is that each scan line requires 2 pulses. So we see:

→ **Pulse inversion harmonics *slightly* decreases the frame rate, which degrades temporal resolution**

The vast improvement of the image quality usually makes using harmonics preferred, regardless of temporal resolution needs.



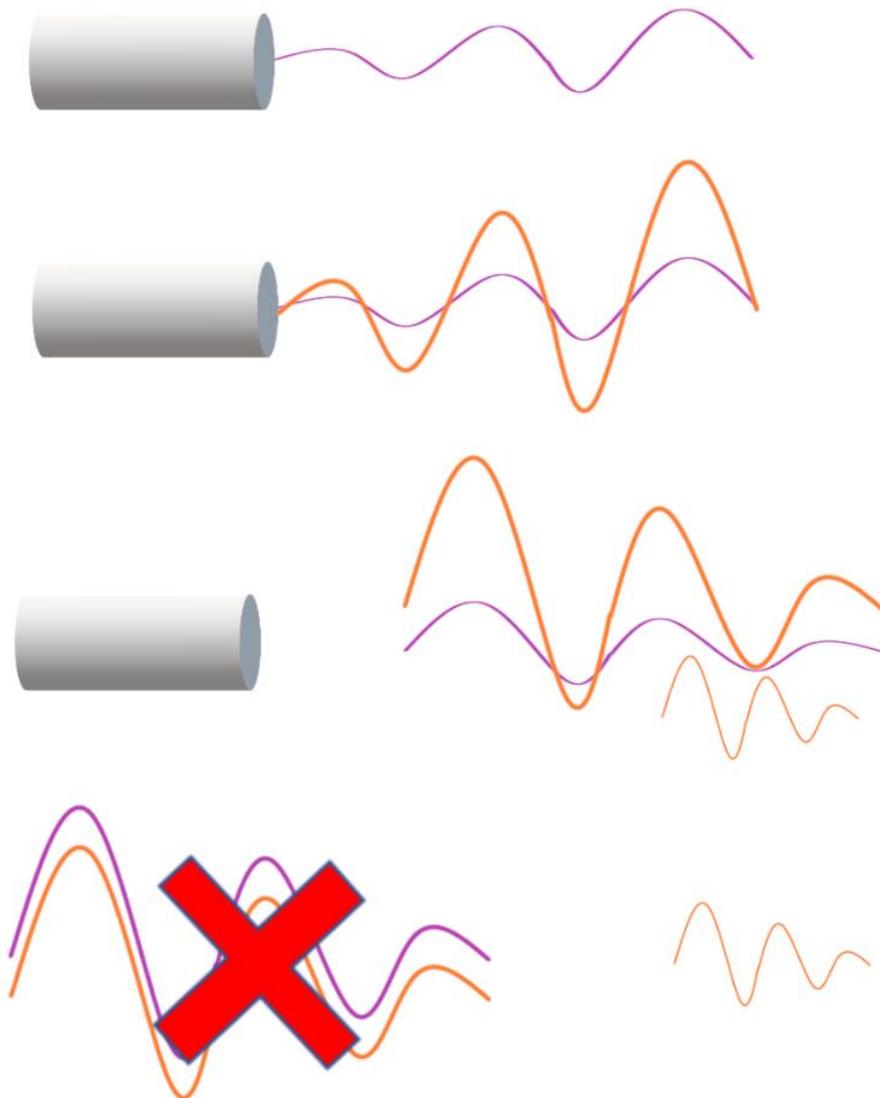
17a.3.2 Power Modulation Harmonics

Pulse inversion harmonics are more commonly used. But, there is a second type of harmonic creation called **power modulation**.

Power modulation follows these steps:

1. A weak beam is emitted
 - Remember these can't create harmonics - only strong beams can
2. Another beam **2x stronger than the weak beam is emitted**
 - The strong beam is the same frequency as the weak beam
3. Fundamental echoes return and the machine doubles the weak echoes to know which strong echoes to ignore
4. Harmonics from the strong beam are process for the image

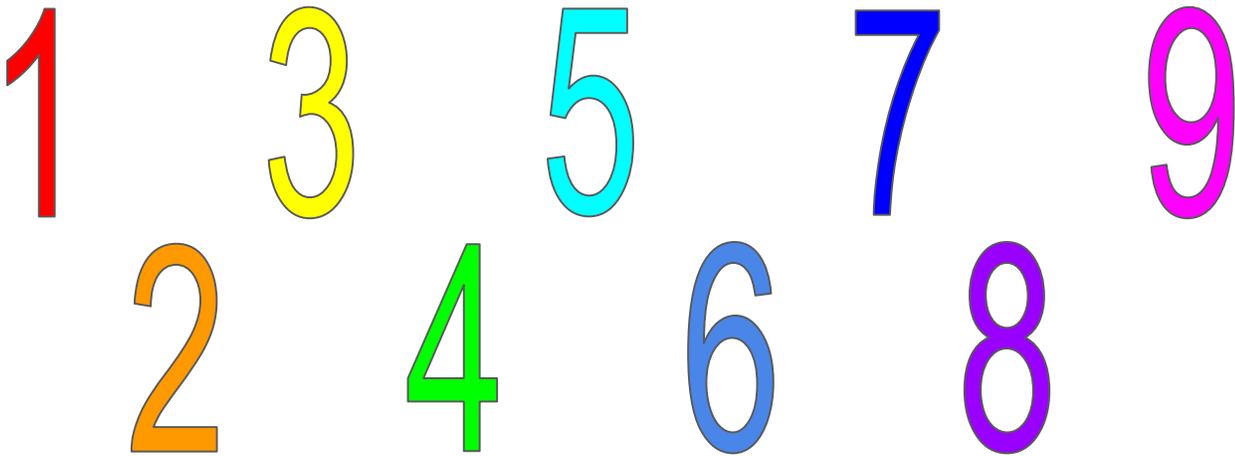
This method also reduced temporal resolution due to needing 2 pulses per scan line.



[Section 17a.4 Activities](#) ← Link to Answers

If the fundamental frequency is 4 MHz the

harmonic frequency is _____ MHz.



If the harmonics frequency is 12 MHz the

fundamental frequency is _____ MHz.

Move the **x** to where tissue harmonics are created and move the **F** to where fundamental frequencies are created:



Tissue harmonics is _____ behavior.

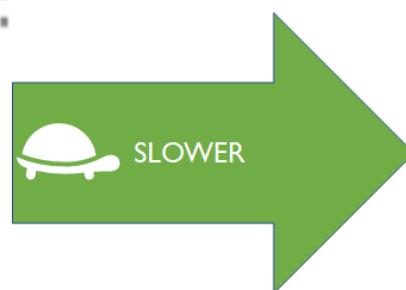
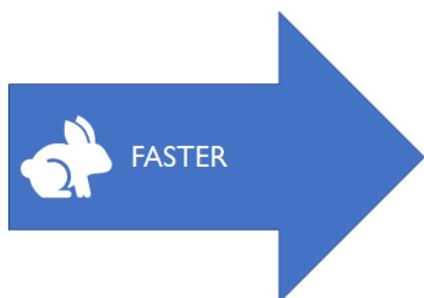
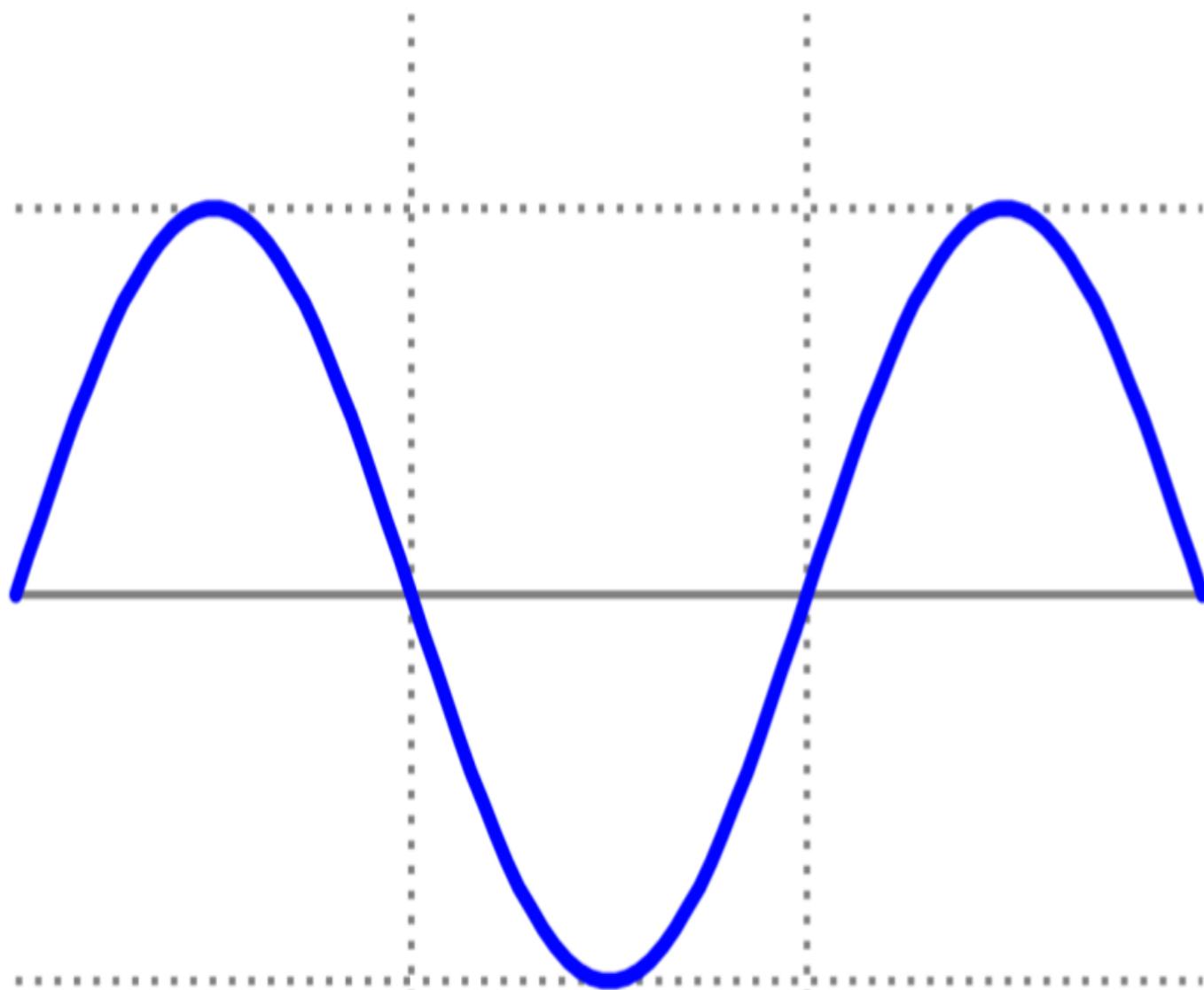


Use the letters below to mark what the statement is true for:

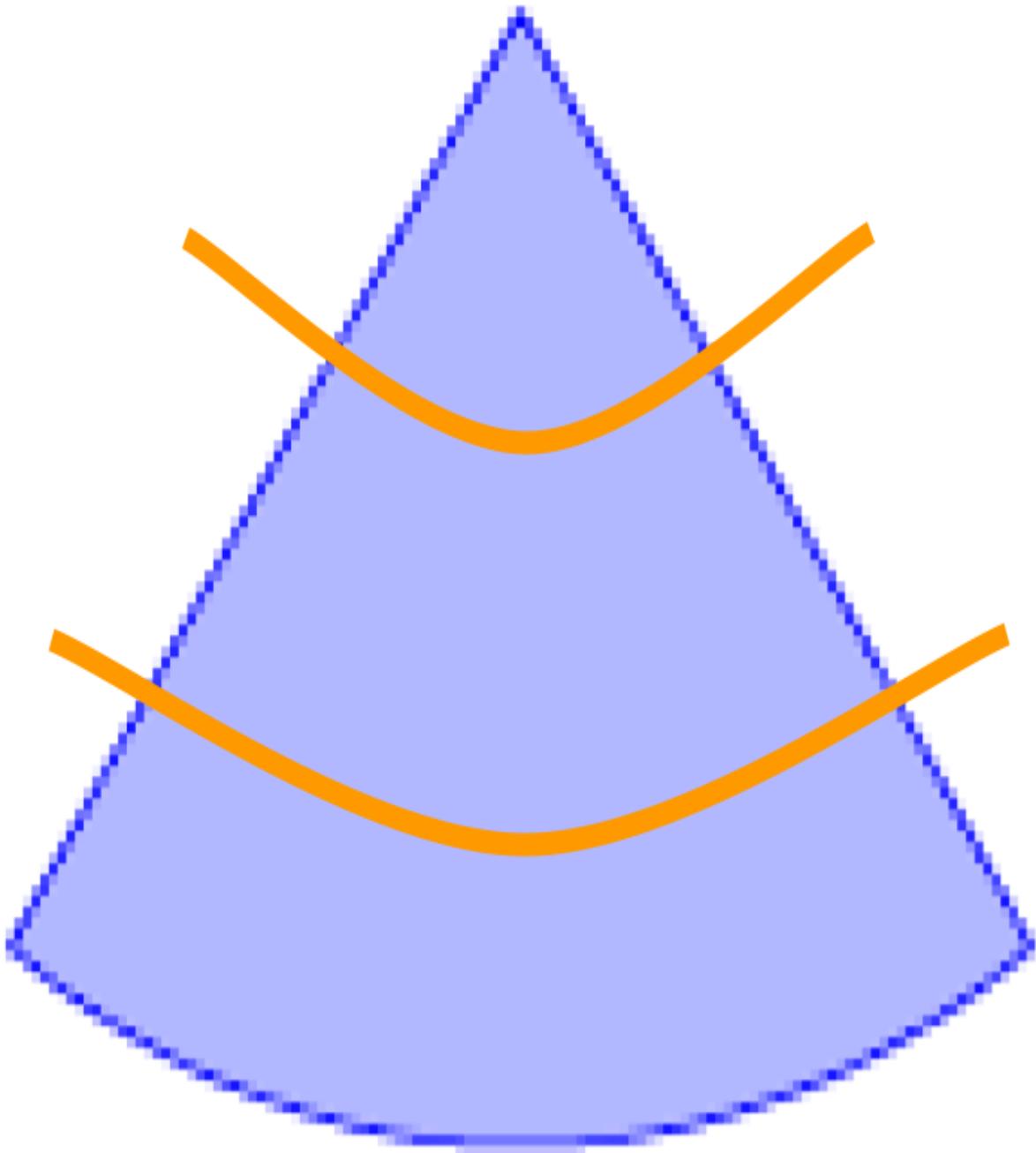
- A. Pulse Inversion Harmonics
- B. Power Modulation Harmonics
- C. Both Pulse Inversion & Power Modulation

	Uses 2 pulses per scan line
	Harmonics echo are a result of a strong beam
	Uses waves that 180 degrees out of phase
	Harmonic echoes construct to become bigger
	Harmonics are created in the tissue
	Degrades temporal resolution
	Uses a weak wave & a strong wave

As sound moves into the body the tissue causes parts of the wave to act differently. Label the what happens to each part:



Place the star where the BEST harmonics are created.



Section 17a.5 Nerd Check!

1. What part of sound wave travels a little faster?
2. What part of the sound wave travels a little slower?
3. What type of behavior do fundamental waves have?
4. What type of behavior do harmonic waves have?
5. How are harmonic frequencies related to fundamental frequencies?
6. Where are harmonic frequencies created?
7. What is called tissue harmonics?
8. Describe the harmonics in the near field, mid field and far field.
9. Why are the harmonics in the far field not helpful?
10. When are harmonic frequencies created in relation to depth?
11. How do harmonic frequencies affect the SNR?
12. What type of beams are needed for harmonics?
13. Why does the focus matter when using harmonics?
14. What do the amplifiers have to do with harmonics?
15. What harmonic is usually used for imaging?
16. What does harmonics do for lateral resolution?
17. What does harmonics do for grating lobes?
18. What does harmonics do to the near field?
19. What does conventional harmonics do to axial resolution?
20. What harmonics method can help correct for poor axial resolution?
21. What is pulse inversion harmonics?
22. Describe the process of pulse inversion harmonics.
23. How many pulses are needed per scanline for pulse inversion harmonics?
24. What resolution suffers when using harmonics?
25. Which harmonics method is more popular?
26. Describe the process of power modulation harmonics.