Medical physics

Lecture:
Ch12 (p1): Sound & Ultrasound in medicine

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- **The plan for lecture:**

1. General properties of sound.
2. Ultrasound waves in medicine.
3. How Ultrasound is produced.

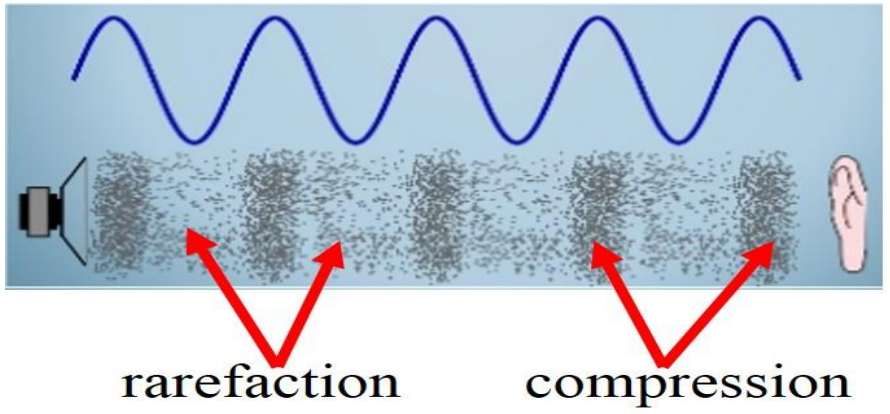
Objective:

To familiarize the physics of ultrasound, and commonly used in diagnostic, imaging and therapeutic

1. General properties of sound:

What is sound

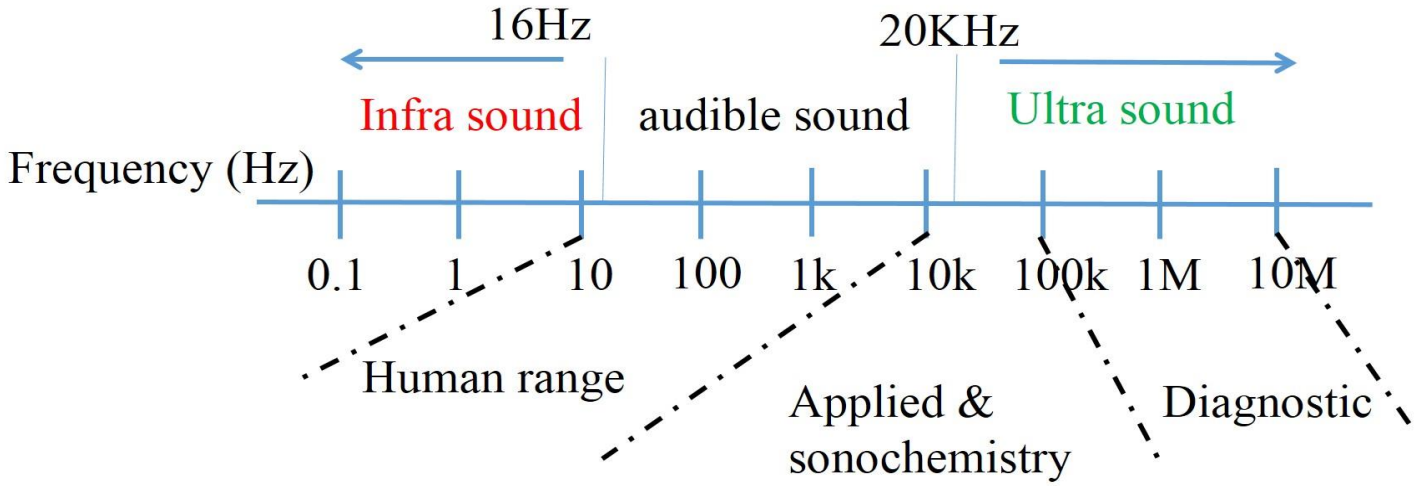
1. Sound is a form of energy just like electricity and light.
2. Sound waves are produced as a result of vibrations as mechanical and longitudinal waves (rarefaction / compression) that can travels a distance through a media as (gas, liquid, air).
3. Cannot travel through vacuum.



Types of Sound

1. Audible Sound

- 20 to 20,000 Hz.
- Audible sound by human.



2. Non-audible sounds are includes:

a. Infrasound waves

1. < 20 Hz (low frequency limit of human hearing).
2. Not audible.
3. Headaches and physiological disturbances.
   (Infrasound waves cause a special effect on human health that occurs with varying frequency and results in varying levels of disability)

b. Ultrasound waves:

1. > 20 KHz
2. Not audible.
3. Medical imaging for diagnosis, treatment and doppler.
4. Average speed of ultrasound in body is 1540m/sec.

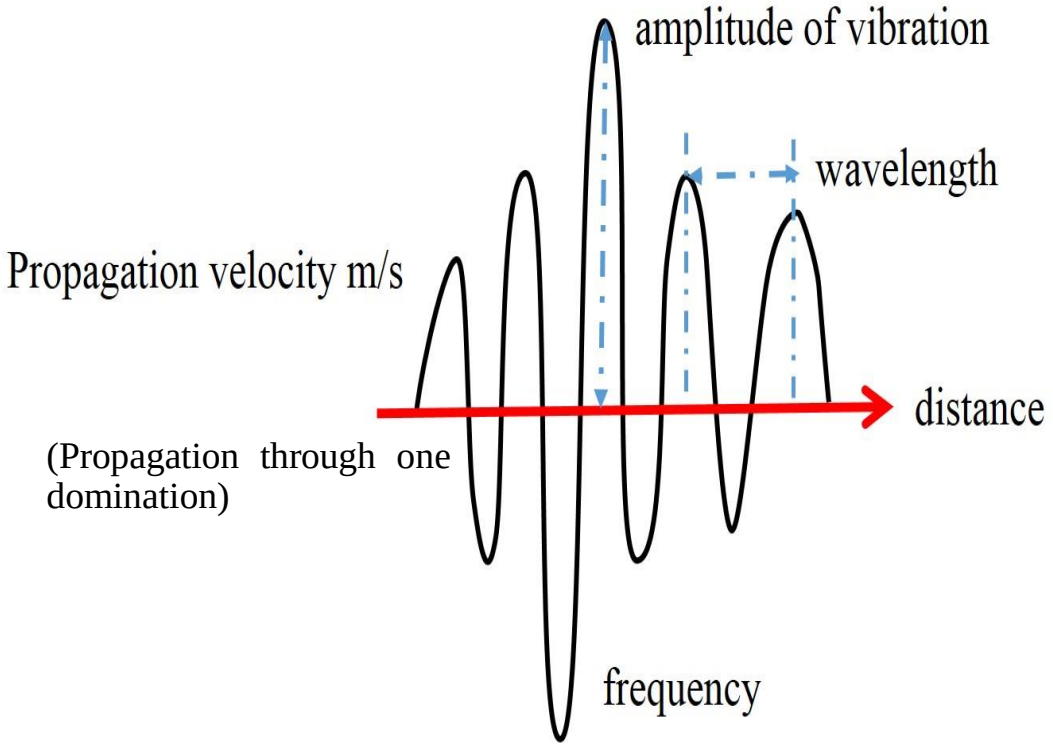
❖ Some animals such as cats, dogs and bats can hear sounds of other frequencies.

Properties of Sound

- Frequency, it describes how many of cycles are completed per second.
- Wavelength, it describes the distance it takes a sound wave to complete one cycle.
- Amplitude, it is the maximum displacement of oscillation in a wave. it describes the extent of the pressure changes.
- Velocity, it describes the distance it takes per unit time. The velocity of sound depends on the properties of the medium which the wave is travelling.

  Solids > liquids > gases

Sound waves move slowly in the gas because the molecules are far apart and are easily compressed.



Ultrasound waves in medicine:

What is the main reasons to use the ultrasound in medicine?

- relatively low cost.
- portability of an ultrasound scanner.
- the non-ionizing nature of ultrasound waves.
- the ability to produce real-time images of blood flow and movement of internal structures such as the beating heart.
- the intrinsic contrast among soft tissue structures that is achieved without the need for an injected contrast agent.

How Ultrasound is produced ?

- **Ultrasound** is produced by passing an electrical current through a piezoelectrical crystal.
- **Ultrasound systems,** the heart of most ultrasound systems is a device called a transducer.

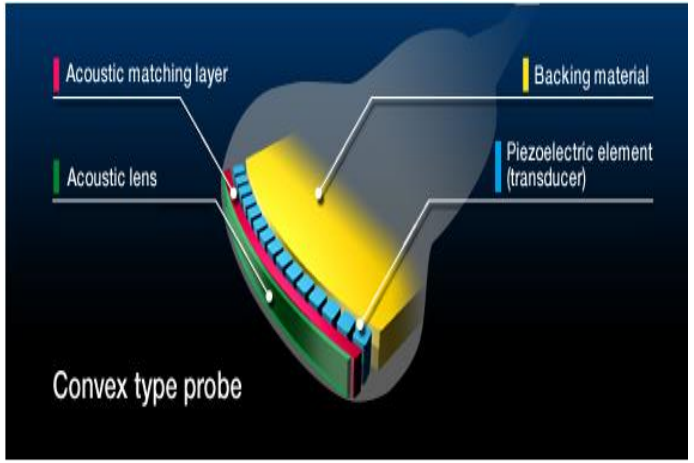
- US transducer also called a probe, is a device that transform signals in one form to a more convenient to produce ultrasound waves that bounce off body tissues and make echoes.
- US transducer receives the echoes and sends them to a computer that uses them to create an image.
- US transducer is a very important part of the ultrasound machine for image reconstruction.

- The US transducer (probe), which consist from:

1. piezoelectric element. It are both transmitter and receiver.
2. Backing material
3. Acoustic lens
4. Acoustic matching layer

- **The function of each transducer element:**

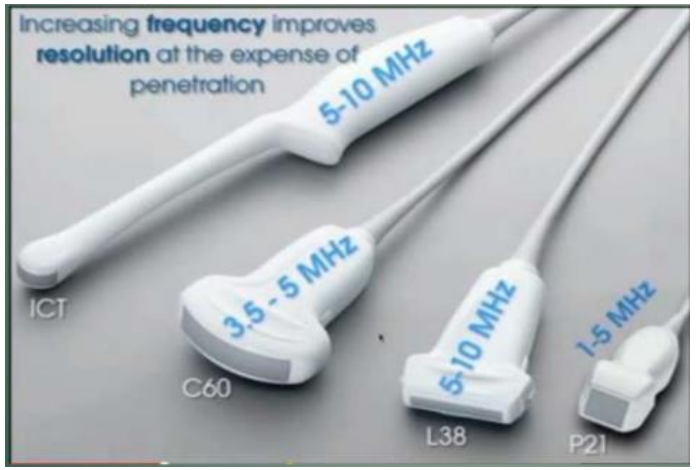
1. Piezoelectric crystal is essential element of transducer to generate US waves by vibration.
2. Backing material to prevent excessive vibration to generate US wave with shorter pulse length to improve resolution in image.
3. Acoustic lens to prevent the US waves from spread and increase the intensity of the beam at the focuses them in the smaller area of slice direction to improve the resolution of image.
4. Acoustic matching layer to provide the interface between the transducer element and the tissue and minimizes the acoustic impedance differences between the transducer and the patient. Where, it is placed on the front surface of the transducer to improve the efficiency of energy transmission into the patient



- **Transducer design:**

Transducer is designed in different shape, size and frequency. That is depend upon the examination for maintaining image quality across different parts of the body.

- **Ultrasound imaging frequency range 1-10 MHz**



Mechanism of ultrasound imaging:

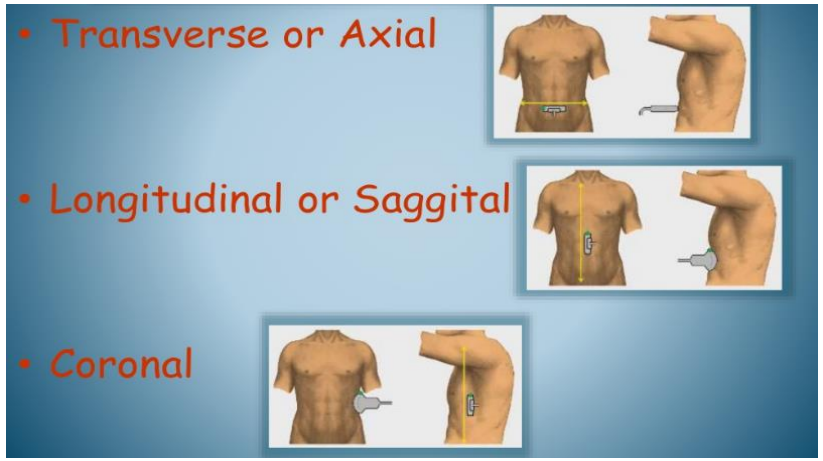
When an electric signal is applied on a transducer system producing high frequency sound pressure waves, which we call ultrasound. More importantly this type of crystal, can work in reverse. It can produce electrical signals, when it detects high frequency sound pressure waves.

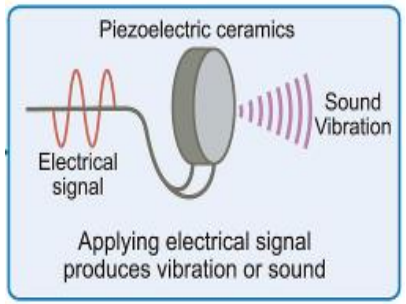
When a transducer directs ultrasound waves into the body, they pass through the skin and into the internal organs of the body.

As the waves encounter tissues with different characteristics and densities, they produce echoes that reflect back to piezoelectric crystal. This happens more than a thousand times a second. Returning echoes are converted into electrical signals

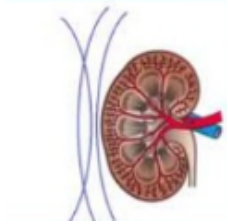
Electrical signals which a computer converts into points of brightness on the image, corresponding to the anatomic position and the strength up the reflecting echoes

Imaging plans of ultrasound

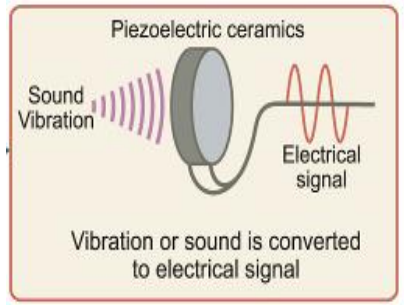




Piezoelectric



The sound waves are reflected by tissues



US image

What is the basic idea of US imaging

- Send US waves into body which are **reflected** at the interfaces between tissues.
- Return time of the waves tells us of the **depth** of the reflecting surfaces.

What is the basic uses of US imaging

Ultrasound imaging uses sound waves to produce pictures of the inside of the body. It helps diagnose the causes of pain, swelling and infection in the body's internal organs and to examine an unborn child (fetus) in pregnant women. It also helps guide biopsies, diagnose heart conditions, and assess damage after a heart attack. Ultrasound is safe, noninvasive, and does not use radiation.

End the p1 of lecture