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Department of Physics

Ultrasonic Attenuation Coefficient and Absorption in Different Tissue

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SUPERVISOR CERTIFICATE

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Abstract

In this investigation we study Ultrasound wave, because Sound has one of the most important tools in today's industries. Defense, medical, and manufacturing sectors extensively use sound and its properties to design better products, and how Ultrasound is produced and detected then Interaction this wave with tissue.

Calculating the Absorption Coefficients in Decibels/cm for different frequency (1 ,2 MHz) and 3 MHz according to the literatures for different Tissue like Kidney, Liver and Bladder. Moreover, Acoustic Impedance is used to determine the fraction of sound intensity reflected at a boundary.

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1- Introduction

Medical ultrasound, also called Solography, is a mode of medical imaging that has a wide array of clinical applications, both as a primary modality and as an adjunct to other diagnostic procedures.

In physics, "ultrasound" refers to sound waves with a frequency too high for humans to hear above the range (usually 20 kHz). Ultrasound images (sonograms) are made by sending a pulse of ultrasound into tissue within the body by using an ultrasound transducer (probe). The sound reflects and echoes off parts of the tissue; this echo is recorded and displayed as an image to the operator (http://dukemil.egr.duke.edu/Ultrasound/k-space/node2.html).

All the different diagnostic ultrasound techniques involve the detection and display of acoustic energy reflected off different tissues within the body. Different body structures have different properties that scatter and reflect sound energy in predictable ways, making it possible to recognize these structures in the two-dimensional, gray-scale images produced by ultrasound scanners.

However, ultrasound techniques can also be used to detect and display flow parameters, making it very useful in vascular imaging (Lippicott W, 2003).

1.1Literature

Ultrasonic imaging is the second most popular imaging modality in medicine (the first being x-rays). It is estimated that over 25% of all medical imaging procedures involve ultrasound. Ultrasonic imaging complements the other major imaging modalities, i.e. x-rays and magnetic resonance (MR) imaging etc. (Hughes, 2001). Ultrasonic waves are advanced longitudinal compression waves, for longitudinal waves the movement of the elements in the medium is parallel to the direction of wave motion, as opposite to transverse waves, such as waves on the sea, for which this movement is perpendicular to the direction of propagation. For compression waves, regions of high and low particle density are generated by the local movement of the elements. Compression areas and rarefaction regions correspond to high- and low-pressure areas, correspondingly (Suetens, P., 2017).

Attenuation coefficient: in the ultrasonic energy attenuation coefficient is the ratio of the middling energy absorbed per unit volume of the middle per unit time to the ultrasonic intensity (Shutilov, V.A. and Alferieff, M.E., 2020).

A new technique is presented where the imaged factor is the mean attenuation coefficient between the probe and the given pixel position. The method is based on the least-mean-squares approximation of short segments of A-scan radiofrequency signals using a physical model. The parametric image shows some of the tissue structures. It can also be used as a preliminary step in estimation of the ultrasound attenuation coefficient. Furthermore, the mean attenuation coefficient is a parameter influencing the space-variant ultrasonography point spread function, so it can be used to improve the spatial resolution of ultrasound image through DE convolution. Testing of the method on images of a tissue-mimicking phantom, and on clinical images of liver and thigh showed relatively good agreement of the estimated attenuation coefficients with the known reference values (Jirık et al., 2004).

Ultrasonic attenuation over the frequency range of 1.5-10MHz has been measured as a function of temperature for porcine liver, back fat, kidney and spleen as well as for a single specimen of human liver, the attenuation in these expurgated specimens rises nearly linearly with frequency. Over the temperature range of approximately 4°-37°C the attenuation decreases with increasing temperature for most soft tissue studied (Gammell et al., 1979). Studied the magnitudes in bovine liver and total attenuation was measured, in the range of 1-6 MHz, by both phase sensitive and phase insensitive insertion loss techniques. Ultrasonic absorption was determined by two thermal methods. The standard “transient thermoelectric” or rate-of-heating method, and a new measurement technique based on the temperature decay following a short ultrasonic pulse were employed for the determination of the ultrasonic absorption coefficient (Parker, 1983).

1.2- present work

In present work calculated attenuation coefficient and acoustic impedance for soft tissue like kidney, liver, bladder by take more than ten disease for each organ then mean±SD were calculated for different frequency such as 1,2 and 3 MHz in luqman hakim center

2- Ultrasonic waves

Ultrasonic waves are sound waves with frequencies above the upper limit of a human's audible range (>20 kHz). "Sonic" means the audible range or sound humans can hear. In some definitions, it also refers to the speed of sound waves in air at 340 m/s. Devices that can generate or detect ultrasonic waves are called ultrasonic transducers, which convert alternating current to ultrasound and vice versa. They operate either through the piezoelectric effect or the magneto strictive effect. Some transducers may produce high-intensity ultrasonic sound (within 20-40 kHz) for cleaning and other mechanical applications. They travel about 100 000 times slower than electromagnetic waves as shown in figure 1, providing an opportunity to display information in time and create delay. They can penetrate opaque materials and can be used to inspect and visualize their internal structure. They can travel through various media (solid, liquid, gas) but not in a vacuum. Ultrasonic waves are advanced longitudinal compression waves. Movement of the element in the medium is in longitudinal waves is parallel to the direction of the wave motion and in transverse waves is perpendicular to the direction of the wave motion (Cheeke, J.D.N., 2017).

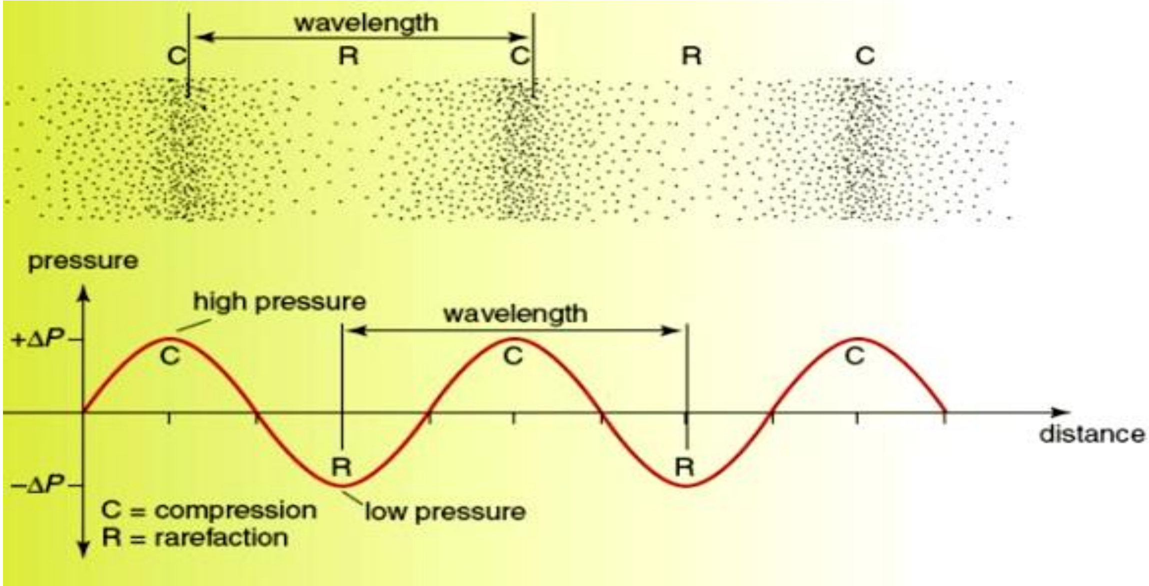

Figure (1): Wave Properties of Ultrasound

2.1-Sonography

Sonography is a diagnostic medical test (noninvasive) that uses high-frequency sound waves, or ultrasound waves, to create images of tissues, glands, organs, and blood or fluid flow within the body. It functions like a camera that takes pictures of body parts or processes in real time This test is also referred to as an ultrasound or sonogram. Sonography uses a device called a transducer on the surface of the skin to send ultrasound waves and listen for an echo. A computer translates the ultrasound waves into an image as shown in figure 2. A trained technician can see, measure, and identify structures in the image. A healthcare provider then reads the images to help diagnose the issue or problem at hand. Sonography is useful for evaluating the size, shape, and density of tissues to help diagnose certain medical conditions. Traditionally, ultrasound imaging is great for looking into the abdomen without having to cut it open. A sonogram is most commonly used to monitor the development of the uterus and fetus during pregnancy. It can also be used to evaluate glands, breast lumps, joint conditions, bone disease, testicular lumps, or to guide needles during biopsies. Sonography can also recognize blood or fluid flow that moves toward or away from the transducer. It uses color overlays on the image to show the direction of the flow. Physicians often order a sonogram before moving on to imaging technologies that have more potential for complications (Rod B., EMT-P-2022).

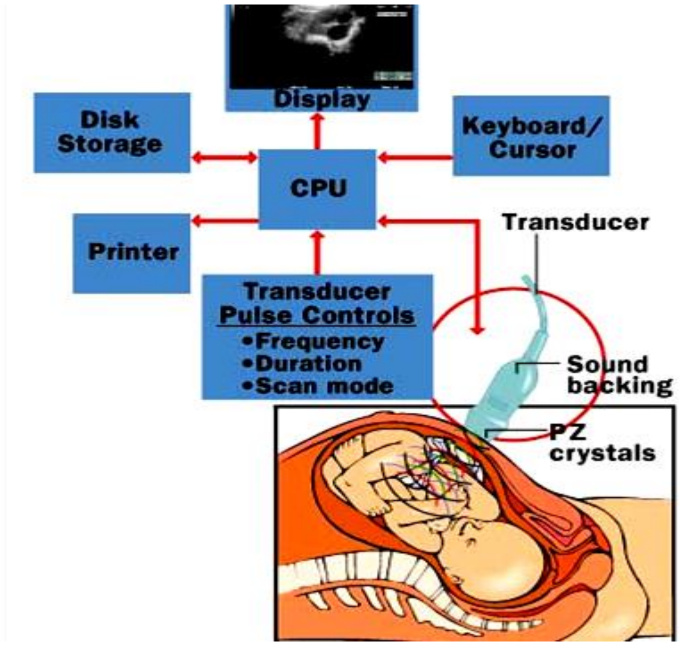

Figure (2); The Parts of an Ultrasound Machine

2.2- Sound wave interaction with tissue

As the ultrasound wave travels through a medium, the medium absorbs some of the ultrasound wave energy. The interaction can cause measurement errors, artifacts, and poor picture quality. The propagation speed of sound waves through tissue is an important element of ultrasound scans. Ultrasound machines assume sound waves travel at a speed of 1540 m/sec through tissue. In reality, the speed of sound is affected by the density and elasticity of the medium through which it is traveling and these factors are not constant for human tissues. The propagation speed of sound is higher in tissues with increased stiffness and reduced density. An understanding of the basic interactions of tissue with ultrasound provides the basis of avoiding errors and misdiagnosis. Tissue interaction has also led to the development of new technologies, such as automatic border detection. Ultrasound waves, when they strike a medium, cause expansion and compression of the medium. Ultrasound waves interact with tissue in four basic manners.

Ultrasound waves, when they strike a medium, can expansion and compression of the medium. Ultrasound waves interact with tissue in four basic manners. Those interactions are reflection, refraction, scattering and attenuation (Si, K., Fiolka, R. and Cui, M., 2012).

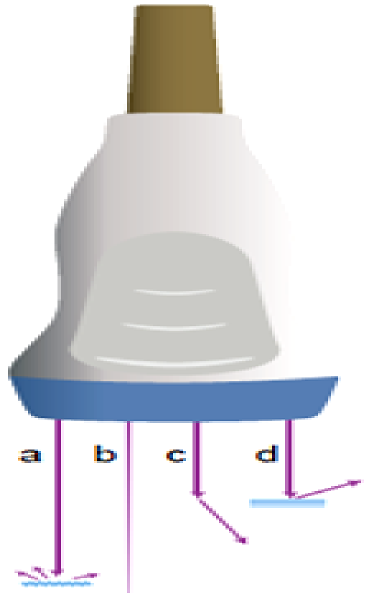

Figure 3; (a) Scattering reflection, b) Attenuation, (c) Refraction, (d) Specular reflection.

2.3- Absorption and Attenuation

Attenuation is the result of an ultrasound wave losing energy. As the ultrasound wave travels through a medium, the medium absorbs some of the energy of the ultrasound wave. The amount of energy absorption, or acoustic impedance, is determined by the product of the density of the medium and the propagation velocity of the ultrasound wave. During attenuation the ultrasound wave stays on the same path and is not deflected. As it passes through tissues of different densities, the amplitude decreases. If all of the ultrasound wave energy is absorbed then structures distal to the point of total attenuation will not be visualized and will appear to be dropped. Energy is lost by reflection, scattering, and attenuation. The loss in energy results in a "noisy" background. If the signal-to-noise ratio is good then a clear picture will be displayed. A poor signal-to-noise ratio results in a blurry picture. Attenuation is frequency dependent. Low frequencies have better penetration and are therefore not attenuated as much as higher frequencies. the factors that affect attenuation are transducer frequency, acoustic impedance and acoustic impedance mismatch. [Harker, A.H. and Temple, J.A.G., 1988]

Attenuation = (Attenuation Coefficient) X Path Length ……..1

Attenuation coefficient = 0.5 * Freq.

(dB/cm) = (dB/cm/MHz) * (MHz)

2.4- Acoustic Impedance

As Ultrasound waves travel through tissues, they are partly transmitted to deeper structures, partly reflected back to the transducer as echoes, partly scattered, and partly transformed to heat. For imaging purposes, we are mostly interested in the echoes reflected back to the transducer. The amount of echo returned after hitting a tissue interface is determined by a tissue property called acoustic impedance. This is an intrinsic physical property of a medium defined as the density of the medium times the velocity of Ultrasound wave propagation in the medium (Chan, V., & Perlas, A. 2010)

$$Z = \rho c \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where Z is Acoustic Impedance

ρ is the density of the medium

c is the speed of sound in the medium

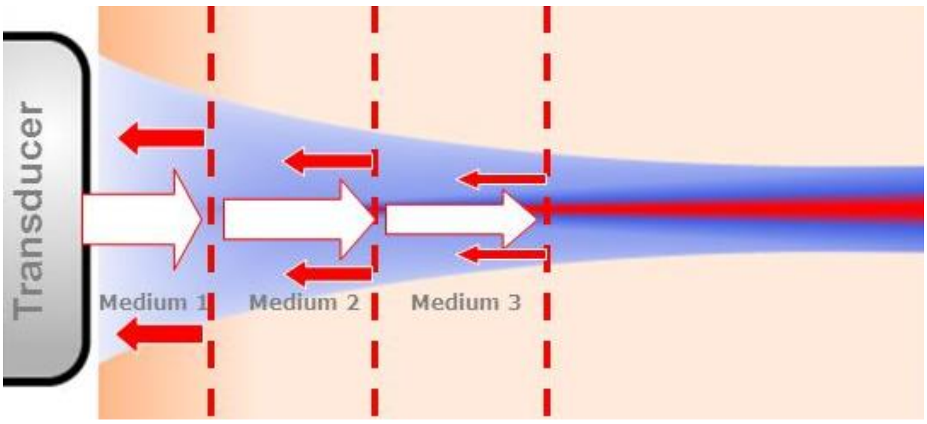

Figure 4; Material characteristics acoustic impedance.

3-Data Reduction and Analysis

3.1- Absorption and Attenuation

By Calculating the Absorption Coefficients in Decibels/cm for different frequency (1 ,2 MHz) and 3 MHz according to the literatures (Goss et al., 1979) for different Tissue, respectively, as shown in table (1)

Table (1) : The Absorption Coefficients in Decibels/cm for different frequency (1,2 and 3MHz) for different Tissue

Tissue	Attenuation Coefficint (dB/cm)at		
	(1MHz)	(2MHz)	(3MHz)
Kidney	1.02±0.281	1.5±0.239	1.66
Liver	0.828±0.328	1.22±0.118	1.45
bladder	0.753±0.082	0.845±0.091	0.95

By plotting the Absorption Coefficients data at different frequency from table (1), against tissue (Kidney, Liver, Bladder) respectively, it seen that at higher frequency, less depth of penetration and more absorption in superficial tissues. but at lower the frequency, the greater is the depth of penetration into deeper tissue (Bladder, Liver, Kidney) respectively. As shown in the figure below:

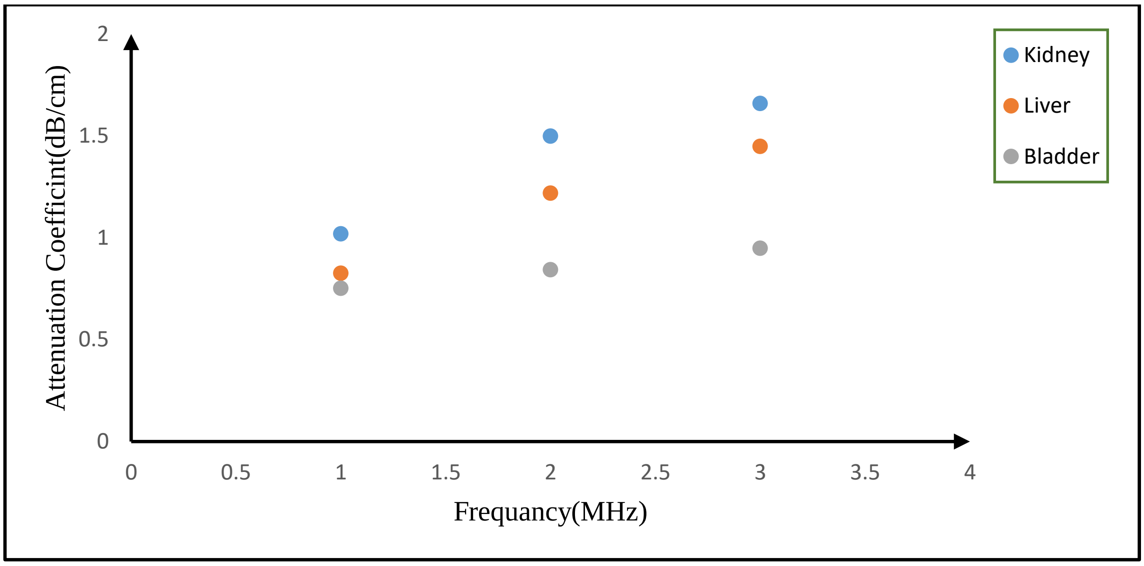

Figure (5): The Absorption Coefficients in Decibels/cm for different frequency (1,2 and 3 MHz) for different Tissue

3.2- Acoustic Impedance

Acoustic Impedance is used to determine the fraction of sound intensity reflected at a boundary. Air-containing organs (such as the lung) have the lowest acoustic impedance, while dense organs such as bone have very high-acoustic impedance by using equation 2 is dependent on the density of the material in which sound is propagated, we determine the acoustic impedance for different soft tissue as shown in (Table 2).

Table (2): Acoustic impedances of different body tissues and organs.

Tissue	**Density (Kg/m3)**	**US Velocity (m/s)**	**Z (10^6 Rayls)**
Kidney	1038	1560	1.63
Liver	1065	1550	1.65
bladder	1058	1540	1.63

4- Conclusions

Throughout this work, the following point are concluded;

1- Ultrasound is medical diagnostic techniques involve the detection and display of acoustic energy reflected off different tissues within the body.

2- Different body structures have different properties that scatter and reflect sound energy in predictable ways

3- Attenuation in US is the rate of decrease of energy when an ultrasonic wave is propagating in a medium.

4- The higher frequency, less depth of penetration and more absorption in superficial tissues.

5- The lower the frequency, the greater is the depth of penetration into deeper tissue.

6- The ultrasound reflects off tissue and returns to the transducer, the amount of reflection depends on differences in acoustic impedance

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