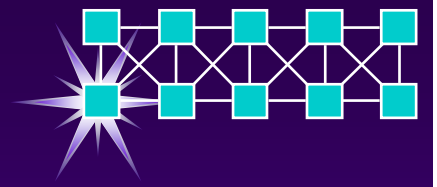
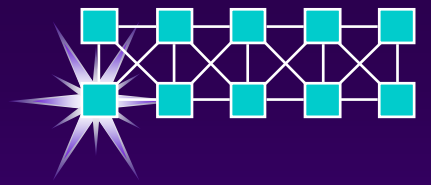
Medical Imaging Systems



- Radiography
- Tomography
- Magnetic Resonance Imaging (MRI)
- Nuclear Imaging Systems
- **Ultrasound Imaging Systems**
- Electrical Impedance Tomography
- Breast Thermography
- Others (**Elastography, Spectroscopy, Ophthalmology**)

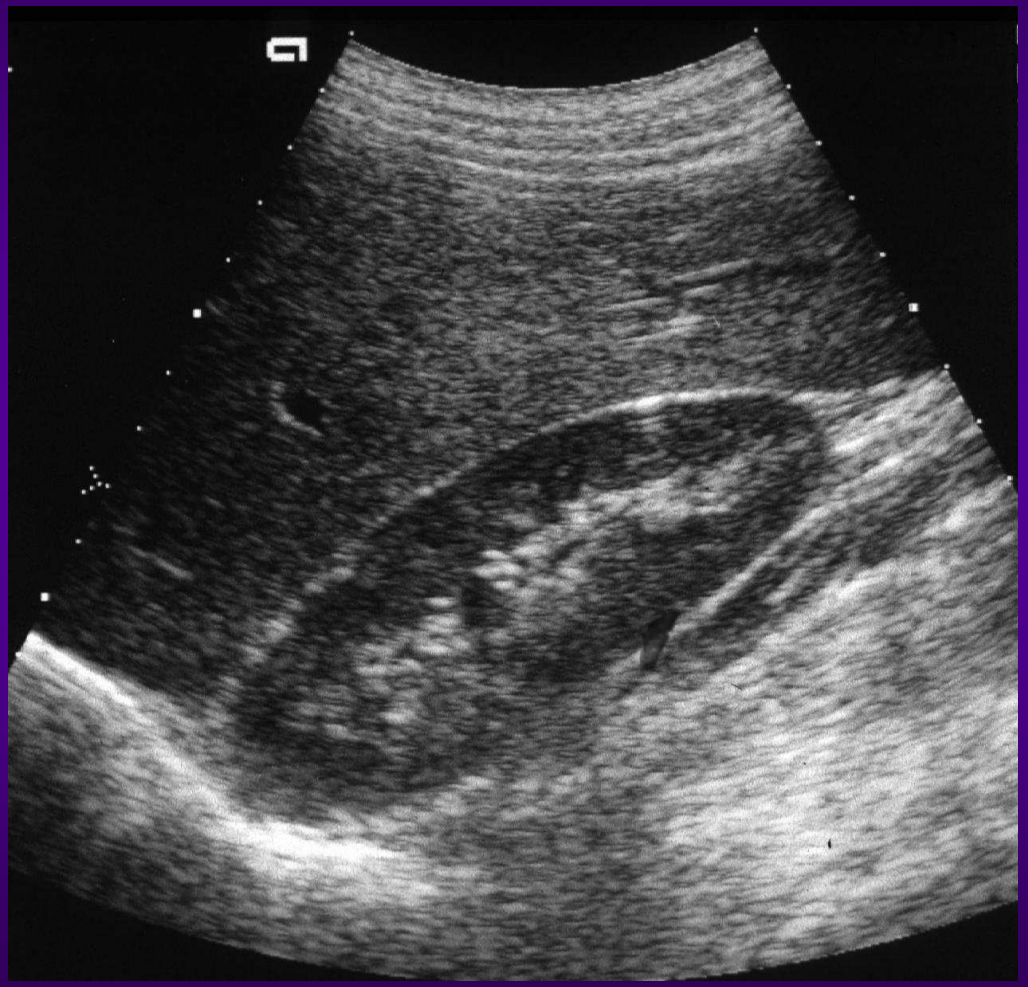


Ultrasound Imaging

First applied to the human body for medical purposes by Dr. George Ludwig at the Naval Medical Research Institute, US, in the late 1940s

Ultrasonography

excellent soft tissue contrast

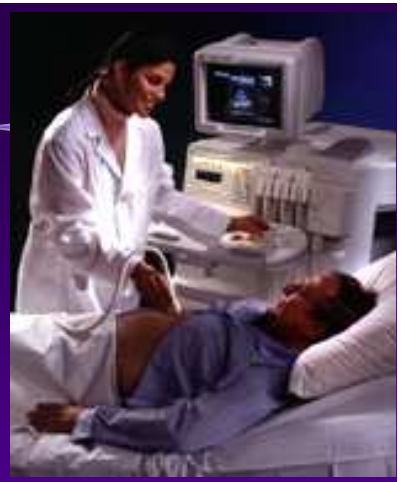


Abdominal sonography:
Excellent soft tissue contrast

- **Most commonly associated with fetal imaging.**
- **Advances in ultrasound technology:**
  - **cardiac,**
  - **vascular and breast imaging,**
  - **cyst identification and**
  - **guidance of a variety of surgical and other therapeutic procedures.**

Equipment of Ultrasound Imaging System

Ultrasound examination

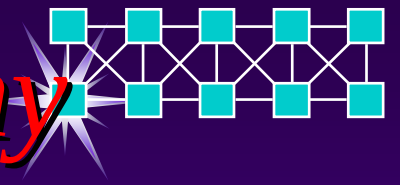


Ultrasound machine

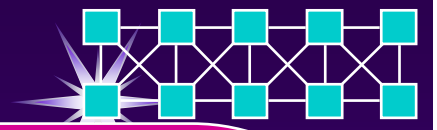
Convex 3.5 MHz
For abdominal and
OB/GYN studies

Micro-convex: 6.5MHz
For transvaginal and transrectal studies

Principle of Ultrasonography



- **Similar to sonar, using high-frequency sound waves as its imaging source.**
- **Use the reflection of a sound wave as it collides with the anatomy**
- **That reflection is converted into diagnostic information via a hand-held transducer passed over the area being imaged.**

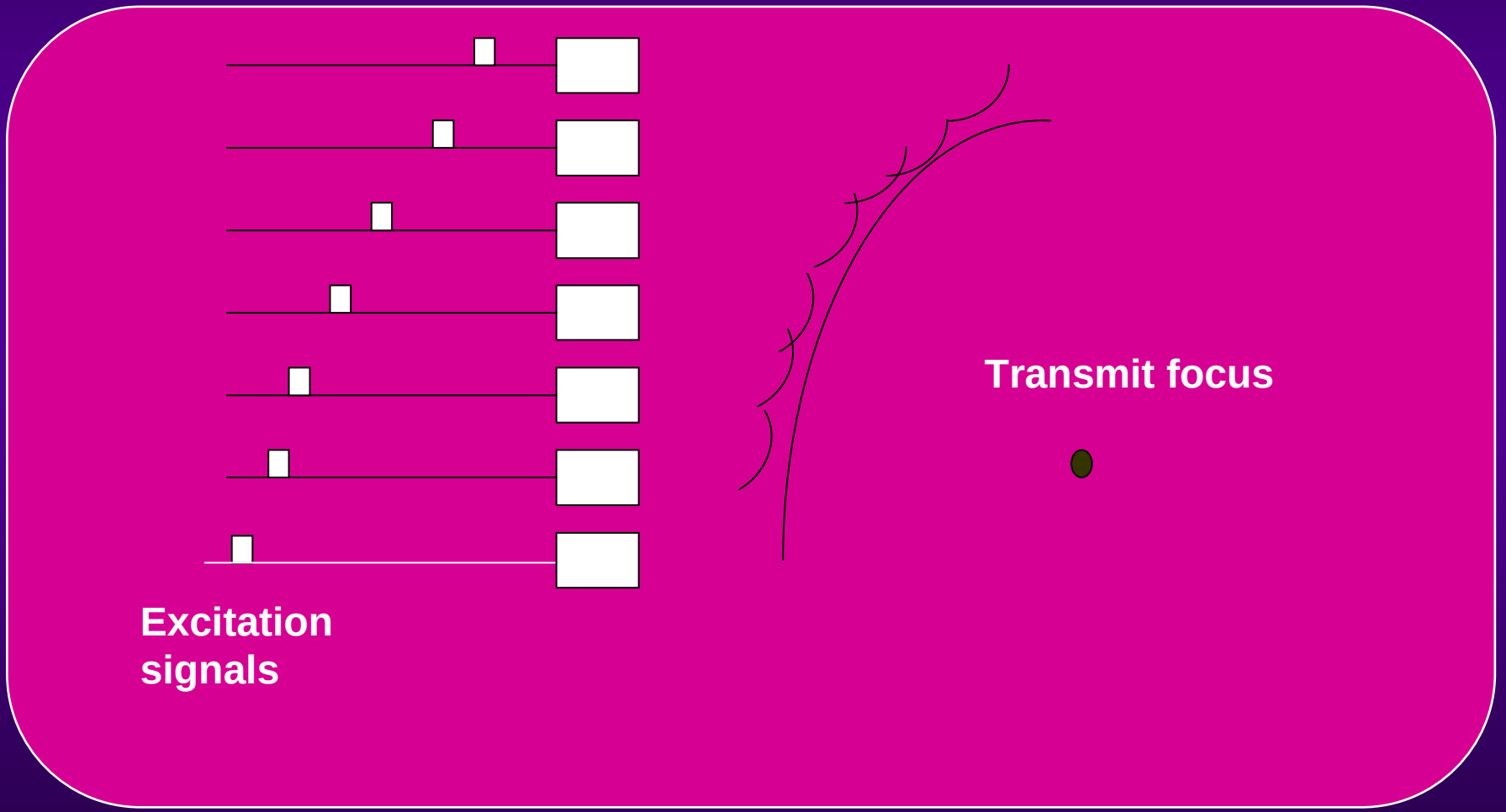


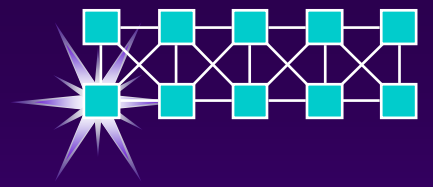
- Ultrasound transducers generate **acoustic waves**

- The most efficient technique: use of the **piezoelectric effect.** (Applying stress on a crystal creates electrical potential and vice versa.)

- The standard material: the **ferroelectric ceramic lead-zirconate-titanate (PZT)**

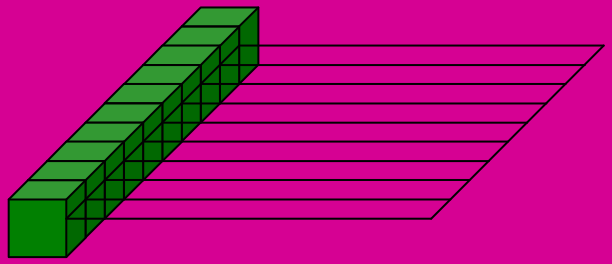
Variable delays are applied across the transducer aperture. Focusing and steering is done by delayed excitation signals as follows:



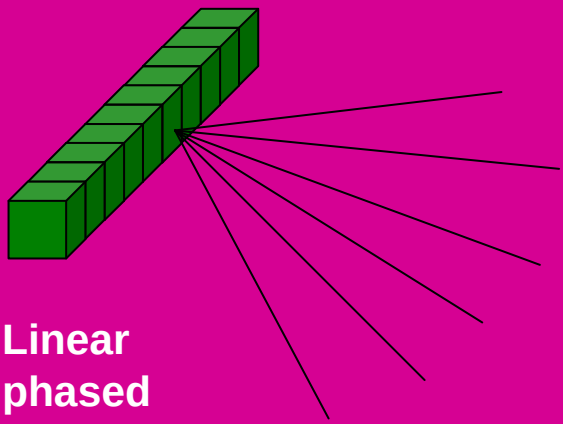


- **The acoustic signal from all elements reach the focal point at the same time.**
- **The net acoustic signal is the sum of all signals.**
- **For receiving an ultrasound echo, the phase array works in reverse.**

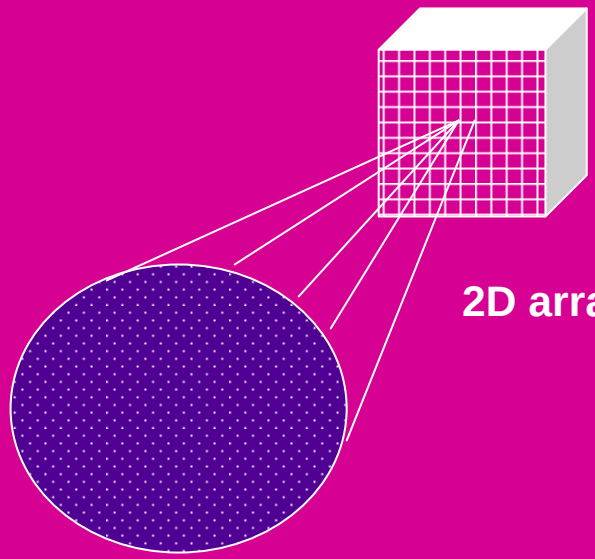
Different Types of Array



Linear

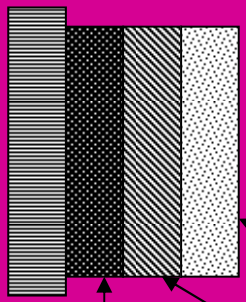


Linear phased



2D array

Backing

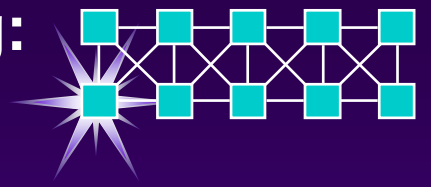


PZT

Matching layer

Face plate

Two basic equations used in ultrasonic imaging:



$$d = \frac{1}{2} tc$$

Where:

d = the one way distance of an object that cause the echo

t = time delay (for the round trip)

c - speed of sound in tissue (between 1450 and 1520 m/s)

The other equation:

Where:

$$S(t) = T(t) \otimes B(t) \otimes A(t) \otimes \eta(t)$$

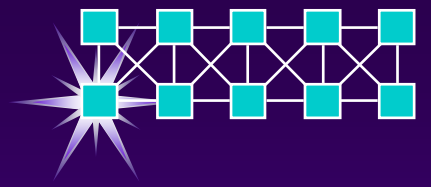
S(t) - Received signal strength.

T(t) - Transmitted signal

B(t) - transducer properties

A(t) - The attenuation of signal path to and from the scatterer

η(t) - The strength of the scatterer



Operational Modes:

A-mode –

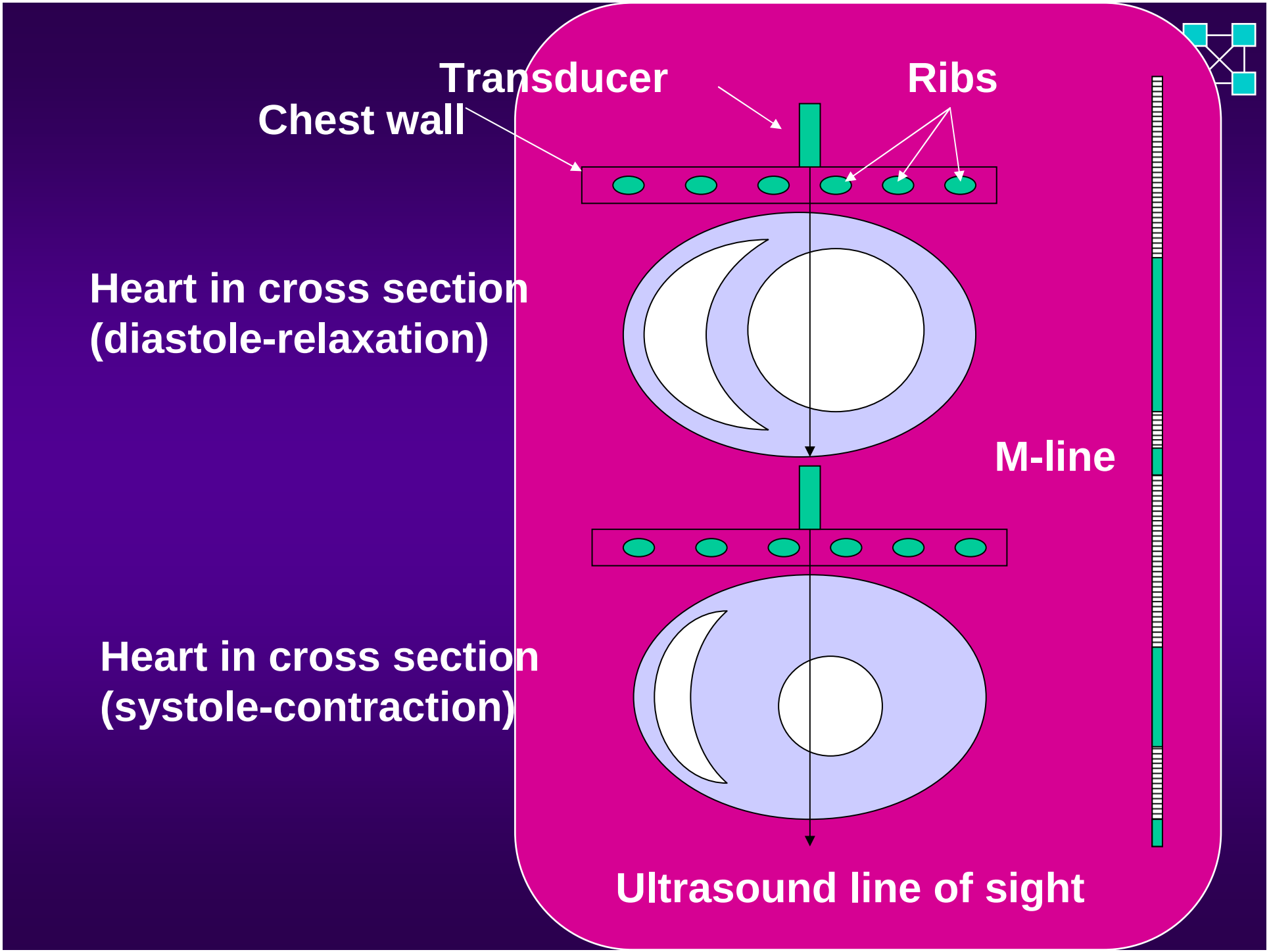
Amplitude of the returned echoes along a single line is displayed on an oscilloscope.

B-mode (2-D) –

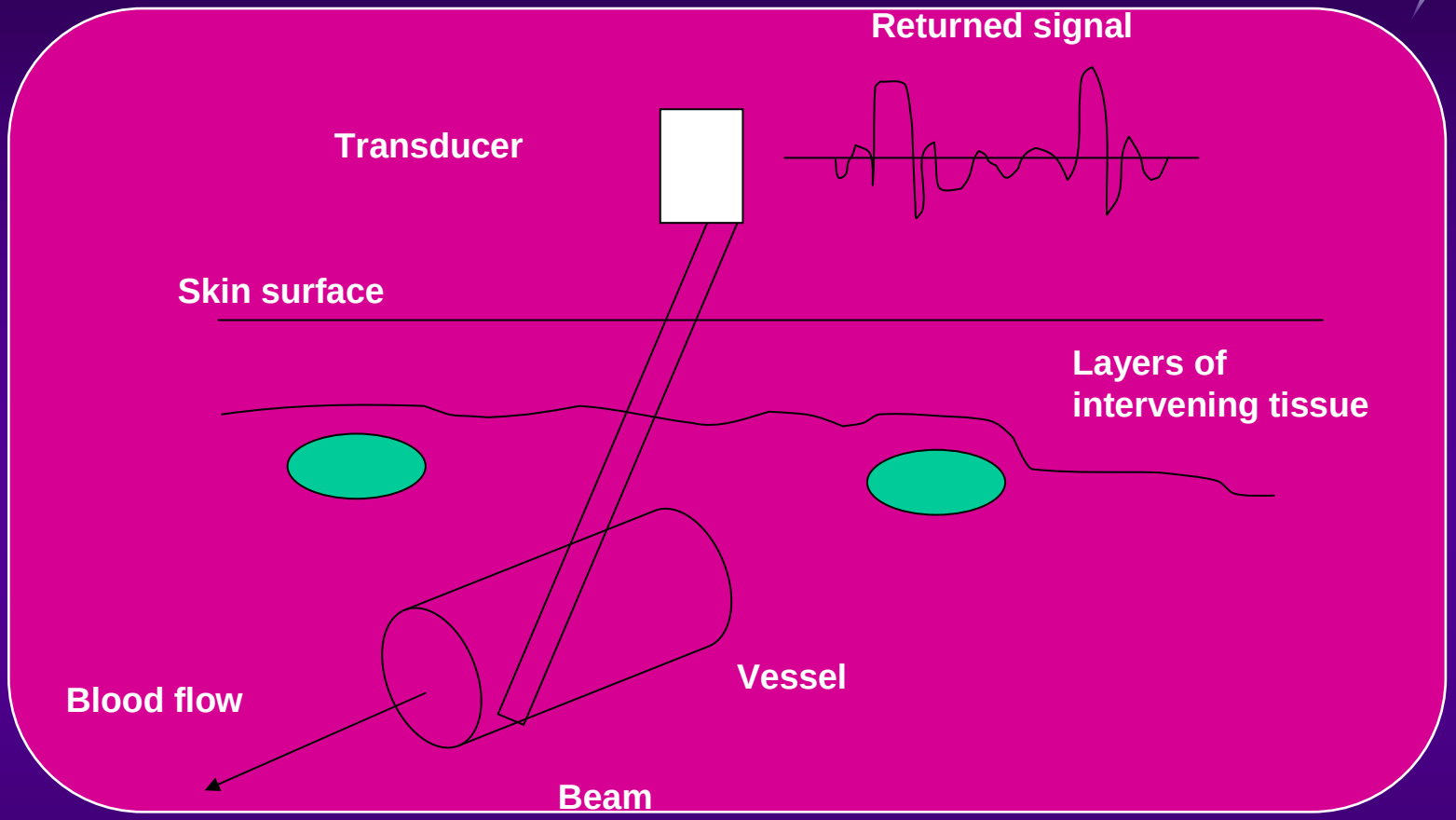
Displaying the strength of the returned echoes as bright spots in their geometrically correct direction and distance.

M-mode –

Followed A mode by recording the strength of the echoes as dark spots on moving light sensitive paper. Wall thickness could be obtained from this mode.

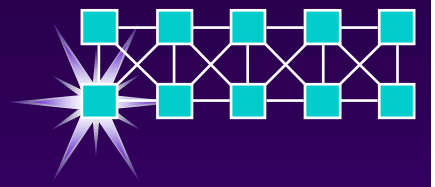

Transducer
Ribs
Chest wall
Heart in cross section
(diastole-relaxation)
M-line
Heart in cross section
(systole-contraction)
Ultrasound line of sight

Ultrasound is also used for measurement of blood flow in the blood vessels as shown below:



The target is red blood cells in a smallest region as possible. One type of system uses the Doppler effect.
The Doppler shift frequency is equal to $2f_c vc$
f_c - transducer center frequency
v - velocity components of the blood cells
c - Speed of sound within tissue.

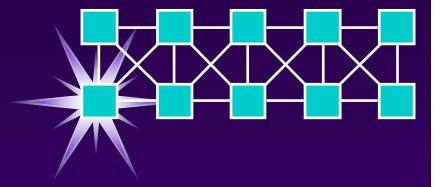
Ultrasound contrast agents



- **Reflection of sound waves depend on the acoustic impedance**
- **Acoustic impedances differences are very small between soft tissues.**
- **Echofarnaceuticals (US Cas) have been proposed to increase acoustic impedance differences at tissue interfaces.**

Fetus Ultrasound

Features



- It is very **safe to use** and does not appear to cause any adverse effects
- It is also **relatively inexpensive** and **quick to perform.**
- Doppler capabilities on modern scanners allow the **blood flow in arteries and veins to be assessed.**