1.0 PURPOSE:

Attenuation and the longitudinal velocity are the most relevant ultrasonic properties of materials for Doppler ultrasound experiments. With the aid of an oscilloscope, the power dissipation and the delay time of a signal are measured and used to calculate the attenuation and longitudinal velocity in the material.

2.0 SCOPE:

2.1 Procedure is to be performed in a containment level 1 (CL1) laboratory.

2.2 Materials are assumed to be cut and ready for experimenting.

3.0 RESPONSIBILITIES:

3.1 Someone trained by a qualified individual may perform this procedure.

4.0 DEFINITIONS:

Attenuation – The loss in power of electromagnetic signals between transmission and reception points due to scatter and refraction.

Function generator – A signal generator that can produce sine, square, and triangle output waveforms. Refers specifically to the Tektronix FG 504 model.

Longitudinal velocity – The speed of sound in a material.

Oscilloscope – The instrument that provides a graphical display of a signal's waveform, showing signal amplitude, period and waveform. Refers specifically to the Philips PM 3365A model.

Pulse generator – A generator of single or multiple voltage pulses with an adjustable pulse rate. Refers specifically to the Tektronix PG 501 model.

Sample – 1" diameter of material of a certain thickness.

Transducer track – The metallic track separating two transducer elements. The distance between the two transducers may be varied. The transducer that has a knob is the signal-transmitting element that is located opposite of the signal-receiving element.

5.0 REFERENCES:

Poepping T. L., Nikolov H. N., Thorne M. L., and Holdsworth D. W., "A Thin-Walled Carotid Vessel Phantom for Doppler Ultrasound Flow Studies,"

6.0 MATERIALS AND EQUIPMENT:

6.1 MATERIALS:

- 1" diameter sample of material

6.2 EQUIPMENT:

- BNC (50Ω) cables
- BNC T connector (1 Male/2 Female)
- Container
- Function generator (Tektronix FG 504)
- Gimbal jig
- Oscilloscope (Philips PM 3365A)
- Pulse generator (Tektronix PG 501)
- Transducer track (transmitter and receiver)

7.0 PROCEDURES:

*Terms which are **italicized and bolded** refer to adjustable dials and buttons. Terms which are* **bolded** *refer to a value or setting.*

7.0.1 HARDWARE CONNECTIONS:

The following table is a list of all the required connections between the four components.

Connection	FG 504	PG 501	PM 3365A	Transducer Track	Connection Method
1	Input	Trig Out	-	-	BNC
2	Output	-	A⊥	-	BNC
3	Output	-	-	Transmitter	Transducer cable
4	-	-	⊥B	Receiver	Transducer cable

Table: Hardware Connections

1. Insert setup diagram.

7.0.1 USING THE FUNCTION GENERATOR:

Only the tabulated dials are relevant for the purposes of this experiment

Dial	**Purpose**
Attenuator	Adjusts for the output voltage level
Frequency Hz	Sets the leading number for the frequency.
Frequency Vernier Multiplier	Sets the multiplier for the leading number.

7.0.1 USING THE PULSE GENERATOR:

Only the tabulated dials are relevant for the purposes this experiment

Dial	**Purpose**
Pulse Duration	Sets the duration of the pulse
Period	Sets the periodicity of the pulse
Variable – Pulse Duration	Changes the multiplier of the pulse duration between (x1) and (x10). Used for increasing the

	pulse duration up to a maximum factor of 10.
Variable – Period	Changes the multiplier of the period between (x1) and (x10). Used for increasing the period up to a maximum factor of 10.

7.0.1 USING THE OSCILLOSCOPE:

Only the tabulated buttons are relevant for the purposes this experiment

Button	**Purpose**
Auto Set	Assigns settings that will trigger and stabilize a waveform into the field of view on the oscilloscope.
A (V – mV), B (V – mV)	Set the voltage increment for the respective channels.
A B	Toggle the channel display between either just A, just B, or both A and B.
TB (s - µs)	Set the time increment.
TRIG DEL (◂ – ▸)	Set the delay of the trigger.
TRIG or X SOURCE	Set the channel in which to trigger.
DIGITAL MEMORY	Toggles between analog and digital display modes
⌋⌈	Begin triggering at either the rise or fall of the waveform.
Button Pad	5 buttons used to navigate the digital control toggled by the DIGITAL MEMORY button.
Dial	**Purpose**
Y pos	Set the Y position of waveform A or B.
X pos	Set the X position of the both A and B waveforms.

7.0.1 STARTUP:

1. Check that there are no exposed wires. If there are any exposed wires, notify the supervisor.
2. Press the green ***Power – Line On*** button on the oscilloscope.
3. Pull power notch on the generator unit.
4. Wait 15min for systems to warmup.
5. Fill a large container with water to completely submerge the transducer track.

△**WARNING:** Remove the transducer track from the container after the experiment is completed. Leaving the transducer track in the water for a prolonged period of time may irreversibly damage the transducers.

7.0.2 DEFAULT SETTINGS:

A. OSCILLOSCOPE SETTINGS:

1. Set all dials to **Cal** on the oscilloscope.
2. Set ***Hold Off*** to **min**.

3. Set ***TB*** (time increment) value on the oscilloscope to **20µs** to get a good view of both signals.

B. FUNCTION GENERATOR SETTINGS:

1. Set ***Frequency Multiplier*** to **10^6**.
2. Set ***Sweep Duration*** to **Off**.
3. Set ***Rise and Fall Time*** to **Fixed**.
4. Set ***Attenuator*** to **0dB**.
5. Set ***Signal waveform*** to a sign wave.
6. Set ***Trigger*** to **Gate**.

C. PULSE GENERATOR SETTINGS:

1. Set ***Pulse Duration*** to **10µs**.
2. Set ***Period*** to **0.2ms**.

7.0.3 LINEARITY TEST:

1. Make sure that the amplitude of the input and output signals have a constant ratio under all voltage settings by varying the ***Attenuator***.

7.0.3 PRE-EXPERIMENTAL CALIBRATION:

1. Measure and record the distance between the transducers.
2. Measure and record the temperature of the water.
3. Toggle the digital display mode by pressing the ***DIGITAL MEMORY*** button.
4. Using the ***Button Pad***, navigate the menu to **Cursors ▸ Select ▸ A, Calc ▸ Ampl ▸ Vpp**. This will output the peak-to-peak voltage in the top right corner of the display screen.
5. Adjust the ***Attenuator*** to set the peak-to-peak voltage to 4V.
6. Using the ***Button Pad***, navigate the menu to **Calc ▸ Time ▸ Freq**. This will output the frequency in the top right corner of the display screen.
7. Adjust the ***Frequency*** dial to set the frequency to 5MHz.
8. Using ***TRIG DEL***, set the trigger delay to **0**.

7.0.4 POST-CALIBRATION DATA ACQUISITION:

There are two important values that need to be acquired from the oscilloscope. The speed of sound is found considering the delay between the transmitted and received signals. The attenuation is found considering the change in amplitude between the transmitted and received signals. Although the discussed procedure is for one sample, it is highly recommended that the procedure be repeated for several samples in a single session.

1. Place material sample inside the gimbal jig. Use the *gimbal jig cap* to secure the sample in place. If the material sample is very thick, the use of a gimbal jig is unnecessary.
2. Mount the gimbal jig on the track in the center between the transducers.
3. Adjust the two degrees of freedom on the gimbal jig to get the highest amplitude of the received signal on the oscilloscope.

A. ATTENUATION

1. Using the ***Button Pad***, navigate the menu to measure the steady-state amplitude (**Vpp**). Record this value for both the received and transmitted signals.

B. SPEED OF SOUND

1. Using ***TRIG DEL***, find the delay of the received signal with respect to the transmitted signal. Set the trigger source to be the transmitted signal. Increasing the trigger delay will move the field of view on the oscilloscope towards the beginning of the received signal. Increase the trigger delay until the beginning of the received signal is in the field of view. The value of the trigger delay is the number of increments that the signal was moved. Multiply the number of trigger delays by the TB value to get the time delay. Decreasing the TB value will increase your accuracy because you will have a better 'zoom' of your received signal to mark its beginning.

4. Repeat steps 1-3 for the same material sample with incremental thicknesses.

7.0.5 CLEANUP:

1. Remove the sample and transducer track from the water container and leave to dry.
2. If coupling gel was used, wash off the coupling gel between sample pieces.

7.3 RISKS TO PERSONNEL AND PRECAUTIONS FOR RISK REDUCTION:

7.3.1 Caustic/Harmful chemical or biological handling instructions/warnings, general safety precautions, protective equipment to be used, etc.

7.3.2 Commonly encountered difficulties or errors, situations that can increase the danger to personnel.

7.4 ANALYSIS:

7.4.1 The voltages are used to find the attenuation.

7.4.2 The time delay between the transmitted and received signal is used to find the speed of sound in the material.

7.4.3 The attenuation of water, α_w, is dependant on the frequency.

7.4.3 Plot the data. Let the y-axis be $\log_{10}A_1$ where A1 is the voltage of the received signal. Let the x-axis be d_s, the sample thicknesses. Draw a line of best fit and calculate the slope.

7.5 CALCULATIONS:

7.5.1 ATTENUATION:

The attenuation coefficient of the sample (α_s) is solved using the following formula:

$\log_{10}(A_1) = (\alpha_w - \alpha_s)*d_s/20 + (\log_{10}(T_1T_2A_0) - \alpha_w*d_{total}/20)$

where,
A_0 = Amplitude of the transmitted signal [V]
A_1 = Amplitude of the received signal [V]
T_1 = Transmission coefficient of the transmitter []
T_2 = Transmission coefficient of the receiver []
d_s = Thickness of the material sample [cm]
d_{total} = Distance between the transmitter and receiver (=20) [cm]
α_w = Attenuation coefficient of water ($=0.002*f^2$) [dB/cm]
α_s = Attenuation coefficient of sample [dB/cm]

7.5.2 SPEED OF SOUND:

$\upsilon_s = d_s/(t_{total} - d_w/\upsilon_w)$

where,
υ_s = Speed of sound in sample material. [cm/s]
υ_w = Speed of sound in water. [cm/s]
d_s = Thickness of sample material. [cm]
d_w = Distance of water. [cm]
t_{total} = The total time delayed between the transmitted and received signal. [s]

7.7 CONTINGENCIES:

7.7.1 SYSTEM FAILS TO START:

Check the wiring to make sure that all hardware is correctly connected together and supplied with power. If the system still fails to start, then inform the supervisor about the contingency.

8.0 REPORTING AND DOCUMENTATION:

8.1 Maintain a document that lists all of the recorded values and calculations.

9.0 REVIEWS AND REVISIONS:

This procedure shall be reviewed for compliance and effectiveness and revised as necessary.

10.0 ATTACHMENTS and REFERENCE FORMS:

List attached documents, manuals, sample forms, etc. in the following format:

ATTACHMENT A. (Name)

ATTACHMENT B (Name)