ECE 345: Linear Systems and Signals

Fall 2020

Lab #1 Report

Note: you can use the equation editor in MS Word or a tool such as LaTeXiT to generate formulas for questions which ask about formulas. Alternatively, you can write your derivation and put a photo into the box.

Part 1 **(18 points)**	**Part 2** **(14 points)**	**Part 3** **(14 points)**	**Part 4** **(18 points)**	**Part 5** **(12 points)**	**TOTAL** **(76 points)**

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Part 1: simulating the received signals (18 points)

(a) (4 points) Write the formula that you derived for the two delays. Show your work.

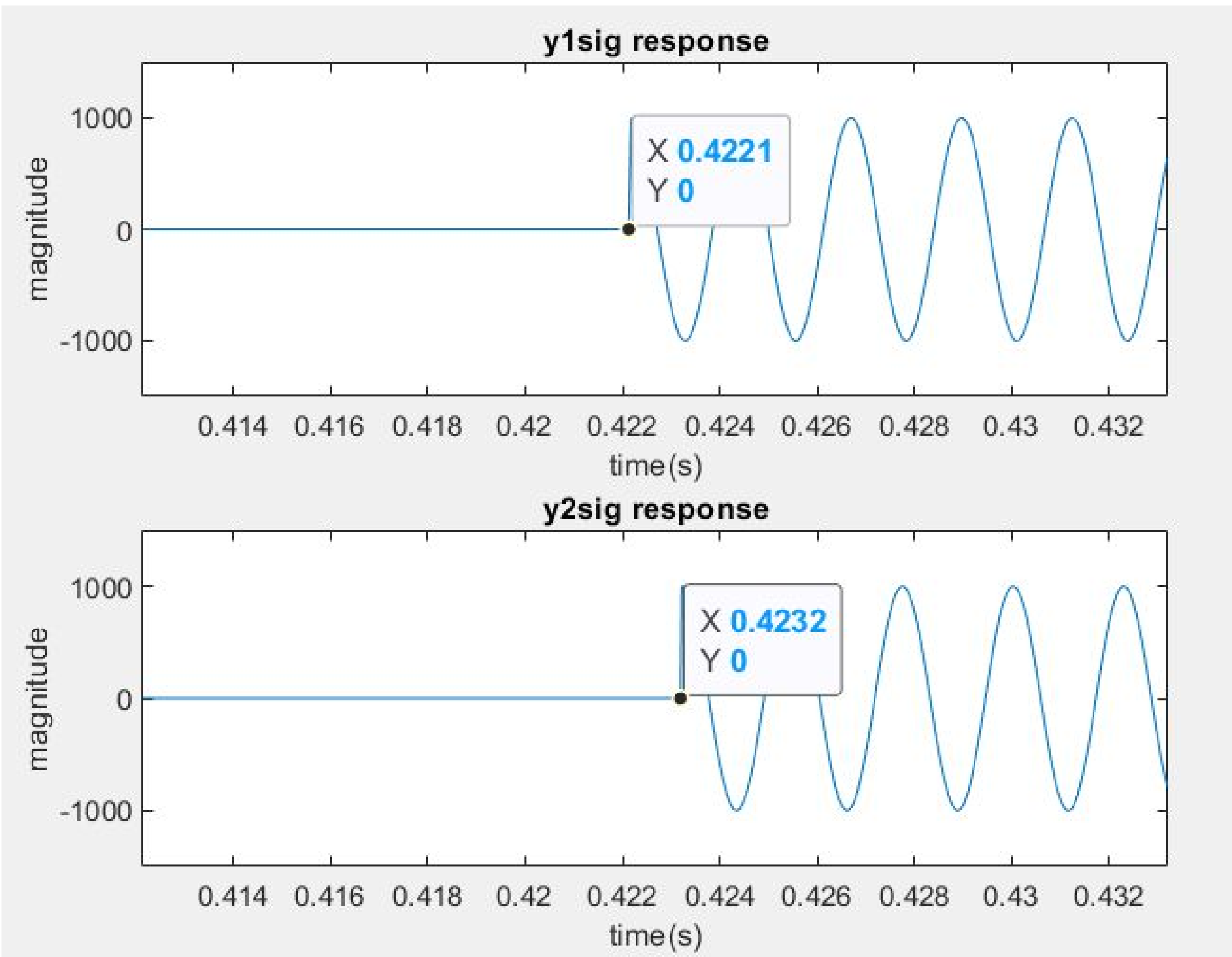
$$\tau_1 = \tfrac{1000}{3}\sqrt{B^2 + (L - 2A)^2}$$

$\tau_2 = \frac{1000}{3}\sqrt{B^2 + (L-A)^2}$

(b) (2 points) What is the frequency of the *s(t)* in Hertz?

$f = \frac{\omega}{2\pi} = \frac{880\pi}{2\pi} = 440\ Hz$

(c) (4 points) Provide a plot of the received signals. Make the plots vertically stacked, so the signal from the first microphone (0,2A) is above the signal from the second microphone (0, A).



(d) (8 points) Provide your function lab1sim() in the .zip file and upload it with this report.

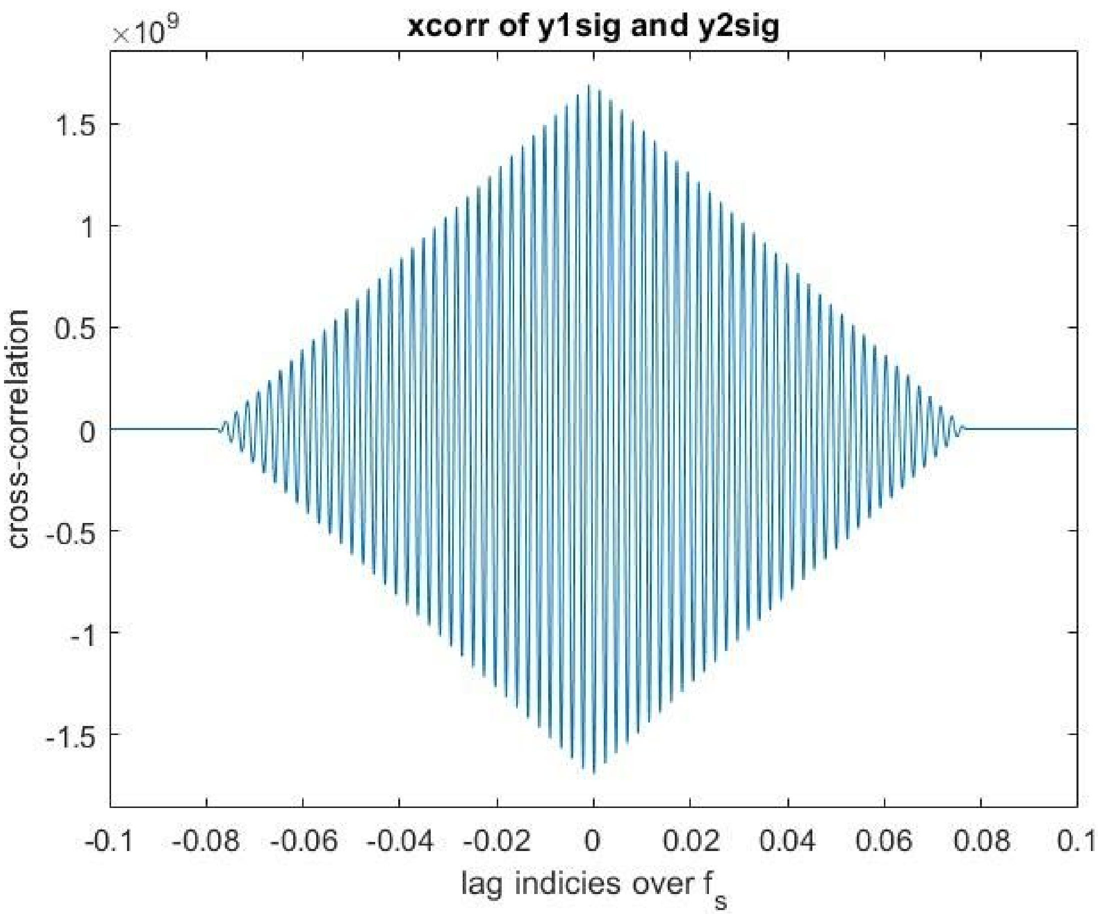
Nothing to write.

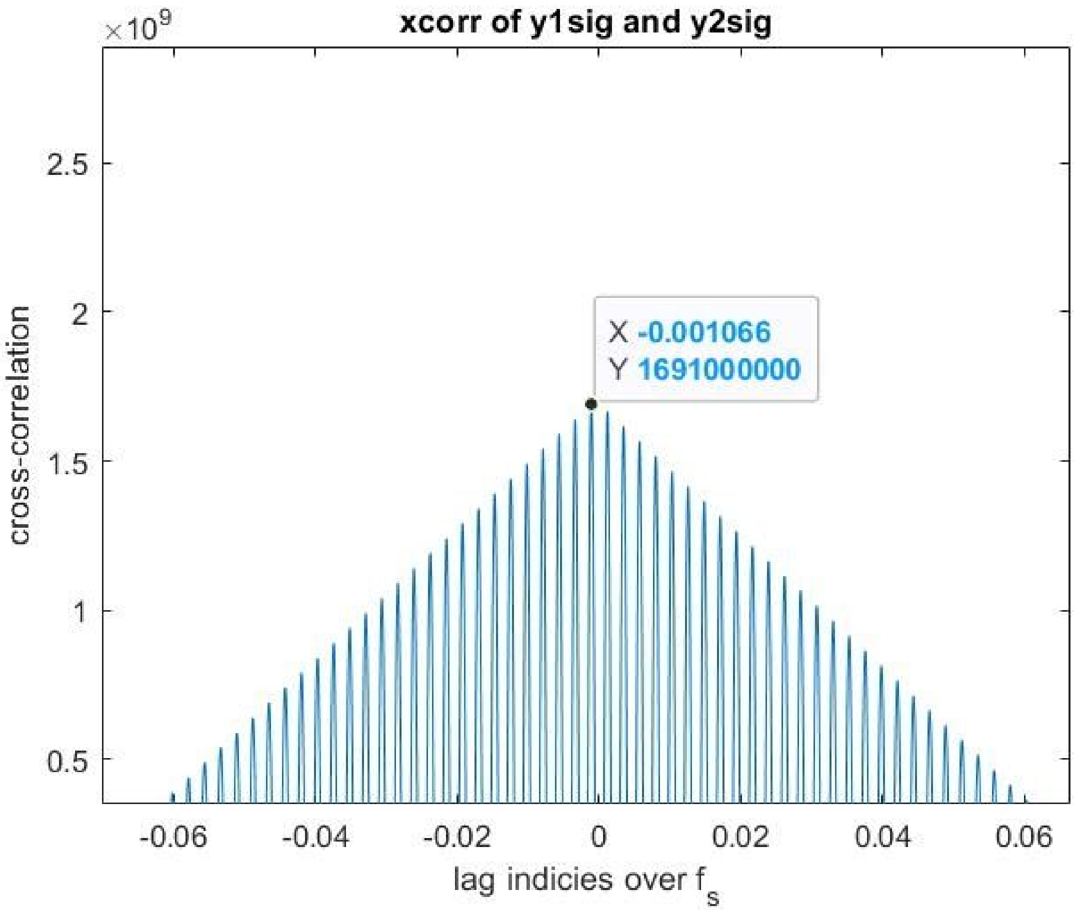
Part 2: estimating the location (14 points)

(a) (2 points) Why can't the receiver use its two antennas to find the absolute delay to each microphone?

The absolute delay depends on the time shift between when the signal was emitted by the speaker and when the same signal was received by a microphone. We only know when a microphone received the signal, but we don't know when the speaker sent it. So we use two microphones to measure a relative delay between signals received to triangulate the position of the speaker. The distance between the speaker and its microphone along with the speed of sound can help us figure out the time delay between when a signal was sent from the speaker to when either microphone received the signal.

(b) (4 points) Give the plots of the xcorr() function requested in the lab. Give both the full plot and the zoomed in plot. Label where the estimate of the relative time shift is on the plot.





(c) (4 points) Provide the formula for L. Show your work.

$\frac{A}{c_s}\sin(\theta) = \tau_1 - \tau_2$

$\tan(\theta) = \frac{L}{B}$

$\theta = \arcsin(\frac{c_s}{A}(\tau_1 - \tau_2))$

$L = B\tan(\theta)$

$L \;=\; B\tan(\arcsin(\frac{c_s}{A}(\tau_1 - \tau_2)))$

(d) (4 points) Give the true and estimated values of L. Explain why they are the same or different.

Estimated: 101.01 for $|\tau_1 - \tau_2| = 0.001066$

True: 100

Our estimation is slightly off, but this may because we are using a rounded value for $|\tau_1 - \tau_2|$, otherwise the results are almost identical.

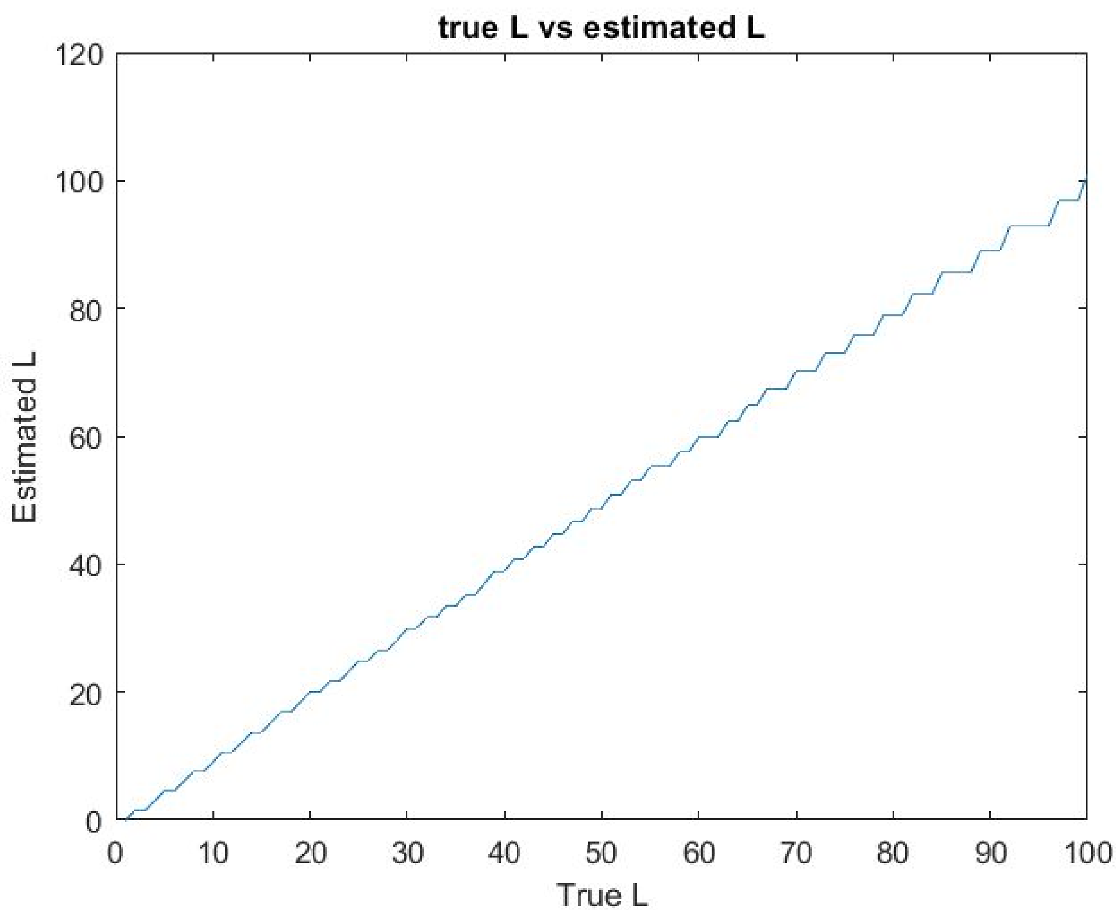
Part 3: automating the estimates (14 points)

(a) (nothing to turn in)

(b) (8 points) Upload your function lab1est() in the .zip file and upload it with this report.

Nothing to write.

(c) (6 points) Provide your plot of the true *L* versus the estimated *L*. Explain in words why the plot looks the way it does.



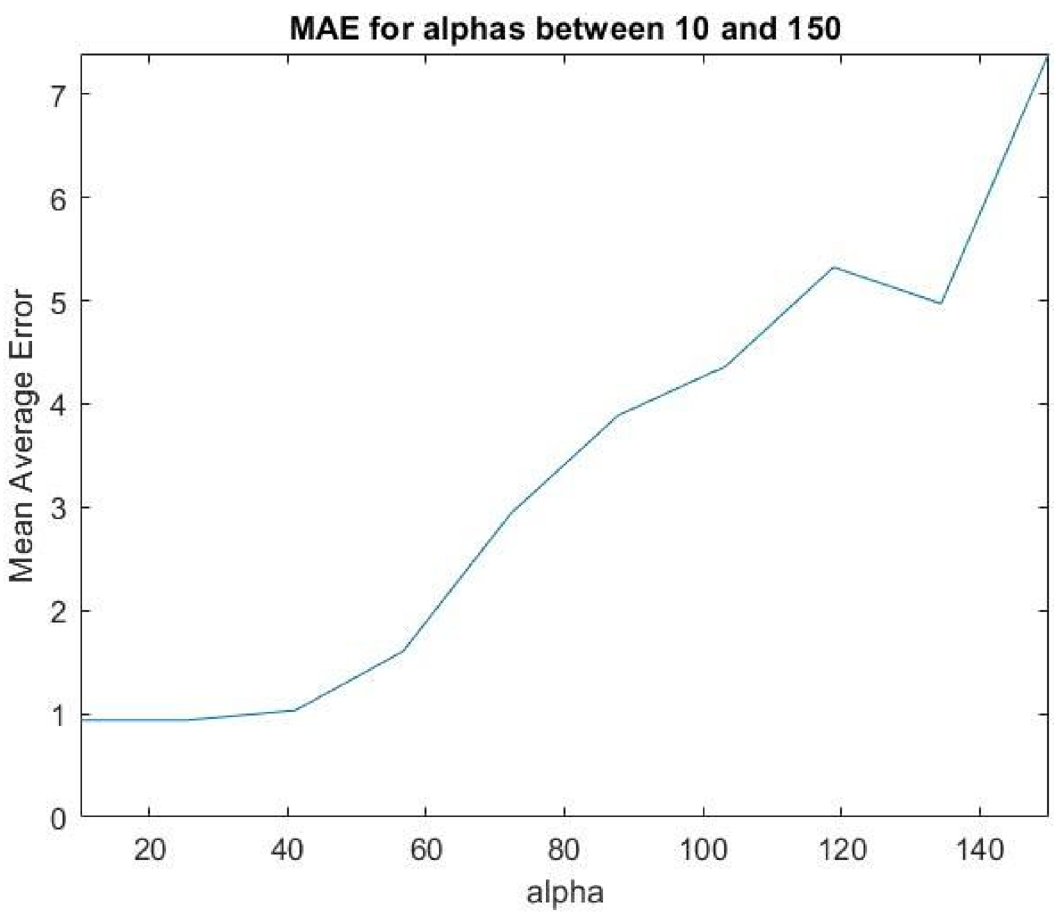
Due to the error gotten from the estimator, the plot of the true L vs the estimated value oscillates. Hence the noise/oscillations on the plot represent the estimated values.

Part 4: impact of noise (18 points)

(a) (8 points) Give the values of the estimated L, true L, and the difference for the two given values of alpha.

The estimated L for alpha 1 is 100.9685. The estimated L for alpha 100 is 96.7655. The difference between the two values is 4.203. The true L is 100 according to the initial L. So the error for alpha 1 is 0.9685 and the error for alpha 100 is 3.2345.

(b) (6 points) Provide a plot of the mean squared error (MSE) as a function of alpha. Explain in words why the plot looks the way it looks.



A higher alpha adds more noise to the signal, so it makes sense that MAE is uptrending as alpha gets larger, but this doesn't necessarily mean it will be uptrending at a constant rate due to the variable amount of added noise.

(c) (4 points) Where does the noise affect the estimator, causing errors?

If the expression for the time shift ($|\tau_1 - \tau_2|$) times $\frac{c_s}{A}$ is a value greater than 1, then taking the arcsin will yield a complex number theta. This creates a complex L at high alphas, typically near the size of the magnitude of the input signal.

Page 5: the bigger picture (12 points)

(a) (4 points) What should be the effect of decreasing A on the estimates and why? (Make sure you think about the noise)

:As A is reduced and approaches 0, the microphones begin to act as one due to essentially being in the same location, which then removes the delay between them, which keeps noise at a minimum. But there would be no sound produced due to the microphones not producing a signal.

(b) (4 points) How would a third microphone in the array help you in the estimation task?

:A third microphone provides more sample points to add accuracy to the estimate for L.

(c) (4 points) Where would you place a third microphone and what might it let you do? (Think about GPS)

:A third microphone could be placed in any location where it forms a triangle with the other two microphones, but for peak sample data, the microphone should be placed so that the speaker is at the centroid of the triangle of microphones, and this arrangement allows for the triangulation of the speaker coordinates.