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Sawa University

College of health and medical techniques

Department of Radiology Tech.

Third Stage

Radiological Equipment techniques

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What is Ultrasound?

Ultrasound or ultrasonography is a medical imaging technique that uses high frequency sound waves and their echoes.
Ultrasound is sound with frequencies greater than 20 kilohertz. This frequency is the approximate upper audible limit of human hearing in healthy young adults..

In ultrasound, the following events happen:

1.The ultrasound machine transmits high-frequency (1 to 5 megahertz) sound pulses into the body using a probe.
2.The sound waves travel into the body and hit a boundary between tissues (e.g. between fluid and soft tissue, soft tissue and bone).
3.Some of the sound waves get reflected back to the probe, while some travel on further until they reach another boundary and get reflected.
4.The reflected waves are picked up by the probe and relayed to the machine.
5.The machine calculates the distance from the probe to the tissue or organ (boundaries) using the speed of sound in tissue (5,005 ft/s or 1,540 m/s) and the time of each echo's return.
6.The machine displays the distances and intensities of the echoes on the screen, forming a two-dimensional image like the one shown in Figure 1.

Figure 1: Ultrasound image of a growing fetus (approximately 12 weeks old) inside a mother's uterus. This is a side view of the baby, showing (right to left) the head, neck, torso and legs.

The Ultrasound Machine

A basic ultrasound machine has the following parts (Figure 2):

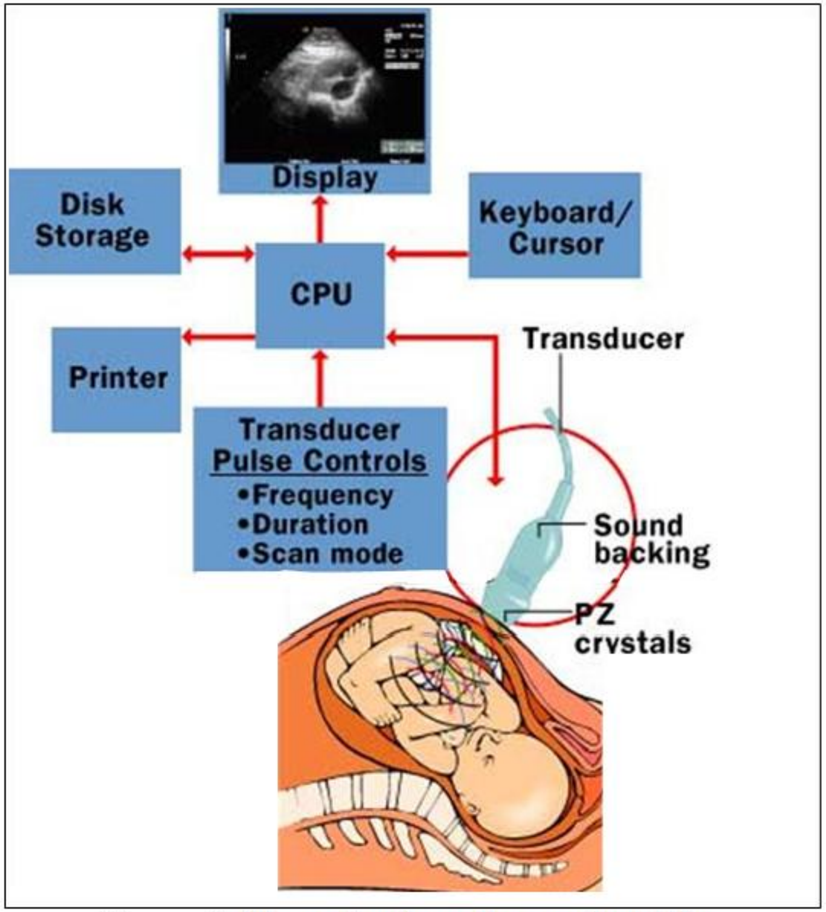

Figure 2: The parts of an ultrasound machine

•transducer probe

- probe that sends and receives the sound waves.

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 .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.

• Central processing unit (CPU)

- computer that does all of the calculations and contains the electrical power supplies for itself and the transducer probe.

The CPU is the brain of the ultrasound machine. The CPU is basically a computer that contains the microprocessor, memory, amplifiers and power supplies for the microprocessor and transducer probe. The CPU sends electrical currents to the transducer probe to emit sound waves, and also receives the electrical pulses from the probes that were created from the returning echoes. The CPU does all of the calculations involved in processing the data. Once the raw data are processed, the CPU forms the image on the monitor. The CPU can also store the processed data and/or image on disk.

• Transducer pulse controls

- changes the amplitude, frequency and duration of the pulses emitted from the transducer probe.

The transducer pulse controls allow the operator, called the ultrasonographer, to set and change the frequency and duration of the ultrasound pulses, as well as the scan mode of the machine. The commands from the operator are translated into changing electric currents that are applied to the piezoelectric crystals in the transducer probe.

• **display**

- displays the image from the ultrasound data processed by the CPU. The display is a computer monitor that shows the processed data from the CPU. Displays can be black-and-white or color, depending upon the model of the ultrasound machine.

• **keyboard/cursor**

- inputs data and takes measurements from the display. Ultrasound machines have a keyboard and a cursor, such as a trackball, built in. These devices allow the operator to add notes to and take measurements from the data.

• **disk storage device (hard, floppy, CD)**

- stores the acquired images

• **printer**

- prints the image from the displayed data

Common features of all transducers and transducer elements

All transducers or transducer elements have the same basic components: a piezoelectric plate, a matching layer and a backing layer, as shown in Figure 5. Usually, there is also a lens, but in array transducers it is usual for one large lens to extend across all the transducer elements. The number, size, shape and arrangement of transducer elements vary according to the transducer type and application.

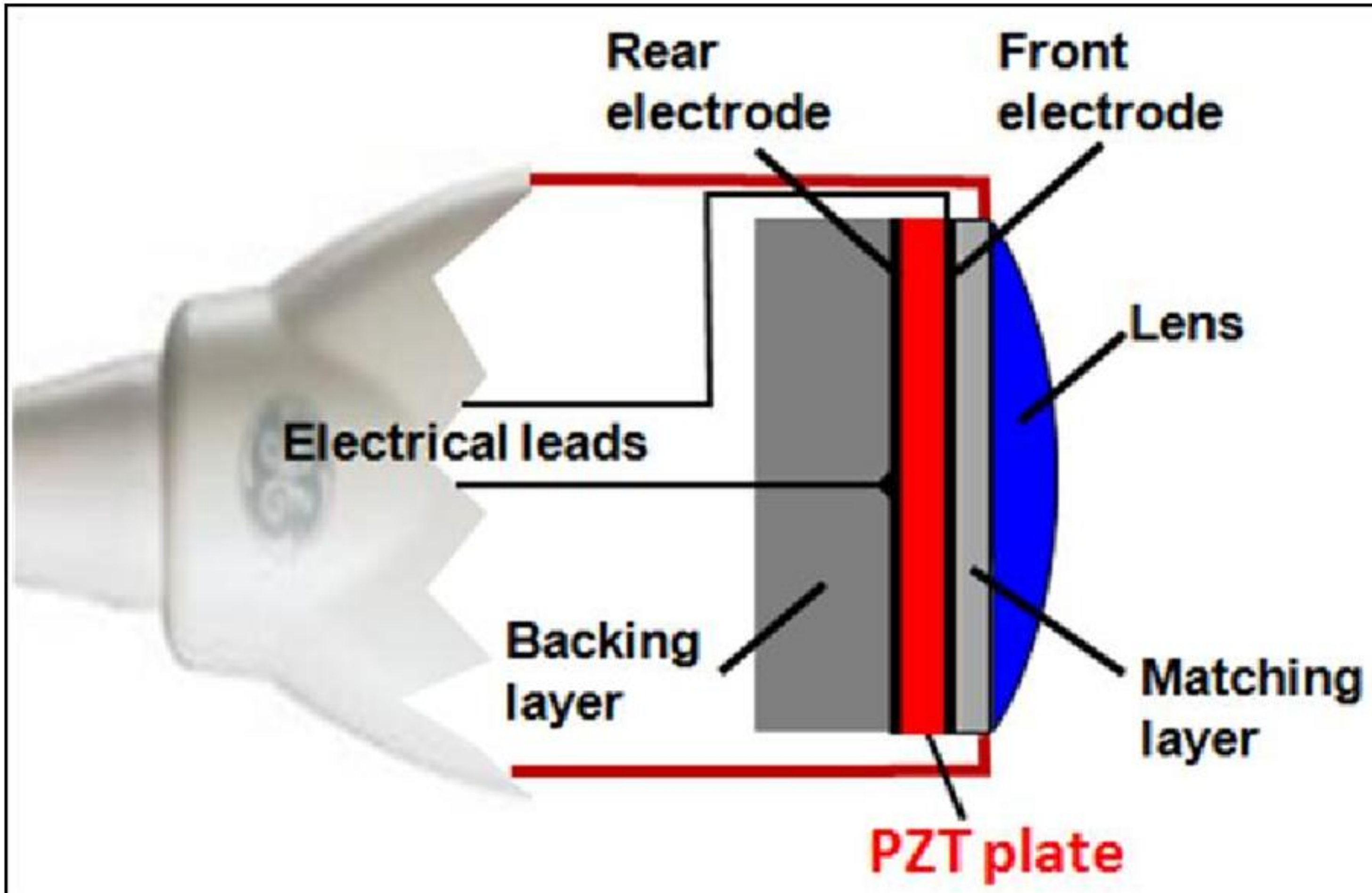

Fig. 5 The basic component elements in an imaging ultrasound transducer.

1. Piezoelectric plate

The actual sound-generating and detecting component is a thin piezoelectric plate. Piezoelectric materials expand or contract when a positive or negative electrical voltage is applied across them and, conversely, generate positive or negative voltages when compressed or stretched by an external force

Some piezoelectric materials, such as quartz, occur naturally but the piezoelectric material normally used for transducers in medical imaging is a synthetic ceramic material: (PZT: lead zirconate titanate) because of its high conversion efficiency. Various types of PZT are available and are chosen according to the properties required, such as high sensitivity, or the ability to cope with large acoustic powers.

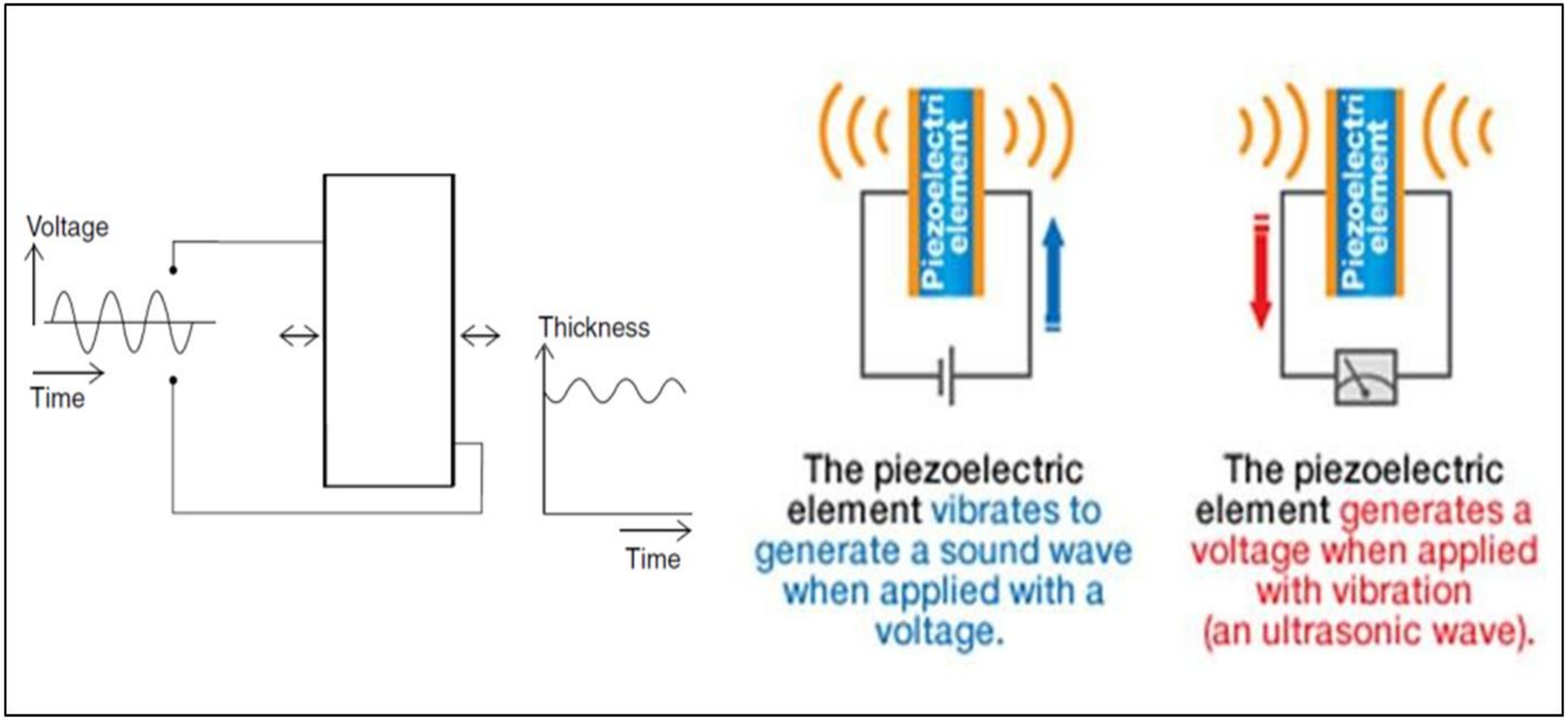

Fig. 6 Changes in voltage across a PZT plate produce corresponding changes in thickness.

- **half-wave resonance:**

The PZT slab vibrates most strongly at the frequency for which its thickness is half a wavelength, giving rise to the term ‘half-wave resonance’. Resonance occurs because an ultrasound wave propagating across the thickness of the PZT plate is partially reflected at the front and back faces, and thus continues to travel back and forth (reverberate) within the PZT plate. As the plate thickness is equal to half the wavelength, the wave travels a full wavelength in the PZT on each round trip. This means that the reflected wave arrives back in phase with the original wave, and adds constructively to it to produce a greater output. A PZT plate with a thickness equal to half a wavelength 1 at the required centre frequency is therefore used, as this will resonate and produce a large output at this frequency.

• Advantage of Backing layer

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 and the ability to absorb ultrasound. The backing material is located behind the piezoelectric element to prevent excessive vibration

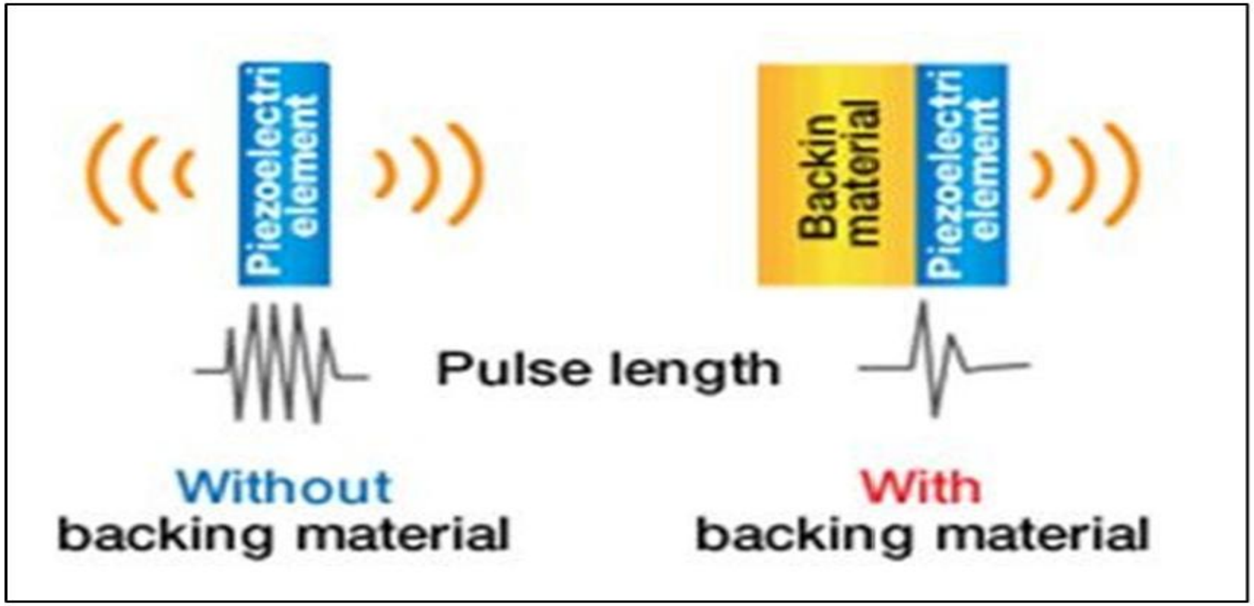

Fig. 7: Advantage of Backing layer

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4. Lens

The acoustic lens is a gray colored part looking like rubber attached to the tip of the probe. Ultrasonic waves transmitted from the probe would spread and travel like light. The acoustic lens prevents the ultrasonic waves from spreading and focuses them in the slice direction to improve the resolution. A lens is usually incorporated after the matching layer. Near the focus of the lens, the width of the beam is least and the transmitted amplitude, or receive sensitivity, is greatest. In linear-array transducers, focusing in the scan plane is achieved entirely by means, and so a cylindrical lens, producing focusing only in the plane perpendicular to the scan plane (elevation plane), is used. In phased-array transducers the lens may have some curvature (focusing action) in the scan plane as well as in the elevation plane, in order to augment the electronic focusing in the scan plane.

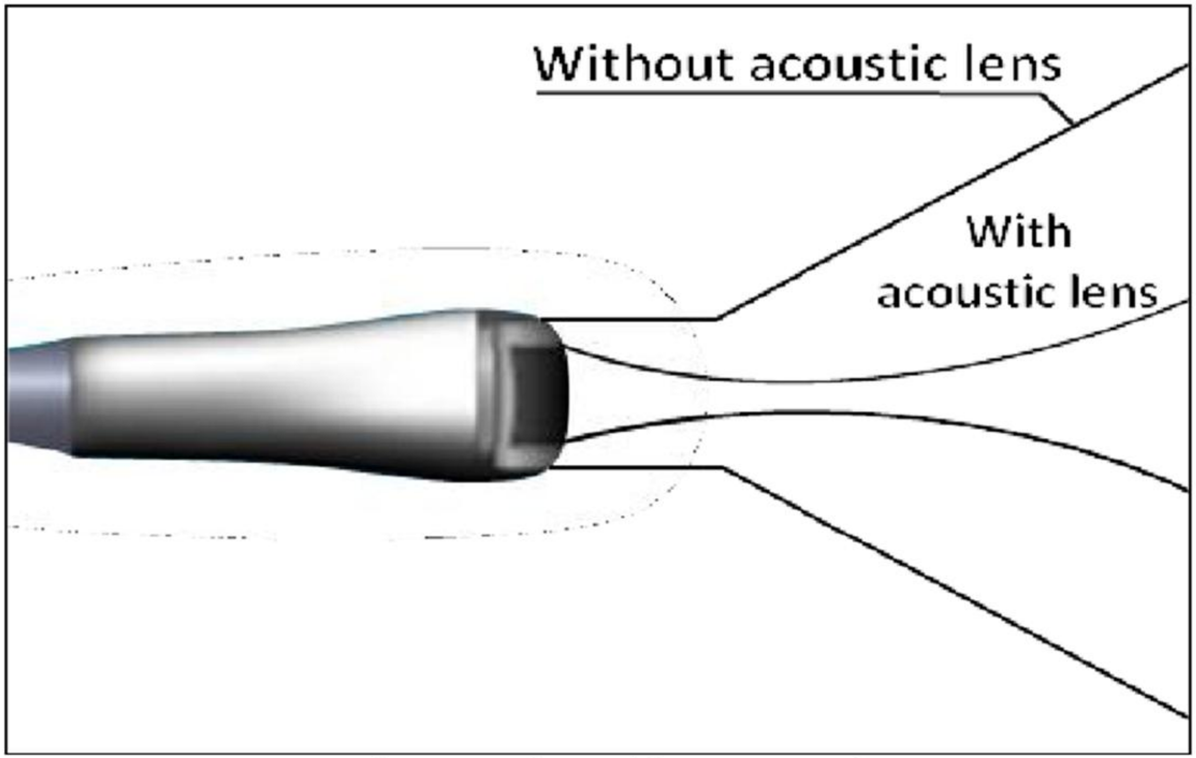

Fig. 10 Linear and curvilinear scan formats.