AM5023- PHYSIOLOGICAL MEASUREMENTS AND INSTRUMENTATION LABORATORY

BIOMEDICAL ULTRASOUND - LABORATORY REPORT

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DETERMINATION OF THE CHARACTERISTICS OF A TISSUE LIKE MEDIUM USING ULTRASOUND

AIM

To determine the speed of sound, acoustic impedance, amplitude attenuation factor and the amplitude attenuation coefficient.

OBJECTIVE

To understand how we view the tissues from ultrasound and how the image is constructed.

APPARATUS REQUIRED

- Tissue mimicking Phantom
- L11-5v Ultrasound Transducer (Verasonics Inc., WA.USA)
- Vantage 64 scanner (Verasonics Inc., WA.USA)
- Vernier Caliper
- Weighing balance

BACKGROUND

The sounds which have a frequency greater than 20kHz, i.e., above the human hearing limit comprise the ultrasound. Thus, the characteristics of propagation of ultrasound are the same as that of any other sound except for the frequency dependent characteristics. Hence ultrasound, just like any other sound, is the longitudinal propagation of alternating compressions and rarefactions in the medium of propagation. The speed at which sound propagates is a property of the medium and so is the amount of attenuation.

Speed of Sound – The speed of sound in a material depends on its compressibility (κ) and density (ρ).

$c=\sqrt{1\kappa\rho}$

However, a simple distance-time-based calculation is possible where a short US pulse is passed through the medium of known distance and the time of echo from the bottom of the medium is noted. Then, the speed of sound is measured as:

$c=2dt$

Attenuation - When the sound wave travels through a medium, it loses energy exponentially with respect to the distance of the travel. This phenomenon is known as attenuation and includes the losses due to scattering, absorption and mode conversion (refraction).

If $A0$ is the initial amplitude and A_z the amplitude at distance z in the medium, then
$Az = Aoe^{-\mu az}$

where μ_α is the amplitude attenuation factor given by rearranging as shown;
a=1zln f_0 (AzA0)

The attenuation coefficient can be calculated by
$\alpha = 20\ (\log_{10} e)\ \mu_\alpha \approx 8.7\mu_\alpha$

PROCEDURE

- The transducer is connected to the ultrasound scanner and ensure that it is placed intact in the slot.
- The phantom is placed on a level, regular surface such as the bottom of a flat container.
- The transducer is placed on the top of the phantom, with care taken that the transducer face is parallel to the surface of the phantom.
- Water is poured such that the transducer-phantom interface is submerged to avoid impedance mismatch due to air being present in between the transducer and the phantom.
- Center frequency is set by the user which will give rise to a sampling frequency 4 times that of center frequency.
- The MATLAB environment is run.
- Echo (reflected waves) known as raw data is detected by the transducer and is beanformed to get the B-mode image
- Data is saved into a .mat file and MATLAB is used to perform the calculations.
- The A line is plotted and the peak intensity values are found.
- The calculations have been for characterization

MATLAB CODE

```
%OPEN THE DATA
load("phantom_raw_data.mat");
data = rf_bbf(:,64,64);
plot(data);
title("A-line");
xlabel('Samples');ylabel('Amplitude');
%calculation
fs = 20*(10^6); %Hz
```

```
n = size(rf_bbf);
%transmit time
[pks,locs] = findpeaks(data);
[sorted_pks,sorted_idx] = sort(pks,'descend');
sorted_locs = locs(sorted_idx);
[pks1,locs1] = findpeaks(data(1:100));
[sorted_pks1,sorted_idx] = sort(pks1,'descend');
sorted_locs1 = locs1(sorted_idx);
n1 = sorted_locs(1);
n2 = sorted_locs1(1);
A1 = sorted_pks(1);
A2 = sorted_pks1(1);
transmit_time = (1/fs)*(n1-n2);
%phantom paramters
dim = [0.08,0.05,0.05];
mass = 0.209;
%speed
speed = 2*dim(3)/transmit_time;
%time of flight
t1 = n1/fs;
t2 = n2/fs;
%depth
d1 = speed*t1/2;
d2 = speed*t2/2;
%attenuation factor
ua = -(1/(d1-d2))*log(A2/A1);
%attenuation coefficient
a = 8.7 * ua;
%density
den = mass/(dim(1)*dim(2)*dim(3));
%accoustic impedance
Z = den * speed;
fprintf('Sampling frequency = %.0f Hz\n', fs);
fprintf('Sampling time = %.8f s\n', 1/fs);


fprintf('No. of Samples = %d\n', n(1));
fprintf('Transmit time = %.8f s\n', transmit_time);
fprintf('Speed = %.4f m/s\n', speed);
fprintf('Attenuation factor = %.4f\n', ua);
fprintf('Attenuation coefficient = %.4f\n', a);
fprintf('Density of Phantom = %d kg/m3\n', den);
fprintf('Acoustic Impedance = %.0f Pa-s/m3\n', Z);
```

OBSERVATION

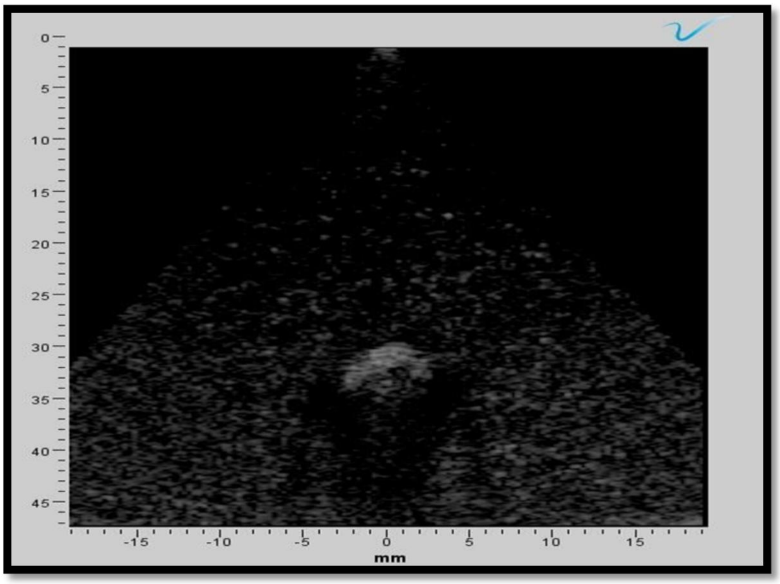

Figure 1 Verasonics B-mode image

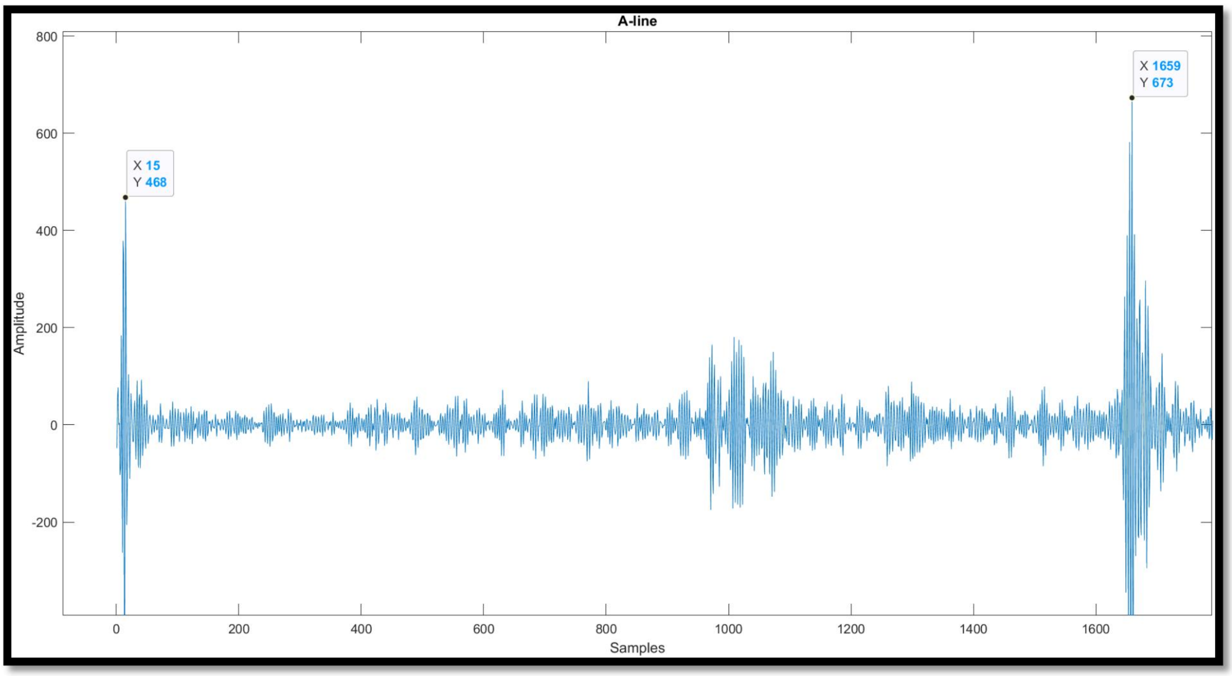

Figure 2: plot of A-line

CALCULATION

The dimension of the phantom is 8 cm x 5 cm x 5cm and the mass is 209 grams. In this case d is 5 cm.

RESULT

```
Sampling frequency = 20000000 Hz
Sampling time = 0.00000005 s

No. of Samples = 2048
Transmit time = 0.00008220 s
Speed = 1216.5450 m/s
Attenuation factor = 7.2655
Attenuation coefficient = 63.2102
Density of Phantom = 1045 kg/m3
Acoustic Impedance = 1271290 Pa-s/m3
```

CONCLUSION

In this experiment we learned how to calculate the characteristics of a tissue such as the attenuation factor, acoustic impedance, speed of sound through the phantom tissue. We therefore get a proper understanding of how ultrasound travels in the body, gets absorbed and reflected and then generates signals which are processed to form images.