Lab #6: Ultrasonic Blood Flow Measurement

Materials Required: Parks Medical Model 811-B flow detector with pencil probe; ultrasonic jelly; blood pressure cuff; stethoscope; alcohol wipes.

Introduction:

Often we are curious about the quality of circulation in various parts of body. There are many ways that we can learn this information:

- Blood pressure measurements. From fundamental physics and physiology, we can infer what blood pressure should be in different body areas under various conditions, so we can make quantitative judgments from blood pressure readings. However, it must be remembered that pressure is not flow!

- Angiography. Angiography is the study of blood vessels using x-rays. A contrast medium must be injected into the vessels to be studied so that they will show up on the x-ray. This is often used to study the quality of circulation in organs such as the heart and brain.

- Ultrasonic Doppler. In this method, a high frequency (usually 8 to 10 MHz) sound wave is aimed into the blood vessel being studied. The moving blood reflects some of the signal at either a higher or lower frequency, depending on its velocity and direction of motion relative to the pickup head. The frequency shift, called a Doppler shift, is directly proportional to the velocity of the blood.

Ultrasonic Doppler

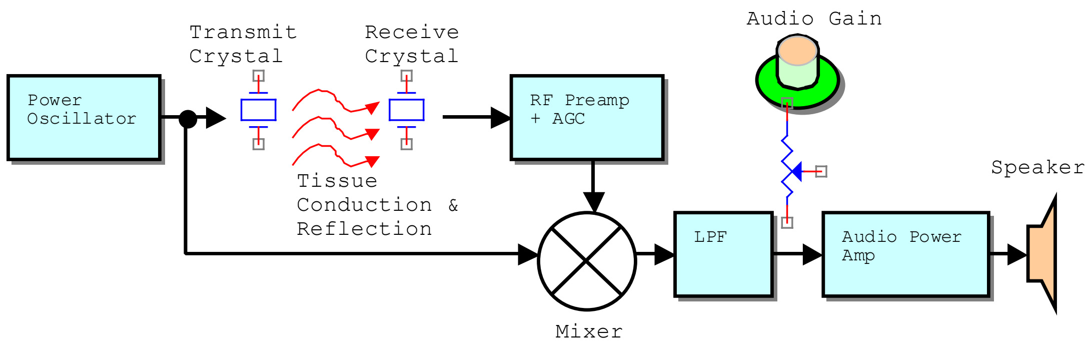

Figure 1: Block diagram of a typical Doppler flow meter

The block diagram of a typical ultrasonic Doppler unit (such as the Parks Model 811-B) is shown in Figure 1. It consists of a power RF oscillator operating in the 8 to 10 MHz region. This oscillator drives the *transmit crystal*, which is a piezoelectric transducer that converts the ac RF signal into a sound wave.

The sound wave travels into the tissue, aided by the ultrasound gel, which provides an impedance match to the tissue and eliminates any air gaps. The wave reflects off the tissue and is intercepted by the *receive crystal*. The frequency at the receive crystal will be shifted up or down according to the relative velocity and direction of the blood.

The receive signal is amplified and passed together with the original oscillator frequency into a *mixer*, which is a nonlinear circuit that produces (ideally) the sum and difference of the two input frequencies. The *difference* frequency will be in the audio range (20 Hz - 20 kHz), and is passed into an audio amplifier and loudspeaker for the operator to hear.

In a more sophisticated unit, the audio signal would be passed into a DSP (digital signal processor) unit, which can perform quantitative calculations based on the signal spectra. These calculations can not only calculate flow, but also provide images of the underlying tissues!

Doppler Technique

Figure 2 shows the proper way of using a Doppler flow meter probe. The technique is contrary to what most people (including medical professionals) would intuitively expect.

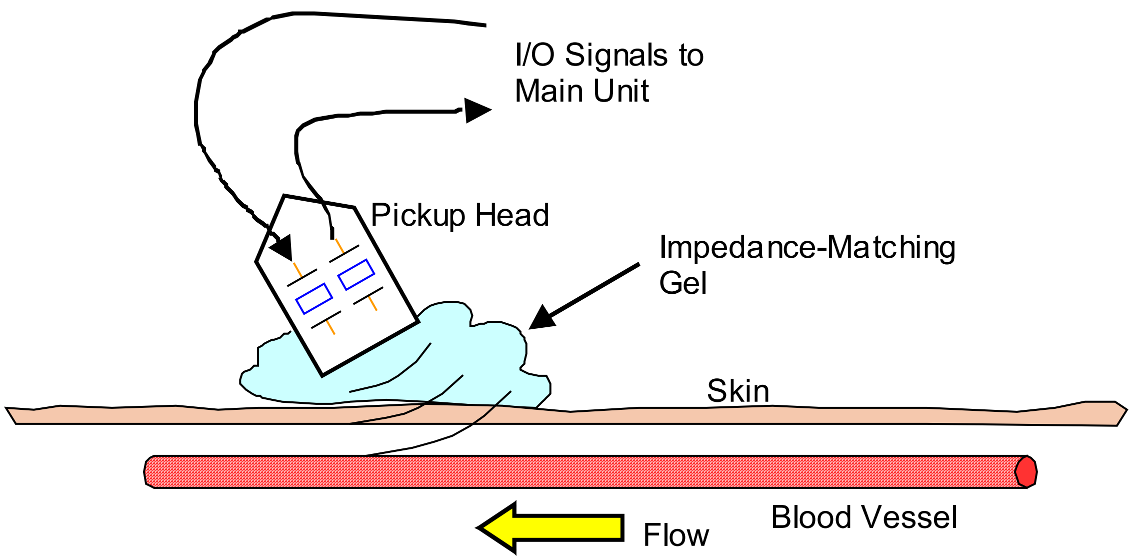

Figure 2: Proper application of a Doppler flow meter probe

The key points of the technique are:

- Ultrasonic gel *must* be used between the probe and skin. Little signal will be picked up without gel, since air is a very poor conductor of HF ultrasound.
- Because the crystals are in the end of the head, the pickup *must* be at an angle to read a Doppler shift. An angle from 15 to 45 degrees is desirable. Placing the probe perpendicular to the skin (the intuitive approach) produces *no* output!
- Whenever possible, move the pickup head and skin together as a unit to "search" for a vessel. Dragging the pickup over the skin produces a loud, distracting sound in the speaker.
- Don't turn up the volume too high; acoustic feedback can result.
- Study and learn the differences in sound produced by arteries and veins. This is the only way to correctly identify them. In general, you will always observe pulsatile flow in peripheral arteries, and smooth flow in peripheral veins.

Lab Procedure:

IMPORTANT: Read the Parks 811-B user's manual before starting the experiment. It's available in PDF form on the course web site.

CAUTION: Do not apply the flow meter probe near the ears or eyes; tissue damage can result from the ultrasound energy.

1. Take your subject's blood pressure using the auscultory method and record it. Leave the blood pressure cuff in place (but deflated) when you've completed the measurement; you'll need to inflate it again in a later step.

2. Turn the Doppler unit on and set the VOLUME control to one-quarter.

3. Explore the left forearm and antecubital space:

   a) Draw a scale outline of the subject's forearm on a piece of graph paper (plain paper will suffice, if graph paper is not available).

   b) Using the Doppler, locate the following important arteries. Place a red dot on the graph paper for each arterial landmark:

      1. Brachial artery as it enters the antecubital fossa.
      2. Bifurcation of brachial artery as it exits the antecubital fossa.
      3. Radial artery (follow this to the wrist and mark its progress in at least two places).
      4. Ulnar artery (follow this to the wrist and mark its progress in at least two places).

      Research Question: Which artery (radial or ulnar) appears to have the larger flow, and what makes you draw this conclusion?

   c) Use the Doppler to locate the following veins. Having the subject slowly alternately making and relaxing a fist can help locate veins. Once you've located a vein, you should hear the steady drone of blood moving through it. Place a blue dot on the graph paper to mark each venous landmark.

      1. Cephalic (this vein is very close and typically lateral to the brachial artery. It is the larger of the two major veins in this area.)
      2. Basilic (this vein is medial to the cephalic vein and brachial artery at the antecubital space).

      Research Question: Does the relative position of a limb (up or down) make a difference in either the arterial or venous sounds obtained from the Doppler? Why?

4. Take your subject's blood pressure again, but this time substitute the Doppler for the stethoscope head:

   a) Is there a significant difference between the systolic readings obtained from the Doppler and stethoscope?
   b) Can you read the diastolic pressure with the Doppler?

5. Explore the left common carotid artery and jugular vein:

   a) Do this exploration very carefully, and do NOT press the probe (or your finger!) into the space!

   b) Identify the carotid artery and jugular vein by sound. (You do not have to draw a a diagram for these).

   Research Question: Does the Doppler reveal the dicrotic notch? What does it sound like?

   c) Have the subject GENTLY perform a Valsava maneuver while you listen to the sound of the carotid artery. Do NOT perform the maneuver for more than 10 seconds, and only do this with the subject seated.

   Research Question: What happens to the sound during this maneuver, and what does it reveal about the effect of the maneuver on cardiac output?

   d) Compare the sound from the subject's right common carotid to the left. Can you hear any significant differences?

6. The Doppler is very sensitive and can pick up blood flow from areas that are usually hard to hear directly with a stethoscope. To demonstrate this, let's take blood pressure at the calf:

   a) Place the blood pressure cuff on the calf (but do not inflate).

   b) Palpate the posterior tibial artery. It is located just behind (posterior to) the medial malleolus. (You will need to do this GENTLY or you won't get a pulse!)

   c) Place the stethoscope head in this location, and measure the blood pressure. You will have to listen very carefully to hear the signal. (It may not be audible in all subjects.)

      TIP: The pressure is actually being measured *at the location of the cuff.*

   d) Repeat the blood pressure measurement, but use the Doppler.

   Research Question: How did the blood pressure compare between the calf and arm, and why was it different?

7. Repeat Steps 1-6 for each member in your group so that everyone gets experience with the Doppler unit.

8. Before storing the Doppler flow meter, please clean the probes. In a hospital, the probes would be sterilized in ethylene oxide gas, as they can't be immersed in any liquid. Complete sterilization isn't needed in our lab.

   a) Leave the probes connected to the unit. Repeated disconnection of the probe will wear out the RCA connectors, leading to degraded performance.

   b) To clean the probe, gently wipe it clean using a soft towel dampened with alcohol. Dry the tip gently.

   c) Replace the red probe cover to prevent accidental damage during storage.

> Do NOT use sharp instruments (or even a fingernail) to scrape gel residue from the probe tip -- it is very delicate! Do NOT immerse the probe in water or any other liquid!