Ministry of Higher Education and Scientific Research
Al-Mustaqbal University College
Radiology Techniques Department

Radiology Equipment Techniques

Al-Mustaqbal University College

2nd Class

Radiology Techniques Department

By

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MS.C. Theoretical Physics

Second Semester

lecture 11: Ultrasound Transducer Instrumentation

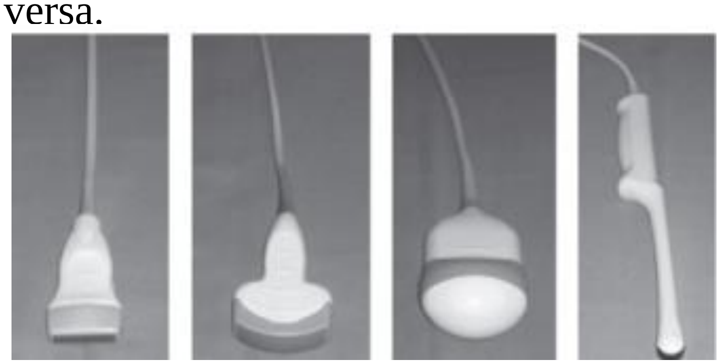
2021/2022

Ultrasound scanners are complex and sophisticated imaging devices, but all consist of the following basic components to perform key functions:

- Transmitter or pulser to energize the transducer
- Ultrasound transducer Receiver and processor to detect and amplify the backscattered energy and manipulate the relected signals for display
- Display that presents the ultrasound image or data in a form suitable for analysis and interpretation
- Method to record or store the ultrasound image

Transducer

A transducer is any device that converts one form of energy to another. In ultrasound the transducer converts electric energy to mechanical energy, and vice versa.



<u>The transducer serves two functions:</u>

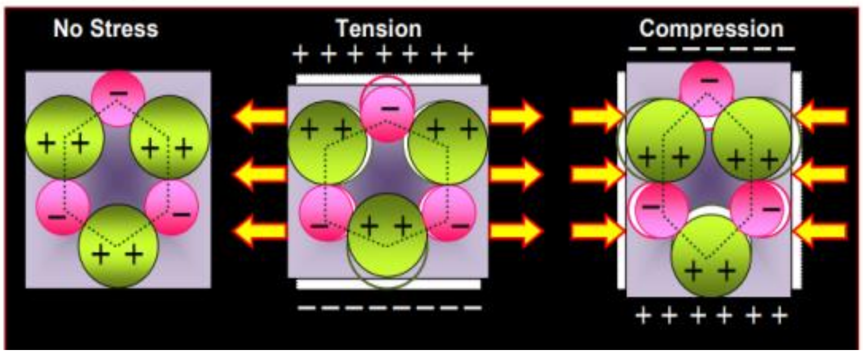
(1) converting the electric energy provided by the transmitter to the acoustic pulses directed into the patient

(2) serving as the receiver of reflected echoes, converting weak pressure changes into electric signals for processing.

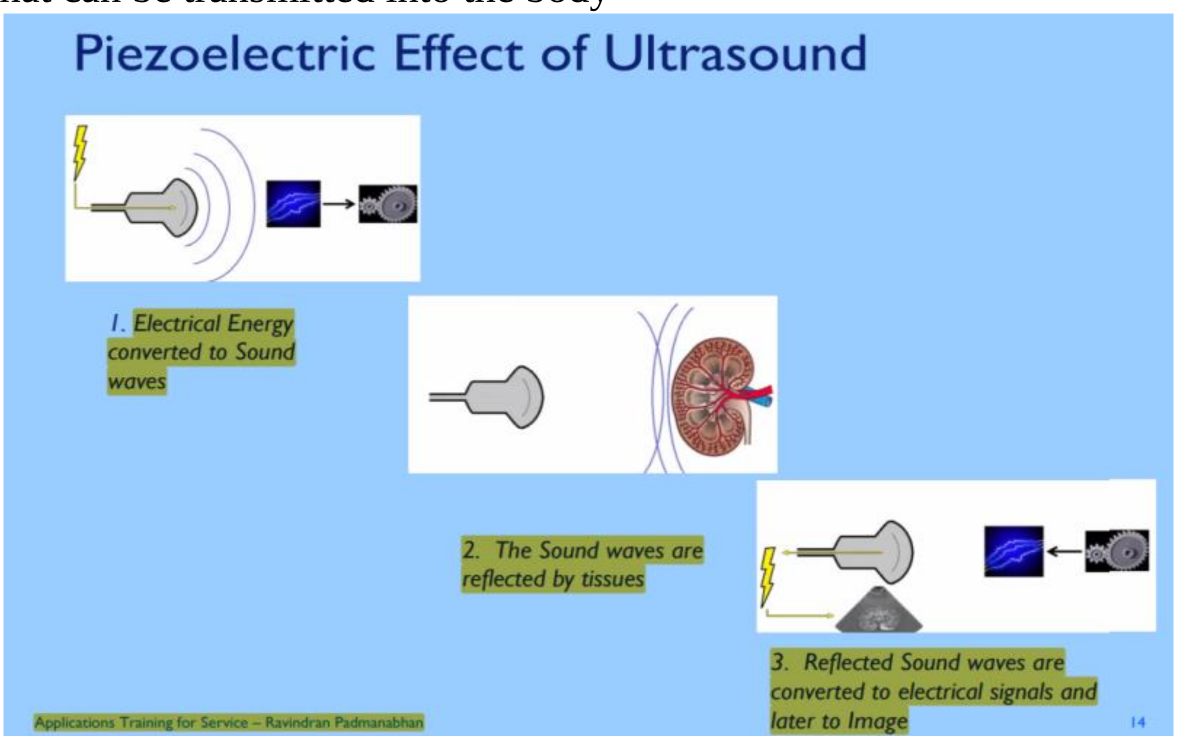
The Piezoelectric Effect

Ultrasound transducers use piezoelectricity, a principle discovered by Pierre and Jacques Curie in 1880.

- Materials have the unique ability to respond to the action of an electric field by changing shape. They also have the property of generating electric potentials when compressed.



Changing the polarity of a voltage applied to the transducer changes the thickness of the transducer, which expands and contracts as the polarity changes. This results in the generation of mechanical pressure waves that can be transmitted into the body



Natural and Synthetic Crystals

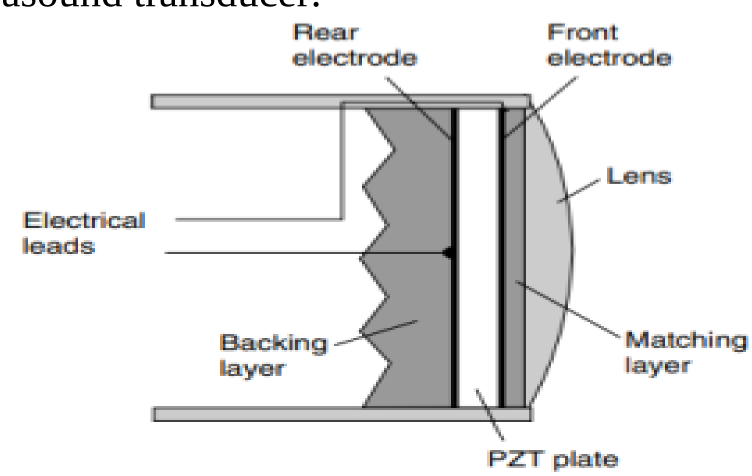
- The first ultrasound crystals discovered to possess piezoelectricity were natural crystals such as quartz.
- There are many different types of synthetic crystals in use today but most are made from a mixture of lead, barium, titanate, and zirconate. These types of synthetic crystals are also known as ceramic crystals.
- The most popular synthetic crystals manufactured today are those made of combinations of lead, zirconate and titanate, abbreviated PZT.
- A relatively recent newcomer is crystals made of hard plastic referred to as polymers.

Pulse-Echo Method

• Ultrasound transducer produces “pulses” of ultrasound waves
• These waves travel within the body and interact with various tissues
• The reflected waves return to the transducer and are processed by the ultrasound machine
• An image which represents these reflections is formed on the monitor

Transducer Construction and Characteristics

The following diagram shows the basic component elements in an imaging ultrasound transducer.



Crystal

The crystals is located at the end of the probe, which is in contact with the patient. The shape of the crystal depends on the transducer type and may be spherical, rectangular, or square.

- Various types of PZT are available and are chosen according to the properties required, such as high sensitivity to a specific frequency in both its sending and receiving modes of operation, or the ability to cope with large acoustic powers.
- This frequency is called the transducer's resonance frequency.
- The PZT slab vibrates most strongly at the frequency for which its thickness is half a wavelength
- The thickness of the piezoelectric crystal determines the transducer's resonance frequency.

$$\upsilon_T = \frac{C_T}{\lambda}$$

$$= \frac{C_T}{2t} \qquad \text{where:} \qquad \lambda = 2t$$

υ_T : resonance frequency, C_T: velocity of transducer, t: thickness of transducer

(H.W)
velocity of ultrasound in quartz = 5740 m/sec and 1.5-mm-thick quartz. what is the frequency?

Damping layer

PZT has one significant disadvantage in that it has a characteristic acoustic impedance that is about 20-times higher than that of the soft tissue.

- This unwanted ringing can be much reduced by having a backing (damping) layer behind the PZT,
- Made of a material with both a high characteristic acoustic impedance ($Z = 3 \times 10^{7}$ kg m^{-2} s^{-1}) and the ability to absorb ultrasound.

Impedance Matching Layer

- The matching layer is a thin layer between the device and the human skin.
- The matching layer is constructed from a material that has a characteristic impedance value that is between the impedance values of the crystal and skin.
- Matching layer can increase the transmission across the front face to 100%,

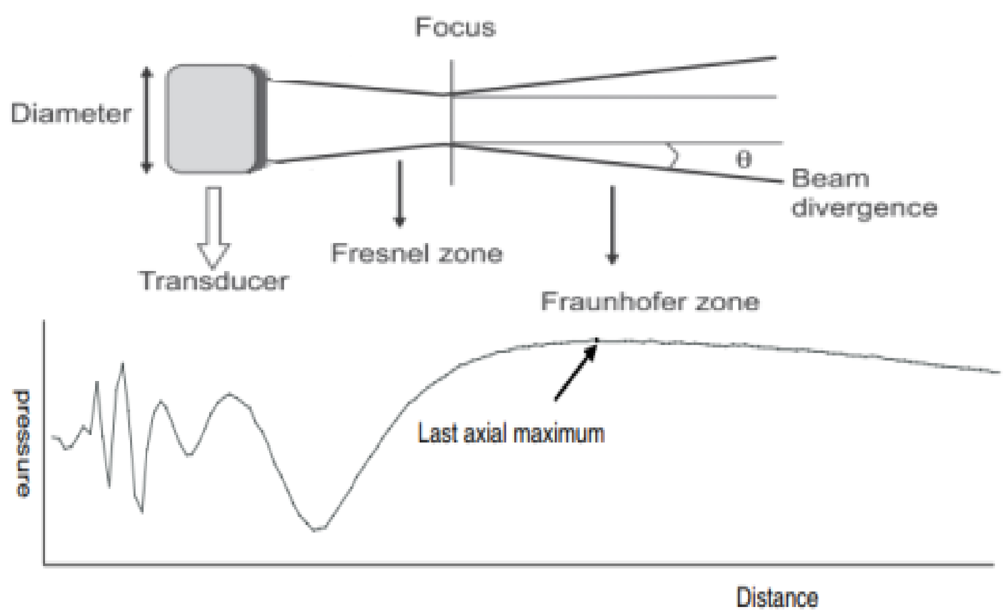
The matching layer impedance is obtained as follows;

$$Z_M = \sqrt{Z_T \times Z_L}$$

where, Z_T impedance of the crystal and Z_L is the impedance of the tissue

- layer thickness equal to a quarter of a wavelength (λ/4)

Ultrasound Beams



An unfocused sound beam is divided into two distinct regions:

1. Fresnel zone or near field, is adjacent to the transducer face, has a converging beam profile

The length of the near field is related to the diameter, D, of the transducer and the wavelength, λ, of the ultrasound by:

$$\text{Near field length} = D^2 / 4\lambda$$

(H.W)

A 2.5 MHz, 13 mm diameter unfocused transducer is selected for scanning an obese patient Assume the average velocity of sound in soft tissue(1540 m/s).

2. Fraunhofer zone or far field is one, in which the beam diverges

$$\sin \theta = 0.61 \; (\lambda / a)$$

- Because of the inverse relationship between wavelength and frequency, divergence is decreased by increasing frequency.
- The major advantage of using the higher ultrasound frequencies (shorter wavelengths) is that the beams are less divergent and generally produce less blur and better detail