

Bottom-head Snare's Effect on Snare Drum Acoustics

Physics 406

Robert Madsen

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1. Introduction

The motivation behind this report is to study the effect of the bottom-head snares on a snare drum's acoustics. I am particularly interested in this instrument because I played it growing up, both in a traditional "concert band setting" as well as in a marching band. Snare drums are unique in that the drummer can easily cause a dramatic change in the sound of the drum.

Throughout the report the snare's role in dampening, harmonic spectrum, and fundamental harmonic shifts is studied. This report will not perform a modal analysis of a snare drum. Such work was completed by Matthew Fischer [1], where he studied the complex modal frequencies produced by the coupling of the top and bottom heads.

The primary challenge in preparing this report was simply studying the sound samples in meaningful ways. Atonal drums are inherently difficult to study due to their very fast decay time and chaotic harmonics.

2. Theory

The sound samples studied throughout this report are a result of 2-dimensional standing waves on the surface of the drum heads. The generic equation for describing such waves is the following:

$$\nabla^2 \psi(r, \varphi, t) - \frac{1}{v^2} \frac{\partial^2 \psi(r, \varphi, t)}{\partial t^2} = 0$$

Where $\Psi(r, \varphi, t)$ is the 2-D physical displacement amplitude of the wave in space (r, φ) and time (t) . v is the longitudinal speed of the wave and ∇^2 is the Laplacian operator, see [2]. Standing wave solutions are the result of specific boundary conditions restricting such waves in either space or amplitude. In this report, the drum is restricted by the rims to which it is bound. As noted in [2], the above equation corresponds to a first-order description of waves and does not take into account real-world complications, such as snares pressed against a drum head, for example. Additionally, the above equation assumes the vibrating system in question to be made of linear, homogeneous, and isotropic materials, see [2]. Since this report is focused on the snare's effect on snare drum acoustics, assuming that the drum heads in question are made of such materials, for example, does not constrain the findings of this report.

3. Data Acquisition

The snare drum measured for this report is the one found in ESB 6105 - a metal-bodied Pulse drum with Remo Ambassador top and bottom heads. The stick used was a VicFirth 5B.

In order to produce high-quality sound samples, a device was fabricated that could consistently strike the drum. Using spare parts found throughout ESB 6105, the following was constructed:



Figure 1: Drum Striker



Figure 2: Sound Sampling Set-up

If the stick is held at approximately the same height, reasonably consistent drum strikes can be achieved. During data acquisition I held the stick vertically, dropped the stick, and caught it again on the rebound.

Three different sound measurements were taken with the snares on and off, without the use of a dampening O-ring. (1) Striking the center of the head, (2) striking the “sweet-spot” of the head (defined to be halfway between the center and the rim) and (3) striking very close to the rim of the head. It should be noted that additional data samples were taken using an O-ring, but were not used in the report. With the extra dampening from the O-ring, the samples could not be adequately studied. Additionally, a stick with a plastic head, the VicFirth 5BN, was also used during sound sampling. However the resulting data was largely indistinguishable from the wooden-tip samples and thus was not used.

4. Dampening of Fundamental Harmonic

When the snares are pressing up against the bottom head of the drum, the bottom head cannot physically vibrate as freely as it could if the snares were off. Additionally, the physical vibration of the snares indicates that acoustic energy is being removed from the system and converted to mechanical energy. The following graphs highlight the snare's ability to accelerate dampening of the fundamental harmonic. Throughout the following figures, the vertical Amplitude axis is represented in a scale that ranges from 0 to 1. This is a dimensionless quantity that results from a 16-bit analog-to-digital conversion, with possible data ranging from -2^{15} to 2^{15} (where 2^{15} corresponds to 1 on the Amplitude scale). This quantity is dependent on the calibration of the microphone used. The horizontal time scale is in seconds, with meaningful data extending to about .09 seconds depending on the sound sample. All of the following graphs were constructed using the `wav_analysis.m` MATLAB script present on the ESB 6105 computers, see [3].

Note that only the dampening of the fundamental harmonic is explored in this section because the data for the lower-order harmonics were inconclusive. Due to the chaotic nature of drum acoustics and the short sound samples, some lower-order harmonics showed bizarre, non-physical behavior, for example gaining amplitude after decaying to zero.

4.1 Center of Drum

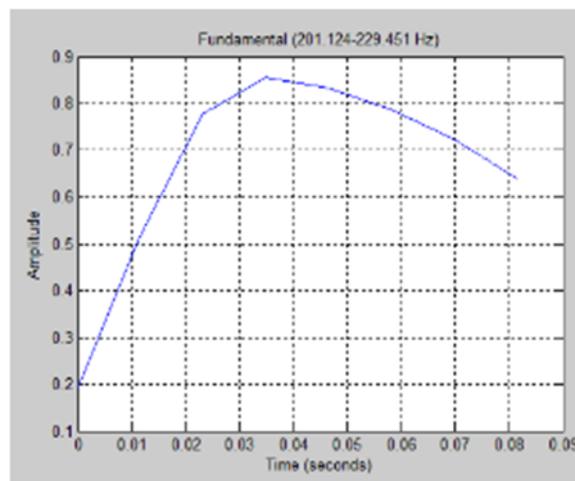


Figure 3: Amplitude vs. Time: Snares Off - Center

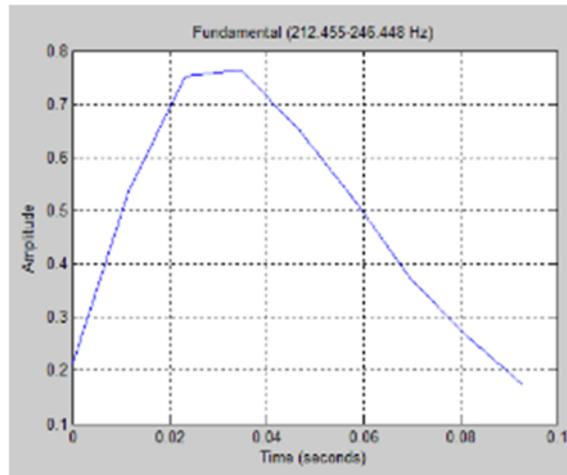


Figure 4: Amplitude vs. Time: Snares On - Center

Time (s)	Amplitude: Snares Off - Center	Amplitude: Snares On - Center
0	.2	.22
0.02	.7	.7
0.04	.85	.71
0.06	.77	.5
0.08	.65	.27

Table 1: Amplitude vs Time, Snares On vs Snares Off, Center

In the case of the Center sound samples, the samples are initially very similar with both samples reaching their peak amplitudes around .035 seconds. Though the Snares On sample decays much quicker, losing 64% of its peak value by .08 seconds, compared to 24% peak value loss for the Snares Off sample.

4.2 Sweet Spot

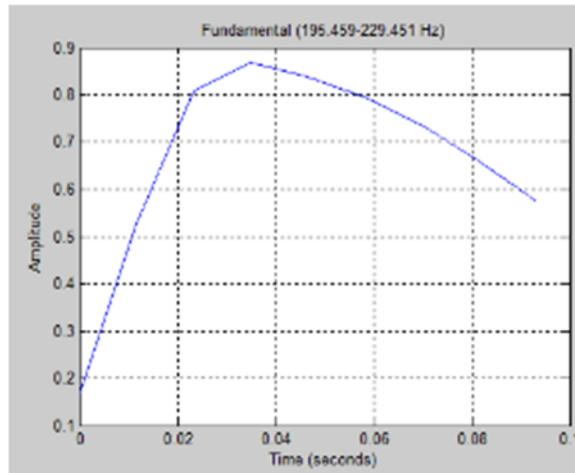


Figure 5: Amplitude vs Time: Snares Off - Sweet Spot

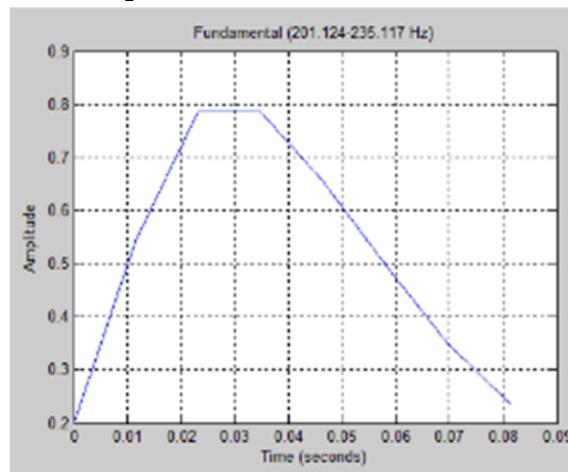


Figure 6: Amplitude vs Time: Snares On - Sweet Spot

Time (s)	Amplitude: Snares Off - Sweet Spot	Amplitude: Snares On - Sweet Spot
0	.18	.21
0.02	.72	.72
0.04	.85	.73
0.06	.78	.48
0.08	.66	.25

Table 2: Amplitude vs Time, Snares On vs Snares Off, Sweet Spot

As with the Center samples, the Sweet Spot samples reach their peak amplitude around .3 seconds. Though by .08 seconds, the Snares On sample has lost 68% of its value, compared to only 23% loss for the Snares Off sample.

4.3 Edge

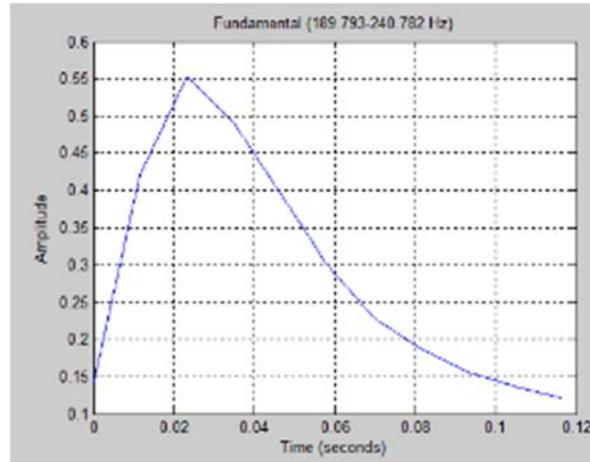


Figure 7: Amplitude vs Time: Snares Off - Edge

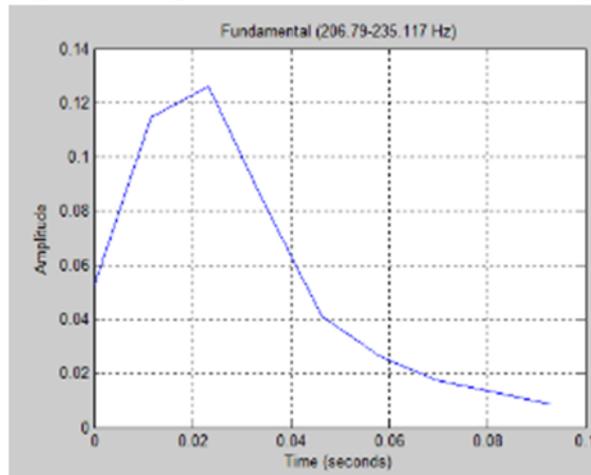


Figure 8: Amplitude vs Time: Snares On - Edge

Time (s)	Amplitude: Snares Off - Edge	Amplitude: Snares On - Edge
0	.15	.058
0.02	.52	.123
0.04	.45	.062
0.06	.28	.025
0.08	.19	.013

Table 3: Amplitude vs Time, Snares On vs Snares Off, Edge

The Edge samples are more difficult to analyze due to the amplitude differences, the Snares Off Edge sample reaches an amplitude of about .55, while the Snares On sample only reaches a peak amplitude of about .125. This is likely due to a poor drum strike when taking the sample.

Though the 2 samples have the same shape - both samples have the steepest slope of decline across all 3 regions of the drum. Suggesting that proximity to the shell of the drum is a main driver to dampening.

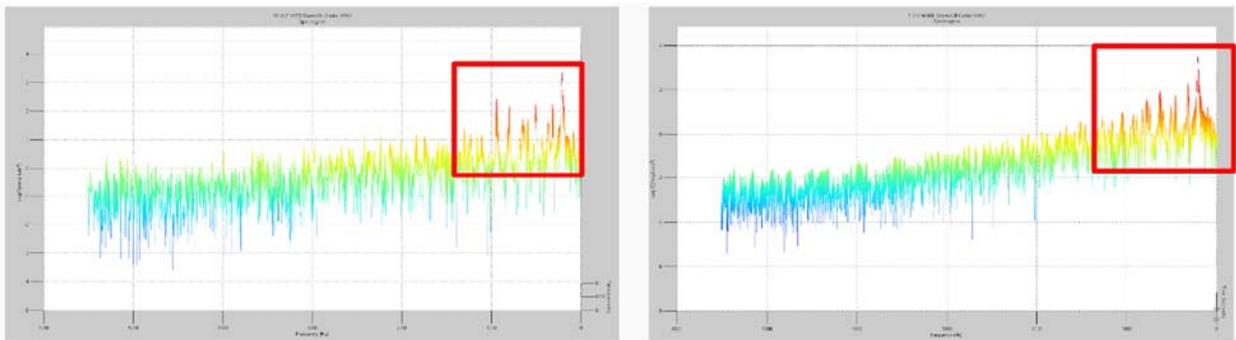
4.4 Conclusion

Although only the dampening of the fundamental harmonic was analyzed, it is clear that the snares play a significant role in the dampening of the drum's sound. Excluding the Edge samples, the drum was able to maintain on average 66% of its peak amplitude .08 seconds after being struck with the snares off, while the drum could only maintain on average 23.5% of its peak amplitude .08 seconds after being struck with the snares on.

5. Harmonics

The following describes the role snares play in the presence of certain harmonics. Since a snare drum sounds dramatically different with the snares on or off, it was little surprise to see different harmonic responses in the data. The vertical axis of the following charts is Amplitude, and the horizontal axis is Frequency (with the frequency values increasing from right to left). The following charts are only intended to display a qualitative view of how the harmonic spectrums are affected by the snares. The red boxes are used to highlight the more significant lower-order harmonics, because the higher order harmonics play little role in the sound of the drum due to their low amplitudes.

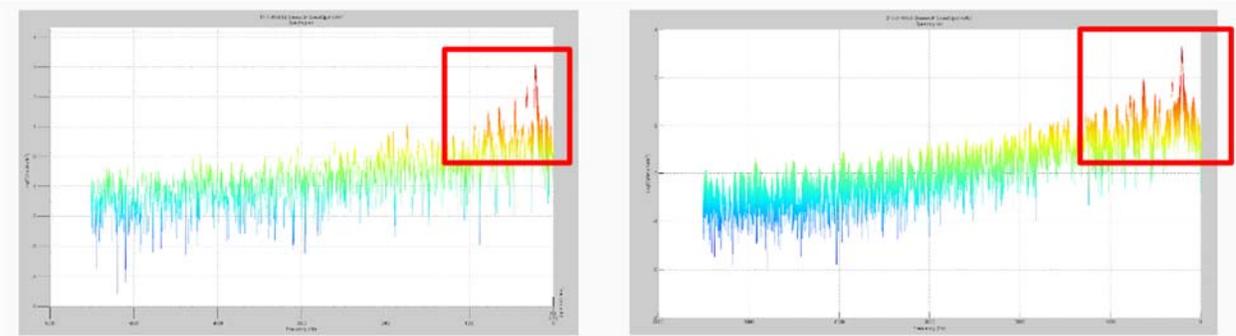
5.1 Harmonic Spectrum



Snares On

Snares Off

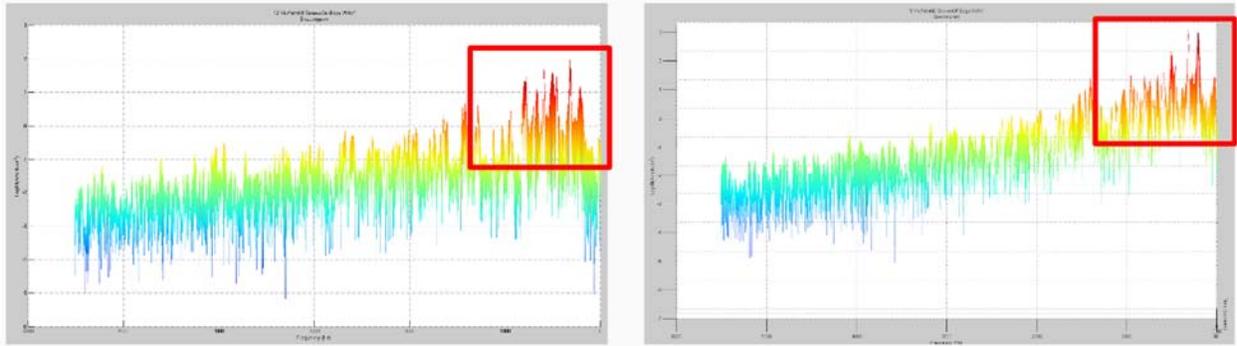
Figure 9: Amplitude vs Frequency, Center



Snares On

Snares Off

Figure 10: Amplitude vs Frequency, Sweet Spot



Snares On

Snares Off

Figure 11: Amplitude vs Frequency, Edge

5.2 Harmonic Shift

Snares play a critical role in the upward shift of the fundamental harmonic. Similar to how shortening the length of a string results in higher frequencies when plucked, the snares help create higher frequencies across the 2-dimensional drum head.

As can be seen in the following figures, the magnitude of the harmonic shift appears to be dependent upon where the drum is struck. Though this apparent location dependency may have resulted from only taking one type of each sound sample.

5.2.1 Center

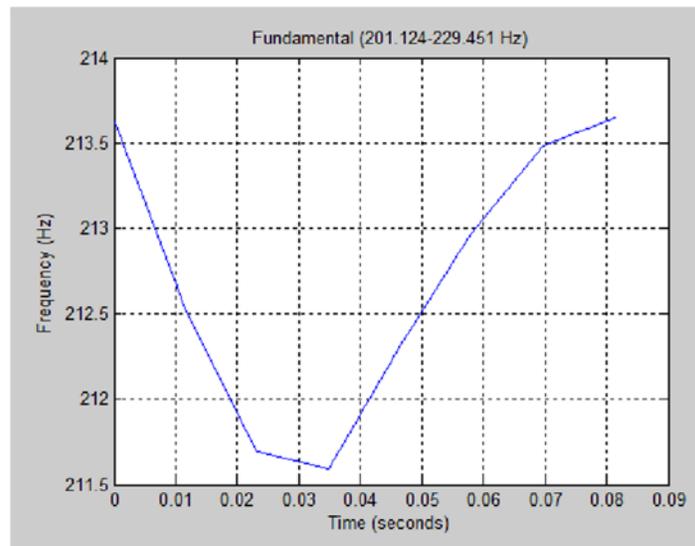


Figure 12: Fundamental Harmonic Frequency vs Time: Snares Off - Center

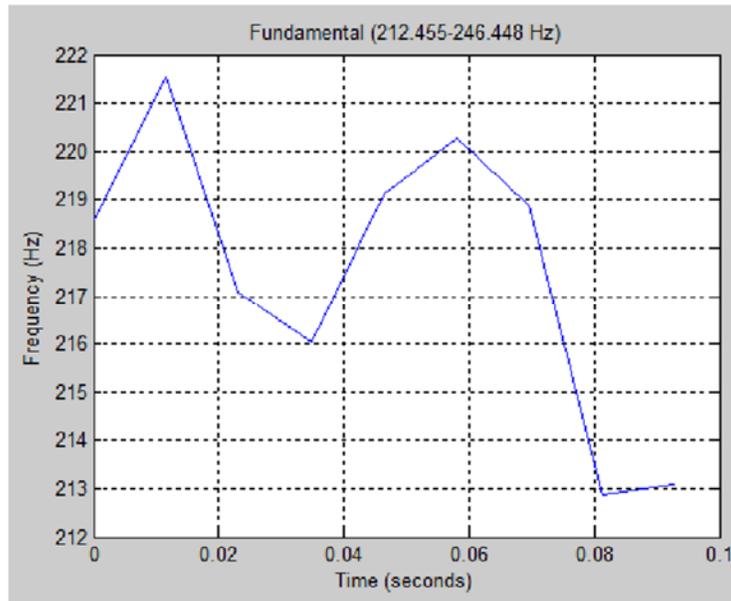


Figure 13: Fundamental Harmonic Frequency vs Time: Snares On - Center

When striking the center of the drum with the snares off, the fundamental harmonic ranges between about 211 Hz and 213 Hz. When the snares are turned on the fundamental shifts to between 213 Hz and 221 Hz, an average shift of about 5 Hz.

5.2.2 Sweet Spot

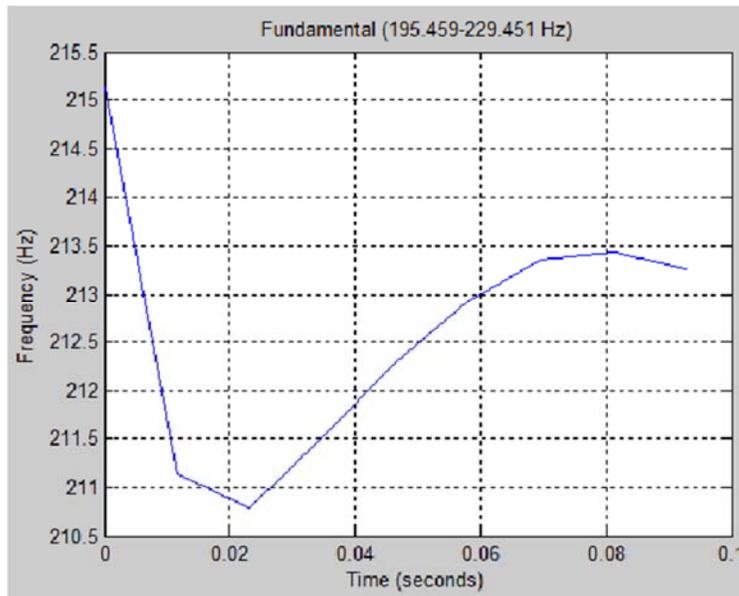


Figure 14: Fundamental Harmonic Frequency vs Time: Snares Off - Sweet Spot

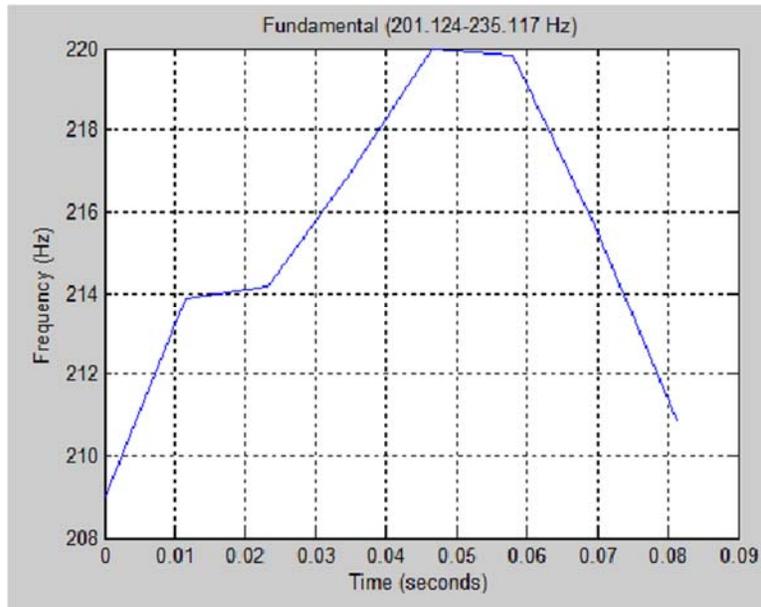


Figure 15: Fundamental Harmonic Frequency vs Time: Snares On - Sweet Spot

When striking the sweet spot of the drum with the snares off, the fundamental harmonic ranges between about 211 Hz and 215 Hz. When the snares are turned on the fundamental shifts to between 209 Hz and 220 Hz, an average shift of about 2 Hz.

5.2.3 Edge

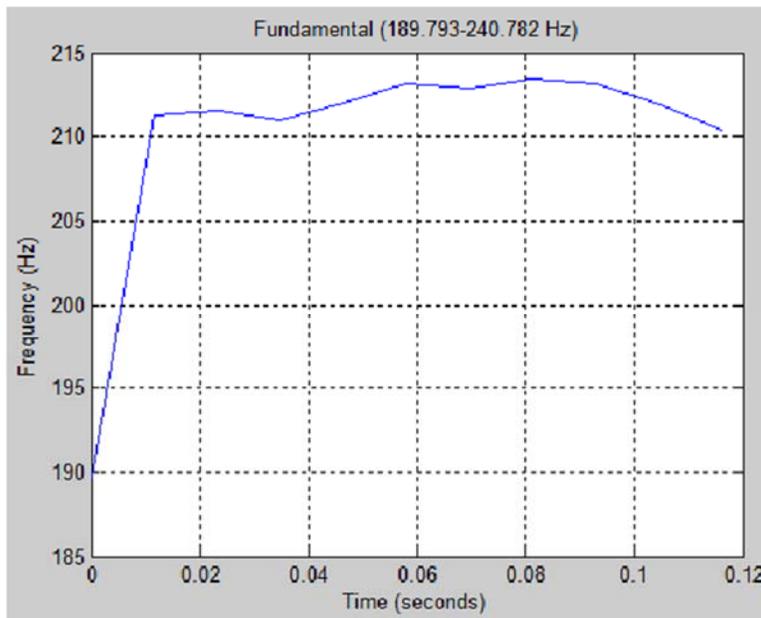


Figure 16: Fundamental Harmonic Frequency vs Time: Snares Off - Edge

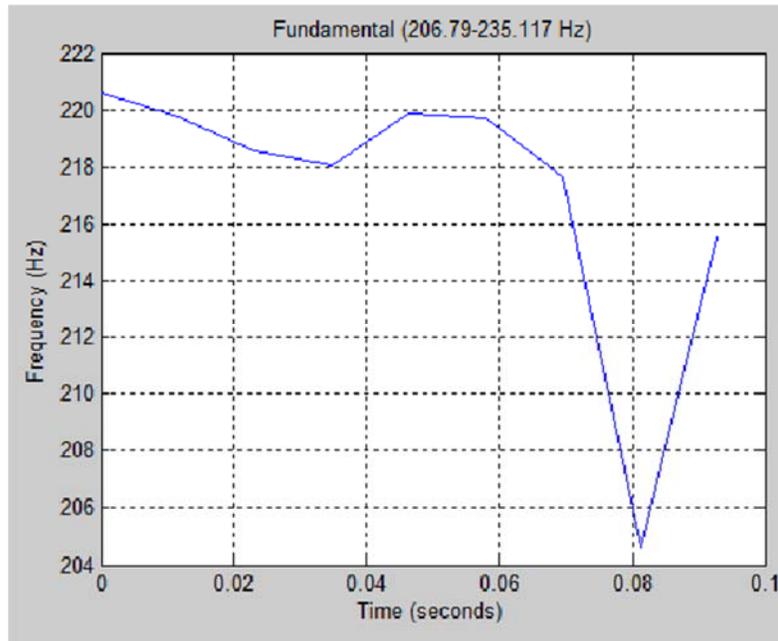


Figure 17: Fundamental Harmonic Frequency vs Time: Snares On - Edge

When striking the edge of the drum with the snares off, the fundamental harmonic ranges between about 190 Hz and 214 Hz, with the harmonic stabilizing around 211 Hz and 213 Hz. When the snares are turned on the fundamental shifts to between 205 Hz and 221 Hz. Though the harmonic appears to be stable at around 219 Hz until about .07s. The resulting average shift is about 9 Hz.

6. Conclusion

Considering the difficulty in studying drum acoustics, this project was a success. Meaningful data acquisition and analysis proved successful despite quick decay times and chaotic harmonics. Though it should be noted that the entirety of this report was based on only 1 of each type of sound sample being recorded. For example, only 1 recording of “VicFirth5B, Center, No Snares” was recorded. Considering the imprecise nature of the device used to strike the drum, see Figures 1 and 2, it is possible that different conclusions would have been drawn with slightly different sound samples. In the future this problem could be resolved by taking multiple samples of the same type.

An idea for further study is to examine the impact of tightening or loosening the snares on the drum’s acoustics. It is likely that very tight snares would greatly accelerate dampening and cause a higher shift in the harmonic frequency.

7. Sources

[1] Fischer, Matthew. "Modal Analysis Of A Snare Drum". (2014): n. pag. Web. 3 Apr. 2016.

[2] S. Errede, "Mathematical Musical Physics of the Wave Equation", ESB 6105, 2016.

[3] S. Errede, *wav_analysis.m*. Champaign-Urbana, IL, 2016.