## M6. Physical principles of ultrasound in medicine. Ultrasonography.

Problems to be prepared:
- Mechanical wave - the generation, propagation mechanism, properties, harmonic wave equation [1] – Chap. 16
- Acoustic wave, ultrasound. The use of ultrasound in the diagnosis and therapy [1] – Chap. 17
- The principle of superposition for waves [1] – Chap. 16-9
- Wave reflection and refraction [1] – Chaps. 33-8 and 33.9
- Ultrasound imaging - the reflection coefficient, transmission coefficient, acoustic impedance
- The phenomena which affect the interpretation of ultrasound images: wave scattering, interference, attenuation of acoustic waves
- The generation of ultrasound in USG units
- A-mode, B-mode and M-mode ultrasonography
- Resolution of the ultrasound imaging. Diffraction [1] – Chap. 35-3
- Doppler effect [1] – Chap. 17-9
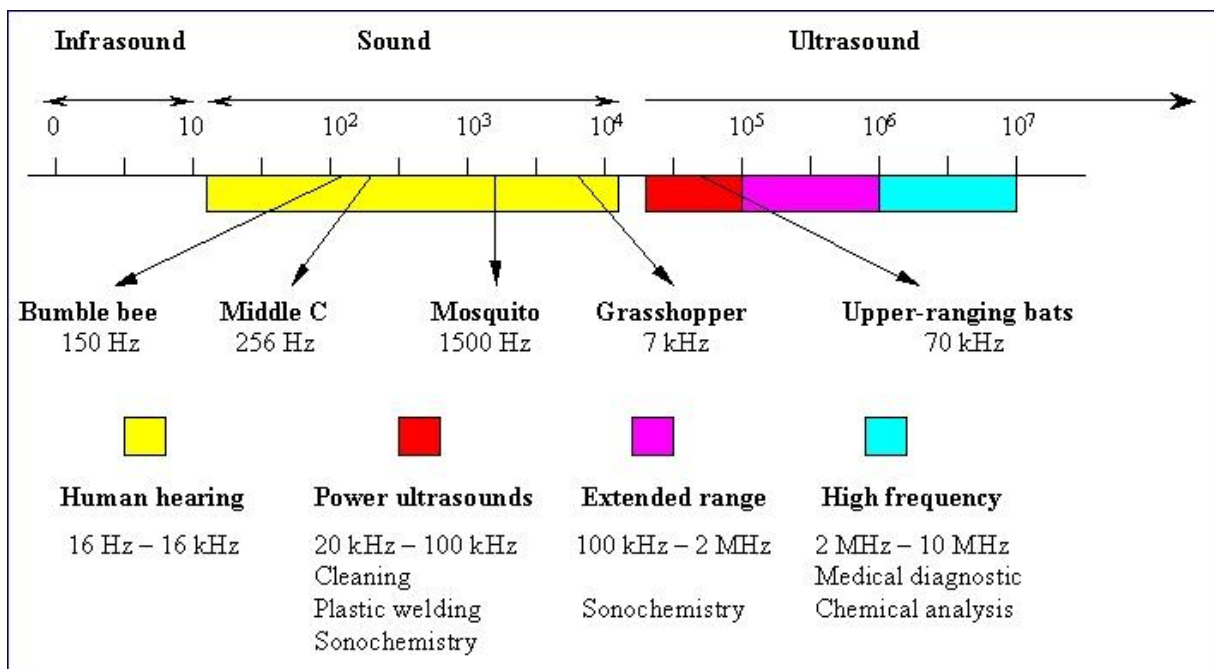
In ultrasonography, a signal generator is combined with a transducer. Piezoelectric crystals in the signal generator convert electricity into high-frequency sound waves, which are sent into tissues. The tissues scatter, reflect, and absorb the sound waves to various degrees. The

sound waves that are reflected back (echoes) are converted into electric signals. A computer analyzes the signals and displays the information on a screen.

Ultrasound information can be displayed in several ways.

A-mode: This display mode is the simplest; signals are recorded as spikes on a graph. The vertical (Y) axis of the display shows the echo amplitude, and the horizontal (X) axis shows depth or distance into the patient. This type of ultrasonography is used for ophthalmologic scanning.

B-mode ultrasonography in which the strength of echoes is indicated by a proportional brightness of the displayed dots. This mode is most often used in diagnostic imaging; signals are displayed as a 2-dimensional anatomic image. B-mode is commonly used to evaluate the developing fetus and to evaluate organs, including the liver, spleen, kidneys, thyroid gland, testes, breasts, and prostate gland. B-mode ultrasonography is fast enough to show real-time motion, such as the motion of the beating heart or pulsating blood vessels. Real-time imaging provides anatomic and functional information.

M-mode: This mode is used to image moving structures; signals reflected by the moving structures are converted into waves that are displayed continuously across a vertical axis. M-mode is used primarily for assessment of fetal heartbeat and in cardiac imaging, most notably to evaluate valvular disorders.
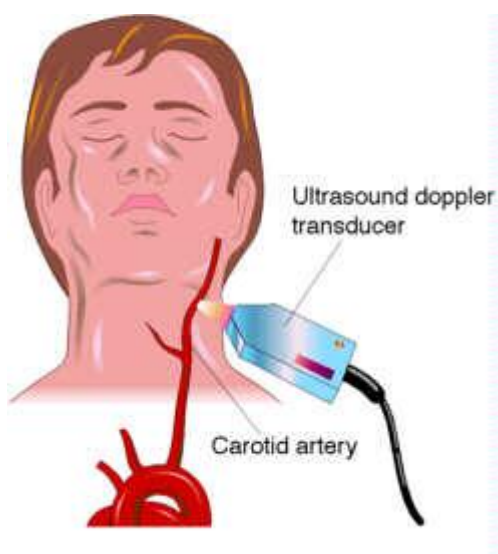
Doppler: This type of ultrasonography is used to assess blood flow. Doppler ultrasonography uses the Doppler effect (alteration of sound frequency by reflection off a moving object). The moving objects are RBCs in blood.

Direction and velocity of blood flow can be determined by analyzing changes in the frequency of sound waves:

- If a reflected sound wave is lower in frequency than the transmitted sound wave, blood flow is away from the transducer.
- If a reflected sound wave is higher in frequency than the transmitted sound wave, blood flow is toward the transducer.

- The magnitude of the change in frequency is proportional to blood flow velocity.

Changes in frequency of the reflected sound waves are converted into images showing blood flow direction and velocity.

Description of experiment

Two-dimensional device combining two-dimensional ultrasonography and Doppler examination with a head line is used during the experiment. The purpose of this exercise is to find the blood vessels of the neck. Next students try to determinate of their dimensions in the presentation of type B and the velocity of blood flow using the Doppler signal analysis.

Instruction

1. Check the power cable is connected.
2. Turn on the device using the green switch on the back of the unit.
3. If you want you can enter your data. Use the **P.Id** key**.** At the bottom of the screen MENU bar will appear. Using the **M1 – M4** keys you can enter the data. Accept the data entered by pressing enter key.
4. Press the **B** key to choose B-mode. Apply the gel on the head and touch the neck. Try to find the blood vessels and thyroid gland. You can chang the examination depth.
   - To increase the examination depth (image zoom out) press the Δ key [Depth]
   - To decrease the examination depth (image zoom in) press the ∇ key [Depth]
5. If the received image is satisfactory, freeze it by pressing ❄ key.
6. Perform measurements of imaged structures. The measurements are possible only under Freeze Frame.
   - Press the **MEAS** key – cursor "x" and measuring menu will be automatically activated
   - Use the trackball or arrow keys to position the cursor to the measurement starting point. Press the **FIX** key – the cursor will set in place. The other cursor (blinking) of the measuring pair will be activated. Use the arrow keys to position the second cursor onto the measuring ending point – the measured distance will be displayed in the left bottom corner of the screen. Press the **FIX** key to activate alternately each of the cursors of the measuring pair. You are able to set four pairs of measurement cursors.

- Each measurement can be modified at any time by pressing the menu key (M1 – M4) corresponding to the relevant measurement. Press the FIX key to select any cursor from the pair. You can to delete all measuring cursors settings by pressing the **Esc**.

7. Print the image by pressing **PRINT** key.

8. Check if there is enough gel on the head, unfreeze the image by pressing and find a blood vessel.

9. Go to The colour Doppler module by pressing the **CF** key. On the screen the Doppler frame will appear. Frame markers delineate the area in which colour velocity flow. Set the frame on the selected vessel by using the arrow keys or the trackball.

10. Switch on Triplex Doppler. When the scanner is in PF or CF mode, turning on TRIPLEX mode is achieved by pressing the **D** key. The line of indicator D and highlighted in green Doppler frame will appear on the screen. Set the frame on the selected vessel by using the arrow keys or the trackball. If the Doppler spectrum is not visible, press twice the **M5** key.

11. Try to find the best position of the head to get a nice Doppler spectrum. Adjust the baseline of the spectrum (press the **Base Line** key and use arrows). You can also adjust volume by pressing the Audio key.

12. If the received image is satisfactory, freeze it by pressing key. After frrezing the image is the unit will automaticly analyze 6 paramiters:

> PSV – Peak Systolic Velocity,
>
> EDV – End Diastolic Velocities,
>
> TAM – Time Averaged Mean peak velocities,
>
> RI – Resistance Index,
>
> PI – Pulsatility Index,
>
> S/D – Peak Systolic to end Diastolic.

14. Print the image by pressing **PRINT** key.

15. Make the conclusions.

[1] Walker J., Halliday and Resnick, *Principles of physics : international student version*, 9 th ed., extended, Hoboken : John Wiley & Sons, Inc., 2011. , ISBN 978-0-470-56158-4