Doppler sonography (Item No.: P5950100)

Curricular Relevance

Area of Expertise: Biology
Education Level: University
Topic: Modern Imaging Methods
Subtopic: Ultrasonic Imaging
Experiment: Doppler sonography

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	20 Minutes	2 Hours	2 Students

Additional Requirements:

- Computer (Windows)

Experiment Variations:

Keywords:

Venous Flow, Arterial flow, Stenosis, Blood flow velocity tracings, Frequency shift, Doppler effect, Doppler angle, Doppler sonography, Colour Doppler, Continuity equation

Overview

Principle

Blood flow studies can be performed with Doppler ultrasound sonography. This technique is used to show, on a realistic arm-dummy, the differences between continuous (venous) and pulsating (arterial) flow as well as the difference in flow through a normal blood vessel and a stenosis.

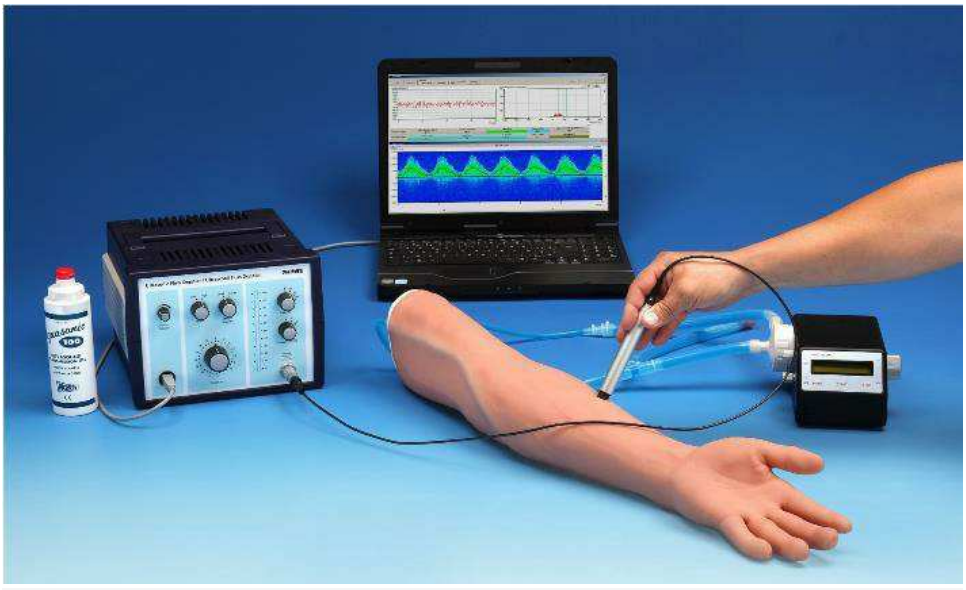

Fig. 1: Equipment for Doppler sonography, experimental set-up

Equipment

Position	Material	Bestellnr.	Menge
1	Basic set Ultrasonic Doppler technique	13923-99	1
2	Extension Set: Medical Doppler Sonography	13923-02	1

Basic Set: Ultrasonic Doppler technique, consisting of:

1 ultrasonic pulse Doppler apparatus
1 centrifugal pump
1 ultrasonic gel
1 liquid for sonography (1l)
1 ultrasonic probe 2 MHz
1 Doppler prisma 3/8"
1 Set of flexible tubes

Extension set: Doppler sonography, consisting of:

1 Arm dummy
1 Doppler probe 2 MHz

Tasks

1. Analyse “blood” flow and search for positive and negative flow components. Explain the differences.
2. Locate the built-in stenosis and compare the spectral distribution up-stream and down-stream of the stenosis.
3. Examine and compare the three pulse modes of the pump.

Safety information

Caution!

This is not a medical device. Do not apply to the human body. Pay attention to the special operation and safety instructions included in the user manual of the ultrasonic sonograph.

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Set-up and procedure

- Connect the arm-dummy with 3/8" tubing to the pump and fill the closed cycle with the Doppler fluid. The tube end fixed to the T-piece marked “FILL IN” must be connected to the pump inlet side. Fix the fill in tube with the supplied funnel to a stand. The level ofthe T-piece must be higher position than the pump head but in a lower position than the arm dummy outlet. Stir the Doppler fluid and fill it slowly in, until the liquid level reaches 3/4 th of the fill in tube high. If some air bubbles are captured in the tubing, change the position of arm and pump to get them out. Switch on the pump in M0 mode at lowest speed and maintain a constant level in the fill in tube until the closed loop cycle is completely filled. Close the tube with the rubber plug. Increase the pump speed to 80 %. Keep on pumping for 5–10 min. Switch OFF and tilt the pump in different positions until all air bubbles trapped in the pump head moved into the filling tube.
- If the arm-dummy was not used for a longer time and the Doppler fluid stayed in theclosed cycle, move the arm dummy and switch on the pump to check that no air bubbles are captured in the closed loop. Let run the pump at maximum speed for at least 5 min to stir up the dummy fluid. If some particles have precipitated on tube walls, use the pulse mode to dilute them.
- Pay attention: air bubbles produce a very strong ultrasonic Doppler signal.
- Operate the pump at medium speed (30–50 %) in M0 (Continuously) mode.
- Fit the 2 MHz Doppler probe to the sonograph. Set “Frequency” to 2 MHz, “Sample Volume” to large and “Power” to high.
- Connect the sonograph to the computer and start up the “PHYWE measure Ultra Flow” software. The software will display the screen shown in figure 2. Do not concern about parameter window, in this set-up we will only work on qualitative results and interpret the results in terms of frequency Doppler shifts. For continuous flow measurements display also the time course window and for the pulsating mode display time course and 10 s section windows.
- Select a vessel on the dummy, apply some couple gel and measure with the Doppler probe a typical signal. Adjust the amplification until sufficient signal amplitude is displayed in the software (Fig. 2) and on the amplitude level LEDs. Adjust also audio volume.

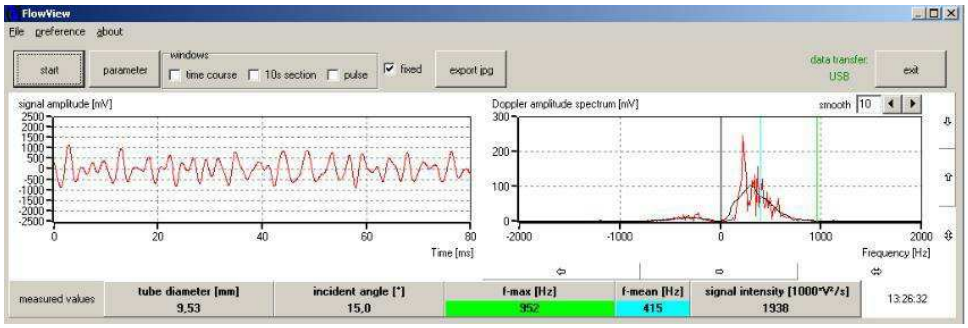

Fig. 2: Typical Doppler signal

- In the spectral window (“time course”), search for positive and negative components of flow direction (Fig. 3). Rotate the Doppler probe by 180°. Compare the two results and explain the differences.

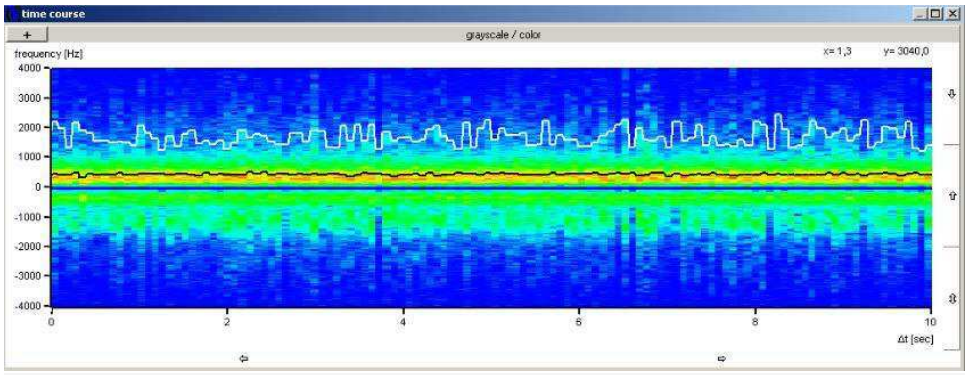

Fig. 3: Typical spectral window

- Move the Doppler probe, following the blood vessels, and search for significant changes in the spectral distribution. Locate the build in stenosis and study the differences of the spectral distribution between the stenosis and a “healthy” blood vessel. Compare the results measured up-stream and down-stream of the stenosis.
- Switch the pump from continuous mode (M0, M1) to pulsating mode (M2, M3, M4). Set the pulse period between 1 and 2 seconds (use the left side upper button on the pump body). For each pulsating mode, save the spectral distribution and compare the results. Explain the differences between the three modes.

Note:

The arm dummy and the probes should be cleaned immediately after use with water or a normal detergent. Dried residues of ultrasonic gel are hard to remove. If necessary use a soft brush. Never use alcohol or liquids with solvents to clean the different parts.

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Evaluation and result

Evaluation

An echocardiogram, within certain limits, produce accurate assessment of the direction of blood flow and the velocity of blood and cardiac tissue at any arbitrary point using the Doppler effect. One of the limitations is that the ultrasound beam should be as parallel to the blood flow as possible. Velocity measurements allow assessment of cardiac valve areas and function, any abnormal communications between the left and right side of the heart, any leaking of blood through the valves (valvular regurgitation), and calculation of the cardiac output cardiac output. Contrast-enhanced ultrasound, using gas-filled micro bubble contrast media, can be used to improve velocity or other flow-related medical measurements.
Although “Doppler” has become synonymous with “velocity measurement” in medical imaging, in many cases it is not the frequency shift (Doppler shift) of the received signal that is measured, but the phase shift (when the received signal arrives).

Velocity measurements of blood flow are also used in other fields of medical ultrasonography, such as obstetric ultrasonography and neurology. Velocity measurement of blood flow in arteries and veins based on Doppler effect is an effective tool for diagnosis of vascular problems like stenosis. In classical physics (waves in a medium), where the source and the receiver velocities are not supersonic, the relationship between observed frequency f and emitted frequency f_0 is given by:

$$f = \left(\frac{v+v_r}{v+v_s}\right) \times f_0 \ , \ (1)$$

where

v is the velocity of waves in the medium
v_r is the velocity of the receiver relative to the medium; positive if the source is moving away from the receiver.
v_s is the velocity of the source relative to the medium; positive if the receiver is moving towards the source.

In this special case, emitter and receiver are fixed in the same ultrasound probe and the blood is moving. Assuming that v_r is $-v_{blood}$, v_s will be v_{blood}.

$$f = \left(\frac{v-v_{blood}}{v+v_{blood}}\right) \times f_0 \quad (2)$$

In the limit where the speed of the wave is much greater than the relative speed of the source and observer, the relationship between observed frequency f and emitted frequency f_0 is given by:

$$f = 1 - \frac{v_{blood}}{v} \times f_0 \quad (3)$$

The frequency change will be:

$$f = -\frac{v_{blood}}{v} \times f_0 \quad (4)$$

The frequency decreases if the blood moves away from the probe.

Results

Figure 4 and Figure 5 show a continuous (venous) flow, with an average Doppler shift of about 500 Hz. In Figure 5, the probe was rotated by 180°. In this case, the frequency shift appears negative, which means that the blood flow moves away from the transducer.

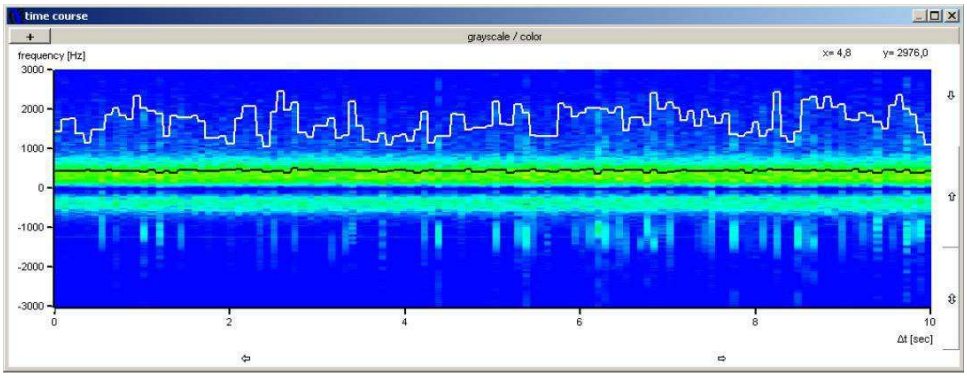

Fig. 4: Typical spectral window

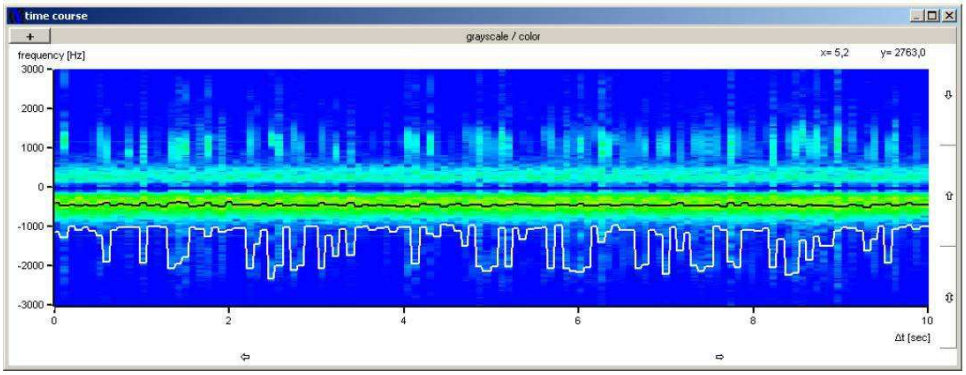

Fig. 5: Typical spectral window as in Fig. 4 but probe rotated by 180°

Figure 6 and 7 show the spectral distribution of a venous flow measured up-stream and down-stream of a stenosis. The differences between the results obtained from a “healthy” blood vessel, measured up-stream of the stenosis and the results from the stenosis influenced flow, measured down-stream of the stenosis are:

1. Local increase of the maximum Doppler shift, corresponding to max. flow velocity.
2. Reduction of the mean Doppler shift intensity and broadening of the spectral distribution.
3. Higher return flow (more negative / positive flow velocity contribution in the spectrum).

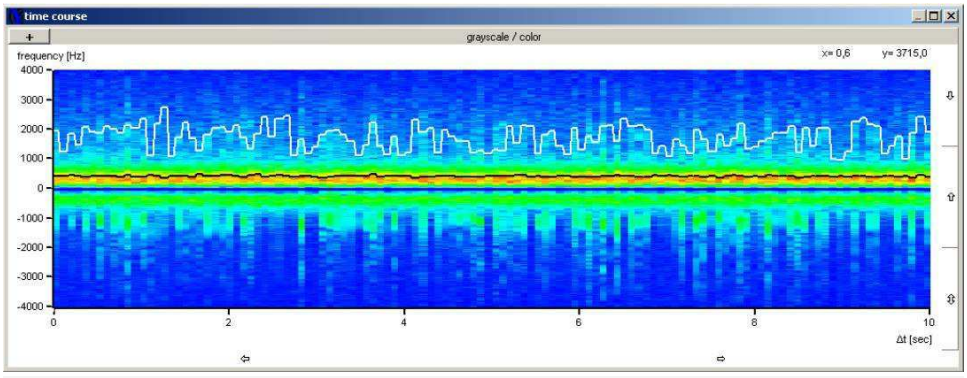

Fig. 6: Typical spectral window as in Fig. 4 but probe rotated by 180°

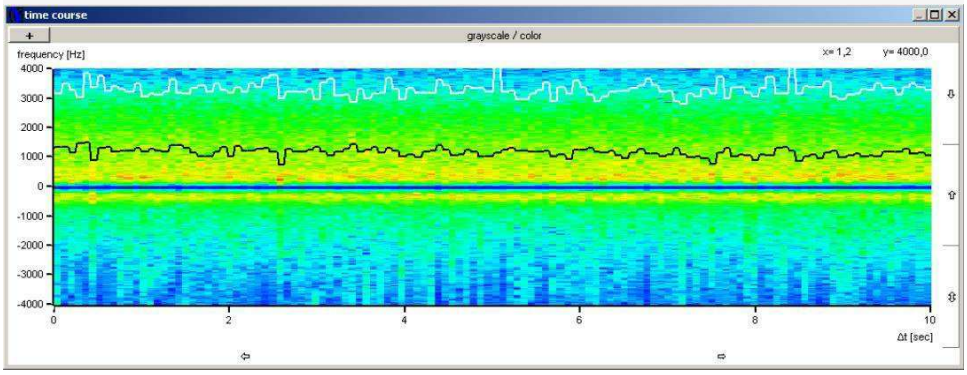

Fig. 7: Typical spectral window as in Fig. 4 but probe rotated by 180°

The following images show the spectral distribution of pulsatile flows. Based on elapsed time between two peaks, the pulse rate can be determined (here, approximately 1 Hz). The difference between the tree pulse pump modes (M2 to M4) is the pulse shape. In Mode 2, we observe a short rise time followed by a slow fall down, Mode 4 behaves exactly in a symmetrical way to Mode 2. In Mode 3, the signal increases and decreases in the same time, the signal is symmetrical.

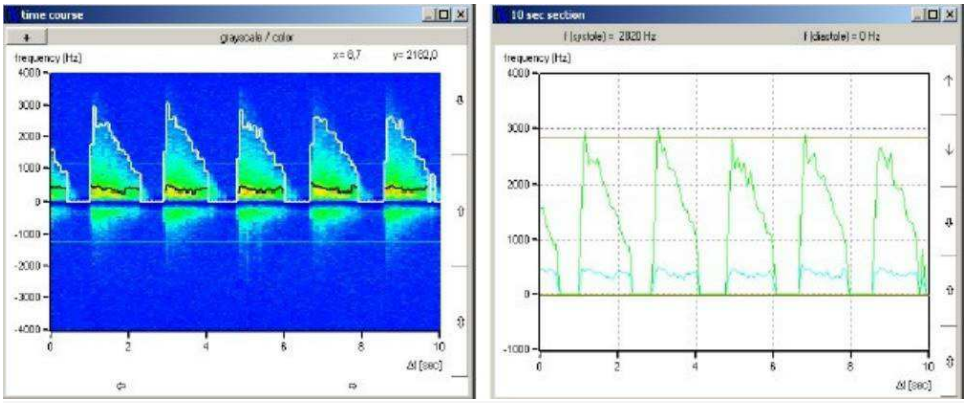

Fig. 8: Typical spectral window pump mode 2

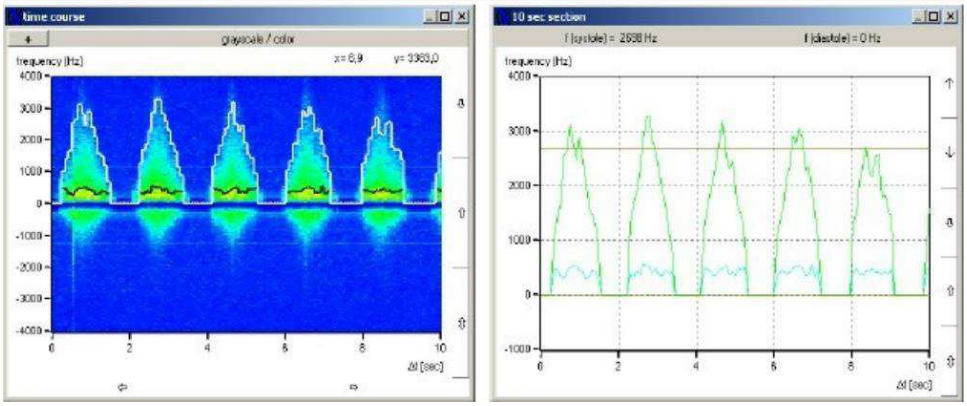

Fig. 9: Typical spectral window pump mode 3

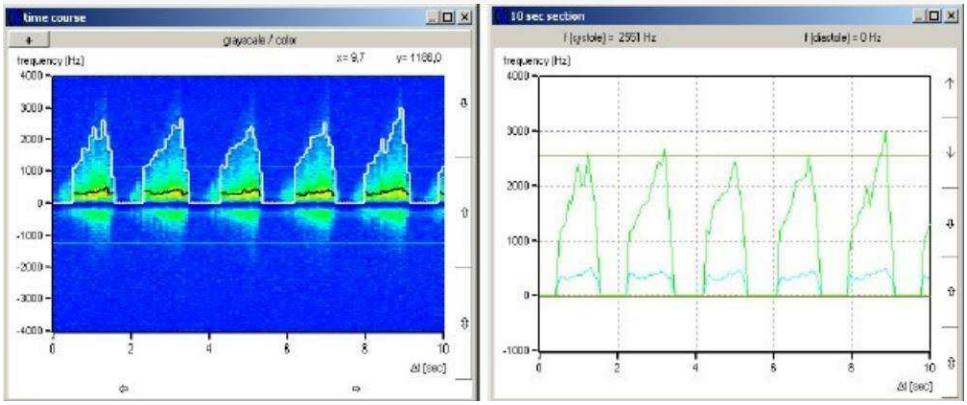

Fig. 10: Typical spectral window pump mode 4