# การสร้างแบบจำลองเครื่องดนตรีไทย ซออู้

# Creating a model of Thai instrument, Saw-U

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Submitted in partial fulfillment of the requirement for
the bachelor’s degree in engineering program
Department of Computer Engineering,
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## คณะวิศวกรรมศาสตร์

## สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง

## ใบรับรองปริญญานิพนธ์

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**หัวข้อปริญญานิพนธ์** การสร้างแบบจำลองเครื่องดนตรีไทย ซออู้

Thesis Title Creating a model of Thai instrument, Saw-U

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# บทคัดย่อ

ในปริญญานิพนธ์นี้ กะโหลกซออู้จำลองจะถูกสร้างขึ้นเพื่อนำมาเปรียบเทียบกับกะโหลกซออู้จริง โดยกะโหลกซออู้จำลองจะถูกออกแบบขึ้นเพื่อถอดแบบสมบัติทางเสียงและการสั่นสะเทือนของกะโหลกซออู้ เป็นการนำเยื่อบางมาประกอบเข้ากับตัวสั่นพ้องของเฮล์มโฮลตซ์ ในการวัด จะใช้ลำโพงในการสร้างสนามเสียงเพื่อกระตุ้นกะโหลกซออู้ และใช้ไมโครโฟนในการเก็บค่าการตอบสนอง เมื่อวิเคราะห์การตอบสนองทางความถี่ พบว่ากะโหลกซออู้จำลองและกะโหลกซออู้จริงมีผลที่คล้ายคลึงกัน และพบจุดสูงสุดการตอบสนองทางความถี่สองจุด โดยจุดที่ต่ำกว่าสัมพันธ์กับการสั่นพ้องของเฮล์มโฮลตซ์และจุดที่สูงกว่าสัมพันธ์กับการสั่นของเยื่อสั่น ความหนาของเยื่อสั่นมีผลต่อการตอบสนองของความถี่ในแบบจำลอง โดยยิ่งหนาจะมีความถี่ที่ต่ำกว่า ความถี่สั่นพ้องเฮล์มโฮลตซ์ของแบบจำลองมีความถี่สั่นพ้องใกล้เคียงกับกะโหลกซออู้จริง ผลการวิจัยของการศึกษานี้บ่งบอกถึงว่าลักษณะทางอะคูสติกของซออู้จริงสามารถคาดการณ์ได้จากแบบจำลอง

**Thesis** Creating a model of Thai instrument, Saw-U
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**Student ID.** 58010120, 58010739, 58011048, 58011317
**Degree** Bachelor of Engineering
**Program** Music engineering and Multimedia
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**Thesis Advisor** Asst. Prof. Dr. Munhum Park

## Abstract

In this thesis, a mock-up instrument was made and compared to an actual Saw-U. The mock-up instrument was designed to approximate the vibro-acoustical properties of the actual instrument resonator; a vibrating membrane coupled with a Helmholtz resonator. A loudspeaker was used to generate soundfield to excite the resonator, and its response was captured by a microphone. By analyzing the frequency response, the model and the actual instruments were found quite similar. Two significant peaks were found; the lower is related to the Helmholtz resonance and the higher, the membrane vibration. The thickness of the membrane affects the frequency response of the model: The thicker the membrane is, the lower the resonance frequency is. The Helmholtz resonance frequency of the model is similar to the one of the resonance frequencies of the actual Saw-U. The findings in this study imply that the acoustic characteristics of the actual Saw-U can be predicted well by the model.

# Acknowledgment

This thesis was completed successfully because of the support from many important people. First, we want to thank Asst.Prof. Munhum Park, our thesis advisor for guiding us and giving us advice through this thesis. Second, the faculty of engineering, department of music engineering and multimedia for providing us with equipment and budget for our research. Thank you Mr. Kajornpop Toboonchuay, the master degree student from the faculty of science, department of applied physics for advice; Mr. Manoch Pudpong, the Saw-U maker for the knowledge and helping us with leather mounting; Mr.Chawarith Prasit, Mr.Sakda sakorntana for helping with this thesis.

Miss Kewalin Hiruncharrukorn
Mr. Pruch Sawetratanastien
Mr. Ravee Changsalak
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# Chapter 1

# Introduction

## 1.1 Background and importance

Saw-U (ซออู้) is a traditional Thai fiddle (Saw, ซอ), of which the pitch range is the lowest among the Thai fiddles, including Saw-Duang (ซอด้วง) and Saw-Samsai (ซอสามสาย). The sound of Saw-U comes from the coconut shell that is mounted with a membrane and, when the string is bowed, the vibration of the string is transferred to the bridge causing the membrane to vibrate. This thesis is focused on finding the characteristics of Saw-U and studying how the membrane and coconut shell (resonator) influences the sound. So, related theories were studied: The Helmholtz resonator, a phenomenon of air resonance in a cavity; the modes of a circular membrane. A model instrument was built, similar to a real Saw-U in terms of the size and material characteristics. The acoustical characteristics was compared between the model and a real Saw-U.

## 1.2 Purpose and objectives

The purpose of this thesis is to study the sound characteristic of the actual Saw-U because Thai instruments have little scientific data about how the instruments produce the sound. The shape of other Thai instruments such as Thai xylophone (ระนาด) and Thai zither (จะเข้) can be controlled but Saw-U is made from coconut shell which is a natural resource and the shape and dimension cannot be controlled. So, the model was made by simplify combining a Helmholtz resonator and a vibrating membrane, as a reference model which is geometrically easier to study, so that the shape could be controlled to compare the frequency response with the actual resonator. The scientific data of this model and the actual resonator were collected.

## 1.3 Research hypotheses

In this thesis, the researcher studied the theories that might explain the production of sound: Helmholtz resonator and modes of a circular membrane. Then these two theories were used to make the model. Both the actual resonator and the model were measured then compared their frequency responses. The assumed hypotheses were

1.3.1 The sound is produced from a resonator.

1.3.2 The underlying theories are Helmholtz resonator and modes of circular membrane.

1.3.3 The major factors might be the volume of the resonator, the size of the sound hole, and the thickness of the membrane.

1.3.4 The material of the resonator might be a minor factor that affects the sound characteristics of Saw-U.

1.3.5 If all conditions are same, the frequency responses of the actual resonator and the model might be similar.

1.3.6 If how the resonator produces sound is known, researcher might find a way to adjust the actual Saw-U, consisting of coconut shell and membrane and to make the frequency response and the sound characteristic of all Saw-U as designed.

### 1.4 Scope of project

1.4.1 Studying the making of the actual Saw-U.

1.4.2 Studying the theories.

Helmholtz resonator and the modes of circular membrane.

1.4.3 Studying the materials used to make a model instrument.

1.4.4 Drawing the model in the FreeCAD program and manufacture it.

1.4.5 Studying how to measure the frequency response.

1.4.6 Setting up the measurement room and prepare the equipment.

1.4.7 Measuring the actual resonator and the model to measure the frequency response by using Python program

1.4.8 Comparing the frequency response between two resonators.

1.4.9 Period of time

Second term, academic year of 2018, 14 weeks.

1.4.10 Subjects used in research work

Subjects used in this project is 01136404 Music Engineering and multimedia innovation project according to the bachelor’s degree program of the Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang.

1.4.11 Research facility

The recording studio of Institute of Music, Science and Engineering in HM building, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang.

1.4.12 Limitation of research

1.4.12.1 Limited time of the research

Time for the research is too short that cannot make more types of other materials for the resonator, so that researcher could compare between the materials.

1.4.12.2 Limited budget for the research

Researcher could make the model in only one material because the budget is limited. The price for making the model is quite high.

## Chapter 2

# Literature review

This thesis is focused on the mechanical behavior of the resonator of the Thai instrument, Saw-U. The sound of Saw-U originates from the coconut shell that is mounted with a membrane. When the string is bowed, the vibration of the string is transferred to the bridge causing the membrane to vibrate. But little is known about how this resonator can produce the sound. In our project, the Saw-U resonator was modeled as the combination of Helmholtz resonator and circular vibrating membrane.

### 2.1 The model of resonator

The resonator was modeled as a system consisting of a circular membrane of radius $a$. The membrane covers the cavity of volume $Vo$ and pressure $P_o$. A circular hole at the opposite side of the membrane is present as to simulate the sound holes of the instrument and to approximate this system as a Helmholtz resonator. The hole is a circular open-ended tube with surface area $S_H$ of length $L$.

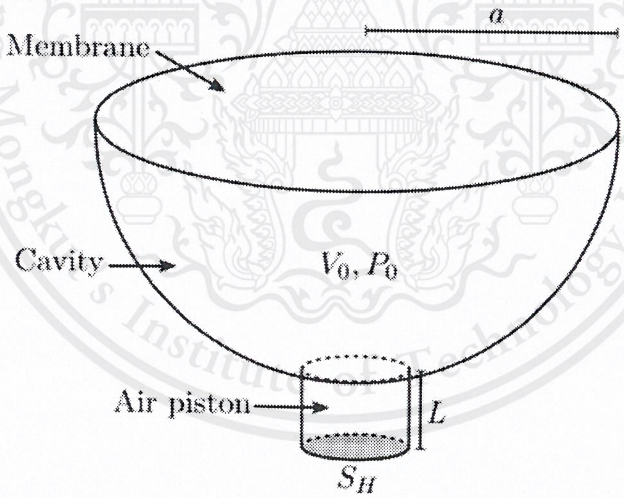


**Figure 2.1** Saw-U modelled by a Helmholtz resonator and a vibrating membrane.

## 2.2 Helmholtz resonator

The Helmholtz resonator is shown in figure 2.2. The air in the resonator acts as a spring and the air in the port acts as a mass which will vibrate because of the air inside the cavity.

When something disturbs the object, the natural frequency of the object will occur. Natural frequency is associated with the standing wave patterns from the vibration of the object. Resonance takes place when one system vibrates at the same natural frequency of a second system, which forces the second object to vibrate at a very high amplitude at the same frequency.

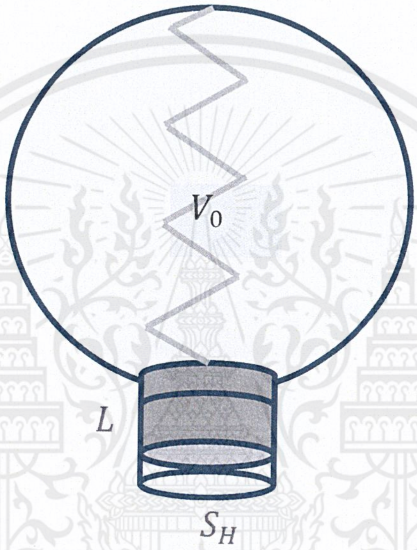


**Figure 2.2** Helmholtz resonator

Resonance frequency of the Helmholtz resonator, $f_{res}$, is proportional to the speed of sound $c$, and the square root of the cross-sectional area $S_H$ of the port, but inversely proportional to the square root of the volume of the resonator excluding the port, and the length of the port $L$ as shown in equation (2.1). So, the Helmholtz resonator has only one resonance frequency.

$$f_{res} = \frac{c}{2\pi}\sqrt{\frac{S_H}{VL_e}} \tag{2.1}$$

In the real resonator, the acoustic pressure at the opening of a tube is not perfectly released, as if there is an extension of the port, and so the effective length, $L_e$ was considered which is longer than the actual length depending on whether the opening is flanged or not. For the circular opening of radius $a$, the surface area is $\pi a^2$.

The length $0.85a$ or $\frac{8}{3\pi}a$ is the correction factor for the flanged end of the port that opens into the interior of the resonator as shown in figure 2.3(b), and $0.6a$ is the correction for the unflanged end of the port that opens to atmosphere as shown in figure 2.3(a). The total effective mass of the air in the tube is given by equation (2.2), when the opening of inner port is flanged.

$$M_p = \rho_0 S_H L_e \tag{2.2}$$

Where $L_e$, the effective length of the port, is

$$L_e = L + (0.85 + 0.85)a = L + 1.7a \quad \text{(outer end flanged)}$$
$$L_e = L + (0.85 + 0.6)a = L + 1.45a \quad \text{(outer end unflanged)} \tag{2.3}$$

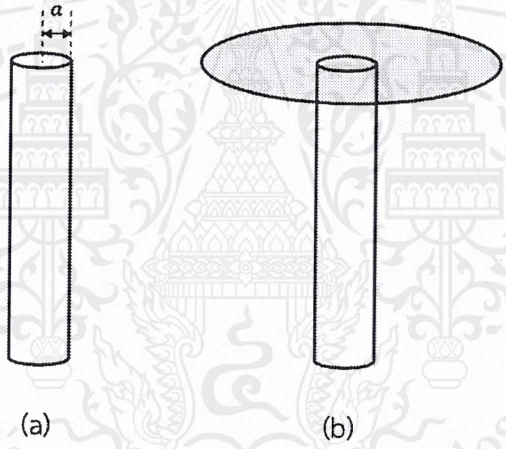


**Figure 2.3** (a) Unflanged end and (b) Flanged end

The system has the stiffness $s$ when the port is fitted with airtight piston. When the mass moves by $\varkappa$, the volume of the cavity is changed by $\Delta V = S_H\varkappa$ and the pressure $p$ is caused by the decompression of the volume

$$p = -B \cdot \frac{\Delta V}{V} \tag{2.4}$$

where $B$ is Bulk modulus.

The force $f$, required to maintain the displacement is $f = S_H p = s\varkappa$. When this pressure pulls down the mass (air), the effective stiffness $s$ is

$$s = \frac{\rho_0 c^2 S_H{}^2}{V}. \tag{2.5}$$

Natural frequency of this mass-spring system $\omega_0$ is

$$\omega_0 = \sqrt{\frac{s}{M_p}} = c\sqrt{\frac{S_H}{LV}}. \tag{2.6}$$

### 2.3 Modes of circular membrane

Modes of vibration are a collection of resonances from standing waves that exist in the system. The characteristic of the standing wave consists of antinodes and nodes. Antinodes are produced at locations where constructive interference occurs, and nodes are produced at locations where destructive interference occurs.

Consider a two-dimensional elastic membrane with uniform thickness, attached to a rigid frame, under the tension that can support transverse vibrations such as drumhead. Due to the phenomenon of resonance, at its resonance frequencies, the membrane can store vibrational energy, and so, the surface vibrates in characteristic patterns of standing waves. These are called normal modes. A membrane has an infinite number of these normal modes, starting with the lowest frequency, called the fundamental mode.

The fundamental frequency of a circular membrane has some similarities to that of a stretched string in that it depends on tension and density. The fundamental mode of an ideal circular membrane is given by:

$$f_1 = 0.766\,\frac{\sqrt{T/\sigma}}{D} \tag{2.7}$$

where $T$ is the membrane tension in N/m, $\sigma$ is density in kg/m$^2$ and $D$ is the diameter of membrane in meter.

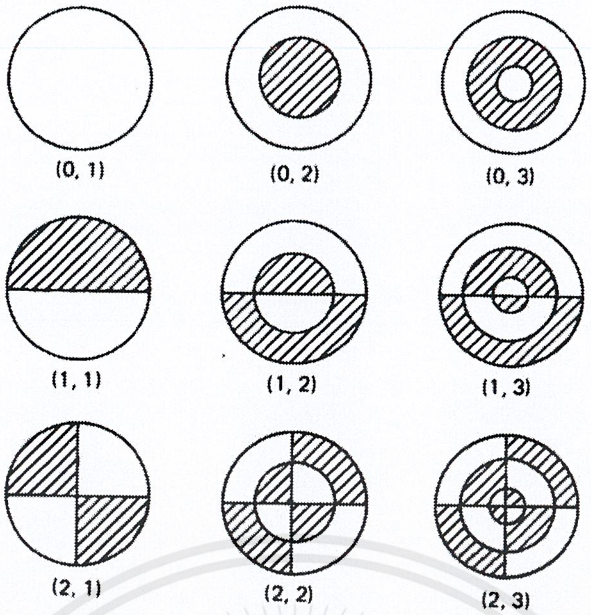


**Figure 2.4** Normal modes of a circular membrane

(**Source:** Fundamental of acoustics book, $4^{th}$edition)

The mode shape of circular membrane with fixed rim is shown in figure 2.4. The modes are designated by the pair of integers $(m, n)$, the integer $m$ is the number of radial nodal lines and $n$ is the number of nodal circles; $n = 1$ is the minimum value and corresponds to a mode of vibration in which nodal circle occurs at the fixed boundary of the membrane. A node is a point (or line) on a structure that does not move while the rest of the structure is vibrating. Figure 2.5 shows the vertical displacement of a circular membrane vibrating in a $(1, 2)$ mode.

For each $m$ there exists a sequence of modes with increasing frequency. Figure 2.6 lists a few of frequencies $f_{mn}$, where the fundamental frequency is $f_{01}$ and others are the overtones of the harmonics of the fundamental.

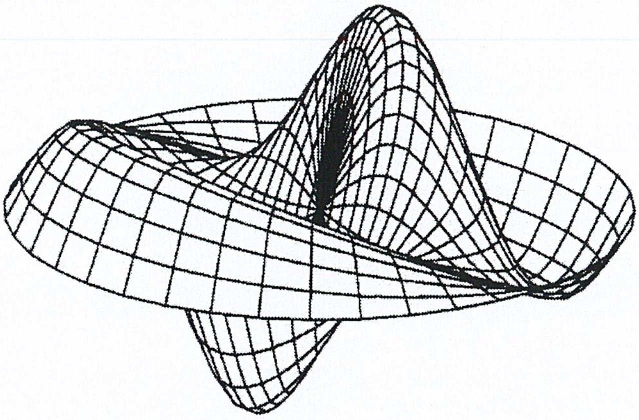


**Figure 2.5** Isometric view of the displacement in a (1, 2) mode

(**Source:** Fundamental of acoustics book, 4$^{th}$edition)

$$\begin{array}{lll}
f_{01} = 1.0f_{01} & f_{11} = 1.593f_{01} & f_{21} = 2.135f_{01} \\
f_{02} = 2.295f_{01} & f_{12} = 2.917f_{01} & f_{22} = 3.500f_{01} \\
f_{03} = 3.598f_{01} & f_{13} = 4.230f_{01} & f_{23} = 4.832f_{01}
\end{array}$$

**Figure 2.6** Normal mode frequencies of a circular membrane

### 2.4 Previous studies

In Thailand, studies about the Thai instrument, Saw-U can be grouped in 3 categories: the production of Saw-U, alternative materials and the sound synthesis. Aree (2011), ธารีไทย (2013), แก้วกองมูล (2014) and Sangmanee (2017) studied the process of making Thai fiddle. Punwaratorn (2016) attempted to use fiberglass to create a resonator. Malin and Meesawat (2015) worked on the sound synthesis of Saw-U. Lastly, Arunrat (1994) studied about re-creating the sound box for Saw-Samsai and the factors which generate the sound are the curvature of the back of the sound box and the volume. He also studied the waveforms of the instrument sounds, but other acoustic properties such as frequency response and spectrum were not investigated.

A theoretical model similar to ours is mentioned in Christensen and Visitsen (1980). They modeled a guitar as figure 2.7, consisting of cavity, top plate and sound hole. A newtonian equation of motion was used to calculate the frequency response. The result explained the principle underlining the 2 lowest resonances of the guitar and predicted the frequency response accurately.

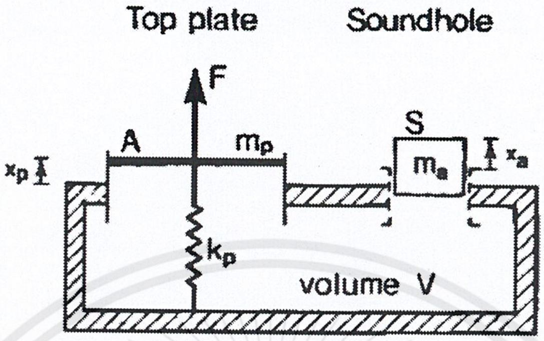


**Figure 2.7** Modeled guitar by Christensen and Visitsen

(**Source:** Simple model for low-frequency guitar function, 1980)

The cavity is similar to our resonator, top plate is similar to our membrane, and the sound hole is the same as in our model. The main differences are the position of the sound hole and the nature of the vibrating structure: Guitar model includes a plate, but our model has a membrane.

# Chapter 3

# Methods

To create the model of Saw-U, researcher had to study the acoustic characteristic of the actual Saw-U by measuring the frequency response of the resonator. The Helmholtz resonator theory was used to explain the principle of Saw-U resonator. In the measurement, the frequency response of both the actual Saw-U resonator and the model was measured, and then compared them to find acoustical differences and to confirm that Helmholtz resonator theory explain the production of the sound by this instrument. The creation process started from the materials selection processed to the assembled of the model. The researcher has set guidelines in order to achieve objectives as follows.

## 3.1 Creating a model of Saw-U

### 3.1.1 Studying the actual instrument

The actual Saw-U was studied to create a model that is similar in acoustic characteristic to the actual one (the shape, the volume, and the acoustical properties of the actual Saw-U was studied). The resonator, in Thai is called “กะโหลก (skull)”, is affected to the sound characteristic. researcher also studied the materials to use for the model. Then the volume of the actual resonator to design the model was measured.

Volume of the resonator model: 1580 $cm^3$

Radius of the membrane: 6 cm

Radius of the hole: 1.5 cm

Length of tube: 5 cm

**Figure 3.1** the actual resonator

3.1.2 Studying the materials

3D-printing was chosen for the resonator model because it is easier to make than other materials and the size and shape of model can be exactly the same as our design. For the materials of the 3D-printing, Polylactid acid (PLA) was used for the resonator and tube, and Polyethylene Terephthalate (PETG) was used for the ring of the membrane. PLA is rigid and quite strong but the easiest to print with good visual quality at low cost PETG is a material less rigid than PLA with good impact resistance, thus stronger than PLA, and it has a slightly softer surface, more suitable to make it as a ring. However, PETG is more expensive than PLA.

**Figure 3.2** Printing the 3D-model

3.1.3 Designing the model

After the materials were chosen for making the resonator, researcher designed by using FreeCAD program. FreeCAD is a general-purpose feature-based, parametric 3D modeler for CAD, MCAD, CAx, CAE and PLM [10]. The model was separated in 3 parts: Ring, resonator, and tube because researcher wanted to measure the model under many conditions.

The design is based on the actual Saw-U that was studied. The volume and radius are equal to the actual Saw-U. See in appendix A.

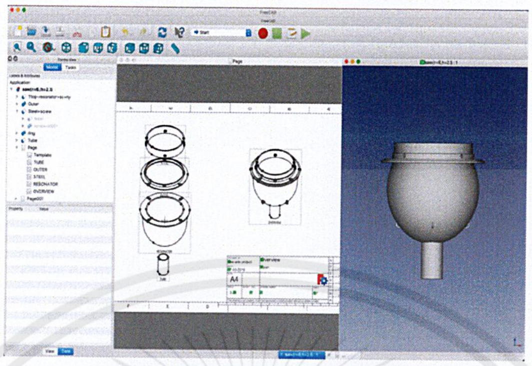


**Figure 3.3** FREECAD Program interface

**Figure 3.4** the 3D-model

3.1.4 Making the membranes

After the ring was printed, then the cow skin was mouted over the rings with varying thickness at the Bang Pakong Fiddle House Workshop. The thickest is number 1, medium thickness is number 2, and the thinnest is number 3.

For the details of the manufacturing process of actual Saw-U at the Bang Pakong Fiddle House Workshop, see in appendix B.

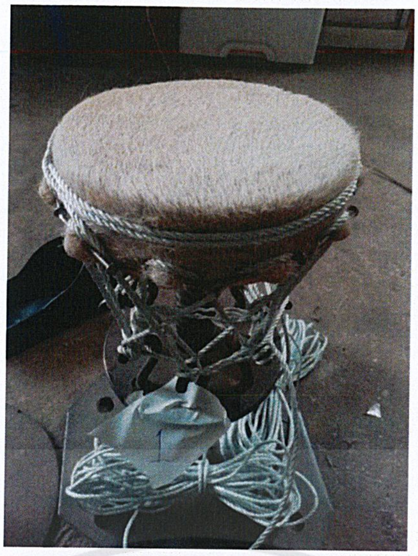


**Figure 3.5** stretching the cow skin

3.1.5 Combining the resonator, tube, and cow skin membrane together.

**Figure 3.6** the complete model

The complete model with the handle was already assembled to compare between the sound quality of the model and the actual, see in appendix C.

### 3.2 Measurement

3.2.1 Equipment

3.2.1.1 Audio Interface Yamaha Steinberg UR22

The UR22 from Steinberg is a two-input, two-output USB 2.0 audio interface that features dual D-PRE microphone preamps coupled with 24-bit/192 kHz converters. With a dedicated high-impedance switch, a separate headphone jack, and phantom power supply. [11]

**Figure 3.7** Steinberg UR22, Yamaha, Hamburg, Deutschland, Germany

(**Source:** https://www.soundonsound.com/reviews/steinberg-ur22)

<u>Specification</u>

- 2-Input / 2-Output
- D-Pre Mic Preamps with Phantom Power
- MIDI I/O
- Latency-Free Hardware Monitoring
- Loopback Function
- USB Bus-Powered
- iPad-Ready
- 24-Bit/192 kHz

3.2.1.2 Microphone DBX RTA-M

The RTA-M is an omni-directional, flat frequency measurement microphone specially designed for the Drive rack series to pick up all frequencies from 20 Hz to 20 kHz, ensuring accurate "pinking"/real-time analysis of your audio. It runs on phantom power (supplied by the Drive rack units) and comes with a clip and case.[12]

**Figure 3.8** RTA-M, DBX, Northridge, California, USA

(**Source:** https://www.bhphotovideo.com/c/product/dbx_RTA_M_Microphone.html)

Specification

- Polar Pattern: omni-directional
- Element: back electret-Condenser
- Frequency Response: 20 Hz - 20 kHz
- Impedance: 250 30% (at 1,000Hz)
- Sensitivity: -63 dB +-3 dB
- Operating Voltage: phantom power 9V-52VDC

### 3.2.1.3 Loudspeaker JBL LSR305

Bi-amplified Studio Monitor with Magnetically-Shielded 5” Low Frequency Transducer and 1” Soft-Dome High Frequency Transducer and Image Control Wave Guide. LSR305 Includes US Power Cord. LSR305/230 Includes international Power Cord.

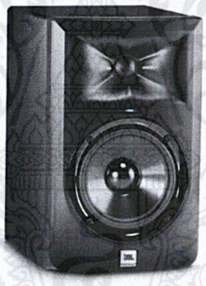


**Figure 3.9** LSR305, JBL, Northridge, California, USA

(**Source:** http://www.jblpro.com/lsr305#.XMa5NpMzbow)

Specification

- JBL
- Frequency range: 43 Hz – 24 kHz
- Max peak SPL: 108 dB SPL C-weighted
- Max peak input: +23 dBu
- LF driver size: 5 in (127 mm)
- HF driver size: 1in (25 mm)

- LF driver power amp: 41 W Class D
- HF driver power amp: 41 W Class D
- LF trim control: +2 dB, 0, -2 dB
- HF trim control: +2 dB, 0, -2 dB
- Input types: (1) XLR, (1) TRS Balanced
- AC input voltage: 100-240 VAC +/- 10% 50/60 Hz

### 3.2.1.4 Sound pressure level meter CEM DT-8852

These meters are designed for noise project; quality control; illness prevention and cure and all kinds of environmental sounds measurement. It is applied to the sound measurement at factory; school; office; traffic access and household, etc.

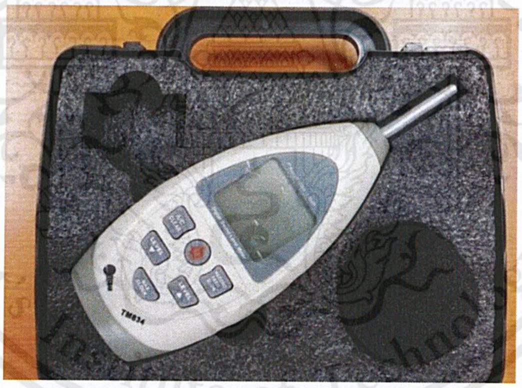


**Figure 3.10** Tm834, Tecman, China

(**Source:** http://www.kbthaiscale.com/product/182/เครื่องวัดเสียง-พร้อมซอฟต์แวร์-usb-sound-level-meter-30-130db-tecman-tm834)

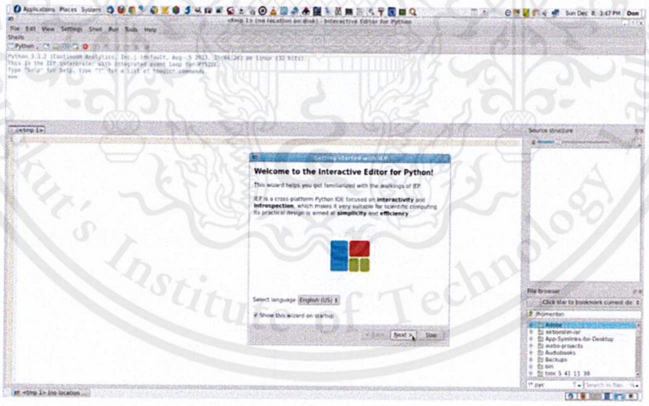
Specification

- Measuring Range: 30~130dBA(35~130dBC)
- Accuracy: ±1.5dB
- Frequency Range: 31.5HZ-8.5KHZ
- Linearity Range: 50dB
- Digits Resolution: 5Digits & 0.1dB

- Time Weighting Selection: Fast/Slow
- Microphone: 1/2 Inch Electret Condense Microphone
- Frequency Weighting: A & C
- Sampling Frequency: Fast 2 times/s
- Slow 1 times/sec
- Power: 1.5V AA*4 Alkaline or DC Adapter
- Weight: 280g
- Size: 221*78*35mm

#### 3.2.1.7 Software Pyzo IEP

The Python programming language is the basis for a large community thriving on open source software, and is used for a broad range of tasks. Python is designed to be easy to read and might well be the easiest programming language to learn. Nevertheless, it is really complete and powerful, and by using extension code, the crucial parts of an algorithm can be made as fast as C [9].



**Welcome to the Interactive Editor for Python!**

This wizard helps you get familiarized with the workings of IEP.

IEP is a cross-platform Python IDE focused on **interactivity** and **introspection**, which makes it very suitable for scientific computing. Its practical design is aimed at **simplicity** and **efficiency**.

Select language: English (US)

☑ Show this wizard on startup

**Figure 3.11** Pyzo IEP

(**Source:** http://dons-deals.blogspot.com/2013/12/pyzo-python-to-people.html)

### 3.2.2 Measurement

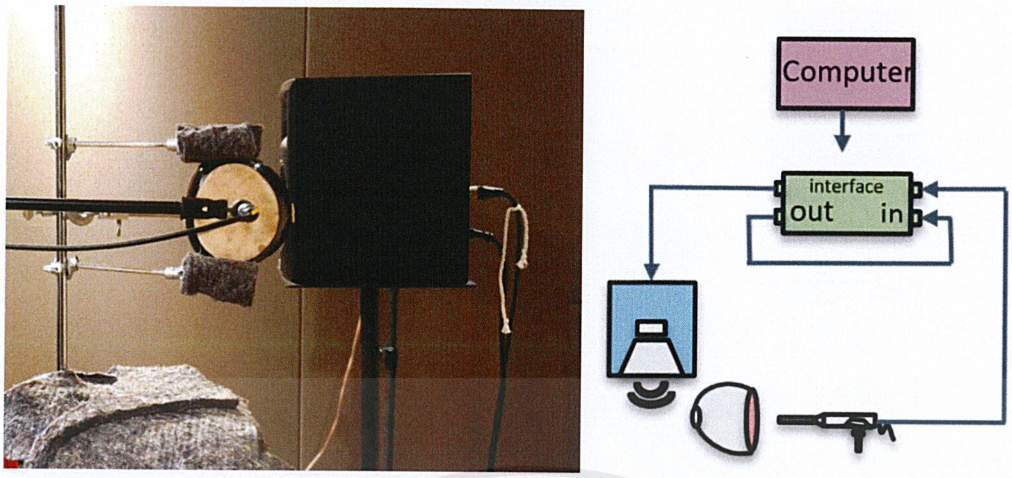


**Figure 3.12** Measurement block diagram

The sound field was measured which is the dispersion of sound energy within given boundaries. The sound source was sine sweep from the loudspeaker, because researcher wanted the resonator to vibrate in all frequencies, and the receiver was the microphone. The height of the loudspeaker was 130 cm and set them at the center of the room, to minimize the sound reflection from the floor, wall, and the ceiling, absorber was used to wrap the loudspeaker stand made of metal. Distance between the microphone and the resonator was 10 cm, because researcher wanted only the first impulse from the results discarding unwanted reflections. Angle between the loudspeaker and the resonator was 90 degree because researcher didn't want the sound from loudspeaker to go directly to the microphone, and to excite only the resonator.

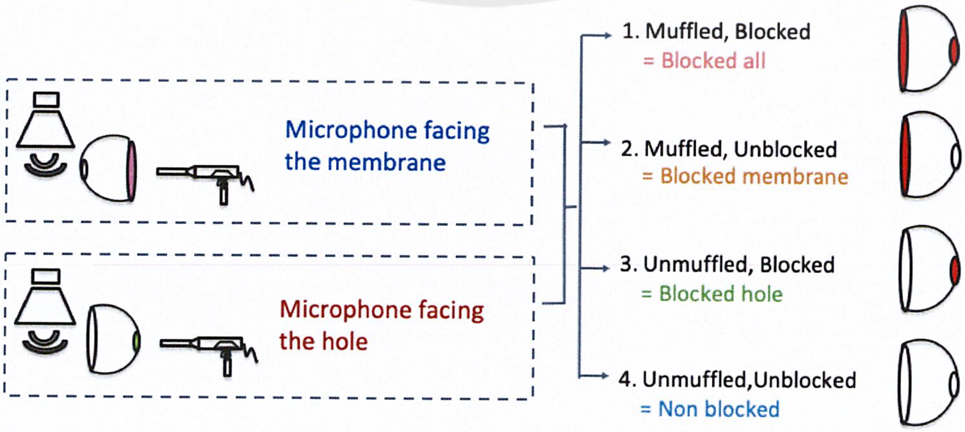


**Figure 3.13** Conditions

There were 8 conditions to measure depending on the facing of the microphone (two conditions; see Figure 3.15) and the muffling of the membrane and the blocking of the hold as follows:

3.2.2.1 Muffled the membrane, Blocked the hole, called "Blocked all".

3.2.2.2 Muffled the membrane, Unblocked the hole, called "Blocked membrane".

3.2.2.3 Unmuffled the membrane, Blocked the hole, called "Blocked hole".

3.2.2.4 Unmuffled the membrane, Unblocked the hole, called "Non blocked".

The membrane was muffled by using the metal rod to touch the middle of the membrane. The hole was blocked by using some soft cloth and tape. Many conditions were measured because researcher want to know what affect the production of sound and which condition will most effectively reveal the differences between the model and the actual Saw-U.

### 3.2.3 Collecting the data

In the data collecting process, data were classified into two parts consisting of the frequency response from the actual resonator and from model resonator. In each part, the result was separated by the condition. Figure 3.16 shows the measured frequency response also including input signal, output signal and impulse response.

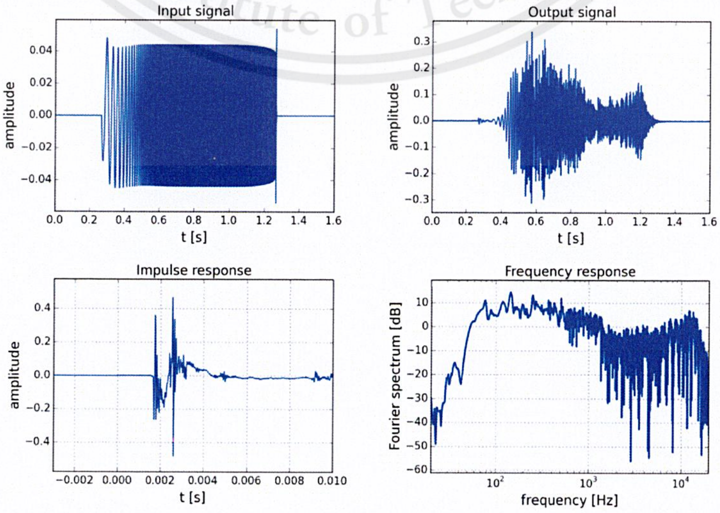


**Figure 3.14** The result form the measurement

### 3.3 Analysis

To analyze the frequency response, the results from the following three conditions, “non-blocked”, “blocked membrane” and “blocked hole” were divided by the frequency response from the “blocked all” condition. “Blocked all” was chosen as a reference because this system may least react to the excitation. Helmholtz resonance frequency was calculated and compared with the measurement by using eq. 2.1.

# Chapter 4

# Results & Discussion

## 4.1 Overview

Figures 4.1 and 4.2 show the frequency responses from actual Saw-U, measured with microphone facing the membrane and microphone facing the hole, respectively. In each graph, "non-blocked", "blocked membrane" and "blocked hole" are compared. Frequency response is shown in logarithm (dB) on the linear frequency scale [Hz].

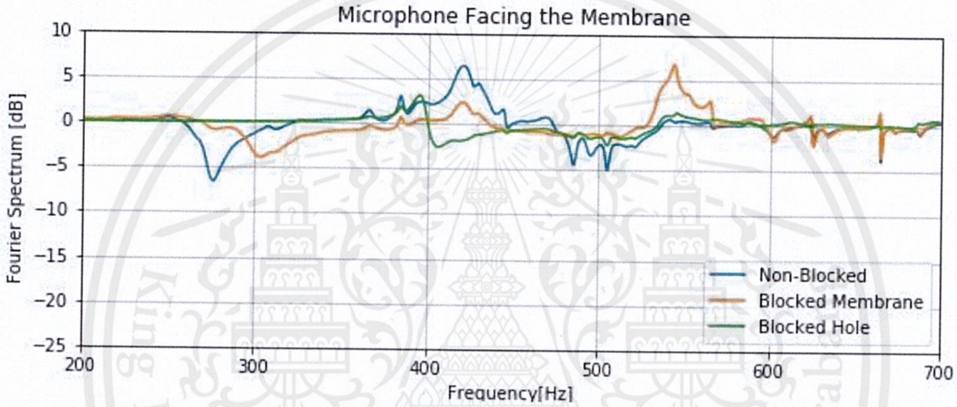


**Figure 4.1** Frequency response of actual Saw-U (microphone facing the membrane)

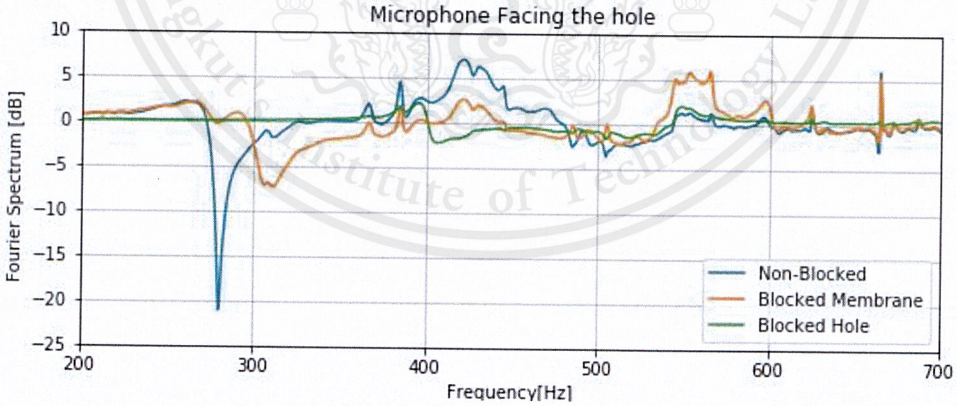


**Figure 4.2** Frequency response of actual Saw-U (microphone facing the hole)

From the results of the actual Saw-U, peaks can commonly be found at 420 Hz and 550 Hz. Both figures 4.1 and 4.2 are similar to each other but are slightly different in level. At 420 Hz, the non-blocked condition has the highest level, followed by the blocked-membrane, and the lowest peak for the blocked hole condition. This is because, when the hole is blocked, there is no hole to act as a port for the Helmholtz resonator. From the calculation, Helmholtz resonance frequency is about 300 Hz. The results from the microphone facing the hole are shown in figure 4.2. The results with the microphone facing the membrane is not shown as the graph because the difference of the low frequency is not precise.

Figures 4.3, 4.4 and 4.5 show the frequency responses, measured with the microphone facing the hole where the model Saw-U was equipped with membrane number 1, 2 and 3 (from the thickest to thinnest) respectively. The graphs below are "non-blocked", "blocked membrane" and "blocked hole" respectively.

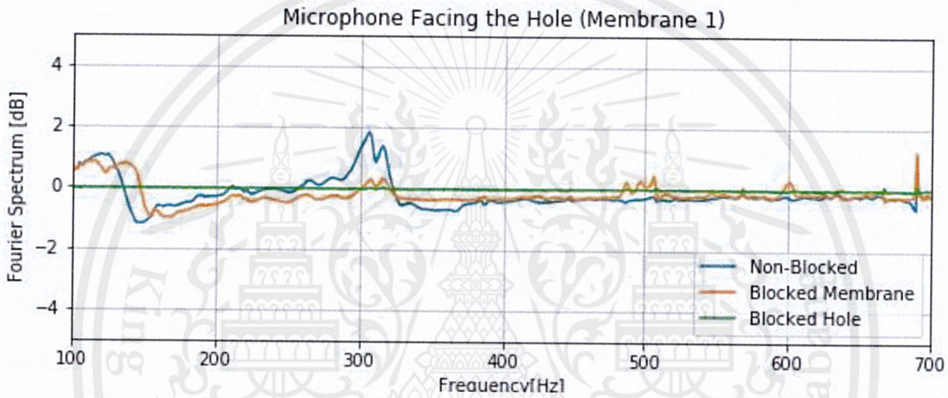


**Figure 4.3** Frequency response of model Saw-U (membrane 1)

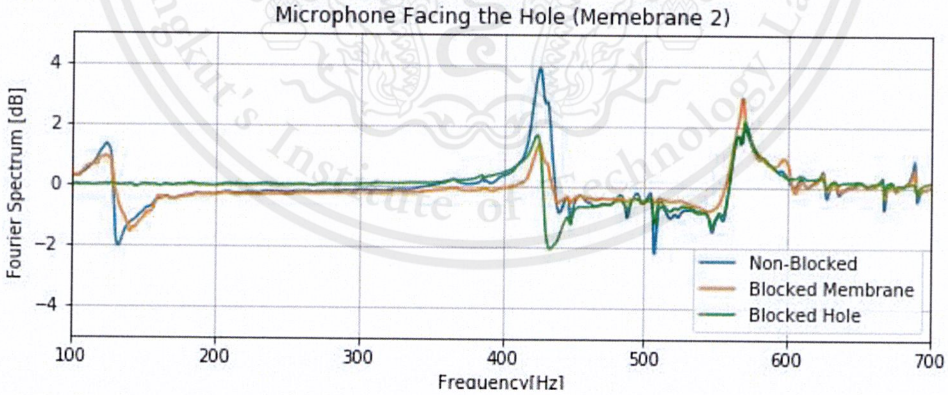


**Figure 4.4** Frequency response of model Saw-U (membrane 2)

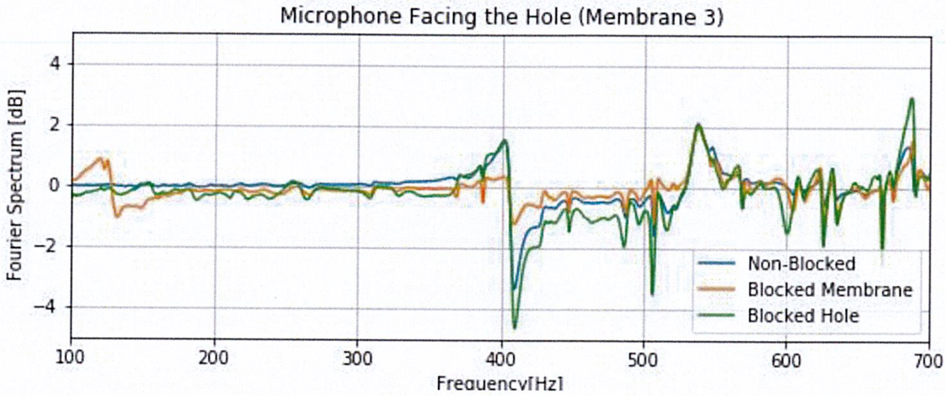


**Figure 4.5** Frequency response of model Saw-U (membrane 3)

From the model Saw-U, the first peak is close to the Helmholtz resonance frequency which is 130 Hz, and the second peak is shifted as the thickness of membrane varied; the thinnest membrane shows the highest frequency.

### 4.2 Actual Saw-U versus model Saw-U

From the results, the frequency response of the actual and the model show similar trends. The frequency response of the blocked-hole condition is flat and the peak is close to the Helmholtz resonance frequency. So, the first peak might have resulted from the hole. The second peak is shifted depending on the tension of the membrane. It can be concluded that the second peak might be from the membrane. The loudness level of the model is lower than the actual Saw-U. This maybe because the body of the resonator of the actual Saw-U also vibrates.

# Chapter 5

# Summary

The 3D-Printing is finished. The acoustic characteristics of the model were similar to those of the actual instrument. From the results, it can be concluded that the thickness of the membrane and the properties of the port affect the frequency response of Saw-U.

Although Saw-U is one of the popular Thai instruments, little scientific data exist regarding the sounding mechanism. The results from the current project provides a set of scientific data which Saw-U makers might be able to use to control the acoustic characteristics of the resonator: By adjusting the volume of the resonator and surface area of the membrane. Also, instrument makers will be able to use the current data to standardize this and similar types of Thai instruments.

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[9] https://pyzo.org/about_python.html

[10] https://sourceforge.net/projects/free-cad/

[11] https://www.bhphotovideo.com/c/product

[12] https://dbxpro.com/en/products/rta-m

# Appendix A

## The drawing of the model

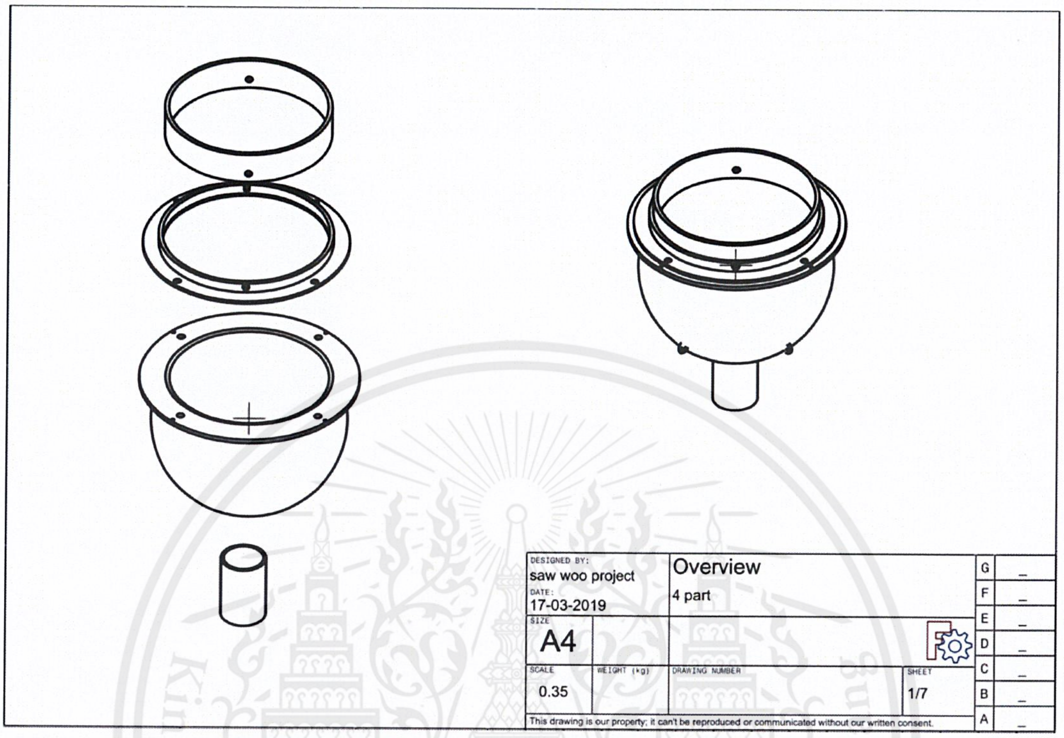


**Figure A.1** Overview of model Saw-U

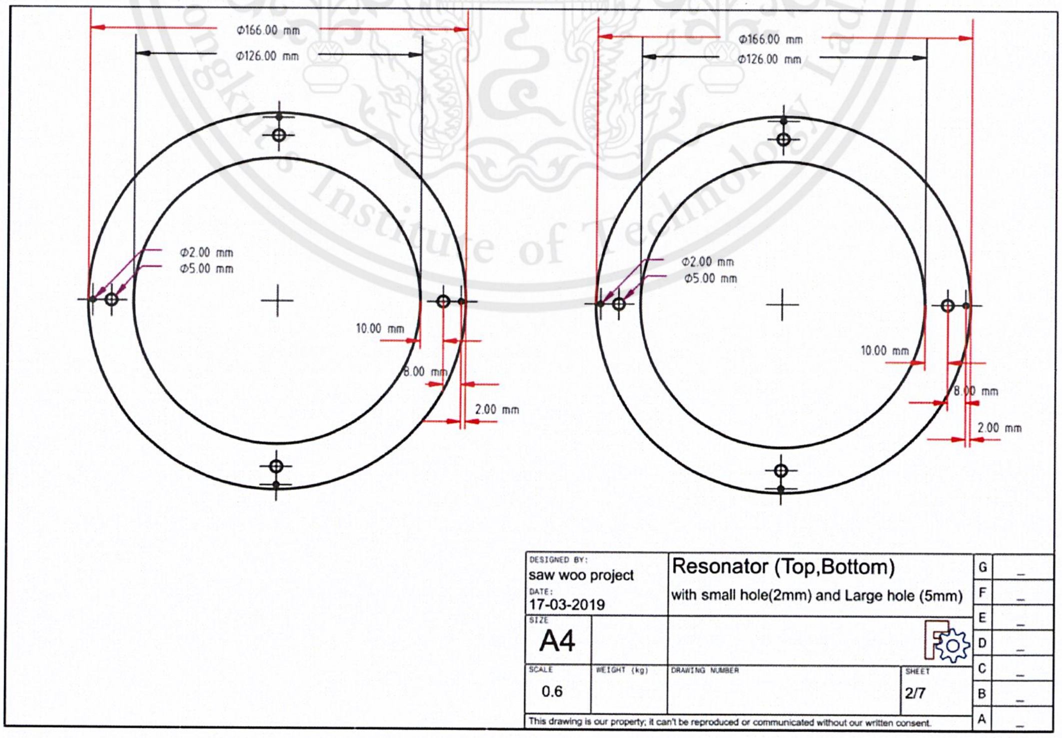


**Figure A.2** Resonator of model Saw-U (Top, Bottom)

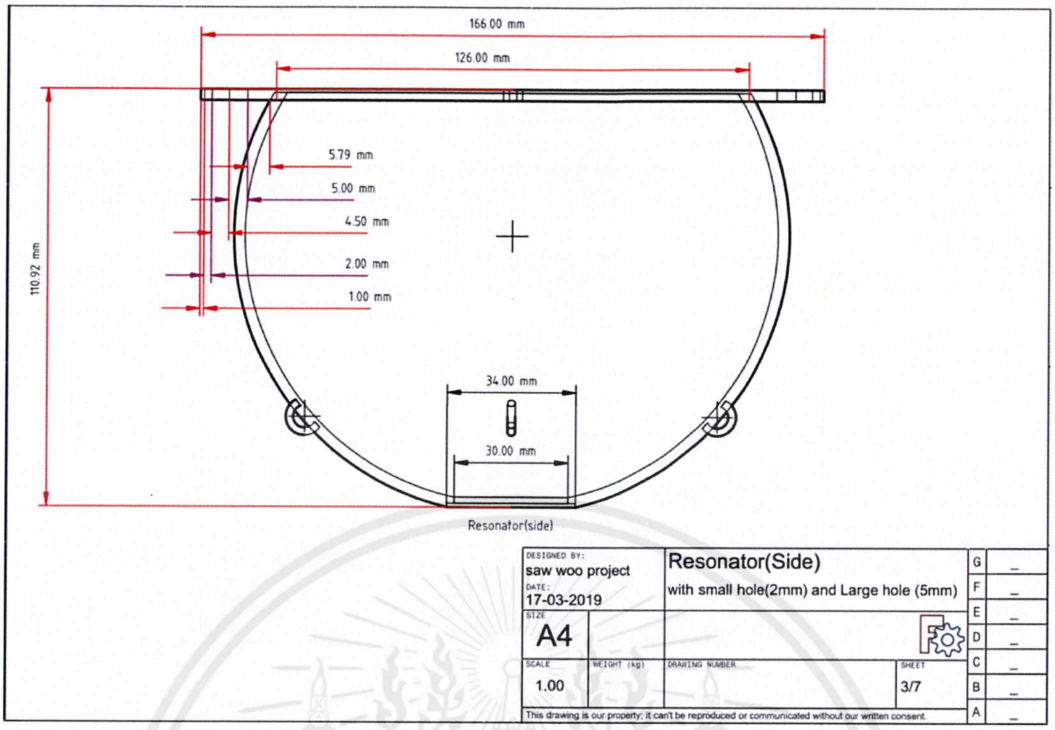


**Figure A.3** Resonator of model Saw-U (Side)

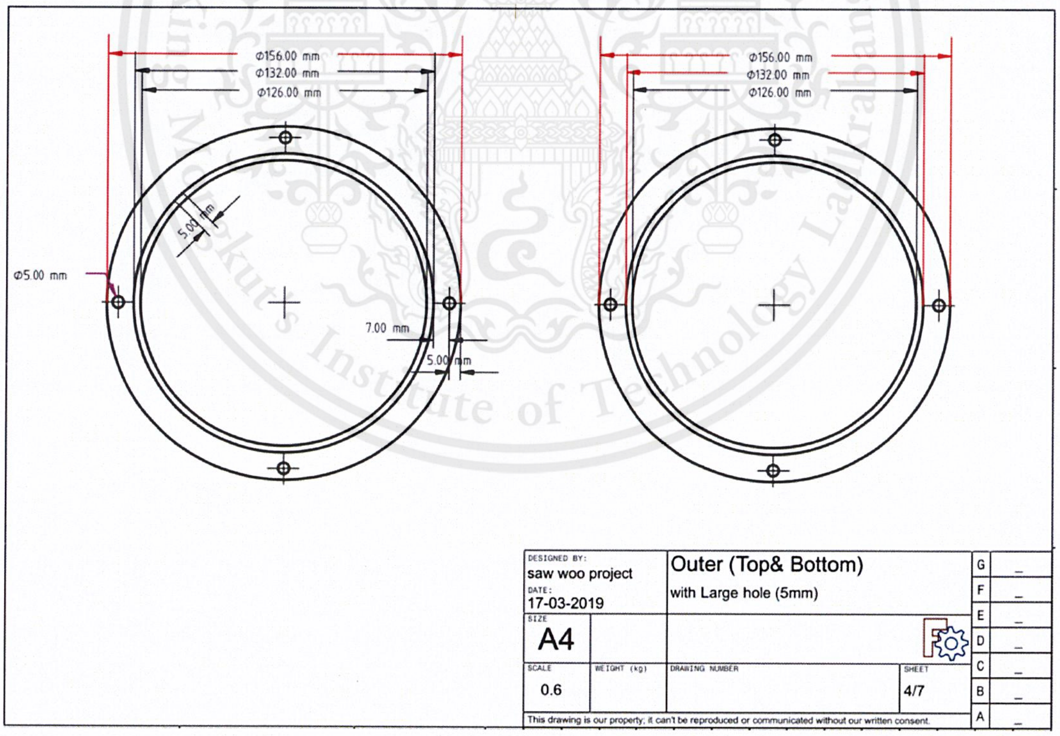


**Figure A.4** Outer of model Saw-U (Top, Bottom)

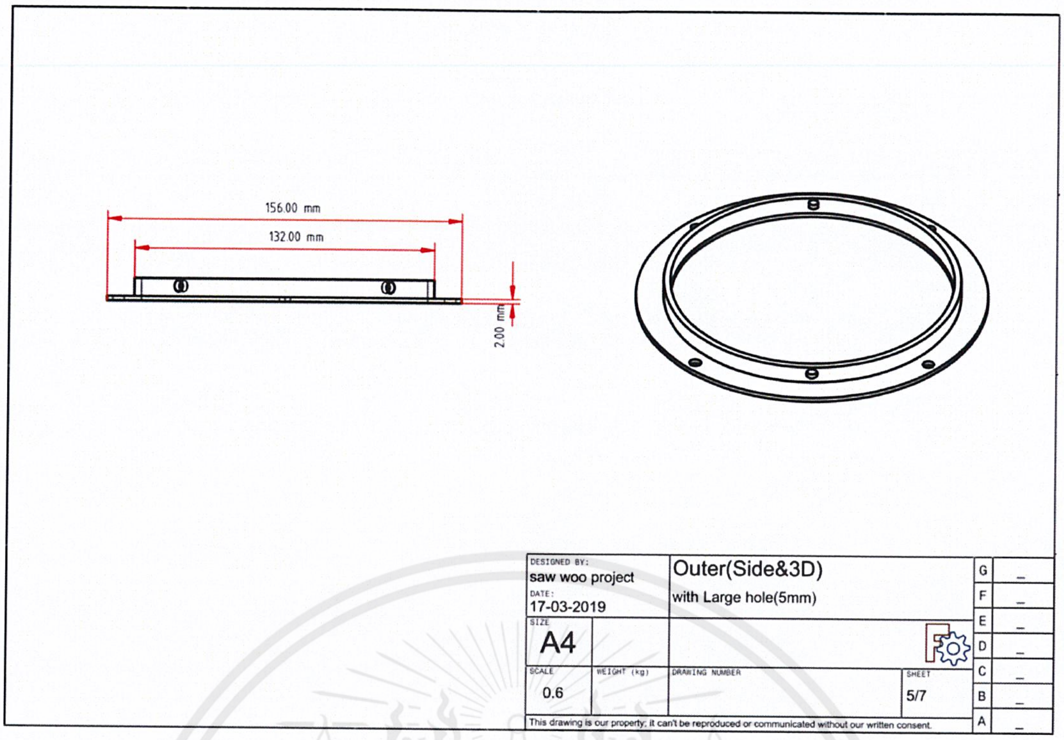


**Figure A.5** Outer of model Saw-U (Side, 3D)

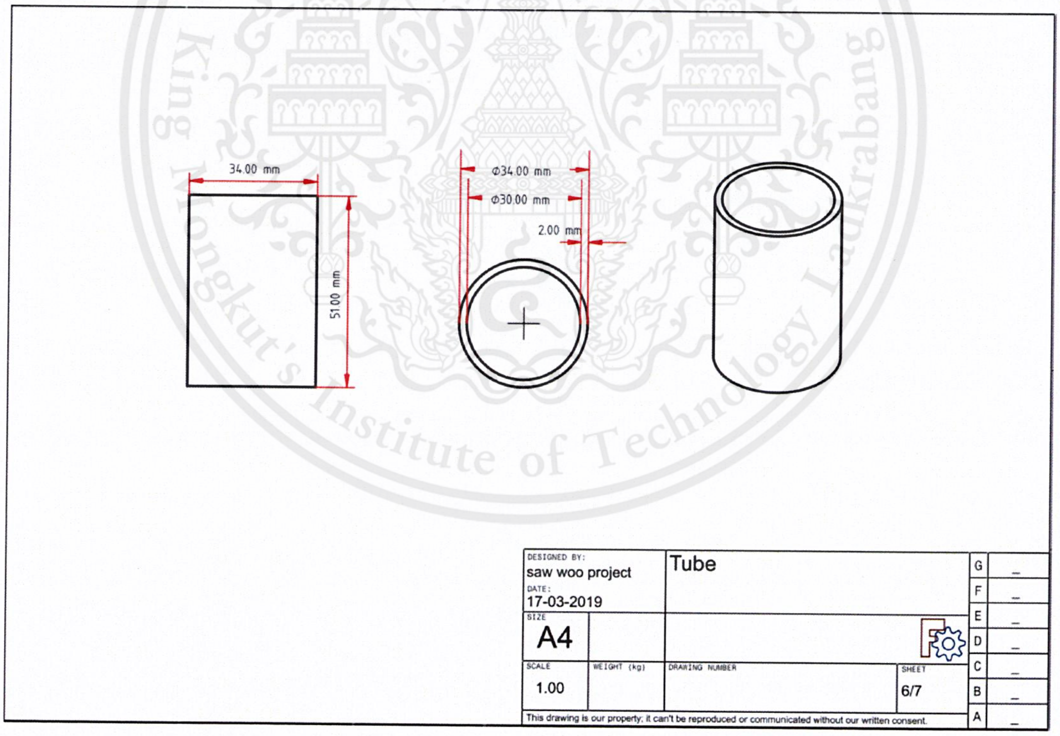
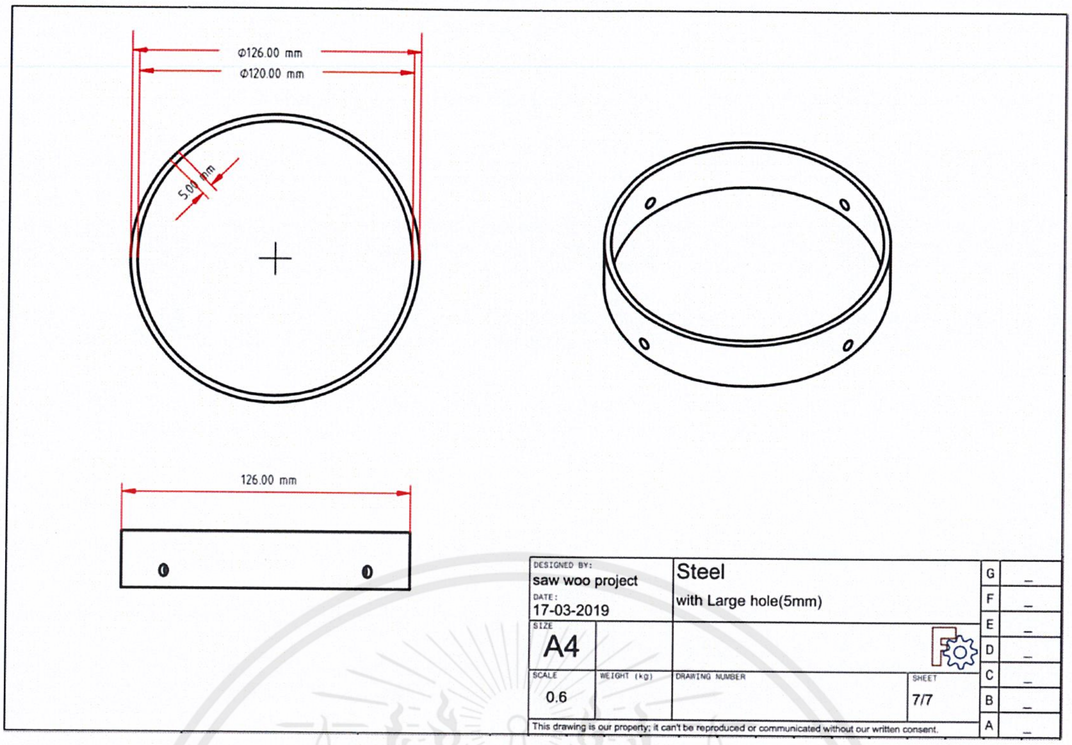


**Figure A.6** Tube of model Saw-U



DESIGNED BY:
saw woo project
DATE:
17-03-2019
SIZE
A4
SCALE
0.6
WEIGHT (kg)
DRAWING NUMBER
SHEET
7/7

Steel
with Large hole(5mm)

This drawing is our property; it can't be reproduced or communicated without our written consent.

**Figure A.7** Ring of model Saw-U

# Appendix B

## How to make the membrane

<u>Corpus modification process</u> (roughly, in 3 steps)

I. **Shell selecting**
   - A. Shell shape
      - 1. Noticeable 3 lobes
         - i. Cooking coconut has no lobe and is spherical.
         - ii. Brahmin-bun-shaped is too long.
         - iii. Elephant-head-shaped is the most suitable.
      - 2. Shape symmetry
   - B. Size is about 45 – 51 cm in circumference (around both ‘shoulders’ and ‘belly’).

II. **Sound hole carving***
   - A. Sizing and positioning – estimate for proper size and position by experience, considering the shape at the back of the shell.
   - B. Pattern selection – according to customer’s liking, however the following are considered:
      - 1. Hole percentage – The more percentage of hole, the brighter and louder the instrument is, but too much might make it less mellow, too less makes it too nasal and quiet.
      - 2. Pore positioning – With character pattern, sound holes are generally positioned around the character (so no hole in the middle of the pattern), while with natural pattern (such as flowers and vines), sound hole can be equally scattered inside the pattern.

III. **Shell’s front shaping* and drumhead installment**
   - A. Shaping – correspond to the shape of the shell for example, if the shell has some bulge on one side, the maker might shape the front to counteract it). Highly depend on maker’s experience. Generally, the shape is like so in the picture below.

**Figure B.1** Shaping

B. Drumhead installment

1. Suitable tension – measure by pushing finger. Highly depend on experience.
2. Suitable leather thickness – the thinner, the louder, but unstable and difficult to play. Too thick, too quiet. Suitable thickness gives satisfied and stable sound quality, and easy to play.
3. Untreated cow's back skin is chosen for proper thickness and elasticity.

*Note: Carving and shaping steps can be switched.

# Appendix C

## The complete model

Researcher wanted to know the sound quality from the resonator model, so researcher made a handle from steel for the model and used the string and the bow same as the actual one.

The results is the sound quality is almost the same, but the actual Saw-U is more resounding than the model.

**Figure C.1** The complete model