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Radiological Physics

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Lecture 6: Interactions of Ultrasound with Tissue 2

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Attenuation

When an ultrasound wave propagates through soft tissue, the energy associated with the wave is gradually lost so that its intensity reduces with distance travelled, an effect known as **attenuation**.

- It refers both absorption and scattering of ultrasound.

$$I = I_0 exp^{-\mu x}$$

$$\mu = \mu_{abs} + \mu_{scatt}$$

The attenuation increases (and hence penetration of the beam reduced) by:

1. Increased distance from the transducer
2. Less homogenous medium to traverse due to increased acoustic impedance mismatch
3. Higher frequency (shorter wavelength) transducers, resulting in less penetration at higher frequencies.

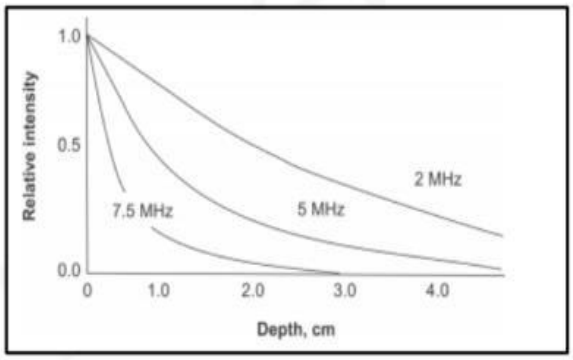
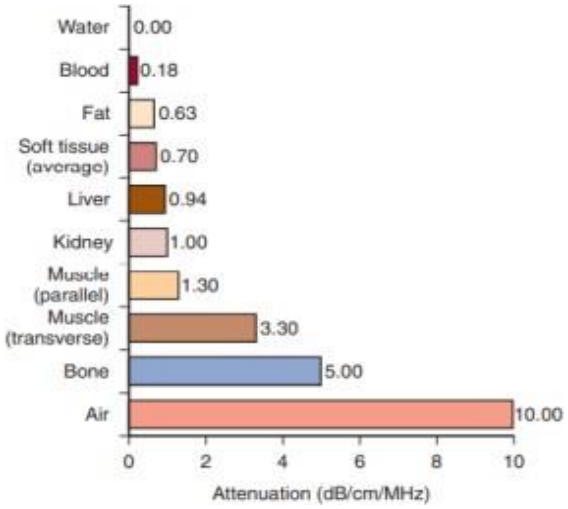


Figure : Attenuation of ultrasound in tissue depth, higher the frequency greater the attenuation

Attenuation is determined by the insonating frequency and the nature of the attenuating medium. Attenuation values for normal tissues show considerable variation.

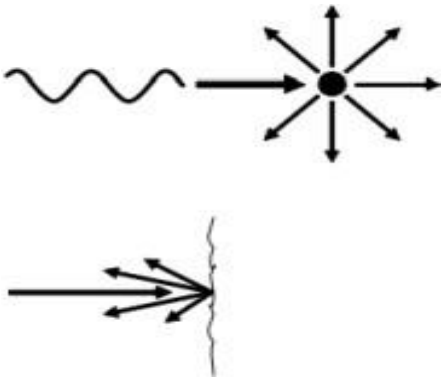


- The attenuation of sound energy as it passes through tissue is of great clinical importance because it influences the depth in tissue from which useful information can be obtained

Scattering

Within the parenchyma of most organs (e.g. liver and pancreas), there are many small scale variations in acoustic properties, which constitute very small-scale reflecting targets (of size comparable to or less than the wavelength).

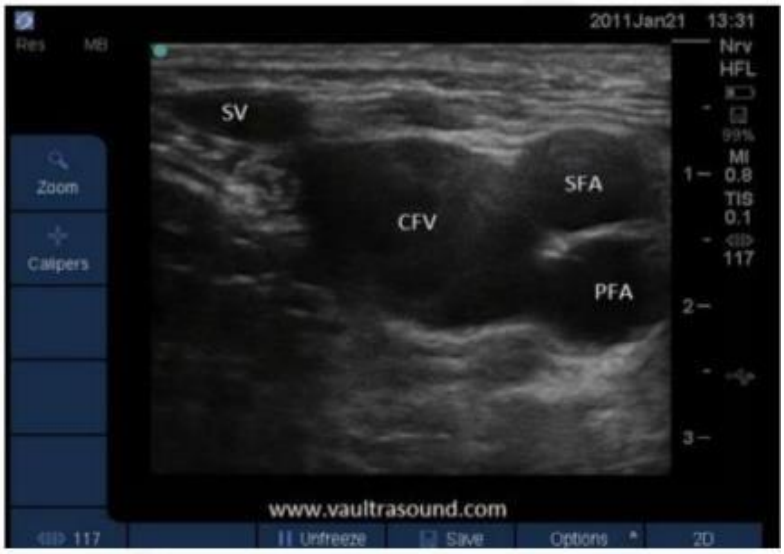
- Reflections from such very small targets do not follow the laws of reflection for large interfaces.When an ultrasound wave is incident on such a target, the wave is scattered over a large range of angles
- Scattering occurs when the size the reflector is $< \lambda$



- Scatter depends on magnitude of roughness.

Smooth surface → low scattering → good image

Rough surface → high scattering → bad image

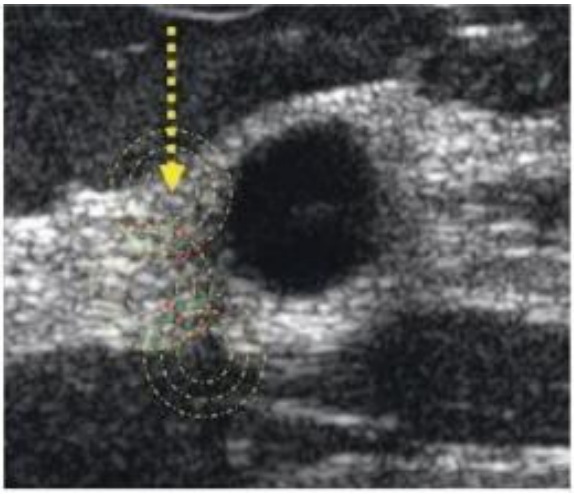


the image of the left saphenous vein (SV), common femoral vein (CFV), superficial femoral (SFA) and profunda femoris (PFA) arteries,

<u>There are two important aspects of scattering for ultrasound imaging.</u>

- Firstly, the ultrasonic power scattered back to the transducer by small targets is small compared to that from a large interface, so the echoes from the parenchyma of organs such as the liver are relatively weak.
- Secondly, as ultrasound is scattered over a wide angle by small targets, their response, and hence their appearance in the image, does not change significantly with the angle of incidence of the wave. Liver parenchyma looks similar ultrasonically regardless of the direction from which it is imaged.

Ultrasound Speckle: Close inspection of an ultrasound image of the breast containing a small cyst reveals it to be composed of numerous areas of varying intensity (speckle). Speckle results from the constructive (red) and destructive (green) interaction of the acoustic fields (yellow rings) generated by the scattering of ultrasound from small tissue reflectors.



Absorption

- Absorption is the process by which ultrasound energy is converted into heat in the medium.
- As it passes through tissue, sound loses energy, and the pressure waves decrease in amplitude as they travel farther from their source. Contributing to the attenuation of sound are the transfer of energy to tissue, resulting in heating (absorption)
- Absorption has been found to be strongly dependent on tissue composition and structure

For example, tissues with high collagen content such as tendons and cartilage show high absorption, whereas those with high water content show lower absorption. Water and liquids such as urine, amniotic fluid and blood have low absorption and low attenuation.