ULTRASOUND AND IT'S APPLICATION ON MEDICINE (ULTRASONOGRAPHY) A Term Paper

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ULTRASOUND AND IT'S APPLICATION ON MEDICINE (ULTRASONOGRAPHY)

A Term Paper

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In Partial Fulfillment for the Requirements of
Master's Degree of Science in Physics

By

Aabiskar Subedi

Exam Roll no: 1941/073

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Recommendation

It is certified that Mr.Aabiskar Subedi has carried out the term paper entitled **"ULTRASOUND AND IT'S APPLICATION IN MEDICINE (ULTRASONOGRAPHY) "** under my supervision and guidance. I recommend the term paper is in partial fulfilment for the requirement of Master's Degree of Science in Physics.

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Advisor

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Date :- July 2019

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Evaluation

We certify that we have read this term paper entitled **"ULTRASOUND AND IT'S USES IN MEDICINE (ULTRASONOGRAPHY)"** submitted by Mr. **Aabiskar Subedi** and in our opinion, it is satisfactory as term paper in the partial fulfilment for the requirement of Master's Degree of Science in Physics.

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ABSTRACT

Ultrasound refers to sound waves above the human range of hearing, 20,000 Hz.This term paper offers the theoretical study of Ultrasound and it's application on different sector as mainly focused on medicine . Ultrasonography, or diagnostic sonography, is used to visualize structures inside the human body, from bones to organs, tendons, and blood vessels, as well as the fetus in a pregnant woman.The transducer makes by the concept of piezoelectric Effect which convert electrical energy into sound energy. The sound waves are reflected by internal structures in the body and hit the transducer in return. These vibrations are then translated by the ultrasound machine and transformed into an image.The depth and strength of the echo determine the size and shapes of the image.Velocity of blood cell often measured by the concept of Doppler Shifts. The basic principles of ultrasound imaging and the physical reasons for many common artifacts are described. In this paper we also discuss about the significance and future prospects of Ultrasonography.

Contents

Chapter 1

Introduction

In physics, sounds are made by vibrations of molecules through which the wave propagates.sound is a vibration that typically propagates as an audible wave of pressure, through a transmission medium such as a gas, liquid or solid.Humans can only hear sound waves as distinct pitches when the frequency lies between about 20 Hz and 20 kHz. Sound waves above 20 kHz are known as ultrasound and is not perceptible by humans.Sound waves below 20 Hz are known as infrasound.In 1794 Lazzaro Spallanzani performed studies on bats that concluded that they could navigate using sound rather than sight (Aird, 1988). Science of Ultrasound began with the development of SONAR(Sound Navigation and Ranging) in the 19^{th} century.In 1826 , Jean-Daniel colladon a swiss Physicist determined the speed of sound in lake Geneva (Aird,E.G 1988).The crash of the Titanic in 1912 increased interest in the development of device to detect underwater objects.The first application of ultrasound technology in medical is credited to the Dussik brother.In the late 1930s and 1940s, Karl Theodore Dussik a neurologist and psychiatrist used aa 1.5 MHz transducer in an attempt to diagnose of brain tumors as (Ahlen & Baagøe, 1999).

1.1 Application of Ultrasound

Ultrasound can't detect objects that are smaller than its wavelength and therefore higher frequencies of ultrasound produce better resolution.The frequency of the sound waves used in Ultrasound is in the range of millions of cycles per second (megahertz, MHz).On the other hand, higher frequencies of Ultrasound have short wavelengths and are absorbed easily and therefore are not as penetrating. For this reason high frequencies are used for scanning areas of the object close to the surface and low frequencies are used for areas that are deeper down in the object.Ultrasound relies on properties of acoustic physics (compression/rarefaction, reflection, impedance, etc) to localize and characterize different types of structures. Ultrasound provides many facilities on these modern society.

1.1.1 SONAR

According to (Nishimori, Handa, Ozasa, Nishida, & Matsumoto, 2007) Sound Navigation and Ranging (SONAR) is a technique that uses sound waves to map or locate objects in the surrounding environment. The premise is quite simple: first, emit a cluster of sound waves in the direction of an object. While a few waves will bounce off it, the remaining waves will be reflected back in the direction of the emitter.It is helpful for exploring and mapping the ocean because sound waves travel farther in the water than do radar and light waves.Primarily use sonar to locate underwater hazards to navigation for ship , search for and map objects on the seafloor such as shipwrecks, and map the seafloor itself.

1.1.2 Ultrasonic Spectacles

It is mainly intended to design a voice based alerting system for the blind people based ultrasonic distance sensor for obstacle detection and voice circuit for voice based announcements. The advantage of this device is voice based announcement for easy navigation i.e. the user gets the voice which pronounces the directions they need to move to reach the destination (Nishimori et al., 2007).

1.1.3 Graphene Production

Ultrasound is a proven a reliable technique to produce high quality graphene, also in large quantities. Researchers have developed slightly different ways using ultrasound, but in general the graphene production is a simple one-step process.Graphite is added in a mixture of dilute organic acid, alcohol, and water, and then the mixture is exposed to ultrasonic irradiation.The acid works as a “molecular wedge” which separates sheets of graphene from the parent graphite.By this simple process, a large quantity of undamaged, high-quality graphene dispersed in water is created (Gao, Zhu, Hu, & Xue, 2017).

1.1.4 Flaws Detection on Metal

As mention by (Hsu, 2006) Ultrasonic Testing is a well-known Non Destructive Testing (NDT) method for detecting the size of the defects and location of the defects in a test material.UT techniques are used to detect both inner (sub-surface) defects and surface defects in structural materials. Ultrasonic testing is done on alloys, concrete, composites, stainless steels and other metals, etc. To receive the ultrasound waveform, basically two methods namely Pulse Echo method and Through Transmission method are used and an instrument like Oscilloscope is used to show the signal as the resultant.This method is widely used in construction and Engineering.

1.1.5 Medicine

The use of sound in medicine started since long time ago. Doctors have used stethoscopes to listen to human body’s internal sounds since the early 19th century and the research in medical ultrasound regained interest in the 1960 and 1970 (Rashid, 2017).Ultrasound became routine in diagnosing as evaluating of kidney function, assessing fetal growth and placement location and so on.Ultrasound imaging has develop to a powerful device in medical aspects.It is used to examine some organs and blood flow and sound reflects at boundary of tissues with different densities. To know detail about Heart diagnose generally used an Echocardiograph.

In Biomedical technology that employs the use of imaging to both diagnose and treat disease visualized within the human body.Radiologists utilize an array of imaging technologies (such as x-ray radiography, Ultrasonography, Electrocardiograph(ECG) , computed tomography (CT), nuclear medicine, positron emission tomography (PET) and magnetic resonance imaging (MRI)) to diagnose or treat diseases.In the list of medical diagnose Ultrasonography is one of the Non-invasive techniques.

1.2 General Objectives

- To understand the basics of Ultrasound and it's application on different field as Sound Navigation and Ranging (SONAR) , Graphene production , Ultrasonics Spectacles and Flaws detection on metal.

Chapter 2

Ultrasonography

In medical field an Ultrasound also called Ultrasonography, is probably the most widely employed imaging tool in medicine today. The technology uses high-frequency $(1-18)$ MHz sound waves inaudible to humans to produce images from inside the body (Duck, Baker, & Starritt, 1998). A device called a transducer that is placed on the skin sends the sound waves into the body and records the echoes as they bounce back, thus defining the size, shape and mass of soft tissues and organs.It is a useful and flexible modality in medical imaging, and often provides an additional or unique characterization of tissues, compared with other modalities such as conventional radiography or CT.

An ultrasound transducer sends an ultrasound pulse into tissue and then receives echoes back. The echoes contain spatial and contrast information. The concept is analogous to sonar used in nautical applications, but the technique in medical ultrasound is more sophisticated, gathering enough data to form a rapidly moving two-dimensional grayscale image (Rashid, 2017).

Some characteristics of returning echoes from tissue can be selected out to provide additional information beyond a grayscale image. Doppler ultrasound, for instance, can detect a frequency shift in echoes, and determine whether the tissue is moving toward or away from the transducer.This is invaluable for evaluation of some structures such as blood vessels or the heart (echocardiography).

2.1 Transducer Probe

The transducer probe is the main part of the ultrasound machine. The transducer probe makes the sound waves and receives the echoes. It is, so to speak, the mouth and ears of the ultrasound machine. The transducer probe generates and receives sound waves using a principle called the piezoelectric (pressure electricity) effect, which was discovered by Pierre and Jacques Curie in 1880 (Aird, 1988). In the probe, there are one or more quartz crystals called piezoelectric crystals. When an electric current is applied to these crystals, they change shape rapidly.The rapid shape changes, or vibrations, of the crystals produce sound waves that travel outward. Conversely, when sound or pressure waves hit the crystals, they emit electrical currents this is called as pulse-echo principle.Therefore, the same crystals can be used to send and receive sound waves.The probe also has a sound absorbing substance to eliminate back reflections from the probe itself, and an acoustic lens to help focus the emitted sound waves.Medical ultrasound transducers contain more than one operating frequency depending upon case study of different organs of body.

Figure 1: Transducer probe (Duck et al., 1998)

2.2 Piezoelectric Effect

Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress. The word Piezoelectric is derived from the Greek piezein, which means to squeeze or press, and piezo, which is Greek for “push”. One of the unique characteristics of the piezoelectric effect is that it is reversible, meaning that materials exhibiting the direct piezoelectric effect (the generation of electricity when stress is applied) also exhibit the converse piezoelectric effect (the generation of stress when an electric field is applied). When piezoelectric material is placed under mechanical stress, a

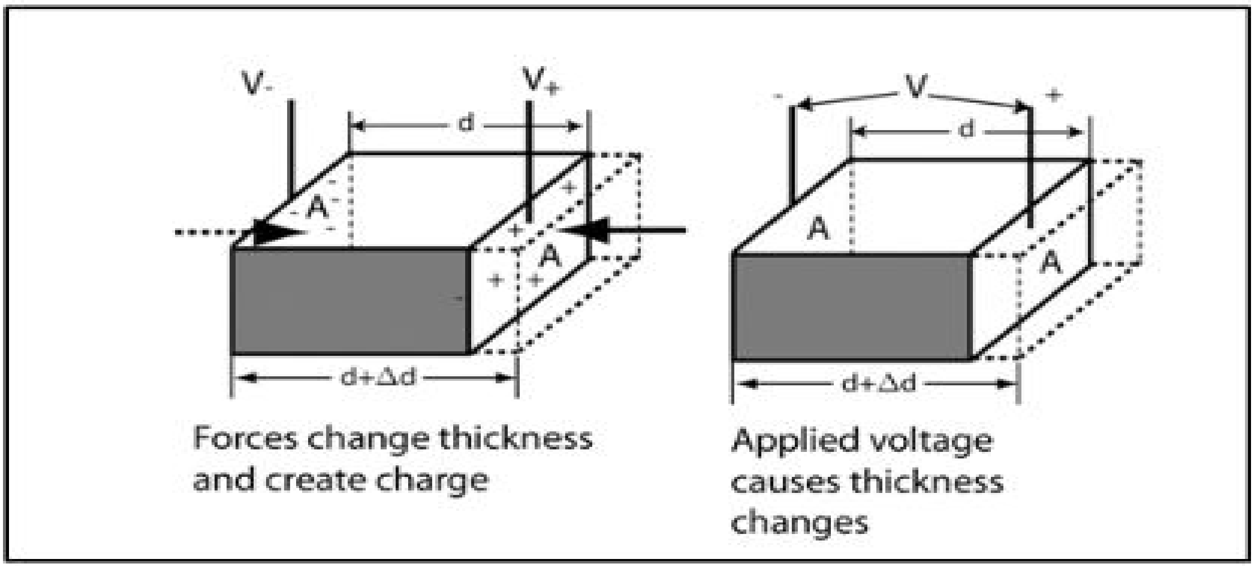

Figure 2: The Piezoelectric Effect (Bhatnagar et al.,2012)

shifting of the positive and negative charge centers in the material takes place, which then results in an external electrical field and the mechanical stress is define in different form as sound wave ,applied force etc. When reversed, an outer electrical field either stretches or compresses the piezoelectric material (Bhatnagar et al., 2012)).

2.3 Mathematical Description

A piezoelectric material develops an internal electric field when strained. On the contrary, a piezoelectric material experiences strain when an electrical field is applied to it. These reactions, electrical field and mechanical behavior, can be in either directions. Meaning that depending on the material, an electrical field in one direction can lead to a mechanical reaction in any direction. As a result, equations governing piezoelectricity are usually expressed with tensors. However, to avoid any complicated calculations, one can consider materials which produce an electric field in only one direction, either parallel or perpendicular to the strain that is applied to it.Equations thus become (assuming no variation in temperature and low frequencies) (Bhatnagar et al., 2012):

$$\vec{D} = d_1\vec{T} + \epsilon^T\vec{E}$$
$$\vec{S} = s^E\vec{T} + d_2\vec{E}$$

$\vec{D}$: electric displacement.

d_1 and d_2 : piezoelectric charge coefficients, respectively for the direct piezoelectric effect and the converse piezoelectric effect.

$\vec{T}$: mechanical stress.

ϵ^T: permittivity at constant stress.

$\vec{E}$: electric field

$\vec{S}$: mechanical strain

S^E : mechanical compliance.

These expressions shows the relationship between the mechanical and the electrical behaviors of those materials. The first equation shows that part of an electrical field applied to the material is converted into mechanical stress. Likewise, the second equation shows that part of a mechanical strain applied to the material is converted into electrical field. One can note that in the absence of electric field E, the second equation is $\vec{S} = s^{\epsilon}\vec{T}$ which is Hooke's Law. Likewise, in the absence of mechanical stress the first equation is $\vec{D} = \epsilon^T\vec{E}$, only describing the electrical behavior of the material. Also, for most materials d_1 and d_2 are nearly equal, that is why they are taken to be both equal to d hence:

$$\vec{S} = S^E(1 - k^2)\vec{T} + \frac{d}{\epsilon^T}\vec{D}$$
$$k^2 = \frac{d^2}{S^E\epsilon^T}$$

where k is known as the electromechanical coupling coefficient. It is an indicator of the effectiveness with which a piezoelectric material converts electrical energy into mechanical energy, or converts mechanical energy into electrical energy. In the case where the electric displacement is equal to zero, the formula becomes:

$$\vec{S} = s^E(1 - k^2)\vec{T}$$

The strain is still proportional to the stress, but the compliance is multiplied by the term $(1 - k^2)$. When k is equal to zero, the equation is simply Hooke's Law, which is logical as it means that all the energy in the material is strain energy. However one must know that this expression of k has been obtained considering that the system is not connected to a circuit. An new expression of k in the case of a system linked to a circuit is now developed.

2.4 Piezoelectric Materials

The piezoelectric effect is found in a number of natural and man-made materials. Commonly used naturally-occurring crystals include quartz, topaz, tourmaline, Rochelle salts and cane sugar. Man-made crystals include the quartz-like langasite and gallium orthophosphate. Common piezoelectric man-made ceramics include barium titanate, lead titanate and lead zirconate titanate, the most common piezoelectric ceramic in use. Other naturally-occurring piezoelectric materials include dry bone, tendons, silk, some woods, enamel, dentin and collagen.Essential properties of piezoelectric materials (Bhatnagar et al., 2012):

- high value of the dielectric constant
- presence of spontaneous polarization in some zones (domains)
- presence of hysteresis loop in polarization-electric field and strain-electric field curves
- dielectric constant increases with increase of temperature
- ferroelectric properties disappear above a special point in dielectric constant - temperature curve (Curie point)

- They are suited for radiating/receiving ultrasonic devices, technological power ultrasonic devices, piezo transformers, piezo drivers and other power ultrasonic equipment.

There is a large array of applications for peizoelectric materials, particularly quartz, which can generate thousands of volts of electricity. One of the most common applications of piezoelectricity is in the electric cigarette lighter. Other common applications include sensors on electric guitars like pick-ups and contact microphones, ultrasound machines, sonar wave detection and generation devices, engine management systems in cars, loudspeakers, fuel injectors for diesel engines and quartz clocks.

Examples of Piezoelectric Materials:

According to (Bhatnagar et al., 2012) the most commonly known piezoelectric material is quartz. But piezoelectric mate-rials are numerous, the most used are :

- Barium Titanate (BaTiO3) : This element is an electrical ceramics, it is usually replaced by lead zirconate titanate (PZT) for piezoelectricity. It is used for microphones and transducers.
- Lead Zirconate Titanate (PZT) : It is considered today one of the most eco-nomical piezoelectric element, hence it is used in a lot of applications.
- Zinc oxide (ZnO)
- Aluminum Nitride (AiN)
- Polyvinylidene Fluoride (PVDF)

2.5 Interaction of Ultrasound with Tissues

As the ultrasound wave travels through tissues.The most important parameters describing the wave are:

- Wavelength
- Frequency
- Velocity
- Intensity
- Attenuation

The first three characteristics are linked together by the formula:

$$v = f \times \lambda$$

v–Velocity of ultrasound (approximately 1540 m/s in the soft tissues),

f–Frequency in Hz

λ–Wavelength in m.

In medical ultrasound diagnostics are used short pulses of ultrasound, which contain a whole range of frequencies. Human tissues are not homogeneous in terms of the ultrasonic waves, and the passage of waves through the tissue leads to refraction, reflection, scattering and absorption of energy (Aird, 1988)

The amplitude and intensity of ultrasound waves decrease as they travel through tissue, a phenomenon known as attenuation. Given a fixed propagation distance, attenuation affects high frequency ultrasound waves to a greater degree than lower frequency waves. This indicates the use of lower frequency transducers for deeper areas of interest.

It is subject to a number of interactions.The most important features are as follows:

- Reflection
- Scatter
- Absorption

When ultrasound encounters boundaries between different media, part of the ultrasound is reflected and the other part is transmitted. The reflected and transmitted directions are given by the reflection angle θ_r and transmission angle θ_t respectively.

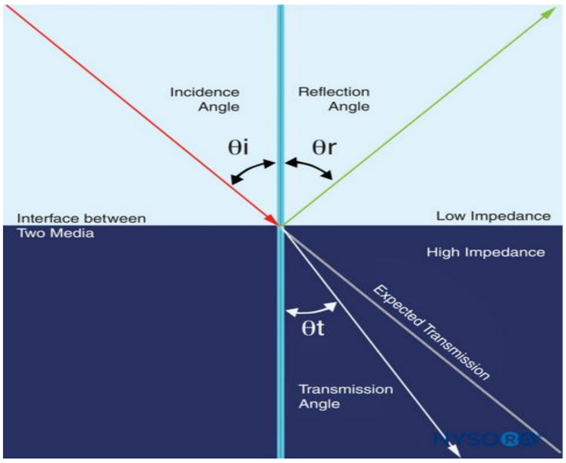

Figure 3: The interaction of ultrasound waves through the media in which they travel (Aird, 1988)

Reflection of sound waves is similar to optical reflection. Some of its energy is sent back into the medium from which it came. In a true reflection, the reflection angle θ_r must equal the incidence angle θ_i. The strength of the reflection from an interface is variable and depends on the difference of impedances between two affinitive media and the incident angle at the boundary. If the media impedances are equal, there is no reflection (no echo). If there is a significant difference between media impedances, there will be nearly complete reflection.

Absorption is defined as the direct conversion of the sound energy into heat. In other words, ultrasound scanning generates heat in the tissue. Higher frequencies are absorbed in a greater rate than lower frequencies. However, a higher scanning frequency gives a better axial resolution. If the ultrasound penetration is not sufficient to visualize the structures of interest, a lower frequency is selected to increase the penetration. The use of longer wavelengths (lower frequency) results in lower resolution because the resolution of ultrasound imaging is proportional to the wavelength of the imaging wave. Frequencies between 6 and

12 MHz typically yield adequate resolution for imaging in peripheral nerve blockade, whereas frequencies between 2 and 5 MHz are usually needed for imaging of neuraxial structures. Frequencies of less than 2 MHz or higher than 15 MHz are rarely used because of insufficient resolution or the insufficient penetration depth in most clinical applications.

Scattering is the redirection of sound in any directions by rough surfaces or by heterogeneous media Normally, scattering intensity is much less than mirror-like reflection intensities and is relatively independent of the direction of the incident sound wave; therefore, the visualization of the target nerve is not significantly influenced by another nearby scattering.

Attenuation As a sound beam propagates through tissue, its intensity decreases with increasing distance. This decrease with path length is called attenuation. Attenuation of medical ultrasound beams is caused by reflection and scatter of the waves at boundaries between media having different densities or speeds of sound and absorption of ultrasonic energy by tissues. As mentioned previously, absorption may lead to heating if beam power levels are sufficiently high.

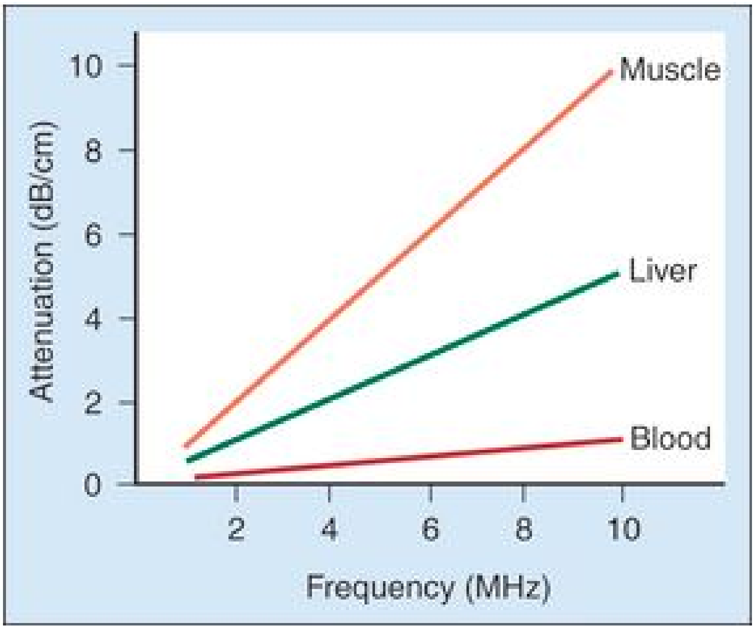

Figure 4: Variation of attenuation with tissue type and frequency (Zagzebski et al., 1992)

The rate of attenuation in relation to distance is called the attenuation coefficient, expressed in decibels per centimeter. The attenuation coefficient depends on both the medium and the ultrasound frequency.

2.6 Ultrasound Imaging

Ultrasonography (sonography) uses a probe containing multiple acoustic transducers to send pulses of sound into a material. Whenever a sound wave encounters a material with a different density (acoustical impedance), part of the sound wave is reflected back to the probe and is detected as an echo.
According to (Zell, Sperl, Vogel, Niessner, & Haisch, 2007) the distance to a reflector is determined from the arrival time of its echo. Thus,

$$d = \frac{cT}{2}$$

Where d is the depth of the interface, T is the echo arrival time, and c is the speed of sound in the tissue. Above Equation is called the range equation in ultrasound imaging(?, ?).

The time it takes for the echo to travel back to the probe is measured and used to calculate the depth of the tissue interface causing the echo. The greater the difference between acoustic impedances, the larger the echo is.Acoustic impedance (Z) is a physical property of tissue. It describes how much resistance an ultrasound beam encounters as it passes through a tissue.Impedance is defined as $Z = \rho v$ where ρ is Density of the medium (in kg/m^3) and v is Speed of sound through the medium (in m/s).

figure 5 shows the density and speed of sound through various media (including various soft tissues) and the associated acoustic impedances. Note that the acoustic impedances for soft tissue do not vary much but that there is a big difference between the acoustic impedance of soft tissue and air and also between soft tissue and bone. If the pulse hits gases or solids, the density difference is so great that most of the acoustic energy is reflected and it becomes impossible to see deeper.

Medium	Density (kg/m^3)	Speed of Ultrasound (m/s)	Acoustic Impedance ($kg/(m^2 \cdot s)$)
Air	1.3	330	429
Water	1000	1500	1.5×10^6
Blood	1060	1570	1.66×10^6
Fat	925	1450	1.34×10^6
Muscle (average)	1075	1590	1.70×10^6
Bone (varies)	1400–1900	4080	5.7×10^6 to 7.8×10^6
Barium titanate (transducer material)	5600	5500	30.8×10^6

Figure 5: The Ultrasound Properties of Various Media, Including Soft Tissue Found in the Body

(Zell et al., 2007).

The frequencies used for medical imaging are generally in the range of 1 to 18 MHz. Higher frequencies have a correspondingly smaller wavelength and can be used to make sonograms with smaller details. However, the attenuation of the sound wave is increased at higher frequencies, so in order to have better penetration of deeper tissues, a lower frequency (3–5 MHz) is used. Medical Imaging offers many different types of ultrasound at our practices . The choice of which type of image to use depends on the goals for a particular test, the phenomena being investigated and what equipment is available.

Several modes of ultrasound are used in medical imaging major modes are as :

2.6.1 A-mode

The A-mode also called as 1-D is the oldest ultrasound technique and was invented in 1930.The transducer sends a single pulse of ultrasound into the medium.Consequently, a one-dimensional simplest ultrasound image is created on which a series of vertical peaks is generated after ultrasound beams encounter the boundary of the different tissue.The distance between the echoed spikes can be calculated by dividing the speed of ultrasound in the tissue (1540 m/s) by half the elapsed time, but it provides little information on the spatial relationship of imaged structures (Potkin et al., 1990). A-Mode consists of a x and y axis,

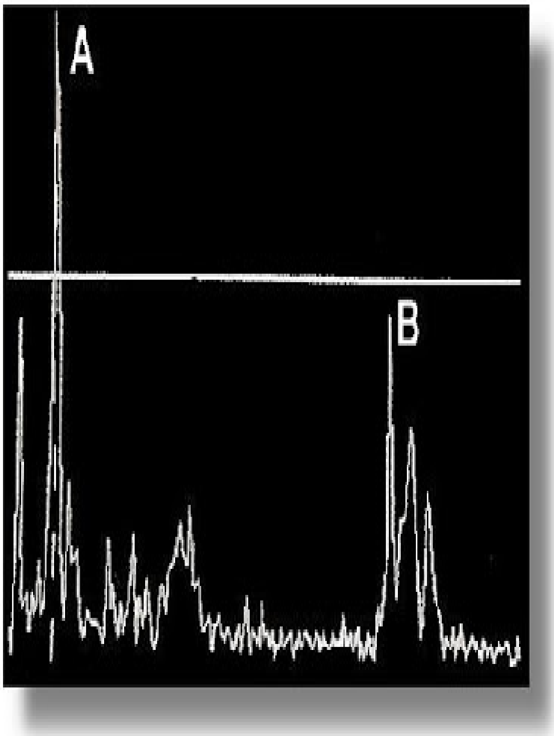

Figure 6: schematic representation of A-modes
(Potkin et al., 1990).

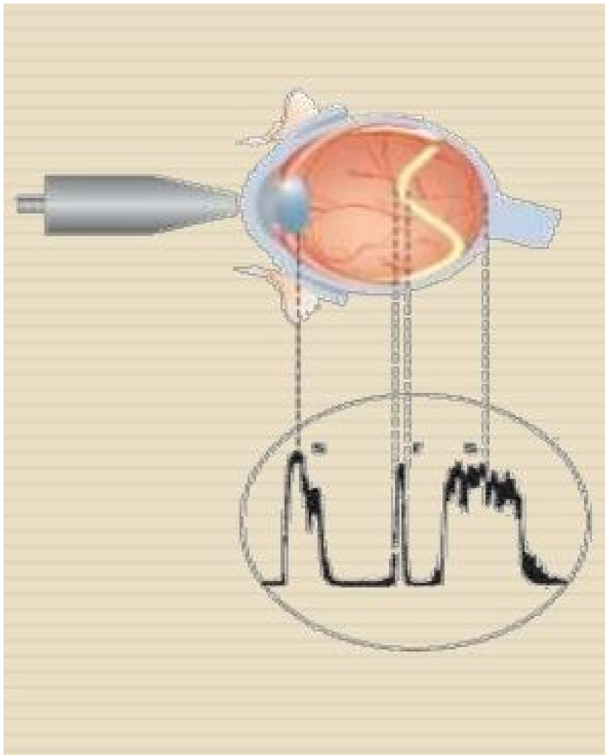

Figure 7: A-modes ultrasound on Ophthalmology
(Potkin et al., 1990).

where x-axis represents the depth and y-axis represents the Amplitude. The above image shows an example of A-Mode display.A-mode (Amplitude-mode) ultrasound is used to judge the depth of an organ, or otherwise assess an organ's dimensions.

2.6.2 B-mode

The B-mode is a two-dimensional (2D) image of the area that is simultaneously scanned by a linear array of 100–300 piezoelectric elements rather than a single one as in A-mode.The amplitude of the echo from a series of A-scans is converted into dots of different brightness in B-mode imaging. The horizontal and vertical directions represent real distances in tissue, whereas the intensity of the grayscale indicates echo strength . B-mode can provide an image of a cross section through the area of interest.B-mode ultrasound (Brightness-mode) is the display of a 2D-map of B-mode data (Rashid, 2017) .

On a grey scale, high reflectivity (bone) is white; low reflectivity (muscle) is grey and no

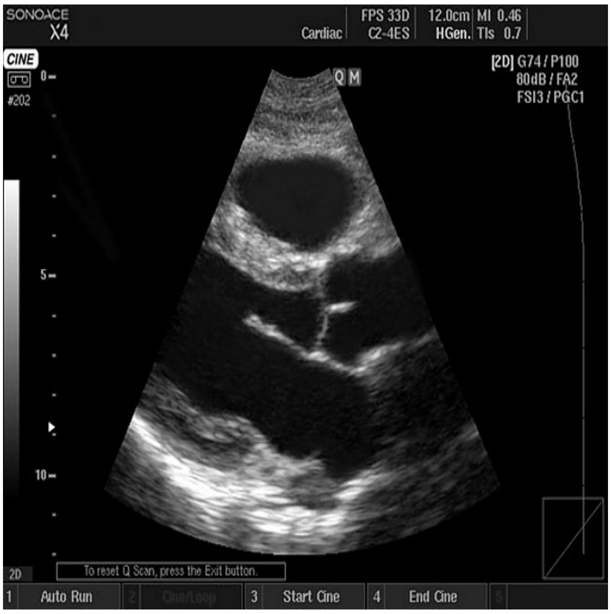

Figure 8: An example of 2D imaging (Zagzebski et al., 1992).

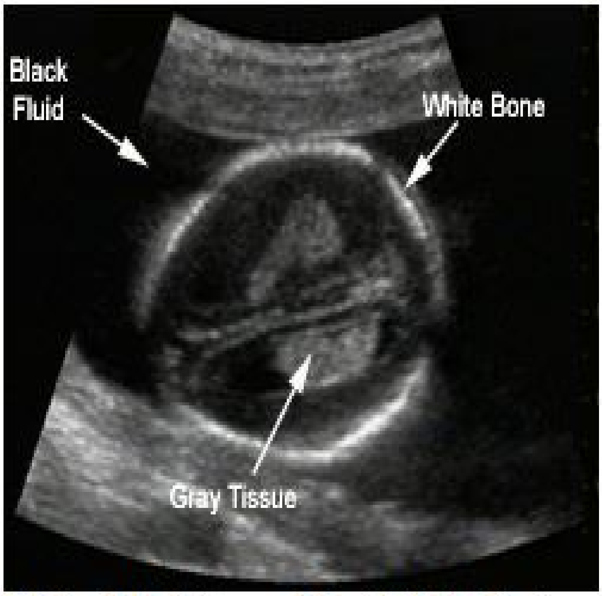

Figure 9: B-Mode image of the fetal brain (Zagzebski et al., 1992).

reflection (water) is black. Deeper structures are displayed on the lower part of the screen and superficial structures on the upper part.While this mode is useful to accurately represent the 2- dimensional structure of the tissues, it does not resolve rapid movements well and may misrepresent the 3-dimensional nature of structures.

2.6.3 M-mode

According to (Saul et al., 2015) in M-mode (motion mode) ultrasound, pulses are emitted in quick succession – each time, either an A-mode or B-mode image is taken. Over time, this is analogous to recording a video in ultrasound.As the organ boundaries that produce reflections move relative to the probe, this can be used to determine the velocity of specific organ structures. This represents movement of structures over time. Initially a 2-D image

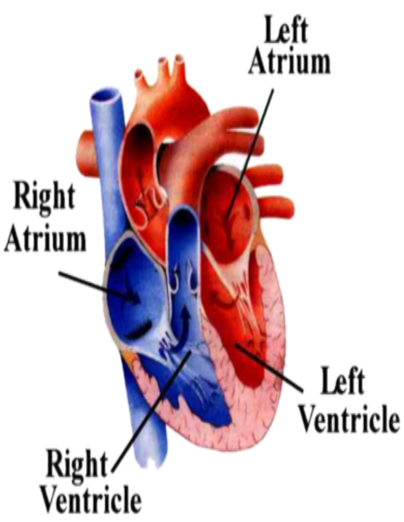

Figure 10: Chambers of the heart (Saul et al., 2015).

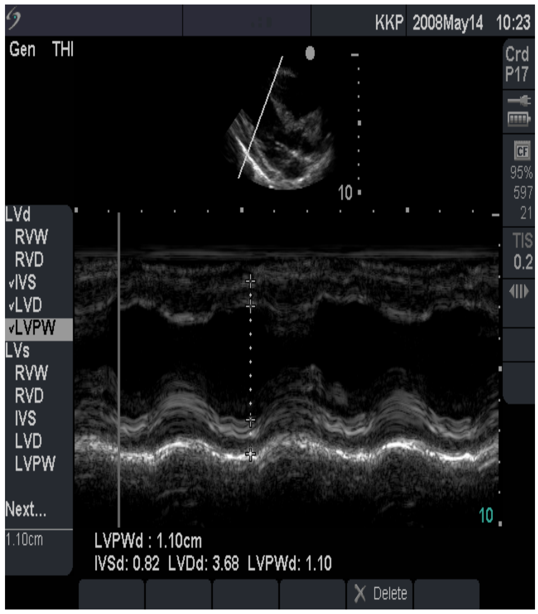

Figure 11: M mode left ventricle showing movement of the walls over time (Saul et al., 2015)

is acquired and a single scan line is placed along the area of interest. The M-mode will then show how the structures intersected by that line move toward or away from the probe over time.The M-mode has good temporal resolution, so it is useful in detecting and recording rapid movements. We can also correlate and time events with ECG or respiratory pressure waveforms traced alongside the M-mode tracings. The M-mode is commonly used for measuring chamber dimensions and calculating fractional shortening and ejection fraction.

2.6.4 Doppler Mode

The term Doppler Shift describes a change in the frequency or wavelength of a sound wave resulting from relative motion between the sound source and the sound receiver.It can be used to estimate the blood flow through blood vessels by bouncing high-frequency sound waves (ultrasound) off circulating red blood cells. A regular ultrasound uses sound waves to produce images, but can't show blood flow.
From Doppler effect ,Doppler frequency shift is found as (Zagzebski et al., 1992)

$$f_d = 2\frac{f_o}{c}cos\theta \times v$$

where,
f_d =Doppler frequency shift
v=Target velocity
f_o=Transmitted frequency
cosθ=angle between directions of sound propagation and of target path.
An echocardiogram (ECG) is an example of Doppler ultrasound. It can be used to create images of the cardiovascular system and to measure blood flow and cardiac tissue movement at specific points.

A Doppler ultrasound can assess the function and state of cardiac valve areas, any abnormalities in the heart, valvular regurgitation, or blood leaking from valves, and it can show how well the heart pumps out blood.This Doppler shift falls in the audible range and is often presented audibly using stereo speakers.
There are two methods of generate wave to employing Doppler principle.

- **Continuous Wave Doppler(CW)**
- **Pulsed Wave Doppler(PW)**

By the above two methods of generating wave for imaging on the basis of Doppler Principle but continuous wave is one of traditional way so mostly use method is pulse wave as below ways:

1. **Color Doppler**: In this mode, the direction of blood flows are depicted in a color map superimposed on the 2-D image.

   It uses pulse wave Doppler signals to derive this image. This is usually done with lower frequency ultrasound waves and hence the resolution of the 2-D image deteriorates in this mode. As it takes many pulses in each scan line to derive the color image, the frame rate is reduced compared to 2-D mode. Reducing the depth and size of the color box and reducing the scanning sector width can compensate for this.

   . The colors indicate the direction of the flow. Blue indicates flow going away from

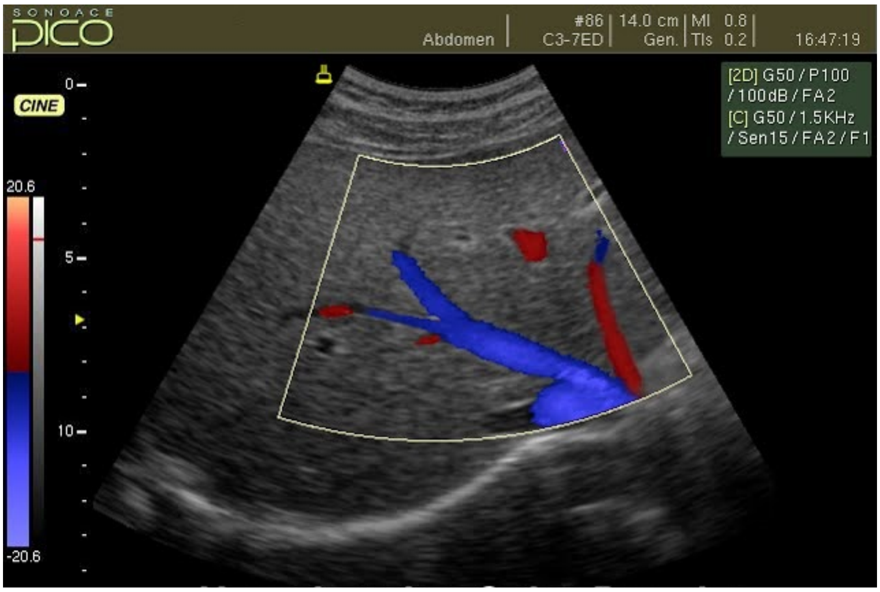

Figure 12: Color Doppler of Hepatic veins.
(Taylor, Burns, & Well, 1987)

   the transducer and red indicates flow going towards the transducer. Blood flowing perpendicular to the scanning plane will appear black. Areas of turbulent flow may be depicted in green or white.No information about velocities is given thus, the technique can only be used for flow direction assessment (Taylor et al., 1987).

2. **power Doppler**: An ultrasound technique that is used to obtain images that are difficult or impossible to obtain using standard color Doppler and to provide greater detail of blood flow, especially in vessels that are located inside organs. Power Doppler is more sensitive than color Doppler for the detection and demonstration of blood flow, but provides no information about the direction of flow. Power Doppler ultrasound is a

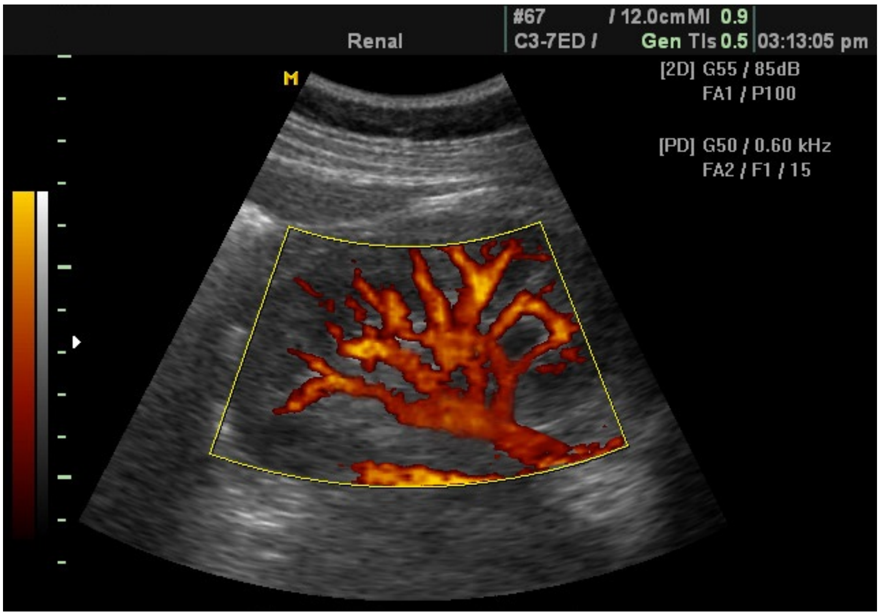

Figure 13: Power Doppler on Renal of kidney.
(Taylor et al., 1987)

technique that encodes the power in the Doppler signal in color and used mostly pulse wave signal for depth observation. This parameter is fundamentally different from the mean frequency shift. The frequency is determined by the velocity of the red blood cells, while the power depends on the amount of blood present. Providing an image of a different property of blood flow, power Doppler has shown several key advantages over colour Doppler, including higher sensitivity to flow, better edge definition and depiction of continuity of flow. While color Doppler is not sensitive enough to detect slow and poor flow in small vessels (Taylor et al., 1987).

3. **Spectral Doppler**: Instead of displaying Doppler measurements visually as in the color and power Doppler methods, spectral Doppler displays the blood flow measurements graphically, displaying flow velocities recorded over time.Utilizing automated Fourier analysis to convert returning sound waves into a series of individual frequencies, spectral Doppler refers to ultrasound modalities which yield graphical representations of flow velocity over time Taylor et al.(1987).

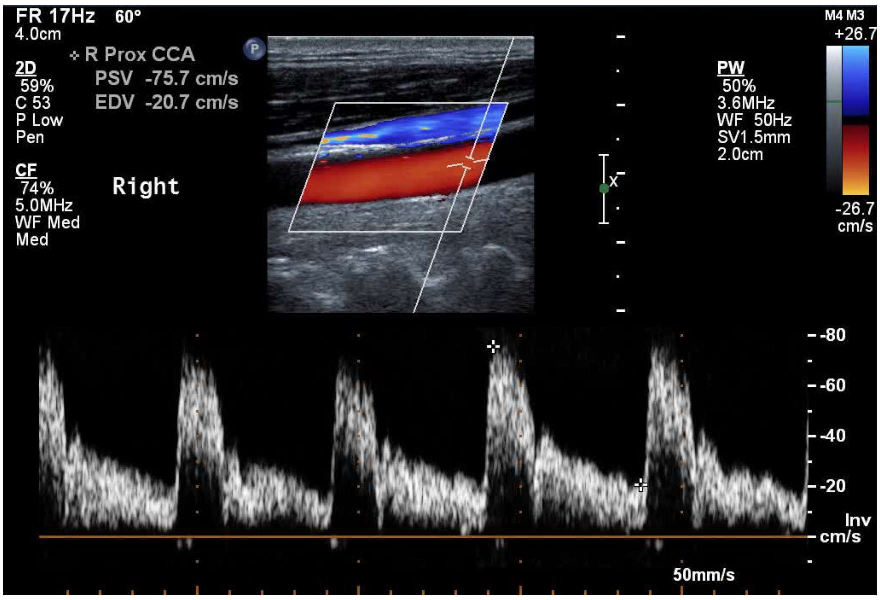

Figure 14: schematic image of Renal by spectral Doppler.
(Taylor et al., 1987)

It permits measurement of maximal and mean velocity. Maximal velocity is equivalent to the highest point of the curve .

2.7 Objectives

In this term paper we will study about the high frequency wave called as an ultrasound , it's history and it's advantage over science .We will also focus on the term Piezoelectric effect that is most important factor to generate ultrasound.Clinical transducer is based on the physics of piezoelectric effect and piezoelectric material.We will study the imaging technique by the principle of echo and interaction of acoustic wave with tissues. We will analyse the different modes of ultrasound for detection of internal structure, detection of distance organ and movement of tissues and their property.We will also interest to study the Doppler effect and it's uses to measure blood flow direction and velocity in veins ,arteries and heart function from Doppler mode of ultrasound. Thus to make the conclusion as uses of ultrasound in medicine called an Ultrasonography is our major objectives.

Chapter 3

Methodology and Instrumentation

Ultrasonography is a noninvasive, painless procedure.The sonographer usually holds a transducer, a hand-held device, like a wand, which is placed or swept on the patient's skin.Ultrasound that travels through soft tissue and fluids, but it bounces back, or echoes, off denser surfaces.These echoes generate electrical signals that are translated by a computer to produce images of the tissues and organs. Ultrasound will travel straight through the gallbladder if there are no gallstones, but if there are stones, it will bounce back from them.Ultrasound will travel through blood in the heart chamber, for example, but if it hits a heart valve, it will echo, or bounce back.The denser the object the ultrasound hits, the more of the ultrasound bounces back.This bouncing back, or echo, gives the ultrasound image its features. Varying shades of gray reflect different densities (Aird, 1988).

In case of Doppler mode (Taylor et al., 1987) there make some technical steps as in Doppler shifts. The transducer make angle less than 60^0 for better visualize.

3.1 Ultrasound Instruments

Ultrasound machines convert the echoes received by the transducer into visible dots, which form the anatomic image on an ultrasound screen. Probes attach easily to a central processing unit or main computer of an ultrasound machine. According to (Zagzebski et al., 1992) the CPU transmits electrical currents that cause the probe to emit sound waves. The CPU also analyzes electrical pulses that the probe makes in response to reflected waves coming back. It then converts this data into images that can then be viewed on an accompanying monitor, stored on disk or printed. Ultrasound scanners also include control knobs, buttons and other command features on the CPU to enable the sonographer to make adjustments, save images and perform other tasks.

Figure 15: Ultrasound machines.
(Aird, 1988)

Many manufacturers offer ultrasound machines (Figure 15), but they all have basic components in common: a transducer which transmit and receive the ultrasound signal, a central processing unit which interprets the signal and a screen which projects the images produced.

3.1.1 Selection Of Probes

The probe is the main part of the ultrasound machine. It sends ultrasound waves into the body and receives the echoes produced by the waves when it is placed on or over the body part being imaged. The shape of the probe determines its field of view. Probes are generally described by the size and the shape of their footprint. Selecting the right probe for the situation is essential to get good images.The focal range of the transducer is inversely related to its frequency as the result of attenuation, or the loss of acoustic energy as the wave travels. Although greater frequency transducers may provide a more detailed picture, the field of imaging will be smaller than with transducers of lower frequency Aird et al.(1988). There are four basic types of probes used:

Figure 16: Types of Probes.
(Bhatnagar et al., 2012)

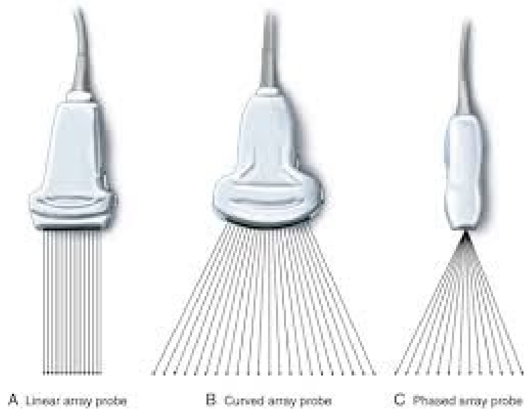

Figure 17: Types of Ultrasound waves through probes.
(Bhatnagar et al., 2012)

1. **Linear probes** – are generally high frequency better for imaging superficial structures and vessels also called vascular probes.

2. **Curvilinear probes** – have widened footprint and lower frequency for transabdominal imaging and widen the field of view.

3. **Phase array probes** – for getting between ribs such as cardiac ultrasound.

4. **Endocavitary probes** – with high frequency and better imaging as transvaginal and transrectal probes.

3.1.2 Ultrasound Gel

In the process of imaging radiologist use gel which is also called as sonography gel. It purpose to conduct sound waves properly.Even with the probe pressed right on the skin, there is enough air in between to diffuse the sound waves from penetrating. The gel fills up all that space instead of air. The sound emitted by the transducer has to penetrate into the body, where it echoes off of various structures. The reflected sound waves then propagate out of the body where the transducer receives them. Without the gel, the sound would have to pass through a layer of air on the way in, and again on the way out. There would not be enough sound left to make a good image (Rashid, 2017).

The gel conducts the sound waves much better than air, so transducing the sound waves through the gel into and out of the body results in a much clearer image due to better transmission of sound.Therefore, a coupling medium, usually an aqueous gel, is applied between surfaces of the transducer and skin to eliminate the air layer.

Chapter 4

Result and Discussion

The Physics behind Ultrasound as Piezoelectric Effect which gives revolution on different sector as science and technology. Ultrasonography is an imaging technique using sound waves to facilitate in a medical diagnosis and it is safe, noninvasive because it does not use any kind of electromagnetic radiation. Whenever transmitted Ultrasound crosses an interface between two tissues with different impedence, some of ultrasound is reflected amount depends on difference in impedence.Imaging is kept by the principle of echolocation also called as pulse-echo principle. To neglect the interference between skin and transducers probe need coupling material called an Ultrasound gel.Ultrasound wave is emit than most of the interaction occurs as Reflection ,Scatter and absorption.All of the above factors make wave attenuation but most of the cause depend on absorption because higher frequency cause more tissue vibration and results in generation of heat, it means transformation of energy.

As familiar physics equation ($v = f.\lambda$) higher frequency probes have smaller depth penetration or wavelength so high frequency probes have good resolution (fine detail) and vice-versa. So to visualize the superficial structure radiologist used as higher frequency wave and for deeper structure they used low frequency ultrasound wave.Many types of ultrasound beam are used for different tissues properties.Most of initial case radiologist prefer curved array probes for transabdominal imaging for widen the field of view and other also depend upon region of interest.

Different modes of ultrasound are used for different tissues location and their properties.A-modes is used for detect the distance of organ mainly used in opthalmology and is one of tradational method for dignoisis. B-mode and M-mode are used for initial diagnosis of the problem abdomen and moving organ respectively.Doppler Ultrasound is very useful technique for the measurement of detect the blood velocity , flow direction and amount of blood presences in heart chamber and blood vessels.

4.0.1 Significance Of Ultrasonography

Ultrasonography is commonly used for diagnosis and study about human internal organs (Rashid, 2017).

- , It uses for treatment and guidance during procedures such as biopsies and Anesthesia.
- It can be used to examine internal organs such as the liver and kidneys, the pancreas, the thyroid gland, the testes and the ovaries, and others.
- An ultrasound scan can reveal whether a lump is a tumor. This could be cancerous, or a fluid-filled cyst.
- A Doppler ultrasound can assess the function and state of cardiac valve areas, any abnormalities in the heart, valvular regurgitation, or blood leaking from valves, and it can show how well the heart pumps out blood.
- Evaluate for plaque buildup and clots and assess for blockages or narrowing of arteries.

Radiologists identify the problems or abnormalities of patients and refer such evidence to doctors.

4.0.2 limitation

Ultrasound waves are disrupted by air or gas and reverberation of sound sometimes give paradoxical result for analysis. Therefore, ultrasound is not an ideal imaging technique for the air-filled bowel or organs obscured by the bowel and small organ. Ultrasound is not as useful for imaging air-filled lungs, but it may be used to detect fluid around or within the lungs. Similarly, ultrasound cannot penetrate bone, but may be used for imaging bone fractures or for infection surrounding a bone. For visualizing internal structure of bones or certain joints other imaging modalities such as MRI are typically used Curry et al (1990).

Chapter 5

Conclusion and Future Prospectus

Ultrasound is widely available, easy to use and less expensive than most other imaging methods.We can get images of the body by recording echoes of ultrasound. Ultrasound is good at imaging soft tissues even pregnancy test it is one of the reliable technique. The Doppler effect can be used to detect blood flow.The accuracy of the test is very much operator dependent. This means that the key to a good test is the ultrasound technician. By use the concept of piezoelectric effect we should generate electrical energy from noise and becomes one of the alternative source of energy. According to (Morgan, Helibrun, & Kahn Jr, 2014) RSNA is a society of radiologists and similar health scientists that seeks to encourage connections between colleagues and provide scientists with a platform for radiology education and research. At RSNA, they introduced an ultrasound consortium to drive the creation of mobile ultrasound solutions. This includes an app-based ultrasound system, which demonstrated at its booth.It uses a transducer capable of connecting to a mobile device and a downloadable app to turn a consumer-grade smartphone of tablet device into an ultrasound machine. The product was developed for market testing and research and is not currently for sale.

Contrast agents are provide for the patient for better Visualization of internal structure by transfer gas-filled micro-bubbles .Today scientists are continuing to study and seek more advanced applications of sound in medicine.

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