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Banner: Spectral Response of Musical Instruments Chladni Patterns and Drum’s impulse response

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Banner: Spectral Response of Musical Instruments – Chladni Patterns and Drum's impulse response

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Abstract

The purpose of this project is to design and build a Chladni plate and double-headed drum for testing Chladni patterns (to individual applied frequencies via a braodband speaker assembly), and impulse response. In addition, this will be used for input and output generation, testing, and measurement of musical instruments for spectral response and impulse response. This report includes the materials used to build the Chladni plate and the double-headed drum. It also includes the spectral response of the drum given the impulse response. This report will go over research, the definition of the problem, device requirements, evolution, and selection of concept, detail design, material selection, testing plans, and final prototype.

Introduction or Background

A Chladni plate consists of a flat sheet of metal or animal skin, and usually the shape of that plate is a circle or square. When the plate oscillates in a particular mode of vibration, the nodes and antinodes form complex symmetrical patterns over the surface of the plate. The position of these nodes and antinodes can be seen using the sand spread on the surface of the plates. The sand vibrates away from the antinodes and gathers on the nodes.

When vibration is induced the sand or salt forms different kinds of patterns depending on the frequency we use, and the places that hold sand or salt called nodes. Chladni patterns provide a kinesthetic, visual, and entertaining way to illustrate standing waves on flat surfaces and are very helpful when making the transition from one-dimensional systems, such as string and wind instruments, to the two-dimensional membranes and plates of the percussion family.

The tools used to see the spectral response were the Discrete Fast Fourier Transform(DFFT) and the Temporal Fast Fourier Transform (TFFT). The DFFT is used to separate the audio at the currently selected position of the waveform to its frequency components. Since the drum's sound is one single sound/impulse, the audio analyzing using the Wavepad app is the mono format shown in Figure 2. That's why it shows in the graph only one single blue line impulse representing the recorded sound.

Hypothesis/Question/Objective

- Chladni patterns demonstrate the drum resonances and the physics of vibrational waves
- Spectral analysis and visualization of an impulse response

Methods

- First we study the ideal circular membrane. This model assumes both uniform density and tension, with no air loading or membrane stiffness. The circular symmetry leads to standing wave patterns characterized by nodal diameters and circles, designated by the integers (m, n). $f \sim (m+2n)^2$
- Next, we setup the plate and drum as in Figure 3.
- Then the impulse response is recorded on Wavepad[R] (Figures 2, 3) and the Chladni pattern is formed at a frequency (544Hz as in Figures 1, 2, 3)
- Finally, the patterns and impulse response are analyzed to elicit some meaning from the observations

Figure 1a. Typical Chladni Pattern on square m=n Al plate- 544 Hz

Figure 1b. Typical Chladni Pattern on drum head- 544 Hz NOTE: less definite pattern due to non-ideal membrane which damps the clean vibrations

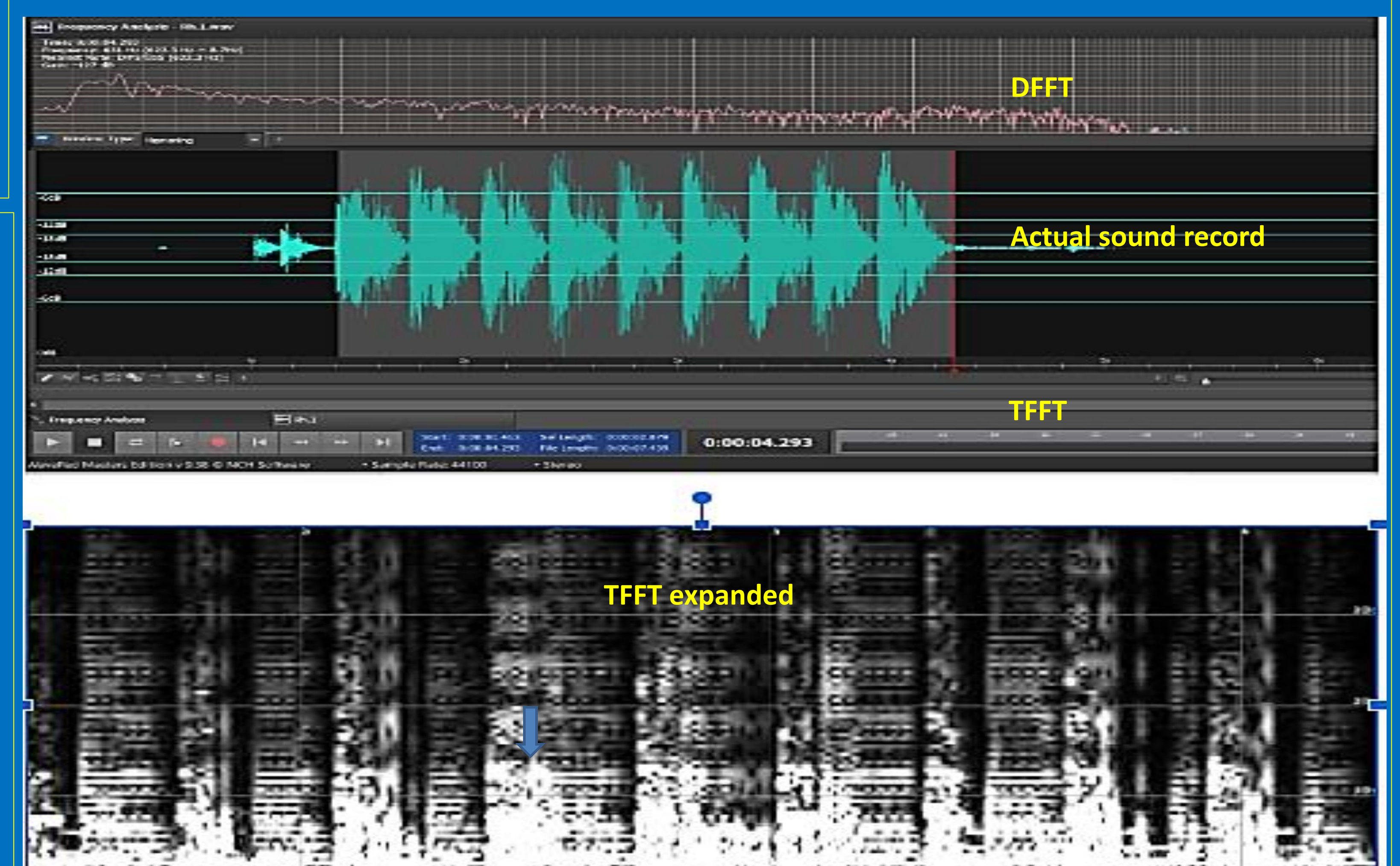

Figure 2. Drum's impulse Response using Wavepad (DFFT,TFFT)

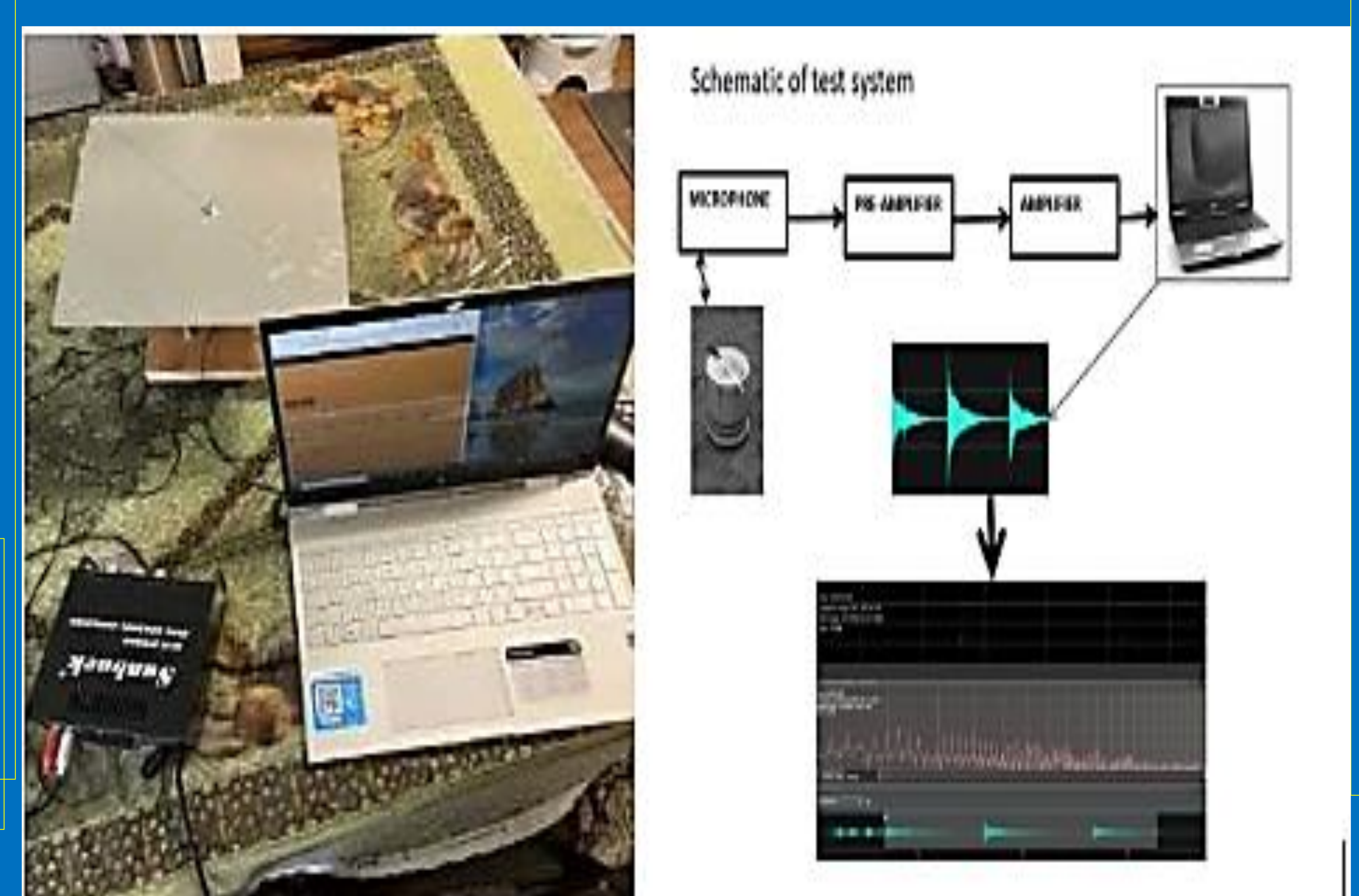

Figure 3. The setups of Chladni pattern (on Al plate) and impulse response NOTE: Both the Impulse and Chladni patterns on the drum lack distinct patterns (Figure 1b) due to the non-ideal elastic properties of the drumhead. However, the aluminum plate is quite ideal in this region of the stress-strain curve and has quite distinct resonance pattern (Figure 1b).

Results

As shown in Figure 1a, the high frequency was used and the nodes are close to each other. The places we see sands are called nodes and the empty ones are antinodes. To visualize the Chladni pattern, we need special frequencies or resonant modes. Figure 1bows the effect of dampening on the drumhead. Figure 2 shows the impulse response of a drum. The tool used to visualize and analyze the DFFT and the TFFT as it shows on the figure is Wavepad software. At the edge part of the drum and at room temperature was a better impulse response. At the center of the drum and colder temperature, we get less impulse response.
Figure 3 shows the functional decomposition of the Chladni pattern and impulse response of the drum.

Discussion/Conclusions/Next Steps

- Where the Chladni plate and the sand move a lot are called antinodes, and the places that are not moving are called nodes. To visualize the antinodes and nodes, we need special frequencies. Those special frequencies are called resonant modes. The antinodes and nodes are caused by waves that are traveling out the center and bouncing off the sides and interfering with each other at the right point, so we get standing patterns. The higher the frequency the closer together nodes are, the lower the frequency the farther the nodes are.
- Traveling through a medium, and if the one end of the medium is fixed, the wave reflects back and forth from one end to the other end. When you send continuous waves down the slinky they reflect back. Then, you get two waves one moving away and the other coming back. The two ropes/spring can not be in both places at the same time, so as the incoming wave reflects back, you can't see the two waves but you can see a combination of two waves. The waves add when they are at top of each other, and subtract when they are opposing one another.
- The frequency and impulse response of the drum at the edge was better than at the center, because the drum has better vibration at the edge due to the head being more rigid. At room temperature, the drum had better sound/frequency response than at the colder temperature, because of the stiffness of the drumhead due to temperature change.
- The wave pad software has been a good tool for showing the difference impulse or frequency response of the drum sounds. The FFT and TFFT at the software have helped show and analyze the frequency response of the drum's sound.
- The Chladni pattern can be used for drumhead materials that are stiffer and less damping. Further testing should be done on high quality tom, kettle, or other quality drum materials.
- This system of tests are very useful when used in mechanical engineering labs and are ready to go as is.

Acknowledgements
Dr. James Masi

References:
Zhou, Quan, et al. "Controlling the Motion of Multiple Objects on a Chladni Plate." *Nature News*, Nature Publishing Group, 9 Sept. 2016, www.nature.com/articles/ncomms12764.
Chladni Plates. (n.d.). Retrieved from https://sciencedemonstrations.fas.harvard.edu/presentations/chladni-plates
Ernst Chladni. (n.d.). Retrieved from https://monoskop.org/Ernst_Chladni
"Physics Tutorial: Standing Wave Patterns." *The Physics Classroom*, www.physicsclassroom.com/class/sound/Lesson-4/Standing-Wave-Patterns...
Dr. Masi's Notes from his Acoustics class.