Work 192. Ultrasonic echography (A-scan)

Purpose

- Determination of the correlation between the echo arrival time, speed of sound, and the distances from the ultrasound source and defects (reflectors) of different sizes.
- Measurement of the speed of sound in a sample, determination of the position and size of the defects.

Safety notes

1. The apparatus is connected to the 220 V power mains.
2. Do not cover openings on the apparatus which are necessary for ventilation.
3. Do not thrust any things into the apparatus: it can lead to short circuit.
4. Before using the ultrasonic probe, ascertain its integrity. If the sensor is broken, replace it.
5. Unplug the sensors by holding the socket. Do not pull the wire!
6. Peak voltage on the sensor's contacts can achieve 300 V. Do not touch the sockets while the apparatus is in work!
7. Do not apply the apparatus to people or other objects except special test samples used in this work.

Experimental setup

1. Ultrasonic echoscope GS200 (see figure 1)
2. Ultrasonic probe (1 MHz, blue)
3. Object to study (a brick with holes, see figures 1–2)
4. Ultrasound transmission gel
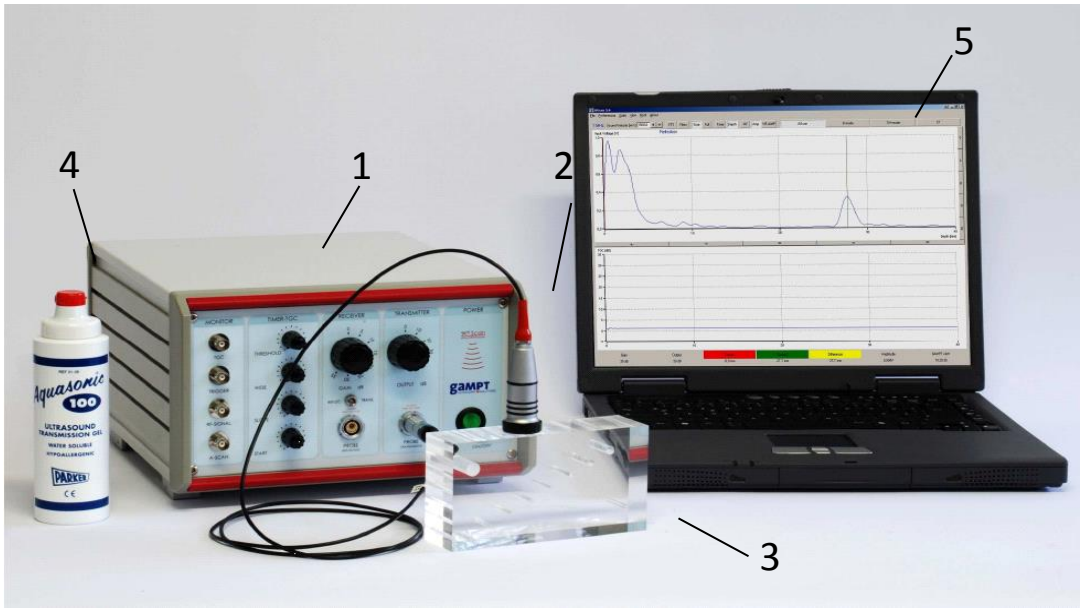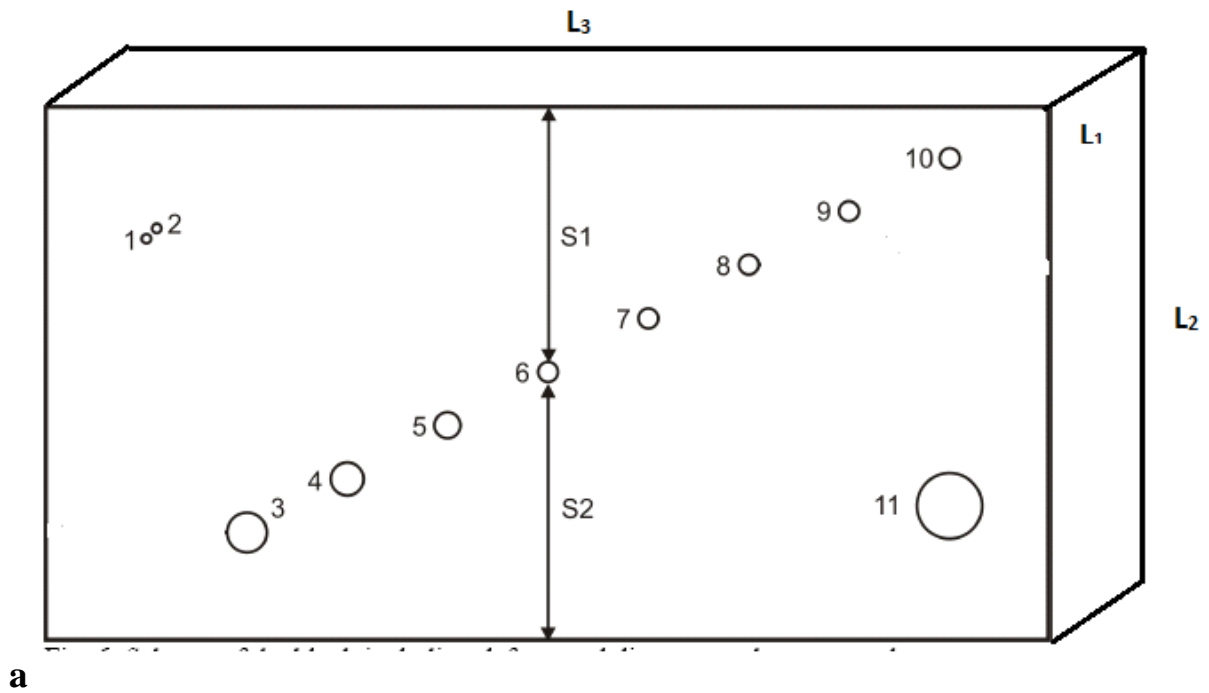5. Laptop
6. Ruler or calipers

Figure 1. Laboratory setup for studying ultrasonic echocardiography. (1) Ultrasonic echoscope GS200; (2) probe (blue, 1 MHz; red, 2 MHz; green, 4 MHz); (3) object to study; (4) gel; (5) laptop.

Fig. 6. Scheme of the block, including el. 2 × s = l dis......

a

b

Figure 2. Model objects for the work: (**a**) a test brick made of polyacryl; (**b**) model of an eyeglobe.

Tasks

1. Measure the size of the brick using a ruler or calipers (the height L2, see figure above).
2. Find the time of the echo arrival.
3. Calculate the speed of sound and measure the distances to the defects in the plastic brick.
4. Measure the distances to anatomical structures in the eyeglobe model.

Conducting the measurements

Preparations (connecting and tuning)

- Connect the echoscope GS200 to the computer.
- Connect the 1-MHz sensor (blue) to the socket "Probe1" (see figure 3). Set the transmitter/receiver mode to "1 | 1" (reflection).
- Launch the program GS-EchoView on the desktop of the laptop.
- In the window "A-mode" find the tab "params" and set the parameters "begin" and "end" to 0 and 100, respectively (see figure 4).
- Get the TGC signal with the shape as that shown in figures 4–5 (tune the time gain) using the handwheels 7–10 of the block C (figure 3). Initial settings of the switchers 3 and 5 (figure 3) of the block B should be

"Gain" = 10, "Output" = 10. If necessary, change these numbers (depending on the studied model).
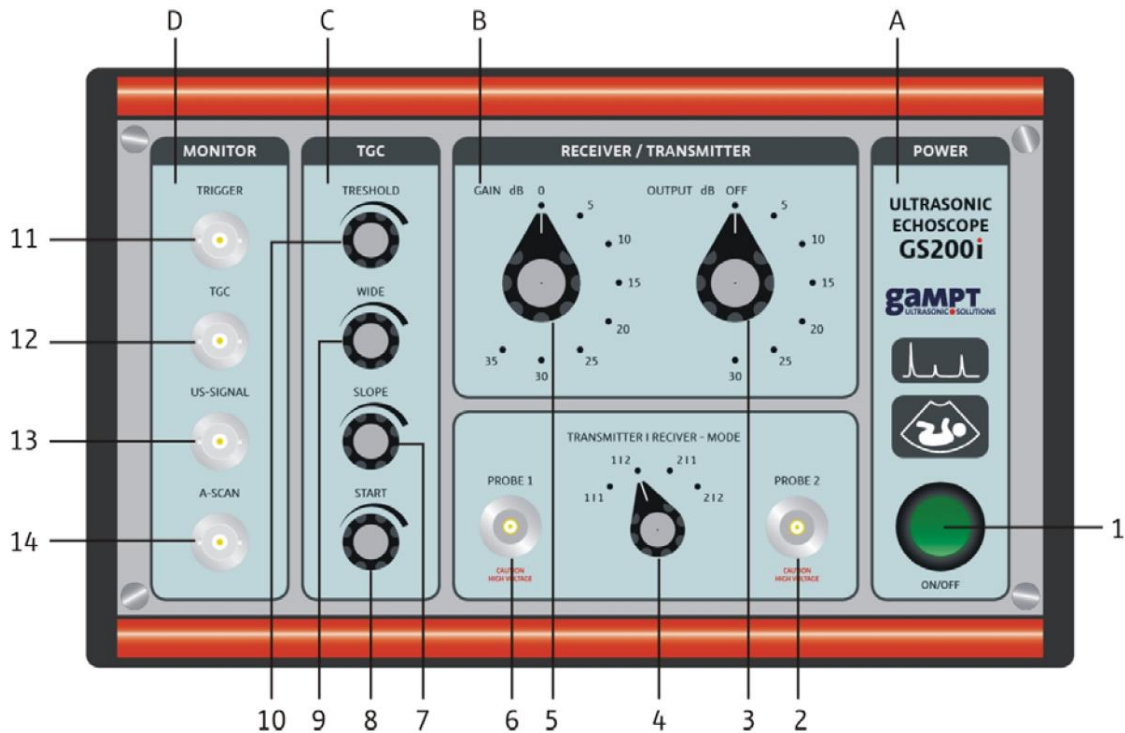

Figure 3. Front panel of the echoscope GS200.

Description of the echoscope's front panel:
A – Power supple
(1) Power on/off
B – Transmitter/Receiver block
(2) Socket for the probe 2
(3) Control of the output signal level
(4) Switcher of receive/transmit regimes
(5) Control of the receiver gain level
(6) Socket for the probe 1
C – Time amplification block
(7) Slope control
(8) Starting point control
(9) Control for the amplification time range width
(10) Control for the gain level
D – Sockets for connecting an oscilloscope
(11) Trigger signal
(12) Time amplification/gain control
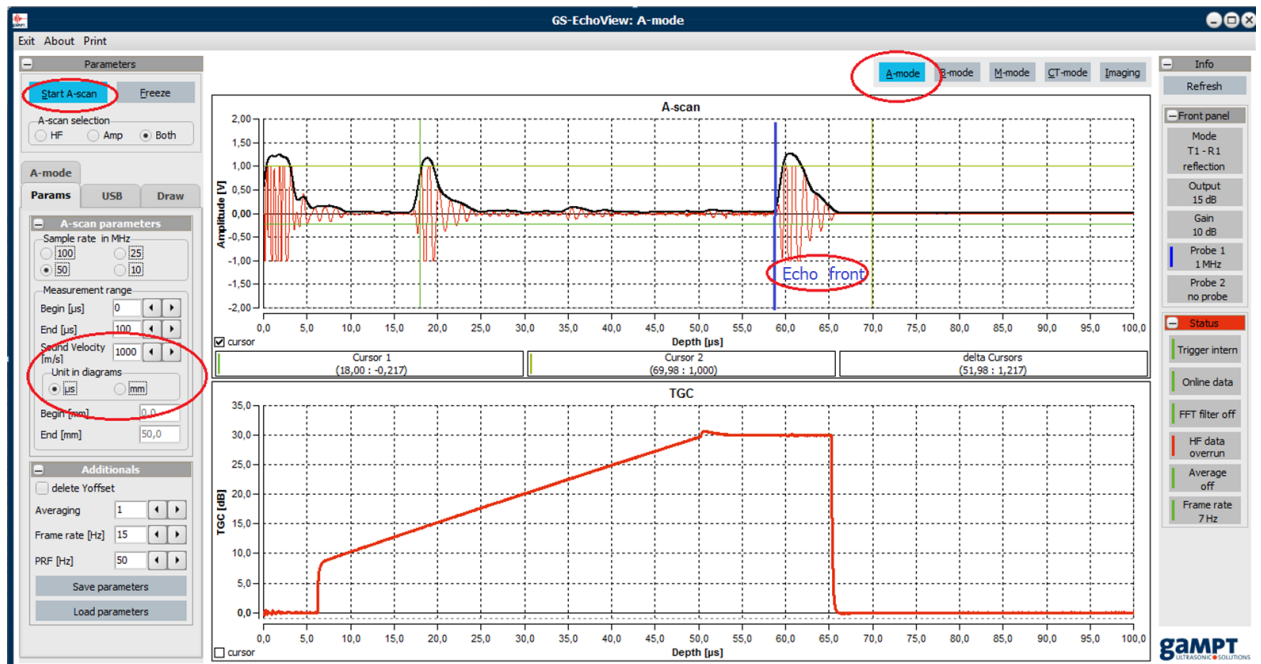(13) Ultrasonic signal
(14) Echo signal
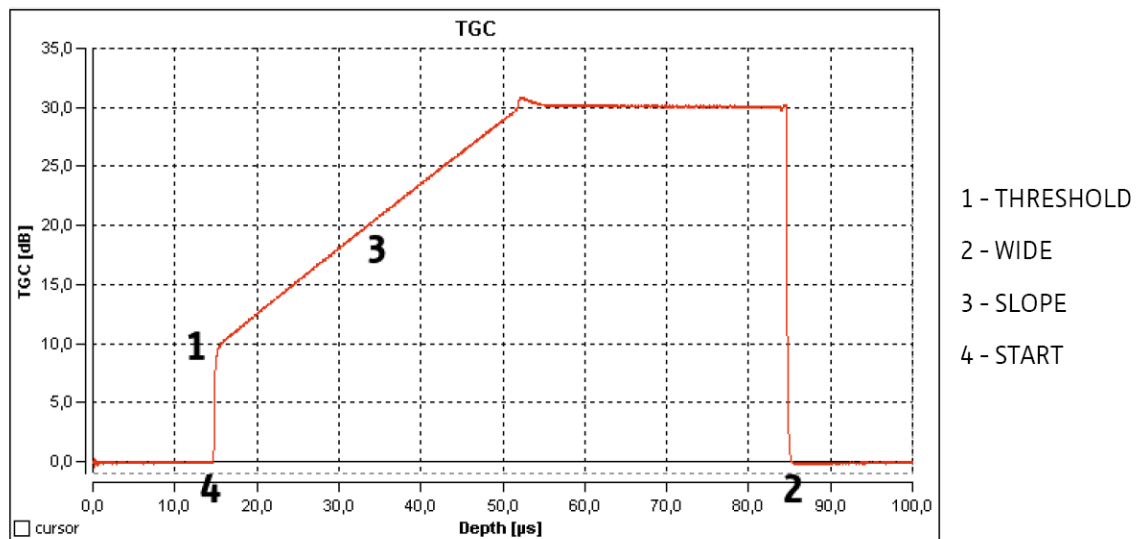
Figure 4. Main window of the GS-EchoView program.

Figure 5. Scheme of controlling the time gain (TGC).

Carrying out the experiment

Exercise 1. Determination of the speed of sound and the distances to the holes in the test brick

1. Measuring the sample length with a ruler
   - Using a ruler, define the height (L2, see figure 2) of the test brick. Write down the results in the table 1 (column "total").

2. Finding the echo arrival time from the side of the brick of the known length for further calculation of the speed of sound:

- Apply a small amount of ultrasonic gel on the brick on the side where you plan to conduct the measurement (one of the long sides, plane L1–L3 in figure 2).
- Put the probe onto the chosen side, covered with gel.
- In the tab "Params – Measurements length" tick the "μs" radiobutton (to measure the echo arrival time in microseconds).
- In the A-mode, start the measurements with the "Start A-scan" button.
- Using the mouse cursor, find the time when the echo returns from the rear side of the brick; measure it with respect to the front side (buildup) of the echo. Note that this echo signal does not disappear when you move the probe (see figure 4)!

3. Calculating the speed of sound
- Using the time found on the previous stage, find the speed of sound using Eq. (1). Before that, transform the units of measurement to the SI units: meters and seconds.

$$c = \frac{2S}{t}, \qquad (1)$$

where c is the speed of sound, S is the way (brick's height), and t is the time of arrival of the echo from the rear side.

- In the tab "Params – Measurements length" set the obtained value of the "sound velocity" (in m/s) and tick the "mm" checkbox (for the unit of measurements of the distance to reflecting objects).

4. Measuring the echo arrival time from the holes along two directions.
- Find the distances to the defects from two sides, in other words, measure distances S_1 and S_2 (see figure 2a) for different holes.
- After you finish the experiments, wipe the probe and the model object with tissue paper.

5. Calculating the size of the holes.
- Calculate the size of the holes based on the found values S_1 and S_2 and the brick length L_2: Рассчитать размеры отверстий, исходя из полученных значений S_1 и S_2 и размера блока L_2:

$$d_i = L_2 - (S_1 + S_2).$$

- To verify the results, measure the hole diameters by the calipers or ruler. Write down the results in the table.

6. Presenting the results.

- Fill in the table like the one below.

Hole	total	1, 2	3	4	5	6	7	8	9	10	11
S_1											
S_2											
Hole sizes from the A-scan											
Hole sizes measured directly											

Exercise 2. Determination of the distances to anatomical structures in the eyeglobe model

1. Apply gel on the eye model approximately on its pupil.
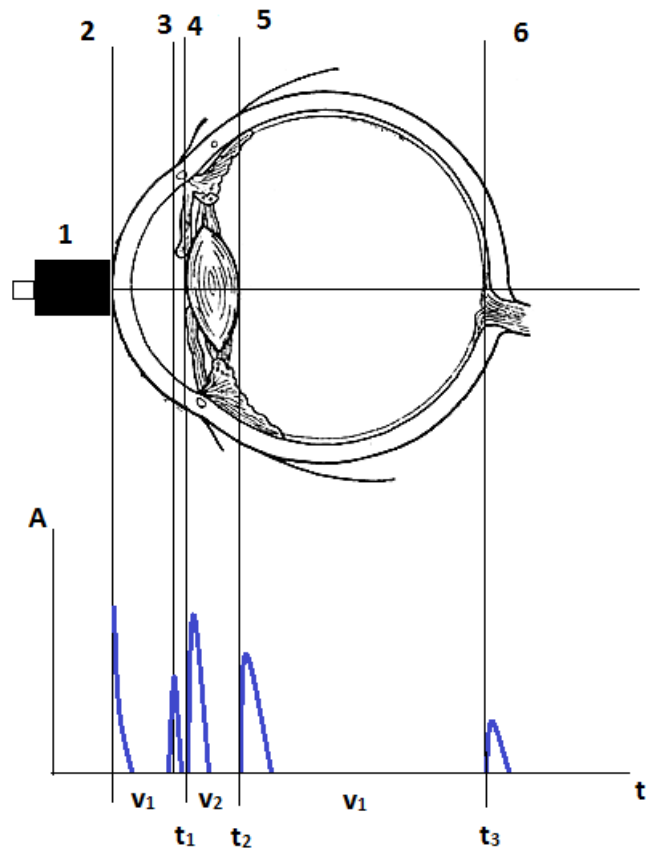2. Record the A-scan of the structures comprising the eye model (figure 6).

Figure 6. Structure of the eyeglobe and corresponding characteristics of the A-scan: (1) ultrasonic probe, (2) cornea, (3) iris, (4) front side of the lens, (5) back side of the lens, (6) retina.

3. Find the echo arrival time from the front and back sides of the lens and from the retina; fill the results in the table.

4. Determine the mean speed in the eye model using the expression
$$v = \frac{v_1\left(t_1 + \left(t_3 - t_2\right)\right) + v_2\left(t_2 - t_1\right)}{t_3}.$$

5. Assuming that the speed of sound in the lens is $v_2 = 2500$ m/s and in other regions of the eye model it is $v_1 = 1410$ m/s, calculate the depth where these structures are located. Write down the results in the table.

Structure	Front side of the lens	Back side of the lens	Retina
Echo arrival time, µs			
Mean velocity, m/s			
Measured depth, mm			
Real depth, mm	9,66	18,91	56,77
Thickness, mm	9,66	9,25	37,96

6. Make conclusion and discuss the obtained results.

Questions
1. Elastic waves. Wave equations. Velocity of elastic waves. Sound waves.
2. Acoustic impedance. Ultrasound.
3. Scheme of an ultrasonic probe. Piezoelectric effect.
4. Methods of ultrasonic investigation. A-regime, B-regime, M-regime.