Characterizing Gelatin Methacrylate (GelMA) Using Ultrasound

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What is **ultrasound** in biomedical *acoustics*?

Benefits & Application of Ultrasound

Diagnostic

"does not produce effects on tissue"

- ➢ Imaging different soft tissues

Therapeutic

"achieves desired mechanical or thermal effect on tissue"

- ➢ Tumor destruction through tissue ablation
- ➢ Inhibition of cancer cell proliferation
- ➢ Drug delivery (ex. past blood brain barrier)

Theranostics

Benefits & Application of Ultrasound

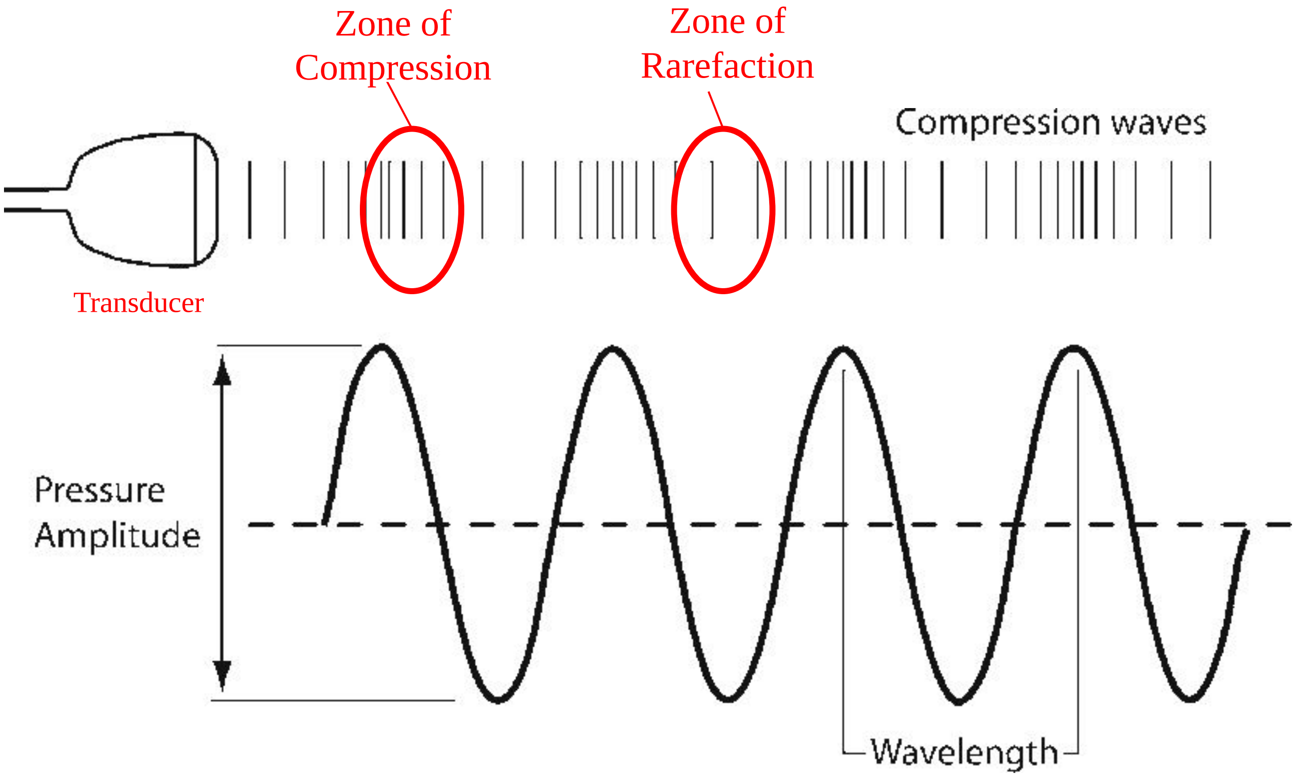
Technical Benefits

- Can be directed in a beam
- Reflects off object borders

Health Benefits

- Non - Invasive
- Inexpensive
- Accessible

Ultrasound Waves

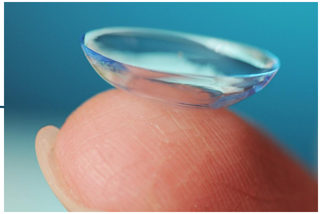


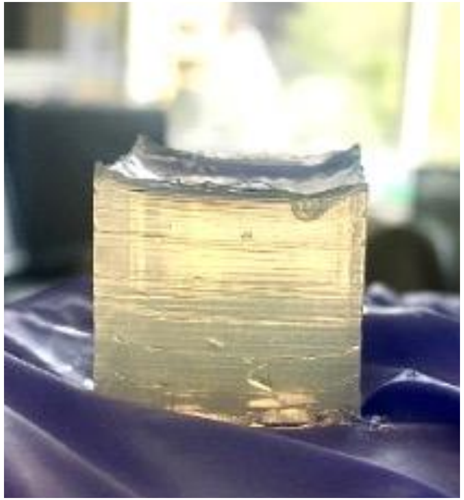
Common Medical Ultrasound Frequencies:
1-18 MHz per second

Human Audible Frequency:
20 Hz - 20 kHz

What is **Gelatin Methacrylate (GelMA)** in *biomedical* acoustics?

GelMA → a type of hydrogel known as a biomaterial





Benefits and Applications

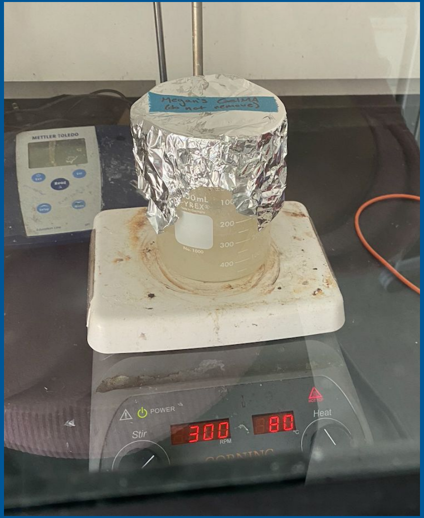
- ➢ Tunable properties - stiffness, viscosity, etc.
- ➢ Tissue engineering
- ➢ Controlled drug delivery

Application in GW's Research

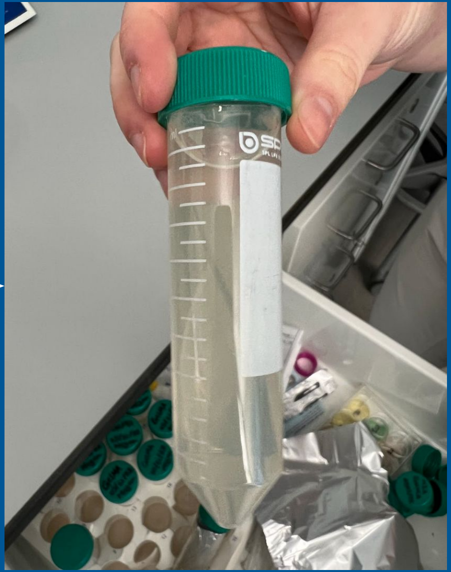
Can we use **ultrasound** to collect data on the speed of sound in **GelMA** to determine if its properties match those of soft tissue in the body?

Experimental Method - GelMA

Synthesized GelMA



Combining GelMA and the photoinitiator in pure water



GelMA solution

Experimental Method - GelMA

Pipette 1000 ml GelMA solution
into 3D mold

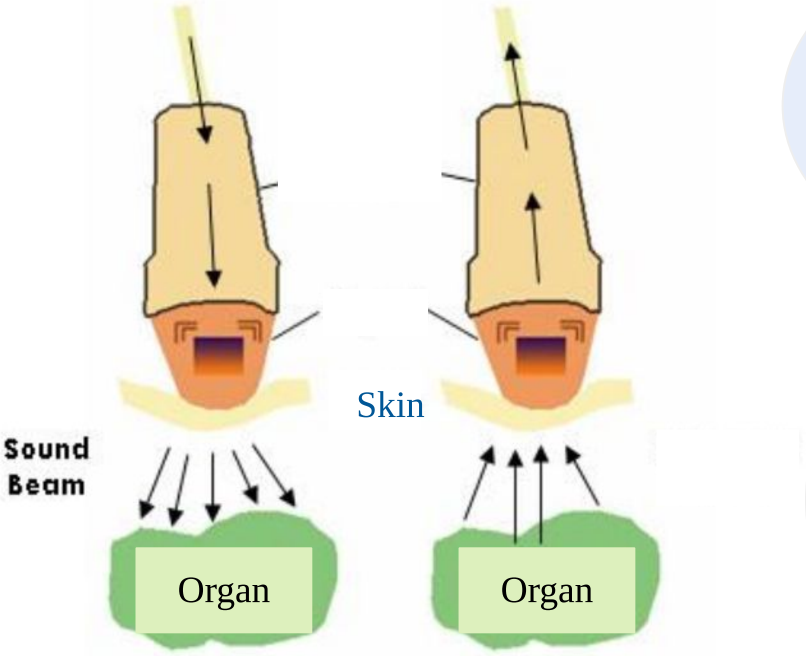
Place under ultraviolet light

GelMA sample

The Pulse-Echo Method

Electric current applied to piezoelectric crystal inside transducers

Crystal's mechanical vibration creates ultrasound waves

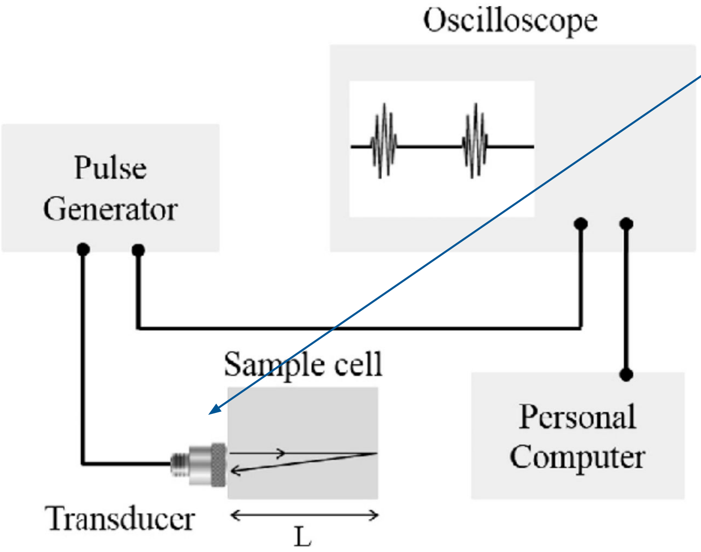


Wave hits organ and reflects to the transducer

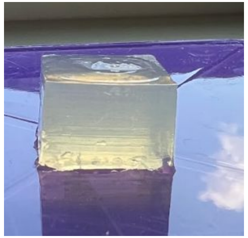
Transducer "listens" for mechanical signal back

Transducer changes mechanical signal back to electrical signal

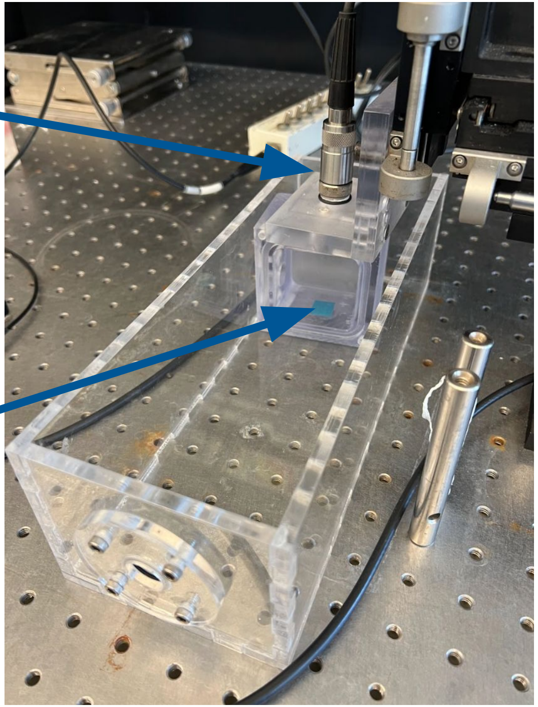
The Pulse-Echo Method



2.25 MHz Transducer



GelMA sample



Computational Method

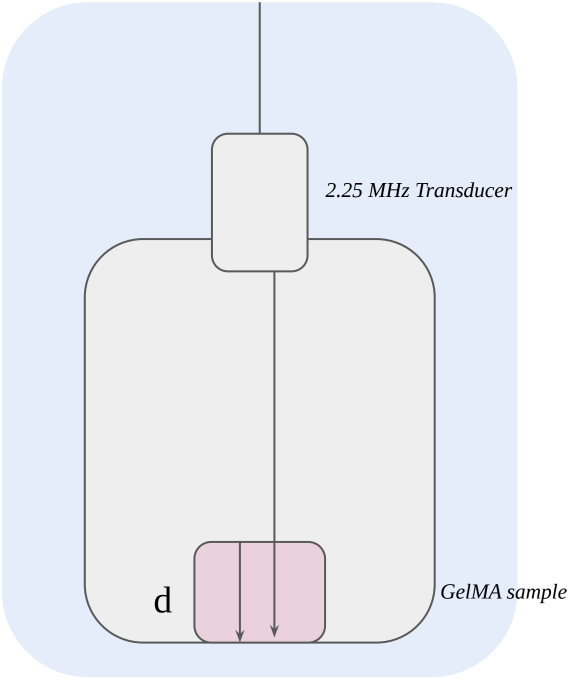
$$C_{sample} = \left(\frac{1}{C_{water}} - \frac{\Delta t}{2d}\right)^{-1}$$

C_{sample} - speed of sound in GelMA sample

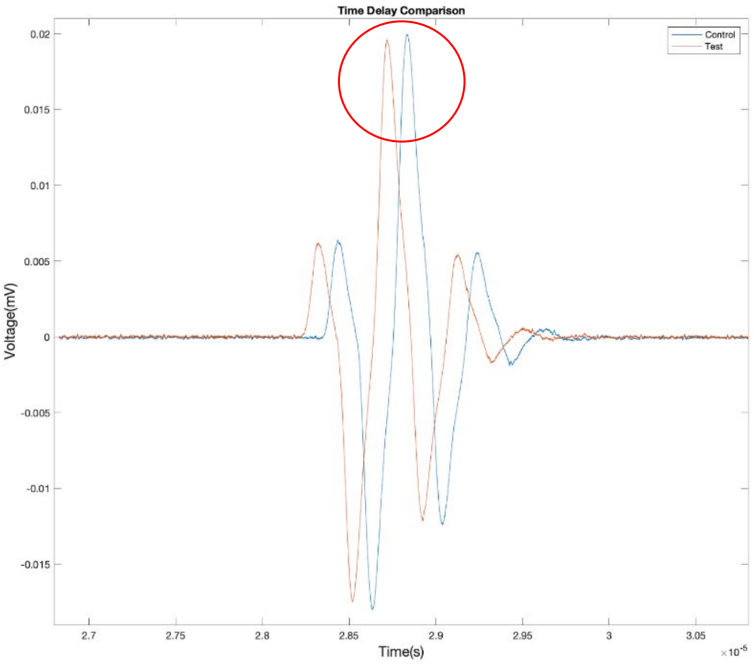
C_{water} - speed of sound in water

Δt - time delay between control and test signal

d - thickness of GelMA sample

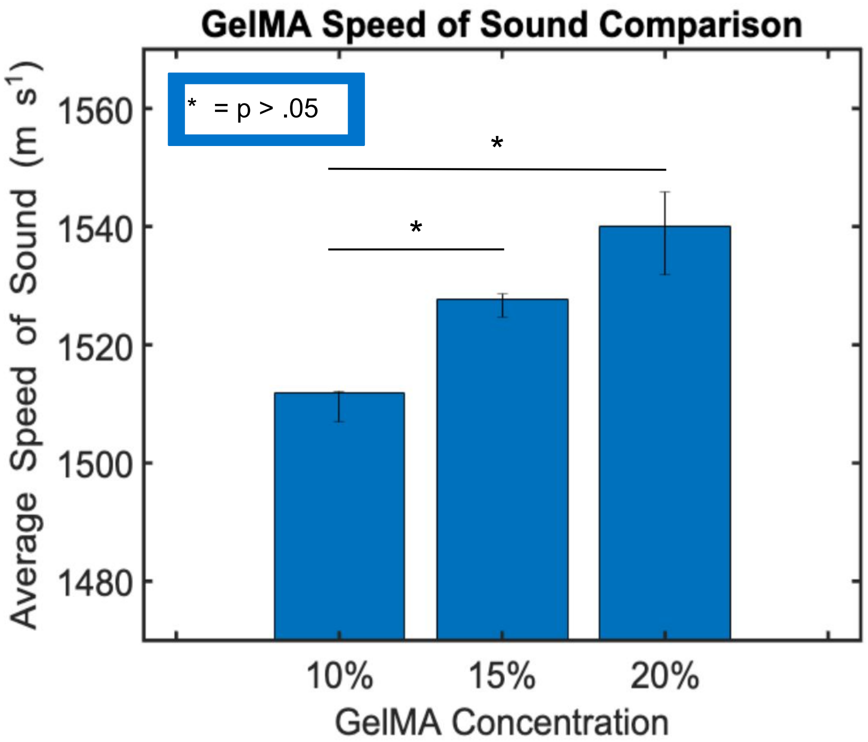


Computational Method - MATLAB



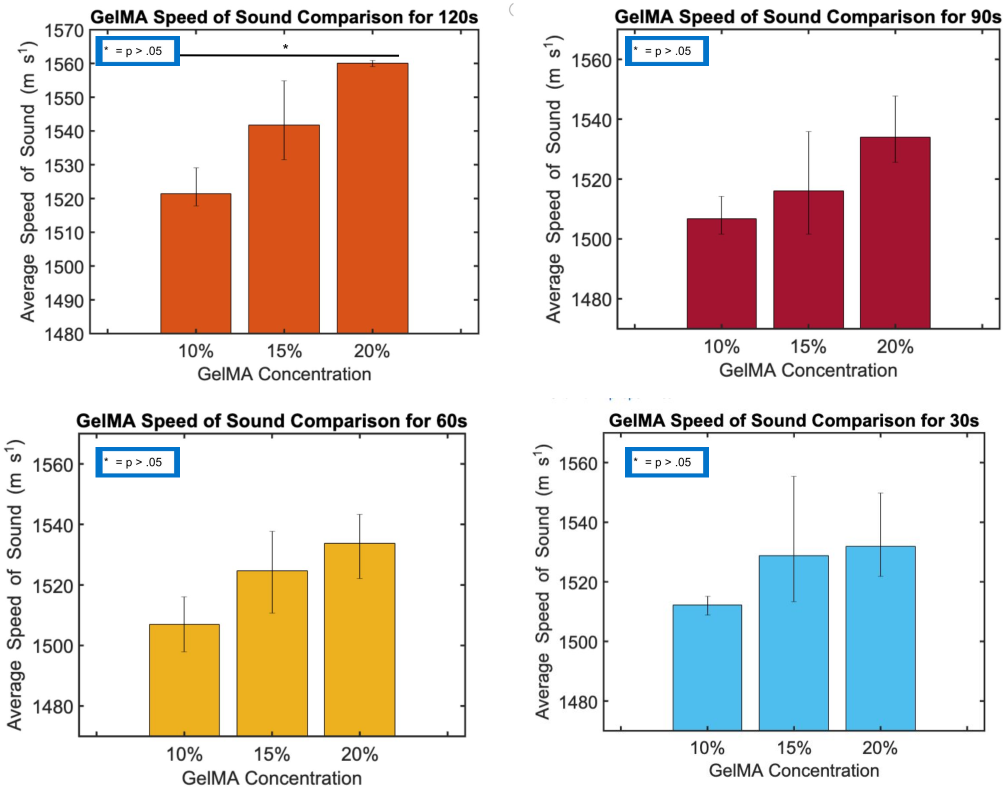
120s Curing Time				
% GelMa	**Set 1**	**Set 2**	**Set 3**	**Average**
10%	1.53E+03	1.52E+03	1.52E+03	1.52E+03
15%	1.55E+03	1.53E+03	1.54E+03	1.54E+03
20%	1.56E+03	1.56E+03	1.56E+03	1.56E+03
90s Curing Time				
% GelMa	**Set 1**	**Set 2**	**Set 3**	**Average**
10%	1.50E+03	1.51E+03	1.50E+03	1.51E+03
15%	1.50E+03	1.54E+03	1.51E+03	1.52E+03
20%	1.53E+03	1.55E+03	1.53E+03	1.53E+03
60s Curing Time				
% GelMa	**Set 1**	**Set 2**	**Set 3**	**Average**
10%	1.50E+03	1.52E+03	1.51E+03	1.51E+03
15%	1.53E+03	1.54E+03	1.51E+03	1.52E+03
20%	1.54E+03	1.54E+03	1.52E+03	1.53E+03
30s Curing Time				
% GelMa	**Set 1**	**Set 2**	**Set 3**	**Average**
10%	1.51E+03	1.52E+03	1.51E+03	1.51E+03
15%	1.51E+03	1.56E+03	1.52E+03	1.53E+03
20%	1.52E+03	1.55E+03	1.52E+03	1.53E+03

Results



10%	1511.79 m/s
15%	1527.81 m/s
20%	1539.95 m/s

Results



Variable Crosslinking Times
(120, 90, 60, 30 seconds)

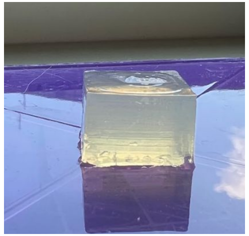
Constant Trend

↑ GelMa Concentration

=

↑ Speed of sound

Conclusion



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Material	Speed of Sound (m/s)
Water	1480
Brain	1550
Kidney	1570
Muscle	1575-1590
Liver	1590
Skin	1730
Bone	2800-4080

List of sound speeds. From Azhari, Haim. *Basics of Biomedical Ultrasound for Engineers*. John Wiley & Sons, 2010.

20% GelMA solution

1539.95 m/s

Human Soft Tissue

1540 m/s

- ➢ The speed of sound through 20% GelMA solution has an approximate value to that of human soft tissue.
- ➢ The speed of sound through GelMA is tunable using different GelMA concentrations.
- ➢ These results support GelMA is a biomaterial suited for usage within replicating human soft tissue.

Future Work + Lessons Learned

- GelMA's viscoelastic analysis using rheological characterization methods
- 3D-printed blood vessels using GelMA
- Noninvasive drug release using ultrasound

Thank you!

Questions?

Citations

Images

Conrad, Steven. “Focused Echocardiography in the ICU”. *Beside Procedures for the Incetivist*, 2010. https://www.researchgate.net/figure/1-Schematic-diagram-of-the-propagation-of-ultrasound-Compression-waves-are-mechanical_fig1_227196268.

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Written

Aliabouzar, Mitra, et al. “Acoustic and Mechanical Characterization of 3D-Printed Scaffolds for Tissue Engineering Applications”. *Biomedical Materials*, vol. 13, p. 055013, 2018, https://doi.org/10.1088/1748-605X/aad417.

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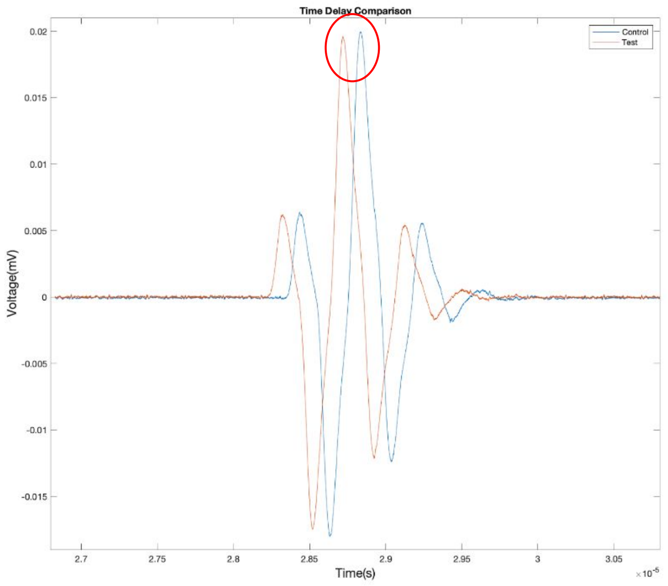
Bonus Slides

Δt

Computational Method - MATLAB



$$\hat{R}_{xy}(m) = \begin{cases} \sum_{n=0}^{N-m-1} x_{n+m} y_n^*, & m \geq 0, \\ \hat{R}_{yx}^*(-m), & m < 0. \end{cases}$$

Time Delay Equation and Value Using Cross Correlation ('xcorr')

```
% cross correlation matrix
[xcorr_amplitudes, xcorr_times] = xcorr(y_signal_1, y_signal_2);
[A, I] = max(xcorr_amplitudes);
% sample time
first_value = x_signal_1(1,1);
second_value= x_signal_1(2,1);
sample_time = second_value - first_value;
% time delay value & calculation
time_delay_value = xcorr_times(I);
% time delay in regards to sampling time
time_delay = time_delay_value * sample_time
```

```
time_delay = 2.6840e-07
```