ECE 280L: Introduction to Signals and Systems
Lab 2: Introduction to SIMULINK

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I have adhered to the Duke Community Standard in completing this assignment.

Contents

1 Objectives

There were a few objectives of this lab, one was to continue to familiarize ourselves with SIMULINK which we'd started to learn in Lab 2. Another objective is to use SIMULINK to create the digital audio effect of a single echo, reverberation and flanging. In addition to this we had to explore changing different variables within the audio effects and note the difference in the output.

2 Background

In this lab we explore 3 different digital audio effects, listed and explained as follows:

- **Single Echo**
  - The single echo effect takes the input signal, delays it by a specified constant and applies a gain of a specific constant (< 1) to it in order to make it quieter than the original. This new delayed input is then summed with the current original input to create a new output with the echo sound included.
- **Reverberation**
  - The simple reverberation effect acts in an almost similar input by taking the input signal and delaying it by a specified constant and applying a gain (< 1), however the output of this is summed with the original signal and the output of that summation is used to create another signal using the same system, and so on. This leads to a seemingly infinite echo effect. Other reverberation techniques, such as allpass, are more complex but create a less distorted output.
- **Flanging**
  - The flanging effect is produced by mixing two identical signals but one is delayed by a small amount that fluctuates according to a sinusoidal input. There is seemingly no repetition in sound as the delay is so short but the output is augmented to create a fluctuating change in sound continually.

3 Results and Discussion

3.1 Single Echo Effect

When the simulation has stopped, switch back to the MATLAB window and listen to the output that was created using the command: soundsc(Echo, 8000).Do you hear an echo?
Yes.
Test your system using the microphone (MIC IN) and a pair of headphones (HEADPHONE). Do you hear an echo?
Yes.
Describe how the SIMULINK model is related to the difference equation.
To find `y[n]` difference equation adds up shifted x[n] signal with lower amplitude on top of original x[n] signal to create

the echo. SIMULINK model takes x[n], shifts it by D=4000 with delay block, changes its amplitude by a=0.8 and adds to original x[n] to create the final signal. Thus difference equation characterizes the SIMULINK model.

What do you hear when a signal is processed using the single echo system?

With the single echo system you hear the original input, be it a sound file or voice input, swiftly followed by a repetition of that sound at a quieter volume. This continues to happen for the duration of the sound, however only one echo is heard.

What effect does changing the parameter, a, have on the output signal?

The smaller a is the less amplitude the echoing signal will have, thus making the echo sound quieter, visa/versa.

What effect does changing the parameter, D, have on the output signal?

D will affect the delay of the echo signal, thus increasing the value of D the time between the original sound and the echo sound will become longer.

Why does the output sound this way? (Relate your observations to the equation describing the system.)

When we recorded our voices or used a sound file as an input to the system we could hear a quieter repetition of this sound which makes sense when looking at the equation, as it takes the input signal and sums it with a version of the signal that has been delayed and has a lower amplitude.

Provide an analytic expression and a sketch for the impulse response, h[n], of the single echo system.

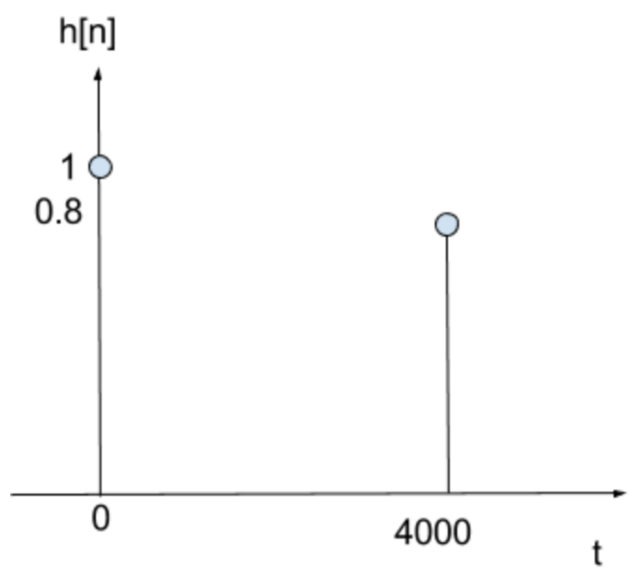

Figure 1: Sketch for impulse response h[n]

$$h[n] = \delta[n] + 0.8\delta[n - 4000] \tag{1}$$

How can you interpret h[n] in terms of your observations?

h[n] characterizes the output signal with single echo. That single echo can be observed in h[n] formula as 0.8[n-4000]. It has value for only n=4000 delay and it has amplitude 0.8.

Assuming a sampling rate of 8000 Hz, how would you choose the delay, D, to achieve a time delay of 0.25 seconds? (Recall that the exponent of z in the delay block corresponds to the number of samples the signal is delayed by.)

We would choose D to equal 2000, this is because with a sampling rate of 8000Hz audio is sampled 8000 times per second, henceforth making D equivalent to 2000 we are delaying the signal by 2000 samples which equates to 0.25 seconds in terms of time.

What properties does the single echo system have (linear, TI, stable, memoryless, causal)?

The echo system is causal as it only depends on past inputs of time, not future, however because of this past dependency we can say it is not memoryless. It is BIBO stable as there is no unbounded term, xs are bounded and 0.8 is a constant. It is Time invariant as delaying it first and then putting into system gives the same output as putting into the system and delaying the final signal. It is also linear as putting into system and then scaling it gives the same as putting scaled inputs to the system.

3.2 Reverberation Effect

Run the simulation and listen to the result using the `soundsc` command in MATLAB. What do you hear?

When we listened to the output of the `soundsc` command using either our voice or sound file as an input we heard the initial sound and then a seemingly infinite diminishing echo, that increased in intensity and distortion the longer the input went on for.

Describe how the SIMULINK model is related to the difference equation.

In difference equation, y[n] is equal to addition of original signal x[n] and shifted and scaled y[n]s. SIMULINK model does the same by adding the output of single echo system to the original x[n] to find y[n]. One important detail about this is that if y[n] has echo, y[n-d] also has an echo with y[n-2d] which has echo with y[n-3] and this goes on. This is an recursive function and in SIMULINK this is interpreted with ever looping signals that changes amplitude and delay each time it loops.

What do you hear when a signal is processed using the simple reverberation system?

Simple reverberation is heard as infinite numbers of single echoes system added on top of each other. So every single sound echoes infinite numbers of times with only lower amplitude in each echo. If earphones are not plugged in, to many sounds are echoed infinity times that nothing is heard except distorted sound.

What effect does changing the parameter a have?

Changing a affects the amplitude of the reverberation signal, which in effect will make it seem as if the reverbed sound is quieter than the initial sound, where the smaller a is the quieter the reverb.

What effect does changing the parameter D have?

D affects how much the reverberated signal is delayed by, which in effect will increase the time between the reverberation sound and the initial sound, creating a longer sounding reverberation e.g. the walls in a room are further away from the source of sound.

Compare the simple reverberation filter with the single echo filter with the same delay and gain. How do they differ?

The single echo creates a less distorted effect as the input sound is only echoed once, whereas the simple reverberation filter will produce a similar sounding echo, however this echo is continued for an infinite amount of time with a diminishing volume so as time goes on the sound becomes much more distorted and intense when compared to the single echo.

Compare the simple and allpass reverberators. How are they similar? How are they different? Why do you think the allpass reverberator sounds more natural?

Simple reverberator simply adds up delayed output back into the system to create this infinite delaying and scaling input back into the system. Allpass has similar operation as it also uses this recursive feature to create echo but instead of adding up the scaled and delayed output, it adds up delayed input and subtracts accelerated and scaled output. As y[n] has echo and y[n+D] has also echo, and as y[n+D] is in future it also has some echoes continuing from y[n]. This subtracting y[n+D] from y[n] yields to removal of some echoes, thus decreases the effect of infinite echoes and results in less distorted and more natural sound.

3.3 Flanging Effect

What do you hear when a signal is processed using the flanging system?

When we listened to the output we were able to hear a distortion effect where our voices or the input sound file seemingly fluctuated in volume and sound continuously. There was a small repetition of the initial sound that also fluctuated to create a further distortion effect.

What effect does changing the gain, delay, and flange frequency have?

Changing the gain in this case will change the volume of the reverberation sound effect e.g. if it is smaller then the reverberation sound will appear quieter.

Plot the low-frequency oscillator, d(n), for these parameters: D = 4000 samples, fs = 8000Hz, fd = 2000 Hz.

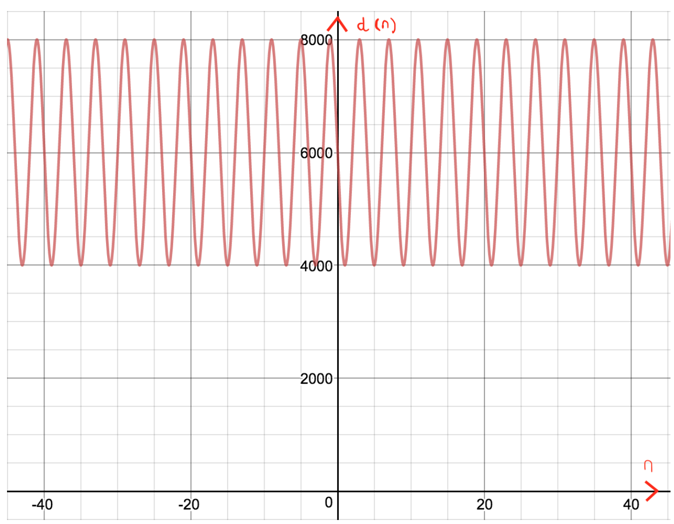

Figure 2: Plot of d(n)

What is the maximum delay when D=4000 and fs = 8000? What is the minimum delay?

The maximum delay is 8000 and the minimum delay is 4000.

4 Conclusion

In this laboratory I was able to practice my SIMULINK skills and learned how to use real-time audio inputs and outputs as part of my SIMULINK systems. I also learned how to create traditional digital audio effects by analyzing the signal systems used to create them and transferring these systems into SIMULINK. In addition to this I learned the importance of each parameter/variable in each system and how it affects the output of the system. Through the exercise involving the flanging effect I also learned how to use sinusoidal input in SIMULINK and used it as part of delay.

References

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