York University
Lassonde School of Engineering
Department of Electrical Engineering and Computer Science

EECS4640/5640: Medical Imaging Techniques

EA-2: Ultrasound Imaging

Objectives

The goal of this experiential assignment (EA) is to become familiar with ultrasound imaging.

Your work will be evaluated based on your EA report. When preparing your report, keep in mind these points:

- Prepare the report with the complete details of your work for each part.
- Include the properly labeled graphs and images for each part in your report.
- Include the **Matlab** code for each part in your report.
- Submit your report (PDF file) in eClass **(Experiential Assignment 2 Report)** by the deadline.

Generating Ultrasound B-Mode Images

Some ultrasound scanners can output the raw ultrasound Radio-Frequency (RF) signal acquired by the transducer. The RF data provided for this lab (mousekidney.mat) was collected during a previous pulse-echo experiment with a 30 MHz transducer. You will create an image out of this RF data. The acquisition settings are as follows: sampling frequency of 500 MHz, 10000 samples per line and 382 lines per image. The lateral dimension of the image is 2cm.

a) Assuming a speed of sound of 1540 m/s, what is the maximum depth in the image?

Hint: use the speed of sound, samples per line, and sampling frequency to calculate the maximum depth.

b) Graph the average power spectrum of the reflected pulse between 3 and 4 mm, 6.5 and 8 mm, and 8 and 15 mm (the x-axis should be frequency in MHz). From the averaged power spectrum, what is the center frequency of the reflected pulse in the depth ranges above?

Hint: The power spectrum for a depth range can be calculated by taking the fast Fourier transform of the raw RF signal within that depth range for each individual scan line (note that you should analyze single-sided power spectrum). The average power spectrum is then obtained by averaging over all the scan lines. For a better comparison between depth ranges, the average power spectrum should be normalized to 1 (by dividing each average power spectrum by its maximum value). The center frequency of the reflected pulse in each depth range can be obtained by finding the frequency associated with the maximum power value in each average power spectrum.

c) Why is the center frequency changing with depth?

d) Design a proper bandpass filter in order to remove high and low frequency noise yet maintain the bulk of the true signal.

Hint: The frequency rang (bandwidth) of the bulk of the signal can be estimated from the graph of the average power spectrum above. You can use the built-in MATLAB functions to implement a butterworth filter with -3dB signal attenuation at the estimated passband frequencies (e.g. a 4^{th} order Butterworth bandpass filter). This filter can be applied using the `filtfilt` function in MATLAB to achieve zero-phase filtering and maintain numerical stability.

i) Plot the filter in frequency domain (the x-axis should be frequency in MHz).

ii) Graph an example of a filtered power spectrum of a single RF line and compare it with the original power spectrum of that single RF line.

iii) Filter all the RF lines independently and display the data (filtered RF lines) as an image with a proper scale (lateral distance on the x-axis and the depth, *i.e.* distance from transducer, on the y-axis, both in mm).

e) Perform an envelope detection on your filtered data.

Hint: MATLAB has a Hilbert transform function with a useful capability for envelope detection.

i) Explain your method of envelope detection.

ii) Graph an example of an envelope-detected RF line and the original RF line (the x-axis should be the depth in mm). Scale your graph (on y-axis) appropriately so it is possible to see what you've done.

iii. Display the resulting image with proper label/unit on the x and y axis.

f) Perform a log compression on the envelope-detected data

i. Display the resulting image with and without bandpass filtering with proper label/unit on the x and y axis.