A CASE STUDY ON THE ACOUSTICAL ASPECTS AND THE BEST LISTENING LOCALITY OF EXPERIMENTAL THEATRE UNIVERSITY OF MALAYA

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CULTURAL CENTRE
UNIVERSITY OF MALAYA
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ABSTRACT

Acoustics of a hall often overlook by most of the people or concert goer. There are many methods to measure the acoustics of a hall moreover many variables that will affect the result of it. Reverberation time of a hall is the most important aspect in acoustics context. However, music profession or non-music profession often value the hall in different way. This work focused on the listening position in Experimental Theatre, University of Malaya. By using six (6) different musical instruments that represent different musical families, the best listening position of each musical instrument in Experimental Theatre are found. Results from this experiment is compared with a survey that participated by music students in University of Malaya. This work is to provide a guideline for future improvement on the usage of Experimental Theatre. Frequency and loudness are used as the instrumentation to measure in the experiment. Results are presented in figures and tables form for better understanding. Questionnaire results are presented here in tables form.

Keywords: acoustics, frequency, loudness

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ABSTRAK

Secara kebiasaanya peminat konsert dan masyarakat secaranya umumnya mengendahkan akustik di dalam sesebuah dewan. Terdapat pelbagai cara untuk mengukur akustik sesebuah dewan. Tambahan pula terdapat pelbagai pembolehubah yang akan menjejaskan akustik tersebut. Di dalam konteks akustik, tempoh kegemaan di dalam dewan adalah aspek yang teramat penting. Namun begitu, profesion musik dan profesion lain-lain akan menghargai dewan dengan cara tersendiri. Kajian ini tertumpu kepada posisi pendengaran di Experimental Theatre, Universiti Malaya. Kajian ini menggunakan enam peralatan musik yang melambangkan kepelbagaian kategori alat musik. Kemudian, posisi pendengaran terbaik bagi setiap peralatan musik telah diketahui. Tinjauan yang melibatkan pelajar musik di Universiti Malaya juga telah dilakukan untuk membuat perbandingan dengan dapatan dari kajian. Kajian ini mempunyai matlamat untuk membuat garis panduan bagi kegunaan Experimental Theater secara menyeluruh. Frekuensi dan kekuatan sesebuah bunyi dijadikan unit mengukur dalam kajian ini. Keputusan telah dibentangkan secara sistematik dan berangka untuk pemahaman yang lebih baik.

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LIST OF SYMBOLS AND ABBREVIATIONS

UM	:	University of Malaya
ET	:	Experimental Theatre
RT	:	Reverberation Time
RQ	:	Research Question
MP	:	Measurement Position
XLR	:	External Line Return
Hz	:	Hertz
dB	:	Decibel
dB SPL	:	Decibel Sound Pressure Level
SI	:	The International System Of Units
ANSI	:	American National Standards Institute
ASA	:	Acoustical Society of America
IEC	:	International Electrotechnical Commission
ISO	:	International Organization for Standardization

CHAPTER 1: INTRODUCTION

1.0 Background

Acoustics is the science of sound which started to be known in the 1700's (Rossing, 2007). It is about the production of sound, the propagation of sound from the sound source to the sound receiver, and also the sound detection and the perception. The scientific study of sound began since the ancient Greece time, derived from a Greek word, *akouein*, with the meaning of to hear.

Historical review regarding the impact of acoustical knowledge on concert hall design showed that there is still some blank area between knowledge and design (Beranek, 2004; Kiekegaard, 1999). Besides, as the fundamental of acoustics, in this thesis, it will focus on frequency and loudness as frequency affects the loudness of sound. Sound will stimulate human brain, at the same time, influencing one's emotion. Additionally, in business context, the relationship between audience behavior and seat selection are often discussed. However, researcher seldom discover this relationship in musical context. Such studies were too limited but actually their relationship are very close (Kawase, 2013).

Therefore, this study aims to provide in-depth information on the relationship among hall acoustics, frequency, loudness and seat selection.

1.1 Statement of the Problem

People prefer to enjoy performances in indoor venue. In Malaysia, there are several popular venues that hold different kind of performances. One of the famous multi-functional hall is Experimental Theatre (ET) of University of Malaya (UM) which located at Petaling Jaya, Kuala Lumpur. Like most of the other hall, until today, there is no research conducted for this hall.

Researcher might have thought when audience choose their preferred seat, they are concern on the acoustical aspects. But actually, audience does not select their seat based on acoustical aspects and it was not their main concern. Public often choose their seats based on visual satisfaction or the cost of their tickets. They are actually not aware on the importance of the hall acoustics. At the same time, audience does not have much information regarding the hall such as hall size, seat quantity, seat location and many more. This is because there is no research conducted for it, led to lack of hall knowledge.

1.2 Purpose of the Study

The purposes of this study are as below:

1. To investigate the best listening locality of six different musical instrument from different musical family in Experimental Theatre.
2. To investigate audience preferred seats locality in Experimental Theatre.
3. To compare the best listening locality and the audience choice of seating in Experimental Theatre.

1.3 Research Questions

Three (3) research questions were framed to guide this study are stated as below:

1. Where is the best listening locality of six different musical instrument from different musical family in ET?
    a. What is the frequency range of six different musical instrument from different family in seven measurement positions (MP2-8) located at ground floor compare with the original reference (MP1) on stage center?

b. What is the loudness level of six different musical instrument from different family in seven measurement positions (MP2-8) located at ground floor compare with the original reference (MP1) on stage center?

c. What is the frequency range of 6 different musical instrument from different family in three measurement positions (MP9-11) located at mezzanine floor compare with the original reference (MP1) on stage center?

d. What is the loudness level of 6 different musical instrument from different family in three measurement positions (MP9-11) located at mezzanine floor compare with the original reference (MP1) on stage center?

2. Where is audience preferred seating locality in Experimental Theatre?

3. What is the difference between the best listening locality and audience choice of seating in Experimental Theatre?

1.4 Significance of Research

To conduct a study to provide an empirical finding on the acoustical planning of Experimental Theatre. From the findings, important information about the acoustics and the best listening spot in Experimental Theatre can be obtained. All the information will be helpful and valuable for all related parties such as ordinary audience and event organizer of ET to provide better enjoyment to audience.

As acoustics determined listening spot, finding will provide useful guide in this area for both professional and non-professional in the field. The findings will prove the choice of the best listening position in the hall for everyone with the knowledge of the acoustics of the hall. With proper data of the hall, changes can be make for better experience for public in the hall. Further improvement also can be make base on the finding on many aspects.

This is also as a reminder for all on the important role of acoustics. Audience should divert their attention to focus more on hearing, not just only on visual satisfaction. Not just the professional should be aware on this, all audience should pay the attention in this area as well.

1.5 Definition of Terms

The following define the terms use in this study: (1) acoustics; (2) frequency and (3) loudness.

1.5.1 Acoustics

According to American National Standards Institute (ANSI) on the most recent American National Standard of Acoustical Terminology, acoustics is the science of sound (2013). It is all about the fundamental of sound. Sound production, control, transmission, reception and also the effect. There are many technical areas in acoustics. Acoustical Society of America has included 14 technical committees that represent different areas of acoustics. It involved physics, engineering, psychology, neuroscience, and others. The branches of acoustics are including architectural acoustics, physical acoustics, musical acoustics, psychoacoustics, electroacoustics, noise control, shock and vibration, underwater acoustics, speech, physiological acoustics and many more. The fundamental sound wave are involved frequency, loudness, amplitude, phrase, time period and wavelength. Pitch, duration, timbre and others are the parameters of sound. Sounds changed throughout duration in terms of intensity, spectrum and frequency (Rossing, 2007). In this study, acoustics is operationally defined as frequency and loudness.

1.5.2 Frequency

Frequency is defined as the amount of routine per unit time. The SI derived unit to measure frequency is Hz. If a travelling sound wave has 440 complete cycles in one second, the respectively frequency of it is 440Hz. In this study, frequency refer to the frequency range of musical instruments that are measured in Hz (Bozkurt, 2012).

1.5.3 Loudness

The attribute of auditory sensation in terms of which sounds can be ordered on a scale expanding from quiet to loud (ANSI S3.20, 1973). In scientific context, loudness is measure by the intensity of sound. *Phons* is the numerical label to identify the loudness level of any sound. The measurement unit of loudness is decibel Sound Pressure Level (dB SPL) (Long, 2006). Loudness is of particular relevance to the dynamic nature of sound where it change in both environmental and musical contexts. In this study, loudness is refer to the level that produce by musical instrument which measure in dB SPL (Patynen, Trevo, Robinson & Lokki, 2014).

1.6 Delimitations of the Study

This study only measures the basic characteristics of sound wave, the frequency and loudness of the acoustics. Acoustics is a very vast subject of study. It involved many components which are very difficult to study in depth. Although RT always use as the guide to the acoustics of performance venue, but due to the limitation of equipment to measure the acoustics details, the measurement of RT is not included in this study.

ET is a multi-functional hall that widely used by the students of University of Malay, especially students at the Cultural Center. Although Cultural Center has students from drama, dance and art department who also used the hall frequently, this study only delimitated to the music students and the survey is not open to public. This study also compared the result of the experiment of acoustics and the survey of preferred seats.

CHAPTER 2: REVIEW OF LITERATURE

2.1 A Brief History of the Acoustic Knowledge

According to American National Standards on Acoustical Terminology, acoustics is the science of sound. It is all about the fundamental of sound. Sound production, control, transmission, reception and also the effect. It also involved the environment or the surrounding. Sound is produced when an object vibrates and compresses the air molecules and thus forming sound waves. Sound travels as longitudinal waves. Noise control is an important area in acoustics context. It is a study about the reduction of the noise pollution and also the study about the effect of it. As different condition will produce different sound, therefore people receive and response to it differently. Each individually accept it in different way as well (Kuttruff, 2007).

Akouein is the Greek word which appear to be the origin word for acoustics. On the year of 1701, Joseph Sauvuer first use the word in the area (Lindsay, 1973). Acoustics is a very wide subject that related to other subject that not just physics or as a branch of physics. For examples, engineering, psychology, speech, audiology, music, architecture, physiology, neuroscience, and many others. While under acoustics, there were many other branches as well, such as architectural acoustics, physical acoustics, musical acoustics, psychoacoustics, electroacoustics, noise control, shock and vibration, underwater acoustics, speech, physiological acoustics, and many others. All of the subjects are mostly from the combinations of physics and also acoustics (Rossing, 2007).

2.1.1 Acoustics in Greece and Rome

Around the end of first century, Roman engineer and also architect Vitruvius first wrote about architectural acoustics in his books De architectura, The Ten Books of Architecture. He talked about theatre's acoustic properties of his time (Rossing, 2007).

In those books, he also provided specific explanation of sound propagation and distinguishes between helpful reflections and disturbing reflections (Baumann, 2011).

Early of the third century in the ancient Greek time, Aristotle already learnt about the nature movement of wave that sound contain compression and also rarefractions of air. He is the person that applied the law of reflection to sound that is very important for the understanding of sound in ancient theaters and closed spaces. Pythagoras in the 6th century is the founder of mathematics for ancient Greece. Through his study of stings vibration and also the musical sounds, he turned the length of vibration string to easy ratios and came up with the consonant musical intervals.

Based on natural good acoustics shell shaped sites, Ancient Greeks changed it into half circle open air theaters with thousands of steeply raking rows of seats for excellent view and also good speaking conditions. For visual purpose, they had Theatron while Odeion is for the listening purpose. During Ancient Rome time, people combine both of the functions into a performance place that named Orchestra. Western architecture in the modern time gain the influence from the Ancient period (Baumann, 2011).

2.1.2 Acoustics in the Middle Ages and Renaissance

On the sixteenth century onwards, the early acoustical tests were mostly about musical acoustics. In the 16th century, there are the famous Galileo Galilei and also Marin Mersenne. Galileo pointed out the connection between the pitch of string to the vibration length. He also putted the vibration time as per unit time to pitch. Mersenne later in time had finished up the law of vibrating strings that Pythagoras did (Rossing, 2007).

From Vitruvius' books that were about ancient theater, Leonardo da Vinci drew the images of propagation of water waves, sound waves and also light rays that are so important up to the date. Serlio's open air theater in 1545 is also one of a rather important early document.

Building constructions in this period of time are mostly based on measurements and geometrical rules. Robert de Grosseteste is the first one who explain the law of reflection based on experiments and mathematics in full. They had files that showed rules on how to design musical spaces with good acoustics. They developed hall into rectangular in shape that called Oratorios (Baumann, 2011).

2.1.3 Acoustics in the 17th Century

In seventeenth century, there was a famous physical acoustician by the name of Sir Isaac Newton. He laid the foundation of physical acoustics by concluding the connection of wave velocity in solid object. During the time of the 18th century, there were big improvement in acoustics as mathematicians use a new algebra method to explain the sound wave movement principles (Rossing, 2007).

From Leonardo's images, Aristotle's law of reflection that later completed by Alhazen to equate incident and reflected angles that also from the 16th century, developed into scientific theory of optics and also acoustics. There are different opinion regarding the acoustics in the 17th century (Baumann, 2011).

2.1.4 The development of acoustics since 17th century to present day

Up to eighteenth century, there are developments on vibration of strings, tubes, plates, harmonics partials and also the wave theory of sound propagation. Nineteenth century is considered as the Invention Era and there were a lot of important studies about room acoustics or architectural acoustics in laters. The understanding of sound propagation and perception had fundamental improvement (Baumann, 2011).

Nineteenth century can be categorized by the individual work of seven acousticians. They were John Tyndall, Hermann von Helmholtz, Lord Rayleigh, George Stokes, Alexander Graham Bell, Rudolph Koenig and also the most famous Thomas Edison. Rayleigh and Helmholtz are the influential people in mathematical acoustics area. Helmholtz built up the physiological acoustics field with his book, On Sensations of Tone (1863).

Meanwhile, Rayleigh was the most influential person in acoustics field. His significance work was his book, Theory of Sound (1877), which has its contribution to acoustics study. It is still a guide to acoustics engineer up to date. An arrangement which known as Rayleigh disk is still in use for sound intensity measurement (Rossing, 2007).

Tyndall was recognized by his work about the fog's effect on sound transmission over air. Stokes's Stokes-Navier's equation is the beginning to most of the sound movement's principles in liquids. Bell is the father of microphone and telephone. Keoing is an acoustical apparatus maker. Among of all the apparatus that he made, the manometric flame apparatus, a vibration microscope, was able to visualize acoustic signals and study vowel. Apart from the great invention of light bulb, Edison contribute a lot to the mass communication field by his invention of phonograph, Vitascope, dictaphone, mimeograph and also storage battery. All of these are great contribution to motion pictures and also sound recording (Rossing, 2007).

20th century is the time where technology comes in and divided into different field. Wallace Clement Sabine is the pioneer of modern acoustics. He is the founder of Architectural acoustics. He was the first acousticians that made quantitative acoustics measurements on indoor venue. He was also the acoustics designer to one of the three finest concert halls in the world, the Boston's Symphony Hall. He introduced a new equation that can measure and increase the reverberation time during the building of the hall. The hall is the very first building that was designed acoustically (Lubin, 2016).

The most common instrument for acoustical measurement is microphone and associations such as ANSI, IEC and ISO listed a list of standards of acoustics field for professionals as guide. In Technical Acoustics, the sound from mechanical vibrations have the frequency band of human hearing around 16 Hz to 16 kHz. Airborne and liquid-borne sound are referring to the vibrations in air and in liquids while structure-borne sound is referring to the vibration in solids. The primary quantity for airborne sound is sound pressure that is identified with microphone. Intensity measurement such as loudness is based on sound pressure that is related to frequency and microphone. Structure-borne sound require surface displacements and velocity or acceleration to calculate (Moser, 2013).

There are different field of studies about acoustics. The four main areas are the Engineering, Earth Sciences, Life Sciences, and also Arts. Musical acoustics and Architectural acoustics are some of the examples of different focus in acoustics area. Each independent area shares the same concept with each other that is about the study of sound (Lindsay, 1966).

2.1.5 Acoustics in the Festival Halls

There are few main problems in acoustics field. For interior acoustics, the size, the shape and the materials used for the room determines the acoustics of the room. All the aforementioned can cause the sound in the room from becoming too loud and boomy, also produce echoes, flutters and frequency anomalies. There will also be hot spots and dead spots in the room that will cause the difficulty to hear in. This will result to muddy sound and also excess reverberation.

Loud room occur when there are hard surfaces in small room while thick surfaces will cause the room to be boomy. To avoid these, soft and thin surfaces should be used on the outer part of the walls. Echoes, flutters and frequency anomalies can be solved by building the suitable shape of room and also using the right materials. Difficulty to hear in is poor ensemble. With correct shape and also materials that combine with absorption and diffusion, there will be no poorer ensemble.

Sound isolation is the main acoustical problem when building acoustics space. In order to obtain the best sound isolation, doors should be solid built with sufficient mass. Windows should have isolating panes while walls on the other hand should be sealed tightly. Ceilings and also the floors should be thickly built in so that sound could not transfer through and also achieve the sound isolation effect.

Mechanical noise such as all the equipment noise which includes heating, ventilation, air condition and lighting is another issue. This problem can be solved by using isolation and treatment (Egan, 2000).

Yan (2005) did a study using equations to calculate shape, scattering effect and non-uniform materials affect on hall reverberation time. The purpose of the study is to develop a semi-empirical model to support concert hall preliminary design. Author obtained all the data of shape, scattering effect and non-uniform materials through literature survey, analytical studies and simulation experiments. With the result of the first stage, author then came up with a simplified model. In the next step, author use the model to calculate empirical data with the Bayesian method to simplify complicated data. In the result author manage to develop a model that is able to calculate the factors that can affect hall reverberation time. It can be use during design and building a concert hall in order to obtain better sound acoustics.

This study is related to my own study in terms of research area and it is also a qualification and experimental study that is similar to my own study. Therefore, it is a very good reference. The author did the research because there are not much of support on the beginning design of concert hall. Although the author only focus on certain acoustical area, the study is still very useful.

Allan (2003) discussed a few modern halls in his research on acoustic architecture in the 20th century. He indicated that the development of performance hall in modern time is into multi-functional hall. These new performance halls had the tendency on matching public desire. To provide such a performance venue with nice design, good acoustics, and suitable for various kind of performance, the cost on the construction and the following maintenance are increasing as well. All of these will affect the overall acoustics of the hall. He emphasized the importance of music acoustics with acoustic architectural science to provide concert halls remarkable sounds. He provided several suggestions on the challenges of concert halls with some encouragement and also some future further problems.

Beranek (2003 & 2004) spent over a period of 40 years from the year 1960 to the year 2002 interviewed and made questionnaire surveys of more than 150 conductors, music critics, and concert aficionados in an effort to determine how world famous concert halls rank acoustically. There were 58 concert halls in total that were ranked accordingly. No hall had less than six qualified raters. Later at the year of 2013, Skalevik did a similar research with internet survey. There were 59 raters to rank 79 halls in total in this study. The combined result of these two studies was the concert hall with highest ranking was Vienna Musikverein hall with 4.8 ranking (Beranek, 2016).

In the recent study, Lokki (2014) tested listeners' preference in nine concert halls including the world famous Boston Symphony Hall that ranked secondly in the two previous studies. Three different periods with different sized orchestras of 20 seconds symphony music was pre-recorded in a sound dead room with real 34 orchestra positions that substitute by loudspeakers. Each instrument was recorded separately with earphones playback and on screen conductor. The recording was playback later on in concert halls. Results shown that all the 17 listeners were divided into two groups. First group will prefer on the floor main area with sound that is clear, loud, full of bass, early reflections, direct sound and beautiful reflections. Second group preferred balcony area with the mixture of reverberation and direct sound that is loud and also enveloping. Famous acousticians Leo Beranek stated that he will prefer the ground floor area with sound clarity (Beranek, 2016).

In a more recent study, Kalkandjiev and Weinzierl (2015) investigate the effect of 14 specific room acoustical conditions on aspects of music performance. They look into the tempo, loudness, dynamic bandwidth and timbre. With the computer generated 14 different room conditions using dynamic binaural synthesis, 12 solo player of violin, cello, clarinet, bassoon, trumpet and trombone play different pieces accordingly. The playing were recorded, measured with ISO 3382-1 and analyzed with hierarchical linear models. This study reported definite approaches of modification to room acoustical circumstances as well as excellent temperament with appreciation to the interplay of musicians with the room acoustical surrounding.

2.2 Acoustics

Acoustics is the science of sound. It is the study of frequency and intensity of vibration through elastic medium. In the early time, acoustics was only about the sound that can be heard by human ear. However, in modern acoustics, it is about all kind of sound including all the others that are not related to human ear. Ultrasonics and seismological disturbances are some of the examples. Technologies are also related to acoustics. Production, transmission and detection of sound are the fundamental of acoustics.

Sound is produced when different pressure occur that result to different density or displacement to elastics medium. Sound transmit when it passes through elastics medium in wave form. Any form of sound source can be use as sound detector. It is detected by the different energy produce during sound transmission and suitable acoustic detector (Blackstock, 2000).

Sound travelled through air in waves form. It is decided mostly by the mass and the elastics properties of the air molecules. The speed of sound can be derived from basic physical principles, types of waves and how sound radiates. Waves contact with a medium by constructive and destructive interface. With the different scale of object that different frequency of sound contacts with, sound can be scattered or reflected. Reflection can be used as distance detector or other acoustical properties without actual measurements. It happened when sound contact with denser medium.

Refraction of sound occur when it contacted with media by certain angle. When it turned into other form of energy, it is absorbed. When it turned into sound shadows, it is diffraction. When different sound frequency as source and receiver through one another with certain speed, it is Doppler Effect. Reverberation time of sound is about the media and the density (Loy, 2006).

Acoustics deals with waves of all frequencies. But human ears are only audible to 20 to kHz frequencies. Infrasonic refer to sound that are below 20 Hz while for those that are above 20 kHz named as ultrasonic.

As science and technology well developed in modern acoustics in terms of sound source, this area can be well controlled by frequency and intensity. The main device for this is transducer. It can change all form of energy to sound energy. The most useful one of all is electroacoustic transducer. It can change electrical energy to mechanical energy of sound. Besides that, piezoelectric and magnetostrictive transducers are very common in scientific and industrial applications of acoustics. Transducer has the function as sound producer and detector.

Acoustics applications are very wide. It is including architectural acoustics, various study of sound waves, underwater acoustics, engineering acoustics, psychological acoustics, communication acoustics, musical acoustics, bioacoustics and medical acoustics. All of these are from the fundamental physical properties of sound waves (Blackstock, 2000).

2.2.1 Frequency

Long (2006) described succinctly about frequency. In acoustics context, frequency is defined as the amount of routine per unit time. As describe by Long (2006), single stable sound is generating by the repetition of forward and backward action of an object at standard intervals. Period is the time interval of such movement relapses. The SI unit for period is second. Easier understanding is if our heart beat 72 times in a minute, period is the sum up time (60 seconds) divided by the amount of beats (72), that is 0.83 seconds of a beat. By inverting the period to get the full amount of full routine of movement in a time interval, is frequency. Previously, frequency is measured by cycles per second (cps) but now the SI derived unit of it is Hertz (Hz) where it took after the German physicist Heinrich Hertz (1875-1894). One hertz is representing a movement occur a time in a second.

Frequency is one of the most important terms to be used to explain sound even if it is not stable in every situation under acoustical content (Rossing, 2007). Reverberation time is usually the only most trustable and manageable under specific circumstances (Kuttruff, 2009). Frequency is one of the acoustical measurement, and is classify under physical quantity measured (Crocker, 1997). But, due to the limitation of research budget, equipments and other issues, frequency was selected as measuring unit.

In recent acoustics study, related to frequency, Adelman-Larsen, Jeong and Stofrings (2018) evaluated two Danish rock halls that are similar in size and low frequency reverberation times but different in high frequency reverberation times with the subjective ratings from 25 professional musicians and sound engineers. They concluded that rock venues have longer reverberation time at mid to high frequencies in empty condition.

Patynen, Trevo and Lokki (2013) indicated that acousticians and practitioners describe acoustic condition in performance spaces with standard objective parameters apart from a few exceptions. These parameters are calculated by integrating the sound energy of the impulse responses overtime. It is inadequate for researching the acoustics in details; especially in the early part of the room impulse response. They proposed a new time-frequency and spatiotemporal presentations based method for constant or standard analysis outcome.

2.2.2 Loudness

Loudness is another important aspect of hall acoustics (Rossing, 2007). It is the subjective perception of sound pressure in acoustics field. It is a psychological term that contained the meaning of human perception of magnitude of auditory sensation. It is commonly described by musicians as 'loud', 'soft', 'moderately soft', 'very loud' and others from musical notations of Italian words *f*, *p*, *mp*, *ff*, or other. However, for scientific usage, all of these terms are descriptive but not precisely enough. Therefore, in scientific context, loudness is measured by the intensity of sound. *Phons* is the numerical label to identify the loudness level of any sound. The measurement unit of loudness is decibel Sound Pressure Level (dB SPL) (Long, 2006).

Fletcher and Munson (1933) did a comparative loudness measurement test on a large group of subjects that have ordinary hearing with showing them a set of controlled sounds. By using just pure tones (sine waves) of short duration, they compared different tone with different frequency and amplitude with a fixed reference tone at 1000 Hz that have 10 dB amplitude. Subjects were listening to the tones with headphones. The duration of each tone is a second where there are 1.5 seconds difference between tones. Then, subjects will determine tones are higher, lower, or equal to the reference tone. They compiled a group of loudness level contours of Fletcher-Munson curves.

Later on at the year of 1956, Robinson and Dadson redo the Fletcher-Munson measurements using loudspeakers in an anechoic chamber. The Robinson-Dadson curves show normal loudness contours for pure tones in human hearing. Since then the 1000 Hz sine wave is always chosen as a reference.

In the recent study by Bishop, Bailes and Dean (2013), they tested musical expertise and the ability to imagine loudness. The study aimed to investigate the possibility of the loudness of famous classical music can be imagined, also to evaluate the relation of the veraciobsnessity of imagined loudness and musical expertise. 58 participants divided into three groups that represent experts, novices and non-musicians. They were asked to adjust a slider to imagined loudness and tapped out the rhythm to indicate imagined timing while listening to passage of famous classical music. The result of the study indicated that an extensive ability is require in order to imagine the loudness of famous music. For experts' musicians, the veraciobsnessity of imagined loudness tended to be greatest. This also supported the envisioned relation of musical expertise and musical imagery ability.

Later in the year 2014, Patynen, Trevo, Robinson and Lokki tested unoccupied European shoe box concert halls with high frequency strong lateral reflections to enhance the musical loudness of the halls. A pre-test was done to understand the transmission chain of the halls. The orchestral dynamics, lateral reflections and directional binaural response was measured and calculated using the binaural dynamic responsiveness method. Result indicated that dynamic range of the hall response is greater in the measured shoebox concert halls.

2.3 Musical Acoustics

Among all of the experimental Sciences, musical acoustics is one of the oldest in it. It is about the sounds produced by musical instruments. It started in modern times by Felix Savart. It first started with the scrutiny of the connection among notes produced by the definite fraction divisions of a stretched string and consonant musical intervals. It then resulted to the first physical law to be express in mathematical terms. It is also led to the idea of a divinely designed cosmos based on exact fractions, fulled with the music of the spheres. All of these also led to to Newton's finding of celestial dynamics and the laws of gravity leading to the modern view of the universe subject to physical laws rather than numerical relationships (Hutchings, 1997; Rossing, 2007).

Musical acoustics remained to take up the central scientific role in the 19th century. This showed in Lord Rayleigh's Theory of Sound (1877) that still support the fundamentals for nearly all of the branch of modern acoustics. Further understanding in waves of acoustics also laid to the mathematical framework for quantum wave mechanics in the beginning part of the 20th century. Now, the physics of vibrating strings is almost complete. Musical acoustics still continues as a difficult and thrill field of research and remains to complete mainstream acoustics in many different ways (Rossing, 2007).

2.3.1 Human Hearing

Smith (1999) explained human hearing in his book, The Scientist and Engineer's Guide to Digital Signal Processing. He mentioned that human ear is one of the most complicated organ in human being body. Message from two ears is collected by equally complex human brain. This let the process double the difficulty. Privilege of two ears is recognize sound direction while the opposite is cannot tell the distance of it.

Transparent skin and cartilage with ear canal formed outer ear that drive surrounding sounds to middle ear and inner ear. After waves hit ear drum, the vibration that occur will go through an amount of small bones that form middle ear. Middle ear act as the carriage of the vibration to inner ear. Inner ear is a small cylinder that contains of fluid. It sends signal to human brain. Different fibers in nerve cell react to different frequencies. These nerve cells also located in inner ear.

Sound intensity is measure by decibel Sound Pressure Level (dB SPL). 0dB SPL is the weakest sound that can detect by human ear. Normal speech is 60dB SPL while 140dB SPL is harmful to ear. Human hearing has the range of 20 to 20kHz and is more sensitive to 1kHz up to 4kHz. However, different density have different frequencies. As guide, 0dB SPL is 3kHz but 40dB SPL is 100Hz.

2.3.2 Keyboard - Piano

The keyboard, the action, the strings, the soundboard and the frame are the main parts of piano. Strings are extending from pin block across bridge to hitch pin rail at the far end. When keys are held down, dampers of piano are raised, and hammers are hit towards strings, making it into vibration. Through the bridge, the vibrations of strings are transmitted to the soundboard (Fletcher & Rossing, 2005).

Notes of piano with respectively frequency have one, two or three steel strings. Notes are being produce by the strings being hit by the hammer of piano. The lower strings being over wrapped with brass or copper wire to stretch the octaves to slightly larger than a 2:1 frequency ratio due to the stiffness of the string. Vibrate string will transfer through a bridge to a flat and ribbed wooden soundboard. Felted hammers hit the strings through a very complex mechanical action. In the same time the dampers from each individual strings will also raise. Two pedals of piano control the motion of the dampers, while another one is to allow only one single string of each note will be hit by the hammer (Benade, 1990).

Soundboard is the main source of sound radiation. Piano strings are held in high tension in order to obtain desired loudness (Fletcher & Rossing, 2005). The volume of piano is control by the force of the finger pressing on the keyboard (Benade, 1990).

Several experiments have done to investigate the physics of piano in order to improve the design and the sound of it starting from the beginning of the birth of piano. Dijksterhuis (1965) did several experiments to test on the key dynamics of both grand and upright piano using equations. But Henderson (1936) and Vernon (1936) pointed out the importance of pianist. Later on, Lieber (1985) did further study on this area.

Strings are the most important elements of piano. Therefore, there are more study regarding the piano string than the other parts of piano. Sanderson (1983) studied the properties of piano strings using several equations. Kock (1937) did experiments on the electrical transmission line of strings by model piano with other materials. Nakamura (1982) continue the study with impedance and mobility analogy.

Conklin (1996) discussed the hammers difference of earliest and modern pianos. He also discussed the mass of hammer in the study. Hall and Askenfelt (1988) discussed the hardness of hammer. Conklin (1996) furthered his study on hammers through the effect of the hardness of hammer to piano tone. Rusell and Rossing (1998) studied the dynamic hardness of piano hammer by using the information from Broch (1984).

The study of the hammer and string dynamics is considering of one of the earliest study of piano. It started with Helmholtz on 1877, continued by fellow Indian scholar that including C.V.Rahman during 1920s to 1930s. Later on, furthered by Askenfelt and Jansson (1985, 1993), Conklin (1996), and Hall (1986, 1987, 1988, 1992).

Conklin (1996) also did a study on the hammer properties to piano tone. He followed the study with the hammer hitting position on string that affect the sound. This topic was first discussed in the late 18th century.

Lieber (1979) discussed the overcompensation situation of soundboard but Wogram (1981) advised that the situation should be avoided in order not to affect the quality of piano. Besides that, Conklin (1996) studied the materials that have been used for piano soundboards.

Nakamura (1983) studied the soundboard of upright piano. He measured the vibrational modes of soundboard without the trimming rim by using the 14 measuring points that selected by Wogram (1981). Conklin (1996) indicated that there was no difference in grand piano soundboards. Therefore, the difference in between the two type of piano soundboard are remain unknown. Further study on piano soundboard radiation and other aspect of the soundboard were done by Wogram (1981, 1988), Suzuki (1986), Kindel and Wang (1987) and Conklin (1996).

Martin (1946) did experiments on the sound decay between strings, bridge and soundboard. Weinreich (1977) discussed the coupling problems of strings. Conklin (1996) discussed the scaling and tuning of piano. The longitudinal string modes of piano is studied by Knoblaugh n the year of 1944. The study has been revised later on by Conklin on the year of 1970.

The tuning and inharmonicity of piano is another issue that discuss the most. Several studies have been done. They are included Burns and Ward (1982), Terhardt and Zick (1975), Houtsma (1987), Martin and Ward (1961), Schuck and Young (1943), Kent (1982) and Corp (1986).

Piano timbre is determined by transient sound. Houtsma (1987) did a demonstration to show the phenomenon. Meyer (1978) and Conklin (1987) further the study in this area. Meyer (1978) also discussed the dynamics of piano in his study. Some other related aspect in this area also discussed by Fletcher (1962), Meyer and Melka (1983).

On the attack sound filed, was studied by Podlesack and Lee (1987), Conklin (1970) and Bork (1995). Dijksterhuis (1965), Henderson (1936) and Vernon (1936) studied the key dynamics of piano.

In the most recent study, Smit and Sadakata (2018) examine the influence of handedness on pianists' skills to adapt their keyboard performance skills to new spatial and motor mappings. 13 right handed and 12 left handed pianists were asked to practice some simple melodies on regular MIDI piano keyboard, then tested with modified melodic contours on reversed MIDI piano keyboard. Different performance duration of practice and test with the total amount of errors played were recorded and used as test measures. They concluded that handedness will effect pianists' abilities to adapt to new spatial and motor mappings.

2.3.3 Brass - Trumpet

Trumpet is a wind instrument of the family of brass. It is very functional of wide range of playing techniques. Trumpet produce sound by blowing air through pursed lips into mouthpiece, the vibration excites the air in the instrument that led to the production of pitch. Just like most of the brass instrument, trumpet need the position and the tension of lips to produce pitch and magnify it. It is named by embouchure. Trumpet has 3 valves to lower the pitch by adding lengths to the tube of the instrument (Berkopec, 2013). The cylindrical tube of wind and brass instruments act as the function of resonators. It must meet a few important factors to provide the best result (Rossing, 2007).

Acoustic impedance is the ratio of acoustic pressure to acoustic volume flow. Berkopec (2013) use it to discuss the frequency of sustainable standing wave for different part of trumpet in his discussion by turning all the action of the sound production of trumpet into countable equation. The author investigated the tube, the bell effect, the bell shape and lip vibration.

Author concluded that multiple of important factors affect trumpet operating. For example, the shape of bell determined the playing condition of trumpet. For high frequencies, the impedance for brass instrument must be decrease rapidly for no reflection. Pressure-controlled valves are in charge of the sound production of the musical instruments of woodwind and brass families. Author also discuss different structures and situation of valve when reed valve is use as the acoustics generator.

This work is about some of the fundamental aspect of the instrument. It is simple and straight forward. Therefore, it is very useful to gain knowledge from it. It is a very good guide but is not for the professional. All the explanation in the work is easy to understand and very useful. But, the simplicity in this work is just not for the professional.

Logie (2012) did a series of experimental studies on the acoustics of brass instruments. The study is to expand the perception of some playability issues on brass instruments. The study contained of three main part that are about the playability issues of brass instruments. They are the slurred transients, the extreme high notes and the cylindrical tubes. The study was focused on the horn, the trumpet and the trombone.

With a series of experimental studies and comparisons to the computational simulations, the analysis of the three brass instruments and computational modeling of slurred transients, the extreme high notes, and the cylindrical tubes as simple brass instrument were tested. This is a qualitative experimental study with good results. The study focus more towards the professional side therefore it may not be a good example for beginner. The study only explored to some of the playability issues but no other fundamental or important acoustics aspect of the musical instruments. Overall the method used in the study is a very good and useful reference.

2.3.4 Percussion - Drum Kit

A three piece drum kit is use in this experiment. It is include a kick drum, snare drum and hit hat. The three fundamental instruments in drum kit. The most important role for drum is to keep time. A kick drum is the biggest drum in drum kit that create the lowest pitch in drum kit as well. Snare drum produce tight and snappy sound. Hi hat teamed up by two cymbals which both are facing each other. Most of the percussion instruments produce sound by hitting the instrument to create vibration regardless the material of the instrument. Percussion are usually hit by drum sticks that make of wood, comprising tip, neck, shaft and butt. It has different sizes, material and thickness (Griffiths, Lawson, Troup, Troup, & Preston, 2015).

Apart from human voice, drums considered one of the oldest musical instrument that may be as old as human race (Fletcher & Rossing, 2005). Early development of drum kit stated back from early 1800s (Nichols, 1997). The amount of issues on percussion instruments is significantly smaller compare to the pervasive studies on other instruments families. The main reason of the problem causes by the relatively simpler acoustics of the instruments (Rossing, 2007). For the acoustics of percussion instruments, there are two most important literatures or references. They are The Physics of Musical Instruments by Fletcher and Rossing (2005) and the Science of Percussion Instruments by Rossing (2000). For the evolution of percussion family, Blade (1970) gave a decisive information in his book Percussion Instruments and their History.

2.3.5 Woodwind - Flute

Woodwind is the simplest musical instruments. They are based on cylindrical pipes which excited by a jet of air blown over one end or basic Helmholtz resonators that the pitch decided by the openings of the mouthpiece and fingered open holes. Woodwind are almost cylindrical or conical tubes in shapes that are play by a reed and jet of air blown over a hole in the wall of the tube. Simple cylindrical and conical tubes retain a harmonic set of resonances independent of their length, which in principle allows a full set of harmonic partials to be sounded when the instrument is artificially shortened by opening the tone holes.

Flute, bass flute or even piccolo all are based on the resonances of a cylindrical tube with the open end and mouthpiece hole giving pressure nodes at both ends. Flute produce chromatic notes by open or close a number of tone holes in the walls of the instrument. Modern flute use felted hinged pads operated by a system of keys and levers. Primitive flute appeared in most ancient cultures (Rossing, 2007).

Flute is Paleolithic instrument. History shown that it is one of the earliest extant musical instrument (Wilford, 2009; Higham, Basell, Jacobi, Wood, Ramsey and Conard, 2012; Atema, 2014).

To learn about the acoustics of flute, it is requiring to first understand the passive linear behavior of the air column, then the operation of air jet generator that maintains the resonator in oscillation to produce sound. Air jets are flow controlled valves that can also act as negative acoustic conductance. Air jets drive the air column at a point of minimum acoustic impedance so that the blowing end of the tube is effectively open. Flute’s generator generates an exact and entire harmonic spectrum according to the fundamental frequency decided by both generator and resonator together. And the role of the resonances of the air column is to shape the spectrum (Crocker, 1997).

Boysen and Ruiz (2017) discussed the basic physics of flute in the performer's view in a more recent study. They compared four different sounds with three fundamental sound characteristics, the loudness, the pitch and the timbre. They used a simple online software Audacity to measure the frequency of the 4 sounds.

2.3.6 Strings – Violin

Felix Savart is the first modern investigator of violin. He was the first person who recommend the thought of the sound post of violin. It is to change violin from dipole to monopole source. This allow violin to have bigger radiation in the low frequency. Violin may be the instrument that has been examined most frequent up to date (Hutchings, 1997).

Woodhouse (2014) did an overall review of violin acoustics from history summary. It is to understand the design and function of violin and also to investigate listeners and players choice and opinion on the musical instrument. Through the discussion in the study of the structure and purpose of violin that just focus on the violin body and bow, we understand that violin has a wide cover range from it physical body to the sound. This is very useful to players, listeners and also the makers of violin as it can be control better.

The acoustics of violin did not really explain in the study and other parts of violin for example strings and materials did not discuss in the study. Therefore, the acoustics part of violin is not clear. It focuses more on the benefit of the user of the instrument. Although the most concern part of my study could not be found in this study but the important of violin are stated in this study. It is very important to learn about the important of an instrument.

In a more recent study, Gough (2016) described the sound excitement, the sound quality and the relationship of vibrations and acoustic properties of violin. Author gave straightforward explanation about the fundamental of violin. He discussed the important element of the musical instrument.

2.3.7 Vocals

Human voice is one of the oldest musical instrument (Rossing, 2007). It is able to make various pitches with the control of different tones and dynamics. Breath is the fundamental of singing. Expelled air is used to form consistent air flow across the vocal cords in order to create sound. The main voice producing component in body is the larynx. It is strong but flexible. It is also the houses of vocal cords. Vocal cords create sound when air pass through it and vibration occur, the velocity of the vibration decide the vocal pitch. A resonate place which put on brighter tone to vocal sound is called nasal cavity. By letting more sound go through the soft palate then into nasal cavity, the result can be improved. Mouth is a place where vocal that create in larynx that will blend and voice out. Before that, tongue will help to shape and articulate the sound the crated in the larynx. Lastly is the lips (Griffiths, Lawson, Troup, Troup, & Preston, 2015).

The classical acoustic theory of speech production seems applicable also to singing. The brief description of the theory is voiced sounds are produced by vocal fold vibrations that chop the airstream from the lungs, thereby producing a train of air pulses. This pulsating airflow is equivalent to a complex tone with a harmonic spectrum and with a fundamental frequency equal to the folds' vibration frequency.

This voice source signal is altered when passing the vocal tract, the mouth and the pharynx, which acts as a tube resonator. For vowels it is open at the lip end and practically closed at the vocal fold end. When the velum is opened, as in nasalized sounds, the vocal tract is complemented by the nasal cavity.

Vocal tract also acts as filter, imposing its frequency curve on the sound radiated from the lip opening. This frequency curve is characterized by peaks, or formants, corresponding to the vocal tract resonances, and by valleys between the peaks (Fant, 1960).

Gramming (1991) studied the vocal loudness and frequency capabilities of the voice. He measured the maximum loudness for male voices at 0.3 meters from the mouth in an anechoic room using. The amounts are to about 85, 95, and 100 dB SPL at low, middle, and high pitches, respectively. For female voices that measured in the same method, the corresponding value for non-singers is near 95 dB for most of the pitch range. However, for singers, they can produce louder tones in the upper half of their pitch range, the maximum difference being about 18 dB. He concluded that singers and non-singers are the same in produce the loudest possible sounds that they can.

But, Sundberg (1997) does not agree with Gramming (1991). He stated that singing students that train their voices at conservatories are reported to reach higher SPL after successful voice education. The cause behind is likely that singing students tend to avoid the kind of phonation that non singers use when producing the loudest possible sounds, as these sounds mostly sound like screams.

2.4 Audience Preferred Seats Locality in a Concert Hall

There are limited studies about audience seat selection in the field. Most of the studies on seating in performance venue are based on acoustics. The very first seat selection system was proposed at the Kirishima International Concert Hall at the year of 1994 (Ando, 2009).

Ando and Noson (1997) ran the test on acousticians at the International Symposium on "Music and Concert Hall Acoustics" (MCHA95) which was held in Kirishima in the May 1995. It is a special facility for seat selection, in order to maximize the individual subjective preference for each listener. Special playback system with multiple loudspeaker was employed. The system used arrows for testing subjective preference of sound fields for listener at the same time. “Water Music” by Handel was the orchestral music source that was chosen. There were 106 of participants in total for this test. Frequency and loudness were involved in the test. Result shown that 60% of the participants chose center area with preferred listening loudness level at 83 dBA and cumulative frequency of preferred range at 80 to 84.9 dBA (Ando, 2009).

Figure 2.1 is an illustration of the Orthodox system for simulating sound fields. It used a seven channel playback system and an anechoic chamber. The source of the sound in the absence of reverberations is recorded, then added back to itself, after a series of delays and gains are dictated. The frontal speaker acts as the simulation to the direct path, while the two front-lateral speakers simulate early the reflections from the stage and walls, and the remaining four rearmost speakers simulate longer reverberation.

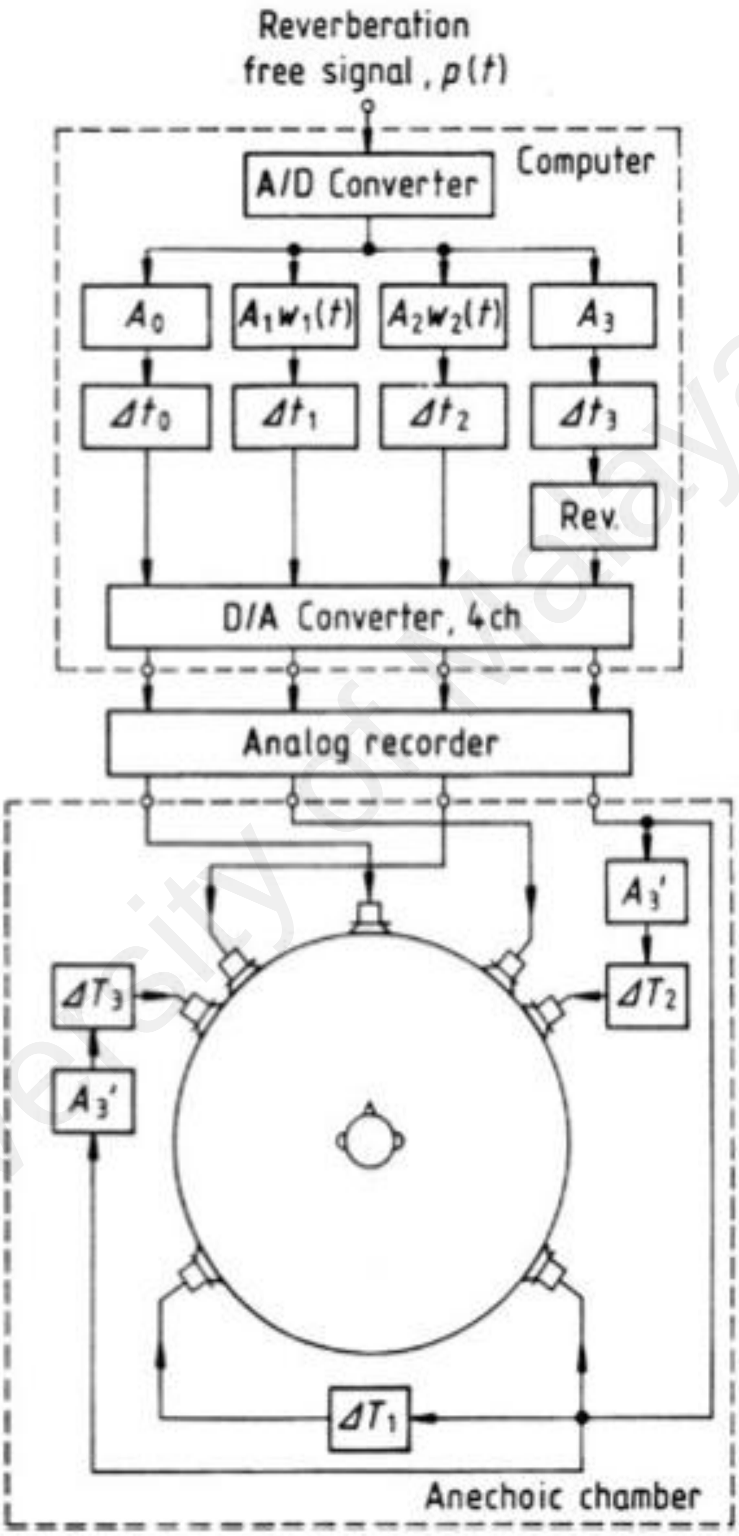


Figure 2.1: Orthodox system for simulating sound fields

Kawase (2013) did a research on the factors that will influence the selection of music majors and non-majors on the seat in a concert hall. All hall that was used for both classical and contemporary performances were chosen by the researcher. The capacity is closed to 3600 seats.

In this study, it comprised of 60 undergraduates of music students with 55 females and 5 males. Their performance experience were in the average of 15.5 years. For non-music majors, there are 60 females and 5 males that summed up to 65 participants, whereby majoring in psychology and foreign language. They had average 6.7 years of performing experience and attend music performance 3.4 times a year.

There were two phrases in the questionnaire survey study. Preliminary survey is to hypothesized participants, criteria while they are choosing their seats. The main survey is based on real live performance module where seating plan of the hall is provided for participants to choose their seats according to different performance and set up as public normally choose their seats base on a chart when they purchase tickets. Participants had to select the seats that they want the most and the least of six different kind of performance. A stage layout of the performance is provided as well. Participants were given three reason to rate by seven point scale on the reason they chose their seats. A blank column was included for participants to state the additional reason about the seats choice.

Two way ANOVA statistics was used to compare the results between the two groups. The results of this study have high similarity between the groups. Regardless of music majors or not, the results showed that people prioritize visual factors and varied in sound quality. From the results of this study, we understand the thoughts of audience when select their seats. But, the importance of audio and visual is still yet to be known.

Which is the priority, what is the relationship between them and also why they will affect seat preference.

This study is very helpful as there are not many researchers that conduct studies in this area and look into this problem. The research design of the study is very helpful as well. Although the question remains, it will still aid in understand audience thoughts further. Further research should also be carried out to find out more to be definite.

2.5 Conclusion

Egan (2000) listed the basic causes, problems and also the solutions of room acoustics. Yan (2005) did a study for concert hall preliminary design. With the use of equations to calculate shape, scattering effect and non-uniform materials affect on hall reverberation time, researcher came out with a semi-empirical model. First of all, researcher collect all the data that required to build a first model, then simplify it for ultimate result. Researcher had simple purpose but like most of the research study, the process is always the hardest, just like this study. Simple purpose but complicated process and work.

Base on Allan (2003) study, he concluded the acoustics of some of the concert hall. He also pointed out the weaknesses of these hall and gave some of his suggestions. Kalkanjiev and Weinzierl (2015) looked into the different aspect of different room. With the different conditions that generated by computer, they record some solo instrumentalist, measured and analyzed. This study is into the detail of room acoustics. The method used was a very good example.

With quantitative research method, Adelman-Larsen, Jeong, and Stofrings (2018) concluded that rock venues have longer reverberation time at mid to high frequencies in empty condition. Patynen, Trevo and Lokki (2013) studied and came out with new calculation for frequency. Later in the year of 2014, together with Robinson, they tested on concert halls' loudness. They concluded that dynamic range of halls' response is greater.

Most of the studies reviewed were scientific studies focus on the physics calculation. However, this study only focus on the frequency and loudness. As conclusion, this chapter review the studies on acoustics and the preferred seat in concert halls. It summarized that frequency and loudness are the most fundamental measure units for acoustics. Therefore, in this study on acoustics, frequency and loudness are used as the basic reference to study the acoustics of the Experimental Theatre of University of Malaya.

Preference of seats in performance venue varied according to audience perspective. The two biggest factors of influence are based on sound and visual. As not much of supporting study regarding audience preferred seat in performance venue, therefore this study needed to be carried out. This study also showed the relationship between acoustics and audience preferred seat in performance venue.

CHAPTER 3: METHODOLOGY

3.1 Overview

This chapter aims to provide a succinct description of the research methodology to address the research questions. The purpose of this study is to investigate the best listening position of different solo instruments from ten different localities among the audience seat in ET. The outline of this chapter was organised as follows: (1) research design; (2) instrumentation; (3) data collection procedures and (4) data analysis procedures.

The following section discuss the method used in this study to examine and address the following research questions:

1. Where is the best listening locality of six different musical instrument from different musical family in ET?
    a. What is the frequency range of six different musical instrument from different family in seven measurement positions (MP2-8) located at ground floor compare with the original reference (MP1) on stage center?
    b. What is the loudness level of six different musical instrument from different family in seven measurement positions (MP2-8) located at ground floor compare with the original reference (MP1) on stage center?
    c. What is the frequency range of 6 different musical instrument from different family in three measurement positions (MP9-11) located at mezzanine floor compare with the original reference (MP1) on stage center?
    d. What is the loudness level of 6 different musical instrument from different family in three measurement positions (MP9-11) located at mezzanine floor compare with the original reference (MP1) on stage center?
2. Where is audience preferred seating locality in Experimental Theatre?

3. What is the difference between the best listening locality and audience choice of seating in Experimental Theatre?

3.2 Research Methods

The following presents the research methods for the study. The sections are organized as follows: (1) research design; (2) equipments; (3) instrumentation; (4) data collection procedures; and (5) data analysis procedures.

3.2.1 Research Design

Various research methodology employed in this study to address different research questions. Experimental research is employed to identify the best listening locality in ET. Frequency affect loudness.

Crocker (1997) explained frequency analyzer that commonly selected to measure frequency in his book and also discuss the function of loudness with frequency. Recently, Kanev, Livshits and Moller (2013) compared the acoustics of the Great Hall of Moscow State Conservatory before and after reconstruction. The acoustic measurement were conducted without audience in the hall with standard technique from ISO 3382 (1997) which including frequency and loudness as well.

In the previous studies, Lokki and Karjalainen (2002) analysed frequency and time resolution of human hearing in small and large concert hall by using Equivalent Rectangular Bandwith to measure. They analysed frequency with ISO 3382 (1997) and loudness with ISO Standard 226 (1987). Survey is employed to define research question 2.

Kawase (2013) applied two way ANOVA statistic to measure the factors that influence music and non-music majors' seats selection in large multi-functional concert hall. Lastly, comparison is done to define research question 3.

Based on the methodology from previous studies, this study used various research methodology to suit different research questions needs. Qualitative study or experiment was used to examine the best listening locality in ET for RQ1. Frequency and loudness of ET was measured. For RQ2, quantitative study was used to obtain the best result. It is also the most suitable research methodology for this RQ. Lastly, for the third RQ, from the results obtained from RQ1 and 2, the results were compared and discussed, to conclude the result for RQ3.

3.2.2 Equipments

Experimental research design will be used to find out the best listening spot for audience. This design is used on testing the effect and the difference of different independent variable to dependent variable. Through the comparison of the data sets, this research design allows researcher to find out the influence of the independent variable. An experimental design should be planned carefully. The connection between two variables will affect the result directly. The following are all important elements, ranging from preparation, conduction, to all the other variables (Chua, 2012).

For data collection of the acoustics study on frequency and loudness, the following equipments were suggested by acoustics expert who is a sound technician. The equipments involved were: (1) Behringer X32 Digital Mixer; (2) Audio Technica shot gun condenser microphone AT8035; (3) XLR Male to Female 10 meters microphone cable; and (4) Sony PXW-X70 camcorder.

Behringer was formed in the year of 1989. It is one of the industry leading pro audio equipment manufacturers. Almost everyone has used a Behringer product at some point. Beginning of the year 2010, Behringer's parent company, the Music Group, acquired two closely linked British companies. Midas that are very well known for class leading love sound mixing consoles. Klara Teknik that make ancillary equipment such as graphic equalisers, system controllers, compressors and the classic DN780 reverb. All the technical expertise of these three companies came out with the compact X32. It is a fully featured, 32 channel, 16 bus digital mixer with various variety of built in effects and handful feature set. It is geared primarily towards live sound (Robjohns, 2012).

Microphone that used in the experiment is Audio Technica shot gun condenser microphone AT8035. It is desirable for long distance pickup. It also have excellent sound rejection from the sides and the rear of the microphone. This microphone's frequency response is from 40-20 kHz and the maximum loudness level is at the 110 dB, 1 kHan at maximum SPL.

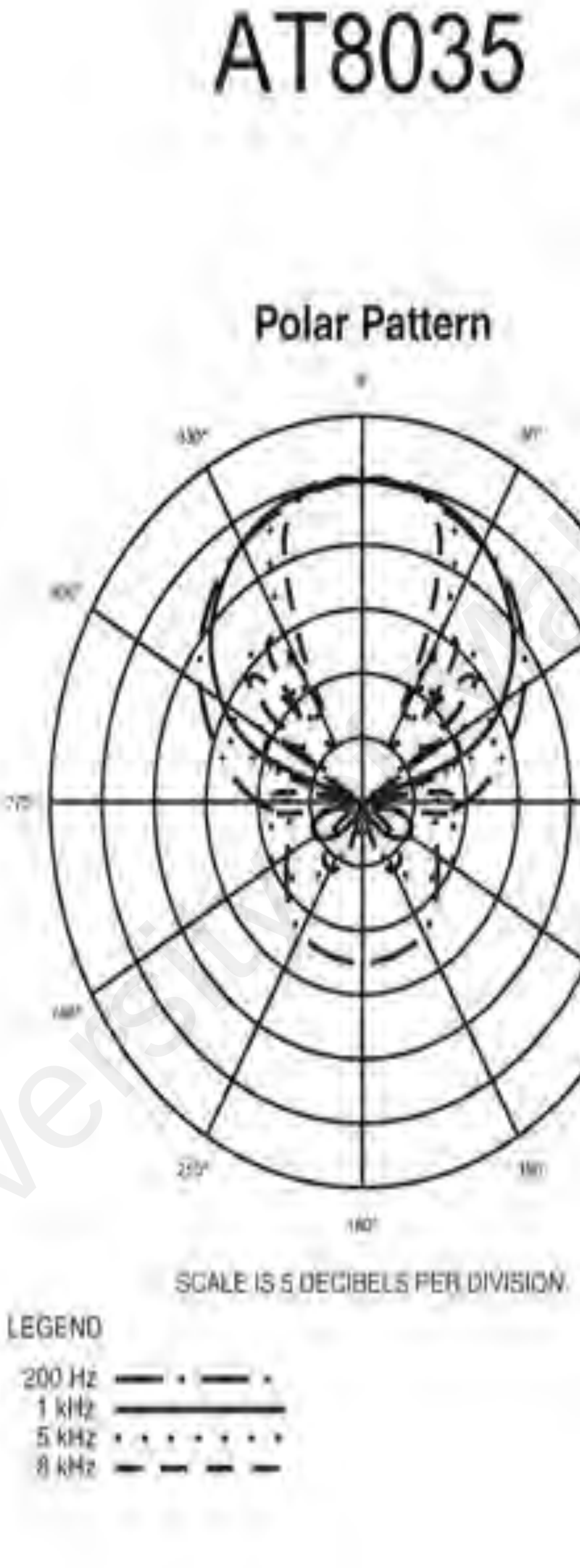


Figure 3.1: AT8035 Polar pattern

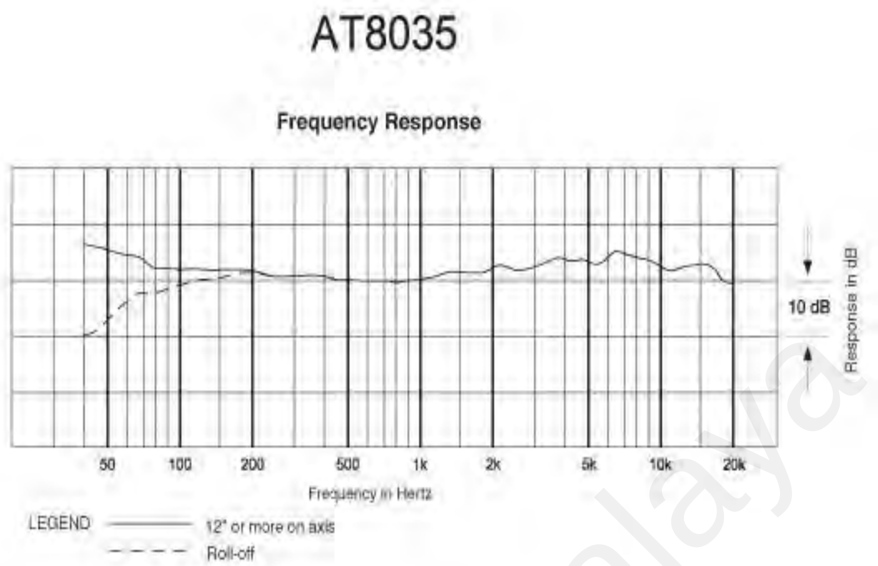


Figure 3.2: AT8035 Frequency response

Cable that used to connect microphone and mixing console is XLR Male to Female microphone cable. As microphone picked up and send balance signal that cancel noise automatically, normal microphone cable do all the job that is require. The cable will just send original signal that are noise free. Lastly, to record the changes of signal in different places, the sony PXW-X70 is used. It is a professional, compact and palm size camcorder with XLR handle units which is perfect for video recording that produce high quality video and easy transmission functions. It is connected to the mixing console with XLR cable to obtain and also record the sound that pick up by microphone.

3.2.3 Instrumentations

Questionnaire is a good tool to obtain the answer of a large population on the research questions. Therefore, to know music student's preference on seating position, questionnaire is the best and actual way to get the quantitative results.

There are a few characteristics about a good questionnaire. First of all, the questionnaire should be prepared according to the background of respondents. Questions should be stated clearly. Secondly, the questions need to be presented in a manner whereby it is professionally structured, simple, short and also in order. It is important as the aforementioned has an effect to the results of the questionnaire. Next, questionnaire needed to have clear instructions that will not confuse respondents.

When forming the questionnaire, opinion of the respondents should be respected. They need to have the freedom to voice out their voice. This is very important to the result as well. Lastly, the originality of the questionnaire and pilot test should be conducted (Chua, 2012).

According to Bradburn, Sudman and Wansink (2004), there are different methods employed for different kind of questions that needed to ask in a questionnaire. How to draft, craft, organise and design a survey from the beginning till the end also stated by the researchers. Therefore, from the reference, the type of question that needed in the questionnaire was created. Lastly, the set of questions was verified by supervisors (Foddy, 1993).

3.2.4 Data Collection Procedures

In this study, different data collection procedures were used for different research questions (RQ). For RQ1, qualitative research was conducted. While for RQ2, quantitative research was conducted. Lastly for RQ3, is to compare the results of RQ1 and RQ2.

The data collection procedures of experiment included the recorded original reference sound of each instrument on stage and the sound from 10 localities of the audience seats in Experimental Theatre (refer Appendix D1 to D2). The experiment was carried out in Experimental Theatre of University of Malaya on 26th of September 2017.

Before the experiment, there were a short meeting session with technician for prior discussion and his professional advice in this field. In order to use the hall for experiment, pre booking of the hall was required but due to the occupancy of the hall, the experiment date was changed for two times. Six (6) different musical instruments were chosen and scheduled accordingly for the recording started from 12:15pm to 1:30pm. Sessionists and time table were chosen and arranged by supervisor before the experiment. Sessionists were undergraduate student from University of Malaya. They are requested to prepare a 10 minutes pieces for the experiment.

On the experiment day, earlier set up was done in the hall for earlier preparation for the recording. First, marking was done to identify the correct position and standardization throughout the experiment. Next, mixing console and microphone was set up and a simple line check was done to confirm the signal that picked up by microphone and received by the mixing console. After that, a very simple sound check was done. Lastly, the changes of the spectrum that shown on the mixing console of frequency and loudness was captured by a video recording including the sound of it.

A video camera was set up to the best position to captured the whole recording process. A headphones was stand by for the reference of the recording engineer. For the recording, sessionists were required to repeat their piece to record for the 11 different recording locality.

Survey was conducted through Survey Monkey to understand audience choice of seating in Experimental Theatre. Before the survey was conducted, questions were design accordingly and was verified by supervisors. Participants of the survey were selected by supervisors from undergraduate students of Cultural Center University of Malaya. There were in total 76 of participants participated in this questionnaire.

3.2.5 Data Analysis Procedures

In order to obtain the best listening locality in Experimental Theatre, the frequencies range and the loudness of six different musical instruments from different musical family were chose to test on. Data were analysed and organised in tables. In order to avoid complexity, data of the listening locality in ground floor and mezzanine floor are separated. They were discussed separately following by respectively tables. Result of questionnaire was collected and analyse through Survey Monkey. They were later organised in tables with discussions.

CHAPTER 4: ANALYSIS OF DATA AND FINDINGS

4.0 Overview

This chapter presents the acoustical analysis of data and the results of the study. This section is organized as follows: (1) Floor Plan; (2) Venue; (3) Acoustics Analysis; (4) Questionnaire Analysis; (5) Comparison of Acoustics and Questionnaire Analysis; and (6) Summary of results.

The results were presented to address the research questions of the study. The research questions included:

1. Where is the best listening locality of six different musical instrument from different musical family in ET?
    a. What is the frequency range of six different musical instrument from different family in seven measurement positions (MP2-8) located at ground floor compare with the original reference (MP1) on stage center?
    b. What is the loudness level of six different musical instrument from different family in seven measurement positions (MP2-8) located at ground floor compare with the original reference (MP1) on stage center?
    c. What is the frequency range of 6 different musical instrument from different family in three measurement positions (MP9-11) located at mezzanine floor compare with the original reference (MP1) on stage center?
    d. What is the loudness level of 6 different musical instrument from different family in three measurement positions (MP9-11) located at mezzanine floor compare with the original reference (MP1) on stage center?
2. Where is audience preferred seating locality in Experimental Theatre?
3. What is the difference between the best listening locality and audience choice of seating in Experimental Theatre?

4.1 Floor Plan

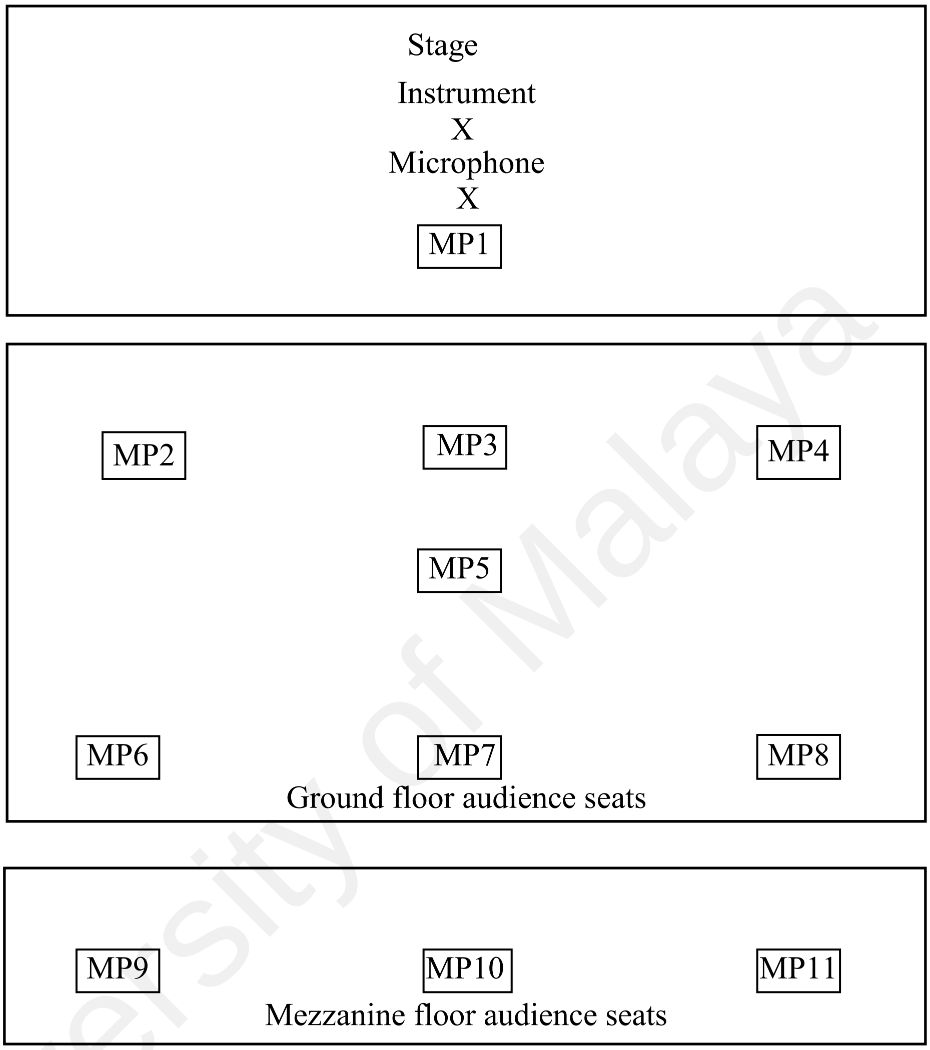


Figure 4.1: Floor plan of ET

Figure above showed the floor plan of ET. Solo musical instruments were placed at the center of the stage. Microphone set up near musical instruments to capture the sound of the musical instrument. This position is marked as MP1 which refer to the original reference sound on stage.

At the ground floor audience seats area, there were 7 listening areas that have been marked in total. They were MP2 to MP8 respectively. The area near the stage in the front part was divided into 3 areas. They were represented by MP2 to MP4. While in the middle section, only the center area was chose and marked as MP5. The last part of the ground floor, there were 3 listening areas as well, which were MP6 to MP8.

There were in total of 3 listening area that were divided at the mezzanine floor audience seats area. These areas were marked as MP9, MP10 and MP11. Each listening area had a microphone positioned to represent the respective area and also act as the equipment to pick up the sounds that transmitted from the stage.

All of the collected data showed by digital mixing console and recorded by video recorder.

4.2 Venue

The Experimental Theatre is located next to the Tunku Chancellor Hall of Cultural Center, University of Malaya. It was constructed together with the Tunku Chancellor Hall in the 1965 to 1966, designed by architect Dato' Kington Loo with the big impact of the Brutalism Architecture and the Modernist movement which was built mostly from bare concrete structure. Incorporating with the modern innovations and systems, the present layout of the Experimental Theatre was built upon Richard Wagner's original concept. The hall features a proscenium stage with a ramp leading to the basement green rooms. At the front of the stage in the Experiment Theatre, there is a hydraulic platform that act as an extension to the front of the stage when was raised. When was lowered, it is also served as an orchestra pit. Hidden above the stage is a structure of grids and rigging to accommodate modern sound and lighting systems. The auditorium consists of tiered stalls and a gallery.

Experimental Theatre can be accommodating up to approximately 435 pax in total. It is a multi functional hall which is suitable for stage performance, conferences, seminars, presentations, product launches and many others.

Figure 4.2: ET

Figure 4.3: ET

4.3 Acoustics Analysis

The acoustic data were computed and conducted using digital mixing console. Figure 4.4 show the example of good spectrum analysis and Figure 4.5 represent the example of bad spectrum analysis. A good spectrum analysis will show average frequency range and loudness level while a bad spectrum analysis will show specific frequency peaking and unbalance loudness level. The acoustical data are presented in the Figures 4.6 to Figures 4.86 below.

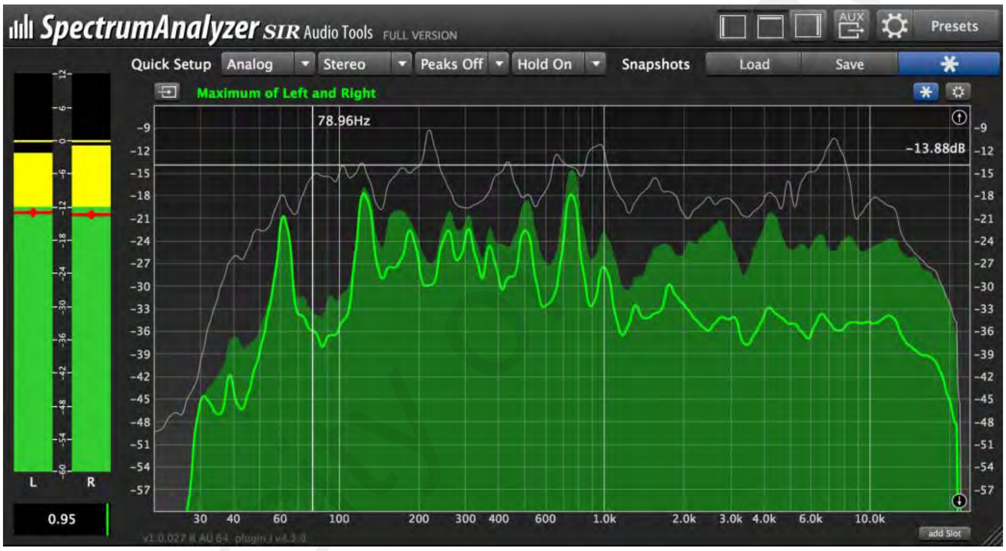


Figure 4.4: Example of good spectrum analysis

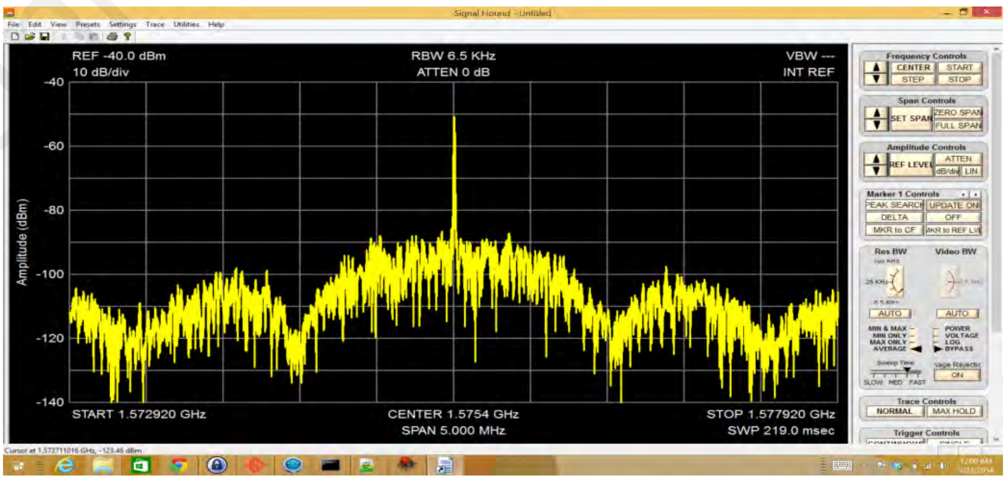


Figure 4.5: Example of bad spectrum analysis

4.3.1 Keyboard-Piano

Piano lowest frequency is 27.5 Hz and the highest is 4186 Hz. The loudness of normal piano practice in room is around 60-70 dB while piano fortissimo can go from 92 to 95 dB.

Figure 4.6 Example of MP1

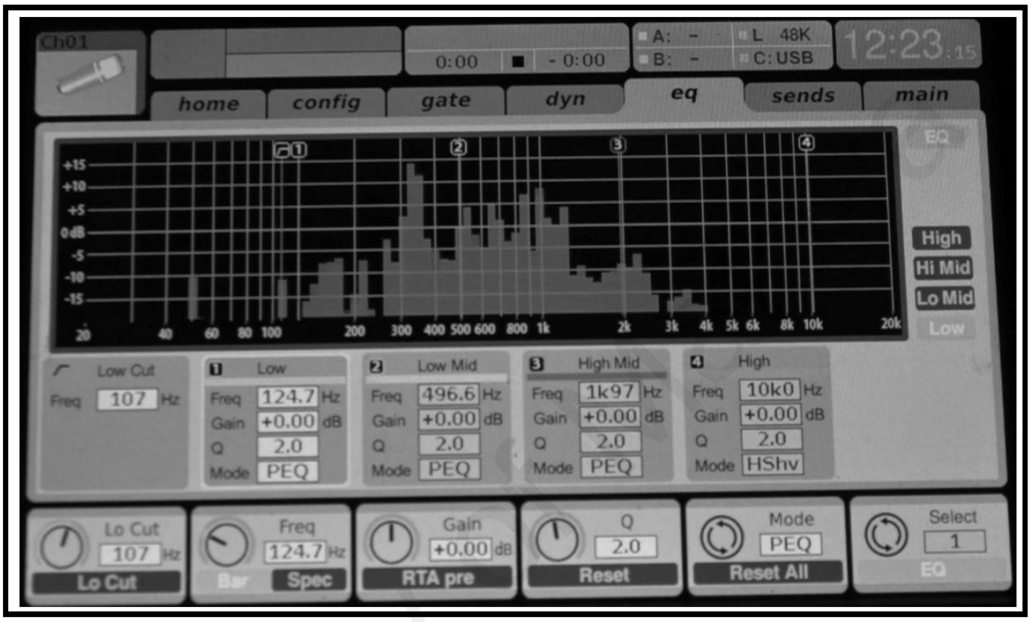


Figure 4.6 show the EQ scene of digital mixing console that captured during data collection of the original piano sound on stage (MP1). The graph shows the frequency (Hz) and the loudness (dB) of the piano. The frequency of the piano on stage is from 100 to 4k Hz with maximum +15dB.

Figure 4.7 Example of MP2

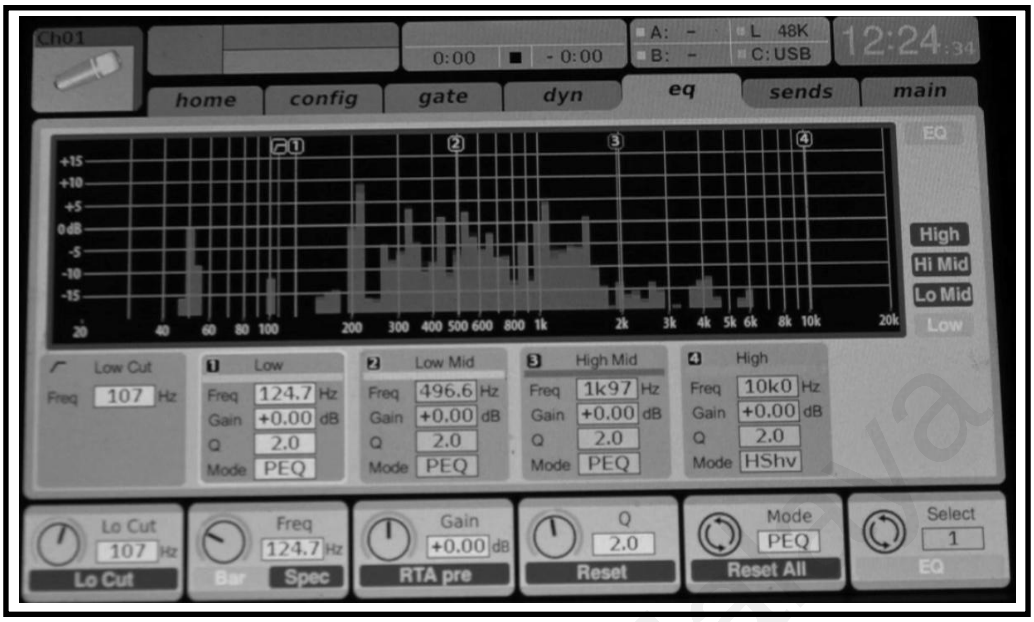


Figure 4.7 show the graph of piano sound from MP2. The frequency of this position is from the low 150 Hz to the high 6kHz and the loudness is +10dB.

Figure 4.8 Example of MP3

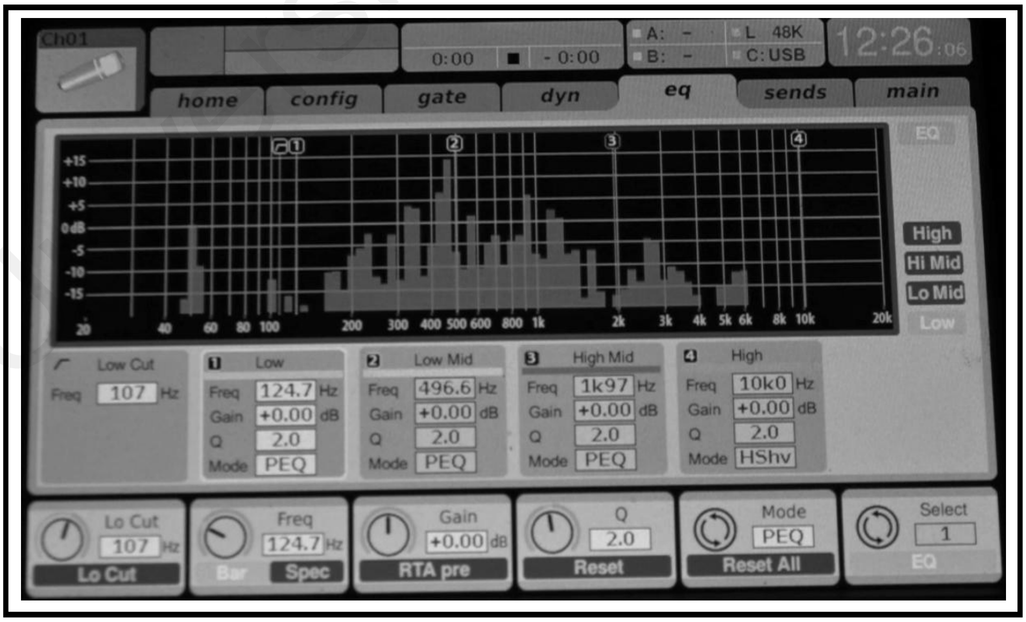


Figure 4.8 present the graph for piano sound from MP3. The lowest frequency from this position is 150Hz and the highest is 7kHz. The peak of this position is +15dB.

Figure 4.9 Example of MP4

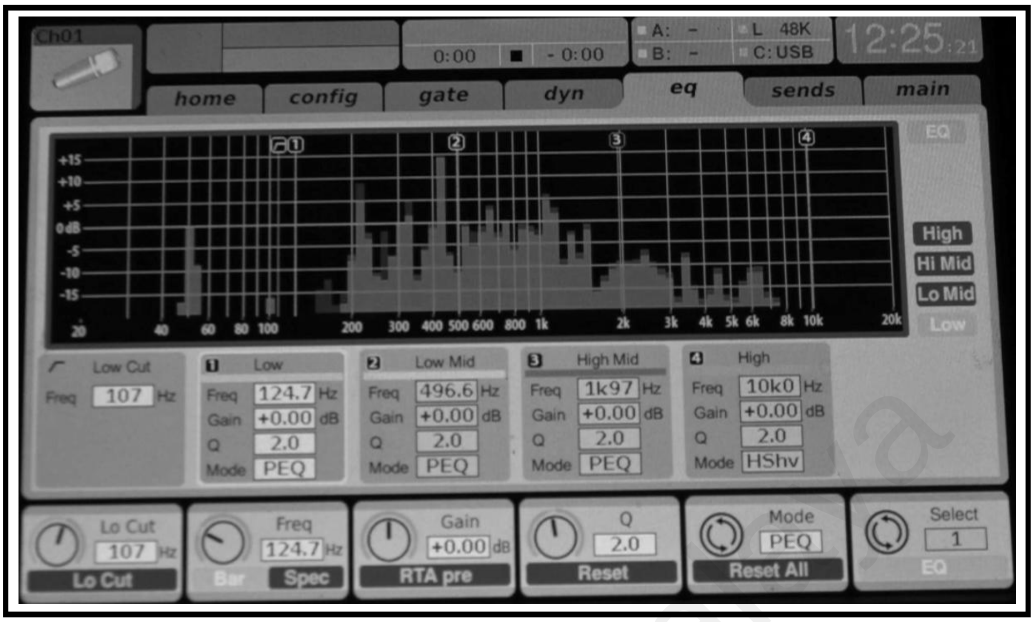


Figure 4.9 is the graph for the position MP4. The frequency is 160Hz to 6kHz and the maximum loudness is at +15dB.

Figure 4.10 Example of MP5

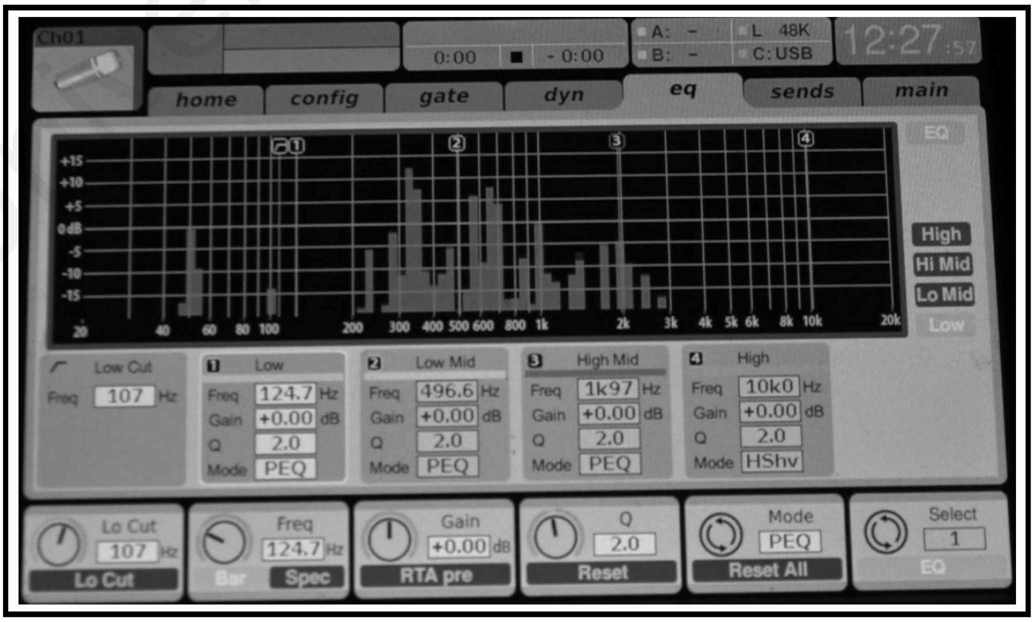
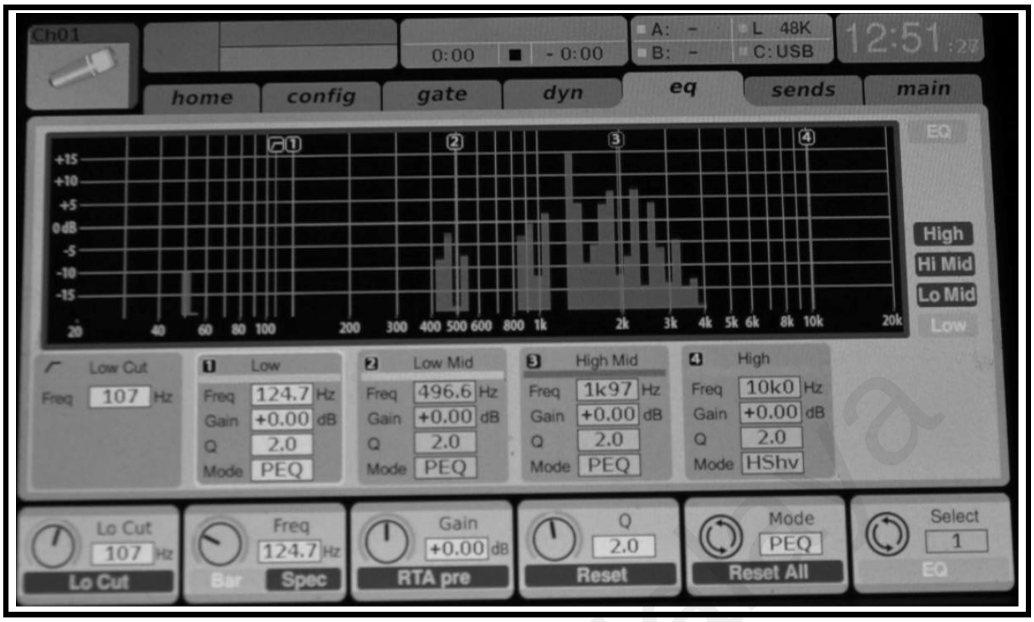


Figure 4.11 Example of MP5



Both figure 4.10 and 4.11 represent the data for MP5. Figure 4.10 shows that the piano frequency range in this position stay mostly in between 200 to 3kHz and the maximum loudness is +13dB. Figure 4.11 shows that sometimes the frequency range is expanded from 120Hz to 6kHz and the peak is increase to +15dB.

Figure 4.12 Example of MP6

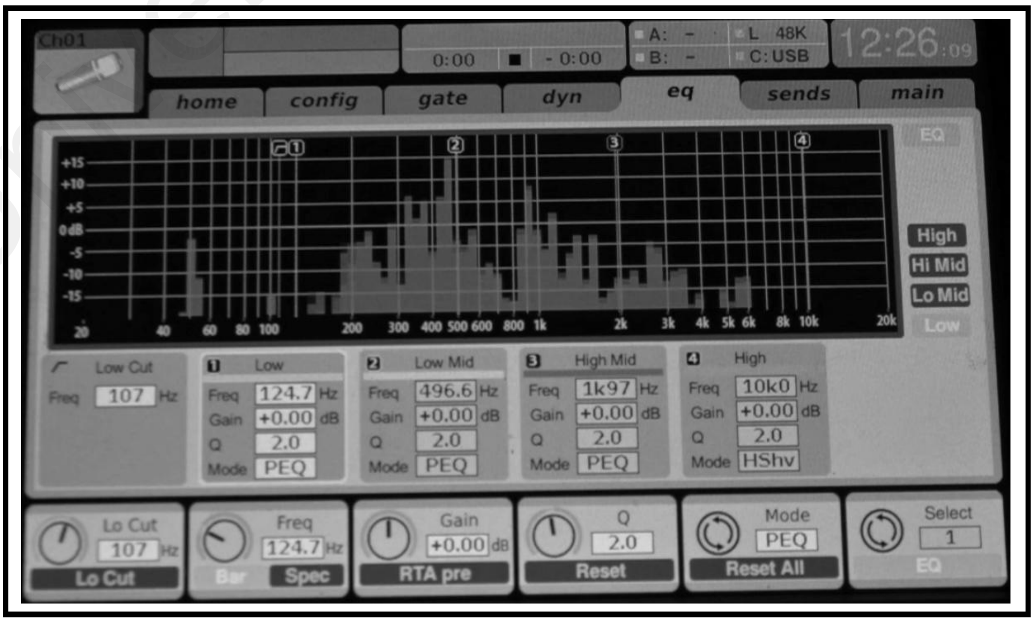


Figure 4.12 shows an example of the obtained sound at MP6. In this position, the frequency range is from 200 to 3kHz. The maximum loudness is +10dB.

Figure 4.13 Example of MP7

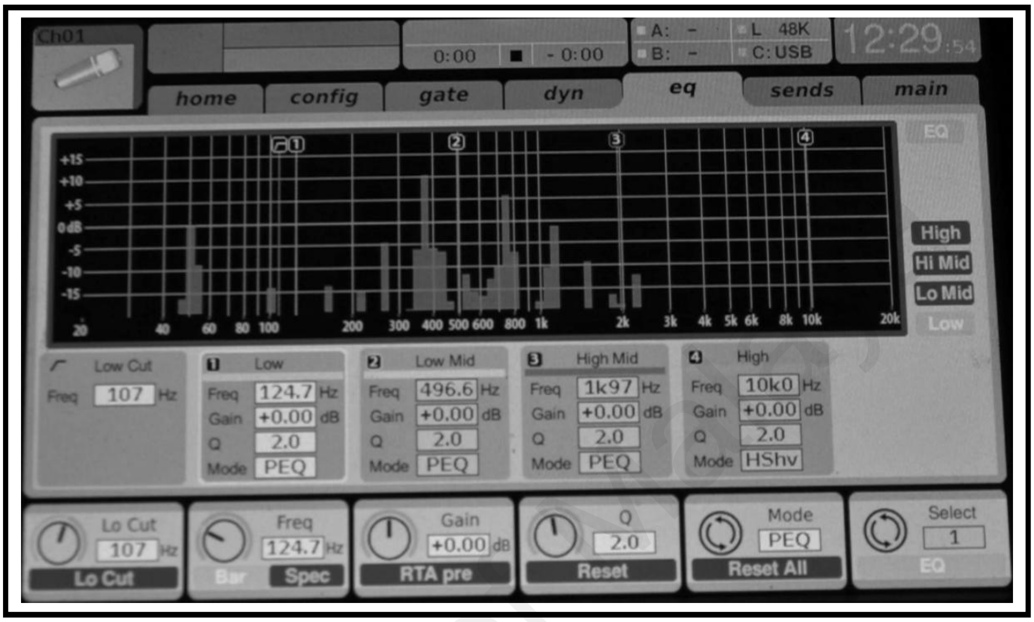
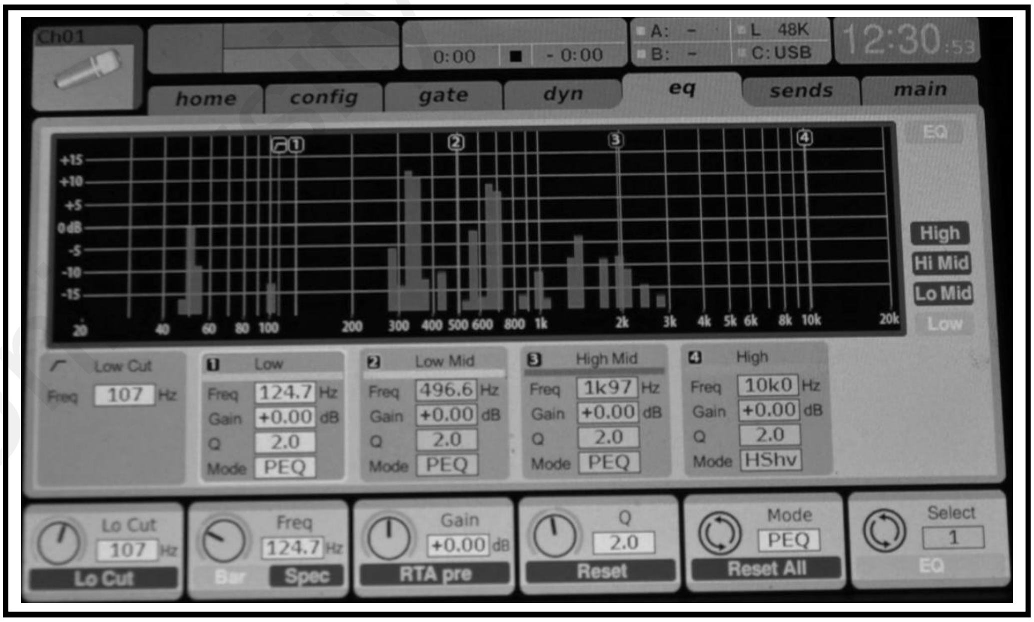
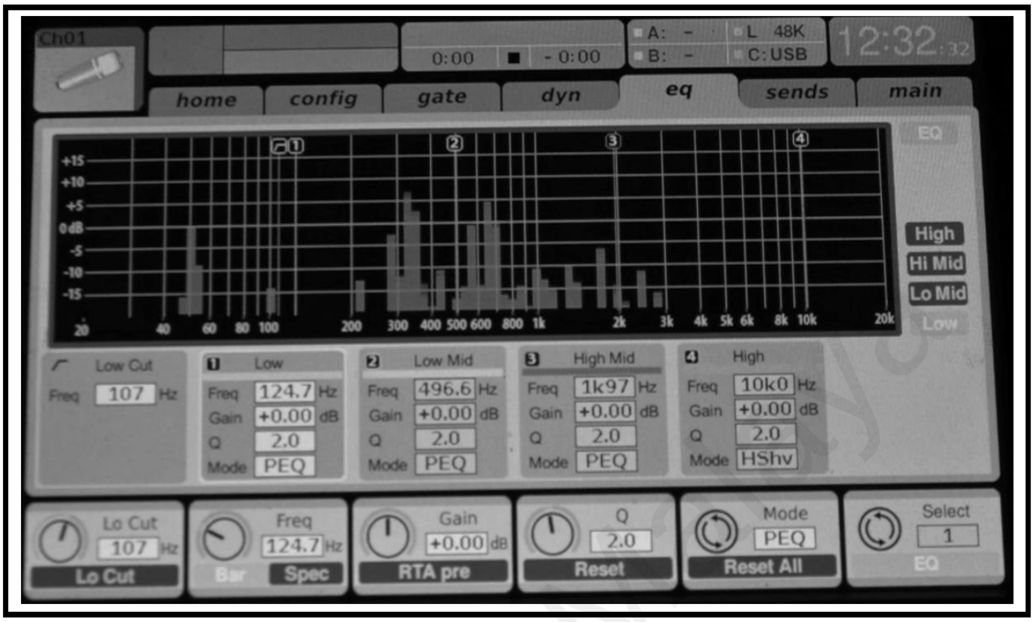


Figure 4.14 Example of MP7



Both figure above show the normal frequency range in this position which is around 150Hz to 3kHz with the peak up to +12dB.

Figure 4.15 Example of MP8



This graph represents the piano sound from MP8. The frequency range of this position is from 200Hz to 3kHz and the maximum loudness is around +10dB.

Figure 4.16 Example of MP9

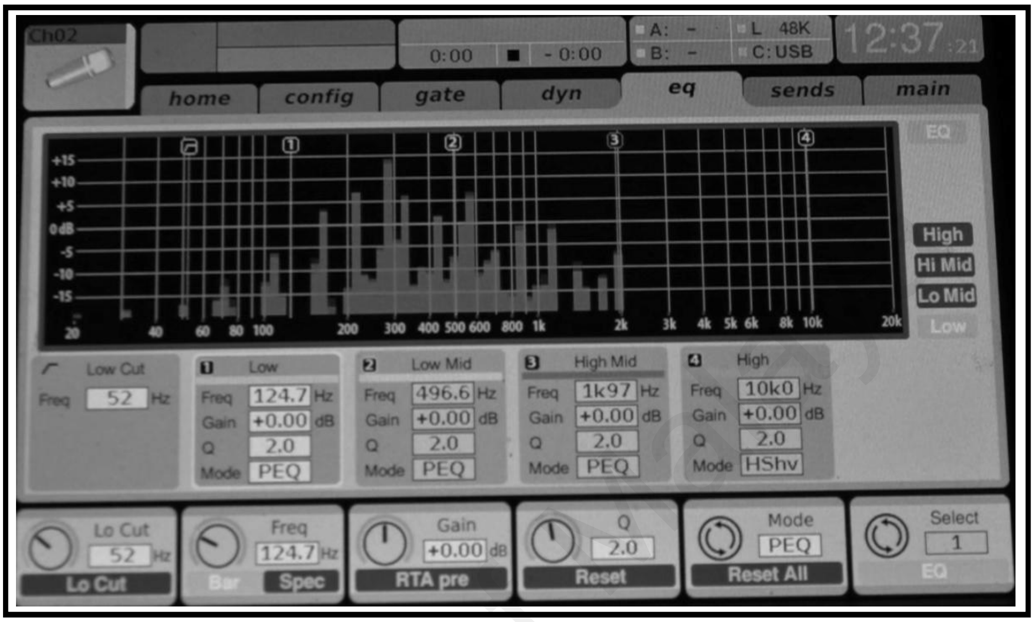


Figure 4.17 Example of MP9

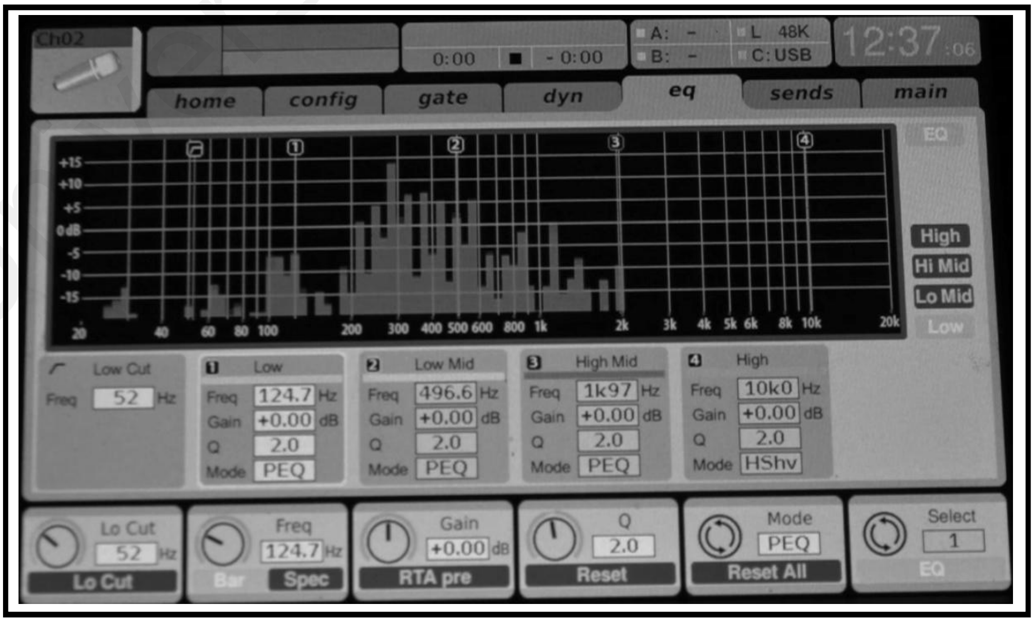


Figure 4.18 Example of MP9

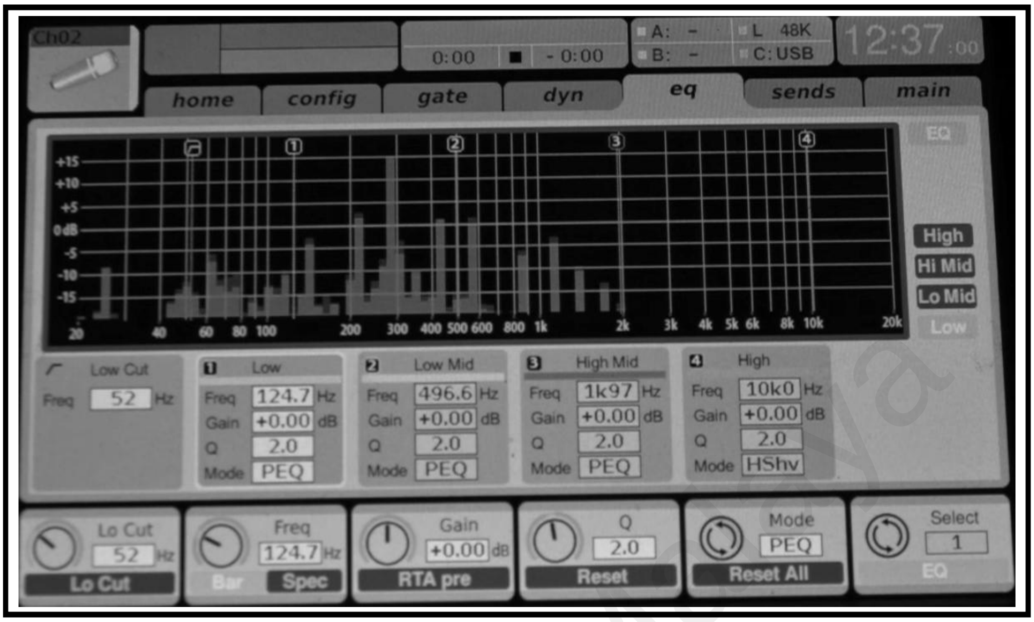


Figure 4.19 Example of MP9

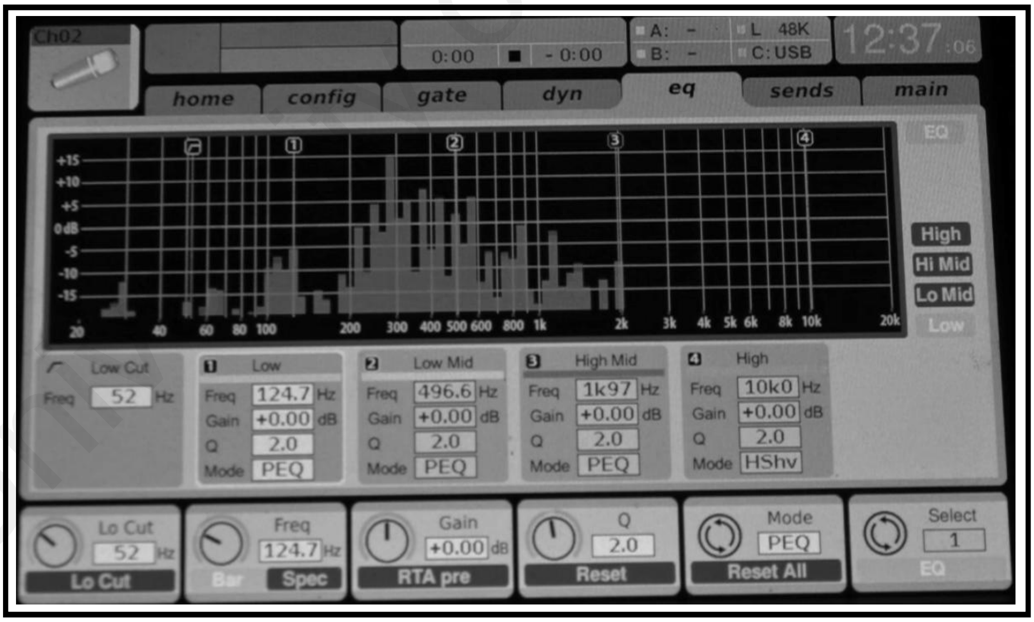


Figure 4.16 to Figure 4.19 are the examples from the result obtain from data collected of MP9. The conclusion on MP9 is that the average frequency range is from the low of 100kHz to the highest of 3kHz with the highest loudness of +15dB.

Figure 4.20 Example of MP10

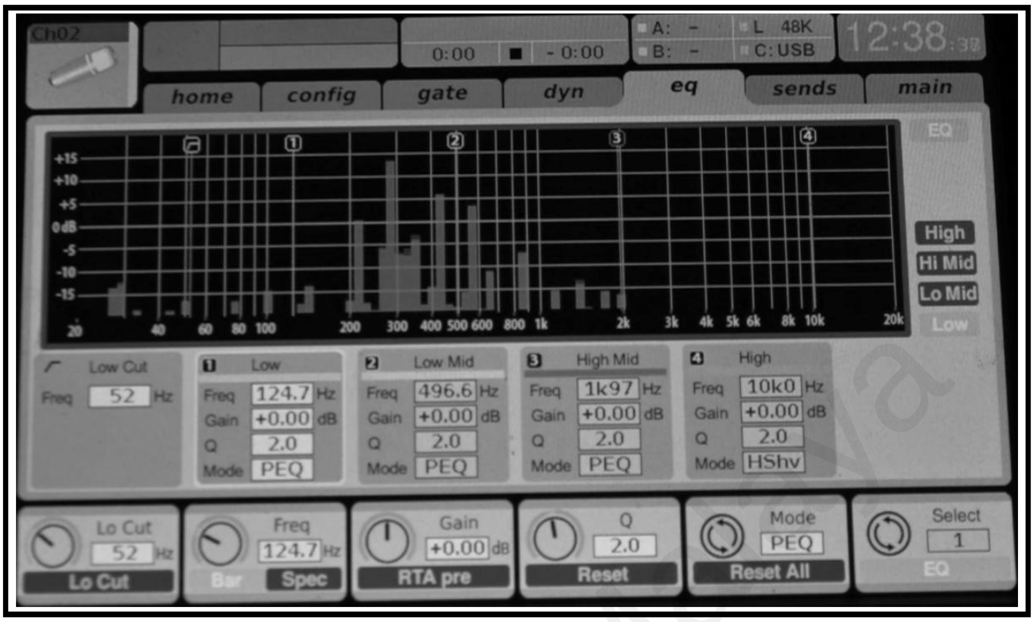
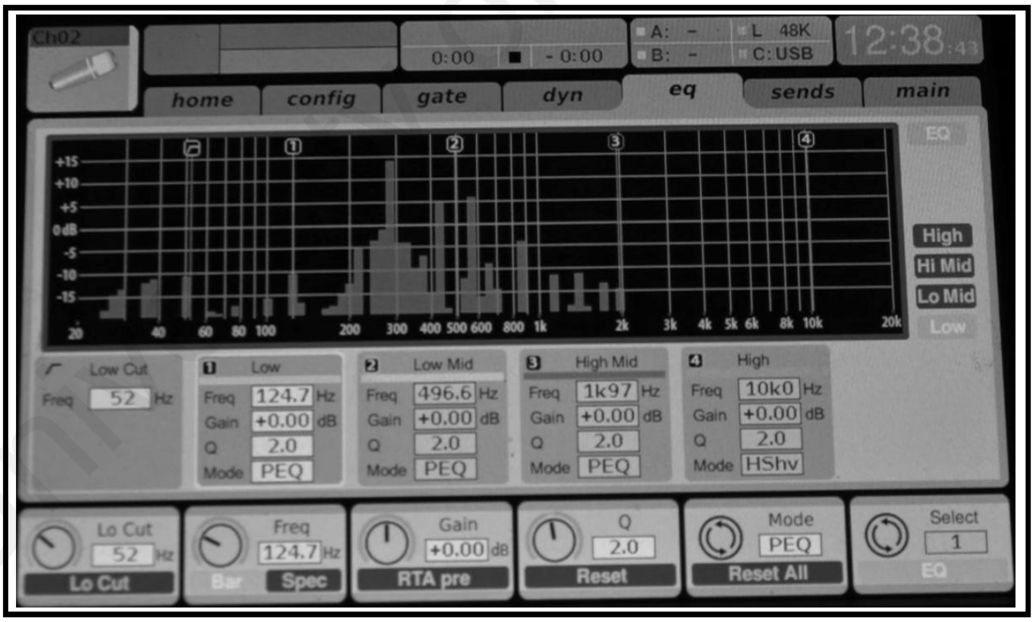
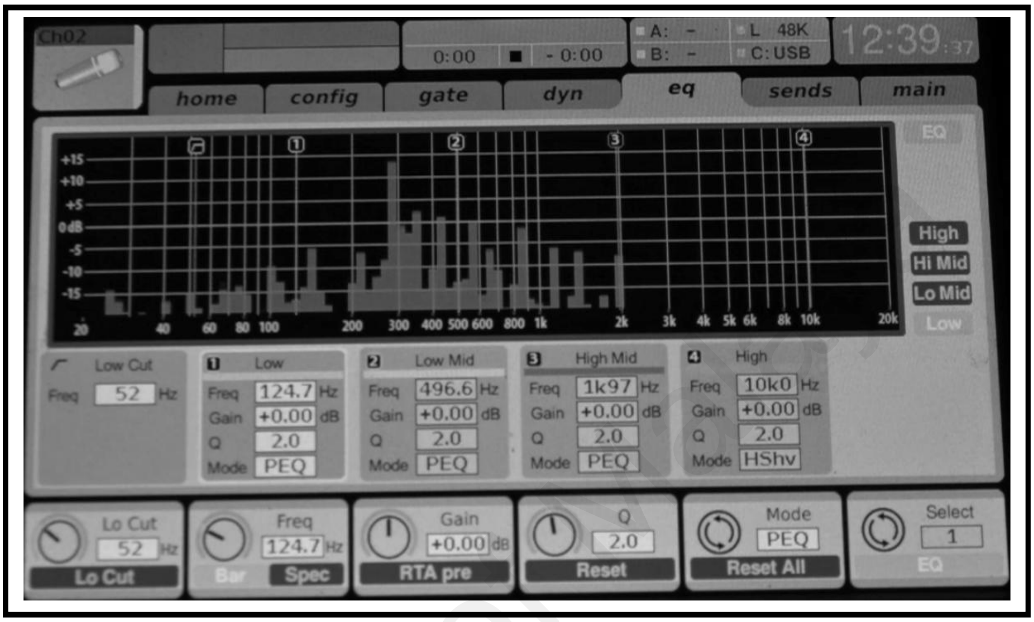


Figure 4.21 Example of MP10



These are some of the example for MP10. Result here shows that MP10 has the frequency range of 200Hz to 3kHz with the maximum loudness level is at +15dB.

Figure 4.22 Example of MP11



The outcome of MP11 is that the frequency range is from 120Hz to 3kHz and the maximum loudness level is at +15dB.

Table 4.1 displays the summary of the acoustic data for keyboard instrument, the piano.

Table 4.1

Summary of the acoustic data for keyboard instrument (Piano)

Keyboard Instrument (Piano)		
Location	Frequency (Hz)	Loudness (dB)
MP1	100-4k	+15dB
MP2	150-6k	+10dB
MP3	150-7k	+15dB
MP4	160-6k	+15dB
MP5	200-3k	+13dB
MP6	200-3k	+10dB
MP7	200-3k	+12dB
MP8	200-3k	+10dB
MP9	100-3k	+15dB
MP10	200-3k	+15dB
MP11	120-3k	+15dB

The original reference sound on stage MP1 has the frequency range ranged from 100Hz to 4kHz. The maximum loudness of it is at the highest of +15dB.

The data in Table 4.1 shows that the frequency range for the 7 measurement positions of audience seats ground floor ranged from 100Hz to 7kHz. MP3 having the widest frequency range. MP5 to 8 have the same narrowest frequency range.

The maximum loudness level in here ranged from +10dB to +15dB. MP3 and 4 both have the maximum loudness level at +15dB. MP 2, 6 and 8 have the lowest maximum loudness level at +10dB.

The 3 measurement positions of audience seats mezzanine floor have the frequency range ranged from 100Hz to 3kHz. MP9 has the widest frequency range while MP10 has the narrowest frequency range.

The maximum loudness level of mezzanine floor all at the highest of +15dB.

The results in Table 4.1 indicate that compare with MP1, the closest to it is MP9, where it has the frequency range ranged from 100Hz to 3kHz and the maximum loudness level at +15dB.

Mezzanine floor has the better sound quality and acoustics because of the natural resonance effect from the building. Starting from MP5 onwards, the signal losing the high frequencies as high frequency cannot travel far compare to low frequency. MP1 is lost of high frequencies as there is no resonance as the ceiling on stage is very high.

4.3.2 Brass-Trumpet

Trumpet has the frequency range from 165Hz to 988Hz. Human hearing can only tolerate up to 80dB of trumpet loudness without hearing damage however it can reach up to 110 dB SPL.

Figure 4.23 Example of MP1.

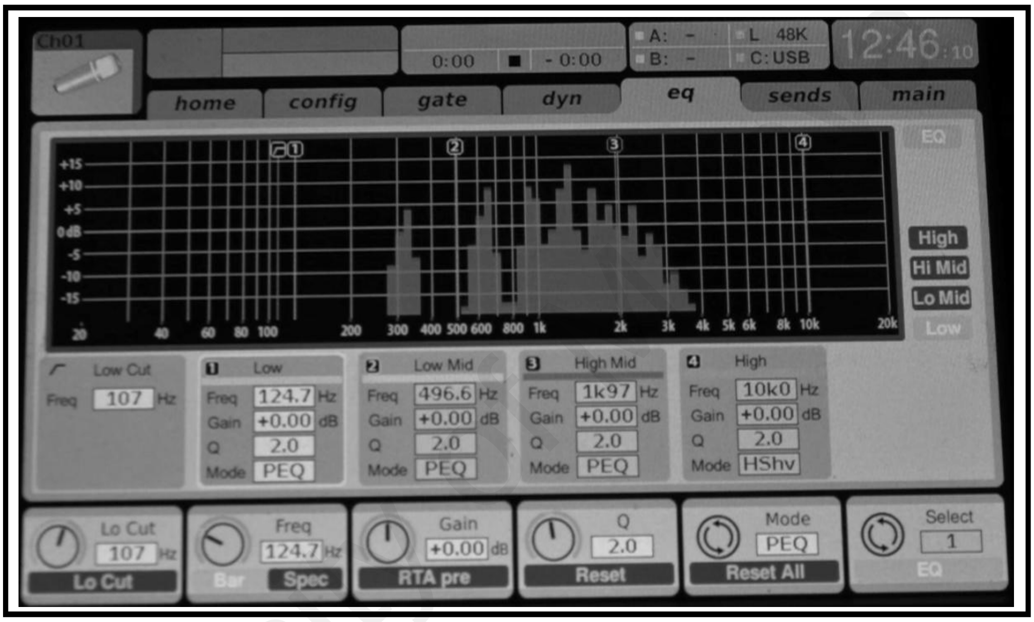
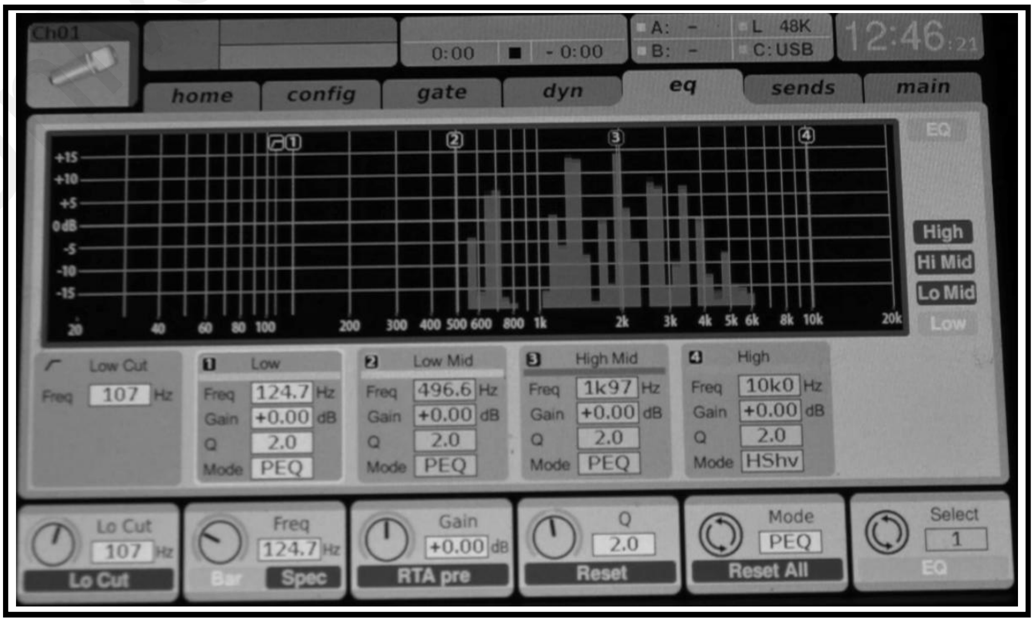
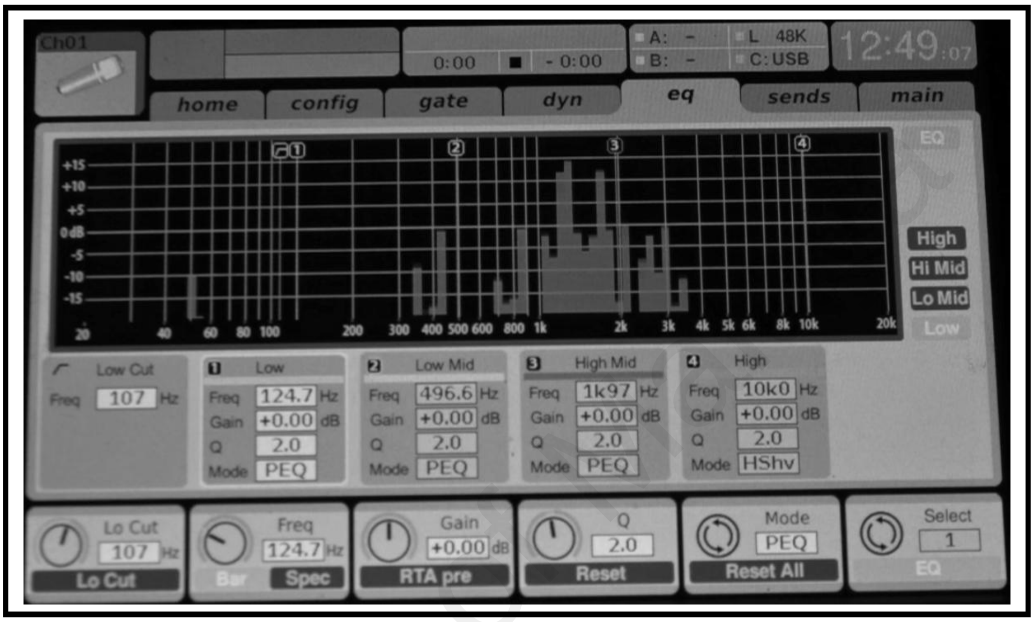


Figure 4.24 Example of MP1.



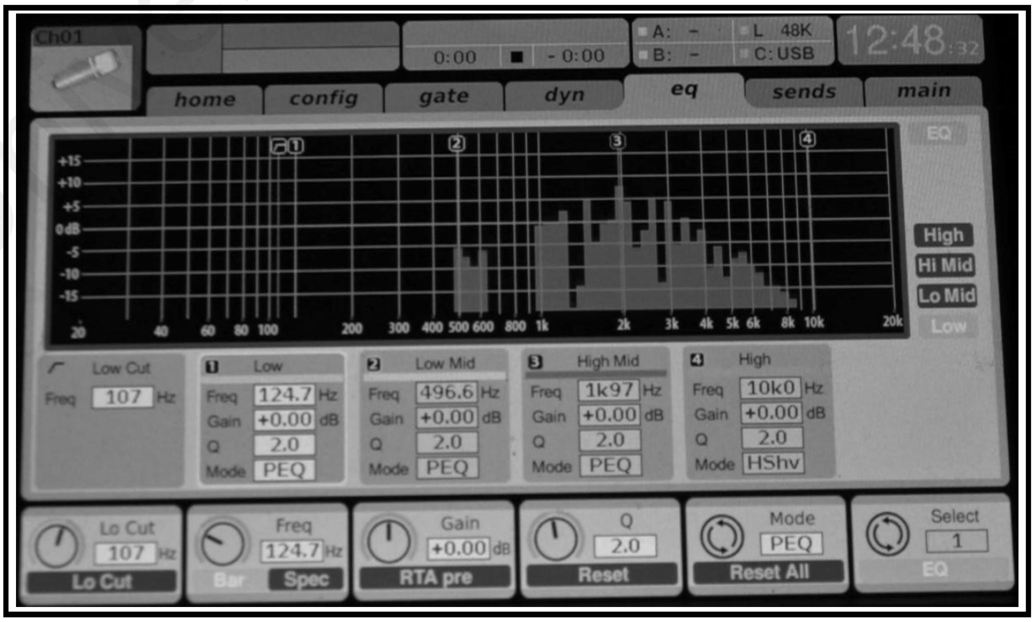
As shown in Figure 4.23, the lowest frequencies are 300Hz while Figure 4.24 show the highest frequencies is at 6kHz. The maximum loudness level is +15dB.

Figure 4.25 Example of MP2



The frequency range in here is from 280 to 7kHz and the loudness is +15dB.

Figure 4.26 Example of MP3



Frequency range is 280 to 10kHz with +15dB in this position.

Figure 4.27 Example of MP4

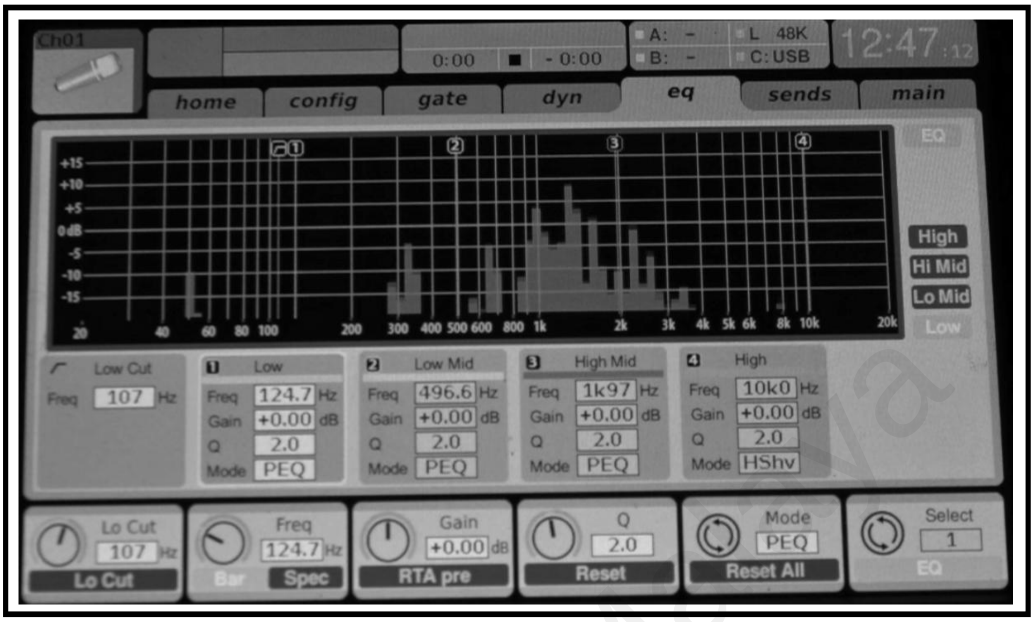


Figure 4.28 Example of MP4

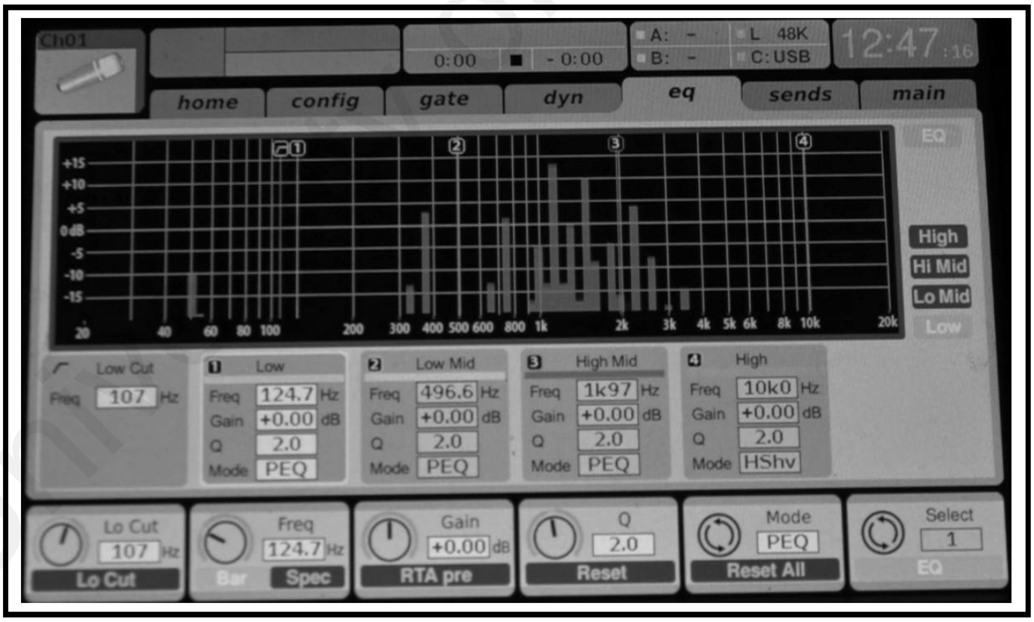
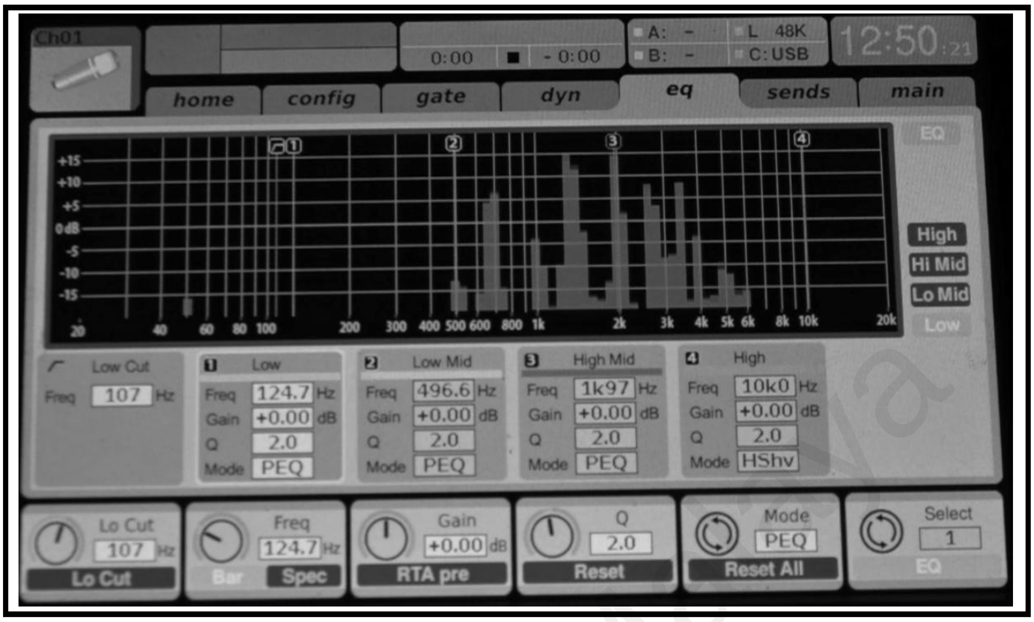


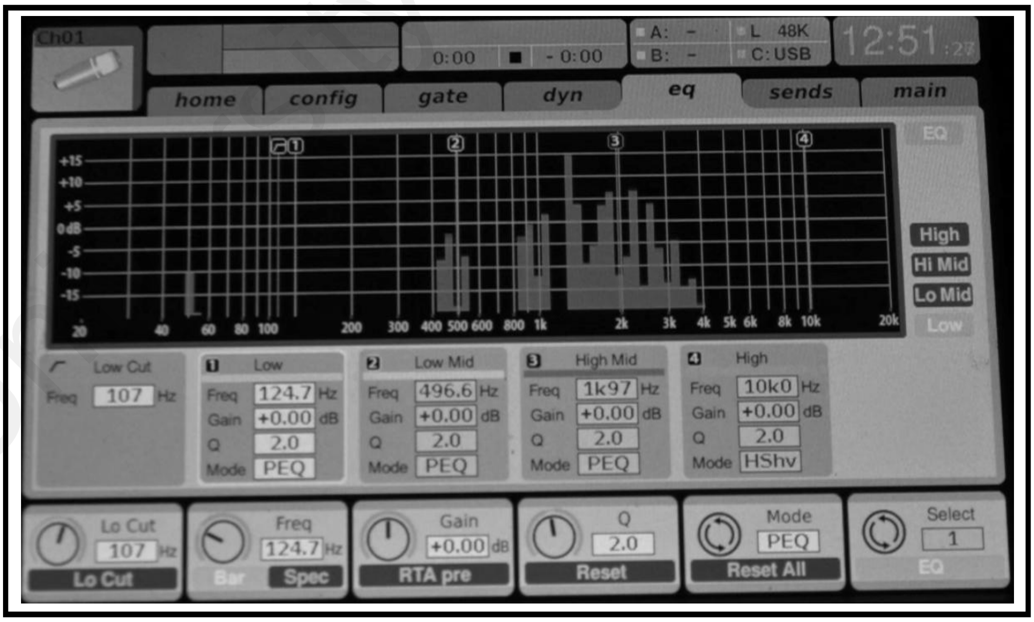
Figure 4.27 and 4.28 represent MP4. Figures show that in this position, the frequency can hit as low as 300Hz to the highest 4kHz with the maximum loudness of +15dB.

Figure 4.29 Example of MP5



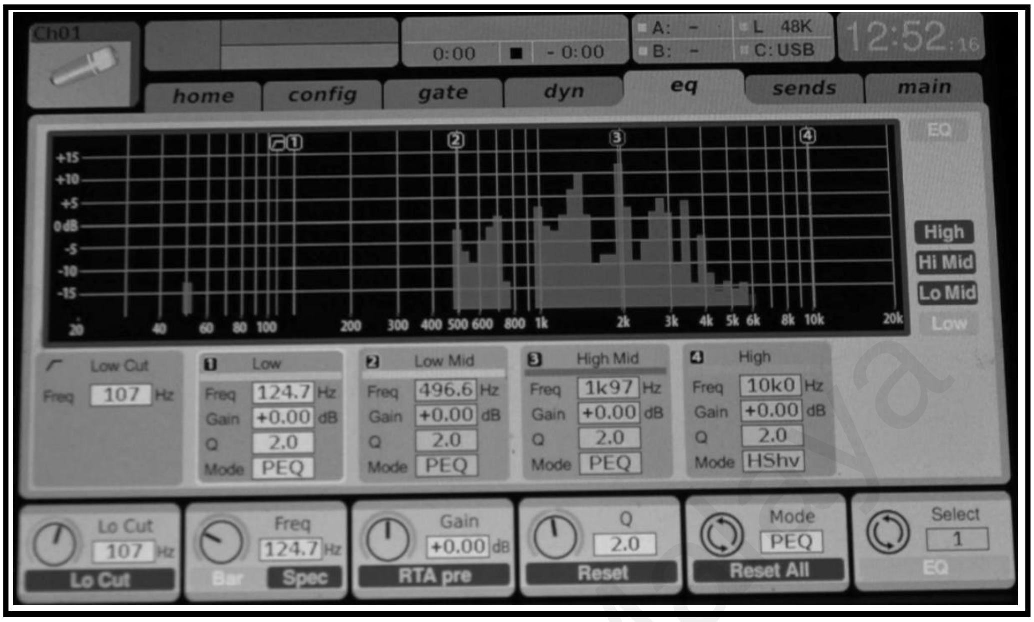
Frequency range in here is from 280Hz to 8kHz and the peak level is +15dB.

Figure 4.30 Example of MP6



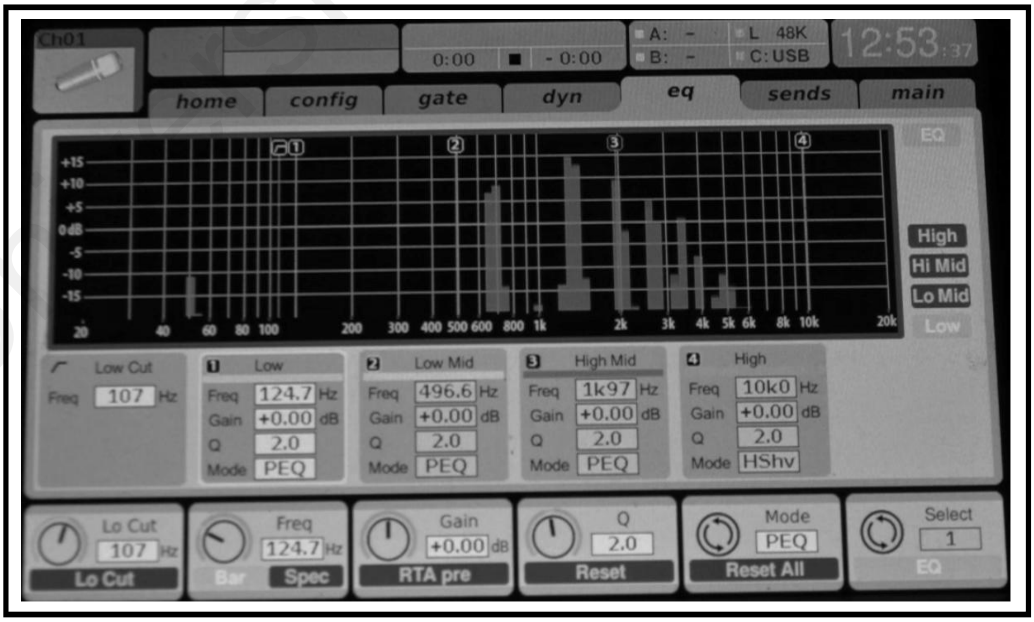
The frequency range of this position is 300 to 4kHz and the loudness is +15dB.

Figure 4.31 Example of MP7



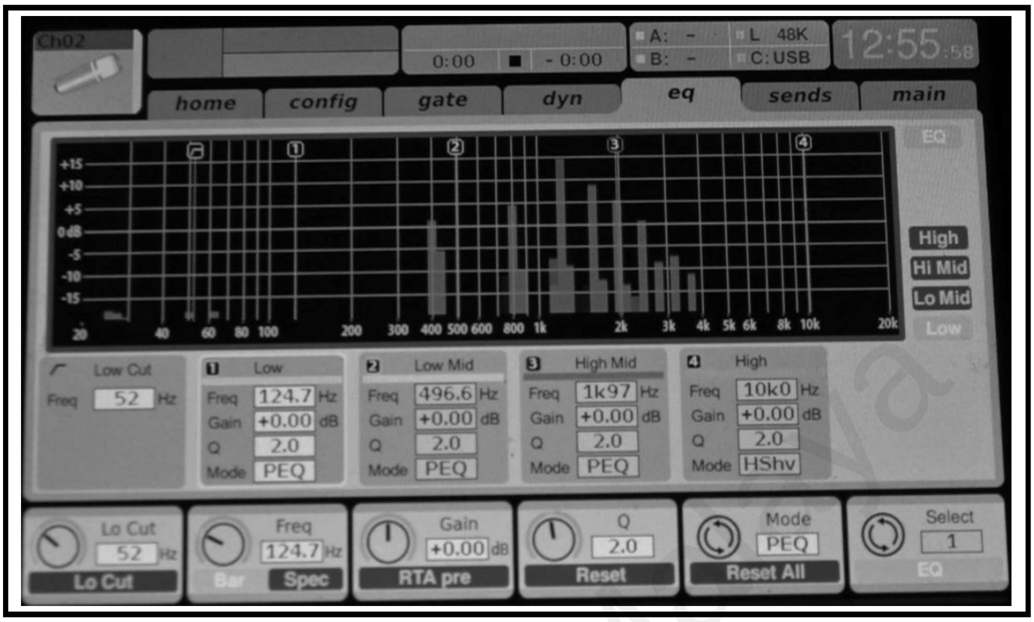
Lowest frequencies in this position is 280Hz while the highest is 7kHz. The maximum loudness is +15dB.

Figure 4.32 Example of MP8



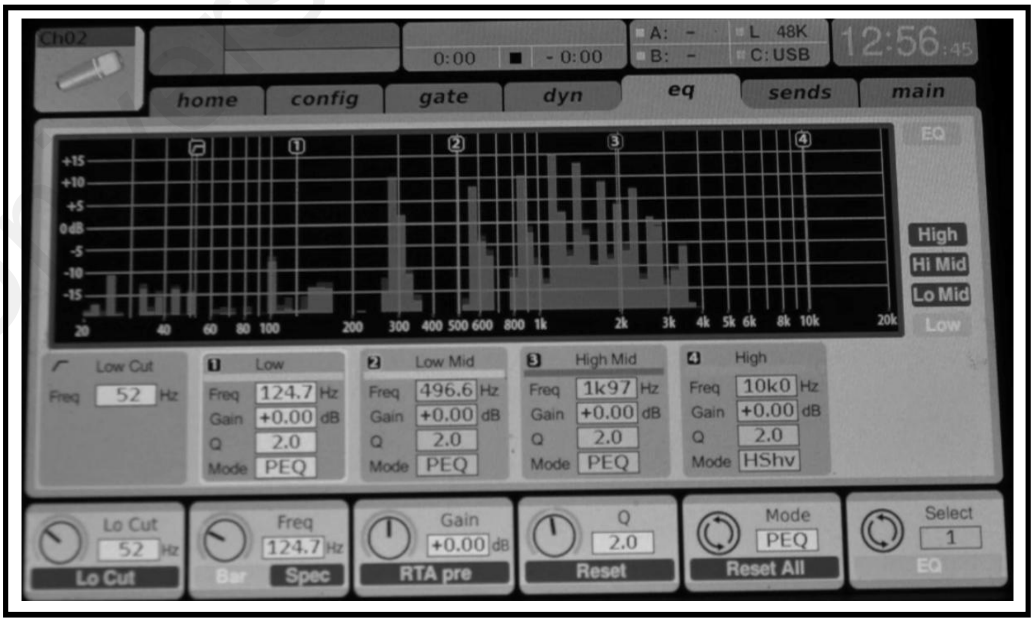
Trumpet sound from this position has the lowest frequencies of 280Hz and the highest 6kHz. The maximum loudness is +15dB.

Figure 4.33 Example of MP9



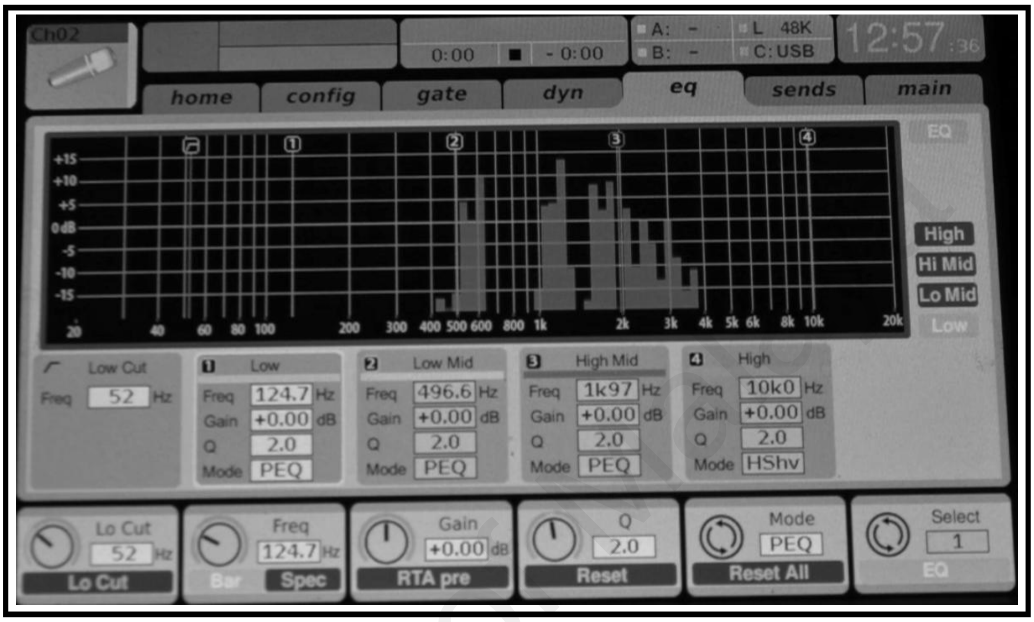
In this position, the frequency range is 300 to 6kHz and the loudness is +15dB.

Figure 4.34 Example of MP10



This position has the frequency range of 300 to 6kHz and the loudness is +15dB.

Figure 4.35 Example of MP11



The position has frequency range of 300 to 5kHz and +15dB loudness.

Table 4.2 displays the summary of the acoustic data for brass instrument, the trumpet.

Table 4.2

Summary of the acoustic data for brass instrument (Trumpet)

Brass Instrument (Trumpet)		
Location	Frequency (Hz)	Loudness (dB)
MP1	300-6k	+15dB
MP2	280-7k	+15dB
MP3	280-10k	+15dB
MP4	300-4k	+15dB
MP5	280-8k	+15dB
MP6	300-4k	+15dB
MP7	280-7k	+15dB
MP8	280-6k	+15dB
MP9	280-6k	+15dB
MP10	300-6k	+15dB
MP11	300-5k	+15dB

The original reference sound on stage MP1 has the frequency range ranged from 300Hz to 6kHz. The maximum loudness of it is at the highest of +15dB.

The data in Table 4.2 shows that the frequency range for the 7 measurement positions of audience seats ground floor ranged from 280Hz to 10kHz. MP3 having the widest frequency range. MP2 have the same narrowest frequency range.

The maximum loudness level in here all ranged +15dB, which indicate that all the measurement positions have the same maximum loudness level.

The 3 measurement positions of audience seats mezzanine floor have the frequency range ranged from 300Hz to 6kHz. MP9 and 10 have the widest frequency range while MP11 has the narrowest frequency range.

The maximum loudness level of mezzanine floor all at the highest of +15dB.

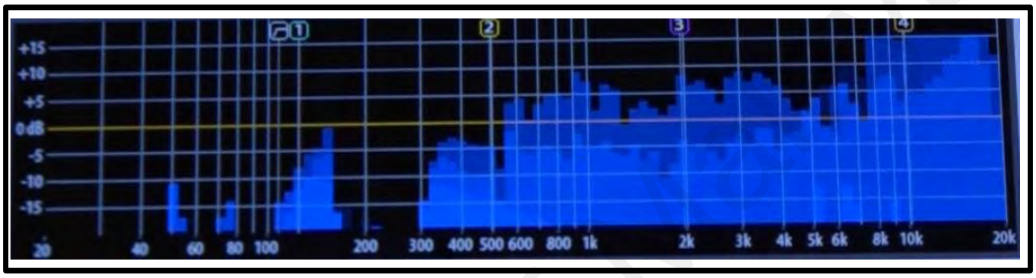
The results in Table 4.2 indicate that compare with MP1, MP9 and MP10 have the same result with it, where the frequency range ranged from 300Hz to 6kHz and the maximum loudness level at +15dB. Apart from that, MP3 has the widest frequency range.

Compare with the fundamental frequency range of trumpet sound, trumpet sound in Experimental Theater have much more high frequencies. All the high frequencies in here are the reverb effect of the musical instrument. This are result to the hall acoustics that have natural resonance to high frequencies.

4.3.3 Percussion-Drum Kit

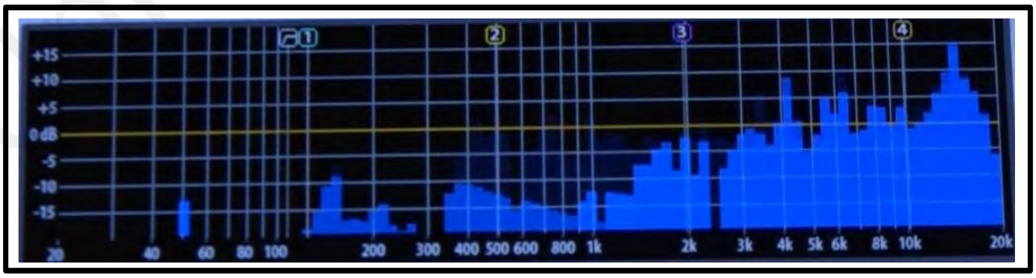
The drum kit that used for the data collection is only including the kick drum, snare drum and also the hi-hat. Normal full drum kit set has the fundamental frequency range of 55Hz to 12kHz. And the highest hearing level is around 115dB SPL.

Figure 4.36 Example of MP1



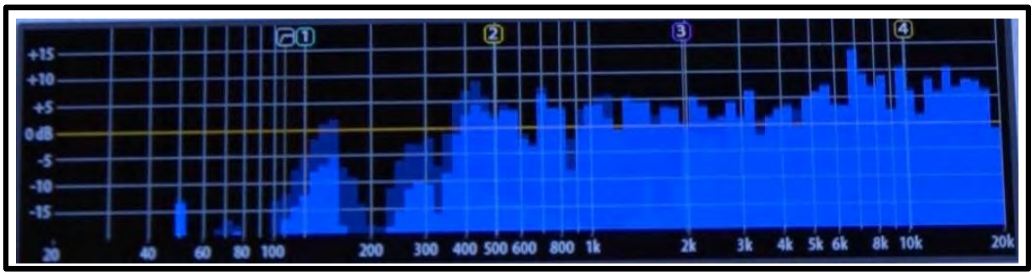
The original reference sound on stage has the frequency range from 80 to 20kHz. The maximum loudness of it is +15dB.

Figure 4.37 Example of MP2



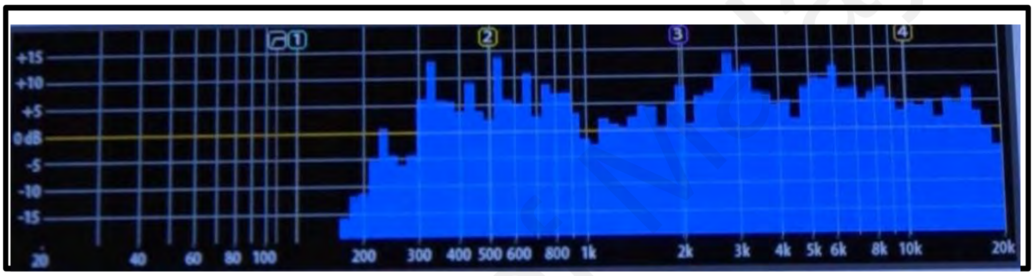
The frequency range in this position is from 80 to 20kHz and the peak level is +15dB.

Figure 4.38 Example of MP3



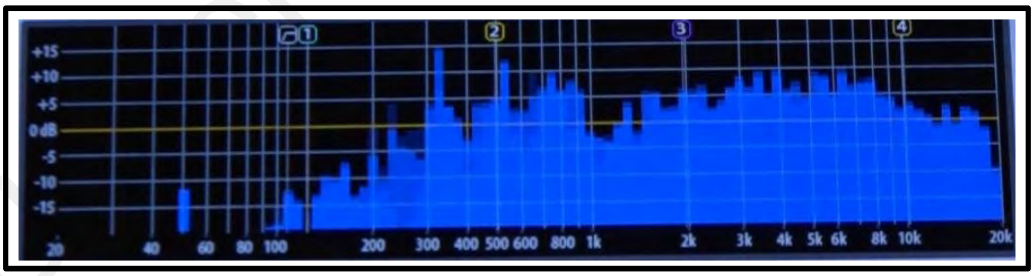
Frequency range in here is from 80 to 20kHz and the loudness is +15dB.

Figure 4.39 Example of MP4



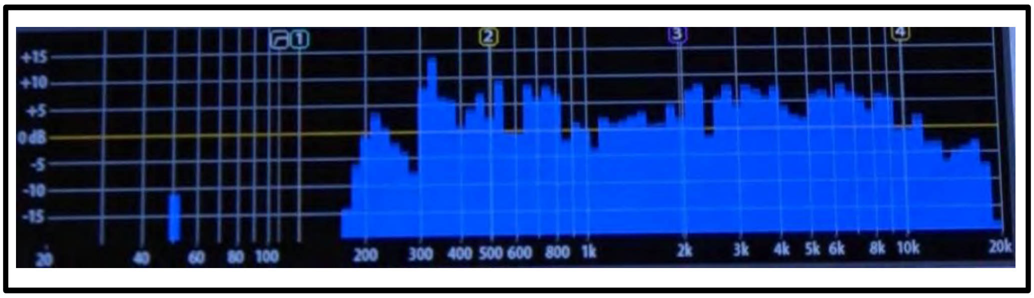
Frequency range in here is from 95 to 20kHz and the loudness is +15dB.

Figure 4.40 Example of MP5



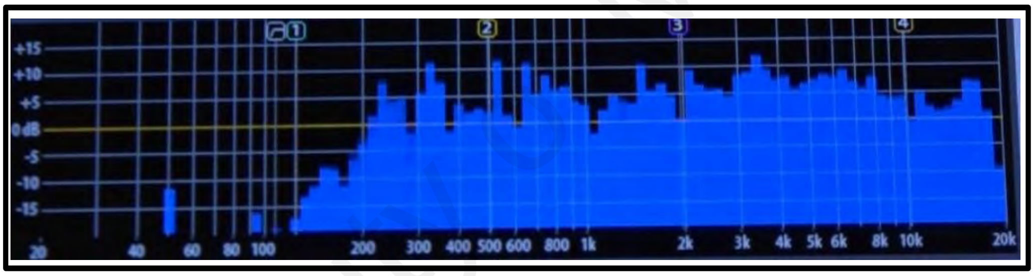
From the data collected in this position, the frequency range is 80 to 20kHz and the loudness is +15dB.

Figure 4.41 Example of MP6



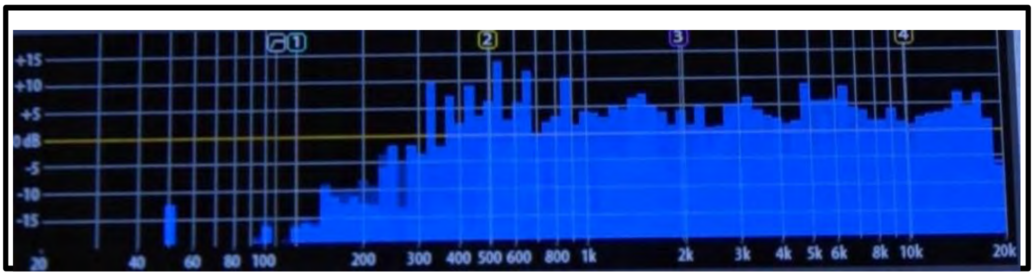
As refer to the data collected, the frequency range in here has the lowest of 80Hz and the highest is 20kHz. For the loudness level, the peak of this position is at +15dB.

Figure 4.42 Example of MP7



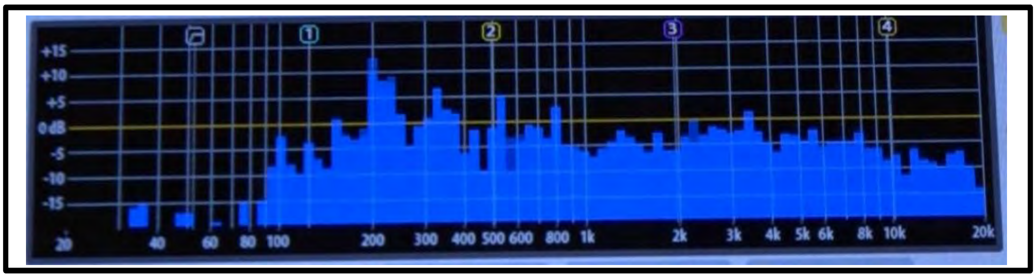
Through the result obtained, the frequency range in this position is from 80 to 20kHz and the peak level is at +15dB.

Figure 4.43 Example of MP8



Frequency range in here is from 80 to 20kHz. Loudness is +15dB.

Figure 4.44 Example of MP9



As shown in Figure 4.44, the frequency range in here has the low resonance at 35Hz up to 20kHz. While for the loudness level, the maximum level in here is +15dB.

Figure 4.45 Example of MP10

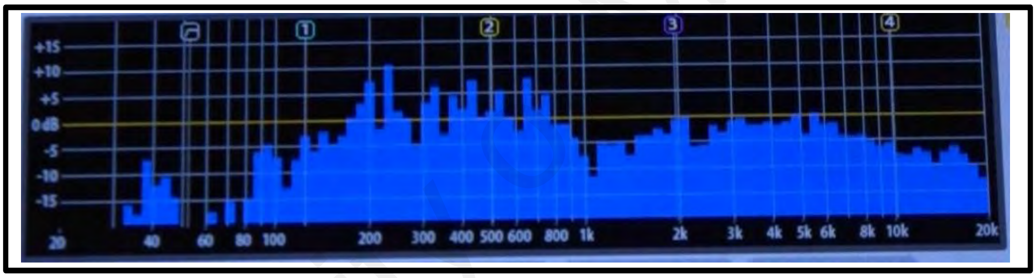
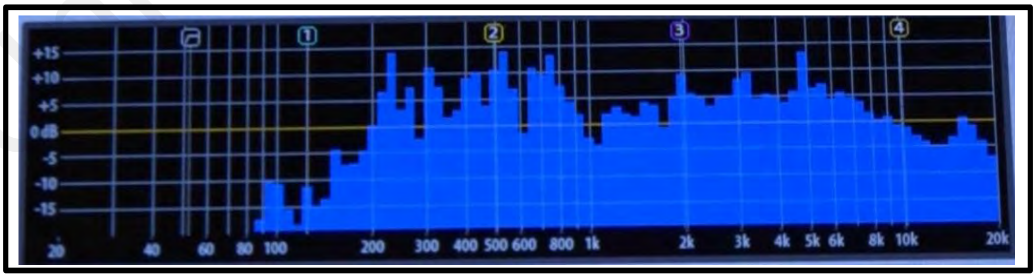


Figure 4.46 Example of MP10



Both Figure 4.45 and 4.46 present the result of this position. The frequency range in here is from the low resonance of 35Hz to the high of 20kHz. The maximum loudness level in here is also +15dB.

Figure 4.47 Example of MP11

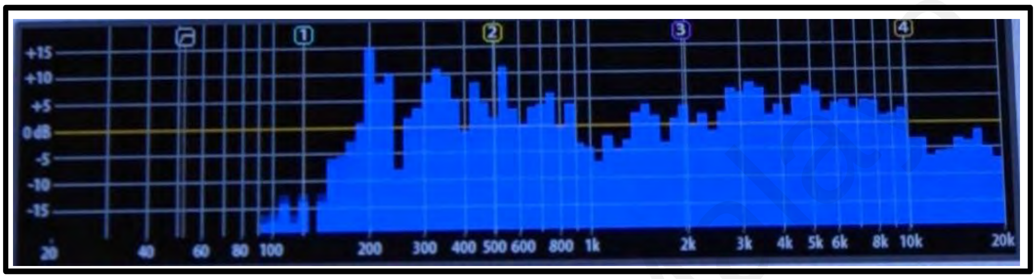
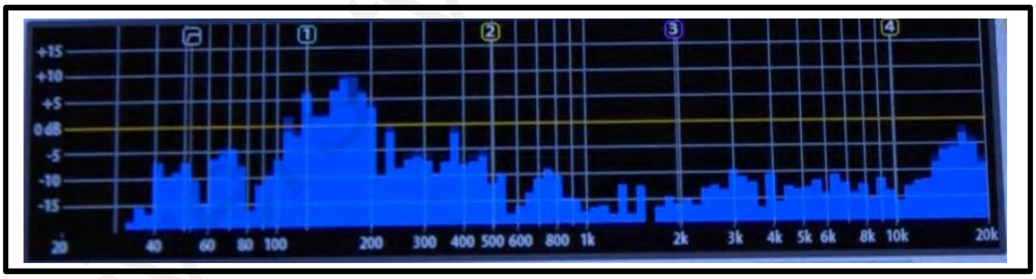


Figure 4.48 Example of MP11



Frequency range in here is from 36Hz to 20kHz and the maximum loudness level is +15dB.

Table 4.3 displays the summary of the acoustic data for percussion instrument, the drum kit.

Table 4.3

Summary of the acoustic data for percussion instrument (Drum Kit)

Percussion Instrument (Drum Kit)		
Location	Frequency (Hz)	Loudness (dB)
MP1	80-20k	+15dB
MP2	80-20k	+15dB
MP3	80-20k	+15dB
MP4	95-20k	+15dB
MP5	80-20k	+15dB
MP6	80-20k	+15dB
MP7	80-20k	+15dB
MP8	80-20k	+15dB
MP9	35-20k	+15dB
MP10	35-20k	+15dB
MP11	36-20k	+15dB

The original reference sound on stage MP1 has the frequency range ranged from 80Hz to 20kHz. The maximum loudness of it is at the highest of +15dB.

The data in Table 4.3 shows that the frequency range for the 7 measurement positions of audience seats ground floor ranged from 80Hz to 20kHz. All the 7 position are the same apart from MP4 that has frequency range ranged from 95Hz to 20kHz.

The maximum loudness level in here all ranged +15dB, which indicate that all the measurement positions have the same maximum loudness level.

The 3 measurement positions of audience seats mezzanine floor have the frequency range ranged from 35Hz to 20kHz. MP9 and 10 have the same frequency range that are just a slide difference from MP11.

The maximum loudness level of mezzanine floor all at the highest of +15dB.

The results in Table 4.3 indicate that most of the measurement positions in ground floor have the same frequency range as MP1. However, the frequency range in mezzanine floor are wider. That is the result to the acoustics of Experimental Theatre that allow the low frequencies resonant more in mezzanine floor.

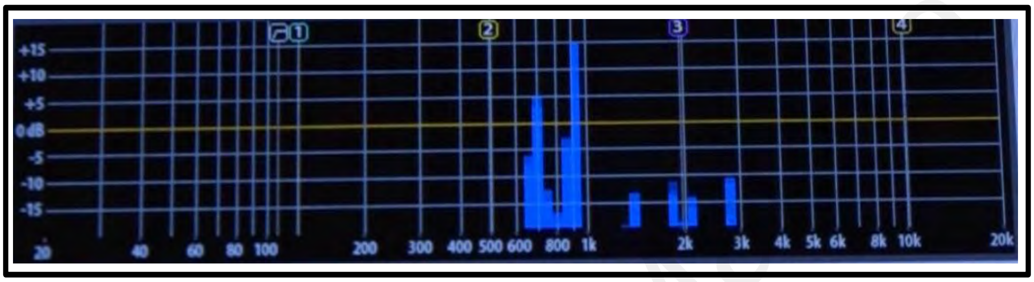
Although the maximum loudness level of all measurement position are at +15dB, however according to the result that show in graph, there are still some difference between them. Solid outcome are represented by more frequencies show in graph.

In conclusion, the best listening zone for percussion instrument that has the similar characteristic in musical acoustics is the stage right area. The musical instrument has the widest response frequency range and at its maximum loudness level in this area. This result is due to the unique musical acoustics of percussion that is different from other musical instrument that response differently to the acoustics in the hall.

4.3.4 Woodwind-Flute

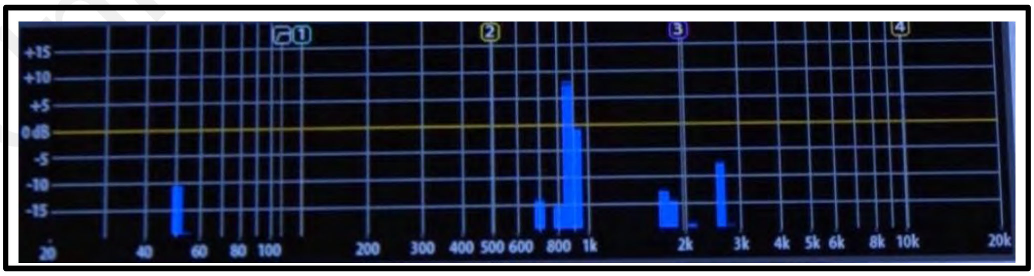
Concert flute frequency range is from 262Hz to 1976Hz. Flute loudness level can hit from 85 to 111dB.

Figure 4.49 Example of MP1



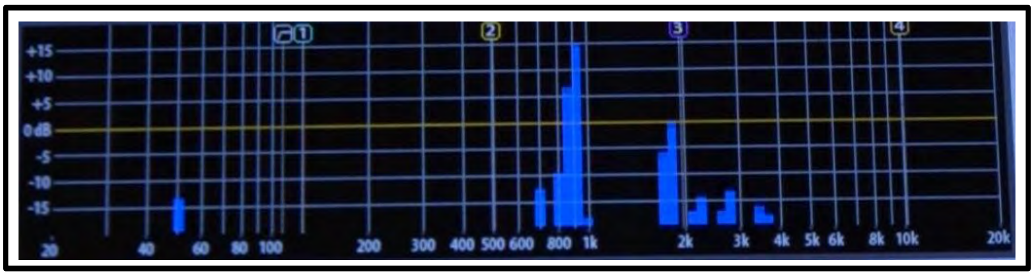
From the result obtained, flute in Experimental Theater has low frequencies at 300Hz and the highest can hit up to 3kHz. The loudness level also can hit up to +15dB.

Figure 4.50 Example of MP2



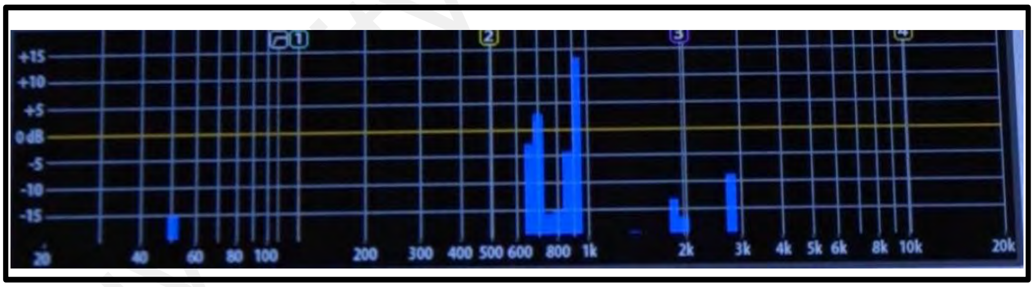
For this position, result shows that the frequency range is from 300 to 4kHz with the highest loudness level at +10dB.

Figure 4.51 Example of MP3



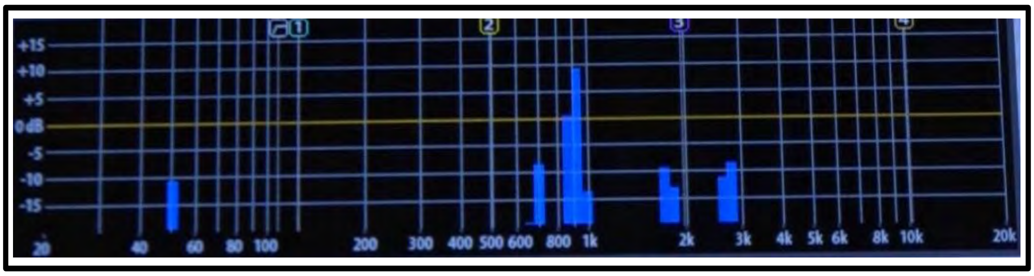
This position has the frequency range at 350 to 3kHz while the maximum loudness level is +15dB.

Figure 4.52 Example of MP4



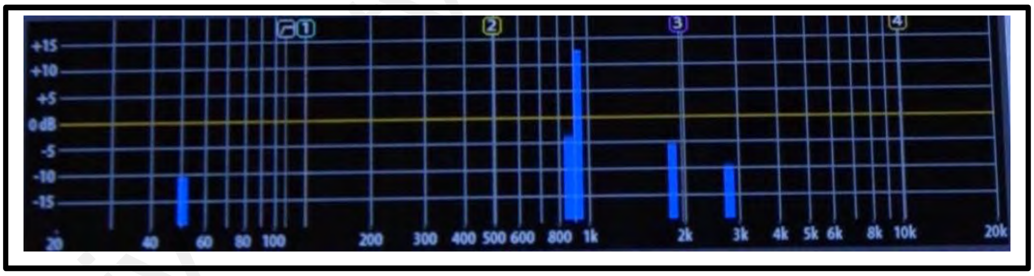
The frequency range in this position is from 400 to 3kHz and the peak level is at +15dB.

Figure 4.53 Example of MP5



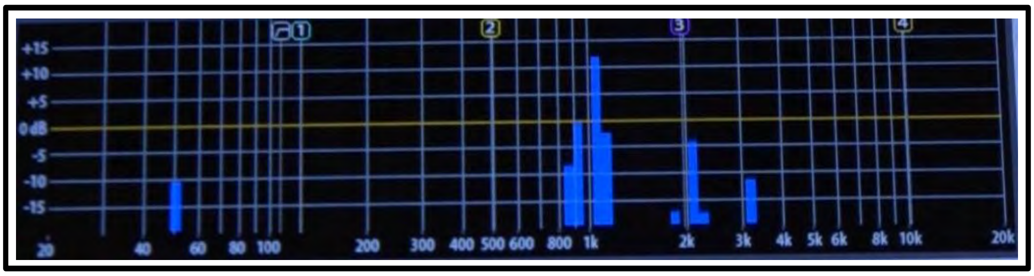
With the frequency range of 400 to 3kHz and the maximum loudness level at +10dB, showed the result of this position.

Figure 4.54 Example of MP6



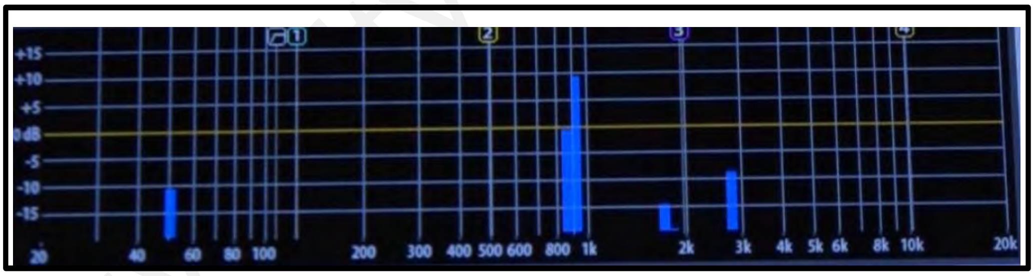
Frequency range at 300 to 3kHz and maximum loudness level at +15dB represent the result for this position.

Figure 4.55 Example of MP7



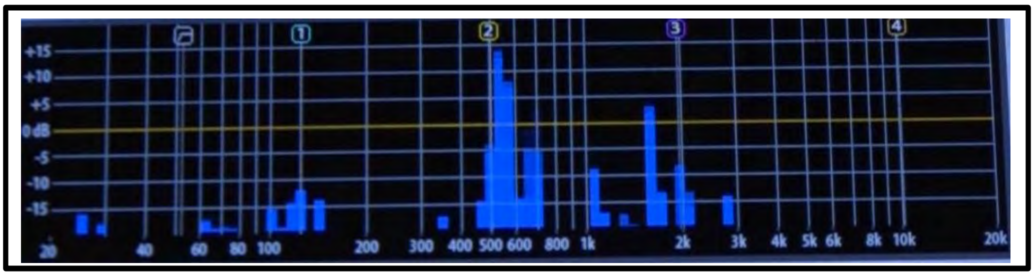
According to the result, frequency range in this position is from 300 to 3kHz and the highest loudness level is +12dB.

Figure 4.56 Example of MP8



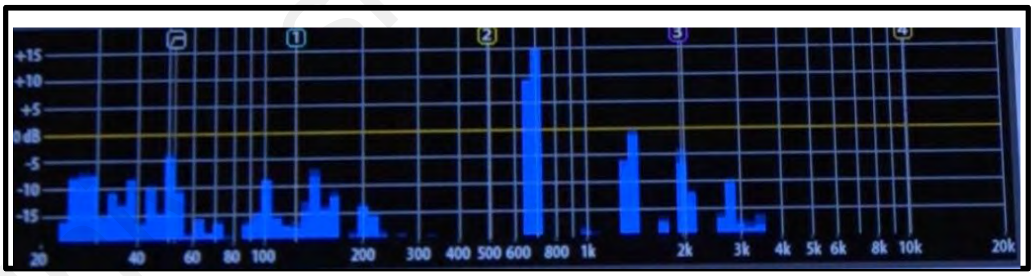
Obtained result showed that the frequency range in here is 400 to 3kHz and the peak level is at +11dB.

Figure 4.57 Example of MP9



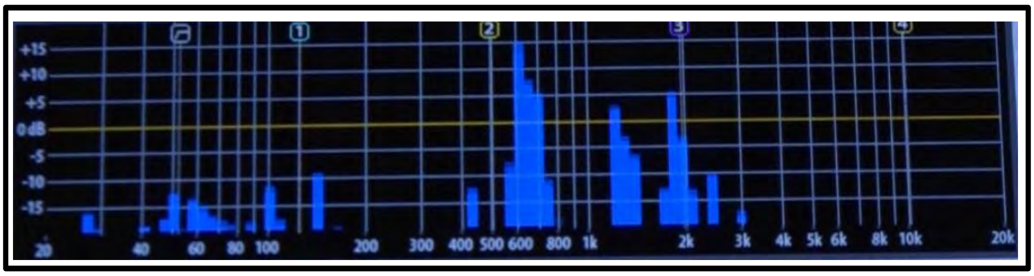
Showing above is the example of the result of mezzanine floor left. The position has the lowest frequencies at 300Hz and the highest at 3kHz. Its maximum loudness level is at +15dB.

Figure 4.58 Example of MP10



The result obtained in this position is frequency range from 300 to 3kHz and the maximum loudness level at +15dB.

Figure 4.59 Example of MP11



Result of this position is the frequency range at 300 to 3kHz and the peak level at +15dB.

Table 4.4 displays the summary of the acoustic data for woodwind instrument, the flute.

Table 4.4

Summary of the acoustic data for woodwind instrument (Flute)

Woodwind Instrument (Flute)		
Location	Frequency (Hz)	Loudness (dB)
MP1	300-3k	+15dB
MP2	300-4k	+10dB
MP3	350-3k	+15dB
MP4	400-3k	+15dB
MP5	400-3k	+15dB
MP6	300-3k	+15dB
MP7	300-3k	+12dB
MP8	80-20k	+11dB
MP9	400-3k	+15dB
MP10	300-3k	+15dB
MP11	300-3k	+15dB

The original reference sound on stage MP1 has the frequency range ranged from 300Hz to 3kHz. The maximum loudness of it is at the highest of +15dB.

The data in Table 4.4 shows that the frequency range for the 7 measurement positions of audience seats ground floor ranged from 300Hz to 4kHz. MP2 having the widest frequency range. MP3 has the narrowest frequency range.

The maximum loudness level in here ranged from +10dB to +15dB. MP3, 4 and 6 have the maximum loudness level at +15dB. MP2 and 5 have the lowest maximum loudness level at +10dB.

The 3 measurement positions of audience seats mezzanine floor have the frequency range ranged from 300Hz to 3kHz. All three measurement position have the same frequency range.

The maximum loudness level of mezzanine floor all at the highest of +15dB.

The results in Table 4.4 indicate that compare with MP1, in ground floor measurement position, MP6 has the same result as MP1 in both frequency range and maximum loudness level. This is the best result obtained from the collected data in this area.

While in mezzanine floor, results show that all three measurement position also have the same result as MP1. Which indicate that this area is a good area to listen to the musical instrument. That may result to flute that is a higher pitch musical instrument which sound will travel higher and straight.

According to all the examples of flute graph, respond signal are lesser. This is due to the musical instrument that only be able to produce one sound or note at the same time which will be only generate certain and less frequency response.

All the low frequencies that shown in all the example graph are the result of the environment noise that capture during the recording. Mezzanine floor show more noise that is noise from air conditional machine that close to the audience seats. Therefore, it had been captured easily. However, it did not affect the result much.

4.3.5 Strings-Violin

The fundamental frequencies for violin is at 196Hz. Next, the instrument harmonics frequencies are able to reach as high as 10kHz. On the loudness side, it is able to reach as high as 103dB.

Figure 4.60 Example of MP1

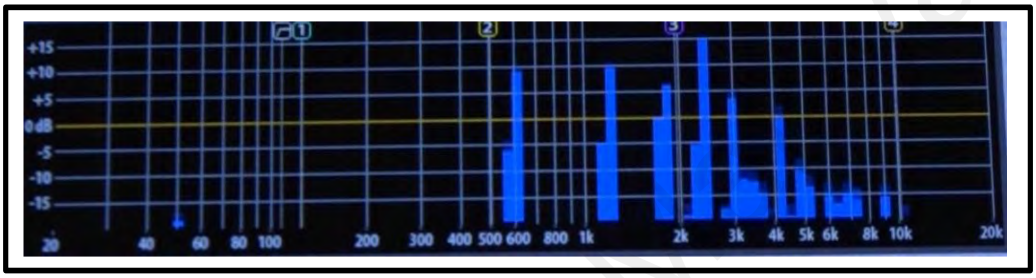
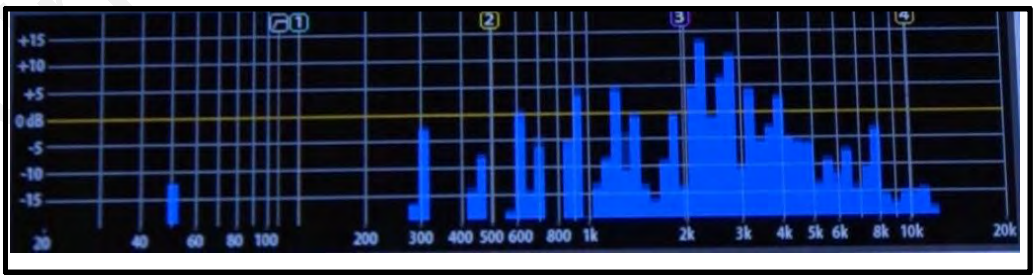


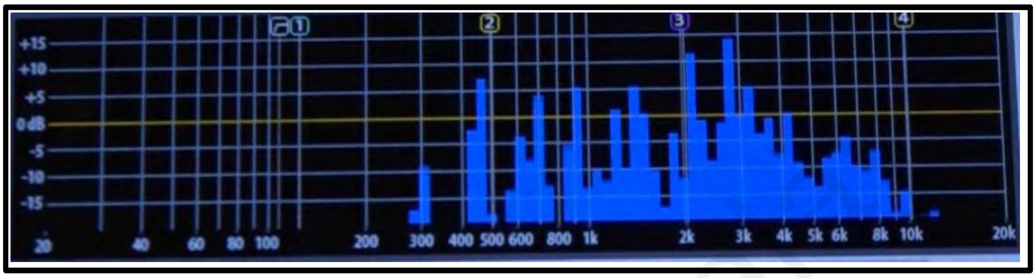
Figure above is the excerpt of the original reference sound on stage that obtained through data collection procedure. From the result, violin has the basic frequencies at 300Hz. It reached all the way up to 10kHz the sound rang up to 20kHz.

Figure 4.61 Example of MP2



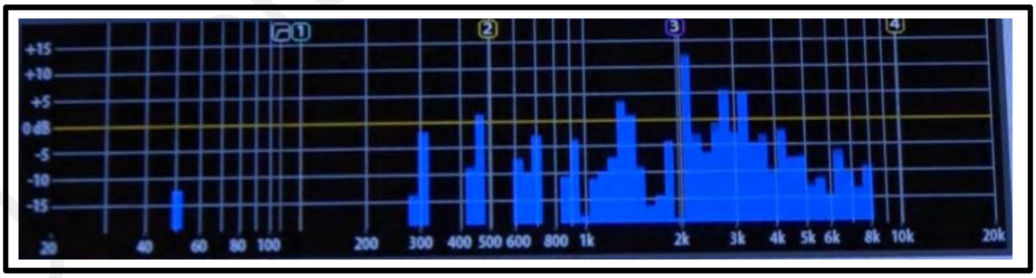
The result from this position is the frequency range from 240 to 10kHz and the maximum loudness level at +15dB.

Figure 4.62 Example of MP3



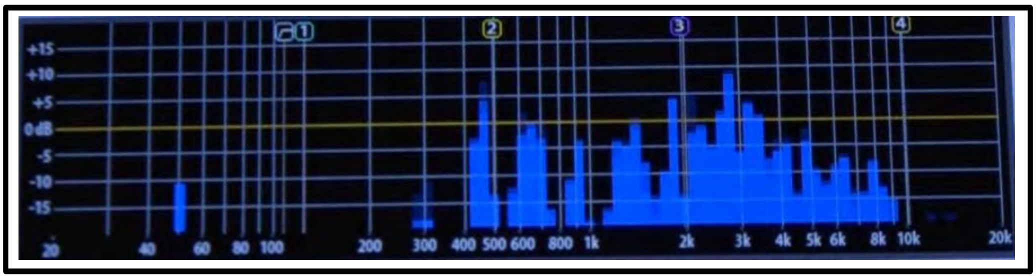
For this position, the result shows that the frequency range is from 280 to 10kHz. The highest loudness level is +15dB.

Figure 4.63 Example of MP4



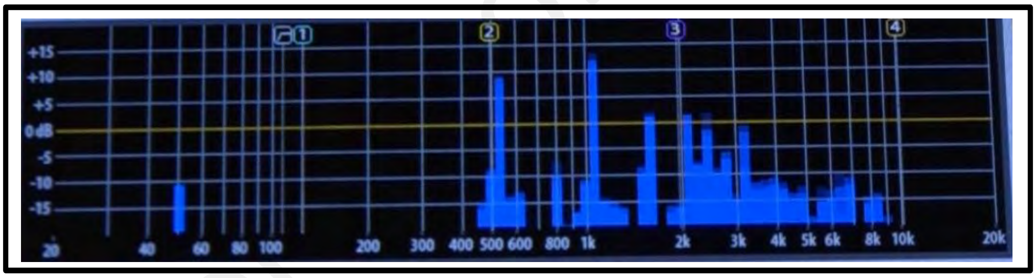
According to the result, the frequency range in here is at 280 to 10kHz and the peak level is +15dB.

Figure 4.64 Example of MP5



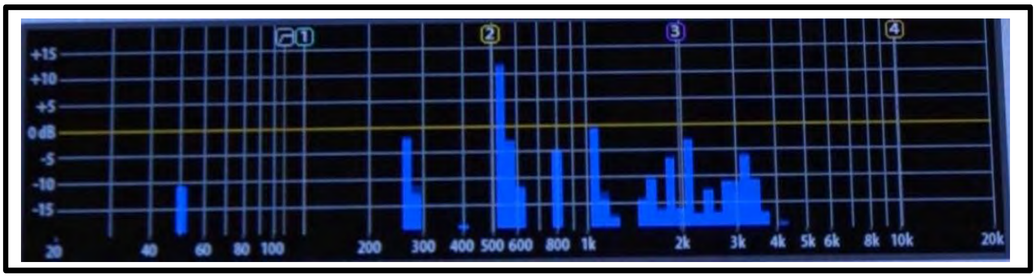
In this position, lowest frequencies are 280Hz and highest is 10kHz. For the loudness level, the peak is at +10dB.

Figure 4.65 Example of MP6



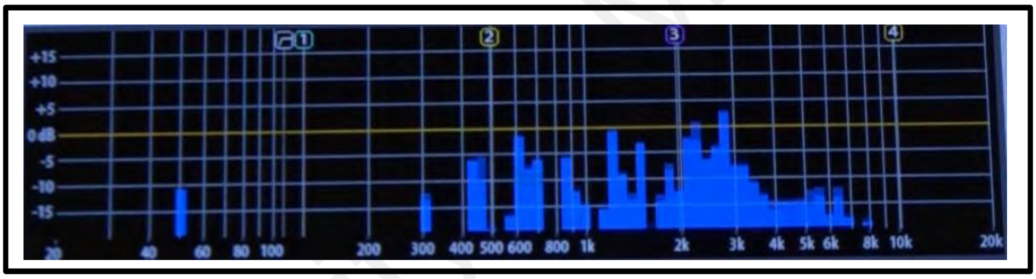
Frequency range from the result of here is 250 to 8kHz. And the loudness level is at the highest of +15dB.

Figure 4.66 Example of MP7



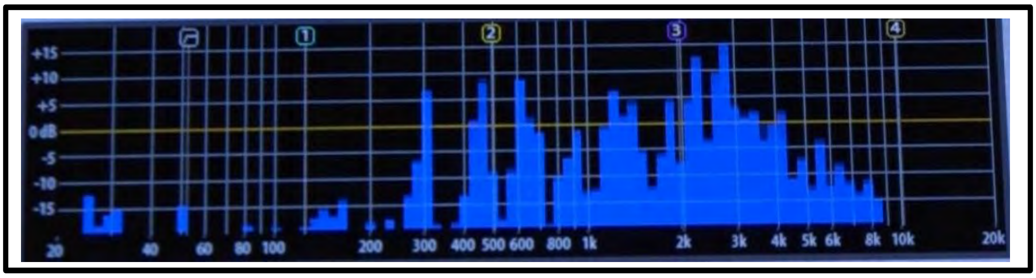
The frequency range in here is 280 to 8kHz. The highest loudness level is +10dB.

Figure 4.67 Example of MP8



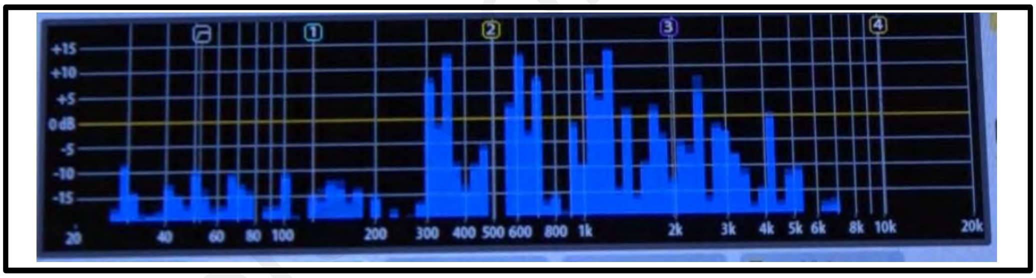
This position has a frequency range of 280 to 8kHz and a lower loudness level of +5dB.

Figure 4.68 Example of MP9



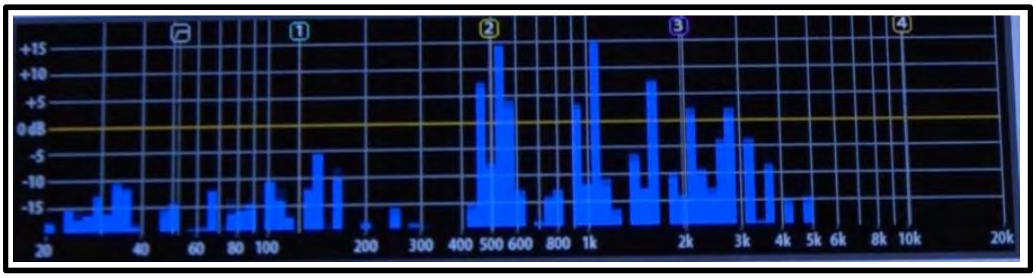
Result showing that the frequency range for this area is from 250 to 9kHz. While the highest loudness level in here is +15dB.

Figure 4.69 Example of MP10



This position has a frequency range from 260 to 9.8kHz and highest loudness level +15dB.

Figure 4.70 Example of MP11



As show at the figure above, the frequency range for this position is from 250Hz to 9kHz and the highest loudness level is +15dB.

Table 4.5 displays the summary of the acoustic data for strings instrument, the violin.

Table 4.5

Summary of the acoustic data for strings instrument (Violin)

Strings Instrument (Violin)		
Location	Frequency (Hz)	Loudness (dB)
MP1	300-10k	+15dB
MP2	240-10k	+15dB
MP3	280-10k	+15dB
MP4	280-10k	+15dB
MP5	280-10k	+10dB
MP6	250-8k	+15dB
MP7	280-8k	+10dB
MP8	280-8k	+5dB
MP9	280-8k	+15dB
MP10	260-9.8k	+15dB
MP11	250-9k	+15dB

The original reference sound on stage MP1 has the frequency range ranged from 300Hz to 10kHz. The maximum loudness of it is at the highest of +15dB.

The data in Table 4.5 shows that the frequency range for the 7 measurement positions of audience seats ground floor ranged from 240Hz to 10kHz. MP2 having the widest frequency range while MP6 have the narrowest frequency range.

The maximum loudness level in here ranged from +5dB to +15dB. MP2, 3, 4 and 6 have the maximum loudness level at +15dB. MP8 have the lowest maximum loudness level at +5dB.

The 3 measurement positions of audience seats mezzanine floor have the frequency range ranged from 250Hz to 9.8kHz. MP10 has the widest frequency range while MP9 has the narrowest frequency range.

The maximum loudness level of mezzanine floor all at the highest of +15dB.

The results in Table 4.5 indicate that compare with MP1, the closest to it are MP3, 4 and 5. All these measurement positions have the same frequency range ranged from 280Hz to 10kHz. The maximum loudness level of all these measurement positions also at +15dB.

Overall, all of the measurement positions have the similar result in this experiment. Although ground floor measurement have the closet result to MP1, but the acoustics of mezzanine floor of having more natural resonance from the building itself will make all sound hearing better with the reverb effect.

4.3.6 Vocals

In this study, male vocalist is used for data collection purpose. Normal male vocalist has the fundamental frequency range from 110Hz to 880Hz. It will ring more than 10kHz. Normal singing level for vocalist is at 100dB.

Figure 4.71 Example of MP1

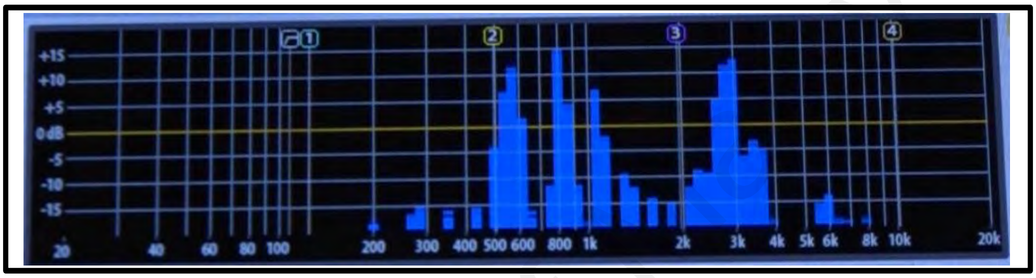
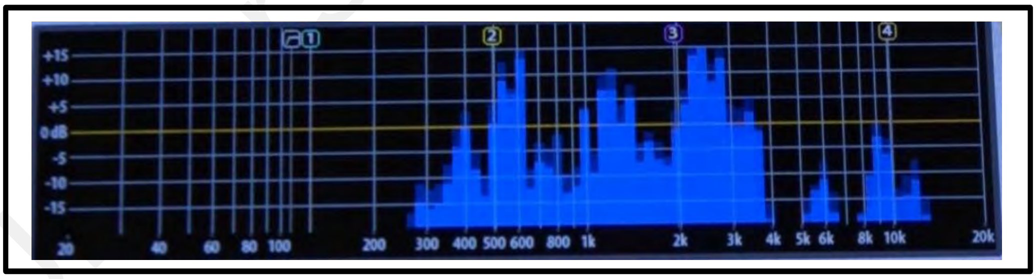
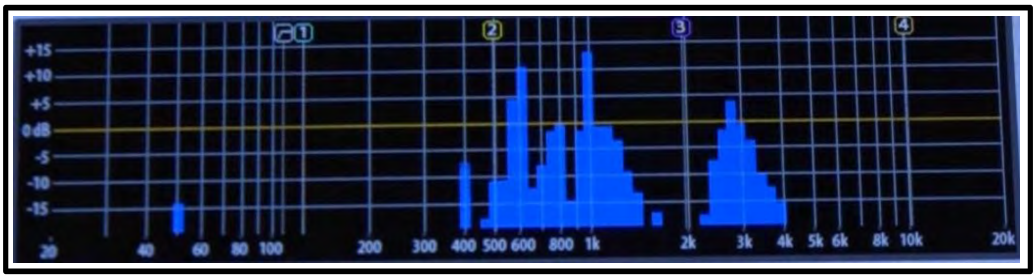


Figure 4.72 Example of MP1



Both figures showing above are some of the examples from the result through data collection process. The result is the original male sound singing on stage has the frequency range from 12o to 10.5kHz and the maximum loudness is +15dB.

Figure 4.73 Example of MP2



From this position, the frequency range obtain is 180 to 10kHz with the maximum loudness of +15dB.

Figure 4.74 Example of MP3

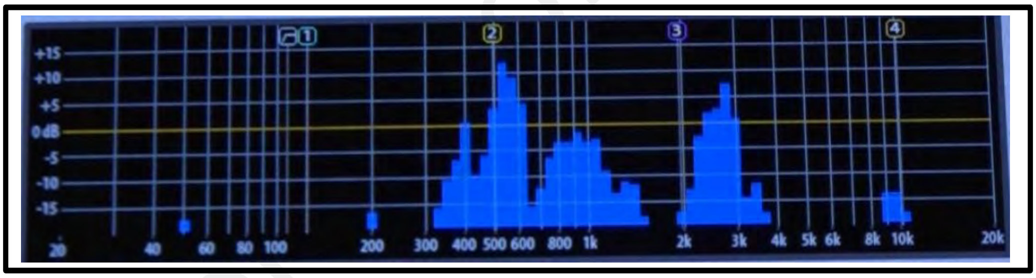
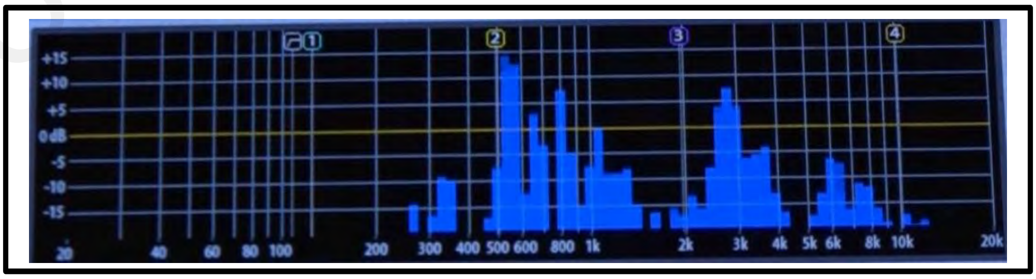


Figure 4.75 Example of MP3



These figures are the example results. The frequency range in here is from 180 to 10.4kHz. And the highest loudness level is +15dB.

Figure 4.76 Example of MP4

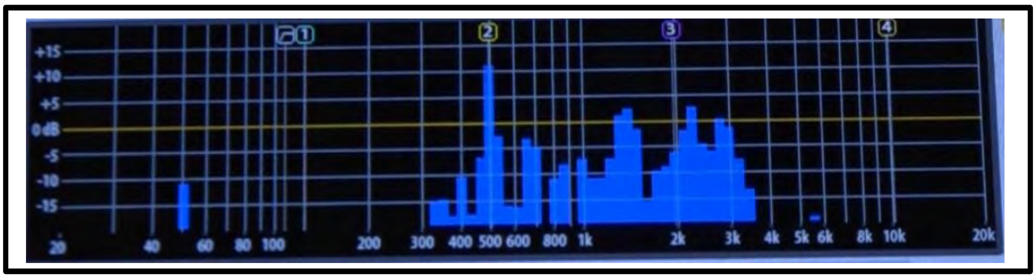
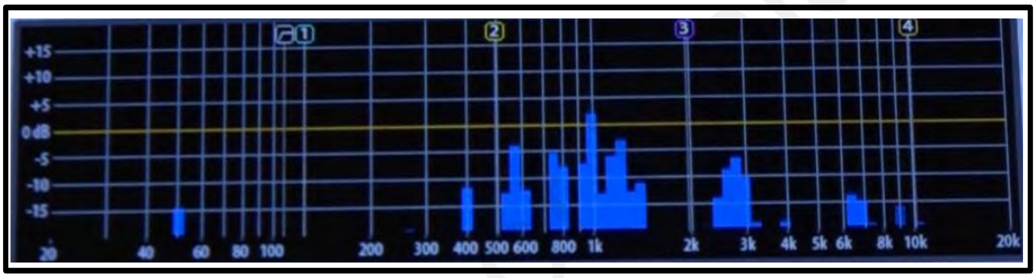


Figure 4.77 Example of MP4



These are the examples from the result gain on data collection. The frequency range show in the result has the lowest frequencies at 200Hz while the highest at 10kHz. The highest loudness level in the position is at +15dB.

Figure 4.78 Example of MP5

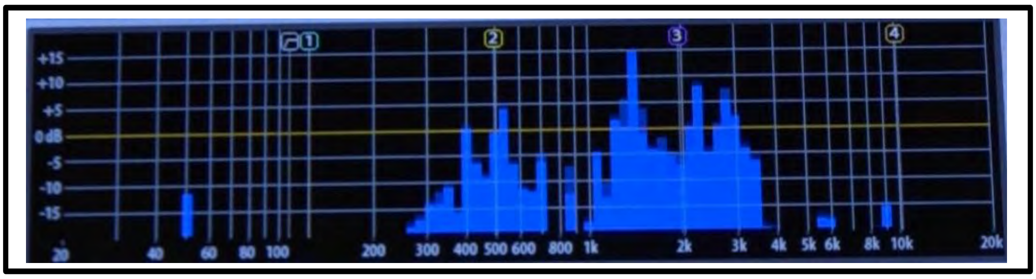
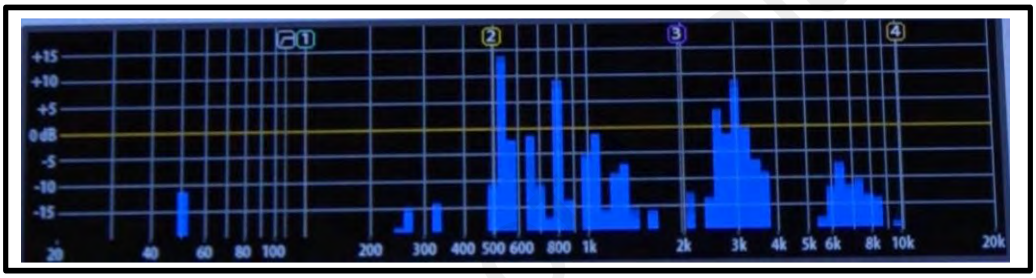
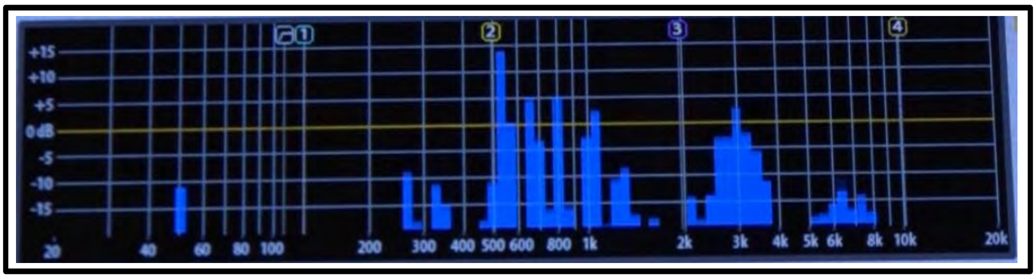


Figure 4.79 Example of MP5



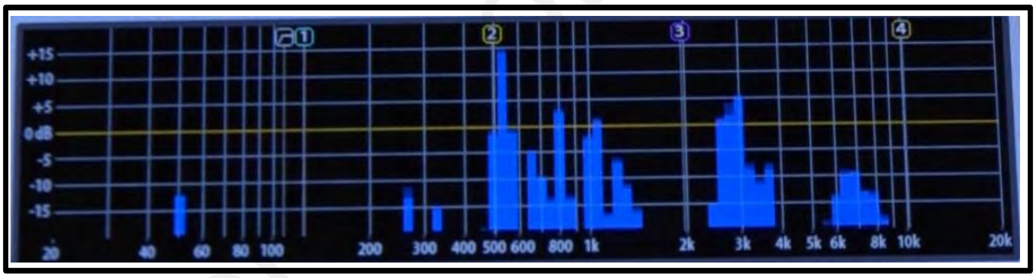
As show as the above figures, the frequency range on this area is from 200 to 10kHz while the loudness level is peaking at +15dB.

Figure 4.80 Example of MP6



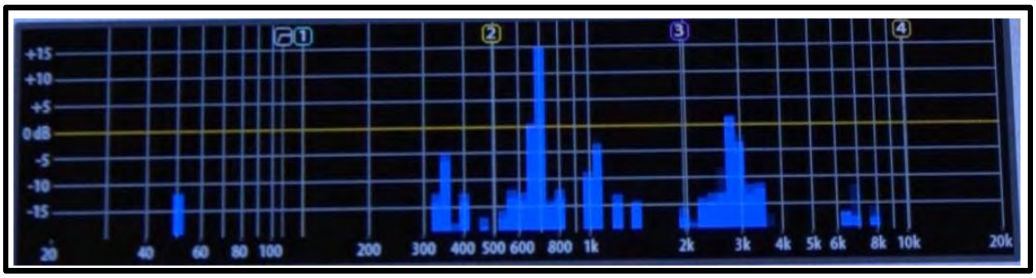
This position has the frequency range at 200 to 10kHz and the maximum loudness level at +14dB.

Figure 4.81 Example of MP7



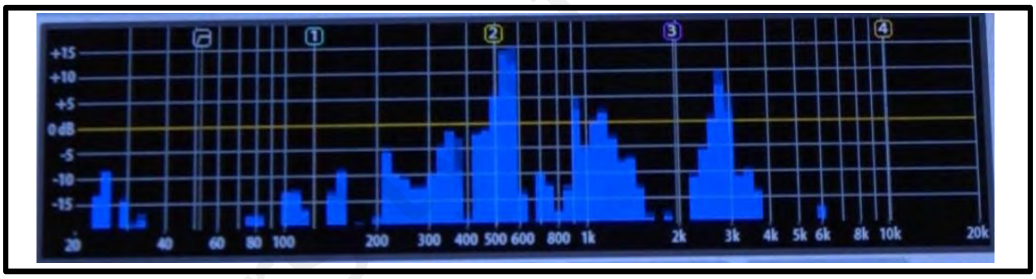
This area has the frequency range at 200 to 10kHz and the maximum loudness level is close to +15dB.

Figure 4.82 Example of MP8



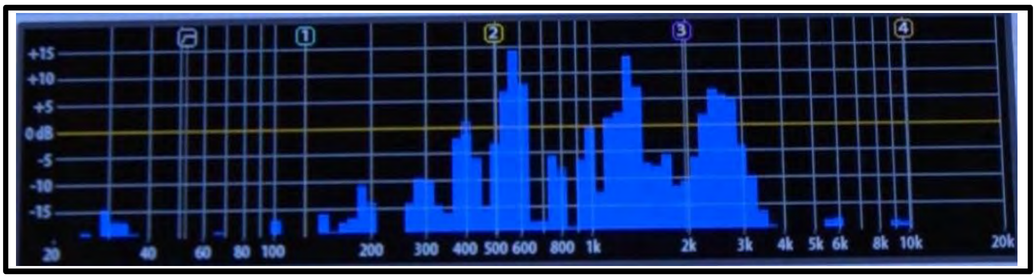
Here is the position with the frequency range of 200 to 10kHz. The maximum loudness level is at +15dB but overall it stayed at +10dB.

Figure 4.83 Example of MP9



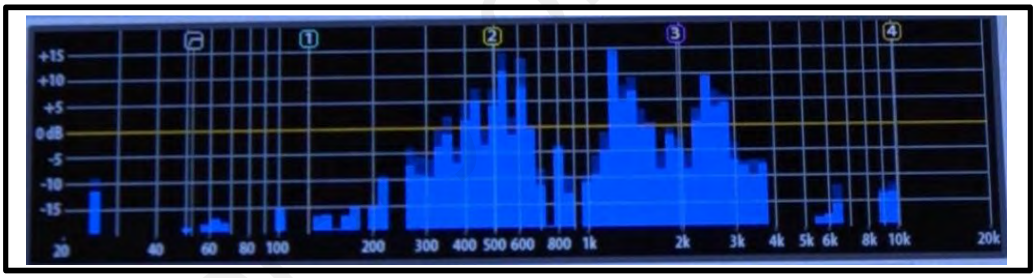
The average frequencies of the sound in this position is from 100 to 8kHz. The loudness level is at the highest of +15dB.

Figure 4.84 Example of MP10



Average frequency range in the position is from 100 to 8kHz. The maximum loudness is as shows in the graph above at the point of +15dB.

Figure 4.85 Example of MP11



Basic frequency range in the area is 100 to 10kHz. Maximum loudness level is +15dB.

Table 4.6 displays the summary of the acoustic data for vocal instrument, the male vocal.

Table 4.6

Summary of the acoustic data for vocal instrument (Male Vocal)

Vocal Instrument (Male Vocal)		
Location	Frequency (Hz)	Loudness (dB)
MP1	120-10.5k	+15dB
MP2	180-10k	+15dB
MP3	180-10.4k	+15dB
MP4	200-10k	+15dB
MP5	200-10k	+15dB
MP6	200-10k	+14dB
MP7	200-10k	+15dB
MP8	200-10k	+10dB
MP9	100-8k	+15dB
MP10	100-8k	+15dB
MP11	100-10k	+15dB

The original reference sound on stage MP1 has the frequency range ranged from 120Hz to 10.5kHz. The maximum loudness of it is at the highest of +15dB.

The data in Table 4.6 shows that the frequency range for the 7 measurement positions of audience seats ground floor ranged from 180Hz to 10.4kHz. MP3 having the widest frequency range. MP4 to 8 have the same narrowest frequency range.

The maximum loudness level in here ranged from +10dB to +15dB. For MP8, overall the loudness level is at +10dB but the maximum loudness is at +15dB. MP6 has the maximum loudness level at +14dB.

The 3 measurement positions of audience seats mezzanine floor have the frequency range ranged from 100Hz to 10kHz. MP11 has the widest frequency range while MP9 and 10 has the same frequency range.

The maximum loudness level of mezzanine floor all at the highest of +15dB.

The results in Table 4.6 indicate that compare with MP1, the closest to it is MP3, where it has the frequency range ranged from 180Hz to 10.4kHz and the maximum loudness level at +15dB. This may result to the high frequencies that are not be able to travel further compare to low frequencies. Therefore, further measurement positions from the stage will start to lose the high frequencies. As clear high frequencies are detected, low frequencies that are not clear is loose.

This result to most of the measurement positions in ground floor lost low frequencies.

The acoustics of mezzanine floor that will enhance low frequencies result to the place have more low frequencies. As the place is further away from the stage, the high frequencies is loose.

4.3.7 Summary of Results of Acoustics Analysis

The following discuss the acoustics of the ground floor and the mezzanine floor versus each musical instruments. All the results that obtained from the experiments that were conducted were compared with the reference example that was also obtained together with all the experimental results.

For piano, results showed that the measurement position located at the mezzanine floor of the Experimental Theatre has the closest result to the reference example in both loudness level and also frequency range.

For trumpet, drum kit and also flute, all the best result that obtained were also at the mezzanine floor of Experimental Theatre. While for violin and vocal, the best listening position were at the ground floor.

Overall, according to the result obtained in all the experiments, the best listening position is at the mezzanine floor of the Experimental Theatre. This is result to the acoustics of the mezzanine floor of the experimental Theatre that are further from the stage and higher from the ground which have more space to allow sound to travel freely.

This is also result to the locality to have better and natural resonance effect that will make sound sounds better therefore it become the best listening locality of all. The open and wider space of the mezzanine floor of the Experimental Theatre also allow sound to travel directly into the space. Therefore, the result obtained in here was better than somewhere else.

As there were three measurement positions in the mezzanine floor in total, based on different musical instruments the results obtained were slightly different but not much.

For piano and trumpet, they have the both high and low frequency with louder volume level, therefore the sound can travel better to the mezzanine floor of the

Experimental Theatre. While for the drum kit, although result showed by the experiment the best result is at the ground floor. But according to graph, low frequency can resonant better in the mezzanine floor and the loudness level can be enhancing better in the mezzanine floor. Therefore, mezzanine floor still can be point out as the best listening position as well.

Flute is an unique musical instrument that most of the frequency are high frequency as flute produce high notes mostly. As high frequency travel in straight line, the space in mezzanine floor will enhance it better therefore the mezzanine floor is still the best listening position to it.

Result showed that the best listening locality of violin and vocal were at the ground floor. These are due to the the musical instruments that are having more high frequency than low frequency. When the sound travel, high frequency that travel shorter distance than low frequency, additional with not much of low frequency and lower loudness level from the musical instruments itself, it got harder to reach to further place.

From the results obtained, we can conclude that the mezzanine floor of the Experimental Theatre is the best listening position in the hall.

4.4 Questionnaire Analysis

A sample of 75 participants was collected. Table 4.7 shows the statistical data on the participants. According to the results, there are 63 females and 11 male participants. One participant did not answer this question of the questionnaire. Out of the 75 participants, there are 11 of them are in the first year of their undergraduate study, 12 in second year, 24 in third year, 26 in fourth year or above and lastly 2 of the participants skipped this question.

And among of the participants, piano is the principal musical instrument to majority of them. 54 respondents (piano) to be exact. Besides that, 12 persons is majoring in classical piano specifically, 5 of them are in the jazz piano field and lastly one of them is majoring in the musical instrument keyboard.

For the others, there are 4 of them in vocal area, 2 in trumpet, three in violin and the rest of them including classical guitar, percussion, flute, classical vocal, alto saxophone and 1 participant skipped this question.

Except for another participant that skipped the question, there are 38 participants attended events 1-2 times in the venue. 25 attended 3-4 times, 6 attended 5-6 times and 2 said that they did not attend any event in the venue. Lastly, 2 participants answered that they had attended event in the venue more than 8 times while one person mentioned that he attended 7-8 times.

Table 4.7

Data on the sample of subjects participating in the study

Demographic		N	%
Gender	Male	11	14.86
	Female	63	85.14
Cohort	Year 1	11	15.07
	Year 2	12	16.44
	Year 3	24	32.88
	Year 4 or above	26	35.62
Principal Musical Instrument	Piano	54	
	Jazz Piano	5	
	Vocal	5	
	Violin	3	
	Trumpet	2	
	Classical Guitar	1	
	Percussion	1	
	Flute	1	
	Alto Saxophone	1	
	Keyboard	1	
Concert Attendance at Experimental Theatre	None	2	2.70
	1-2	38	51.35
	3-4	25	33.78
	5-6	6	8.11
	7-8	1	1.35
	more than 8 times	2	2.70

Table 4.7 Statistical data on participants.

From the result that shown in the table blow, out of the total 75 participants, one participant did not answer this question. And among the rest of the 74 participants, the seating zone that chose by most of the participants, 29, is the house center area. Follow by that is house back center area. There were 16 participants has chosen this area. Next is the mezzanine center that chose by 12 participants.

In the parallel fourth place, is the house left and house center area. Both were also chosen by 6 participants individually. There were also 2 participants that has chosen house back left area. Besides that, there were another 3 participants chose house front right, house back right and mezzanine right. Therefore, the mezzanine left area did not choose by any of the participant.

As compare with the acoustical data that collected during experiment, the results are various. According to the result of acoustical data, the best listening position is at the mezzanine floor. But the result of survey show that among the participants, the preferred listening zone is at house center area of Experimental Theatre.

This may result to the reason of the participants when they choose their preferred seating area where participants may have different perspective other than acoustical consideration.

Table 4.8

Preferred seating zone in Experimental Theatre.

Seating Zone	N	%
House Center	30	40
House Back Center	16	21.33
Mezzanine Center	12	16
House Front Center	6	8
House Front Left	6	8
House Back Left	2	2.67
House Front Right	1	1.33
House Back Right	1	1.33
Mezzanine Right	1	1.33
Mezzanine Left	0	0

Table 4.8 Preferred seating zone in Experimental Theatre.

Table below show the result of the musical events that attended by all of the 75 participants. This is the only question in the questionnaire that answered by all of the participants. In the total of 100% result, ensemble performance has been chosen by 74.67%. Following by solo performance that has 73.33% of ranking. Next is the orchestra performance with 60% ranking.

There were 50.67% of responses on big band performance. Lastly, there were 16% of responses on other performances. Among this performances, they are including jazz, showcase, competition, dance, drama, theater and some others.

Table 4.9

Concert or musical event type

Type	N	%
Ensemble	56	74.67
Solo	55	73.33
Orchestra	45	60
Big Band	38	50.67
Other (please specify)	12	16

Table 4.9 Concert or musical events type.

There were 2 participants had skipped this question, therefore there were only 73 participants in total answered in this question. Table 4.10 shows the result on the way participants choose their seat in Experimental Theatre. Based on the ranking, participants ranked the way they choose their seating zone based on sound averagely highest with 2.73 where highest is 4.

Second is based on visual with 2.64 ranking. In the third place is based on genre of performance of 2.45 rank. Last but not least is based on performer that had 2.25 ranking.

Table 4.10

Reason when choosing seating area.

Reason	Ranking
Based on sound	2.73
Based on performer	2.64
Based on visual	2.45
Based on genre of performance	2.25

Table 4.10 Reason when choosing seating area.

Lastly, some of the participants leaved their opinions. Some gave the reason why their will prefer the seating zone, some gave thoughts on the venue acoustics, some gave opinion on certain seating zone and some commented on the placement and seating environment of the venue.

4.5 Comparison of Acoustics and Questionnaire Analysis

According to the results of the qualitative analysis, the best listening locality in ET is at the mezzanine floor. The acoustics of the hall is the main reason that cause the results obtained. However, based on the results that shown in the qualitative analysis, the preferred seating locality of ET is the house center area. The main reason that cause the obtained of the results is the limited access to the mezzanine floor. Therefore, the results of both research analysis were varied.

4.6 Summary of Results

To conclude, the results of this study from both research analysis is varied. According to the results, the best listening locality in ET is mezzanine floor. However, the preferred seating locality is house center. This is due to the lack of information regarding of the hall. Therefore, it affect the cause to the results of this study.

CHAPTER 5: DISCUSSION, IMPLICATION AND RECOMMENDATIONS

The research results that are related to the research objectives and questions will be discussed in this chapter. Since there are no previous studies, the result cannot be compared. The main findings, research conclusions and the implications will be showed in this chapter. Furthermore, some appropriate research that to be conducted in the future will also be suggested based on the main results. A conclusion of the research report will also be included at the end of this chapter.

5.0 Overview

Overall, the result obtained in this study is just a rough guide and reference to the development of the Experimental Theatre in the future. The purpose of this study was to investigate the best listening locality in Experimental Theatre and audience choice of seating in Experimental Theatre. This study focused on the audience perception of indoor venue. Experiment was carried out in ET to test on the best locality. It was measured by the frequency range and the loudness of musical instruments. While audience choice of seating in Experimental Theatre was conducted through questionnaire.

5.1 Summary of the Results

Based on the result obtained, the best listening position for most of the musical instruments from different family is at the mezzanine floor. From the data shown in mixing console, the widest frequency range and the highest loudness level of all the musical instruments that were tested on is at the mezzanine floor. This is due to the better acoustics environment at mezzanine floor that have more reverberation effect.

Most of the participants in the survey chose the house center zone as their preferred seating zone in ET. It was 39.19% in total. Besides that, most of the participants ranked how they choose their seats based on sound the most at 2.73.

Based on the results from the previous studies on the acoustics of concert halls that also included the studies from Architectural Acoustics, for examples Allan (2003); Yan (2005); Loy (2006); Bishop, Bailes, Freya and Dean (2013); Patynen, Trevo and Lokki (2013); Patynen, Trevo, Robinson and Lokki (2014); Lokki (2014); Kalkandjiev and Weinzierl (2015); Beranek (2003&2004, 2016); and Adelman-Larsen, Jeong and Stofrings (2018), every different hall with different acoustics has different best listening locality. Dependent on the acoustics of the hall, the best listening zone can be anywhere, House Front, House Center, House Back, Balcony Area or any other zone.

Also, concert goer's seat selection is also varied depending on different consideration. Their consideration can be for example ticket price, performance, sound, visual, or any other aspects. Therefore, regardless the professionalism of the audience, their seat selection always varied. Perhaps the profession from performance industry will always consider their seating choice based on their profession.

The result of the survey may also due to the lack of awareness to the acoustics of the performance venue. Public especially the non-profession of the industry often unaware to the importance of the acoustics to the performance venue or performance. Besides that, public may be lack of information regarding to the performance venue therefore it leads to the method when choosing a seating area is based on other aspects.

5.2 Discussion of Findings of the Study

The following presents the findings and discussion: (1) Best listening locality in ET; (2) Audience choice of seating in ET; and (3) Comparison between best listening locality in ET and audience choice of seating in ET.

5.2.1 Best listening locality in Experimental Theatre

The result of this study indicates that most of the musical instruments have the best listening position at the mezzanine floor of the Experimental Theatre. Although different musical instruments have different musical acoustics, but the acoustics of the Experimental Theatre affect the results the most. The acoustics of the mezzanine floor of the Experimental Theatre with more resonance make sound sounds better in the area.

The hall design, hall shape and also the stage influenced the result to the experiment. As ET is a multi-functional hall, the design of the hall is not perfectly for music performance. Therefore, the result obtained in this experiment may be vary as the other. The acoustics of multi-functional hall is different with concert hall.

Traditional concert hall or music hall started from the Ancient Greek and Rome time till 20th century. These halls that have high acoustics demand for musical performance are mostly in rectangular or shoebox shape with maximum reverberation time (Ang, 2016). Multi-functional hall that need to meet the requirement of contemporary concept of concert hall will have different acoustics with the professional music hall in the 21st century. They may not in the best acoustics shape and the main focus of the building may no longer be the acoustics area (Allan, 2003). For example, the Verizon Hall in Philadelphia.

It is a multifunctional hall that rebuilt in the 21st century with new design and concept. It was designed and built by famous architect, Rafael Vinoyl and focused a lot on the acoustics area. But, the hall still received certain amount of criticism in this area. Further improvement were done to further improve the acoustics of the hall but yet the hall still received negative feedbacks (Allan, 2003).

Although the architect design Verizon Hall with the best acoustics as possible, but Verizon Hall is still a multi-functional hall where it is hard to meet the certification of every demand. Just as the same as ET. However, both hall still can make further improvement to the hall in order to make the most effort to achieve the ideal result.

5.2.2 Audience choice of seating in Experimental Theatre

Results from the survey shown that majority of the participants preferred the house center seating zone based on the sound in the area. This was due to the unawareness to the acoustics of the building. Public are not familiar with this area and often ignore the issue. Although previous study shown that best concert hall in shoebox shape and with maximum reverberation time, the best listening position was at the ground floor, however it is only referring to professional music hall but not multi-functional hall (Beranek, 2016). Therefore, the result was varied.

The survey result was similar to few previous studies. For example, Ando and Noson's survey that conducted in the year of 1997of concert hall that focuses on the acoustics area only. Majority participants chose center area as their preferred listening zone.

Later on were interviewed by Beranek in 2003 and 2004, internet survey by Skalevik in 2013 and the study by Lokki in 2014 of world famous concert halls' acoustics. All studies indicated that most of the participants preferred house center area.

While majority of studies are focus on acoustics field of professional music halls, Kawase (2013) study involved classical and contemporary halls. The survey result shown that visual factors was the first priority when they choose their seats and their perception on sound quality were varied.

As the participants of the survey were the music students of UM's Cultural Center Music Department that use ET frequently, they will choose their preferred seating locality based on their profession. However, there are no proper study that have done before regarding the acoustics of ET. Also, the best listening zone, the mezzanine floor of ET is often close or reserved, students have no access to the area. And the multifunctional hall ET may not in its best acoustical condition. Therefore, the results of experiment and survey are varied. More detail research on ET can be done in order to improve the acoustics and to provide better performance of ET.

5.2.3 Comparison between best listening locality in Experimental Theatre and audience choice of seating in Experimental Theatre

From the result of the experiment that carried out in Experimental Theatre, the best listening locality is at the mezzanine floor. However, based on the survey that conducted, audience preferred seating locality was at the house center area that located at the ground floor although majority of them stated that they choose their seating area based on the sound. The experiment is based on the acoustical aspect. But, questionnaire is based on personal opinion where people may not make their choices from professional aspect. Therefore, the result from both qualitative and quantitative research are not the same. The final findings of this study still can be used as a reference for further improvement of the Experimental Theatre in the future.

5.3 Conclusion

The findings from this study indicated some noteworthy conclusions:

1. The best listening locality for most of the musical instruments is at the mezzanine floor of the Experimental Theatre.
2. Audience preferred seating locality in Experimental Theatre is house center.
3. The best listening locality and audience choice of seating in Experimental Theatre were varied.

5.4 Implications of the study

The findings of this study suggested to create awareness on acoustics to the public. First of all, this study showed that the best listening locality is at the mezzanine floor of Experimental Theatre. This is an important finding as it indicated the best listening locality in ET is the mezzanine floor that always ignore by the public, not any other area.

According to Beranek (2016), part of concert goers will have preferred balcony area for various reasons, to be specific, for visual and sound purpose. This shown that the acoustics of balcony area is as good as other area regardless the reasons when choosing a seat, the acoustics, the shape of the hall and also the type of hall. Balcony area is considerable.

Secondly, the implication of this study is ET can improve the hall acoustics to provide better performance quality. Through this study, the researcher hoped that the audience are able to choose their preferred seating zone correctly in the future. Besides create awareness on the important of acoustics in a hall, through the qualitative study in this research, the perception of public towards Experimental Theatre were obtained. Therefore, further improvements can be done in the future. Perhaps, other area such as management side can also be improve other than acoustics area only through the results from this study as the ultimate purpose of this study is to provide valid reference for future improvements of Experimental Theatre.

5.5 Recommendation for future study

This study has attempted to provide the best listening locality in Experimental Theatre. Therefore, it is suggested that the acoustics of the hall to be investigated professionally in future studies. This study has provided simple acoustics of the hall. Future research should include an investigation of the most important element in acoustics which is the reverberation time of a hall as majority of previous studies mainly focused on the reverberation time of halls.

Reverberation Time of a hall is the international standard and guideline on the acoustics of a hall (Ang, 2016). Acousticians ranked the acoustics of a hall based on the reverberation time of the hall as well (Beranek, 2016). Therefore, in order to provide professional acoustics information about Experimental Theatre, the reverberation time of Experimental Theatre should be first investigate.

Furthermore, this study has provided suggestions in undergraduate music students in University Malaya choice of seating in Experimental Theatre. In future, further survey should conduct with the participation of public. The survey should add in more professional elements such as interview or survey that conducted previously by Beranek (2003 and 2004) and Skalevik (2013) on professional in the field to provide more professional information about Experimental Theatre.

As the development of hall construction in the 21st century is towards multifunctional hall like Verizon Hall in Philadelphia (Allan, 2003) and Experimental Theatre of University of Malaya, more study and review regarding about contemporary hall should be done for further improvements and developments in this field. This can be beneficial to both the professional like acousticians in this field and also the public.

5.6 Closure Remarks

Overall, the study contributed to the body of knowledge in acoustics and audience choice of seating in Experimental theatre. It provided evidence for the best listening locality and audience preferred seating zone of the hall. It implied that the best listening locality of Experimental Theatre is the mezzanine floor while audience chose the house center zone as their preferred seating locality in Experimental Theatre. Combining the findings from this study provides some new ideas for further study and future research.

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