UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

School of the Arts

A research dissertation submitted in partial fulfilment of the requirements for the degree

Master of Music (Music Technology)

Name:
Avuyile Ngqangweni

Department:
School of the Arts (Music)

Contact details:
avukhngqang@gmail.com

Supervisors:
Dr Miles Warrington
Dr Ntshengedzeni Netshivhambe

Recording the mbira of Southern Africa: A case for establishing empirical acoustic-based recording methods of traditional instruments

Avuyile K.H. Ngqangweni
19387492

A research dissertation submitted in fulfilment of the requirements for the degree

Master of Music (Music Technology)

School of the Arts (Music)
Faculty of Humanities
University of Pretoria

Date

February 2023

Declaration

I declare that the work that has been presented in this dissertation is my own original work and has not previously been submitted for degree purposes at any other university.

Signature:

Date: 25 March 2023

Ethics statement

The author, whose name appears on the title page of this dissertation, has obtained, for the research described in this work, the applicable research ethics approval. The author declares that they have observed the ethical standards required in terms of the University of Pretoria's code of ethics for researchers and the policy guidelines for responsible research.

Abstract

For this research an experiment was done in an attempt to establish a method for recording the mbira of Southern Africa. This work is important because it seeks to address some gaps in knowledge pertaining to recording practices of indigenous instruments. The idea was to bridge the gap between ethnomusicology and music technology to improve studio practices for recording African musical instruments, specifically the mbira. An experiment was carried out to determine how the acoustic properties of the mbira together with well-known standard recording techniques could assist in providing practitioners with information about best-practice for recording such an instrument. A recording technique to record the mbira was established. A mixed methods approach was implemented so that both qualitative and quantitative data could be obtained. This included the collection of quantitative data using investigative techniques and conducting interviews with participants to collect qualitative information. A summary of the findings may be found in the final chapter of this dissertation.

Acknowledgements

I would like to thank my supervisors, Dr Miles Warrington and Dr Ntshengedzeni Netshivhambe, for the guidance and support that they offered me throughout the course of my research. I would like to thank Dr Netshivhambe for assisting me during our travels to record participants in Limpopo, for participating in the experiment and for introducing me to mbira players from the Venda and Shona communities. Thank you, Dr Warrington, for providing the opportunity to work as your recording assistant.

I would like to thank the mbira players for participating in the experiment; their assistance was much needed and appreciated. I would also like to thank the mbira players for allowing me to make video recordings of them playing the mbira. Sincere thanks to the mbira players for the valuable knowledge they shared during the interviews I conducted with them.

I would like to thank my sister, Thulani Mkhize, for her assistance in editing my work and advising me on my research. I would also like to thank my parents, Sizwesamawethu and Hlonelwa Ngqangweni, for their support and for giving me the opportunity to further my studies. I greatly appreciate it.

Keywords:

Mbira

Recording techniques

Microphone techniques

Acoustics

Materials

African music

Traditional music

Ethnomusicology

Technology

Contents

List of Tables

Chapter 1: Introduction

1.1 Introduction and background

The mbira is an important member of the lamellophone family and originated in diverse and numerous African countries. These include South Africa, Mozambique, Zimbabwe, Angola and the Democratic Republic of the Congo (McNeil & Mitran, 2008, p. 1169). Tracey (1974) identifies the mbila deza and dipila as the most common types of mbira found in South Africa. The mbila deza is the mbira of the Venda people of South Africa, and it is comparable to the mbira dza vadzimu of the Shona people of Zimbabwe, with slight differences in the layout of the notes. There are many different types of mbiras on the African continent, but one of the most well-known types is the mbira dza vadzimu. Ethnomusicological research has helped expand researchers' understanding of diverse musical systems throughout Africa, but much of this knowledge has not been re-evaluated (Blacking, 1976, p.4). This research study aims to assist in bridging such gaps in ethnomusicological knowledge, as well as in identifying verifiable recording methods for the mbira and outlining processes needed for other African traditional instruments where acoustic analysis together with recording techniques have not been explored. In essence, this study uses music technology as a tool for investigating the heritage and recording possibilities of the Southern African mbira.

Due to their focus on a particular culture's music, ethnomusicologists were well-positioned to acquire deep insight and understanding about traditional African music. They believed that traditional African music should be preserved. For example, ethnomusicologist Hugh Tracey recorded indigenous Zimbabwean music and amassed hundreds of recordings over the years. However, no concrete link between instrumental organology, acoustics and recording techniques may be found in these archives. In the Western classical tradition, the standard orchestral instruments have been extensively researched in terms of their acoustic properties and preferred recording techniques. This is supported by a large and well-known body of literature including volumes by Fletcher and Rossing (1998), Rayburn and Eargle (2012), as well as Huber and Runstein (2014). On the other hand, according to Tracey (1955, p. 6), "[i]t is rare that any African recordings are made under ideal conditions, and even the best equipped studio is not necessarily the right place for recording items which may sound best only in the background". It is thus clear that, at least for the most part, African traditional instruments have been omitted from the controlled environment of studio audio analysis and acoustic investigation. Furthermore, the study of the acoustic properties that regulate how materials react to sound waves, which we would perceive as sound in the context of African instruments, appears to be an epistemological oversight. Therefore, the acoustic properties of the mbira were investigated, and an example instrument was subjected to various recording techniques under studio conditions.

The acoustic features of the mbira are its wooden soundboard, metal keys, the resonance, and its dynamics. There are several implications for recording a mbira, but for this purpose the mbira being is being recorded to establish a technique to record it. It is important to consider the cultural significance of the mbira and the potential impact of it being recorded. The recording process itself can have an impact on the sound quality of the mbira.

1.2 Research questions

Main research question:

How could an acoustic analysis of materials and other specific features yield best-practice approaches to recording the Southern African mbira?

Sub-questions:

What are the acoustic considerations when recording the mbira?

What materials are used to make a mbira?

Why are these materials used to make a mbira?

What microphone technique (including aspects such as microphone type, position, settings and calibration) would be best for recording a mbira?

1.3 Aims of the study

The aim of this study is to determine the best possible recording technique for the mbira of Southern Africa. It also seeks to identify the gaps in knowledge regarding studio-related techniques for recording African musical instruments in general, and to provide insight into best-practices for establishing these procedures.

1.4 Methodology

The researcher needed to acquire quantitative and qualitative data to achieve the aim of this research. Most of the data that was used was primary data because most of the data was collected by the researcher. Various data collection techniques were used in the methodology, and these will be discussed at a later stage.

1.5 Chapter layout

The first chapter of this dissertation consists of the introduction, which discusses the aims and objectives of this study. The second chapter covers the literature review, which includes topics such as the history of the mbira, sound field capturing, the wood acoustics of the mbira and organology. The third chapter presents the methodology, addressing topics such as the research approach, research design, data collection techniques, sampling strategy, data analysis and interpretation. The fourth chapter includes the results, and the fifth chapter consists of the conclusion. These chapters are followed by the reference list and appendices.

1.6 Delimitations

The researcher did not scientifically identify and analyse the mbira’s wood. Instead, respondents were asked about the materials used to make the instruments.

The research focuses on the Southern African mbira only. Mbiras from other parts of the continent were excluded from this study.

The researcher was unable to use ribbon and shotgun microphones during the experiment. It was also not possible to record a mbira with a calabash or pick-up.

Not all the recording techniques in the practical application of the microphone experiment were used due to a lack of time and resources.

The researcher did not use a vibration metre to measure the frequencies and vibrations of the mbira.

Chapter 2: Literature review

2.1 Introduction

For a long time, oral literature has been the foundation of spreading knowledge in Africa. As such, numerous musical societies in Africa practice music through imitation. The Venda, for instance, have mbira players in South Africa where youngsters imitate the songs and dances adults perform. Children try to partake in the adults' musical practices (Arom, 1991, p. 14). In some musical societies, this music should be played in a strict manner, in a particular time or space. The connection between oral culture and the creation of musical instruments is clear in traditional African religions such as Mbilamutondo music, which is a native musical performance of the Venda.

Certain practices, such as harvest celebrations and customs, still assume a fundamental role in African traditional religions. There are various African traditions and the greater part of them have no compositions relating to their specific experiences; however, researchers have provided evidence of certain traditions that impact social practices. African traditional religious practices are thought to involve spiritual forces found in mountainous regions, rivers and forests (Grosz-Ngaté, Hanson & O'Meara, 2014, p. 105). In the Shona culture, the mbira is used in a traditional ritual known as *bira*. In this ritual, a family gathers to call upon the ancestors to help a distressed relative.

Cultural dance plays a significant role in all aspects of life in a society (Harper, 1969, p. 280). Cultural dance is utilised as an expression and also to perform certain roles, such as those in religious ceremonies, marriages and burials. African dance depends on spoken language and may be seen as a type of communication exhibiting emotion and beliefs through movement (Welsh-Asante, 2010, p. 13). This is unique in terms of indigenous musical specialisation, in which musicians are exceptional performers of their instruments.

Music and dance are strongly related in African custom. In an African customary setting, hearing music will certainly lead to rhythmic bodily movements (Arom, 1991 p. 10). In numerous African social orders, there is no single term for 'music' as imagined by the West. Rather, it is something physical. Arom highlights that in African cultures, music is not expressed verbally (1991, p. 11). Thus, it is important to highlight the lack of a single, all-embracing definition for music in African creative and ceremonial settings, as perceived by Western ethnomusicologists.

The mbira is part of a group of musical instruments called lamellophones, and is plucked to produce sound. The Encyclopedia Britannica (2016) characterises a lamellophone as "any musical instrument consisting of a set of tuned metal or bamboo tongues (lamellae) of varying length attached at one end to a soundboard that often has a box or calabash resonator". The beliefs in African cultural practices are rooted in this oral tradition and provide historical knowledge pertaining to the cultural life and understanding of society. There are social orders in Africa that continuously rely upon African tradition. Mugovhani (2009) writes about indigenous knowledge systems, customs and creating musical instruments. Mugovhani (2009) highlights that the trees that were utilised to construct musical instruments had important functions known by previous generations of practitioners. Songs, namely *Nhemamusasa, Nyampora* and *Mukutiende*, have been passed down orally and serve religious ceremonial needs.

2.2 The history of the mbira

Holdaway (2008) highlights that the origin of the mbira is accepted to have occurred in two African regions. The origin of the mbira with metal keys may be traced back to approximately 700 AD. The mbira with bamboo keys, which is uncommon today, originated around 1000 BC (Holdaway 2008). The mbira's tuning and the design of the keys could possibly date back 500 years from the present. Hugh Tracey, who had a profound passion for mbira music, began recording this instrument in 1929 (Holdaway, 2008). He later spent time travelling across Africa, recording the sound of the mbira. During his voyages, Tracey taught himself to play various kinds of mbiras and determined how to document their tunings. The mbira of the Shona people in Zimbabwe plays an important part in their traditional beliefs. The Shona populace accepted that the mbira was given to them by their god and that the instrument's sound could attract the spirits of their ancestors (Holdaway, 2008).

The *mbira dzaVadzimu* means 'voice of the ancestors' and is otherwise called the *nhare*. This mbira may be traced back to the sixteenth century or what is known as the Mwenene Mutapa period. Since that time, the construction of the *mbira dzaVadzimu* has changed. Matiure (2013) outlines the historical background of the *mbira dzaVadzimu* and its evolution from a sacred musical instrument that connected the living to the spiritual world to a form of entertainment. According to Tracey (1963, p. 23), "[t]he *mbira dzaVadzimu* is the oldest known form of mbira to be played by the Shona people of Southern Rhodesia".

A group of archaeologists found evidence of the mbira as an ancient musical instrument dating back to between 1500 and 1800 AD (Berliner, 1993, p. 28). In 1589, Father Dos Santos, a missionary, became the first person known to refer to the mbira. A few centuries later, Charles and David Livingstone were the first to distribute a sketch of the mbira. The design on the soundboard and the shape of the mbira's keys may differ (Berliner, 1993, p. 30). The keys of the *mbira dzavadzimu* are thicker and wider than those of a *matepe*, which are slim and narrow. The soundboard of the *njari* is 'tray-shaped' with no base wall, while a *mbira dzavadzimu* has a base in place (Berliner, 1993, p. 31).

Matiure (2013, p. 86) highlights that not all metal wires are appropriate for making the mbira, since the wire should have a high carbon content. It is accepted that the tuning arrangement of the *mbira dzaVadzimu* stems from its predecessors (Matiure, 2013, p. 92). Matiure (2013, p. 92) additionally examines the ancient mbira tuning systems, known as *mavembe*, which were first utilised during the tenth century. These were used to summon *Makombwe* and family spirits.

The mbiras played by the Shona people of Zimbabwe are the focal point of Berliner's (1978) research, yet this author additionally examines mbiras from as far afield as Ethiopia and Cameroon. Various kinds of mbiras are played by the Shona people. Unfortunately, Berliner (1978) neither refers to the specific part of the African continent from which these diverse mbiras derive, nor to the materials utilised to make the instruments. The focal point of this author's research is the mbiras of Southern Africa. For the Shona people of Zimbabwe, the mbira is a tool used to connect the living and the dead. Mbira music has overlapping rhythms and is repetitive.

Nketia (1975, p. 77) describes the various types of mbiras and their distinctions, addressing the number of keys, the kind of wood used as a soundboard, as well as the presence or absence of a calabash. The mbira ordinarily has a mechanism that creates a buzzing, vibrating sound. Mbira players utilise snail shells, beads, seashells and pebbles to produce this vibrating sound. This is done to increase the proportion of noise.

Mbira music is firmly embedded in tradition and is believed to be 1000 years old as well as being utilised in a ritual called mukwerera, which is a rain-making ritual. The mbira is closely connected to spirituality and religion. It is believed that mbira players may have the ability to calm wild creatures, and that the mbira gives ancestors the ability to possess the afflicted (Berliner, 1978, p. 187).

Maldonado-Torres (2007) highlights colonisation as a political and monetary relation whereby the freedom of one country is determined by the power of another country. The colonisation of Africa brought about the capture and oppression of Africans, who were shipped to America and the Caribbean (Bulhan, 2015, p. 242).

Bascom (1953) highlights the impact colonialism and missionaries had on African practices and beliefs. This author suggests that it would have been better if the missionaries had attempted to study and comprehend African religion before they rejected it. Bascom (1953, p. 493) states the following: "By a variety of means the missionaries tried to undermine African religion, with varying success. The negative approach of condemning it as evil was adopted when the positive approach of showing the virtues of Christianity did not prove adequate." Mothoagae (2018) highlights that Christianity among the Batswana people depended on the idea that all that is African was characterised as sinister, idolatrous and heathen.

Watkins, Madiba and McConnachie, (2021, p.20) highlight that in recent years, there has been an increase in demand for a decolonised curriculum at South African universities. However, there is still little to no agreement on what a decolonised curriculum entails, particularly in the setting of most music departments, which, with the help of university administration, maintain a curriculum dominated by American jazz and Euro-American art music. These types of music are heavily subsided at expense to the restoration and continuation of African traditional music and art music education. Hugh Tracey, the founder of ILAM (International Library of African Music) has drawn attention due to his alleged involvement in promoting British colonisation (Watkins, Madiba and McConnachie, 2021, p.21). His musical instrument collection and records were seen as the spoils of colonial privilege. Tracey has collected recordings, photographs, and videos. With more than 3000 recordings recorded over the course of 50 years starting in the 1920s, his Sound of Africa and Music in Africa series have been supplemented by seventeen more collections owned by his son Andrew, Dave Dargie and others. These collections are made up of photographs, visual and audio recordings.

Chidanyika, T. (2008, p. 91) highlights that the historical significance of the mbira during and after the struggle for Zimbabwean independence, as well as the international success of some Zimbabwean musicians like Thomas Mapfumo, Stella Chiweshe, Oliver Mtukudzi, and the late Bhundu Boys, played a significant role in popularising and expanding the genre of mbira music. Early performances, instruction, and recordings by now-famous mbira and marimba players and teachers like the late Dumisani Maraire and the late Ephat Mujuru had a significant impact on the introduction of Zimbabwean music to the West in general and musical instruction.

The mbira may have various names, such as *likembe* and *kalimba*, and might be built in various shapes and sizes, yet the development of the different types of mbiras is fundamentally similar. The *mbira dzavadzimu* is believed to be the most traditional mbira.

The customary religious ceremonies of the Shona sometimes feature the mbira as a solo instrument. The mbira is generally accompanied by *hosho* players, who sing and clap. *Hosho* players assume an important role, as they set and maintain the tempo.

In Uganda, there are various kinds of mbiras with different ranges that are played in an ensemble setting. However, in Zimbabwe, Shona mbira ensembles feature similar mbiras. In the northern parts of Mozambique, a mbira player might be accompanied by another instrumentalist drumming on the calabash resonator with two sticks (Berliner, 1978, p. 15).

The above literature offers an overview of mbira history. Subsequently, it is possible to gain insights from literature regarding the acoustic measurements of the materials used to craft mbiras, leading toward an understanding of the instrument's acoustic properties. This data was used in conjunction with microphone techniques to determine best-practices for recording the mbira.

2.3 Acoustics

Acoustics is an extensive field that relates to academic disciplines such as engineering, music, audiology, as well as architecture. It is an aspect of physical science in which mechanical vibrations are examined (Pulkki & Karjalainen, 2015, p. 23). Physical acoustics is an important area of acoustics, in which the propagation of sound in liquids, gases and solids is investigated (Rossing, 2007, p. 5). It also seeks to examine the way sound interacts with a medium through which it propagates, including the diffraction, absorption, refraction and transmission of sound (Rossing, 2007, p. 16).

According to Pulkki and Karjalainen (2015, p. 15), "[s]ound, from a physical point of view, is a wave physically propagating in a medium, usually air, and in most cases is caused by a vibrating mechanical object". The occurrence that triggers a sound or vibration is called its excitation or source (Pulkki & Karjalainen, 2015, p. 16). A sound wave or vibration may multiply in a medium, and it might either be improved by reverberation effects or weakened due to losses that change it into other energy structures. Sound waves and vibrations may be seen as a shift between potential and kinetic energy, beginning from a simple case and moving toward an overall case of sound propagation. With this in mind, the vibrating body may be assumed to be that of the mbira. Thus, the mbira's sound is produced through the excitation of a vibrating element. When the key of a mbira is struck, the sound produced by the vibration of its keys will contain multiple frequencies. The lowest of these frequencies determines the pitch heard by the listener and is known as the fundamental tone (McNeil & Mitran, 2008, p. 1169). This frequency-propagating vibration displaces the air and causes the air pressure to change (Rossing, 2007, p. 1). The hearing range of humans begins at a frequency of around 16 Hertz (Hz), and extends to approximately 20,000 Hz (Blauert, 1997, p. 2). This frequency range is within that of the mbira. McNeil and Mitran (2008, p. 1170) highlight that the mbira's vibration is responsible for the pitch of the various keys, and that its frequency ranges from 117 to 948 Hz. Lastly, the mbira produces a slowly decaying sound produced by the vibration of its keys and has a narrow dynamic range (medium-quiet to medium-loud), unlike that of the piano, which is wider.

2.3.1 Sound and resonance

Since it is now clear how sound is produced by vibrating objects, further aspects and properties of sound propagated by vibrating objects through mediums such as air may be addressed. Each frequency of the object – in this case, the mbira – is linked to one of several standing wave patterns by which the mbira could vibrate. The harmonics of a musical instrument are its natural frequencies. If another object pushes an instrument's frequencies, it vibrates at one of its harmonics, resulting in resonance. Resonance is a phenomenon regularly found in physical systems (Pulkki & Karjalainen, 2015, p. 18). It occurs when an object vibrates at a sympathetic frequency to that of another object, causing the second object to vibrate as well.

Assuming the energy of a musical instrument's sound is not enough, a soundboard, such as that of a mbira, has more resonance and might assist with increasing the volume of the sound source. Simultaneously, the resonance adds to the sound and, if constructed correctly, may make it more interesting.

2.3.2 Sound pressure

According to Pulkki and Karjalainen (2015, p. 24), "[t]he most important physical measure in acoustics is sound pressure". Sound pressure is the variation of pressure from the static pressure in a channel which is regularly air because of a sound wave at a particular point. Sound pressure is significant since it may be measured easily. Kim (2010, p. 313) highlights that a decent condenser microphone may accurately alter sound pressure into an electrical signal. Since sound pressure shifts over an enormous reach in Pascal units, it is more helpful to use the calibrated scale of the decibel (dB).

2.3.3 Electroacoustics

Pulkki and Karjalainen (2015, p. 67) highlight that the subject of electroacoustics connects acoustics and electrical engineering. Certain physical phenomena may be utilised to change an electrical signal, voltage or current into a sound, or vice versa. Electroacoustic tools, especially microphones, amplifiers and earphones, are fundamental in speech correspondence, sound innovation and multimedia sound (Pulkki & Karjalainen, 2015, p. 67). Electroacoustic gadgets are also significant in acoustic measurements and the logical exploration of different parts of sound. There are various ways by which electrical energy may be changed into acoustic energy. Of all these options or opportunities for completing this function, a few have become predominant in microphones. Microphones may be piezoelectric, electrostatic and electrodynamic. Mitchell (2008, p. 598) suggests that an electroacoustic transducer contains three components: the diaphragm, suspension and motor. The diaphragm is supported by the suspension, which allows it to move in a controlled manner and then applies a force that is proportionate to the movement from its placement and provides a damping energy that is parallel to the speed of movement that assists to keep the diaphragm from oscillating in a manner that is not required.

Differences in acoustic power are understood as varieties of loudness with high accuracy and little delay, although timbral variations or pitch transitions might be vague and heard less accurately. Comprehensively, the more powerful parts as far as their impact on listeners are those like acoustic intensity. Dean and Bailes (2016, p. 105) point out that intensity variations are a predominant driver of supposed change, and in case they were the only driver they would deliver the evident change variable pointless.

Decibels are useful for audio experts. Decibels and levels deal with humans' perception of loudness (Ballou, 2008, p. 24). This is important to note, since the loudness of the mbira will determine which microphones are best suited for recording this instrument. The loudness of a sound is based on a given ratio which produces the same result. In the case of the mbira, the loudness that it produces will be determined by how much pressure is used to strike the key. According to Ballou (2008, p. 23) "[s]ubjective testing has shown that the power applied to a loudspeaker must be increased by 26 percent to produce an audible sound". In other words, the ratio of 1.26:1 will create an audible change in sound level. An increase of 1 watt (W) to 1.26 W, or an increase of 100 W to 126 W, will produce an audible change in sound level. There are other factors, such as the distance between the microphone and the sound source, which determine the sound level produced. The loudness of a sound source, in this case the mbira, is relative to its acoustical level or acoustic power. Acoustic power is expressed using decibels (Ballou, 2008, p. 26).

Frequencies are also important to audio practitioners. When a mbira key is struck, the frequencies propagate as a wave that radiates outwards. Unlike the increase of the sound ratio of 1.26:1 used for decibels, frequencies increase depending on the number of Hertz. A 2:1 ratio means that 200 Hz would be double the frequency range of 100 Hz, which represents an octave. Ballou (2008, p. 27) suggests that doubling a frequency yields an octave increase in relative pitch. It is important to measure the frequency range of the mbira to ensure that the architectural acoustics within the room in which the mbira will be recorded are suitable. Architectural acoustics may produce negative effects on the sound produced within a room. The shapes of surfaces also have a profound effect on the performance of the sound.

2.3.4 Materials and acoustics

Unlike for many African musical instruments, the available information pertaining to the acoustics of Western classical instruments is well-established. Therefore, to obtain a better understanding of the purpose of this study, a good example to consider would be a Western classical instrument, such as the violin.

The violin consists of four strings, a fingerboard, bass bar, top plate, tailpiece, ribs, neck, sound post, two F-holes and a back. According to Campbell and Greated (1998, p. 204), the back board is made from a hardwood called ebony. The strings may be made of nylon, steel, or gut. The ribs, back and neck are carved from curly maple. The bow is made from Pernambuco wood and the bow hair comes from horses’ tails.

Huber and Runstein (2014, p. 164) state that the frequency range of the violin runs from 196 Hz to above 10,000 Hz. When recording the violin, a microphone displaying a flat frequency response should be used, and it should be placed at a 45-degree angle to the instrument’s front face (Huber & Runstein, 2014, p. 164). The acoustic room settings and the style of the music will determine the distance of the microphone from the violin. If the violin is mic’d at a long distance, the sound produced will be mellow and well-rounded, while a scratchy sound will be produced if the microphone is placed near the violin (Huber & Runstein, 2014, p. 164). The recommended distance between the microphone and the instrument should be about 90 centimetres to 2.5 metres (Huber & Runstein, 2014, p. 164).

Information regarding acoustics and microphone techniques pertaining to the violin are consistent throughout various literary sources. This information served as a guide in finding acoustical information for the mbira and consequently aligning best-practice recording techniques for the instrument.

Most musical instruments are made of wood and/or metal. According to Fletcher and Rossing (1998, p. 719), "[w]ood consists of cellulose, hemicellulose and lignin and these materials are organised into structural elements constructed on tracheid cells". Dry wood, such as the wood used to make mbiras, will contain a loss peak at a frequency range between 50 to 100 kHz, but this peak frequency may change with temperature (Fletcher & Rossing, 1998, p. 722). Like other materials, wood changes over time, and this occurs when an instrument is played. However, these changes cause little damage to the instrument and therefore result in little to no change in its acoustic behaviour. Kumbani, (2020, p. 236) highlights that the metal keys of a mbira are made from a set of flattened iron bars that are fixed on to a wooden bar and it is some-times enclosed in an open gourd that also functions as a resonator to amplify the sound. Metal keys are found in most mbira variants. Unfortunately, there is no literature that addresses the metal components of the mbira keys in detail.

2.3.5 Waveforms

The plane wave is a focal idea in acoustics. Plane waves are waves in which any acoustic variable is consistent at any given time on any plane opposite to the direction of propagation (Jacobsen & Juhl, 2013, p. 11). In a restricted space, a long distance from a sound source in free space, the shape of the circular wavefronts is insignificant and the waves may be perceived as locally plane. Harmonic waves are produced by sinusoidal sources, such as a speaker driven with a pure tone (Jacobsen & Juhl, 2013, p. 11). Most of the sound waves, including the melodic sounds that reach our ears, are not standing waves. Typically, when a wave is created, it goes outward, progressively dispersing out and diminishing in strength. When the wave comes across an object, it may echo or divert. Waves may also become trapped between at least two surfaces, echoing backward and forward. When a mbira key is struck, it starts to vibrate and sets up standing waves on the key. The mbira will only vibrate in particular ways as characterised by the limited keys.

When sampled by electroacoustic systems, sound fields are regularly examined frequency by frequency. Linearity suggests that, in a sinusoidal waveform, the frequency will produce a sound field that shifts harmonically with the frequency at all positions (Jacobsen & Juhl, 2013, p. 13). Since the frequency is provided, all that should be established is the amplitude and phase at all positions. Significantly, the connection between the sound pressure and the particle speed in this impedance field is undeniably more confounded than in a plane propagation wave. A plane wave that imposes on a plane rigid surface opposite to the direction of propagation will be reflected. The physical clarification of the way that the sound pressure is indistinguishably zero a quarter of a wavelength from the reflecting plane, is that the incident wave should travel a wavelength before it returns to a similar point; the incident and reflected waves are thus in antiphase, and since they have a similar amplitude, they cancel one another out (Jacobsen & Juhl, 2013, p. 16).

Waveforms are visual depictions of the sound pressure level or voltage level as it moves through a medium over time (Huber & Runstein, 2014, p. 44). Waveforms created by an oscillator generally have fundamental characteristics that include frequency, wavelength, velocity, phase and amplitude, and these characteristics determine the quality of sound.

Frequency refers to the rate an electrical signal, acoustic generator or vibrating mass repeats within a cycle of negative and positive amplitude (Huber & Runstein, 2014, p. 47). The higher the rate of repeated vibration is within a cycle, the higher the frequency will be. Similarly, the lower the rate of repeated vibration is within a cycle, the lower the frequency will be. Huber and Runstein (2014, p. 48) suggest that the velocity of sound waves travelling through air at a temperature of 20 degrees Celsius is 344 metres per second. The speed of sound in air is faster in warmer temperatures than in colder conditions.

The amplitude of a wave is the height between the centre line of a waveform and the peak (Huber & Runstein, 2014, p. 44). The peak amplitude value is known as the crest and the lowest point is known as the trough. According to Huber and Runstein (2014, p. 45), “[t]he greater the distance or displacement from that centreline, the more intense pressure variation, electrical signal level, or physical displacement will be within a medium”. The amplitude of a waveform may be measured in various ways, such as the measurement of the positive and negative peak signal levels. This is known as the peak-to-peak value.

A waveform that has frequency and amplitudes but starts its cyclic periods at different times is out of phase (Huber & Runstein, 2014, p. 51). Phase is measured using degrees and is also known as a time delay between multiple waveforms. The delay in the waveforms is said to cause variations in their phase degree angles, which could be anywhere between 0 and 360 degrees. According to Huber and Runstein (2014, p. 53), “whenever two or more waveforms arrive at a single location out of phase, their relative signal levels will be added together to create a combined amplitude level at that point in time”. If two waveforms were completely out of phase, they would cancel each other out and this would result in an amplitude level of zero. If two waveforms have exactly the same shape, the frequency and peak amplitude are said to be in-phase. In this case, the two waveforms will effectively double the amplitude. Phase-shift results from the time delay of two waveforms (Huber & Runstein, 2014, p. 53). This can occur when two microphones are placed at different distances when recording a mbira. A delay is created from this when the two recordings are played simultaneously. This delay may also occur when a single microphone simultaneously picks up the direct sound from the mbira as well as any reflected sounds. The quality of a microphone's pick-up response is dependent on variables such as the distance between the sound source, how the microphone is placed and the acoustic environment in which the microphone is used (Huber & Runstein, 2014, p. 109). As a signal propagates through a medium, the its strength reduces. The frequency and phase will be the same, but the scale of the signal will be reduced due to attenuation. The higher the decibels, the higher the signal strength. The lower the decibels, the more attenuated the signal. This means that attenuation will cause a signal to weaken while it travels through a medium.

2.3.6 Reverberation time

Swallow (2011, p. 133) highlights that reverberation is a replicated acoustic environment created to a mix that sounds more spacious, and it may give the effect of being in a certain type of venue. In acoustics, RT60 refers to reverberation time. RT60 is a measure of the amount of time a sound requires to decay by 60 dB in a space that has a diffuse sound field – a room large enough for reflections from the source to travel to the microphone from all directions at a similar level. Researchers may utilise the RT60 decay, spectrogram and decay plots to determine the decay of low frequencies in small rooms. The larger the room, the lengthier the decay. Similarly, the decay would be more rapid in a smaller room. A decay time of around 0.3 seconds is seen as decent. However, this includes the entire recurrence range, from low to high. The researcher used pink noise to conduct an RT60 test at the current live room attached to the student studio at the University of Pretoria. Pink noise was played for four seconds, then stopped for four seconds whilst simultaneously being recorded using a flat-response side-address large diaphragm condenser microphone with omnidirectional polar pattern. This process was repeated a total of four times at 60 decibels. The sound took 281 milliseconds to decay.

2.3.7 Material properties

It is important to consider the general principles that determine the materials used to make an instrument, as well as the material properties and complex structures of natural materials such as wood. The materials of an instrument influence the acoustic behaviour of the sound they produce, and this is evident in idiophones, such as cymbals and bells, where the entire instrument vibrates and radiates its sound (Fletcher & Rossing, 1998, p. 711). The researcher conducted an analysis of the mbira's keys with Dr Maggi Loubser, who is a senior lecturer at the University of Pretoria. This was done to identify the type of material used to make the mbira keys. The full report, also discussed further in subsequent sections, may be viewed in Appendix 2, page 72.

2.3.7.1 Wood in musical instruments

Wood plays an important role in the design and building process of many musical instruments (Bremaud, 2012, p. 807). The properties of wood impact the acoustic response and mechanical resistance of the instrument. The vibrational properties and physical acoustics of wood will ultimately depend on the instrument itself. Vibrational properties and physical acoustics are important for the mbira's soundboards, which radiate the vibration of the mbira keys and thus determine the quality of sound produced.

To stiffen the wood used for musical instruments, it has traditionally been treated with primers, varnishes or minerals (Schwarze, Spycher & Fink, 2008, p. 1095). This treatment may improve cell bonding, but it also increases density and vibrating mass because the substance obstructs the cell lumina, lowering the speed of sound through the wood. This treatment will not change the density of the wood, but rather increases the degree of the cell wall structure, which is considered unfavourable for wood processing. Another method for improving the acoustic properties of wood is to reduce its density through fungal or bacterial degradation (Schwarze et al., 2008, p. 1096). Recently, a new heat treatment has been used to improve the acoustic properties of resonant wood. The negative effect of this treatment is that the material becomes brittle, causing problems in the device manufacturing process. Schwarze et al. (2008, p. 1096) highlight that most of the described treatments change the wood's cell wall structure. This negatively affects the properties of the composite intermediate layer, which plays a fundamental role in determining the overall stiffness of the wood. In similar bulk materials, ignoring surface effects, the speed of sound is controlled by two mechanical properties, namely elastic modulus and density. In wood with strong anisotropy, the speed of sound will vary with direction and increase due to any discontinuities in the amalgamated interlayer, such as those caused by bacterial degradation.

Fioravanti (2014, p. 311) defines wood science as a discipline in which the construction, as well as the physical and mechanical conduct of wood, is reviewed. Wood science may provide helpful information to preserve wooden heritage. Wood maturing addresses the aftereffect of the connection of numerous factors that persistently change their state. This creates results that, as far as quality and intensity are concerned, could shift from one situation to another. Discussed now, are the causes of damage in wood structures.

The most reliable decay element to be evaluated is that dictated by biological damage. This may occur, however, by certain insects or their larvae, causing mechanical detriment to an instrument by eliminating a specific piece of the material and potentially impacting its physical and acoustical performance (Fioravanti, 2014, p. 311). To a lesser extent, yet still notable and significant, are variations influenced by pressure of physical or mechanical origin. Similarly, as with some other authentic wooden objects, dampness may harm a musical instrument such as the mbira. Dampness varieties may cause contracting or expanding, deformation to the mbira’s structure, or in the most unwanted scenario, failure. Fioravanti (2014, pp. 311–312) highlights that these distortions and failures are affected by wood anisotropy, which is portrayed by the solid contrast between shrinking or enlarging longitudinal and transversal directions. The longitudinal direction refers to the bearing corresponding to the wood grain, while the transversal direction is that opposite to the grain.

Cracks or any other continuous deformation are unwanted in the preservation of wooden musical instruments. Often, they result from an incorrect assessment of the environmental conditions to which the instrument has been exposed. During a performance, a wooden musical instrument is simultaneously exposed to loading and dampness variation. The loading is primarily determined by the instrument’s tuning (Fioravanti, 2014, p. 312). In a wooden musical instrument such as the violin, the pressure applied by the performer through the bow is minor. After it is tuned, the instrument has an adaptable conduct, displaying two primary forms of deformation: a general bending influencing the entire violin, as well as an intricate disfigurement of the midsection that causes two bumps to have a focal hollow. Fioravanti (2014, p. 312) highlights that such a degree of a period is additionally ready to initiate a dampness variation in wood, which is prompted by the contrast in relative humidity between the composition case and concert hall, as well as by the humidity delivered by the player during the performance.

2.3.7.2 The acoustics of the mbira

Berliner (1980) wrote an article about John Kunaka, a virtuoso mbira player. Kunaka was also known for making the mbira *dzaVadzimu*, as he was a skilled carpenter. A well-known group of mbira players, Mhuri yekwa Rwizi, had commissioned Kunaka to make instruments for them. This article highlights Kunaka's skill in crafting mbira soundboards and tuning. Kunaka made mbiras using hardwood from a tree called *mubvaropa*, a Shona word that translates to "you came for blood" (Berliner, 1980, p. 61). Other woods used by Kunaka came from local trees named *mukanda* and *murira*, and were used to make the mbira's soundboard.

Berliner (1980) outlines one of the processes by which the mbira may be constructed. The process starts by felling a tree, such as a *mubvaropa*, for the mbira's soundboard. The scientific name for this tree, also known as *muninga*, is *Pterocarpus angolensis* (Berliner, 1980, p. 61). Kunaka chopped one and a half pieces of wood and divided them lengthwise. Kunaka then measured a piece of wood five inches wide, two inches thick and eighteen inches long. The soundboard was left to dry for one to two weeks before Kunaka continued working on its construction. If the keys are mounted onto the mbira too soon, they will eventually loosen when the soundboard is dry. The bridge of the mbira is fashioned from a piece of iron measuring 0.125 by 0.5 by 7.75 inches.

The soundboard of the mbira is shaped by its maker, and this may vary from one type of mbira to another (Berliner, 1978, p. 9). Many of the mbiras in the south-eastern parts of Africa have been described as board-shaped, box-shaped and bell-shaped. The mbira has numerous names, which are determined by the region of the continent from which it originates. The most common names for the mbira are *likembe*, *kalimba*, *sansa* and *mbira*. Berliner (1978, p. 13) states that mbira keys may be made from copper, iron, steel, brass, redwood strips, maize stems or pieces of bamboo.

Nketia (1974, p. 77) mentions the different types of mbiras and their differences, which may involve the number of keys, the type of wood used for the soundboard, or the presence or absence of a calabash. The mbira usually has a device that produces a buzzing, vibrating sound. To create this sound, mbira players often attach snail shells, beads, seashells and pebbles to the instrument. This contributes toward a greater variety of timbre.

2.3.7.3 Wood acoustics of the violin

To obtain a better understanding of wood and its acoustic properties, a good example to discuss would be the violin, since the instrument is well-understood and widely known. The condition of resonant wood is essential for acoustic violin quality (Schwarze et al., 2008, p. 1103). The procedure described herein contemplates the process for qualifying wood with the goal of manufacturing a good solitary device. The violin’s tonal properties include high projection, volume and dynamic range, as well as the sensitive variation of tonal colours. These directly correlate with the material quality of the violin’s resonance plates, which correlate positively with the velocity of the longitudinal sound waves and negatively with wood density. A material with a high speed of sound to density ratio increases the instrument’s sound emission, implying that the plate amplitudes are large in relation to the force that excites the strings. This resonance enhancement distinguishes between a violin of average quality and one suitable for a top soloist. The precise effect of bending strength on the violin will also be determined using a newly designed violin made from fungal-treated wood plates. Furthermore, the vibration factor’s influence on the acoustic quality of resonant wood, as well as the effects of its modification on the final properties of the violin, will be examined.

A method of developing the acoustic properties of wood is to diminish its density by parasitic or bacterial degradation. Thermal treatment is one of the methods used to work on the acoustic properties of reverberant wood. The disadvantage of treatment is that the material becomes fragile, causing issues when musical instruments are assembled. Schwarze et al. (2008, p. 1096) highlight that, in a homogeneous mass of material, overlooking surface effects, the speed of sound is directed by two mechanical properties, which are the modulus of elasticity and the density. This, however, is not necessarily recommended for a mbira.

2.3.7.4 Wood acoustics of the mbira

Like all melodic instruments with various vibrating parts, the pitches created by the individual keys are connected to each other in a coordinated manner, referred to as the tuning of the instrument (McNeil & Mitran, 2008, p. 1169). Throughout Africa, numerous mbira tunings are used, stemming from tune and harmony designs predominant in nearby cultures. Furthermore, they also mirror the creativity of individual expert players. Mbira keys are curved, with considerable pairing between extended, curving and twisting vibration modes (McNeil & Mitran, 2008, p. 1172). The mbira’s keys transmit sound, which causes the soundboard to vibrate. The surface space of the soundboard is larger than that of the keys, allowing the keys to vibrate proficiently when the soundboard is excited. McNeil and Mitran, (2008, p. 1172) highlight that the connection of a key to the soundboard is advanced by ensuring that vertical contact at three focal points of the mbira occurs. These are the edge of the soundboard, the fastener pushing on the top of the key, and the fret pushing against its lower part. Longitudinal vibrations of a key produce forces which act against the frictional contact and are not likely to create massive excitation of the soundboard. In this way, the focus is on the relative acoustic effectiveness of sound radiation from the key movement, considering that the force of acoustic waves transmitted by curving methods of a key are enhanced by the soundboard, while those related to consistent or distorting methods are not thereby enhanced.

2.4 Organology

Von Hornbostel and Sachs (1961) highlight that ancient Chinese people classified musical instruments based on their materials. Distinctions were made between wood, metal, stone, bamboo, gourd, hide and silk. According to Von Hornbostel and Sachs (1961, p. 5), "[s]ound-instruments are divided into three major categories: Stringed instruments, wind instruments and percussion instruments". There are, however, many instruments that do not fit into these categories. Wind instruments are further divided into woodwind and brass instruments. It is important to note that some brass instruments, such as cornets and bass horns, were originally made of wood. In many cases, woodwind instruments, such as flutes, saxophones and clarinets, are made of metal (Von Hornbostel and Sachs, 1961, p. 6).

According to Von Hornbostel and Sachs (1961, p. 7), Mahillon subdivided woodwind instruments into four branches, namely reed instruments, cup-mouthpiece instruments, mouth-hole instruments and polyphone instruments. Mahillon also divided drums into several groups, namely double-skin drums, vessel drums, frame drums and kettle drums. Idiophones are classified as struck idiophones, concussion idiophones or clappers, percussion idiophones, shaken idiophones or rattles, scrapped idiophones, split idiophones, plucked idiophones, or clack idiophones (lamellae, which could have a shell, such as a calabash, used as resonator). Certain instruments, including some mbiras, do not have a resonator.

Cowdery (1999) highlights two organology essays written about African and African American lamellophones. This author mentions the mbira, a lamellophone. The various forms of the instrument, as well as its tunings, playing techniques and history are discussed. The Lala people of Zambia have two types of kalimba lamellophones called the *kankobele* and the *ndandi*, each with its own musical style. Van Dijk (2010, p. 85) highlights that the

Lala kalimbas are classified as both lamellophones (*lamella* refers to a small, thin plate) and idiophones.

2.5 Microphone theory

Huber and Runstein (2014, p. 109) highlight that a microphone is a transducer that alters one form of energy into another consistent form of energy. Microphones contain diaphragms, which respond to changes in air pressure. The movement of the diaphragm is then changed into an electrical waveform. This electrical waveform is a simple duplicate of the first. For the most part, either dynamic or condenser microphones are used. Dynamic microphones do not need external power to work, but condenser microphones include capacitors, which require electrical power. This is known as microphone theory. Experimenting with the placement of percussion instruments and then recording them may assist in determining optimal instrument placement by virtue of the sound quality captured by the microphones. This will also assist in providing acoustical information about the space in which such experiments take place.

Rayburn and Eargle (2012) provide invaluable insight regarding the acoustical conditions in which certain types of microphones can be used. Furthermore, they provide extensive information on the different types of microphones that are available and how to make use of them through illustrations of recording sessions. This is important, since this information allows readers to better understand the production of the sound, such as that derived from the mbira. It also aided in the process of choosing microphones for this project that would be best-suited to the frequencies produced by the mbira. Factors such as microphone sensitivity and frequency response affected the quality of the mbira recordings. Microphones that possess the range of sound that may pick up the frequency range of the mbira were chosen, and this source has provided the information needed to do so. Rayburn and Eargle (2012) has a chapter that deals with condenser microphones, which are widely used in music recordings, including recordings of acoustic instruments.

The room in which the participants perform will not only affect the acoustical quality of the sound they produce, but also the sense of how they perform (Davis, Patronis & Brown, 2013, p 25). It is important to note that the environment in which an instrument is played always influences its sound. An outdoor recording setting is referred to as a free field, which is a sound field free from boundaries and uninterrupted by other sound sources (Davis et al., 2013, p. 171). Recording the mbira in an outdoor environment may cause problems such as those that can lead to the material effects of sound such as reflections and diffraction from the ground and solid objects or refraction caused by wind variations and its speed. A space with noise, too much reverberation time and faulty geometrical shapes, is not an acoustically ideal location for recording (Davis et al., 2013, p. 191). Other conditions, such as the air temperature and differences in it, may influence the speed of sound in the air, thus diminishing the quality of the mbira recordings. Factors such as the wind blowing against a sound source, including the mbira itself, will cause the sound to refract. The wind does not 'blow' the sound, it refracts it (Davis et al., 2013, p. 176).

The mbiras used for the purpose of this research were recorded using condenser and dynamic microphones. Berlin (2015) is a website that highlights that the diaphragm of a condenser microphone can track the sound waves more precisely than that of a dynamic microphone with a substantial moving coil attached due to its low mass. Condenser microphones offer better sound quality. Of all microphone types, condensers have the broadest frequency reaction and the best temporal reaction. Additionally, condenser microphones typically offer a higher sensitivity and lower noise level than dynamic microphones, which is why this type was used to record the mbira.

The diaphragm of a condenser microphone is an extremely thin and tensioned foil. Inside the microphone cartridge, the other piece of the capacitor, the back plate, is positioned near the diaphragm (Jacobsen & Juhl, 2013, pp. 32–33). When the diaphragm moves because of the sound pressure, the capacitance varies, creating an electric voltage corresponding to the instant sound pressure. The microphone should be as small as possible so as not to interrupt the sound field. Jacobsen and Juhl (2013, p. 33) highlight that this is against the requirement of a high sensitivity and a low basic noise level. Typical-sized microphones are 12,7 mm microphones with a width of around 13 mm. At low frequencies, such as those under 1 kHz, such a microphone is much smaller than the wavelength and does not significantly upset the sound field. In this frequency range, the microphone is omnidirectional, since the sound pressure is scalar and has no bearing (Jacobsen & Juhl, 2013, p. 33).

2.5.1 Phasing

Izhaki (2012, p. 161) highlights that phase defines the time relationship between two or more waveforms. Sine waves may be used to demonstrate phase, which is measured in degrees. The degree of phase shift not only depends on the time difference between the two sine waves, but also on their frequency. For the same time period, different frequencies will have different phase shifts.

Phase metres are a common part of large format control panels (Izhaki, 2012, p. 98). They measure the phase constancy between the left and right channels of the mix. The metre scale increases from -1 to +1. The +1 position indicates that the two channels are completely in phase, which indicates that they produce the same signal. On the other hand, -1 denotes that the two channels are perfectly phase inverted. Similarly, an indication of 0 denotes that each channel plays something different. A positive reading usually indicates that there is a strong phase, while a negative reading would be problematic.

2.5.2 Sound field capturing

According to Tashev (2009, p. 2), "[c]apturing sound starts with the conversation of the acoustic wave in the air to an electrical signal by one or more microphones". The microphones could have distinct qualities and may provide a more desirable sound for the processing steps that follow. The microphone signal is filtered, pre-processed and amplified. An analogue-to-digital converter transmits customisation and quantisation and converts the audio into a digital stream. One of the first stages of a recording system consists of an acoustic echo reduction system. The acoustic echo reduction system eliminates the sound emitted by the speaker from the received signal. At the end of the processing, the localised audio remains. In this case, the mbira's sound is captured with some reverberation. Tashev (2009, p. 7) highlights that the captured sound includes a combination of wanted and unwanted signals. In this case, the sound of the mbira is the wanted signal and the unwanted signal could be the reverberation.

2.5.3 Reverberant and direct sound fields

A reverberant sound field is created by reflections from the walls in a room with little to no absorption (Munjal, 2013, p. 118). When a mbira is played in a reverberant room, the sound pressure level will be diffused; even if the microphone were to be moved to another part of the room, the sound pressure level would remain constant throughout the room. If the room is free from echo, the reverberation and reflection would be non-existent and there would be a direct sound field. According to Munjal (2013, p. 118), "[t]he direct sound field is categorised by a spherical or hemi-spherical wavefront and its sound pressure level, or the intensity level is directed by the inverse square law". Direct and reverberant sound fields will vary depending on the acoustic absorption of the walls, ceiling, doors, windows, floors, furniture, carpets, as well as the number of people in the room (Munjal, 2013, p. 118). When two or more sounds are added to a sound field, they may influence the complete field in an unexpected way. At any moment in time the pressure values increase.

A person who sits in the direct field of a mbira will have an awareness of sound dominated by the that emanating from the mbira. However, the mbira's sound will drown out the reflected sound from other parts of the room. The space that divides a sound from a transducer can be seen as a transmission medium where acoustic signals are altered and taken according to the acoustic characteristics of the environment. According to Majeed, Abbas, Amin, Chaudhry, and Jamal (2007, p. 31), "the impulse response h(t) of the acoustic channel between the source and sensor in a reverberant room represents all the multiple reflections from the surrounding surfaces that reach the sensor in addition to the direct sound". A variety of paths between the source and device are created when the sound reflects from walls and other objects. The diffusion will differ from one path to another due to the different lengths of the paths. Different duplicates of the signal will reach the sensor after the direct wavefront. When a wavefront strikes a surface, a portion of that wavefront is reflected and absorbed.

According to Fahy and Gardonio (2007, p. 376), "[a]t all points on the surface of the body the sound field particle velocity normal to the surface must be zero". One of the properties of a steady sound field is that the volume is somewhat higher than the level of sound propelled in a room by the sound source. It is important that the energy distribution within a sound field is evenly dispersed. When the energy of the sound field is perfectly dispersed, it is referred to as a diffuse field. This means that the amount of energy flowing to a room equally propagates in all directions within the room. The energy from a mbira forms its own sound field, known as a direct field.

2.5.4 Transducers

The mbira is a transducer in that it takes the vibrations of the metal keys, which represent the medium, then amplifies them through the wood. The vibrations are then converted into sound pressure waves, which are perceived as sound. Huber and Runstein (2014, p. 41) highlight that a microphone is another type of transducer, in that sound pressure waves vibrate on the microphone's diaphragm. The sound pressure waves are converted into consistent electrical voltages. Variations in design may impact the quality of sound between speakers, microphones and other transducers.

Majeed et al. (2007, p. 32) suggest that microphones may be classified according to their type of transduction. Microphones are transducers, which means that they convert energy from one form to another. This could be the conversion of sound energy into an electrical signal, which is known as acoustic transduction. The microphone recording technique, as well as the environment in which it is used, influences the microphone's performance. When a mbira key is struck, the sound pressure produced causes movement on the microphones diaphragm, realising the transduction. The microphone will interpret this vibration caused by the mbira as an amplitude response. Additionally, sensitivity impedance and polar patterns are important factors in the performance of microphones.

Frequency refers to the level of the electrical signal, acoustic energy generator or vibrating mass repetition within a cycle of positive and negative amplitude (Huber & Runstein, 2014, p. 47). The higher the rate of repeated vibration within a cycle, the higher the frequency will be. Similarly, the lower the rate of repeated vibration within a cycle, the lower the frequency will be. The speed of a wavelength is determined by how fast it travels from one point to another. This is called velocity and also depends on the temperature of the ambient air. Sound will travel faster in warmer temperatures than in colder conditions. Huber and Runstein (2014, p. 48) state that the velocity of a sound wave travelling through the air at 20 degrees Celsius is approximately 344 metres per second.

2.5.5 Induction

Induction is different from transduction. A microphone will convert acoustic energy into electrical energy through induction. When the mbira key is struck and the sound travels into the microphone, the sound pressure wave will cause the microphone to vibrate. The microphone contains a wire coil within a magnet, which causes the wire to move in a magnetic field, thus creating an electric current through the wire. This is known as induction. The loudness of the mbira will affect the amplitude of the vibration, and its pitch will affect the frequency of the current. During a recording session, disturbances such as vibrations and noise may occur. Modifying the system or source is required to control the vibrations (Munjal, 2013, p. 80). One of the ways in which vibrations may be controlled is by reducing the excitation. Active vibration control is another way by which a system may reduce vibration by applying variable control input.

2.5.6 Shannon's sampling theorem

Dodson (1992, p. 253) suggests that Shannon's sampling theorem has served as the foundation of effective practical techniques for digital and analogue conversion. Shannon was able to use the sampling theorem to create the theoretical similarity of analogue and digital signals. According to Dodson (1992, p. 253), "the sampling rate specified in the Sampling Theorem is crucial and for lowpass signals must exceed the Nyquist rate in order to prevent aliasing; higher rates also lead to smaller errors in digital/analogue conversion". Shannon's analysis of a communication system consists of the following five elements: an information source, which could be a physical reading; a transmitter; a channel; the receiver; and the destination. Shannon's theorem has an application of distinct sequences involving a stream of 1s and 0s. Most of these signals are analogue and consist of numerous frequency waves (Dodson, 1992, p. 254). The frequency components of an analogue signal could be produced by an oscillator, a person's voice, or an instrument such as the mbira. These signals are bounded and cannot vibrate above a certain limit. Such signals are assumed to have a maximum frequency and are thus 'bandlimited' (Dodson, 1992, p. 254). Shannon's sampling theorem highlights that the maximum frequency of an analogue signal is limited by its samples, taken every ½ watt per second. Sampling above the Nyquist rate may be used to avoid aliasing difficulties and to reduce attenuation, but sampling below the Nyquist rate may lead to high frequencies appearing as low frequencies.

2.5.7 Microphone placement

Huber and Runstein (2014) provide a general guide for the microphone placements when recording different instruments. There are several microphone guidelines that may be used depending on the desired recording instrument. Huber and Runstein (2014, p. 146) highlight that a dynamic microphone will often yield a rugged or punchy character, whereas a ribbon microphone will most likely yield a mellow sound. Condenser microphones usually produce a sound that is clear, present and full-range. The sound of a condenser microphone will vary depending on the grill, design and size of the capsule.

Dyar (1961, p. 49) emphasises that recording circumstances may be isolated according to location (indoors or outdoors), audience, accompaniment and type of performance, such as solo or group. Each of these situations presents its own challenges when deciding on a microphone technique. In many cases, an ethnomusicologist will likely record audio in an outdoor environment. This indicates that the ethnomusicologist would not be working in a better sound-controlled environment such as a recording studio. The fundamental issue is that a microphone's ability to discern individual sounds does not match that of human ears. A human ear can distinguish whether or not the room echoes. In outdoor spaces, a person can tell where a sound is coming from and concentrate on it, but a microphone cannot listen to this effectively. When a group of spectators such as an audience is not included, readily accessible materials such as blankets may be used to make acoustic screens that prevent echoes and resonances in a live room. Similarly, interested bystanders may be asked to stand behind the receiver, forming an acoustic wall. In an outdoor environment, the effect of the wind should be taken into account. In such an environment, using a blanket as a wind screen to form a pocket of quiet air around the microphone could be useful (Dyar, 1961, p. 49).

According to Dyar (1961, p. 49), "the first rule of microphone placement then is to make a short test recording and listen to it, either through a loud-speaker or a close-fitting pair of earphones". In an indoor environment, microphones should be tried in as many areas as possible. Each time they are moved, a brief test recording should be made and listened to. A listener may discover that a specific microphone may work best when it is placed close to or further away from the performer. Dyar (1961, p. 50) suggests that recording a soloist proves more difficult than recording a group. This is due to the expanded sound energy produced by the group, allowing the sound to stand out against background interference. Using more than one microphone when recording a musical instrument such as the mbira may cause some issues, such as phasing. Since the sound waves take more time to get to one amplifier than the other and on the grounds that they need to travel further at the same time, they are diminished in power when they arrive at the microphone that is further away (Dyar, 1961, p. 50). The more unobtrusive parts of the presentation are lost as a result of being counterbalanced or distorted when the two electrical signals are merged. Performances recorded with more than one microphone will generally have an unnatural quality. The most practical method is to try different combinations of microphone locations. It is also important to remember the required techniques that were studied while recording individual mbira performers with one microphone, paying attention to sampled audio for fundamental environmental characteristics and relative equilibrium, both musical and noisy, between the performers and their accompaniment (Dyar, 1961, p. 50). With training, it is possible to achieve a realistic outcome using an appropriately placed microphone.

2.5.8 Stereo sound imaging

Young (2018) highlights that stereo imaging is the general term for processing techniques that allow the width of the stereo image to be adjusted. The fundamental requirement for binaural sound localisation is not known, even though much of the research in this field has managed the issue. Acoustic intensity, wave phase, and the time of arrival of wavefronts have been recognised as viable elements when they are dichotic or diverse comparative with two ears.

2.5.9 Microphone specifications

The primary performance specifications of a microphone are its directional properties, output sensitivity, output source impedance, frequency response measurements, equivalent self-noise level and maximum operating sound pressure level for a stated percentage of a total harmonic distortion (Eargle, 2004, pp. 105–106). Frequency response information should consistently express the physical measuring distance so that an evaluation of impact in directional microphones may effectively be made. The sensitivity of a microphone is presented by stating the output root mean-square (RMS) voltage, and this is done when the microphone is placed in an open 1 kHz sound field at a pressure of 1 pA RMS. For studio quality microphones, the reference distortion cut-off is set as the acoustical signal level at 1 kHz, which will create close to 0.5% total harmonic distortions at the microphone's yield (Eargle, 2004, p. 112). It is challenging to determine the measurements of a microphone's distortion, since acoustical levels in the dynamic range of 130 to 140 dB are required. These levels are difficult to produce without amplifier distortion. A pistonphone (mechanical actuator) arrangement may be utilised with pressure microphones where a decent acoustical seal can be made, yet this is futile with any gradient microphone. Typically, gradient and pressure-gradient microphones rely on the differences of these to pick up patterns. Unidirectional microphones are a supposition of these numerous studio quality microphones. The distortion that is present at extremely high levels results not from the nonlinearities of the diaphragm's movement but from electrical over-burden of the amplifier stage following the diaphragm (Eargle, 2004, p. 112). Certain manufacturers create microphone distortion by infusing a comparable electrical signal, equivalent to what the diaphragm movement would create in a high sound field, and then measuring the subsequent electrical distortion at the microphone's yield. This strategy is based on the presumption that the assembly of the diaphragm does not deliver distortion, and that any deliberate distortion is the aftereffect of electrical overload.

Various double microphone mounting procedures have been produced for stereo recording and are characterised in acoustically suitable designs (Eargle, 2004, p. 184). Many of these are circular, some intentionally head-shaped. While many of these microphones function well enough for direct stereo pick-up, others might be more suited to the prerequisites of binaural recording. An optimal pressure microphone reacts only to sound pressure, and not to the directional orientation of the sound source. The microphone receives the sound through an active opening. Generally, a pressure microphone displays some directionality along its principal pivot at short frequencies, primarily due to diffraction effects. Only as the frequency moves toward the boundary of the microphone diaphragm does it begin to depart altogether from omnidirectional reaction. For certain studio-quality pressure microphones, this will become significant above around 8 kHz (Eargle, 2004, p. 22). Pressure-type microphones are among the earliest microphones, and the capacitor pressure microphone is generally utilised today in music recording just as in instrumentation and applications used for measurements. The capacitor microphone is recognisably referred to in the sound industry as the condenser microphone, utilising an earlier electrical term for ‘capacitor’. There are small openings in the back plate that are equally circulated on a uniform grid. During the back-and-forth movement of the diaphragm, the air caught in the openings dampens the diaphragm’s movement at its primary reverberation, which is ordinarily within the scope of 8 to 12 kHz (Eargle, 2004, p. 24). The diaphragm is normally made of a plastic material, such as Mylar, onto which a thin layer of metal, frequently gold, is attached. Aluminium, nickel and titanium have also been used as diaphragm materials (Eargle, 2004, p. 24). Operating in parallel with the stress of the actual diaphragm is the additional stiffness caused by the air captured behind it. The diaphragm and air are both are important to maintain the high reverberation recurrence of the diaphragm assembly. A small passageway tube connects the inside air mass to the outside, giving a slow leaking passage, so that static environmental pressure will even itself out on the two sides of the diaphragm under all environmental conditions. When capacitor microphones are used for conventional recordings, broadcasts and sound support applications, changes that occur due to temperature and barometric pressure differences may mostly be ignored (Eargle, 2004, p. 29). The essential result of temperature increase is a decrease of diaphragm pressure, which in turn causes an increase in the diaphragm’s sensitivity and a reduction in bandwidth.

Pulkki and Karjalainen, (2015, p. 70) believe that a decent microphone should change a wide scope of frequencies, perhaps from 20 Hz to 20 kHz, with a level frequency reaction, low distortion and noise, as well as a desired directional pattern. Although numerous conversion standards have been applied, many microphones, including the carbon microphones found previously in telephones, have become out of date. Presently, the main innovation is the condenser microphone and its modifications. The sound pressure alterations noticeable in the air cause one of the condenser’s electrodes to move whilst the other remains stable. If an electric charge is available, an adjustment of distance between the electrodes will alter the voltage between them (Pulkki & Karjalainen, 2015, p. 70). This voltage signal is enhanced inside a similar microphone unit when it may be taken through a cable to sound hardware over reasonable distances. A variation of the condenser and electret microphones requires the use of an electret substance with electric charge inside, between the electrodes, so that no outside voltage is required. Additionally, an inherent amplifier is needed. Electret microphones have discovered widespread use, particularly owing to portable gadgets. A well-known type of microphone is the dynamic microphone. The dynamic microphone works according to the electrodynamic theory that was also used in the dynamic loudspeaker; however, it is presently used to change movement into an electrical signal (Pulkki & Karjalainen, 2015, p. 70). When a wire in a magnetic field moves, a voltage is generated between the terminals of the wire. Pulkki and Karjalainen, (2015, p. 71) highlight that if a microphone is sensitive to the particle speed in the air, the directional pattern is a dipole that responds at the main axis from the front and back. It does not respond from the sides. A cardioid microphone is highly responsive from the front and delicate from the back. It would be conceivable to develop maximally directional microphones that are sensitive to sound deriving from a restricted spatial point. Microphone ranges, along with signal processing, may be used to create systems where the directional pattern of the signal is simple to deal with electronically.

2.5.10 Sound absorption coefficients

Sound absorption coefficients are commonly utilised to distinguish and rank sound-retaining materials used to decrease noise (Han, Herrin & Seybert, 2007, p. 1701). This is important and also has contextual relevance, since it assisted the researcher in knowing what type of room would be suitable for recording the mbira. The standards that guide absorption measurements do not particularly focus on the detailed measurement of low absorption coefficients. These concerns fall into three regions, namely tube construction, microphone phase error correction, and the correction for latent tube mitigation (Han et al., 2007, p. 1701). These principles realise the significance of making precise phase measurements and provide techniques by which to measure and amend phase error. Even phase-matched microphones may blunder significantly when estimating low sound absorption coefficients if the phase error is not amended. The guidelines prescribe a microphone shifting approach to determine the microphone phase error. Han et al. (2007) provide information on how to correct microphone phase error. While utilising the two-microphone technique, the phase error between the microphones cannot be avoided and should be corrected. The microphones are subject to a similar sound pressure and phase, so a measurement of the transfer function decides the microphone phase and amplitude error immediately (Han et al., 2007, p. 1702).

Concave rooms were avoided to prevent causing the sound reflections to converge and to ensure that the sound of the mbira would scatter better. Ballou (2008, p. 29) suggests using a convex surface since it scatters sound waves.

Below is a table of the absorption coefficients of materials that were in the room in which the mbira was recorded. The measurements of absorption coefficients range from 0 to 1. If the absorption coefficient is 1, no sound energy is reflected. If the absorption coefficient is 0, the sound energy reflects at a rate of 100%.

Table 1: Absorption coefficients

Carpet floor	0.01 at 125 Hz	0.02 at 250 Hz	0.06 at 500 Hz	0.15 at 1 kHz	0.25 at 2 kHz
Brick wall (painted)	0.01 at 125 Hz	0.01 at 250 Hz	0.02 at 500 Hz	0.02 at 1 kHz	0.02 at 2 kHz
Concrete block	0.1 at 125 Hz	0.05 at 250 Hz	0.06 at 500 Hz	0.07 at 1 kHz	0.09 at 2 kHz
Adults (1 to 10 people)	0.25 at 125 Hz	0.35 at 250 Hz	0.42 at 500 Hz	0.46 at 1 kHz	0.5 at 2 kHz

2.6 Key researchers

Various researchers have contributed to mbira literature. Several of these researchers have been mentioned in this chapter. The key researchers in this section are related to ethnomusicology. Important researchers who contributed to mbira literature are discussed below.

2.6.1 Ethnomusicologists and the mbira

John Blacking, a trained ethnomusicologist, was influential in the study of African music. Blacking began writing academic articles in the 1950s and published 100 recordings and books. Blacking is best known for his work *How Musical is Man?* (Blacking, 1976), which covers topics such as the role of music in a society and the practices of Venda cultures. Blacking also wrote a book called *Venda Children's Songs* (Blacking, 1967), which provides a description of the Venda musical instruments and ideas about music. The book also includes rhymes, counting games and play songs. There are songs for boys, girls and both genders. The book also provides daytime and night-time songs.

Berliner (1993) authored a prolific book about the mbira, mbira music and traditional African music. In the book, topics such as the arrangements and shapes of mbira keys are discussed. The author highlights the development of polyphonic music, which is created when the mbira is played. The book also provides readers with an understanding of melodic African music, particularly that of the mbira. According to Berliner (1993, p. 9), "[in] the Shona language the word mbira is both singular and plural and can be used to denote either one or more individual keys". Berliner states that the mbira has many regional names, of which the most common are *likembe*, *sanzhi*, *mbira* and *kalimba* (1993, p. 9). Berliner also suggests that there are types of mbiras that may be found in countries such as South Africa, Zimbabwe, Mozambique, Ethiopia, Angola and Gambia (1993, p. 10). The book contains a variety of figures of the various arrangements and shapes of mbira keys.

Berliner (1978, p. 60) suggests that mbira players change the tuning of their instruments to create more varied sounds. Tracey (1970, p. 46) states that the mbira he brought in 1932 was reasonably in tune with another mbira when he took it with him to Zimbabwe in 1969. Stone (1998, p. 750) refers to mbira players as 'mbirists'. Stone's article is the only source of literature in which the researcher found this term for mbira players. Stone (1998, p. 751) writes that the mbira is often played as a solo instrument, but there are instances where the mbira is accompanied by drums which accompany a singer. One of three drums, namely the *mhito*, *dandi* or *mutumba*, may be used to accompany the mbira. This is relevant to this research study, since the researcher recorded solo players who accompanied the mbira vocally.

Gimenez Amoros (2018) analyses the repatriation of recordings from the International Library of African Music, providing a study of the African sound archive. In his book, Gimenez Amoros intended to raise awareness by circulating African music cultures abroad. Gimenez Amoros (2018, p. 22) highlights the study of lamellophones, specifically that of the mbira, in Southern Africa. He also examines the *nyunganyunga* (heptatonic mbira of the Shona), *matepe*, mbira *dzavadzimu* and *njari*. The heptatonic mbiras discussed, descend from the eight-keyed kalimba (Tracey, 2015, p. 129). The *nyunganyunga* is possibly one of the oldest mbiras, deriving from the Nyungwe of Mozambique (Tracey, 1961, p. 44). Many recordings at the International Library of African Music feature *njari* performers. This may demonstrate that the *njari* was a popular type of mbira in Zimbabwe between the 1950s and 1970s (Gimenez Amoros, 2018, p. 25). Gimenez Amoros does not provide information pertaining to microphone or recording techniques for the mbira. This research study will hopefully fill this gap in the literature.

Tracey (1961) expresses concern over ethnomusicologists incorrectly naming one of Africa's most important musical instruments. The mbira was given names such as 'kaffir piano', 'hand piano' and 'thumb piano'. Tracey highlights that all plucked idiophones in the south-eastern parts of Africa share the same name – mbira (Tracey, 1961, p. 20). The author does, however, state that there are different local names for the mbira to distinguish one type of mbira from another. Tracey recorded the Valley Tonga mbira players, who use a smaller instrument called *kankowela* or *kankobela*, a name used by the Lozi (Tracey, 1961, p. 21). Names such as 'kaffir piano' and 'hand piano' were given to the mbira by Western researchers. However, this study aims to contribute to the decolonial agenda in its methodology of using technology to unlock educational and developmental techniques of understanding indigenous instruments.

Dworkin (2007) translated poems and Shona mbira *dzaVadzimu* music. This author also taught a course entitled *World Humanities*, in which she incorporated Shona music for the mbira *dzaVadzimu* that she had learned to play. In this course, students discovered ways in which the mbira, its repertoire and social functions raise concerns about the arts, creativity, originality and translation (Dworkin, 2007, p. 83). Dworkin highlights that mbira performers do not learn to play by reading scores; rather, their understanding of music originates from their ancestors (Dworkin, 2007, p. 84).

Tracey (2013) notes that the appearance of the modern *hera* has changed. The *hera* now features additional notes and resembles the layout of the *nyonganyonga*. Tracey concludes that the *nyonganyonga* must be the predecessor of the *hera* (2013, p. 23).

Van Dijk (2010) conducted field research in Zambia, where he discovered the kalimba, an important musical instrument of the Lala people. Van Dijk studied the *Cibombe* and *Ipupo* ceremonies, and discovered two types of mbiras, namely the *kankobele* and the *ndandi*. Van Dijk highlights that the *kankobele* has been part of the Lala musical culture for centuries, while the *ndandi* was introduced in Chibane which is in Mozambique during the 1930s (2010, p. 85). The author also describes the materials used to craft the Lala kalimba, as well as its tuning plans and the differences between the *kankobele* and *ndandi*. The *Cibombe* is a ceremony during which dance songs are performed with the accompaniment of three drums (Van Dijk, 2010, pp. 89–90). Unfortunately, the proceedings of *Ipupo* ceremonies are not described.

Reuster-Jahn (2007) describes the *luliimba*, a llamellohone from north-eastern Mozambique. The *luliimba* is a *Makonde/Mwera* type, and its uniqueness has garnered interest among researchers. According to Reuster-Jahn (2007, p. 7), “there is no tradition concerning the origin of the instrument”. While certain people know of the instrument, there are few *luliimba* players.

Reuster-Jahn (2007, p. 14) highlights that the *luliimba* is performed at a special event called *nngoma ja luliimba* or *ukana gwa luliimba*, which translates to ‘the beer of *luliimba’*. The event is a public performance that lasts throughout the night. This event has no connection to any spiritual or ritual practices. During this event, beer is brewed, and people build a beer stand called *liteteele*. The *luliimba* is accompanied by a drum called *ngwacala* or *cingaanga*, which is struck with two sticks. In these performances, participants sing and dance. The *luliimba* is performed by men, and the sons of the players inherit the instruments. Reuster-Jahn (2007, p. 17) highlights that her interviewees had received their *luliimbas* from their fathers.

2.6.2 Mbiras of Zimbabwe

Among the Shona, there are five common types of mbiras. These are the *njari*, *mbira dzavadzimu*, *matepe*, *kalimba* and *mbira dzavaNdau* (Berliner, 1993, pp. 29–30). These mbiras vary in terms of physical characteristics and musical style. The function in the culture of each type of mbira also varies. The mbira has various tunings and musical styles throughout Africa. The tunings are based on melodic patterns prevalent in the culture from which the instrument is derived. In certain cultures, the mbira may be used as a form of entertainment, while other cultures use it in religious ceremonies (Berliner, 1993, p. 15).

Stone (1998) discusses the mbira music of the Shona of Zimbabwe. This journal article highlights the development of Shona music and the archaeological excavations in Zimbabwe that confirm the early importance of the mbira. The article describes the mbira as the distinguishing feature of Shona music (Stone, 1998, p. 745). Stone explains that the mbira is used extensively throughout Africa and that the Shona frequently use it in their rituals (Stone, 1998, p. 745). A group of people known as the *Korekore* used a kind of mbira which they termed *hera*, *munyonga* and *madhebhe* (Tracey, 1970). Tracey’s article mentions a form of mbira known as *njari*, which came from the Zambezi River valley in the eighteenth century. The *njari* has been used in rituals involving spirits known as *mashare* (Stone, 1998, p. 745). Another type of mbira is the *karimba*, which is also known as the kalimba in many areas. It is usually smaller than other mbiras and is not used in rituals. Stone’s article also discusses the tuning of the mbira and how the mbira sounds with overtones rather than fundamental tones. This is important and is linked to this research study; the researcher recorded more than one type of mbira from different parts of the Southern African region.

Berliner (1976) proposes that, in Zimbabwe, the word *kudeketera* is used by mbira players to refer to the verbal accompaniment of mbira. *Kudeketera* is regarded as one of the most important aspects of Shona mbira music. In this article, Berliner aims to fill a gap in Shona music literature by providing readers with aspects of *kudeketera*, such as its performance, interpretation and social function (Berliner, 1976, p. 452). Berliner's work is based on material he collected during his research concerning Shona mbira music. During religious ceremonies, participants accompany the mbira by singing lines of *kudeketera* during each mbira piece. *Kudeketera* lines may be improvised while simultaneously playing the mbira, clapping or playing *hosho* (gourd rattles). These lines may also come in the form of Shona oral literature, including proverbs, poems and story songs. *Kudeketera* lines may have various meanings and have also been used in music accompanying Venda rituals (Berliner, 1976, p. 455). Young *kudeketera* singers learn by listening and then imitating the styles of older musicians who are respected performers. Later, they add their own style to the music.

Tracey (1969) states that the Zambezi area of Zimbabwe is home to the richest mbira culture in Africa. It was difficult for him to find a mbira to play, so Tracey took it upon himself to make one. Tracey highlights that tuning the reeds of a mbira was the most difficult part of its construction. He also describes how the reeds should be placed, and that the tuning of each reed is dependent on its length, flexibility and weight.

Tracey (1970) introduces the reader to an instrument called *matepe* or *hera*, a type of mbira found in Zimbabwe. The author proposes that the *matepe* is associated with the mbira *vadzimu*, which are ancestral spirits known as *mbondoro*, meaning 'lion'. When there is a ritual involving the *mbondoro* or the *vadzimu*, one or more mbira players are usually present to perform songs. Tracey (1970) describes the body of the *matepe*, highlighting its length and breadth, as well as the materials used to construct the instrument. He also describes how the *matepe* is held and played, and provides notes on transpositions.

Tracey (1969) describes various forms of the mbira throughout Zimbabwe. There are two similar types of mbiras, known as the *madebe dza mondoro* and the *hera*, which are said to have originated in the Nyongwe area and are only found in the north-eastern part of the country. These two mbira types are used in rituals connected with ancestral worship. These mbiras are distinct from others in that the soundboard is made from a soft wood called *mupepe*. Tracey also lists other types of mbiras, such as the *njari duku, njari huru, mbira dza Watonga, timbila, karimba* and *mbira dza Wandau*.

Turino (1998) highlights how the mbira became a prominent instrument at a national level in Zimbabwe and later throughout the world. Turino proposes that the mbira was used locally among the Zezuru, who are a group of Shona people living within the area surrounding Harare. Turino also states that the mbira became prominent during the late 1980s with bands such as that of Thomas Mapfumo (Turino, 1998, p. 85). Shona dances and the mbira were also performed in rallies around Harare. Turino discusses the role of radio, electric band music, and Thomas Mapfumo in popularizing the mbira.

2.6.3 Recording the mbira

The reason for recording different mbiras is that according to Berliner (1993, p. 17), "[w]hile different types of mbira in Africa have elements of sound production in common, their history and social function, as well as morphological and musical style can be very dissimilar." It is likely that a mbira player who has mastered his or her own mbira may not be able to perform on another type of mbira. The researcher recorded different mbiras because this study focuses on the mbiras of Southern Africa, which has more than one type of mbira.

2.6.4 Summary

In summary, the literature review highlights the history of the mbira in Southern Africa, and discusses its materials and acoustics by comparison and examination from those of a Western classical instrument. The chapter addresses various topics, such as microphone placement, sound field capturing, microphone theory, waveforms, electroacoustics and organology. This chapter also discusses the types of mbiras and the different names for mbiras found in Southern Africa. A section in the literature review provides sources for recording and microphone techniques.

Chapter 3: Methodology

3.1 Introduction

This chapter describes the research methodology used, including the researcher's chosen research approach, research design, sampling strategies, data collection techniques, data analysis and interpretation.

3.2 Research approach

Creswell and Plano Clark (2011) discuss six mixed methods research designs. Topics covered in this source include different aspects of the research process, such as collecting, analysing and interpreting data. This source guided the researcher on processes required to gather information about mbiras and to address the research questions. Furthermore, analysis as a process of data collection would be necessary. Creswell (2011) describes important ways of examining data to obtain the results needed to answer the research questions.

The research was undertaken using a mixed methods approach. The mixed methods approach is a combination of qualitative and quantitative research (Johnson, Onwuegbuzie & Turner, 2007, p. 123). This research approach requires data collection and analysis of both quantitative and qualitative viewpoints in a single series of studies. During the quantitative portion of the research approach, the aim was to collect data using investigational techniques and similarly, for the qualitative aspect, to conduct interviews with several respondents. The interview questions and respondents' answers may be found in Appendix 1. Undertaking a qualitative research method provides tools to explore problems where the information and multiple perspectives of the respondents are respected (Creswell & Plano Clark, 2007, p. 7). The mixed methods research approach provided more data with which to study the research problem than would have been available had only qualitative or quantitative data been used exclusively. (Creswell & Plano Clark, 2007, p. 12). The two types of data add value to this study by providing more detail to the research approach. To this end, the researcher collected quantitative information on the mbira regarding its acoustic and material properties and subsequently attempted to develop a recording technique for the mbira. The recordings were also analysed.

3.3 Research design

An exploratory sequential design was used for this study. An exploratory sequential design is a mixed methods approach (Creswell & Plano Clark, 2011, p. 82). The sequence began with the quantitative phase of the research, which was followed by the qualitative phase. Broadly, this study required the investigation of recording techniques of microphones and the acoustic properties of a mbira to obtain quantitative data together with the qualitative apparatus. The latter apparatus was designed in such a way as to question selected respondents in relation to the construction of the instruments. Furthermore, to determine the type of microphone with which to record a particular instrument, it is important to consider the following: directional properties, frequency response measurements, as well as the sensitivity of the microphone device.

Rayburn and Eargle (2012, p. 129) explain that obtaining the acoustical information of a musical instrument will help in identifying its materials and the manner in which these are produced. It is advisable to use a microphone with a frequency response that suits the range of frequencies produced by the instrument being recorded. Additionally, Rayburn and Eargle (2012, p. 130) note that the microphone should be placed at a distance where the preferred tone quality is best. To assist in choosing the correct microphone, the recording engineer must understand the sound radiation properties of the instrument. Additionally, there are many websites and online resources offering information about microphones and their applications. These include, but are not limited to, Shure (2020), *Forum für Mikrofonaufnahmetechnik und Tonstudiotechnik* (n.d.) and *Audio Engineering Society* (2020). These resources offer much information pertaining to the use of microphones, including choosing a microphone, understanding frequency charts, frequency response and sound pressure level (SPL).

Acquiring acoustical information is needed in order to ascertain why certain materials are used to construct certain instruments. Seeking the wisdom of master mbira players, the researcher addressed the issue of determining the material properties of mbiras. In summary, the qualitative phase of this study served the purpose of explaining the preliminary results in more depth; in other words, the data collected from analysing the acoustical properties aided in answering the questions pertaining to the materials used to craft the instruments.

The explanatory design further serves the purpose of using a qualitative aspect, such as those detailed in section 3.1, to explain primary quantitative results. This allowed the researcher to develop qualitative questions, obtain sampling measurements (sound) and undertake data collection to ensure the support of the quantitative outcomes.

3.4 Procedure and data collection

There is a vast amount of knowledge about microphones and recording procedures and outcomes. It is important to consider this in the context of the mbira's acoustics.

Owsinski (2009, p. 100) highlights that the best and most expensive recording equipment does not guarantee good recorded sound. He implies that, in music recording, approximately 50% of the overall sound quality is provided by the player and their instrument. The space or room in which the recording takes place adds 20% of the sound quality, and the microphone used contributes 10% thereof. The final 20% is determined by microphone placement and technique. The placement of the microphones is known as the acoustic equalisation (EQ), and affects how well the sound of the instrument is captured. The critical part of this study is therefore to create a link between the data about the acoustic properties of the mbira and any potential methods this might have when used in conjunction with well-established recording techniques. This would be better than thoroughly repeating everything that is well-established and already known about using microphones as tools of measuring/capturing sound.

Since this study followed a mixed methods approach, the data collection process consisted of certain key components, such as the collecting, sampling and recording of data. The data collection period was determined by how long it took to ascertain the right recording techniques, the length of time it took to record the instruments, the number of participants and how long it took for the interviews to be completed. This took a period of eight months to complete. Respondents were chosen based on their knowledge about the instrument, as well as their skill in performing and making a mbira. The researcher contacted the players via mutual acquaintances. Once the musicians were contacted, the researcher organised the events of meeting and recording the respondents. As highlighted earlier, information pertaining to quality traditional African music recordings is rare and most recordings are not kept in optimal conditions.

According to Tracey (1955, p. 6), "[i]t is rare that any African recordings are made under ideal conditions, and even the best equipped studio is not necessarily the right place for recording items which may sound best only in the background". The study of the acoustical properties that dictate how materials react to sound waves, which would be perceived as sound in the broader context of African instruments, appears to be absent from the epistemology of mbira recordings.

The researcher obtained information from open-ended questions, open-minded observations, as well as video recordings and photographs. The participants provided data based on questions that did not limit their answers (Creswell & Plano Clark, 2011, p. 177). The mbira players were also observed while playing and holding the instrument. The information was collected in the form of records from computer-based tracking data (video and audio) and progress summaries.

The mbira recordings were first saved onto a hard drive, and then imported into audio software, namely Reaper and Pro Tools[1], for analysis of the audio samples/stems. This was done by means of sound level metres, microphones with good pick-up responses, external sound cards (audio interfaces) and spectrum analysis software. Finally, the most appropriate or best-fit recording techniques for the mbira were determined using a set of varied recording methods. These included variations in microphone placement, pick-up pattern, frequency response, type of microphone and diaphragm size. Photographs of the recording techniques may be seen in Appendix 3. As indicated earlier, the critical departure point relates to the already established recording techniques for other instruments as discussed in the literature review. In Appendix 7, a table of the frequency analysis data provides information such as the peak frequencies and amplitude response curves of the recording techniques. This table also includes links to screenshots of the peak frequencies and amplitude of the recording techniques that were used when the mbira was recorded.

A frequency spectrum analysis plugin used in Reaper recorded the frequencies and amplitude of the mbira. Since the plugin does not allow an export function, the researcher took videos of the plugins in operation. All the Reaper files with the audio files as recorded for analysis are included. Furthermore, Sonic Visualiser[2] was used for the process of exporting amplitude-frequency data graphs and there is additional data available from the Reaper spectrum analysis plugin. These are given further discussion and context with appendices in section 3.6.

The use of music recordings in music analysis and other musicological studies has grown in importance. A recording enables the researcher to examine music from the performer's point of view, rather than analysing music using notation only. Users have the option to 'view' the music by means of Sonic Visualiser. Sonic Visualiser is a graphical user interface for computational music analyses that would normally require knowledge of digital signal processing and music information research (Thompson, 2021, p. 702).

---

[1] https://www.avid.com/pro-tools
[2] https://www.sonicvisualiser.org/

3.5 Quantitative analysis

The purpose of this experiment was to discover the best possible recording technique for the mbira under studio conditions. This was part of the quantitative phase, which allowed the researcher to consider factors such as the sensitivity, directional properties and frequency response measurements of the microphones used. The distance between the microphone and mbira helped in determining the preferred tone quality. The process that was used to collect data has incorporated components such as recording and sampling data. Once recordings were made using the various microphone techniques, the recordings were saved onto a hard drive and analysed using audio software such as Reaper. These steps were completed by means of a microphone with a suitable pick-up response, an external hard drive and sound level metres. Software such as Reaper is suitable for frequency tracking and other systems of measurement. The files were presented in 24 bit/48 kHz WAV format sample rate. The researcher ensured that the track files started at the exact same time within the DAW projects. It is important to note that besides the microphone setups and specifications, there were various other factors that impacted the information received. These include the gain of the microphone channel, the pre-amplification of the microphone's signal, the room resonance, as well as the volume of the monitor speakers.

3.6 Qualitative analysis

The qualitative information was compiled by conducting interviews with selected respondents questions about the construction of the instruments. The participants were required to be able to play the mbira and to be knowledgeable about the materials that were used to construct the mbira. This qualitative approach was chosen because there was no other method of obtaining information about the materials used to build the mbira. These two data sets helped the researcher to understand how the performers relate their way of doing things in their environment, as well as how to record the mbira. A mixed methods design also allowed the researcher to freely use both qualitative and quantitative methods to address the research problem (Creswell & Plano Clark, 2007, p. 13). Respondents shared their knowledge about the mbira, providing the researcher with qualitative information.

Furthermore, a mixed methods research approach allowed the researcher to select the most relevant and valuable aspects of both qualitative and quantitative research methods. Additionally, respondents who took part in the study could benefit from the quantitative data obtained through the chosen mixed methods approach (Creswell & Plano Clark, 2011, p. 98). For this study, a mixed methods approach facilitated an in-depth understanding of the respondents' perspectives. This approach also allowed the methods of recording and mic'ing a mbira to be examined with consideration to the acoustics and materials of the instrument.

3.7 Sampling strategy

The sampling process applies to both qualitative and quantitative research. Purposeful sampling procedures were used to select participants. Selected participants who have experienced the key notion being explored in a particular study are referred to as purposeful sampling participants (Creswell & Plano Clark, 2011, p. 173). The participants chosen for this study come from the Venda, Shona and Malawian communities. The researcher planned to interview a minimum of three respondents, and selected these participants based on their skill and knowledge regarding the mbira, as well as on their Southern African heritage.

The data collected from the respondents took the form of audio and video recordings of their mbira performances is quantitative data. The participants responded to interview questions regarding the materials used to make their respective mbiras which is qualitative. These materials were then analysed.

In terms of gathering quantitative data, the mbiras were physically analysed by examining the different woods that make up the instrument's soundboard and the materials used for the keys. The different types of wood may be compared using data on the wood's acoustic characteristics, thermal conductivity and range of density. Furthermore, in terms of the sound propagation of the various mbiras, density, pressure and temperature are all critical factors that affect the speed of sound and therefore the overall acoustic behaviour of the instrument being tested (Deloughry, 1997, p. 11). The researcher determined that the use of different types of wood in the construction of soundboards across mbira varieties may not produce the same sound when each mbira is played. This is evident from comparisons of mbira playing styles and music styles. According to Ulrike (2006, p. 1439), "[u]sing material property charts on which acoustic properties such as the speed of sound, the characteristic impedance, the sound radiation coefficient, and the loss coefficient are plotted against one another for woods".

In terms of gathering qualitative data, the researcher recruited a small number of participants who provided detailed information about each mbira. Since there are few mbira players, a small group of participants from whom to collect data was most suitable.

3.8 Data analysis and interpretation

Creswell and Plano Clark (2011, p. 203) attest that in a mixed methods approach, quantitative and qualitative data should be analysed separately. The data was analysed for the purpose of addressing the research questions. The analysis of the data collected by means of the mixed methods approach allowed the researcher to interpret the data and the results.

According to Creswell and Plano Clark (2011, p. 210), research findings may be explained by comparing the interpretation of data and results with information collected by researchers in the past. The researcher may also subjectively interpret the data and the results to address how the qualitative findings link or correspond with the quantitative findings. This was indeed the case in this study, as shall be seen in the summary of findings in Chapters 4 and 5.

The researcher made video recordings of the frequency spectral analysis of the various recording techniques and polar patterns used to record the mbira, to create a visual display of the amplitude of the frequencies over time. The different microphones, recording techniques and polar patterns used in the experiment were compared. It is important to note that the gain structure of the microphones was set at different levels. The researcher also compared the recording techniques by listening to the studio recordings and considering the frequency spectral analysis to determine the best recording technique for the mbira. A link to the recordings of the spectral frequency analysis may be found in Appendix 4. Sonic Visualiser was used to obtain the peak frequencies of the mbira from each recording technique. A table of the peak frequencies from each recording technique may be seen in Appendix 7.

A physical analysis of the mbira was also conducted. A full, detailed analysis of the mbira may be found in Appendix 2. The mbira consists of a wooden base with metal keys, secured with a metal bar and wire. An analytical technique known as X-ray Fluorescence spectroscopy to identify the inorganic elements that comprise a material was used. The wooden base and metal keys of the mbira were examined in this case. The metal rod securing the keys was analysed and the wire securing the positioning rod was examined from the back. The wooden base was analysed from the front and from the back side. According to the analysis in Appendix 2, the metal keys contain traces of Iron, Manganese, Chrome, and Zinc. Nickel, Titanium, Calcium, and Potassium were found in the mbira's wood. It is believed that the iron and manganese found on the wooden part of the mbira are traces of rust from the metal keys.

3.9 Ethical considerations

Interviewed participants were given letters of informed consent to ensure that they understood the purpose of the interview and their role in it. The participants were then asked to sign the letter of informed consent. To protect their privacy, the participants names were not included in the interview transcripts. Participants were asked, but not required, to answer all the interview questions. The researcher chose to omit as much identifying information as possible to protect the participants' anonymity. Additionally, no identifiable data, such as email addresses, was gathered. The data will be stored in the University of Pretoria repository, where it will be preserved and owned by the University of Pretoria. Students and researchers from the broader global university-based community can obtain access to the University of Pretoria repository.

3.10 Research quality

In determining the validity and trustworthiness of the outcomes, this research study aimed to meet the level of quality, for quality, reliability and credibility. This was done by providing accurate information to ensure that the information being provided is factual and well-researched. Citing credible sources such as academic journals, news articles, and government reports has helped establish credibility.

Chapter 4: Results and Findings

4.1 Mbira recordings

4.1.1 Introduction

For this research study, the mbira recordings that were made were first stored on a hard drive and then saved as audio software for analysis. This was done using sound level metres, microphones with a good pick-up response, an external soundcard (audio interface) and spectrum analysis software. Sonic Visualiser and Reaper were used to track the best frequency amplitude curves produced by the mbira in the recording process. Reaper was used to track the frequencies of the recordings in real time. Sonic Visualiser was used to obtain peak frequency and amplitude data from the recordings. Table 2 on page 53 includes details about the frequency range, polar patterns and sensitivity of each individual microphone. Table 3 on page 54 specifies sound field sampling properties and stereo techniques, and also offers information about the microphone techniques and directional patterns. This is relevant to the mbira recordings, as these stereo microphone techniques played an important part in the microphone experiment (detailed in section 4.2 of this chapter).

Various recording methods were employed to determine the best recording technique for the mbira; these included variations in microphone placement, pick-up pattern, frequency response, type of microphone and the size of diaphragm. This was done to determine an overall frequency range and to obtain information regarding the instrument's acoustic abilities. Examining the sound propagation of the various mbira types in terms of the density and pressure are critical factors that affect the speed of sound and therefore the overall acoustical behaviour of the instrument (Deloughry, 1997, p 11). Photographs of the recording techniques used to record the mbira may be seen in Appendix 3.

4.1.2 Recordings

The researcher met with professional mbira players to record mbira songs. Recording took place in three separate music recording studios. The first recordings were done in a small studio in Johannesburg. The researcher later travelled to the Limpopo Province in South Africa to record two Venda mbira players. The Venda mbira players were recorded both separately and together. A link to the videos of the Venda mbira players may be found in Appendix 5. The recordings of the main microphone experiment (outlined in section 4.2) took place in a student project studio at the University of Pretoria, where two participants performed separately. Two types of mbiras were recorded, namely the mbira *dzavadzimu* and the mbira *dzamadeza*. The studio recordings were very helpful owing to the ideal conditions they provided to record the mbira.

The microphones that were used in the experiment included top address, side address, large diaphragm, small diaphragm, dynamic and condenser microphones. The microphones are listed in Table 2 which is on page 53. The researcher has outlined a set of available apparatuses which represent the microphone techniques used and their specifications. The researcher applied each apparatus according to the available literature on microphone techniques. As the mbira's wooden soundboard and metal keys produce its sound, the size and shape of the mbira's soundboard has an impact on the sound it produces. The mbira's size allows for it to be recorded using a set of several recording techniques. These include mono recording techniques with differences in the polar patterns, as well as stereo techniques (see Table 3 on page 54).

The researcher considered the specifications of the microphones, their designs and their capabilities. Based on the information in Appendix 7, which consists of a graph of the peak frequencies and amplitude of the recording techniques from Sonic Visualiser, the researcher could see the peak frequencies, as well as the amplitude of each peak frequency. The Shure 57A Beta (mono recording technique) had a peak frequency response of 129 Hz with an amplitude of -65 dB, and a peak frequency of 797 Hz with an amplitude of 97 dB. The AKG C414 B-TL II (mid side recording technique) had the best frequency response of all the microphones used, with a peak frequency of 129 Hz with an amplitude of -83 dB, and a peak frequency response of 958 Hz with an amplitude of -92 dB.

4.1.3 Top address microphones

When the researcher recorded using the Sennheiser e914, the XY technique had a higher amplitude response than the spaced pair technique. This is because the microphone is closer to the mbira in the XY technique than in the spaced pair technique. The researcher suggests that the XY technique is more suitable than the spaced pair technique, as the XY technique captures more of the mbira's sound than the spaced pair. The spaced pair technique did not have the same gain structure as the XY technique.

The researcher suggests that the Sennheiser MKH30 is more suitable for recording the mbira than the Sennheiser MKH40 microphone. This is because the Sennheiser MKH30 captured a higher peak frequency of the mbira's sound than the Sennheiser MKH40 and this may be seen in the table presenting the frequency data analysis in Appendix 7. The researcher deployed a stereo microphone technique using the Sennheiser MKH30 and MKH40 utilising the mid side recording technique to do so. The mid side recording technique has a higher amplitude than the mono recordings of the microphones. The differences in the amplitude of the mid side technique and mono technique may be seen and heard in the recordings of the frequency spectral analysis in Appendix 4. The gain structure of the Sennheiser MKH30 was not the same as that of the Sennheiser MKH40. Sonic Visualiser presented the researcher with the peak frequencies and amplitude of the top address microphones.

4.1.4 Side address microphones

The cardioid polar pattern of the AKG C414 B-TL II delivered a clearer sound than the bidirectional polar pattern. This is audible in the studio recordings of the mbira, which may be listened to in Appendix 6. The researcher suggests using the mid side recording technique to record the mbira, using the AKG C414 B-TL II in a stereo technique as compared to the XY technique. The researcher suggests using the omnidirectional polar pattern to record the mbira using a mono recording technique as compared to the cardioid and bidirectional polar patterns. This is because the recording techniques that were used to record the AKG C414 B-TL II did not have the same gain structure.

The spaced pair technique of the Neumann TLM 103 produced a low amplitude signal, whereas the XY technique delivered a higher amplitude level than the spaced pair technique. The difference in the amplitude may be seen in the recordings of the frequency spectral analysis of the two techniques (see Appendix 4). Therefore, the researcher suggests that the XY technique is more suitable than the spaced pair technique when recording the mbira in a stereo technique. The gain structure of the XY technique was not the same as the gain structure of the spaced pair technique.

The cardioid pattern of the Rode K2 produced the lowest amplitude, whereas the omnidirectional polar pattern produced the highest amplitude response. Proof of the differences in the amplitude of the two polar patterns may be seen in the recordings of the frequency spectral analysis (see Appendix 4). The researcher therefore suggests that the omnidirectional polar pattern be used when recording the mbira with a Rode K2 microphone in a mono recording technique.

The bidirectional polar pattern of the Rode NT2A produced a low amplitude response, and the microphone did not pick up much of the mbira's sound. The cardioid polar pattern produced a higher amplitude response than the bidirectional polar pattern, and this is may be seen in the recordings of the frequency spectral analysis in Appendix 4. Appendix 7 shows that the mono recording technique with a bidirectional polar pattern had lower peak frequencies than the mono recording technique with a cardioid polar pattern. The cardioid polar pattern also picked up a clearer sound than the bidirectional pattern, and this may be heard in the studio recordings of the two polar patterns (see Appendix 6). The omnidirectional polar pattern picked up a higher amplitude response than the bidirectional and cardioid patterns. The omnidirectional polar pattern captured more of the mbira's sound than the cardioid and bidirectional patterns. This may be seen in the video recordings of the frequency spectral analysis in Appendix 4. Consequently, the researcher believes the omnidirectional polar pattern to be the most suitable pattern with which to record the mbira using the Rode NT2A in a mono recording technique. The Rode NT2A featured the same gain structure for each polar pattern.

Notably, more noise was produced by the Samson CO3 than the other microphones. This challenging issue may be heard in the mbira studio recording (Appendix 6). The bidirectional polar pattern in the mono recording technique had a higher amplitude response than the cardioid pattern, and this may be seen in the recordings of the frequency spectral analysis of the two polar patterns in Appendix 4. However, the level of noise produced by the microphone in the bidirectional polar pattern results in the bidirectional microphone being less desirable when recording the mbira. This can be heard in the mbira studio recordings in Appendix 6. The level of noise produced by the omnidirectional polar pattern in the mono recording technique was higher than that produced by the bidirectional and cardioid patterns; therefore, the omnidirectional polar pattern is the least desirable pattern to use when recording the mbira. The researcher suggests that the cardioid polar pattern is the most suitable polar pattern to use when recording the mbira with the Samson CO3 microphone in a mono recording technique.

The spaced pair technique in a cardioid polar pattern captured the sound of the mbira without the interference of noise. The spaced pair technique with the use of the omnidirectional polar pattern was less desirable, as it produced some noise, which reduced the quality of sound in the mbira recording. This may be heard in the mbira studio recordings in Appendix 6. The XY recording technique had a higher amplitude response than the spaced pair technique, and this may be seen in the frequency spectral analysis recordings of the two recording techniques in Appendix 4. This is because the microphones were positioned closer to the mbira in the XY technique than in the spaced pair technique. The mid side technique captured a higher amplitude response than the spaced pair technique, and this may be seen in the video recordings of the frequency spectral analysis in Appendix 4. The distance between the microphone and mbira are closer in the mid side technique than it is when using the XY technique. The mid side technique was less desirable than the XY technique because of the level of noise it caused. The noise level of the mid side technique may be heard in the mbira studio recordings in Appendix 6. The researcher suggests that the XY recording technique is the most suitable stereo technique to use when recording the mbira using a pair of Samson CO3 microphones. The Blumlein technique has the highest amplitude response of the stereo recording techniques used in this experiment, as may be seen in frequency spectral analysis videos in Appendix 4. However, the level of noise in the recording was the highest when using the Blumlein technique, and may be heard in the mbira studio recording in Appendix 6. The Blumlein technique is therefore unsuitable when recording the mbira. Sonic Visualiser was also used to obtain the peak frequencies and amplitudes of the side address microphone recordings of the mbira and the data can be seen in Appendix 4.

4.1.5 Mid side

Different microphone techniques used with different polar patterns were compared. This section details the researcher's use of the same recording technique with different microphones to ascertain which microphone works best with which technique when recording the mbira. The mid side recording technique was used with the AKG C414 B-TL II, Samson CO3, Rode NT2A, Sennheiser MKH30 and Sennheiser MKH40 microphones. The level of noise produced by the Samson CO3 microphone using the mid side technique results in it being the least desirable microphone to use with this technique. The mid side recording using the AKG C414 B-TL II microphone produced less noise and had a higher amplitude than the Samson CO3. This may be observed and heard in the video recording of the frequency spectral analysis in Appendix 4. The AKG C414 B-TL II had the highest amplitude response of all the microphones used to record the mbira in the mid side technique, and the Rode NT2A had the lowest sound amplitude response. This data may be seen in the frequency spectral analysis of the microphones in Appendix 4. The Sennheiser MKH30 and Sennheiser MKH40 had the best sound quality of all the microphones used to record the mbira using the mid side technique and did not cause noise-related issues. This may be heard in the in the mbira studio recordings in Appendix 6. The researcher suggests that, from the available microphones, the Sennheiser MKH30 and Sennheiser MKH40 were the most suitable for recording the mbira using the mid side technique. The researcher obtained the peak frequencies and amplitude of the mid side mbira recordings through the use of Sonic Visualiser. The frequency analysis data of the mid side recording techniques may be found in Appendix 7. The acoustics of the mbira were suitable for the instrument to be recorded using the mid side technique.

4.1.6 XY

Different microphones used with the XY technique were compared. The AKG C414 B-TL II, Neumann TLM 103, Rode NT2A, Samson CO3 and Sennheiser e914 microphones were used with the XY technique. The Sennheiser e914 had the best frequency response curves of the various microphones used with the XY technique, and this may be seen in the frequency analysis data in Appendix 7. Sonic Visualiser was used to determine the peak frequencies and amplitude of the XY recording techniques used in the experiment. Appendix 4 was used to get the frequency spectral analysis of the XY technique. Appendix 4 contains the links to video recordings of frequency spectral analysis of the mbira. There are links to the mbira studio recordings of the XY technique in Appendix 6. The XY technique is suitable for recording the acoustics of the mbira. This may be heard in the studio recordings of the XY technique which may be found in Appendix 6.

4.1.7 Spaced pair

The researcher used the spaced pair technique to record the mbira, using the Neumann TLM 103, Rode NT2A, Samson CO3 and Sennheiser e914 microphones. The spaced pair technique caused the mbira recordings to sound more distant than the recordings made using other techniques. This may be heard in the mbira studio recordings in Appendix 6. The distance between the microphones and the mbira resulted in a reduction of intensity. The researcher would not recommend the use of the spaced pair technique to record the mbira. Once again, Sonic Visualiser was used to retrieve the peak frequencies and amplitudes of the spaced pair recording of the mbira. These may be seen in Appendix 7. Appendix 4 contains the studio recordings made using the spaced pair technique. Since the mbira is a small instrument, its acoustics are not suited to the spaced pair technique. This becomes clear when the spaced pair technique is compared with the other stereo techniques. Photographs of the spaced pair technique may be seen in Appendix 3.

4.1.8 Mono recording techniques

The researcher compared different microphones used with a mono recording technique. Photographs of the mono recording techniques may be found in Appendix 3. Recordings were made using the cardioid polar pattern. The microphones that were used to record the mbira in a mono cardioid polar pattern were the AKG C414, Rode K2, Sennheiser e914, Rode NT2A and Sennheiser MKH40. The recording made with the Rode K2 microphone sounds more distant than the recordings made with the other microphones. This may be heard in the mbira studio recordings in Appendix 6. The Rode K2 captured more background noise than microphones such as the AKG C414, Sennheiser MKH40 and Sennheiser e914, and this affected the quality of the recording. The recordings of the Samson CO3 had noise coming from them, which may be heard in the mbira studio recording in Appendix 6. The researcher would not recommend the use of the Rode K2 in a mono recording technique with a cardioid polar pattern, due to the issues mentioned above. The researcher recommends the Sennheiser e914, Sennheiser MKH40, Rode NT2A and AKG C414 microphones when using a mono recording technique with a cardioid polar pattern.

The AKG C414 B-TL II, Rode K2, Rode NT2A, Samson CO3 and Sennheiser MKH30 microphones were used to record the mbira using a mono recording technique in a bidirectional polar pattern. The mono recording with the bidirectional polar pattern resulted in the mbira sounding more distant than when it was recorded using a mono recording technique with a cardioid polar pattern. This may be heard in the mbira studio recordings in Appendix 6. The researcher would not suggest the use of the mono recording technique with a bidirectional polar pattern as it would not be the most suitable recording method to use. Better results were achieved from the cardioid polar pattern than from the bidirectional pattern, and this is evident when listening to the mbira studio recordings in Appendix 6.

Cardioid, supercardioid, bidirectional and omnidirectional microphones were used to record the mbira with a mono recording technique to determine which polar pattern would be most suitable. Photographs of the mono recording techniques may be seen in Appendix 3. The microphones used for this comparison included an AKG C414 B-TL II with a cardioid polar pattern, a Rode K2 with an omnidirectional pattern, an AKG C414 with a bidirectional pattern and a Shure Beta 57A with a supercardioid pattern. The Rode K2 with an omnidirectional polar pattern captured the highest amplitude, and this may be seen when comparing the video recordings of the frequency spectral analysis in Appendix 4. The disadvantage of this polar pattern is that it also captures other sounds around the mbira, which are audible in the recording. The amplitude of the AKG C414 B-TL II with a cardioid polar pattern was not as high as that of the Rode K2 with an omnidirectional polar pattern. Unlike the omnidirectional pattern, the cardioid pattern does not capture other sounds around the mbira. The Sennheiser e914 recording is a cardioid like the AKG C414 B-TL II, but the Sennheiser e914 is a top address microphone whereas the AKG C414 B-TL II is a side address microphone. The Sennheiser e914 microphone has a lower amplitude than the other microphones used in this part of the experiment. This may be seen in the video recordings of the frequency spectral analysis of the mbira in Appendix 4. Although the Shure Beta 57A had the highest gain level compared to the other microphones, it did not record the highest amplitude.

An omnidirectional polar pattern with a mono recording technique was also used to record the mbira. The microphones with which these recordings were made included the Rode NT2A, Rode K2, Samson CO3 and AKG C414 B-TL II. The Samson CO3 was not suitable for recording the mbira because of the amount of noise produced by the recording. This is audible in the mbira studio recordings in Appendix 6. The researcher would not recommend the use of the Samson CO3 in an omnidirectional polar pattern. Of the four microphones used, the Rode NT2A had the lowest amplitude response, and this is evident in the frequency spectral analysis in Appendix 4. However, the Rode NT2A also had the lowest amount of background noise. The peak frequencies and amplitudes of the mono recording techniques were obtained by means of Sonic Visualiser. The researcher has provided links to the frequency data analysis of the mono recording techniques in Appendix 7. The acoustics of the mbira are suitable for recording the instrument using a mono recording technique. This may be heard in the mbira studio recordings in Appendix 6.

4.1.9 Stereo recording techniques

Recordings of the mbira using various stereo microphone techniques and microphones were made and the researcher compared the recordings to one another. The Samson CO3 using the Blumlein technique captured the sound of the mbira, but the recording also includes much noise, which may be heard in the studio recording in Appendix 6. It is for this reason that the researcher would not recommend the use of the Samson CO3 with the Blumlein technique. The Sennheiser e914 using the XY technique adequately captured the full range of the mbira; however, noise from the right-hand side of the microphone blemished the recording. This may be heard in the studio recording of the mbira in Appendix 6. The Neumann TLM 103 microphone using the XY technique produced a better sound quality than the Samson CO3 using the Blumlein technique. As may be heard in the mbira studio recordings in Appendix 6, the Neumann TLM 103 did pose noise-related challenges. The Sennheiser MKH30 and Sennheiser MKH40 using the mid side technique offered the best sound quality compared to the other stereo techniques that were used to record the mbira, as is audible in the mbira studio recordings in Appendix 6. The researcher thus recommends the use of the Sennheiser MKH30 and Sennheiser MKH40 using the mid side technique to record the mbira in a stereo technique. The researcher used Sonic Visualiser to gather the peak frequencies and amplitudes of the stereo recording techniques used to record the mbira.

4.2 Microphone experiment

4.2.1 Introduction

The objective of this experiment is to propose an effective solution to the problem as defined. The current set of circumstances in music recording is that African musical instrument practitioners have not developed recording and microphone techniques – in this case, a recording technique for the mbira. Generally, ethnomusicological recordings are made in a recording studio setting. However, recording participants in an unsuitable environment such as a rural settlement makes this a challenge. For instance, Stone (2008, p. 44) recorded two young ladies singing a children's melody in a local area compound on the outskirts of Arusha in Tanzania. Even when quality microphones are used, factors such as the acoustic treatment of a room designed to record musical instruments may impact the sound of a recording. The goal of the experiment in this study is to formulate a technique for recording the mbira of Southern Africa. It also seeks to recognise gaps in the information regarding studio-related recording methods of African instruments in general, and to contribute knowledge regarding best-practices according to which these methods may be established. Conducting this experiment gave the researcher the opportunity to develop a recording technique that could potentially improve the recording practices used for the mbira, and possibly also those used for other traditional African musical instruments.

Table 2 below presents the specifications of the microphones that were used in the experiment. Information pertaining to the microphones' polar patterns, frequency range and sensitivity is also given.

Table 2: Microphone specifications

Microphone	Type	Polar Pattern(s)	Frequency Range	Sensitivity
2x Samson CO3	Condenser	Supercardioid, Omnidirectional, Figure-8	40 Hz to 18 kHz	10mV/Pa
Shure Beta 58A	Dynamic	Supercardioid	50 Hz to 16 kHz	-51.5 dBV/Pa at 1 kHz
Shure Beta 57A	Dynamic	Supercardioid	50 Hz to 16 kHz	-51 dBV/Pa (2.8 mV)[1]
Rode K2	Condenser	Cardioid, Figure-8, Omnidirectional	20 Hz to 20 kHz	-36.0 dB re 1 V/Pa (16.00mV at 94 dB SPL) ± 2 dB at 1 kHz
2x Rode NT2A	Condenser	Cardioid, Figure 8, Omnidirectional	20 Hz to 20 kHz	-36.0 dB re 1 V/Pa (16.00mV at 94 dB SPL) ± 2 dB at 1 kHz
4x Sennheiser e-914	Condenser	Cardioid	20 Hz to 20 kHz	7 mV/Pa
Sennheiser MKH40	Condenser	Cardioid	40 Hz to 20 kHz	25 mV/Pa ±1 dB
Sennheiser MKH30	Condenser	Figure-8	40 Hz to 20 kHz	25 mV/Pa ± 1 dB
2x Neumann TLM103	Condenser	Cardioid	40 Hz to 20 kHz	23 mV/Pa
2x AKG C414B-TL II	Condenser	Omnidirectional, Cardioid, Hypercardioid, Figure-8	20 Hz - 20 kHz	12.5 mV/Pa; -38 dB (dB re 1 V)

Table 3 below specifies stereo techniques and their sound field sampling properties. This table includes the names of the stereo microphone techniques, the polar pattern of each microphone, the spacing of the technique, the percentage of the direction by level difference.

Table 3: Stereo microphone techniques and their sound field sampling properties

Stereo System Name	Polar Pattern	Microphone Angle	Microphone Spacing	Direction By Level Difference	Direction By Time Difference
AB60	2 Omnidirectional	0 Degrees	60 cm	0%	100%
AB90	2 Omnidirectional	0 Degrees	90 cm	0%	100%
AB120	2 Omnidirectional	0 Degrees	120 cm	0%	100%
XY60	2 Cardioid	0 Degrees	0 cm	100%	0%
XY90	2 Cardioid	0 Degrees	0 cm	100%	0%
XY120	2 Cardioid	0 Degrees	0 cm	100%	0%
ORFT	2 Cardioid	110 Degrees	17 cm	61%	39%
2 Blumlein	2 Figure-8	90 Degrees	0 cm	100%	0%
NOS	2 Cardioid	90 Degrees	30 cm	42%	58%
EBS	2 Cardioid	90 Degrees	25 cm	47%	53%
DIN	2 Cardioid	90 Degrees	20 cm	53%	47%
RAI	2 Cardioid	100 Degrees	21 cm	53%	47%

4.2.2 Microphone techniques

The experiment of recording a mbira as outlined this chapter was conducted at the University of Pretoria. The experiment involved the use of various microphones placed at different positions. Mono and stereo recording techniques, as well as multiple sets of microphones, were used to record the mbira. The Blumlein, mid side, XY and coincident microphone techniques were used for this experiment. In another recording technique employed by the researcher, microphones were placed above the mbira. In the experiment the researcher was using a mono microphone technique with a close microphone placement of roughly 10 to 15 centimetres. According to Rayburn (2012, p. 217), "[c]oincident microphone arrays consist of a pair of directional microphones located virtually one atop the other and both individually adjustable in their lateral pickup angles". The researcher used top and side address microphones to record the mbira using various microphone techniques.

Rayburn (2012, p. 221) highlights that the Blumlein array delivers an excellent sense of acoustical space, owing to the reverberant and reflected signals in the recording space. It is also highlighted that the crossed cardioid arrays may be spread over an angle of 90 to 135 degrees. The absence of the anti-phase components means that the crossed cardioid has good monophonic compatibility. The Blumlein technique requires figure-8 or bidirectional microphones rather than cardioid microphones. This technique involves the placement of the microphones with their polar patterns in a straight line at a 90-degree angle so that the microphones are perpendicular to one another. The microphones are also panned left and right. When two microphones are used to attain a consistent stereo image, it may be referred to as a stereo microphone technique (Huber & Runstein, 2014, p. 139). These techniques include the XY pair, spaced pair, and mid side pair.

The cardioid polar pattern is commonly used with the XY pick-up, as well as with the Blumlein technique (Huber & Runstein, 2014, p. 139). The disadvantage of the spaced pair technique is that phase may occur (Huber & Runstein, 2014, p. 139). This could happen due to the time it takes for the sound to travel from one microphone to the other. Huber and Runstein (2014, p. 140) suggest that the M (mid) is generally a cardioid pattern microphone, and the S(side) is generally a figure-8. Rayburn (2012, p. 222) highlights that the M component of a cardioid pattern is forward-facing, and a figure-8 pattern, which has the S component, is side-facing. The mid side technique uses the cardioid pattern, which faces directly toward the sound source – in this case, the mbira. The second microphone has a figure-8 or bidirectional pattern, which is perpendicular to the cardioid microphone.

According to Rayburn (2012, p. 230), the ORTF (Office de Radiodiffusion Television Francaise), which is a near coincident pair places microphones at an angle of 110 degrees from each other. The microphones are panned left and right. This technique allows for the management of interaural timing and level differences. The advantage of this technique is that interaural timing differences are captured; however, its disadvantage is phase interference. The near-coincident technique combines delay effects and amplitude to produce a stereo sound stage (Rayburn, 2012, p. 229). Sounds travelling on the right-hand side will reach the microphone on the right before reaching the microphone on the left. A coincident microphone pair indicates that two microphones occupy the same point in space. The two microphones are aligned in space and therefore should align in time. The advantage of this technique is that it prevents phase interference.

In this controlled experiment, the recording techniques used to record the mbira were the same for microphones with the same polar patterns. The variables that changed in this experiment were the microphones. Photographs were taken of the recording techniques that were used during the experiment. A stereo recording technique was used to record the mbira, using microphones of the same model. Another recording was also made, with a single microphone positioned above the mbira. These recordings were compared to the recordings made using two microphones of the same model.

4.2.3 Sessions

The pair of Rode NT2A microphones was recorded using the XY, mid side, and spaced pair techniques in cardioid and omnidirectional polar patterns. One Rode NT2A microphone was positioned above the mbira, and was used to record the instrument using the XY recording technique. A Rode K2 microphone was used to record the mbira in a mono recording technique, during which the microphone was placed above the mbira. The bidirectional, cardioid and omnidirectional polar patterns were used to record the mbira in a mono recording technique. Two AKG C414 B-TL II microphones were used to record the mbira using the XY, mid side and spaced pair techniques in a cardioid pattern. A single AKG C414 B-TL II microphone was also used to record the mbira using the cardioid and omnidirectional polar patterns. A Neumann TLM 103 microphone pair was used to record the mbira by means of the spaced pair technique in both cardioid and omnidirectional patterns. The mbira was also recorded with a single microphone using a cardioid polar pattern.

Two Samson CO3 microphones were used to the record the mbira using the XY, mid side, Blumlein and spaced pair techniques in cardioid and omnidirectional polar patterns. A single microphone was placed above the mbira and was used to record the instrument in cardioid and omnidirectional polar patterns. The Sennheiser e914 microphone pair was used to record the mbira using the XY, mid side, ORTF and spaced pair techniques in a cardioid polar pattern. A Sennheiser MKH30 microphone with a bidirectional polar pattern, as well as a Sennheiser MKH40 with a cardioid polar pattern, was used to record the mbira. The Sennheiser MKH40 and MKH30 were then used as a stereo pair to record the mbira using the mid side technique. Single Shure Beta 57A and 58A microphones were used to record the mbira in mono. Photographs of the above-mentioned recording techniques may be viewed in Appendix 3.

The mbira recordings were stored on a hard drive and then saved as audio software for analysis. Various recording methods were employed to identify the best recording technique for the mbira. These methods involved variations in microphone placement, pick-up pattern and frequency response, type of microphone and size of diaphragm. Studio recordings of the mbira may be found in Appendix 6. The sound propagation of the various mbira types was examined in terms of their density, pressure and temperature, which are critical factors that affect the speed of sound and therefore the overall acoustical behaviour of the instruments (Deloughry, 1997, p. 11).

The mbira dzavadzimu was recorded in a studio in Johannesburg. A mono recording technique was used to record this mbira with a Samson MTR201 condenser microphone. The researcher recorded two mbira dzamdeza players in the Limpopo Province. A mono technique was used to record the mbira dzamadeza with Samson MTR201 condenser microphones.

The recordings of the experiment took place at the University of Pretoria, where the researcher could use various microphones and recording techniques to determine the type of microphone and recording technique suitable for the mbira. Stereo and mono recording techniques were used to record the mbira with AKG C414 B-TL II microphones. A mono recording technique was employed to record the mbira using cardioid, bidirectional and omnidirectional polar patterns. The mbira was also recorded with Neumann TLM 103 microphones using stereo recording techniques. The researcher was not able to use the Neumann TLM 103 in a mono recording technique due to time constraints. The spaced pair and XY stereo recording techniques were used to record the mbira with a pair of Neumann TLM 103 microphones.

Since only one microphone was available to use for this part of the experiment, only the mono recording technique was used to record the mbira using the Rode K2. However, the Rode K2 was used with various polar patterns, namely cardioid, bidirectional and omnidirectional patterns. Stereo recording techniques were employed to record the mbira with Rode NT2A microphones. A mono recording technique was also used with one Rode NT2A microphone in three polar patterns, namely bidirectional, cardioid and omnidirectional patterns. The stereo recording techniques that were used to record the mbira with the Rode NT2A microphones include the spaced pair, XY and mid side techniques. Using the spaced pair technique, the mbira was recorded with Rode NT2A microphones in cardioid and omnidirectional polar patterns.

The researcher used Samson CO3 microphones to record the mbira according to various stereo microphone techniques, including the Blumlein, spaced pair (with both cardioid and omnidirectional polar patterns), XY and mid side techniques. Recordings were also made with a Samson CO3 microphone using a mono recording technique with bidirectional, cardioid and omnidirectional polar patterns. The Sennheiser e914 was used with stereo and mono techniques. The XY and spaced pair recording techniques were used to record the mbira in a stereo technique. One of the Sennheiser e914 microphones was used to record the mbira in a mono recording technique. This technique was useful as it could capture the sound of the mbira without noise in the recording. A Sennheiser MKH30 was used to record the mbira in a mono recording technique, and this recording was compared to the mbira recording made with a Sennheiser MKH40. The Sennheiser MKH30 is a bidirectional microphone, whereas the Sennheiser MKH40 is a cardioid microphone.

4.2.4 Data collection process

This experiment depended on certain research processes, such as data collection and analysis, in order to answer the research questions in Chapter 1. The research approach of this experiment incorporates data collection and the analysis of quantitative points of view. The aim of the quantitative data collection is to use investigational techniques to conduct the experiment. In Chapter 3 the researcher discussed both qualitative and quantitative methods.

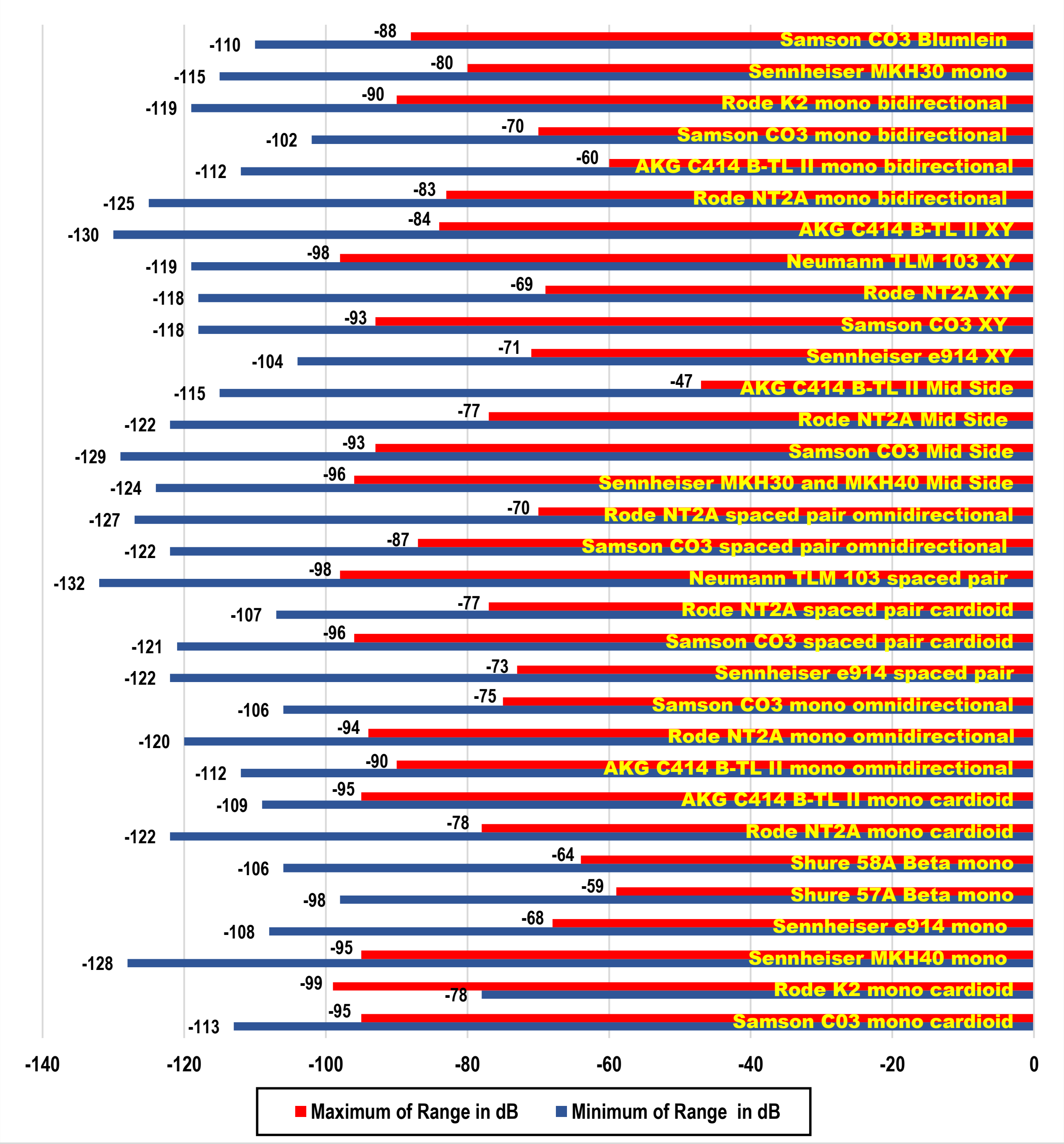
4.2.5 Polar patterns

Lewitt (2021) highlights the essential understanding of the basic principles of polar patterns in order to gain optimal results from every recording. Selecting the right microphone pattern may aid in avoiding unwanted frequencies. The polar pattern of a microphone pertains to its sensitivity to sounds coming from separate angles to its main axis. The discussion of the polar patterns is important because the polar patterns affect how a microphone would sound and this is linked to the results of the experiment.

The cardioid pattern is the most sensitive to sounds coming from the front and less sensitive to sounds coming from the sides and the back. Lewitt (2021) highlights that it is simple to obtain a dry signal, as the cardioid pattern blends out a bad sounding room. The supercardioid pattern is more direct than the cardioid, and is most sensitive to sounds that come from the front. It also picks up sound from the back, but the sound it picks up from the sides is reduced. Bidirectional microphones pick up sound from both the front and the back in equal measure. Hypercardioid microphones have good forward-facing polar sensitivity, but are less sensitive from the back. These microphones also have reduced pick-up sensitivity from the sides. Microphones with a shotgun pattern capture sound from the front, rejecting much sound from the sides and only pick up a small amount of sound from the back. The omnidirectional pattern picks up sound from all directions. According to Lewitt (2021), “[i]t picks up very high frequencies with more directivity leading to higher side rejection of the signal for these frequencies (this effect turns the omni into figure-8 at the 16 kHz mark)”.

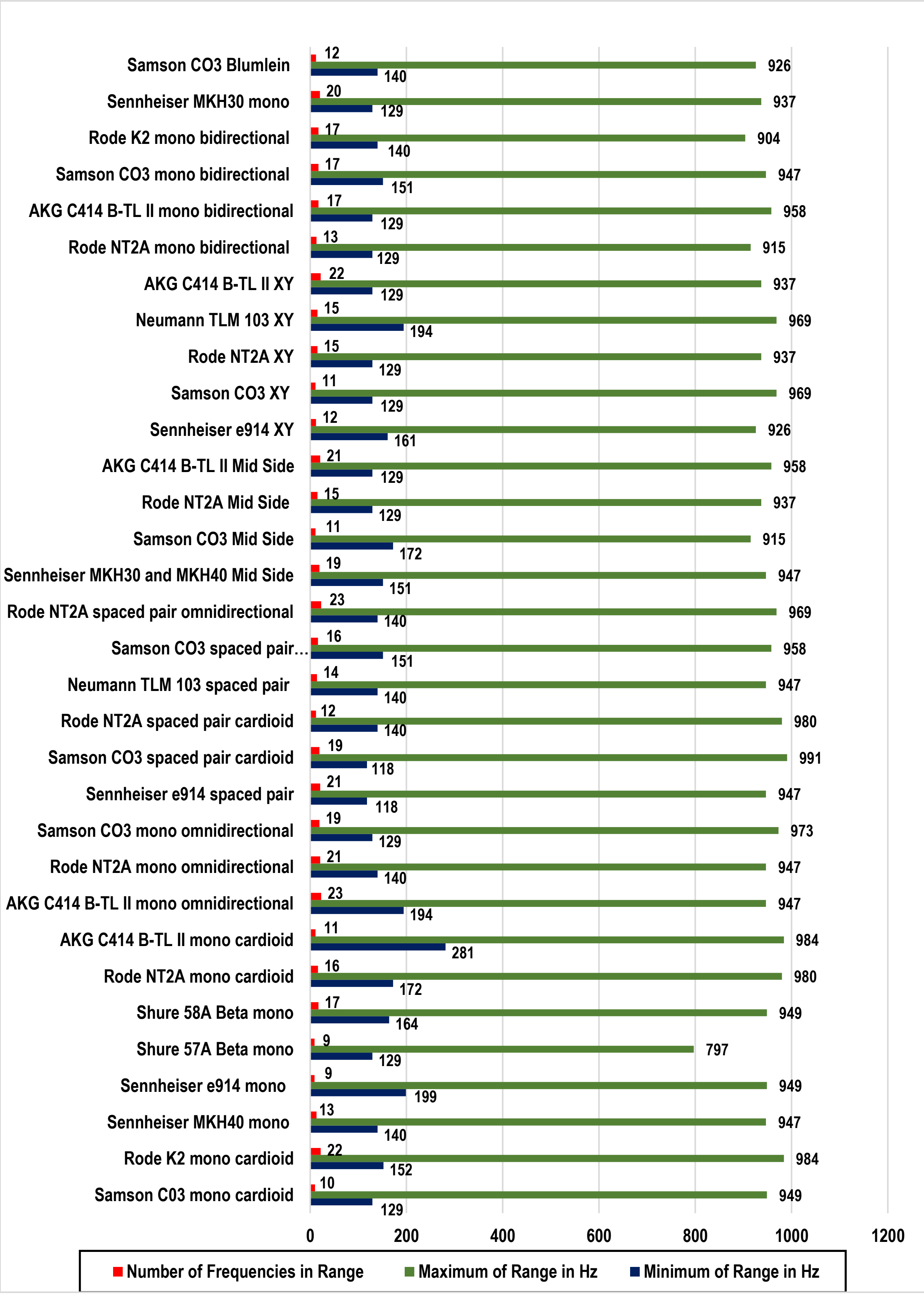
4.3 Visual Summary of findings

Select peak frequency amplitude in dB



The graph displays the microphones that were used and the recording technique that was used to record the mbira along with the select peak frequency amplitude measured in decibels (dB). The blue parts of the graph represent the minimum of range in dB of the select peak frequencies that are within the range of the mbira providing the quantitative data sets of amplitude of the microphones. The red parts represent the maximum of range in dB providing the quantitative data sets of the amplitude curves of the microphones. Each recording technique that was used to record the mbira during the experiment has a select peak frequency amplitude displayed on the graph. The select peak frequency amplitude levels displayed on the graph are from the data sets as tabled in Appendix 7.

Select peak frequency (within the mbira range)



The graph displays the microphones that were used and the recording techniques that were used to record the mbira along with the select peak frequency measured in hertz (Hz). The red parts display the number of frequencies in range of the recording technique used to the record the mbira. The green parts display the highest frequency recorded for that recording technique in Hz. The blue parts display the lowest frequency recorded for that recording technique in Hz. The select peak frequencies displayed on the graph are from the data sets as tabled in Appendix 7.

Finally, it is clear from these visualisations that the AKG C414 B-TL II in the mid side recording technique has the best frequency and amplitude response. These visualisations coupled with the frequency spectral analysis in Appendix 4 and the frequency analysis data from Sonic Visualizer in Appendix 7 clearly shows that with the given available equipment the AKG C414 B-TL II in the mid side technique is the most suitable recording technique to record the mbira.

Chapter 5: Conclusion

This study examined links between the acoustic properties of the mbira and various recording techniques. The acoustic properties of the mbira are important because suitable microphones should be used to record the instrument. This has more often than not been an overlooked part of conducting recordings of African musical instruments. The acoustic properties of the mbira are based on the acoustic nature of its materials and how sound is transmitted through the adjoining structural elements. The acoustic properties of the mbira depend on its density. Knowing the acoustic properties coupled with the recording techniques was helpful because it connected the acoustic properties of the mbira with the results. The researcher conducted an experiment, recording the mbira using various techniques. The results of the experiment give an indication of what systems to use given the available equipment (the reader is referred to earlier Table 2). Based on the results of the peak frequencies and amplitudes of the recording techniques utilised in the experiment (see Appendices 4 & 7 as discussed), the researcher has recommendations on what type of microphone to use, what recording technique to use and what type of polar pattern to utilise when recording the mbira. The study had some limitations such as not having enough time to record some microphones using all the polar patterns available for that microphone and not being able to use other types of microphones such as shotgun microphones.

The microphone technique that had the best peak frequency and amplitude was the AKG C414 B-TL II mid side recording. This is based on the information pertaining to the peak frequencies and amplitudes of the recording technique.

The researcher would have liked to record the mbira with a shotgun microphone. Unfortunately, a shotgun microphone was not available for the experiment.

In Reaper, the frequency spectral analysis was used to determine the best microphone and technique to record the mbira, based on the amplitude of each recording technique that was used. This was done via visual determination. Sonic Visualizer was used to see the peak frequencies and amplitude of the mbira recordings.

Despite the efforts of ethnomusicologists to record indigenous African musical instruments, more research is needed to develop techniques for recording African musical instruments in a studio environment. This research study has provided a possible solution for recording African musical instruments in a suitable environment, such as a recording studio. The advantage of recording in a studio was helpful because the sound quality of the recordings is better in a studio environment. Recording in a studio also allowed the researcher to have more control over the environment. Much of the research questions were answered in the interviews which can be seen in Appendix 1.

The strengths of the mixed methods approach allow for the triangulation of data, which means that findings can be compared and contrasted across different methods and types of data sources. This increases the robustness of the study's results. Using both qualitative and quantitative methods enabled the researcher to capture a wider range of data, including rich insights from a participant's experience. The mixed methods approach is more flexible than purely quantitative or qualitative designs because they allowed the researcher to adjust their methods in response to the data collected during the course of the project. One of the weaknesses of the mixed methods approach is that it is time consuming. Conducting a mixed methods approach requires more time and resources than conducting pure qualitative or quantitative research. The complexity of mixed methods approach can make it more challenging to design, implement, and interpret results.

This study has shown the need for researchers to experiment with African musical instruments, such as the mbira, to identify best-fit recording techniques for these instruments. More research on recording best-practices for other indigenous African musical instruments should therefore be conducted. The researcher hopes that this dissertation and the work that was involved in the recording process will change how ethnomusicologists approach the recording of African musical instruments, and that African musical instruments will be recorded in a studio setting.

References

Arom, S. (1991). *African polyphony and polyrhythm: musical structure and methodology*. (M. Thom, B. Tuckett, & R. Boyd, Trans.). Cambridge University Press.

Azim, E. (1999). On Teaching Americans to Play Mbira like Zimbabweans. *African Music*, *7*(4), 175–180. www.jstor.org/stable/30249828

Ballou, G. (2008). *Handbook for sound engineers* (4th ed.). Oxford: Focal Press.

Bascom, W. (1953). African Culture and the Missionary / Les Missions et la Culture Africaine. *Civilisations*, *3*(4), 491–504. www.jstor.org/stable/41377571

Berliner, P. (1975). Music and Spirit Possession at a Shona Bira. *African Music*, *5*(4), 130–139. www.jstor.org/stable/30249729

Berliner, P. (1976). The Poetic Song Texts Accompanying the Mbira Dzavadzimu. *Ethnomusicology*, *20*(3), 451–482. doi:10.2307/851045

Berliner, P. (1978). *The Soul of Mbira*. Chicago: University of Chicago Press.

Berliner, P. (1980). John Kunaka, Mbira Maker. *African Arts*, *14*(1), 61–88. doi:10.2307/3335674

Berliner, P. (1993). *The soul of mbira : music and traditions of the Shona people of Zimbabwe : with an appendix, building and playing a Shona karimba* (University of Chicago Press). University of Chicago Press.

Blacking, J. (1967). *Venda children's songs: a study in ethnomusicological analysis*. Witwatersrand University Press.

Blacking, J. (1976). *How musical is man?* (Ser. John danz lectures). Faber and Faber.

Blauert, J. (1997). *Spatial Hearing: The Psychophysics of Human Sound Localization*. The MIT Press.

Brémaud. (2012) Acoustical properties of wood in string instruments soundboards and tuned idiophones: Biological and cultural diversity. *Journal of the Acoustical Society of America, Acoustical Society of America*, *131*(1), 807–818. https://asa.scitation.org/doi/10.1121/1.3651233

Britannica, T. Editors of Encyclopaedia (2016, October 12). *lamellaphone. Encyclopedia Britannica*. https://www.britannica.com/art/lamellaphone

Bulhan, H. A. (2015). Stages of colonialism in africa: from occupation of land to occupation of being. *Journal of Social and Political Psychology*, 3(1), 239–256. https://doi.org/10.5964/jspp.v3i1.143

Campbell, M. & Greated, C. (1998). *The musician's guide to acoustics*. Oxford: Oxford University Press.

Castro, J. (July 30, 2013). What is Pink Noise? *Live Science.* https://www.livescience.com/38464-what-is-pink-noise.html

Chidanyika, T. (2008). Zimbabwean mbira music on an international stage : chartwell dutiro's life in music, by c. dutiro and k. howard : book review. *Journal of the Musical Arts in Africa*, 5(1), 91–95.

Creswell, J. W. (2011). *Educational Research: Planning, Conducting, and Evaluating Quantative and Qualitative Research*. New Jersey: Pearson Education International.

Creswell, J., & Plano Clark, V. (2007). *Designing and Conducting Mixed Methods Research*. Thousand Oaks, CA: Sage

Creswell, J. W., Plano Clark, V. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, California: SAGE Publications

Cowdery, J. (1999). *Music in Art*, *24*(1/2), 96–99. http://www.jstor.org/stable/41563335

Davis, D., Patronis, E., & Brown, P. (2013). *Sound system engineering 4e* (4th ed.). Taylor and Francis.

Dean, R. & Bailes, F. (2016). Modeling Perceptions of Valence in Diverse Music: Roles of Acoustic Features, Agency, and Individual Variation. *Music Perception: An Interdisciplinary Journal*, *34*(1), 104–117. https://www.jstor.org/stable/26417351

Deloughry, W. (1997). *New modular science for Gcse*. (Volume 2), Oxford: Heinemann.

Denis, P. (2007). Missionaries from within: the contribution of indigenous to evangelisation in Southern Africa. *Studia Historiae Ecclesiasticae*. *33*, 6–23.

Dodson, M. (1992). Shannon's Sampling Theorem. *Current Science*, *63*(5), 253–260. http://www.jstor.org/stable/24095490

Dokmanić, I., Parhizkar, R., Walther, A., Lu, Y. & Vetterli, M. (2013). Acoustic echoes reveal room shape. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(30), 12186–12191. http://www.jstor.org/stable/42712566

Durán, L. (2007). Ngaraya: Women and Musical Mastery in Mali. *Bulletin of the School of Oriental and African Studies, University of London*, *70*(3), 569–602. www.jstor.org/stable/40378939

Dworkin, J. (2007). Translation as Performance: Lyric, Mbira, and Multiplicity in the Classroom. Transformations: *The Journal of Inclusive Scholarship and Pedagogy*, *17*(2), 75–89. www.jstor.org/stable/10.5325/trajincschped.17.2.0075

Dyar, T. (1961). Techniques and Devices - Microphone Placement. *Ethnomusicology*, *5*(1), 49–51. doi:10.2307/924308

Eargle J. (2004). *The microphone book : from mono to stereo to surround : a guide to microphone design and application* (2nd ed.). Elsevier Focal Press.

Electronic Media I Fall. (2015). *Basic Microphone Theory*. https://theremin.music.uiowa.edu/EMS.Files/Handouts/2015/F.2015/EMS.F2015.MicrophoneTheory.pdf

Everest, F. & Pohlmann, K. (2015). *Master Handbook of Acoustics* (6th ed.). New York: McGraw-Hill Education.

Fahy, F. & Gardonio, P. (2007). *Sound and Structural Vibration: Radiation, Transmission and Response* (2nd ed.). Elsevier/Academic.

Fioravanti, M. (2014). Conservation of Historical Wooden Musical Instruments: Advance in Understanding Material Aging. *Music in Art*, *39*(1–2), 311–316. http://www.jstor.org/stable/90012967

Fletcher, N., & Rossing, T. (1998). *The physics of musical instruments* (2nd ed.). New York: Springer.

Gelfand, R. & Gelfand, M. (1964). *Witch Doctor*, London: Harvill.

Gimenez Amoros, L. (2018). *Tracing the mbira sound archive in zimbabwe*. Routledge.

Grosz-Ngate, M., Hanson, J. H., & O'Mmeara, P. (Eds.). (2014). *Africa, Fourth Edition* (4th ed.). Indiana University Press. http://www.jstor.org/stable/j.ctt16gh7ps

Han, J., Herrin, D. & Seybert, A. (2007). Accurate Measurement of Small Absorption Coefficients. *SAE Transactions*, *116*, 1701–1705. http://www.jstor.org/stable/44687938

Hansen, C. (1951). Fundamentals of acoustics. *American Journal of Physics* - AMER J PHYS. 19. https://www.researchgate.net/publication/228726743_Fundamentals_of_acoustics

Harper, P. (1969). Dance in Nigeria. *Ethnomusicology*, *13*(2), 280–295. doi:10.2307/850150

Hirtle, P. (1977). Architectural Acoustics Consultant. *Music Educators Journal*, *63*(7), 140–142. doi:10.2307/3395241

Holdaway, M. (2008). *The Kalimba: A Brief History of an Ancient Instrument from Africa*. https://www.kalimbamagic.com/newsletters/newsletter4.02/newsletter4.02_assets/KalimbaHistoryII.pdf

Huber, D. & Runstein, R. (2014). *Modern recording techniques* (8th ed.). New York: Focal Press, Taylor & Francis Group.

Jacobsen, F. & Juhl, P. M. (2013). *Fundamentals of general linear acoustics*. John Wiley & Sons.

Jaffe, D. (1987). Spectrum Analysis Tutorial, Part 1: The Discrete Fourier Transform. *Computer Music Journal*, *11*(2), 9–24. doi:10.2307/3680316

Johnson, R., Onwuegbuzie, A. & Turner, L. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, 1(2), 112–133.

Kadis, J. (2012). *The science of sound recording*. Elsevier Science.

Kaemmer, J. (1989). Social Power and Music Change among the Shona. *Ethnomusicology*, *33*(1), 31–45. doi:10.2307/852168

Kim, Y.-H. (2010). *Sound Propagation: An Impedance-based Approach*. Wiley.

Kubik, G. (1964). Generic Names for the Mbira. *African Music*, *3*(3), 25–36. www.jstor.org/stable/30249572.

Kumbani, J. (2020). Music and sound-related archaeological artefacts from southern africa from the last 10,000 years. *Azania: Archaeological Research in Africa*, 55(2), 217–241. https://doi.org/10.1080/0067270X.2020.1761686

Kyker, J. (2009). Carrying Spirit in Song: Music and The Making of Ancestors at Zezuru Kurova Guva Ceremonies. *African Music*, *8*(3), 65–84. www.jstor.org/stable/20788928

List, G. (1968). The Mbira in Cartagena. *Journal of the International Folk Music Council*, *20*, 54–59. Doi:10.2307/836073.

Lewitt (2021) *Microphone polar patterns*. https://www.lewitt-audio.com/blog/polar-patterns.

Llamas-Garro, I., De Melo, M. T. & Kim, J.-M. (2018). *Frequency measurement technology* (Ser. Artech microwave library). Artech House.

Majeed, S., Abbas, F., Amin, Y., Chaudhry, A. & Jamal, H. (2007). A review of transduction techniques used in acoustics echo cancellation. 31–36. Iris. https://www.researchgate.net/publication/234831146_A_review_of_transduction_techniques_used_in_acoustics_echo_cancellation.

Maldonado-Torres, N. (2007). On the coloniality of being. *Cultural Studies*, *21*(2/3), 240-270. https://doi.org/10.1080/09502380601162548.

Matiure, P. (2013). Mbira dzavadzimu (nhare): Historical and cultural legacy. *Latin American Report*, *29*(1), 79–101.

McCormick, T. & Rumsey, F. (2014). *Sound and Recording: Applications and Theory* (7th ed.). Routledge.

McNeil, L. E. & Mitran, S. (2008). Vibrational frequencies and tuning of the African mbira. *The Journal of the Acoustical Society of America*, *123*(2), 1169–1178. https://doi.org/10.1121/1.2828063

Mothoagae, I. (2018). The reordering of the Batswana Cosmology in the 1840 English-Setswana New Testament. *HTS Theological Studies*, *74*(1), 1–12. Doi:10.4102/hts.v74i1.4786

Mugovhani, N. G. (2009). Mbilamutondo music and instruments in venda culture. *South African Journal of Art History*, 24(3), 45–54.

Munjal, M. L. (2013). *Noise and vibration control* (Ser. Iisc lecture notes series, v. 3). World Scientific Publishing Company.

Musiyiwa, M. (2013). Hit songs and the dynamics of postcolonial Zimbabwe: A study in popular music trends, 1980-2009. *African Music*, *9*(3), 59–91. http://www.jstor.org/stable/24877315

Neumann.Berlin. (2015*). What is a condenser microphone?* https://www.neumann.com/homestudio/en/what-is-a-condenser-microphone

Nketia, J. (1974). *The music of Africa*. W.W. Norton & Company ; First edition.

Nketia, J. (1975). *The music of Africa*. London: Gollancz.

Ones, C. (2012). A Modern Tradition: The social history of Zimbabwean marimba. *African Music*, *9*(2), 32–56. www.jstor.org/stable/24877253

Onwubiko, S. (2017). Acoustics in African music instrument technology: Training the baton bearer for sustenance in music education in Nigeria. *The Journal of the Acoustical Society of America*, *141*(5), 3556–3556.

Owsinski, B. (2009).*The Recording Engineer's Handbook* (2nd ed.). Boston: Cengage Learning PTR.

Owsinski, B. (2014). *The Recording Engineer's Handbook* (3rd ed.). Boston: Cengage Learning PTR.

Pedgley, O. & Norman, E. (2012). Materials Innovation in Acoustic Guitars: Challenging the Tonal Superiority of Wood. *Leonardo Music Journal*, *22*, 17–24. http://www.jstor.org/stable/23343799

Pendowski, M. (2019). Practical and Creative Ideas for Optimizing the Show Choir Combo. *The Choral Journal*, *60*(5), 63–70. https://www.jstor.org/stable/26870157

Perman, T. (2012). Sungura in Zimbabwe and the Limits of Cosmopolitanism. *Ethnomusicology Forum*, *21*(3), 374–401. www.jstor.org/stable/23271889

Pulkki, V. & Karjalainen, M. (2015). *Communication Acoustics: An Introduction to Speech, Audio and Psychoacoustics*. Wiley; 1st edition.

Quilliam, M. (2015). Musical Transformation and Transmission: Towards Interpretive Learning of Zimbabwean Music in a North American World Music Academy. *The World of Music*, *4*(2), 119–135. www.jstor.org/stable/43774597

Rayburn, R. A. (2012). *Eargle's microphone book : from mono to stereo to surround : a guide to microphone design and application* (Third). Elsevier Science.

Rayburn, R. & Eargle, J. (2012). *Eargle's Microphone Book: From Mono to Stereo to Surround – A Guide to Microphone Design and Application* (3rd ed.). Waltham: Focal Press/Elsevier.

Records of African Music. (1948). Newsletter. *African Music Society*, *1*(1), 27–30. www.jstor.org/stable/30250277

Reuster-Jahn, U. (2007). The Mwera Lamellophone Luliimba. *African Music*, *8*(1), 6–20. http://www.jstor.org/stable/30249996

Rossing, T. (2007). *Springer handbook of acoustics*. Springer Science+Business Media: New

York.

Scherzinger, M. (2001). Negotiating the Music-Theory/African-Music Nexus: A Political Critique of Ethnomusicological Anti-Formalism and a Strategic Analysis of the Harmonic Patterning of the Shona Mbira Song Nyamaropa. *Perspectives of New Music*, *39*(1), 5–117. www.jstor.org/stable/833534

Scherzinger, M. (2003). Erratum/Addendum: Negotiating the Music-Theory/African-Music Nexus: A Political Critique of Ethnomusicological Anti-Formalism and a Strategic Analysis of the Harmonic Patterning of the Shona Mbira Song Nyamaropa. *Perspectives of New Music*, *41*(2), 256–258. www.jstor.org/stable/25164533

Schwarze, F., Spycher, M. & Fink, S. (2008). Superior Wood for Violins: Wood Decay Fungi as a Substitute for Cold Climate. *The New Phytologist*, *179*(4), 1095–1104. http://www.jstor.org/stable/25150531

Stone, R. M. (Ed.). (1998). *The garland encyclopedia of world music* (Vol. Volume 1, 70frica /, Ser. Garland encyclopedia of world music, v. 1). Garland Pub.

Stone, R. (2008). *The garland handbook of African music* (2nd ed.). New York: Routledge.

Sujatha, C. (2010). *Vibration and Acoustics: Measurement and Signal Analysis*. McGraw-Hill Education LLC.

Swallow, D. (2011). *Live Audio: The Art of Mixing a Show*. Routledge.

Tashev, I. (2009). *Sound Capture and Processing: Practical Approaches*. Wiley.

Thompson, D. (1975). A New World Mbira: The Caribbean Marímbula. *African Music*, *5*(4), 140–148. www.jstor.org/stable/30249730.

Thompson, M. (2021). Sonic Visualiser: Visualisation, Analysis, and Annotation of Music Audio Recordings. *Journal of the American Musicological Society, 74*(3), 701–714. https://doi.org/10.1525/jams.2021.74.3.701.

Tracey, A. (1961). Mbira Music of Jege A. Tapera. *African Music*, *2*(4), 44–63. www.jstor.org/stable/30249529.

Tracey, A. (1963). Three Tunes for 'Mbira dza Vadzimu'. *African Music*, *3*(2), 23–26. www.jstor.org/stable/30249555.

Tracey, A. (1969). The Tuning of Mbira Reeds: A Contribution to the Craft of Mbira Making. *African Music*, *4*(3), 96–100. www.jstor.org/stable/30249662.

Tracey, A. (1970). The Matepe Mbira Music of Rhodesia. *African Music*, *4*(4), 37–61. www.jstor.org/stable/30249681.

Tracey, A. (1971). The Nyanga Panpipe Dance. *African Music*, *5*(1), 73–89. www.jstor.org/stable/30249960.

Tracey, A. (1972). The Original African Mbira? *African Music*, *5*(2), 85–104. www.jstor.org/stable/30249709.

Tracey, A. (1974). The family of the mbira: The evidence of the tuning plans. *Zambezia*, 3(2), 1-

10.

Tracey, A. (2013). Predicted mbira found. *African Music*, *9*(3), 21–24. www.jstor.org/stable/24877312.

Tracey, A. (2015). Deza. Grove Music Online. Retrieved 2 Jul. 2019, from https://wwwoxfordmusiconlinecom.uplib.idm.oclc.org/grovemusic/view/10.1093/gmo/9781561592630.001.0001/omo9781561592630-e-4002285584.

Tracey, H. (1950). African Music. *The Nyasaland Journal*, 3(2), 16–18. www.jstor.org/stable/29545619.

Tracey, H. (1953). Bantu Music. *Theoria: A Journal of Social and Political Theory*, (5), 55–62. www.jstor.org/stable/41801376.

Tracey, H. (1955). Recording African Music in the Field. *African Music Society Journal*, 1(2), 6-

11. http://www.jstor.org/stable/30249421.

Tracey, H. (1961). A Case for the Name Mbira. *African Music*, *2*(4), 17–25. www.jstor.org/stable/30249527.

Tracey, H. (1969). The Mbira Class of African Instruments in Rhodesia (1932). *African Music*, *4*(3), 78–95. www.jstor.org/stable/30249661.

Trimble, O. (1935). Intensity-Difference and Phase-Difference as Conditions of Stimulation in Binaural Sound-Localization. *The American Journal of Psychology*, *47*(2), 264–274. Doi:10.2307/1415830.

Turino, T. (1998). The Mbira, Worldbeat, and the International Imagination. *The World of Music*, *40*(2), 85–106. http://www.jstor.org/stable/41699198.

Turino, T. (2010). The Mbira, Worldbeat, and the International Imagination. *The World of Music*, *52*(1/3), 171–192. www.jstor.org/stable/41700030.

Ulrike, G. (2006). Wood for sound. *American Journal of Botany*, 93(10), 1439-1448.

Van Dijk, M. (2010). The Lala kalimba: The correlation between instrument and style. *African Music*, *8*(4), 84–100. http://www.jstor.org/stable/23319452.

Von Hornbostel, E. & Sachs, C. (1961). Classification of Musical Instruments: Translated from the Original German by Anthony Baines and Klaus P. Wachsmann. *The Galpin Society Journal*, *14*, 3–29. Doi:10.2307/842168.

Vorländer, M. (2011). Sound fields in complex listening environments. *Trends in amplification*, *15*(3), 106–115. https://doi.org/10.1177/1084713811408348.

Watkins, L., Madiba, E., & McConnachie, B. (2021). Rethinking the decolonial moment through collaborative practices at the international library of african music (ilam), south africa. Ethnomusicology Forum, 30(1), 20–39. https://doi.org/10.1080/17411912.2021.1938628.

Weisser, S. & Quanten, M. (2011). Rethinking musical instrument classification: Towards a modular approach to the Hornbostel-Sachs System. *Yearbook for Traditional Music*, 43, 122–146. Doi:10.5921/yeartradmusi.43.0122.

Welsh-Asante, K. (2010). *African Dance (Second, Ser. World of dance)* (2nd Ed). Chelsea House Publications.

Young, J. (2018). *Home Studio Mastering.* Routledge.

Appendices

Appendix 1: Interview questions and answers

Questions:

1• In your professional playing, have you recorded an mbira and if so, do you know what microphone technique you used to record the mbira?

2• In your own words, what materials would you suggest be used to make the mbira?

3• In your own experience, why do you think these materials are being used to make the mbira?

4• In your professional opinion, how long has the mbira that you play been in existence?

5• What is the name of the specific mbira that you use to perform?

6• How many keys does your mbira have?

Answers:

Participant 1

1: Yes, I have recorded the mbira. The truth is I do not know which microphone technique is being used to record the mbira since I am just a performing artist and instrument specialist. I am not familiar with the sound engineering part of it.

2: The most important thing about the material is the *gwarira*, which is the wood used to place the keys on. The wood that is used in Shona, we know it as *mukwa* or *mvamaropa.* In South Africa they call it *kiat* that is mostly brown wood. It is the same wood used to make marimbas because when it vibrates it produces good sound. You can use other types of wood, but they won't resonate as well as *mukwa*, *kiat* or *mvamaropa*.

3: I should think that just like we are doing now, we experiment with things, then we get a result. In olden days people did not have entertainment. They had to create their own entertainment. That is how they discovered which wood is best to make sound. Just like the steel pan; if you go to the mineworkers in Trinidad, they did not have anything to use because of the different materials they have, so they resolved to using the drums as an instrument and that is how they got the steel pan now.

4: It has been in existence for quite a long time. In a lot of African countries, you will discover that they used to have their own mbira. We have a variety of mbira in Africa, especially in the southern parts. If you see Zambia, Mozambique, or other parts, they've got their own type of mbira, but it’s only how unique that instrument is to them and also how popular that unique instrument is in that country and how it has been exposed and marketed to make it known. A lot of African countries have nice instruments, but in Zimbabwe the popular instrument is the mbira.

5: The *nare*, which is *mbira dzavadzimu*. *Mbira dzavadzimu* is the one that I was playing for you, and in most cases, the *mbira dzavadzimu* has 24 keys and upwards, depending on the manufacturer. These days, people are still experimenting with instruments and different designs are coming. Some are good and some are not desirable. It is called the *mbira dzavadzimu* because it is used to appease their ancestors.

6: Twenty-four keys. The player himself can go and request that they add an extra key for them, but in all the instrument has 24 or 25 keys.

While the researcher was in the province of Limpopo, two Venda mbira practitioners were recorded and interviewed.

Participant 2

1: Yes, I have recorded mbira before. I have recorded the mbira alone and with other musical instruments. I was never conscious of how the microphones were positioned or what type of microphone was being used to record.

2: When we grew up, we found out that the materials that were used are the same materials that derive from a tree called *mutondo* and that tree we would go to the mountain and chop a huge chunk of wood and is shaped and cut it to size. Once the wood has been cut to size and shaped, it is *gombe.* That is the material we use, and it works. It’s not just anybody who makes the mbira. It is made by a particular person who possess the skill to build the instrument. I believe this is a tradition that should continue because it has survived for a very long time.

3: Those are the materials we grew up knowing and we are still using to this day. We do not question tradition, we just follow it. The *mutondo* tree is light, so that is why it is used compared to other trees. When playing the instrument, it will not be too heavy to play.

4: I was born in a family where this was the culture. There are many family members of mine who would play the mbira. There was also an instrument builder in the family named *Mugunda*. He made the mbira in the family. This culture of mbira in the family made me fall in love with the mbira. It felt like a calling. I have brothers that play the mbira but are not as good as me.

5: *Mbira dzamadeza.*

6: My mbira has 27 keys. The mbira has the diatonic notes of a scale, but it can be tuned differently. There are one or two notes that might not be perfectly tuned.

Participant 3

1: I have recorded the playing the mbira before but not in the studio. There was a lady that came to my place. She had a boom microphone and she recorded me. That is my exposure to recording the mbira.

2: I am a mbira maker and I learned how to make the mbira from my parents. We would go to the mountain and fetch the *mutondo* tree, cut it to the right size and shape and bring it back. My parents are the ones who taught me how to play as well. When the mbira is made there is a steel used called *bokrata* which are cut into various sizes to create various pitch. The mbira has every one of those notes. The resonator that is used traditional comes from a tree called *mpapa*, and the mbira would be put inside the resonator to amplify the sound. Nowadays, people use modern materials such as steel or plastic.

3: Adding to what "_" said, it is not only that the wood is light and easy to carry, but also resonant. It is different from other trees in that sense. It can produce good quality sound. Another thing is that most woods are easily destroyed by termites, but the termites do not eat the *mutondo* tree even when the tree has been cut down.

4: It has been around for a long time. I learned from the Tsonga's version that they have then later started making the mbira for the Venda people.

5: I play the *mbira dzamadeza*.

6: My mbira has 27 keys and 2 octaves.

Appendix 2: Analytical report of the mbira

Analytical report Mbira composition: Avuyile Ngqangweni

X-ray Fluorescence spectroscopy is an analytical technique used to identify the inorganic elements that makes up a material. It works on the principle of exciting the atoms by irradiating the sample with X-rays, as the atoms relax back to their ground state, they emit X-ray photons characteristic of a specific spectral line of a specific element. This enables us to identify the elements making up the material. If an infinitely thick, homogenous specimen is analysed it is also possible to quantify the elements, but in most artefacts the non-destructive manner of analysis limits us to qualitative analysis. Elements between Mg en U on the periodic table can be identified. C, N, O and H, making up organic materials are too light to be detected with this technique, but the presence of organic matrices are seen in large background scatter.

For more information on the technique with specific reference to cultural heritage objects, refer to: Bezur, A., Lee, L., Loubser, M. and Trentelman K. 2020. Handheld XRF in Cultural Heritage: A Practical Workbook for Conservators. Getty Conservation Institute. ISBN 1937433625, 9781937433628. The book is available from the GCI website as a free, downloadable pdf: https://gty.art/3a7Mjaa

The Mbira consists of a wooden base with metal keys, fastened with a metal rod and wire.

Both the wooden base and the metal keys and their fastening system were analysed.

Figure 1 Mbira

First looking at the metal parts: The keys were cleaned with isopropyl alcohol to remove surface contamination (sweat and oil). A large key was analysed as well as the back end of the keys. The metal rod fastening the keys was also analysed and the wire fastening the positioning rod was analysed from the back.

The wooden base was analysed from the front and from the back side.

Van Wouw House
299 Clark Street, Brooklyn
University of Pretoria
Private Bag X20 Hatfield 0028
South Africa
Tel +27 (0)829228184
Email maggi.loubser@up.ac.za

Maggi Loubser
Programme Manager and Senior Lecturer
MSocSci Tangible Heritage Conservation
Faculty of Humanities
School of the Arts

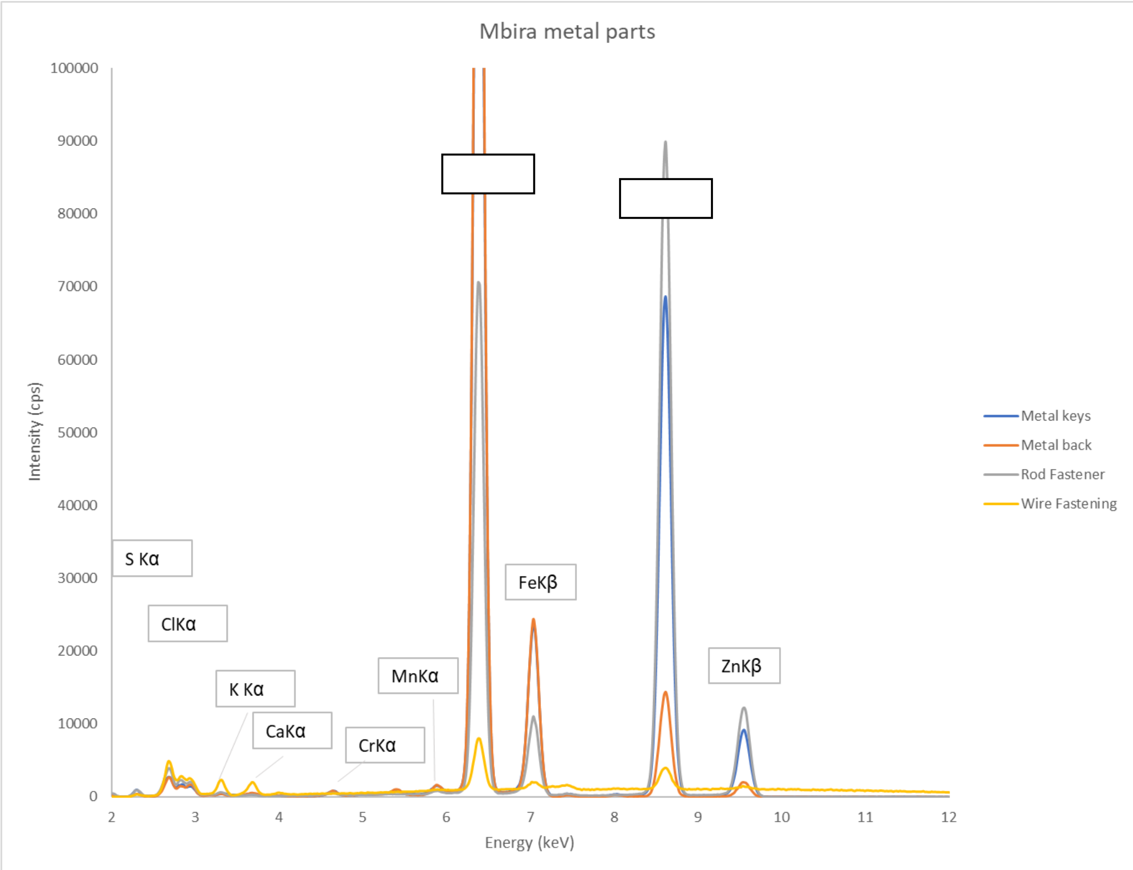


Figure 1 XRF spectra of the metal parts

From the composition Iron (Fe), Manganese(Mn), Chrome(Cr) it can be deduced that it is tool steel, and the large Zinc peak (Zn) shows that the steel was galvanised. (A protective Zn layer plated onto the steel to prevent it from rusting). The rod fastener has the same composition, but the Zn is much higher, because on the keys the plated layer has been rubbed off over time. The wire fastening shows scatter (the background is higher), and this is because the wood surrounding it was analysed as well.

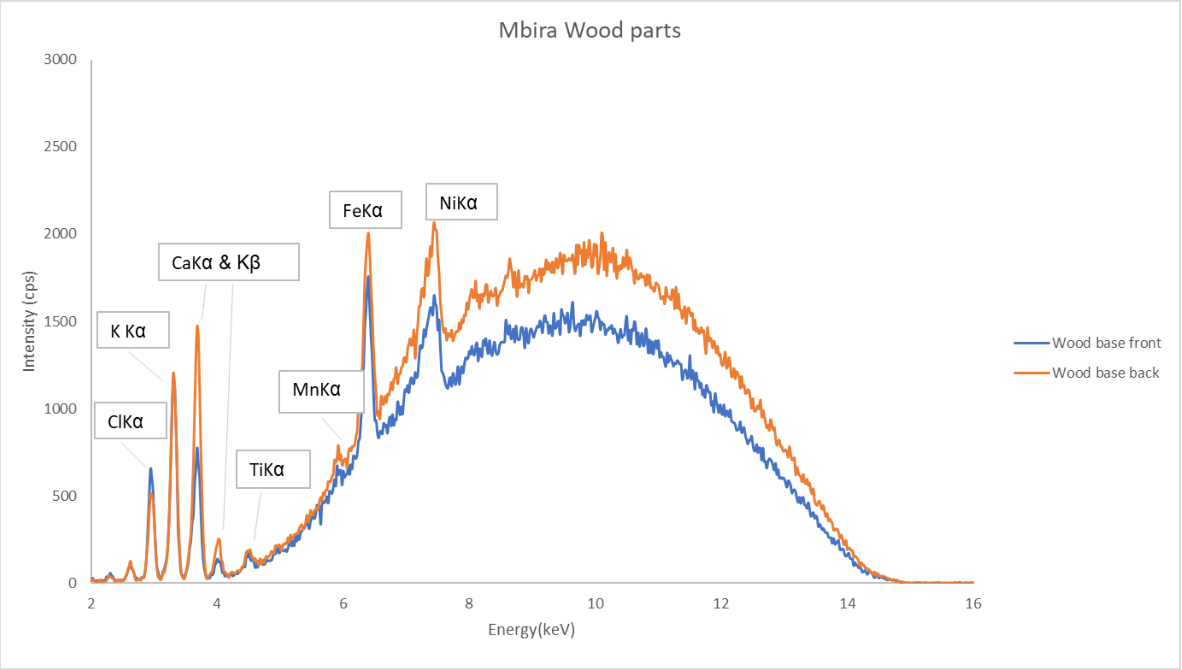


Figure 2 XRF spectra of the wooden parts

On the wooden parts it is easy to see the scatter due to the light matrix. (the flat humpy continuum under the peaks). There are traces of Nickel (Ni), Titanium (Ti), Calcium (Ca) and Potassium(K), which are often present in wood treatments, present. The Chlorine (Cl) peak seen in both spectra is possibly due to sweat on the players hands. The Iron (Fe) and Manganese (Mn), on the wooden parts could be traces of rust that over time came off the keys and were embedded in the base.

If you have any further questions, please contact THC.

Regards

Maggi Loubser

16 November 2020

Appendix 3: Photos of the recording techniques

Figure 1: Rode NT2A Spaced Pair

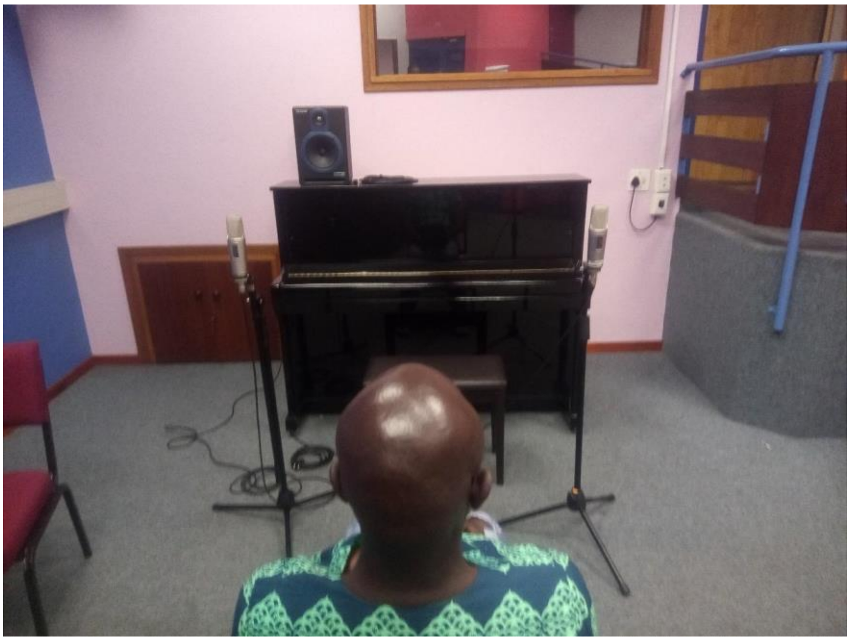


Figure 2: Rode NT2A Spaced Pair

Figure 3: Rode NT2A Mid Side

Figure 4: Rode NT2A Mid Side

Figure 5: Rode NT2A Mono

Figure 6: Rode NT2A XY

Figure 7: Rode NT2A XY

Figure 8: Sennheiser MKH30 (Bidirectional) and Sennheiser MKH40 (Cardioid) Mid Side

Figure 9: Sennheiser MKH30 in mono

Figure 10: Sennheiser MKH40 Cardioid in mono

Figure 11: AKG C414 Bidirectional in mono

Figure 12: AKG C414 Bidirectional in mono

Figure 13: AKG C414 Mid Side

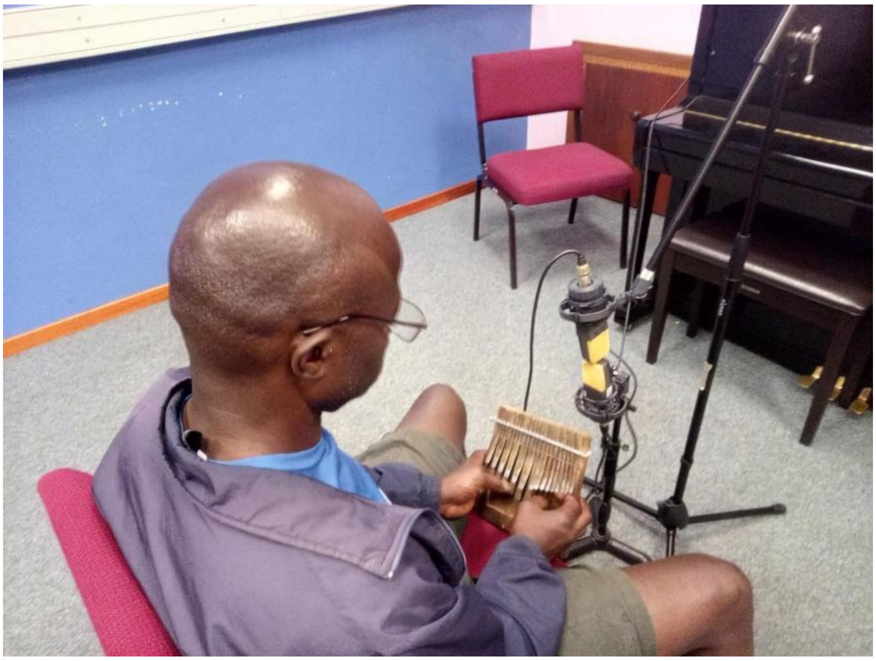


Figure 14: AKG C414 Mid Side

Figure 15: AKG C414 XY

Figure 16: AKG C414 XY

Figure 17: Shure 57A Beta in mono

Figure 18: Shure 58A Beta in mono

Figure 19: Neumann TLM 103 XY

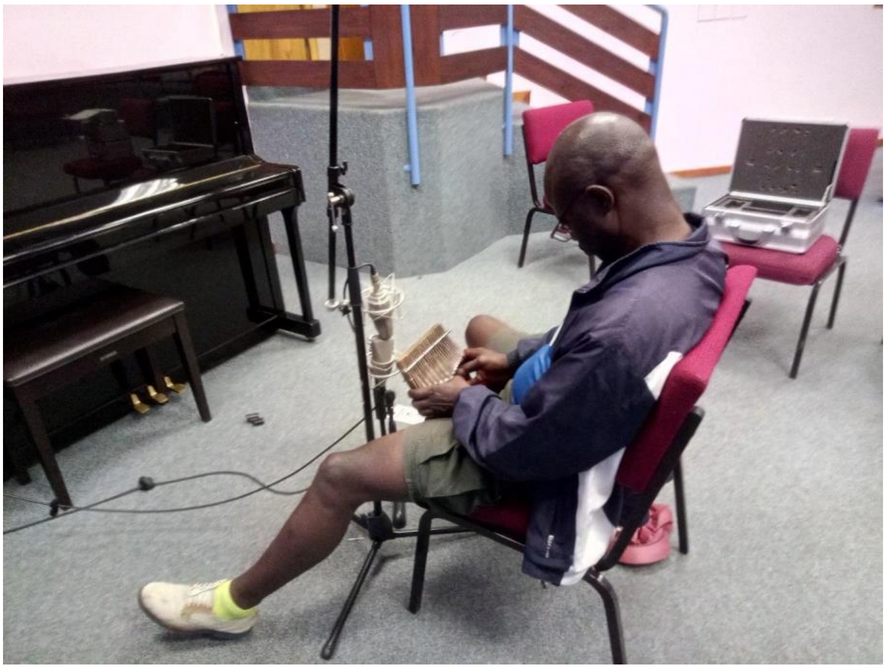


Figure 20: Neumann TLM 103 XY

Figure 21: Rode K2 in mono

Figure 22: Samson CO3 Spaced Pair

Figure 23: Samson CO3 in mono

Figure 24: Samson CO3 Bidirectional in mono

Figure 25: Samson CO3 Bidirectional in mono

Figure 26: Samson CO3 Mid Side

Figure 27: Neumann TLM 103 Spaced Pair

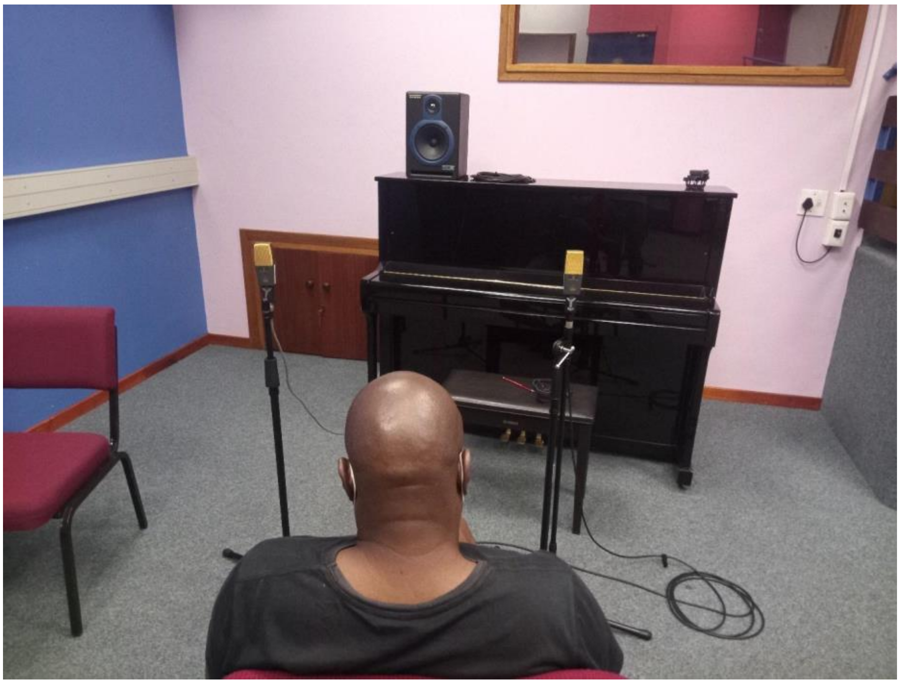


Figure 28: AKG C414 Spaced Pair

Figure 29: AKG C414 in mono

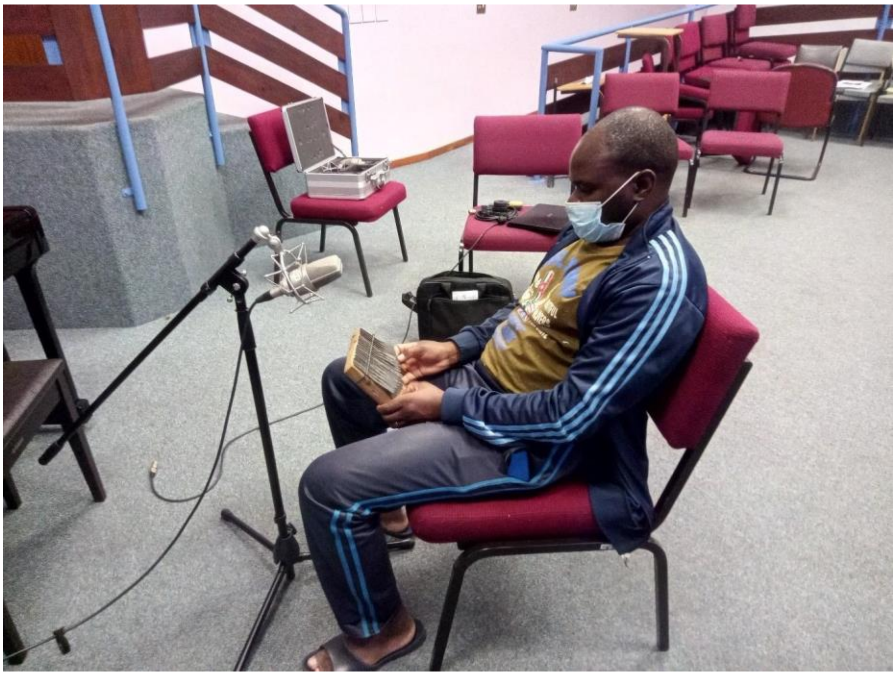


Figure 30: Neumann TLM 103 in mono

Figure 31: Sennheiser e914 Spaced Pair

Figure 32: Sennheiser e914 Spaced Pair

Figure 33: Sennheiser e914 XY Pair

Appendix 4: Links to video recordings of frequency spectral analysis of the mbira

Microphone	**Recording Technique**	**Link**
AKG C414 B-TL II	Mono (Bidirectional)	https://drive.google.com/file/d/1EVCQZvyNKDpzVMhjhlHbFEtFammR8Uns/view?usp=sharing
AKG C414 B-TL II	Mono (Cardioid)	https://drive.google.com/file/d/1EUdcE8pMu-dLBjofbNAWqCqcND54QEIP/view?usp=sharing
AKG C414 B-TL II	Mid Side	https://drive.google.com/file/d/1EW3Yo7KtAg9egf9psftJ5zkdjfz9u8Q_/view?usp=sharing
AKG C414 B-TL II	Mono (Omnidirectional)	https://drive.google.com/file/d/1EVtcks4h-z4Y93btSK8jWWjlqZUGh2ED/view?usp=sharing
AKG C414 B-TL II	XY	https://drive.google.com/file/d/1EXBIEWmP8vBPWk_4NeRUt2J5ih7tI1U7/view?usp=sharing
Neumann TLM 103	Spaced Pair	https://drive.google.com/file/d/1EWrXl2BSKaHlPTJI4RjHyxNwwV4x8ksF/view?usp=sharing
Neumann TLM 103	XY	https://drive.google.com/file/d/1E_z-S9vfrf2hDeNpmMhd5-1qJ88iGBr4/view?usp=sharing
Rode K2	Mono (Bidirectional)	https://drive.google.com/file/d/1EeJ3pyj7RMJOlyWhJZzGcA0xpGq7-ald/view?usp=sharing
Rode K2	Mono (Cardioid)	https://drive.google.com/file/d/1Ed_ZTXaN_VfxHc3FJpWyZlMN6Jk9p0ap/view?usp=sharing
Rode K2	Mono (Omnidirectional)	https://drive.google.com/file/d/1EeZwoLxyzuH2FePMQXLEL9Fbt2EWeFXP/view?usp=sharing
Rode NT2A	Mono (Bidirectional)	https://drive.google.com/file/d/1EeVJDn628I8raN-c76rZkj4GTv9FsErN/view?usp=sharing
Rode NT2A	Mono (Cardioid)	https://drive.google.com/file/d/1EfrtfB13x9j3KFuvrOX-KkqyvlCkXNtR/view?usp=sharing
Rode NT2A	Mid Side	https://drive.google.com/file/d/1EeoCf_Dw9tCTxP4Hu2MC12p8LcxhKOAa/view?usp=sharing
Rode NT2A	Mono (Omnidirectional)	https://drive.google.com/file/d/1EhHFmQEdMXW2PvwLRA4yiD6Hoo3xJ0Tr/view?usp=sharing

Rode NT2A	Spaced Pair (Cardioid)	https://drive.google.com/file/d/1EkKgdSewlsixulfNSUgYoxBD0btG_A-i/view?usp=sharing
Rode NT2A	Spaced Pair (Omnidirectional)	https://drive.google.com/file/d/1Egm8zhOXiytl6RDbdfYXL-9U9-XjDBIp/view?usp=sharing
Rode NT2A	XY	https://drive.google.com/file/d/1Ej1UcKeJCXtjU0ZJbVbKJvIVMvncoltE/view?usp=sharing
Samson CO3	Mono (Bidirectional)	https://drive.google.com/file/d/1EaoimsrdvxnKT8tx2WW9UANexjxLZKno/view?usp=sharing
Samson CO3	Blumlein	https://drive.google.com/file/d/1Ec_ZuptmKKlf4w58dYbplVzCFoHB3z7f/view?usp=sharing
Samson CO3	Mono (Cardioid)	https://drive.google.com/file/d/1EbgkxbwPKx6kxvJcT_tv3xch7RcyeIHv/view?usp=sharing
Samson CO3	Mid Side	https://drive.google.com/file/d/1EcsU_KdxMAdZUUq8mvJkDb1cUqU-bICQ/view?usp=sharing
Samson CO3	Mono (Omnidirectional)	https://drive.google.com/file/d/1EciE8joErzVzwTOVLKf7eNg87JBu2cmO/view?usp=sharing
Samson CO3	Spaced Pair (Cardioid)	https://drive.google.com/file/d/1EdH4oaBA6a4cpCv1Wf1WrGCxkZRFtEVw/view?usp=sharing
Samson CO3	Spaced Pair (Omnidirectional)	https://drive.google.com/file/d/1Ecxu4irfpqz8MQW7ZLkcxQr38b3PRt3u/view?usp=sharing
Samson CO3	XY	https://drive.google.com/file/d/1EdU56A87-1bM1NONqjwn_enm1UyJaFrM/view?usp=sharing
Sennheiser e914	Mono	https://drive.google.com/file/d/1EuF_NJv1i1vMxF2_qAY8UfRHtdhbI2zS/view?usp=sharing
Sennheiser e914	Spaced Pair	https://drive.google.com/file/d/1EsrDhKDDEdLCulSQeg3tqLCA30wc2TNK/view?usp=sharing
Sennheiser e914	XY	https://drive.google.com/file/d/1Eui-MYMqAX08cCRbzF-_bhhWcTBnCmeN/view?usp=sharing
Sennheiser MKH30 and MKH40	Mid Side	https://drive.google.com/file/d/1Ep63vnMGDH2kFmGeTyXkRCOQBGDSfIR6/view?usp=sharing

Sennheiser MKH30	Mono	https://drive.google.com/file/d/1EoWZWtqNtZDUfxqo3GFpegdyacnMUFkg/view?usp=sharing
Sennheiser MKH40	Mono	https://drive.google.com/file/d/1EqudpPf0TXluLwbosqO6WoshcHLH0FUP/view?usp=sharing
Shure 57A Beta	Mono	https://drive.google.com/file/d/1EpR6y2WmTNDsE123skBt2D4JaEyXNcbh/view?usp=sharing
Shure 58A Beta	Mono	https://drive.google.com/file/d/1Er9abN2sq7_ihdNV_lHZ6sgdsmnLkJk7/view?usp=sharing

Appendix 5: Links to mbira video recordings

Video	**Link**
Mbira recording	https://drive.google.com/file/d/1d-OhtjFRDoMfbkzI7s3KERj88Inwc36R/view?usp=sharing
Two mbiras recorded	https://drive.google.com/file/d/1tiezG4WSrSLgd3D8UZPqpsCQWcCtUV-E/view?usp=sharing

Appendix 6: Links to mbira studio recordings

Microphone	Recording Technique	Link
AKG C414 B-TL II	Mono (Bidirectional)	https://drive.google.com/drive/folders/1FFVk-jFQqdoRUcDI9-1FXlfrtF1Yiaed?usp=sharing
AKG C414 B-TL II	Mono (Cardioid)	https://drive.google.com/drive/folders/16MFn5c9pTfb3EglKYFFA9IEU6mfcLUkF?usp=sharing
AKG C414 B-TL II	Mid Side	https://drive.google.com/drive/folders/1u_BYGAYMyeGbCSTUoiQVDXaLmFHOAEyW?usp=sharing
AKG C414 B-TL II	Mono (Omnidirectional)	https://drive.google.com/drive/folders/16Lf4lkYpPMCsPjDYOtLD31qVlpfOLF12?usp=sharing
AKG C414 B-TL II	XY	https://drive.google.com/drive/folders/1OU1U3gL2JqVMRVEa2eqll1KSDj-gr3lT?usp=sharing
Neumann TLM 103	Spaced Pair	https://drive.google.com/drive/folders/1G2PYdCqLsH9h2VCmLPbrRmcXRMj-zGyG?usp=sharing
Neumann TLM 103	XY	https://drive.google.com/drive/folders/1Fns7h5oxAWxBGA6OXbZMYnkodi0bJ7td?usp=sharing
Rode K2	Mono (Bidirectional)	https://drive.google.com/drive/folders/1Gj95J1z2BNR4ErA9hZmpZrUyWUvr3as-?usp=sharing
Rode K2	Mono (Cardioid)	https://drive.google.com/drive/folders/1GmvQ9L07tqjJapUz4gCMCsttN4SAq2dH?usp=sharing
Rode K2	Mono (Omnidirectional)	https://drive.google.com/drive/folders/1GuZ-aM8dHUDkakGcxA8Wb2NGOrXeIYCi?usp=sharing
Rode NT2A	Mono (Bidirectional)	https://drive.google.com/drive/folders/1Hyg-62g2zBP8V3ntRWe357cun_a8ZlJw?usp=sharing
Rode NT2A	Mono (Cardioid)	https://drive.google.com/drive/folders/1H81cg4g7YQ4KvrF1tJV0OnLd3WW-0MQT?usp=sharing
Rode NT2A	Mid Side	https://drive.google.com/drive/folders/1Hoe0-kBDSzNBOoIEvMZU7XhTS7Y7Ajd-?usp=sharing
Rode NT2A	Mono (Omnidirectional)	https://drive.google.com/drive/folders/1I-kNGHTiEMnIu8i1J1YWi8JMzY9RzfZf?usp=sharing
Rode NT2A	Spaced Pair	https://drive.google.com/drive/folders/1HyQq_b3GXgEKva7KjI_KNbCiYIbmtKfe?usp=sharing

	(Cardioid)	
Rode NT2A	Spaced Pair (Omnidirectional)	https://drive.google.com/drive/folders/1I-eJyYqhmDFv0IAeDz-2duQazXhTP5Bx?usp=sharing
Rode NT2A	XY	https://drive.google.com/drive/folders/1HpVks0ZQww937mWr3iBQTEYetZZg8SJS?usp=sharing
Samson CO3	Mono (Bidirectional)	https://drive.google.com/drive/folders/16C2yBmZXJRhunOLbO28rrffWtwjSRsBB?usp=sharing
Samson CO3	Blumlein	https://drive.google.com/drive/folders/16C2DSCx9gZGf9oxcIRURAO_eC3mMaezc?usp=sharing
Samson CO3	Mono (Cardioid)	https://drive.google.com/drive/folders/16BAb92LE60iBNiJxhrgAuU2I0f1ezTp9?usp=sharing
Samson CO3	Mid Side	https://drive.google.com/drive/folders/16B4RV4UW1RW8XLJT9g2nkuPIm3TzlLNh?usp=sharing
Samson CO3	Mono (Omnidirectional)	https://drive.google.com/drive/folders/16Avxm11lMCZlJdcPTbm201q9coLHrhWd?usp=sharing
Samson CO3	Spaced Pair (Cardioid)	https://drive.google.com/drive/folders/16AH-uCXcPwL5rbheZLMnnd8nuow9i0qR?usp=sharing
Samson CO3	Spaced Pair (Omnidirectional)	https://drive.google.com/drive/folders/167x1zpuP5eYr0fjwG0Cu2c4K2Py3Xtmq?usp=sharing
Samson CO3	XY	https://drive.google.com/drive/folders/166TZycwwEFOucTiBTHmSRNB2KosEdfyi?usp=sharing
Sennheiser e914	Mono	https://drive.google.com/drive/folders/13t-24-uQBwoJlBburMwcmdcdwCy5ixYG?usp=sharing
Sennheiser e914	Spaced Pair	https://drive.google.com/drive/folders/1xbLvu-I8ASkiFMbhDuEmqFa7roevafBU?usp=sharing
Sennheiser e914	XY	https://drive.google.com/drive/folders/16MTu0nUedaWD3MICM-Y4KRAmWLVo8aMe?usp=sharing
Sennheiser MKH30 and MKH40	Mid Side	https://drive.google.com/drive/folders/13rRlyfezY_yBr_HEZ5pCNV_dtTeX0V-h?usp=sharing
Sennheiser MKH30	Mono	https://drive.google.com/drive/folders/13r3motOKxXi9aVoZtbmZUmMaqK4Hyb6T?usp=sharing

Sennheiser MKH40	Mono	https://drive.google.com/drive/folders/13rCT9nhU10CN5sJfKlHFLyCsjrK8CJaU?usp=sharing
Shure 57A Beta	Mono	https://drive.google.com/drive/folders/13lBPMQc83Dc89qzttmWNVC3P2XSt8_Lj?usp=sharing
Shure 58 A Beta	Mono	https://drive.google.com/drive/folders/13nK5RmyVZ43VuJ62BdqH_uWcD4zSKIBM?usp=sharing

The links in the above table are folders which contain audio files and session files with the plugin settings that were used for the data collection. The files may be accessed by downloading them onto a hard drive and then running the session (installation of Reaper will be necessary).

Appendix 7: Frequency analysis data – visualisation of recorded sound data from Sonic Visualiser

Microphone & Polar Pattern	Peak Frequency vs Amplitude Graph	Select Peak Frequencies (within the mbira range)	Corresponding Select Peak Frequency Amplitude
Samson C03 mono cardioid	https://drive.google.com/file/d/1NlkVh-dk2pBuxTFSE9Ld9CbqINP6Fy9w/view?usp=share_link	129 Hz	-98 dB
		234 Hz	-96 dB
		293 Hz	-95 dB
		340 Hz	-103 dB
		422 Hz	-103 dB
		480 Hz	-105 dB
		656 Hz	-107 dB
		738 Hz	-112 dB
		844 Hz	-114 dB
		949 Hz	-113 dB
Rode K2 mono cardioid	https://drive.google.com/file/d/1Nw7_Aotaiwp0JJtmXYkyc2gGSzjBbg8w/view?usp=share_link	152 Hz	-78 dB
		188 Hz	-80 dB
		211 Hz	-79 dB
		258 Hz	-82 dB
		281 Hz	-82 dB
		316 Hz	-85 dB
		340 Hz	-88 dB
		398 Hz	-84 dB
		434 Hz	-89 dB
		469 Hz	-90 dB

		516 Hz	-89 dB
		551 Hz	-91 dB
		574 Hz	-90 dB
		598 Hz	-93 dB
		621 Hz	-93 dB
		691 Hz	-93 dB
		762 Hz	-93 dB
		832 Hz	-99 dB
		914 Hz	-96 dB
		961 Hz	-95 dB
		984 Hz	-95 dB
		984 Hz	-95 dB
Sennheiser MKH40 mono	https://drive.google.com/file/d/1O0VatK9R7-HLaAeY6gd-WErcFlUbj_ZT/view?usp=share_link	140 Hz	-95 dB
		172 Hz	-101 dB
		226 Hz	-103 dB
		291 Hz	-101 dB
		398 Hz	-104 dB
		452 Hz	-111 dB
		571 Hz	-116 dB
		624 Hz	-120 dB
		678 Hz	-125 dB
		721 Hz	-118 dB
		840 Hz	-121 dB
		904 Hz	-128 dB
		947 Hz	-120 dB

Sennheiser e914 mono	https://drive.google.com/file/d/1O3NiilYUs8beEYnZ2g8vQ7upsaGBBWxT/view?usp=share_link	199 Hz	-68 dB
		387 Hz	-75 dB
		504 Hz	-105 dB
		562 Hz	-104 dB
		621 Hz	-108 dB
		715 Hz	-107 dB
		809 Hz	-104 dB
		867 Hz	-108 dB
		949 Hz	-108 dB
Shure 57A Beta mono	https://drive.google.com/file/d/1NzHEfN8ctQuQRvboQQgfhVhnkbTKvev8/view?usp=share_link	129 Hz	-65 dB
		164 Hz	-65 dB
		246 Hz	-59 dB
		328 Hz	-61 dB
		363 Hz	-87 dB
		469 Hz	-93 dB
		527 Hz	-98 dB
		668 Hz	-96 dB
		797 Hz	-97 dB
Shure 58A Beta mono	https://drive.google.com/file/d/1NzEwGwycxSnuJsnpKaJM0g8lDfoz2rlj/view?usp=share_link	164 Hz	-67 dB
		199 Hz	-79 dB
		234 Hz	-82 dB
		270 Hz	-64 dB
		328 Hz	-73 dB
		410 Hz	-93 dB

		445 Hz	-97 dB
		492 Hz	-96 dB
		539 Hz	-74 dB
		586 Hz	-93 dB
		633 Hz	-106 dB
		703 Hz	-101 dB
		797 Hz	-100 dB
		844 Hz	-105 dB
		914 Hz	-103 dB
		949 Hz	-93 dB
		949 Hz	-93 dB
Rode NT2A mono cardioid	https://drive.google.com/file/d/1NrxdkwkjybglyVuZX172rKXELM09tjVJ/view?usp=share_link	172 Hz	-91 dB
		215 Hz	-90 dB
		269 Hz	-78 dB
		323 Hz	-83 dB
		388 Hz	-89 dB
		452 Hz	-102 dB
		528 Hz	-105 dB
		571 Hz	-108 dB
		614 Hz	-106 dB
		668 Hz	-109 dB
		711 Hz	-122 dB
		797 Hz	-94 dB
		851 Hz	-105 dB
		894 Hz	-106 dB
		937 Hz	-108 dB

		980 Hz	-107 dB
AKG C414 B-TL II mono cardioid	https://drive.google.com/file/d/1Nct0GMvwdSwPOBeNwTubEmrKFOpRJAod/view?usp=share_link	281 Hz	-95 dB
		387 Hz	-101 dB
		492 Hz	-111 dB
		586 Hz	-112 dB
		621 Hz	-108 dB
		703 Hz	-108 dB
		750 Hz	-111 dB
		832 Hz	-107 dB
		879 Hz	-111 dB
		984 Hz	-109 dB
		984 Hz	-109 dB
AKG C414 B-TL II mono omnidirectional	https://drive.google.com/file/d/1NciTNaDJrpOQlirfa_ZR9u-2HDtlWZkt/view?usp=share_link	194 Hz	-90 dB
		226 Hz	-92 dB
		258 Hz	-92 dB
		280 Hz	-95 dB
		312 Hz	-92 dB
		345 Hz	-98 dB
		377 Hz	-99 dB
		398 Hz	-100 dB
		420 Hz	-101 dB
		452 Hz	-100 dB
		484 Hz	-103 dB
		517 Hz	-109 dB
		538 Hz	-106 dB

		614 Hz	-106 dB
		646 Hz	-107 dB
		668 Hz	-107 dB
		711 Hz	-108 dB
		775 Hz	-110 dB
		807 Hz	-108 dB
		840 Hz	-111 dB
		872 Hz	-108 dB
		926 Hz	-111 dB
		947 Hz	-112 dB
Rode NT2A mono omnidirectional	https://drive.google.com/file/d/1NrH1VyF3ikXJCDYHXtI-sMteJbr9r2ET/view?usp=share_link	140 Hz	-83 dB
		172 Hz	-91 dB
		194 Hz	-106 dB
		237 Hz	-95 dB
		301 Hz	-94 dB
		323 Hz	-98 dB
		345 Hz	-111 dB
		377 Hz	-107 dB
		431 Hz	-101 dB
		484 Hz	-104 dB
		506 Hz	-114 dB
		538 Hz	-106 dB
		635 Hz	-111 dB
		711 Hz	-113 dB
		743 Hz	-115 dB
		775 Hz	-114 dB

		807 Hz	-108 dB
		851 Hz	-116 dB
		872 Hz	-116 dB
		904 Hz	-120 dB
		947 Hz	-111 dB
Samson CO3 mono omnidirectional	https://drive.google.com/file/d/1NleFPgLvv6LGDe5begBoGAoGWhX6T9EG/view?usp=share_link	129 Hz	-77 dB
		152 Hz	-75 dB
		188 Hz	-77 dB
		223 Hz	-78 dB
		258 Hz	-81 dB
		305 Hz	-79 dB
		375 Hz	-86 dB
		445 Hz	-85 dB
		480 Hz	-91 dB
		539 Hz	-91 dB
		598 Hz	-94 dB
		656 Hz	-93 dB
		703 Hz	-101 dB
		738 Hz	-95 dB
		773 Hz	-98 dB
		820 Hz	-95 dB
		867 Hz	-99 dB
		902 Hz	-95 dB
		938 Hz	-95 dB
		973 Hz	-106 dB

Sennheiser e914 spaced pair	https://drive.google.com/file/d/1O2v_67ZcpKqByW_86gVWdNryCm6m4MB6/view?usp=share_link	118 Hz	-89 dB
		161 Hz	-90 dB
		205 Hz	-73 dB
		248 Hz	-96 dB
		291 Hz	-96 dB
		334 Hz	-100 dB
		366 Hz	-100 dB
		409 Hz	-104 dB
		420 Hz	-94 dB
		474 Hz	-75 dB
		517 Hz	-73 dB
		560 Hz	-91 dB
		603 Hz	-103 dB
		668 Hz	-112 dB
		689 Hz	-114 dB
		732 Hz	-107 dB
		786 Hz	-106 dB
		829 Hz	-122 dB
		861 Hz	-112 dB
		904 Hz	-114 dB
		947 Hz	-111 dB
Samson CO3 spaced pair cardioid	https://drive.google.com/file/d/1Nl57coj731M9qZ2auTC9pTTkwLXUn7Z6/view?usp=share_link	118 Hz	-98 dB
		151 Hz	-103 dB
		183 Hz	-99 dB
		248 Hz	-100 dB
		301 Hz	-96 dB

		334 Hz	-106 dB
		366 Hz	-103 dB
		398 Hz	-99 dB
		463 Hz	-109 dB
		528 Hz	-117 dB
		581 Hz	-111 dB
		624 Hz	-114 dB
		689 Hz	-109 dB
		775 Hz	-118 dB
		797 Hz	-119 dB
		818 Hz	-121 dB
		861 Hz	-116 dB
		947 Hz	-115 dB
		991 Hz	-117 dB
Rode NT2A spaced pair cardioid	https://drive.google.com/file/d/1Nr-3eC58J2fY7SWUjCpmIAGz3s_YRVIk/view?usp=share_link	140 Hz	-97 dB
		172 Hz	-93 dB
		215 Hz	-95 dB
		269 Hz	-80 dB
		334 Hz	-96 dB
		441 Hz	-77 dB
		538 Hz	-98 dB
		603 Hz	-103 dB
		668 Hz	-107 dB
		711 Hz	-97 dB
		775 Hz	-99 dB
		829 Hz	-95 dB

		947 Hz	-96 dB
		980 Hz	-105 dB
Neumann TLM 103 spaced pair	https://drive.google.com/file/d/1NyUo9S9er_-xVcElBR1b-ejcwJuvSt6t/view?usp=share_link	140 Hz	-98 dB
		183 Hz	-103 dB
		226 Hz	-105 dB
		269 Hz	-104 dB
		301 Hz	-99 dB
		420 Hz	-107 dB
		463 Hz	-112 dB
		538 Hz	-116 dB
		624 Hz	-112 dB
		689 Hz	-107 dB
		775 Hz	-117 dB
		851 Hz	-117 dB
		883 Hz	-132 dB
		947 Hz	-117 dB
Samson CO3 spaced pair omnidirectional	https://drive.google.com/file/d/1NjbfySFtPgXnulSYJvyn9_8izDZIDqqt/view?usp=share_link	151 Hz	-97 dB
		172 Hz	-98 dB
		248 Hz	-95 dB
		301 Hz	-87 dB
		345 Hz	-97 dB
		398 Hz	-96 dB
		474 Hz	-107 dB
		549 Hz	-105 dB
		624 Hz	-106 dB

		700 Hz	-111 dB
		754 Hz	-106 dB
		818 Hz	-114 dB
		857 Hz	-114 dB
		904 Hz	-122 dB
		937 Hz	-118 dB
		958 Hz	-114 dB
Rode NT2A spaced pair omnidirectional	https://drive.google.com/file/d/1NqIYULe3rxr53MTzAr1d2CSX74qQuXIE/view?usp=share_link	140 Hz	-89 dB
		161 Hz	-82 dB
		226 Hz	-70 dB
		269 Hz	-81 dB
		323 Hz	-86 dB
		377 Hz	-97 dB
		398 Hz	-96 dB
		420 Hz	-99 dB
		441 Hz	-83 dB
		495 Hz	-96 dB
		538 Hz	-110 dB
		571 Hz	-113 dB
		624 Hz	-110 dB
		678 Hz	-113 dB
		711 Hz	-118 dB
		732 Hz	-109 dB
		764 Hz	-113 dB
		807 Hz	-115 dB
		851 Hz	-118 dB

		872 Hz	-117 dB
		883 Hz	-122 dB
		937 Hz	-127 dB
		969 Hz	-107 dB
Sennheiser MKH30 and MKH40 Mid Side	https://drive.google.com/file/d/1O66E1EH5Mi3rYVJZhl4zqOt6hHbUXbMN/view?usp=share_link	151 Hz	-103 dB
		172 Hz	-96 dB
		205 Hz	-101 dB
		237 Hz	-99 dB
		269 Hz	-111 dB
		301 Hz	-101 dB
		355 Hz	-103 dB
		398 Hz	-102 dB
		517 Hz	-111 dB
		581 Hz	-115 dB
		603 Hz	-112 dB
		668 Hz	-114 dB
		689 Hz	-111 dB
		732 Hz	-116 dB
		797 Hz	-122 dB
		840 Hz	-122 dB
		894 Hz	-124 dB
		926 Hz	-119 dB
		947 Hz	-120 dB
Samson CO3 Mid	https://drive.google.com/file/d/1Nn0iSpfE9lPlTWM-u4VfPP19XCb-	172 Hz	-97 dB
		301 Hz	-97 dB

Side	3XFu/view?usp=share_link	388 Hz	-99 dB
		495 Hz	-105 dB
		581 Hz	-121 dB
		624 Hz	-111 dB
		678 Hz	-111 dB
		743 Hz	-119 dB
		786 Hz	-127 dB
		851 Hz	-114 dB
		915 Hz	-129 dB
Rode NT2A Mid Side	https://drive.google.com/file/d/1Nvdzya404T0rVp-zE9dOOKKOzq_O_RXy/view?usp=share_link	129 Hz	-93 dB
		194 Hz	-77 dB
		248 Hz	-77 dB
		301 Hz	-85 dB
		377 Hz	-97 dB
		420 Hz	-99 dB
		484 Hz	-105 dB
		528 Hz	-107 dB
		571 Hz	-107 dB
		635 Hz	-109 dB
		700 Hz	-119 dB
		743 Hz	-113 dB
		807 Hz	-118 dB
		861 Hz	-122 dB
		937 Hz	-117 dB
AKG	https://drive.google.com/file/d/1Ng	129 Hz	-83 dB

C414 B-TL II Mid Side	a_IYA_7ibstCY3e62aeoqoFPM-6-hE/view?usp=share_link	161 Hz	-98 dB
		183 Hz	-94 dB
		215 Hz	-85 dB
		269 Hz	-85 dB
		291 Hz	-85 dB
		355 Hz	-47 dB
		398 Hz	-70 dB
		474 Hz	-95 dB
		506 Hz	-104 dB
		549 Hz	-104 dB
		614 Hz	-101 dB
		635 Hz	-101 dB
		668 Hz	-105 dB
		711 Hz	-86 dB
		743 Hz	-109 dB
		786 Hz	-101 dB
		829 Hz	-106 dB
		894 Hz	-106 dB
		915 Hz	-115 dB
		958 Hz	-92 dB
Sennheiser e914 XY	https://drive.google.com/file/d/1O1tRB-89Q-jfH8veImLa17uMELUGjnlw/view?usp=share_link	161 Hz	-84 dB
		280 Hz	-71 dB
		366 Hz	-98 dB
		409 Hz	-89 dB
		463 Hz	-77 dB
		517 Hz	-69 dB

		571 Hz	-79 dB
		646 Hz	-96 dB
		711 Hz	-101 dB
		786 Hz	-104 dB
		851 Hz	-98 dB
		926 Hz	-103 dB
Samson CO3 XY	https://drive.google.com/file/d/1Nh_BanC6WmD5bAKOxFsI-NKjqAciOslh/view?usp=share_link	129 Hz	-93 dB
		194 Hz	-103 dB
		291 Hz	-98 dB
		388 Hz	-109 dB
		441 Hz	-103 dB
		506 Hz	-108 dB
		668 Hz	-110 dB
		732 Hz	-114 dB
		797 Hz	-115 dB
		894 Hz	-116 dB
		969 Hz	-118 dB
Rode NT2A XY	https://drive.google.com/file/d/1NpzxmF_kwfn72w4yBZVkE1GNu6zA8sXH/view?usp=share_link	129 Hz	-92 dB
		161 Hz	-91 dB
		205 Hz	-95 dB
		269 Hz	-69 dB
		323 Hz	-80 dB
		377 Hz	-103 dB
		452 Hz	-106 dB
		484 Hz	-97 dB

		538 Hz	-73 dB
		581 Hz	-87 dB
		657 Hz	-110 dB
		732 Hz	-102 dB
		797 Hz	-105 dB
		894 Hz	-116 dB
		937 Hz	-118 dB
Neumann TLM 103 XY	https://drive.google.com/file/d/1Ny0x_Q61SCBtJZCzUa7O51Q4PoH2NF1a/view?usp=share_link	194 Hz	-102 dB
		237 Hz	-98 dB
		291 Hz	-105 dB
		323 Hz	-108 dB
		366 Hz	-107 dB
		409 Hz	-116 dB
		474 Hz	-111 dB
		528 Hz	-117 dB
		581 Hz	-118 dB
		646 Hz	-113 dB
		711 Hz	-113 dB
		764 Hz	-119 dB
		807 Hz	-117 dB
		872 Hz	-116 dB
		969 Hz	-118 dB
AKG C414 B-TL II XY	https://drive.google.com/file/d/1NbsNMQMcGdvNdRW2Jva6_s67q0sMT-Gc/view?usp=share_link	129Hz	-84dB
		172 Hz	-87 dB
		205 Hz	-91 dB

		258 Hz	-100 dB
		291 Hz	-112 dB
		334 Hz	-102 dB
		398 Hz	-106 dB
		431 Hz	-108 dB
		484 Hz	-106 dB
		538 Hz	-113 dB
		571 Hz	-114 dB
		592 Hz	-116 dB
		624 Hz	-116 dB
		668 Hz	-118 dB
		700 Hz	-119 dB
		754 Hz	-117 dB
		818 Hz	-125 dB
		840 Hz	-121 dB
		851 Hz	-124 dB
		883 Hz	-127 dB
		915 Hz	-130 dB
		937 Hz	-129 dB

[redacted]			
Rode NT2A mono bidirectional	https://drive.google.com/file/d/1NtqLY8vI0pIjJBDYyvMw_phiN4GQfIBo/view?usp=share_link	129 Hz	-92 dB
		194 Hz	-83 dB
		269 Hz	-99 dB
		334 Hz	-84 dB
		388 Hz	-90 dB
		517 Hz	-113 dB

		581 Hz	-116 dB
		635 Hz	-125 dB
		668 Hz	-123 dB
		721 Hz	-116 dB
		797 Hz	-122 dB
		840 Hz	-123 dB
		915 Hz	-121 dB
AKG C414 B-TL II mono bidirectional	https://drive.google.com/file/d/1NfiLY32yimI8j-pjqW9Zu7Hdk3B9wJxc/view?usp=share_link	129 Hz	-81 dB
		205 Hz	-79 dB
		269 Hz	-60 dB
		312 Hz	-79 dB
		366 Hz	-86 dB
		452 Hz	-91 dB
		495 Hz	-77 dB
		538 Hz	-64 dB
		592 Hz	-82 dB
		635 Hz	-93 dB
		657 Hz	-95 dB
		700 Hz	-94 dB
		743 Hz	-99 dB
		829 Hz	-86 dB
		883 Hz	-112 dB
		915 Hz	-104 dB
		958 Hz	-102 dB
Samson	https://drive.google.com/file/d/1OA	151 Hz	-70 dB

CO3 mono bidirectional	926blpdoauXzw8vG7VTBNnxd7x7qXD/view?usp=share_link	226 Hz	-81 dB
		258 Hz	-82 dB
		301 Hz	-75 dB
		345 Hz	-86 dB
		398 Hz	-80 dB
		452 Hz	-88 dB
		517 Hz	-90 dB
		549 Hz	-93 dB
		581 Hz	-90 dB
		614 Hz	-89 dB
		646 Hz	-95 dB
		689 Hz	-90 dB
		786 Hz	-92 dB
		840 Hz	-98 dB
		904 Hz	-96 dB
		947 Hz	-102 dB
Rode K2 mono bidirectional	https://drive.google.com/file/d/1NwrGp3p6K8rnnGB-MWJlDE-hoE-x1yqz/view?usp=share_link	140 Hz	-90 dB
		194 Hz	-90 dB
		248 Hz	-91 dB
		301 Hz	-95 dB
		345 Hz	-95 dB
		388 Hz	-101 dB
		441 Hz	-101 dB
		484 Hz	-101 dB
		528 Hz	-105 dB
		614 Hz	-111 dB

		668 Hz	-114 dB
		700 Hz	-112 dB
		732 Hz	-110 dB
		764 Hz	-112 dB
		829 Hz	-117 dB
		861 Hz	-117 dB
		904 Hz	-119 dB
Sennheiser MKH30 mono	https://drive.google.com/file/d/1O18MPztpOqoBQCBXATa6TRR_ODE9iabk/view?usp=share_link	129 Hz	-80 dB
		161 Hz	-83 dB
		205 Hz	-96 dB
		237 Hz	-90 dB
		258 Hz	-90 dB
		291 Hz	-93 dB
		323 Hz	-91 dB
		355 Hz	-91 dB
		420 Hz	-98 dB
		441 Hz	-109 dB
		484 Hz	-93 dB
		538 Hz	-97 dB
		592 Hz	-104 dB
		624 Hz	-103 dB
		668 Hz	-95 dB
		711 Hz	-107 dB
		775 Hz	-102 dB
		807 Hz	-111 dB
		904 Hz	-107 dB

		937 Hz	-115 dB
Samson CO3 Blumlein	https://drive.google.com/file/d/1NpY2869alpY4LutVZkGgr9kW9gVfMlLs/view?usp=share_link	140 Hz	-93 dB
		172 Hz	-88 dB
		215 Hz	-97 dB
		301 Hz	-88 dB
		388 Hz	-90 dB
		474 Hz	-99 dB
		549 Hz	-103 dB
		581 Hz	-109 dB
		668 Hz	-105 dB
		797 Hz	-105 dB
		861 Hz	-104 dB
		926 Hz	-110 dB