Exercise 3 Pulse Echo Imaging

Purpose: To understand the concept of pulse-echo imaging in ultrasound.

Matlab code: PulseEcho.m contains a simple simulation for an ultrasound pulse echo system. This is the basis for solving the exercises. The file is downloadable from Blackboard.

1. Draw a block diagram of the pulse-echo system (This is not expected to be handed in).

2. Consider an object of 1 cm thick layer of fat submerged in water, at depth 2 cm. Vary the pulse length T_p and center frequency f_0.
   a. Which values for T_p and f_0 give good resolution?
   b. Which values for T_p and f_0 give good signal to noise ratio?
   c. Suggest a value for T_p and f_0 that gives both good resolution and good signal to noise ratio.

3. Vary the thickness of the fatty layer. Look in particular at thicknesses $\lambda/2$ and $\lambda/4$. Explain what happens.

4. Now change the medium impedance function to model the signal from muscular tissue (2 cm thick) in water (starting at depth 1 cm). The acoustic impedance is on average $1.66\,\mathrm{kg/s/m^2}$, and we assume that the impedance varies periodically (sine function) with an amplitude of $0.02\,\mathrm{kg/s/m^2}$, and period 0.385 mm.
   a. Plot the received signal for frequencies $f_0 = 2.0$ MHz and 4.0 MHz (pulse length $T_p = 2 \cdot 10^{-6}$ m).
   b. Why is the signal so different for the two frequencies used?

5. We shall now turn to a piece of liver, 2 cm thick, starting at depth 1 cm. The acoustic impedance for liver is on average $1.66\,\mathrm{kg/s/m^2}$, with a Gaussian distributed spatial fluctuation, with a standard deviation of $0.02\,\mathrm{kg/s/m^2}$. We assume that the correlation length is less than 0.01 mm.
   a. Plot the received signal using two pulse lengths ($f_0 = 2.5$ MHz) $T_p = 0.6 \cdot 10^{-6}$ m and $T_p = 3.0 \cdot 10^{-6}$ m.
   b. Simulate several times, and observe how the speckle-pattern varies. Try to describe in words how the pulse length affects the received signal.

Good Luck!