ULTRASOUND PHYSICS 2025-2026

3.st Stage

Lecture 1 - Theory

INTRODUCTION & OVERVIEW

Lecturer

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References: **المصادر:**

Thayalan, K., and Ramamoorthy Ravichandran. *The physics of radiology and imaging*. JP Medical Ltd, 2014.

2.1 Introduction and Overview

Unlike light and x-ray, sound requires a medium which propagate through it such as water or soft tissue and it is consists of longitudinal vibrations in much the same way as a compression can be seen to travel along the length of a spring as shown in figure 1.

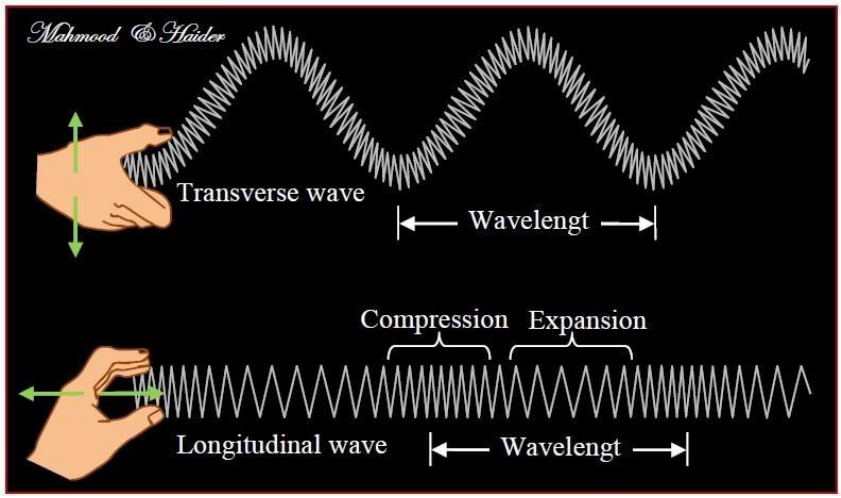

Figure 1: Examples of longitudinal and transverse waves

Diagnostic Ultrasound (ultrasonography) is an ultrasound-based diagnostic imaging technique used for visualizing subcutaneous and examination of different parts of human body structures including tendons, muscles, joints, vessels and internal organs for possible pathology or lesions using high frequency sound waves, which are emitted from a probe and directed into the body. Ultrasonography commonly used during pregnancy and usually recognized widely by the public.

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

There are many variables involved in the production, detection and treatment of ultrasound data, which are, for the most part, under the control of the operator. All the different imaging techniques, ultrasound is the most affected by the skill and experience of the operator, both in the acquisition and interpretation of images. Diagnostic ultrasound offers advantages over other imaging modalities, and the most important of these advantages do not use ionizing radiation, making it safer, especially in imaging during pregnancy. The other important feature is its ability to image in real time, making it simple to perform live active and passive range of motion studies, in addition to the low cost. In summary, the feature of ultrasound:

- ✓ Uses no ionizing radiation ✓ Safe in pregnancy
- ✓ Has no known side effects
- ✓ Inexpensive
- ✓ Portable
- ✓ Minimal preparation of patients
- ✓ Painless
- ✓ Gives direct vision for biopsies

Some problems with ultrasound imaging are that the diagnostic images sometimes cannot be obtained because of the size of the patient, or because the ultrasound beam cannot navigate the areas of air-filled or bone in such cases, the cross-sectional imaging with CT or MRI can be used instead.

Medical treatment can be given after a proper diagnosis or identify the disease properly. After the first use of ionizing radiation (x-ray) by Roentgen in 1895 to visualize the interior of the body has been the only way for decades. However, during the second half of the twentieth century was the discovery of new imaging methods are quite different from those of the X-rays. Was one of the most important of these ways is ultrasound, which showed the particular potential and greater benefit of imaging which relies on X-rays.

During the last decade of the twentieth century, became the use of ultrasound in medical practice and hospitals are increasingly common in all parts of the world. Proved much the scientific research the benefit of ultrasound and sometimes superiority in many cases commonly used X-ray techniques, resulting in significant changes in diagnostic imaging procedures.

Sound is a physical phenomenon that carries energy from one point to another. In this respect is similar to radiation, but differs from the radiation that does not pass through the vacuum and that means it needs to matter in order to transfers from one place to another. This is because the sound waves are actually vibrations that pass through the material. If there is any substance, nothing can vibrate and sound cannot exist.

One of the most important features in the sound is frequency, defined as the rate of vibration source of sound and material that passes through it. Sound frequency is measured in a basic unit called the hertz, and defines the hertz as one vibration, or cycle, per second. Pitch is the term commonly used as a synonym for sound frequency.

Examines medical uses high-frequency sound waves to look inside the body. These sound waves are too high for the human ear can hear. There is a specific extent of the frequencies in the human ear can hear or respond to them. The human ear in young adults can hear the frequency extent from 20 Hz to 20,000 Hz. The extent of frequencies greater than this limit is called ultrasonic frequencies (**Ultrasound**). Frequencies in the extent of 2 MHz (million cycles per second) to 20 MHz are used in diagnostic ultrasound which is too high for the human ear can hear. Where, ultrasound is used as a diagnostic tool because it can be focused into small, welldefined beams that can **probe** the human body and interact with the tissue structures to form images. Acoustic waves are shed

on the internal organs through a small scanner called **transducer** of hand-holding which is placed in direct contact with the patient's skin to be imaged. Transducer has a crystal vibrate and a scanner unlike the sound or echo to form an image.

The **transducer** (probe) is the small hand-held component of the ultrasound imaging equipment that resembles a microphone and it performs several functions as will be described in detail later. Its first function is to produce and send the ultrasound pulses when electrical pulses are applied to it. A short time later, receives the echoing waves when the transducer is pressed against the skin and converted back into electrical pulses that are then processed by the system and formed into an image.

Produces echo by the surfaces or the boundaries between the two different types of tissue in the form of bright white spots in the image. Many surfaces in general produce a white or gray background can be seen in the image. And the absence of reflecting surfaces within the fluid, such as the cyst, dark spots appear in the image. For this reason, the ultrasound image, sometimes called a **Brightness modulation "B mode"** image, which is a display of echo producing sites within the anatomical area.

Another physical characteristic that can be imaged with ultrasound devices are processes the echoes produced by blood flowing and blood vessels. That is a special application of ultrasound uses the Doppler principle, which the measures the direction and speed of blood cells as they move through vessels. A computer collects and processes the sounds and graphs or constitutes images with different colors representing the different flow velocities and directions that represent the flow of blood through the blood vessels.

2.2 Definition Ultrasound

- **Physical Definition;** Ultrasound (ultrasonic) is the term used to describe sound of frequencies above 20 000 Hertz (Hz), beyond the range of human hearing. The term "ultrasonic" applied to sound refers to anything above the frequencies of audible sound.
- **Medical Definition;** Diagnostic Medical Ultrasound is the use of high frequency sound to aid in the diagnosis and treatment of patients and the frequency ranges used in medical ultrasound imaging are 2 - 15 MHz.

2.3 Properties of Ultrasound

Sound is a pressure disturbance (vibration) transmitted through all forms of matter: gases, liquids, solids, and plasmas as mechanical pressure waves that carry kinetic energy. A medium must therefore be present for the propagation of these waves, since cannot travel through a vacuum.

2.3.1 Type of Waves Depends on the Medium

Ultrasound and sound waves propagate in a **fluid** (gases and liquids) as **longitudinal waves**, in which the particles of the medium vibrate with and for along the direction of propagation, alternately compressing and rarefying the material.

In hard tissues like bone, ultrasound can be transmitted as both **longitudinal** (compression) and **transverse** (shear) **waves**; in the latter case, the particles move perpendicularly to the direction of propagation.