# A STUDY OF MUSICAL INSTRUMENTS' ACOUSTICS IN SELECTED CHURCH AUDITORIA IN SOUTH-WESTERN NIGERIA

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**14/68BE001**

**A Ph.D. THESIS SUBMITTED TO THE DEPARTMENT OF THE PERFORMING ARTS, UNIVERSITY OF ILORIN IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY DEGREE (Ph.D.) IN THE PERFORMING ARTS.**

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**2020**

## CERTIFICATION

This thesis has been read and approved as meeting the requirements for the award of a degree of Doctor of Philosophy in Performing Arts in the Department Performing Arts of the University of Ilorin, Ilorin, Nigeria.

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## Declaration

This thesis entitled “A Study of Musical Instruments’ Acoustics in Selected Church Auditoria in South-Western Nigeria” is an original work and has not been submitted elsewhere for the award of any degree or certificate.

..... .....

Adekogbe, Olatunbosun Samuel Date

## Dedication

I dedicate this research to God Almighty, the provider and giver of good health and abundant life full of HIS Grace.

## ACKNOWLEDGEMENTS

My deepest gratitude goes to the Almighty God the giver of life, the Immortal, Invisible, the only wise God for the grace to accomplish this seemingly impossible task successfully.

To my supervisor, Professor Solomon Ikibe who painstakingly offered his time and knowledge to critically contribute to this work, his scholarly impartation, brotherly advice and care towards this work are hundred percent invaluable. I will forever be grateful unto you and I pray that the peace of God which passes all human understanding will continue to be with you and your family forever.

My inhibited appreciation goes to my push-full and vibrant former Head of Department, Professor AbdulRaheed Adeoye for his encouragements at every stage of study, not only that, i am also very satisfied with administrative prowess, constancy and above all, his friendly but strict relationship with students. I pray that the mercy of God will always go with you and your house.

I will also like to thank Dr. 'Segun Oyewo who was the Postgraduate study coordinator when I started this programme, your encouragement both in Ilorin and Ife had been very helpful. My sincere thanks also go to Dr. Peju Shuaib, the Postgraduate study coordinator, for her friendly relationship and vibrancy in coordinating the affairs of the Postgraduate study in the Performing Arts Department. I equally thank Professor Austin Emielu for his friendship relationship and academic comradeship.

To other lecturers in the Department, Professor Ayobami Akinwale who was the Dean, Faculty of Arts when I was admitted for the Doctoral study, Professor Ziky Kofoworola (Retired) who took special interest in me, Dr. Jeleel Ojuade, Dr. Dolapo Ojediran, Dr. Tayo Arinde, Dr. Taiye Adeola, Mr. Shina Adegbite who has been my friend in Bauchi during our National Youth Service Scheme, Mr. Felix Akinsipe, Mr. Abdulmalik Amali, Mr. Kehinde Olalusi, Mr. Taiwo Olalusi, Mr. Kazeem Rufai, Mr. Femi Atteh and all the non-academic staff for their contributions both directly and indirectly to the success of this work, you are all deservedly appreciated.

Special thanks to my colleagues in the Department of Music, Obafemi Awolowo University, Ile-Ife, former Dean of the Faculty of Arts, Professor Gbemisola Remilekun Adeoti, current Dean of the Faculty of Arts, Professor O.M.A. Daramola, the immediate past Head of Music Department, Professor Femi Adedeji, our father in the Department of Music, Professor 'Yemi Olaniyan. I also want to thank Dr. Myke Olatunji, the current Head, Department of Music, Dr. 'Femi Abiodun, Dr. 'Segun Titus, Dr. Victor Ajayi, Mr. 'Tayo Omosilade, Mr. 'Dele Omolaye and Mrs. Mary Omotosho. I equally appreciate all the

Non-Teaching Staff of the Department of Music, Obafemi Awolowo University, Ile-Ife. My appreciation goes to Mr. Alemede Emmanuel for his moral support.

My Special gratitude goes to Professor EfereObuato for his financial assistance at the troubled moments of this research. I also express my sincere gratitude to my friend and brother from another mother, Mr. Elijah AdebiyiIjaola, for his moral, financial and spiritual contributions to the success of this research. I thank all the Ministers of God, the congregations, the choir and the sound engineers in all the selected church auditoria in south-western Nigeria.

To my wife, Barrister Olubunmi Adekogbe and my two wonderful daughters; Peculiar Adekogbe and Pleasant Adekogbe for enduring my absence, unusual nagging and sometimes denials of certain financial and social requests which I couldn't meet up with during this research. I love you all. Thanks so much.

## ABSTRACT

Exposure to excessive sound volume has been a major challenge to grapple with in church auditoria in Nigeria. This exposure to excessive sound has become a source of noise pollution and it is dangerous to human health. To control the noise pollution being experienced, this study, therefore, examined musical instruments' acoustics in selected church auditoria in South-western Nigeria. The objectives of the study were to: (i) examine the congregants' perception of musical sound in selected church auditoria in South-western Nigeria; (ii) establish the factors that determine good and bad musical sound; (iii) measure the volume of musical sound in relation to the church auditoria; (iv) assess the level of sound decibel (dB) perceived at each worship service; (v) investigate the acoustic parameters of each church auditorium;and (vi) evaluate the acoustical treatment of the various church auditoria.

This study adopted descriptive research method using the quantitative and qualitative designs. The tool for data collection were participant-observation, oral interviews and questionnaires on church congregants, pastors, choristers and sound engineers. The study population comprised eleven interviewees, and 959 questionnaires in six churches – three Orthodox and three Pentecostal – using A4DaTuner to measure the sound pressure level in each church auditorium. The Place Theory of Sound Perception (PTSP) by Bekesy (1928) was applied in the study as the theoretical framework.A simple percentage was used to analyse the data.

The findings of this study were that: -

(i) 100% of the congregation perceived musical instruments' acoustics as sound for praising and worshipping God;

(ii) the representation of good (89.57%), bad (7.63%) andrelative (2.8%) of musical instruments' acousticsin relation to Sound Clarity(SC), Sound Pressure Level(SPL), Reverberation Time(RT)} and Auditorium Acoustic Parameter(AAP) were obtained;

(iii) the musical sound volume in five auditoria with (83.33%) did not take the sizes of the auditoria into consideration while one with (16.66%) did;

(iv) the average sound decibels of 98dB were recorded in all the selected church auditoria which is higher than the recommended 60dB for normal human hearing by the World Health Organisation (WHO);

(v) using the acoustic parameters such as acoustic floor tiles, wall tiles, wooden-roofing materials and sound absorbers; one church auditorium with (16.66%) of the selected auditoria was acoustically treated while the other five with (83.33%) were not; and

(vi) The acoustic treatment of five with (83.33%) of the selected church auditoria were not adequatefor the high volume of musical sound output while one with (16.66%) was adequate.

The study concluded that there was excessively high volume of sound which has been the order of church worship sessions resulting into physical and emotional disturbances of the congregants and the environment in South-western Nigeria. The study recommended that minimal musical instruments' acoustics volume of 60dB as suggested by WHO be upheld to set acceptable optimal standards for sound production in church auditoria. This should be appropriately legislated by the Federal, State and Local governments, while the congregants also be adequately educated to reduce the hazards of noise pollution.

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# CHAPTER ONE
# GENERAL INTRODUCTION

## 1.0 Background to the study

Musical instruments acoustics is concerned with how musical sounds are generated, transmitted, received and perceived. This study on musical instruments' acousticsin purposively selected church auditoria in South-Western Nigeria examines how musical instruments are commonly received, perceived and translated in accordance with how each musical instrument produces sound. In this connection, discussions on acoustics as the science of musical sounds, its impact on church auditorium and the human hearing sensations form the basis for this study. Connecting musical instruments acoustics to its practical uses in church auditoria, coupled with other activities such as liturgical and emotional values in worship services. In a worship situation, the Clergy, the congregation and the choir engage in interaction and inter-action through the emanating musical sound inside the church auditorium.

Although, musical sound is heard every day and night, either willingly or unwillingly but, the understanding of its productions, transmissions, perceptions and interpretations are not usually considered important. Besides, the socio-cultural phenomenon of sound especially, with high wattage of volume is also of great concern to this study, more so that musical instruments sound relates with human in a particular cultural environment where such sound is produced and directly absorbed in all manners of low, middle and high frequencies. Previous researches by scholars such as Daramola (2009) had focused on digital sound production, Adedeji (2012) on human voice production and Olaniyan (2007) on sound production of the Yoruba Dundun ensemble but, this area of research on musical instruments acoustics in worship auditoria has not been attended to in those researches, this study intends to take up the place of the missing knowledge.

In the area of musical instruments production, reception and perception, through the knowledge of acoustics and psychoacoustics of music, certain questions such as: (i) what are the challenges of musicologists, church musicians and performers of music in this century with regards to the issue of acoustics? (ii) What is the congregation's perception of good and bad

musical sound? It is on this premise that this research is intends to bridge any existing gap in musical instruments acoustics and church auditorium acoustics to purposively reconcile the two vital elements of worship in order to reduce, if not completely eradicated, the effects of loud musical instruments sound on the human health.

## 1.1 Statement of the Study Problem

The exposure to excessive sound volume has been a major issue to grapple with in church auditoria during worship services. This exposure to excessive sound has become a source of noise pollution and dangerous to human health.Musical instruments produce basically sound and sound is produced when an object is made to vibrate, causing ripples or longitudinal waves which can be calibrated in frequencies. These vibrations reach the ear and decoded by human brain as musical instruments sound. With technological inventions, sound reinforcement equipment was developed which convert electrical energy to acoustic energy and amplified through amplifying sleeve engines and speaker systems to get to a larger audience as the practice in modern church auditoria in south-western Nigeria.

Sound reinforcement system has both positive and negative values considering that the human ear has hearing limitations between the threshold of hearing to the threshold of pain when the human ear can no longer be comfortable with certain decibels sound. Since Church auditoria are built without consideration for wattage of sound volume and room volume equivalence of the sound producing environment because, every room has a specific volume of sound it can carry and any musical instrument sound produced beyond this volume endangers human health and structural condition of the auditorium because of the impact of that excessive sound volume. Musicologists and performing artists should be more concerned with proper control of sound of musical instruments in church auditoria in order not to endanger the lives of worshippers and worship auditorium. However, certain questions about sound interactions between the listeners, musicians and the acoustics condition of church auditoria are raised to guide this study; these questions are stated in the research questions in 1.3.

## 1.2 Aim and Objectives of the Study

The aim of this study is on musical instruments' acoustics in selected church auditoria in South-Western Nigeria. The specific objectives of this study are to:

i. examine congregation perception of musical instruments sound;
ii. establish the factors of good and bad musical instruments sound;
iii. measure the volume of musical sound in relation to the size of the selected church auditoria
iv. investigate the acoustic parameters of each church auditorium;
v. determine the level of sound decibel (dB) perceived at each worship service and
vi. ascertain the acoustical treatment of the various church auditoria.

Through this research therefore, possible suggestions and recommendations were made to the church governing council on the need to consider all necessary factors in the building of worship auditoria and the three levels of government in Nigeria in order to preserve health of the congregantsand other worshippers during worship sessions.

### 1.3 Research Questions

The following questions will guide us in his study:

i. How has the church congregation perceived musical instruments acoustics?
ii. What actually represents a good and bad musical instruments acoustics?
iii. Is the musical instruments sound production in consonance with church auditorium volume?
iv. Are church auditoria acoustically featured?
v. What is the level of sound decibel (dB) perceived in the selected church auditoria?

### 1.4 Justification for the Study

Exposure to excessive musical sound in most church auditoria is recently a major cause of hearing disorders and other health challenges in Nigeria. Considering the daily or weekly time spent in churches with participation in or on listening to musical sound production through praise singing without a proper musical sound volume control. In this connection, Nagata (2001, pp. 34-48) in his discussion argues that 'loudness' syndrome has encroached into religious worship

centres with the heavy wattage of sound blaring from Hi-fi equipment in churches, especially the modern Pentecostal churches since the 1990s. There seems to be also a ‘war’ of sounds in churches today to win more converts or show superiority over their ‘less endowed’ colleagues without considering audience size and other implications for architectural and environmental acoustics. Nagata’s submission only discussed the loudness syndrome but, not how musical instruments sounds are perceived. Also, Schaffer (2005 p.65) discusses musical instruments sound’s loudness as related to power as dependent on amplifying equipment with volume controls but did not discuss the perception of such musical instruments sound by the hearers.
Emielu2013 (pp. 45-56) asserts as follows:

> Sound is considered noisy when it is played at excessive volume with distortion of pure signals. It then becomes unpleasant to the human ear. A major distinction between sound and noise is that sound is regarded as noise when it becomes a source of inconvenience to the conveniences of man and animal. Noise pollution is not unique or peculiar to developing countries alone; it is a common occurrence and of highest magnitude in most of the advanced countries.

Complimenting Emielu’s position, Fletcher 1991 (p. 20) writes on the volume level situation between intensity and loudness of musical sound, his argument is basically that the relationship between the two is linear and analogous and with this linear status, it is most likely to affect how such sound is received and finally perceived.Oyedepo and Saadu (2010: pp. 563-577) write that:

> almost everyone has had one experience of being temporarily "deafened" by a loud noise”. This "deafness"though,not permanent, but, it often occurs by a sound in the ears, and this could be heardby another person. In the same manner, the human ear returns to normal after few hours to the sound perception. This shift in normal human ear is referred to as temporary threshold shift.

For many years as a church musician, my argument has always been on the need to adequately improve the acoustics nature of church auditoriums in order to meet the evolving challenges of loud sound production in this century.

There is the need to take into consideration what wattage of sound any room can accommodate? It is unfortunate that sound amplifying systems are installed in churches with several loud speaker's systems are set up in the church without proper acoustic consideration of the sound producing environment but, for the purpose of using musical sound as a strategy to call attentions of people to believe that such church has moved to another level of worship and high praises. This is done without any consideration for the effects of high volume of musical sound on the immediate environment of the church location.

Nagata (2001: p.5) in his discussion argued that 'loudness' syndrome has encroached into religious worship centres with heavy wattage of sound blaring from Hi-fi equipment in churches, especially the modern Pentecostal churches since the 1990s. There seems to be also a 'war' of sounds in churches today as a results of persistent high volume of musical sound, this practice is used as a bait to win more converts or show superiority over the 'less endowed' surrounding churched without considering audience size and other implications for architectural and environmental acoustic factors. In some of the church services attended as part of the data collection for this research, it was found out that any attempt to reduce the volume of music or the preacher's microphone was usually met with vehement resistance and sometimes open confrontation between the sound engineer and the pastor or church musicians.

Ochuko (2013: pp. 470-476) in his investigation of the amount of noise generation in selected industrial places in Benin City, Nigeria recorded that: "the average decibel of noise generation in Sawmills, Electro-acoustic market and food processing industrial locations resulted into 90dB". It can be observed from the examples above that, there is very little research if at all, on musical instruments' sound volume especially, in church auditoria. It is on this premise that this study is conducted to

proffer possible ways of resolving problems arising from loud musical instruments' sound acoustics in selected church auditoria in South-Western Nigeria. It is of a great concern and worrisome, the wattage of musical sound Nigerian church worshippers are exposed to when measured in decibels and the pitch at which the musical sound emanating from church auditoria are dangerous to human health.

### 1.5 Scope of the Study

The scope of this research covers the study of musical instruments'acoustics in selected church auditoria in South-western Nigeria with focus on the Cathedral Church of Saint Peters, Ake in Abeokuta, Our Saviours' Church in Ikenne and Dominion Center Church, Ile-Ife, Celestial Church of Christ, Akobo Ibadan, Iyeru Okin African Church Offa and The Redeem Christian Church of God, Ilesa. Concentration was on the of musical instruments' acoustics of these selected church auditoria. This study considered musical instruments acoustics to be a source of noise especially, when it is played at excessive loud volume with distortion of pure sounds that becomes unpleasant to the human ear and poses danger to the health of the worshippers. A major difference between musical sound and noise is when musical instruments' sounds' volume is greater than the room volume where such musical sound is produced. However, this study would only limit its scope to the selected church auditoria in South-western Nigeria.

### 1.6 Significance of Study

The need to embark on this research stems from the fact that several investigations have been previously done by researchers and scholars such as such as Daramola and Adekogbe (2010, pp. 65-76) in the area of sound and acoustics with focus on music in analogue and digital recording studios, music production in concert and theatre halls, and emphasis on sound production. Also, Airo, Olkinuora and Pekkarinen (1996. pp. 82–89) in the area of the usage of headphones volumes at normal loudness to avoid partial deafness and to also allow for an individual to be able to hear oncoming traffic or pay attention to environmental factors in one way or the other. Senturia, Marcus and Lucente (1980, pp. 23-32) have also researched on the "minimum acoustic pressure audible to the young human

ear adjudged to be in good health to be ‘approximately 20 ×10−6 Pa”. The studyconsidered loud music from headphones applicationas one of thegeneral dangers caused by the users and can lead to dangerous health situations.

The perception of musical instruments sound productions and the acoustics conditions in church auditoria have been neglected. This research intends to fill this gap and set a research template for sound production in church auditoria because church auditoria nowadays have become another avenue for musical sound production with a high concentration of high wattage of sound volume and also suggests possible solution to sociological problem of war of sound in church.

## 1.7 Research Methodology

Field work is very critical to a musicological research; hence this investigative research is being conducted in the south western and north central Nigeria especially Abeokuta, Ikenne, ile-ife and Ilorin where identifiable church auditoria suitable for the research were located. Church auditoria outside the purposively selected cities were also observed for the purpose of gathering materials for this research. The research rests principally on participant observation, oral interview of acousticians and administration of questionnaire on congregation perception of good and bad sound within the church auditoria. The relevant materials for review includes oral interview, literary publications, articles, academic journal, review of publications at seminars and workshop on music technology, acoustics and psycho-acoustics of sound, and music production.

There are ten identified church auditoria in south western Nigeria, five Orthodox and five Pentecostal churches. Six of these church auditoria were purposively selected and considered for this research based on musical practices and the structure of these church auditoria. The research rests principally on participant observations, oral interview of selected experienced sound technicians, experts from the Ear, Nose and Throat (E.N.T) and the application of questionnaires to probe the effects of high wattage of musical instruments sound on human ear. Other relevant materials were sought for from the internet, libraries and archives, articles from published journal, books, newspaper, magazines and periodicals. In order to get to an accurate judgement,

measurements of church auditoria volume in conformity with decibel (dB)of musical sound emanating from the selected auditoria, devices such as Sound Meter dB and A4 DaTuner were applied for sound measurement and expression of finding in frequency (*f*) and decibels (dB).

The data collected were empirically analysed using qualitative and quantitative methods through the description of finding and calculations of decibels of sound in each sound measurement per church auditorium and the summation of all sound measurements to arrive at the cumulative percentile number of decibels in each of the selected church auditoria m to arrive at the study findings.

## 1.8 Limitation of Study

The study experienced certain constrictions. First is in the area of non-willingness of the worshippers to grant audience for interview and filling of questionnaires. The second factor is the lack of understandings of musical instruments acoustics among the congregants. The third factor was the difficulty faced at the initial stage of the research to convince the congregants to accept the fact of the health hazards attached to loud musical instruments sound because most worshippers are used to high wattage of musical instruments sound productions during worship sessions. Also, the attitudinal problems of the selected people, such as sound engineer, pastors/clergies and members of the praise band, for interview almost resulted into making the research impossible. Lastly is the limitation of the worshippers' understanding of loud musical instruments acoustics' phenomenon. The study is however limited to the study of musical instruments' acoustics in selected church auditoria in South-Western Nigeria.

## 1.9 Operational Definition of Terms and Concepts

The need to define certain registered words in this study is imperative. Such terms and concepts as applied in this study are defined in order to remove ambiguity and to channel proper interpretations and und eventual understandings of these operation terms and concepts. These are as stated below:

**Auditorium Acoustics**

Auditorium in this context refers to a big hall used for lectures, conferences, workshops and worship purposes while acoustics is referred to as sound generation, its transmission, reception and perception. Auditorium acoustics is used as a broad term to describe how sound behaves with relatives to sound waves and how it interacts within a particular closed or opened sound producing environment. Mostly, each auditorium acoustics will react to all the objects within it differently and to different frequencies of either musical or speech sound.

**Brass Acoustics**

Brass musical instruments are classified into such musical instruments as the B-flat Trumpet, Trombone, Euphonium, Tuba, B-flat Horn and French horn. Brass acoustics are therefore related to how brass musical instruments generate and disseminate musical sound.

**Keyboard Acoustics:** Keyboard musical instruments are classified as all musical instruments using a keyboard which are operated by the human fingers. Most common among these are the piano, electronic organ and pipe organ but excluding synthesizers and digital pianos. Keyboard acoustics therefore has to do with how these musical instruments produce sound in high, middle and lower pitches within a particular sound producing environment.

**String Acoustics:** The properties of the vibrations of string are fundamentals of its acoustics. These two are produced simultaneously. However, these frequencies depend so largely on the length and tension of the strings to produce acoustically desired musical sound. Musical instruments in this category are Violins and Guitars.

**Wind Musical Instruments Acoustics:** Production of sound in wind instruments rests wholly on the focusing air into the mouth piece that causes the vibrations of the reed to produce sound by placing the lips on the ligature.

However, the application of definition of terms in this study applies to musical instruments acoustics as related to the selected church auditoria in terms of production, the process of musical acoustics as practiced and produced in the selected church auditoria and the acoustics of each church auditorium with regards to the size of the auditorium and the wattage of sound emanating from such.

# CHAPTER TWO

# REVIEW OF LITERATURE

## 2.0 Introduction

Relevant materials for review in this study include information from the internet, archival studies, and articles in journals, magazines, newspaper reports, related books on musical instruments acoustics and musical sound productions. Considering the importance of musical activities in a worship session especially, in church auditoria, Riedel (1983, pp. 24-28) states that in worship spaces, music is solely taken as a fundamental aspect of worship. This shows that acoustic treatment of any sound producing environment must be considered important during the design process of any church auditorium in order to allow for a better perception of musical sound productions, more so that variouschurches have diverse ways of worship which are either indigenous or western in nature. Furthermore, Yoichi and Dennis (1995, pp. 94-105) are of the opinion that "the need to sing or pray together on a special day in a Korean temple brings worshippers together in the front courtyard of the main worship building rather than sitting inside the building". It is therefore, apparent that the main function of a temple in Korea is not always the case in all worship auditoria; this is to convince that requirements for acoustic parameters of an auditorium is determined by the usage purpose of the space. From Yoichi and Dennis discussions above, it is important to note that these requirements have changed because of the change in the church auditoria architectural understanding and musical orientation in this modern century. It is therefore, needed to comprehend the needs for acoustic treatment of an auditorium design as a foundation for acoustical requirement and treatments needed to enhance good musical instruments acoustics within such worship environment.

## 2.1 The Goals of Appropriate Acoustical Design of Church Auditorium

Although, musical activities during a church worship session requires good and active communication between the choir and band members and the worshippers. It requires that every

worshipper is respected, not only as worshippers but, for good musical conversation with one another. The ultimate aim of any worship service is not only to preach the word to the congregants but, also to worship God with hymns and praises and it is necessary to produce sufficient volume but, not excessive, of musical sounds such that could be heard at every sitting position within the worship auditorium. Musical instruments'sound should be heard properly and not deficient in some manners acoustically, the participants may feel a sense of alienation as observed by Riedel (1983, p. 22) that:

> every worshiper in the church service must be in an equal acoustical position, because everyone is equal in the house of God. It is therefore pertinent to say that all the angles within the church auditorium should be vantage positions where worshippers can hear and participate in musical activities during worship sessions.

Despite the fact that the type of musical instruments and sound equipment usedfor musical practices in church auditoria rest on the liturgical, theological, doctrinal and mode of worship of each church denomination, the location of the praise band, the choir, and the worshippers need to be considered accordingly. Acoustic Sciences Corporation Magazine (2002, p. 23) notes that:

> the general consideration for the music performing group is to produce musical instruments' sound that travels through entire worship auditorium in order to afford the worshippers to hear musical instruments sounds as produced, otherwise members feel like they are singing only into the air.

Listeners in any church auditorium have a dual function as musical instruments sound receivers and also as sound sources because both the instrumentalists and the singers partake in the worship songs. Berry and Kinzey (1954, p. 331) posit that worshippers, doubled as sound producers and receivers should perceive musical instruments sound and songs as produced. This musical instruments sound perceptive challenge affects reactions to such worship and the musical instruments sound which depend largely on the final sound production output, either from the main speakers or surround speakers as positioned within the church auditorium. The

principle of musical instruments sound and acoustics design of church auditoria are to provide good musical communication among instrumentalists with support from the congregation to aid all possible musical interactions with each other in a worship session. D'Antonio (2005, p.8) posits that where these interactions lack, there is the possibility of communication distortion and lack of congregational perception of musical instruments sound which may result into a conflict of musical instruments sounds. Figure 1, as provided by D'Antonio (2005, p.8) expresses the desired position of the pipe organ, the choir, the console and the preacher all facing the congregation as sound receiver.

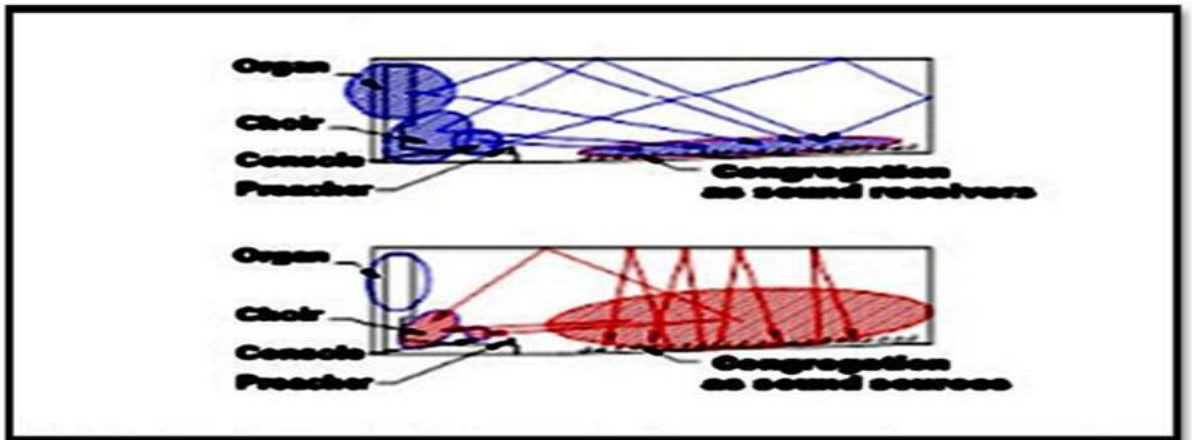


Figure 1: Interaction of sound sources in a church auditorium. (D'Antonio (2005, p.8)

It could however, be observed from the two styles of arrangements that the congregation is always at the receiving end of the produced sounds, either musical or speech in any church auditorium during any worship session. This study is so much concern about what effect has this on health of the congregants in the identified and especially the selected church auditoria in south western Nigeria.Church auditoria in recent times have several categories of purposes as a result of liturgical styles of each church. These purposes are specifically aligned to the structure of the church auditorium. For example, Cathedral churches in terms of structure gives considerations for the organ sound, singing of the Gregorian chants, the Tedium, the Canticles and the Gloria because these worship musical styles form the basis of worships.

On the contrary, Lubman (1983, p.389- 402) writes that "evangelical churches may have a large volume as a cathedral but contemporary Gospel music are usually played using an electronic organ, guitar and digital drum sets". Church auditoria are used for different purposes;

church auditoria are no longer used only for worship but, also for many other events like Sunday school, religious gathering, and recreational purposes, theseactivities require another acoustic condition to make it well functional apart from being used for worship activities.

## 2.2 Loudness of Musical Instruments Sounds

Generation of overtones are created by any musical instruments sound emanating from any acoustic condition. This happens as theconsequence of reverberation of sound undulating motion from hindrances which returns to sound generation point. Greene and Porcello (2005, pp. 12-25) submit that reverberation accounts for the reason why human ear perceives the fundamental sound from the source of musical instruments and its several reverberations from reflectiveouter part. Green and Porcello further gave an illustration to buttress this submission as provided in figure 2:

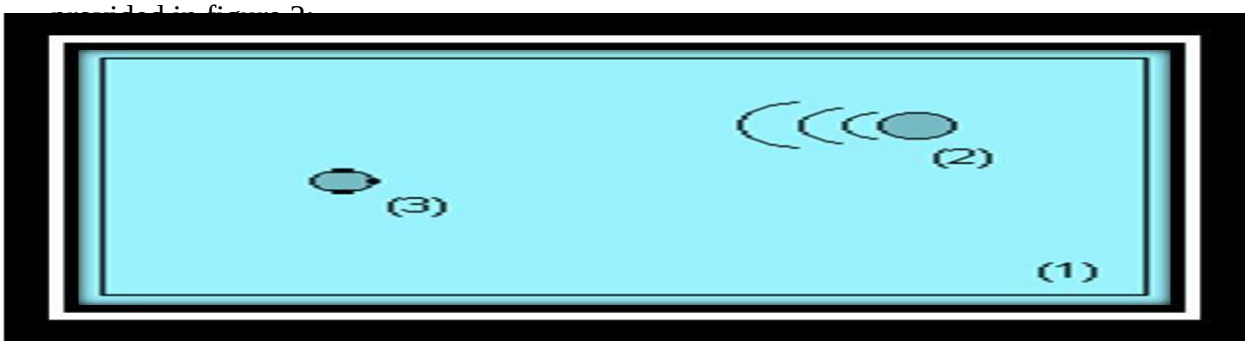



Figure 2:Source of an acoustic sound and its several reflections (Green & Porcello:2005, p. 16)

In the above illustration, Green and Porcello assume (2) to represent the signal of sound and (3) the listener in a particular sound producingenvironment, representing (1) to be the sound source where an application of a short sound impulse is made to the intense manner of musical instruments sound from the source as at the time of production to perception by the human ear.

Thèberge (1997, pp. 84-102) in his comments observes that “the direct signal (sound) with the highest intense manner of sound comes first, then the primary reflections from floor, ceiling and the walls with lower intensity as depended on the length and the properties of the materials”. Thèrberge’s submission reflects that this speed of such sound is seconded by several other sound reflections that are rapidly reducing itsquality. Similarly, Ballon (2000, pp. 45-65) asserts that “in a real situation, musical instruments sound impulses are lengthier than the time of

arrival of first reflections, that is why reverberation, in terms of loudness, is superimposed on a source sound". Michael and Andrew (2016, pp. 3229 3239) also write that:

> in a case of a natural reverberation of acoustic property of a room, frequency spectrum is expected to change. High frequencies fade faster than lower frequencies; this is the reason why a timbre of the reflected sound is softer and more muted than of the original one.

Room volume is a vital element that determines loudness of musical instruments' acoustic and this is premised on the worship style with the number of participants. The pre-research investigation has established that Roman Catholic church auditorium requires anextended reverberation time than Pentecostal church auditoria because of mode of worship that is based on Gregorian chants as contrary to more of praises and worships in the Pentecostal churches. Also, Malecki (2014, pp. 151-155) in his work on auralization of several churches and listening comparison, notes that "Roman Catholic churches need a very big volume than contemporary churches" because of the nature of building structure and the style of worship services, more so in auditorium acoustics where the congregation is the major sound absorbing element which also requires that "as the number of participant increases, the room volume should be increased relatively in order to achieve the ideal musical instruments loudness". This factor was never noticed to have been considered in the Nigerian church auditoria structural design; rather concentrations are on the auditorium beautification and aesthetic values which are reflected in the altar backdrops, tilled floor and beautiful plastic chairs which are considered as sound reflectors rather than absorbers.

### 2.3 Musical Instruments Acoustics Perception in Church Auditoria

Musical instruments' acoustics are produced by tremblingmaterials which include musical instruments and musical equipment such as loudspeakers, microphones and mixer consoles and of course, the human voice. Vercoe (1997, pp. 307-326) observes that:

> the mechanical vibrations of these objects travel in the immediately adjacent direction of the air to those vibrating objects. Each back-and-forth vibration produces a corresponding

sound pressure level (SPL) and pressure decrement level (PDL), otherwise known as rarefaction, in the air.

This suggests that a wholeforce that pushes the sound to change occurs when the air pressure goes from zero to maximum, then to minimum, and back to zero again. The cyclic change of pressure, according to Meddis and Hewitt (1991, pp. 2883-2894) is that "sound travel outward from the vibrating object, forming a pattern called a sound wave which is a series of pressure changes moving through the air''.

Writing on perception of sound, Gaver (1993, pp. 285-313) writes that "sound perception is subjective, loud sound is equally relative because sound considered loud to one individual might not be loud to another individual". In line with Gaver's position, Glasberg and Moore (2000, pp. 82-98) write that "there are different models of loudness applicable to time-varying sounds". A situation experienced by the researcher has equally shown that human beings perceive sound differently, this was observed in a worship service at Gospel Faith Mission Church, Ile-Ife where a particular musical sound has caused a discomfort to one of the ministers and at the same time served as a tool for enjoyment to another minister under the same musical instruments sound producing environment. In this situation, the emanating loud musical sound has caused one of the pastors to vomit thrice during the said service, at the end of the service; the host pastor suggested what it will cost the church to retain that same sound equipment because he has enjoyed every bit of the loud musical instruments sound productions. Also, to affirm this sound annoyance, Geoff, Leventhall and Benton (2003, p. 28) establish that high wattage of musical sound can cause nausea, headache and dizziness. Complimenting this fact, Guski (1999, pp. 45-56) proposes that "noise annoyance is partly due to acoustic factors and partly due to personal and social moderating variables".

Moreover, Benade (1990, pp. 531-535) maintains that "sounds are perceived through hearing, hearing is achieved through the ear and the ear has a threshold of what volume of musical instruments sound it can accommodate. Any sound beyond what the threshold of human

ear can take is considered as dangerous to human health". On this note, Ighoroje, Marchie and Nwobodo (2004, pp. 9-14) assert that:

> Sound is considered noisy when it is played at excessive volume with distortion of pure signals. It then becomes unpleasant to human ear. A major distinction between sound and noise is that sound is regarded as noise when it becomes a source of inconvenience to the conveniences of man and animal. Noise pollution is not unique or peculiar to developing countries alone; it is a common occurrence and of highest magnitude in most of the advanced countries

In another subject relating to the perception of musical instruments sound, Smith (1997, pp. 227-262 observes that "sound perception in terms of combination of tones especially, when two tones that are close in frequency are played at the same time; beats generally are heard at a rate that is equal to their frequency difference". In other words, when the frequency difference exceeds what the human ear can tolerate, the beat sensation disappears and musical tone roughness appears and this is when musical sound turns to noise. Schaeffer (1997, pp. 265-288), as captured by the Place Theory of Sound Perception (PTSP), is of the opinion that "the sound processing performed by the ear and the brain is extremely complex, and difficult because it involves subjectivity of hearing, listening, understanding and comprehension of musical sounds".

## 2.4 Basic Concept of Musical Instruments Sound Perception

Sound is produced by trembling objects. These include musical instruments, musical equipment such as loudspeakers microphones and the mixer console, and, of course, human vocal cords. Vercoe (1997, pp. 307-326) observes that "the mechanical vibrations of these objects move the air which is immediately adjacent to them, alternately "pushing" and "pulling" the air from its resting state". Each back-and-forth vibration produces a corresponding compression (pressure increment) and rarefaction (pressure decrement) in the air. A complete pressure change, or cycle, occurs when the air pressure goes from rest, to maximum, to minimum, and back to rest again. Meddis, & Hewitt (1991, pp. 2883-2894)consider these "cyclic

pressure changes to travel outward from the vibrating object, forming a pattern called a sound wave which is a series of pressure changes (cycles) moving through the air".

On the concept of sound perception, Gaver (1993a, pp. 285-313) writes that "sound perception is subjective, loud sound is equally relative because sound considered loud to one might not be loud to another". In line with Gaver's position, Glasberg and Moore (2000, pp. 82-98) writes that "there are different models of loudness applicable to time-varying sounds". A situation experienced by the researcher has equally shown that human perceives sound differently as observed in a worship service in Ile-Ife where a particular musical sound has caused a discomfort to one and at the same time served as a tool for enjoyment to another in a situation where the emanating loud musical sound has caused one of the pastors to vomit thrice and at the end of the service, the host pastor suggested retaining that same sound equipment for the church because he has enjoyed every bit of the loud musical sound productions. Moreover, Benade (1990, pp. 531-535) maintains that "sounds are perceived through hearing, hearing is achieved through the ear and the ear has a threshold of what volume of sound it can accommodate. Any sound beyond what the threshold of human ear can take is considered as noise". On this note, Ighoroje, Marchie and Nwobodo (2004, pp. 9-14) assert that:

> Sound is considered noisy when it played at excessive volume with distortion of pure signals. It then becomes unpleasant to human ear. A major distinction between sound and noise is that sound is regarded as noise when it becomes a source of inconvenience to the conveniences of man and animal. Noise pollution is not unique or peculiar to developing countries alone; it is a common occurrence and of highest magnitude in most of the advanced countries.

In another subject relating to the perception of musical sound, Smith (1997, pp. 227-262) observes that:

> sound perception in terms of combination of tones, when two tones that are close together in frequency are sounded at the same time, beats generally are heard at a rate that

is equal to their frequency difference. In other words, when the frequency difference exceeds 15 Hz, the beat sensation disappears and musical tone roughness appears and this is when musical sound turns to noise.

Schaeffer (1991, pp. 265-288) is of the opinion that "the sound processing performed by the ear and the brain is extremely complex, and difficult because it involves subjectivity of hearing, listening, understanding, comprehension of musical sounds".

## 2.5 Sound Systems in a Worship Auditorium

It is fundamentally necessary that sound systems have to put in a worship auditorium. These systems are usually for the purpose of amplification of natural sound as used during each worship session. This is applied for the purpose of, according to Carvalho and Silva (2010, p. 146)"achieving variable acoustics of the space". In this regard, attention is directed on how the sound systems communicate with the auditorium's innate acoustics, rather than the beauty of the of the design of the loudspeakers and other sound sources. In this connection, Carvalho and Silva (2010, pp. 145-156)writes that"a consideration of two different types of loudspeaker to be installed in an auditorium; one is the traditional Public Address Systems (PAS) intended for the modification of the early part of the impulse response of the hall, and two, the reverberation-enhancement systems intended for modification of the later part".

Normally, public address sound systems are available for the purpose of capturing a wider area beyond the main auditorium, in this connection, Engel and Kosala (2005, pp. 173-181) write that:

> the most important technical specification for Public Address System (PAS) loudspeakers relates to their directivity, either in terms of vertical and horizontal radiation angles or in terms of directivity index factor to produce the amount of intensity emitted in the axis direction of the directive loudspeaker, and the averaged intensity emitted by the same loudspeaker integrated over all directions. When loudspeakers are placed in a room, the sound field close to the loudspeaker will be dominated by the direct sound, whereas at longer distances, this component is negligible compared to the (diffuse) reverberant sound.

Most of the sound sources observed in worship places are specifically for speech but not really for vocal music and a variety of other musical instruments. With the fact that human voices may be female or male, vociferous or gentle and available musical instruments might be range from simple acoustic guitar to a pipe organ or even to other brass and woodwind instruments. Pre-recorded accompaniment is also very common which are often played before the commencement of a worship service. In addition to these desired sound sources, there may be other certain undesired sound generations in and around the church auditorium, undesired sound such as noise from the installed air conditioning, other noise sources from vehicles become a problem just like when the pipe organ overpowers the choir. Berard (2014, pp. 1-16**)** considers the loudspeakers as "desired sound source for the congregation, but they can become an undesired source for microphone pickup through which feedback (an annoying howl or ringing sound) can occur in a sound system if microphones admit too much of the loudspeakers". The template of a desired location of musical instruments and equipment is expressed in figure 3:

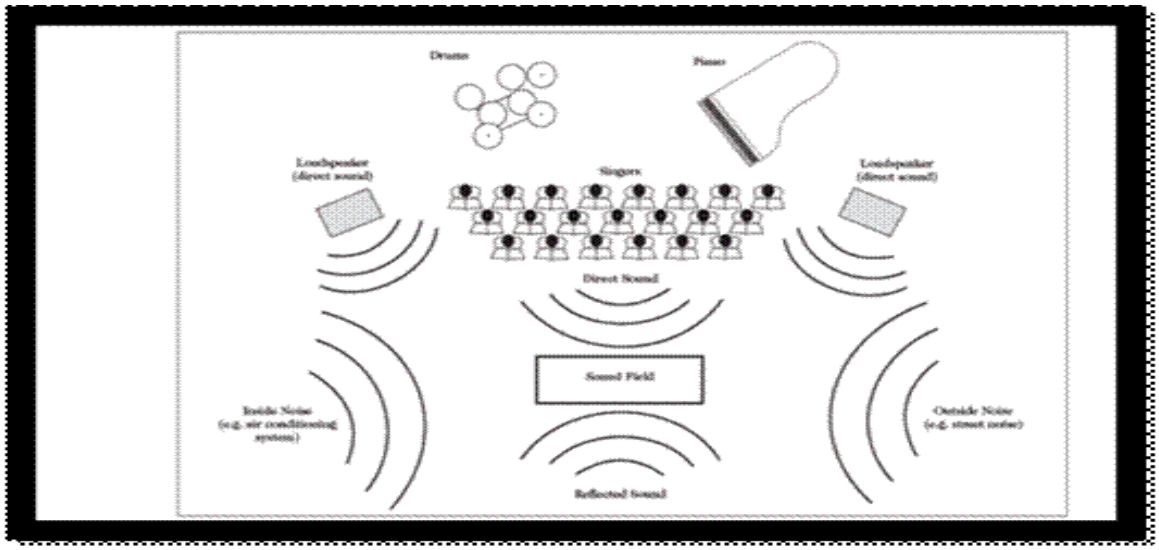



Figure 3: *Sound sources and sound field (www.sources.com accessed July 24, 2015)*

Writing on the acoustics of a room as an important as the sound source, Berard (2012, pp. 521-528**)** opines that:

> room acoustics are a function of the size and shape of the room, the materials covering the interior surfaces, and even the presence of the congregation. The acoustic nature of an area may have a positive or a negative effect on the sound produced by voices, instruments, and

> loudspeakers before it is picked up by microphones or heard by listeners; absorbing or diminishing some sounds while reflecting or reinforcing other sounds.

To this end, Małecki (2014, pp. 151-155**)** notes that "strong reflections can contribute to non-desirable sound in the form of echo, standing waves, or excessive reverberation". Also, Kosala & Engel (2013, pp. 1144-1152). states that:

> this is a clear position that sound sources may be categorized as desired or undesired, and the sound produced by them may be further classified as being direct or indirect. In practice, the sound field or total sound in a space will always consist of both direct and indirect sound, except in anechoic chambers or, to some extent, outdoors, and can only be experienced when there are no nearby reflective surfaces.

Musical instruments acoustics in church auditoria has always been affected by the reverberation time (RT) of the church auditorium, the structural and musical instruments' acoustics cannot be separated from one another. Beranek (2004, pp. 1121-1129) writes that "reverberation time (RT) is an important acoustic parameter that affects the ability of musicians, either in church auditoria or in concert hall, to perform excellently because these factors complement one another". In a complimentary statement, Schroeder (2007, pp. 244-245) opines that "the longer reverberation time (RT) would result in less sound clarity in any auditorium and creates a difficulty in audibility perception of musical instruments and instrumentalists during a musical performance". To this end, Beranek (2008, pp 255-256) is of the opinion that "using the principle of impulse response at a position in space can determine acoustic parameters associated to that position including reverberation time, subsequent reverberation time, sound clarity, frequency contents, and loudness". For that reason, Bernamou (2010, pp. 345-356) in his study of preference of reverberation time writes that "to find one the most preferred auditorium acoustics for musicians and audience in an enclosed space, is really important to design an auditorium acoustics for that enclosed space".

Griesinger (2011, pp. 15-23) observes that "the natural sound gain of a room can also affect musical instruments acoustics". Griesinger gives three factors namely:

the natural sound gain of an auditorium, volume and the ensemble of the musical instruments of which variation in volume is quite enormous. Keeping one of the three constants would lead to unacceptable or impractical variation in the other two factors. However, one should not consider these constraintsas compromises to music and musical acoustics especially in church auditoria.

The dependency of musical instruments is on two vital determinants; the musical instruments acoustics and structural acoustics. These two determinantsdictate the reverberant status of musicalinstruments sounds in any auditorium, the fundamental acoustics of musical instruments are vitally important with regards to how musical instruments produce sounds. Hansler and Schmidt (2004, pp. 433–451) suggest four common attributes used to describe musical instruments sound, these are "loudness, pitch, timbre, and duration". Each of these qualities depends on one or more measurable physical parameters, for example, loudness depends mainly on sound pressure, pitch depends mainly on frequency with lesser dependency on sound pressure and envelope. Hansler and Schmidt further state that "timbre includes all the attributes by which sounds with the same pitch and loudness are distinguished".

## 2.6 Musical Instruments and Sound Level Measurement (SLM) in Church Auditoria

Sound level measurement in church auditoria has to do with sound pressure level (SPL) which can only be determined by use of Sound Meter Reader (SMR) that is commonly used, as postulated by Krug (1993, pp. 22-38) in the measurement of noise pollution research or investigation that"It should be noted however, that reading from a sound meter does not ascertain the possibilities of accurate facts on how sound is perceived by individual because perception of sound is subjective especially in Africa where sound is arrogated to power and affluence. Adesiya (2005, pp. 40-62) also argues that "if two individual engage in an argument, the public always have the notion the higher voice between the two is winning the argument". Adesiya (2005, pp. 40-62) further states that "technically, volume is referred to as sound-pressure-level and is measured in units called decibels (dB). Subjectively, one decibel (1dB) is the smallest difference in loudness that the human ear can supposedly perceive. Objectively, at sixty decibels

(60dB), the loudness of sound is still perceivable as scientifically approved by the World Health Organisation (WHO)".

Nagata (2001, p. 42) posits that "in a church auditorium, the perceived sound consists of directly primary radiated sound from the source and reflected sound various surfaces of the hall especially, walls and ceiling. This reflected musical sound is usually confused for reverberation because, the perceived sound consists of both primary and reflected sounds." McAdam & Bregman (1979, pp. 26-60) posit that:

> the primary sound determines the perceived volume level because this is appreciably louder in the sense that sound becomes softer in proportion to the square of the distance travelled and the reflected sound travels a much longer distance, and sound is partly absorbed and diffused by the reflecting surface.

Arising from the above argument, it is opined that all reflected sounds normally play an insignificantposition in the realpick out volume level. Thèberge (1999, pp. 67-85) complements this by stating that "primary sound and reflected sound are essentially two separately arriving sounds of different volume levels".In other words, this could be regarded as fundamental and residual musical sounds.

Commenting on another characteristic of hearing, Rosch (1978, pp. 546-566) writes that "the combined sounds are perceived as being only as loud as the louder of the two sound-sources. The louder sound determines the apparent volume level; the less loud sound does not add appreciably to the perceived volume level". This statement by Rosch was as a result of his demonstration in a room with separate four loudspeakers by putting one loudspeaker in each corner of the room and playing musical sound with different volume levels, this produced a situation to believe that the sound was only emanating from the trend of the loudest speaker despite the variations in intensity which as small as a few decibels. It was very clear and provided a situation as if the other three speakers were muted. Our daily experience of musical sound perception has put it that larger part of the sound- producing environments are full of sound reflecting materials and substances because, one or two of these objects are usually closer

to the sound source, reflecting surfaces are proportionally much farther away as far as our understandings can guide us. Therefore, this has conditioned our ears to hear but could not distinguish between the connection between the fundamental and the harmonics sound where the volume of the reflected sound has some lower decibels than the primary sound.

Theobviousinteraction of the volume of the precise and non-precisemusical sound require preservation in order to make musical instruments acoustics in church auditoria natural. The main factor for this reason, according toScherer (1998, pp. 1131-1142) is that:

> one is quieter, calmer, more relaxed, and more concentrated than usual during a church praise and worship session because perception of subtle musical sound is realized; therefore, the proportionate volume level of reflected sound relative to primary sound is not noticeable.

Figure 4 expresses the flowing order of sound measurement level as propounded by George (1938, pp. 150-186) using the Place Theory of Sound Perception (PTSP).

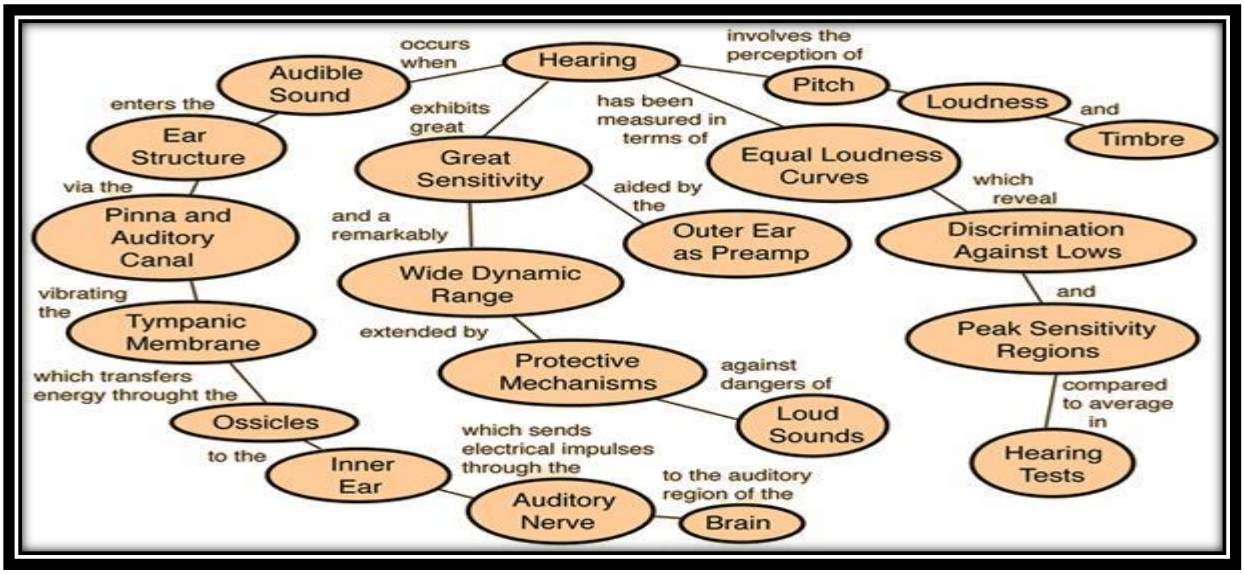



*Figure 4: Hearing and perception of sound (Georg: 1938, p. 172)*

Measurement of sound pressure level (SPL) requires sound metre readers such as A4 DaTuner in order to provide accurate percentage of produced sound and sound received in connection to the sound producing environment in the case of a worship auditorium. This is a digital process to assist in plotting a graphical explanation of sound intensity, sound frequency and sound decibel. Table 1 reflects the various sound pressure levels (SPL) with its

corresponding sound intensity. These are arranged in order of gravitational effect on the human ear to complement the earlier explanation on the nature of musical sound and how such is received and perceived as accessed on (http://www.sengpielaudio.com/TableofsoundPressureLevels)

Table 1: Sound level and sound intensity

| **Table of sound levels l (loudness of noise) and Corresponding Sound Pressure and Sound Intensity** | | | |
|---|---|---|---|
| **Sound sources**<br><br>**(noise)Examples with Distance** | **Sound pre**<br><br>**ssure Level Lp d B SPL** | **Sound pressure *p***<br><br>**N/m² = Pa Sound field quantity** | **Sound intensity I W/m²Sound energy quantity** |
| Jet aircraft, 50m away | 140 | 200 | 100 |
| Threshold of pain | 130 | 63.2 | 10 |
| Threshold of discomfort | 120 | 20 | 1 |
| Chainsaw, 1m distance | 110 | 6.3 | 0.1 |
| Disco, 1m from speaker | 100 | 2 | 0.01 |
| Diesel truck, 10m away | 90 | 0.63 | 0.001 |
| Curbside of busy road, 5m | 80 | 0.2 | 0.000 1 |
| Vacuum cleaner, distance 1m | 70 | 0.063 | 0.00000 01 |
| Conversational speech, 1m | 60 | 0.02 | 0.000 000 01 |
| Average home | 50 | 0.006 3 | 0.000 000 1 |
| Quiet library | 40 | 0.002 | 0.000 000 01 |
| Quiet bedroom at night | 30 | 0.000 63 | 0.000 000 001 |
| Background in TV studio | 20 | 0.0002 | 0.000 000 000 1 |
| Rustling leaves in the Distance | 10 | 0.000 063 | 0.000 000 000 01 |
| **Hearing threshold** | 0 | 0.000 02 | 0.000 000 000 001 |

*(http://www.sengpielaudio.com/TableofsoundPressureLevels.htm accessed on May 30, 2015)*

### 2.6.1 Concept of "Loudness of Musical Instruments Acoustics" in Church Auditoria

On the “loudness concept of musical instruments acoustics”, Smith (1997, p. 243) writes that “recent shifts in the aesthetic value of audio loudness is a symptom of broader shifts in attitudes about social harmony and techniques for managing musical sounds and musical acoustics in an auditorium”. This might be as a result of Africans cultural attachment to general loud sound which is usually displayed when two Africans are engaged in an argument or receiving a phone call, anyone standing few meters away could hear such conversations very audibly. In this connection, Emielu (2013, pp. 45-56) opines that “in Africa, sound is arrogated to power and thelouder the sound, the more powerful the producer of such sound”. Sound has often been used as a channel of oppression, intimidation, challenge and even to create a call for an undue attention.This cultural factor is practised anywhere around us; in the theatres, concert halls, film houses, churches and even in the hospitals where there should be minimal generation of noise in order not to disturb patients on admission.Aldred (1978, pp. 60-78) opines that “it is interesting to think for a while about the notion of a sound being “not loud enough” or being “too loud”, because it appears that these two phrases do not refer to the same concept”.

Based on Aldred concept, it can be deduced that a sound is not loud enough if it is not easily audible and difficult to make sense of it. Thus this notion of loudness as observed by Vorländer (2008, pp. 118-201) is similar to “intelligibility, rather than acoustical factor”, this is a relative notion which holds that sound intelligibility depends on the acoustical environment and background noise, there are at least, two different notions as given by Sandell (1995, pp. 209-246) regarding loudness, one is that “a relative notion related to intelligibility, and two,“a more absolute one related to an unpleasant or even painful feeling”. It is worthy to say that a sound is too loud in the sense of intelligibility. For example, a television volume when it becomes an impediment to audibility to a particular conversation in a room, as observed by Vorländer (2008, pp. 118-201) that the notion “f loudness is multiform, and therefore cannot be mapped to a singular sound volume situation”. It could therefore be submitted that the notion of loud musical sound in church auditoria is an emotion factor as worshippers are emotionally attached to church auditorium musical instruments acoustics. Submitting on this, McAdam and Bregman (1979, p.

40) state that “loudness of musical instruments acoustics is not only about objective properties of the external world, but also about our cultural world or more precisely about the effect of sounds on our organism”. In addition to this, Sreedhar (2000, p. 118) puts it that:

> Many listeners have subconsciously felt the effects of over-compressed songs in the form of auditory fatigue, where it actually becomes tiring to continuelistening to the music. ‘You want music that breathes. If the music has stopped breathing, and it’s a continuous wall of sound, that will be fatiguing’ says Katz. ‘If you listen to it loudly as well, it will potentially damage your ears before the older music did because the older music had room to breathe.

Sreedhar’s opinion above suggests an equilibrium position in the musical instruments sound production. The balancing of the high, middle and the low frequencies should produce a well breathing and lively musical sound with no tiring or boring effects on the listeners.

### 2.6.2 Church Auditorium Volume and Reverberation Time

There is a strong relationship between the church auditorium volume and Reverberation Time (RT). Sabine (2002, pp. 213-214) observes that the interaction of the volume of a room (V) and the wholesuperficialpart (S) of the sound producing environment determine the length for “a sound to fade off from its original intensity”. Auditorium volume is dependent on the building design in terms of the expected space and building materials used. Ternström and Sunberg (1986, pp. 1206-1229) submit that

> when designing a church auditorium, a look at the impact of the used materials on the average reverb time must be considered. Ternström and Sunberg further provide an example that choosing between metal and wood studs will change the diaphragmatic behaviour of the walls thereby changing the amount of low frequency of musical sound to absorb as against its relative high and middle ranges.

Nagata (2001, pp. 43-48), in his comment samples the reverberation and time responses of two churches with the calculation done per second on the frequency of sound emanating from these churches. His example of Church A and Church B is graphically reflected in figures 5 and 6:

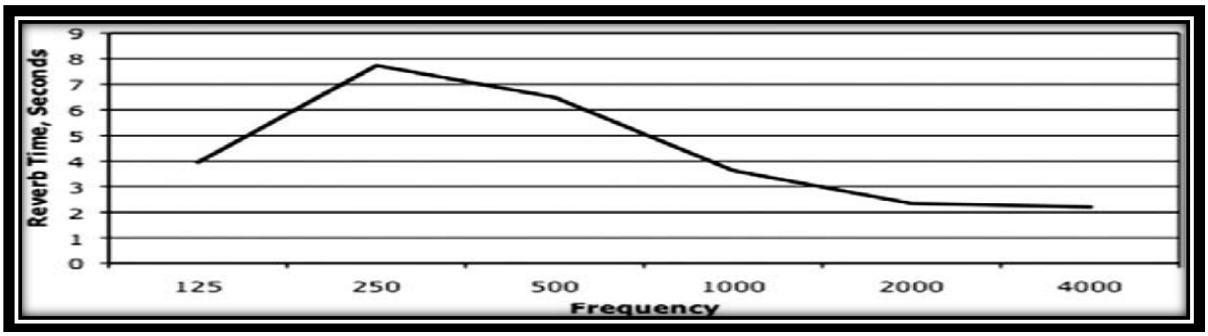



*Figure 5: "Reverb Time vs Frequency of Hypothetical Room"*Nagata (2001, p. 41)

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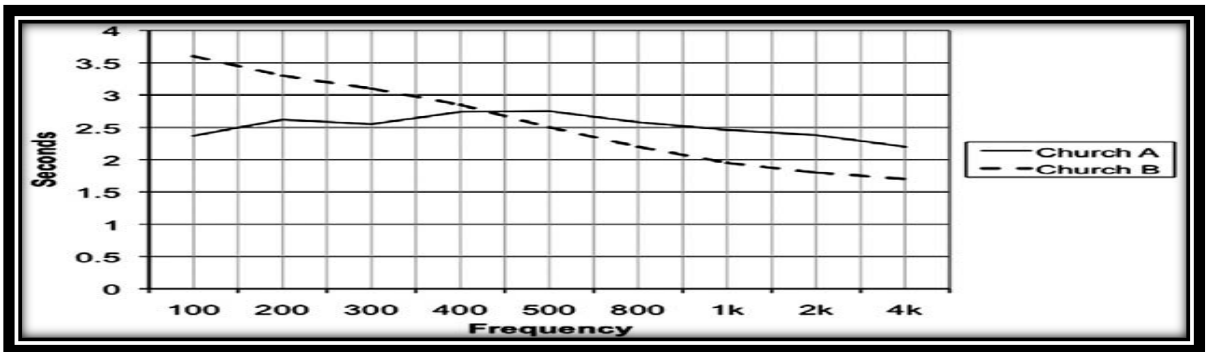



*Figure 6:"Reverb Time vs Frequency of Two Hypothetical Churches"*Nagata (2001, p. 42)

It could be noticed that figure 5 and 6 show reverberation time versus frequency for the two churches with "average reverberation times of very close to 2.5 seconds" though, these two church auditoria musical instruments acoustics sound remarkably different. The observation here is that Church B musical instruments acoustics sound will be "rich and full whereas church A musical instruments acoustics sound will be thin and harsh" because of the differences in per seconds' frequencies. Nagata states that "clearly, one number is not sufficient to describe these rooms". One vital factor in the determinant of room reverberation time is the number of participants per service in the church auditorium at a particular time of worship.

## 2.7 Musical Instruments Production, Transmission and Reception inAuditoria

The process of sound production, transmission and reception in auditoria depends largely on the acoustic factors of such auditoria. Acoustics therefore is seen as the scientific study of the behaviour of sound production, transmission, reception and the effects of sound in a given space. Enendu (1994, pp. 87-102) defines acoustics in simple term as the movement of sound in the air when he states that "Sound is essentially the movement of air in the form of pressure waves which radiates from a source and radiates in all directions". In his owncontribution, Anderton (1978; pp. 28-40) writes that the waves of sound travel across the air to generate a wavy flow to

provide a sound perception. Sound production, transmission and reception in church auditoria should be managed to arrive at a decibel of musical instruments sound that should be within the threshold of human ear. Oyedepo and Saadu (2010; pp. 563-577) opine that identification of noise hazards in a church auditorium may expose worshippers to excessive sound volume which may be too dangerous to the health of worshippers. Assessment of Sound Level Meters (SLM) according to Sabine (2002, p. 213) has four principal grades of precision as shown in Table 2.

Table 2: Sabine's grades of precision

| | |
|---|---|
| **0 – Laboratory reference meter** | + 0.4Db |
| | |
| **1 – Precision** | + 0.7Db |
| **2 – General purpose** | + 1.0Db |
| **3 – Survey** | + 1.5Db |

(Sabine: 2002, p. 213)

The prima impartial standard used for the description of such acoustic quality of a church auditorium is the Reverberation Time (RT) which measures the duration of the decay after extinction of the musical instruments sound source above an active span of 60db. The subjective parameter related to the RT is the impulse of the perception of the reverberance. In practice, it is easier to differentiate between the perceived reverberance during the musical phrase and the perceived reverberance once the musical phrase is over. Arthur (2002, pp. 600–610) opines thatthe "Reverberation Time (RT) of the room is directly related to fundamental sound while the former is closer to the first fade off time and often calculated over a decay of 10 or 15dB". Ashrae (1991, pp. 56-68) gives the reasons why "reverberation time (RT)" is the first applied standard for the description of the acoustics of a church auditorium is that it is the only standard that does not vary with the source and receiver positions.

### 2.7.1 Reverberance of Musical Instruments Acoustics in Church Auditoria

Recently, one of the most serious challenges facing musical instruments acoustics in church auditoria is the problem of reverberance. However, Knudsen and Harris (1950, pp. 208-228) write that the Sabine's equation is applicable to enclosures where the audibility is diffused but,when the audibility is not diffused, the audibility fades off curvature remainsunconventional

and the distinguishing factor between what isnoticed and worked out in terms of Reverberance would be clearly seen.

**(a)Warmth and Brilliance of Musical Instruments Acoustics in Church Auditoria**

Warmth and brilliance as defined by Rossing (1982, pp. 192-208) is the reverberation time at low frequencies related to higher frequencies above 500 hertz. Rossing additionally observes that at low frequencies, within the sound producing environment (auditorium), Warmth as a term is used to explain a cold flatness to the music as contrast to brilliance, which refers to a bright, clear and ringing musical acoustics sound and any one of these two qualities is desirable in moderation in church auditoria music production. For example, Steeneken and Houtgast (1980, pp. 318–326) suggest Bass Ratio (BR) as an objective measure of warmth with the following formula:

$$BR = \frac{RT_{125\,Hz} + RT_{250\,Hz}}{RT_{500\,Hz} + RT_{1000\,Hz}}$$

The provision on the above formula is that the numerator as an average of Reverberation Time (RT) that is measured in the "125 Hz and 250 Hz octave bands", and the denominator as an average of Reverberation Time (RT) thatis measured in the "500 Hz and 1000 Hz octave bands". Applying the practical demonstration of the formula on the perception of the pipe organ sound at the Cathedral Church of Saint Peter, Ake Abeokuta and Our Saviours' Church, Ikenne, it was discovered that pipe organproduces the lowest frequencies of sound than any other harmonic musical instruments. Steeneken and Houtgast formula is applicable and relevant in the selected church auditoria.

**(b)Balance of Musical Instruments Acoustics in Church Auditoria**

Berry and Kinzey (1954, pp. 164-166) write that many churches have upgraded to digital from an older analogue console in the quest for dynamic routine of musical sound equipment. This statement may or may not be true, depending on the brand and model of the digital sound

equipment procured. Similarly, there are digital mixers that will actually help a church sound engineer to be moreskilful and actually manage the mixer console more easily.

There are many factors to consider in the achievement of musical balance in a worship auditorium. These factors include the ceiling, plastic or wooden seats and other fittings that are either sound reflectors or absorbers. Fry (1979, pp. 139-142) suggests that "heavy and thick materials such as hard plaster, several layers of laminated dry wall, or concrete are preferred to use at ceiling area". Fry suggests that "if hard but thin materials are used, it may possibly absorb low frequencies of sound and make the auditorium sound unbalanced". Commenting on musical balance in worship auditorium, Gilford (1979, pp. 17-31) examines the management of sound connection cables, audio system, audio gear, microphones and other audio connecting materials to facilitate good musical instruments acoustics in a worship auditorium. A template on proper positioning of musical instrument in a worship auditorium for a better sound balancing and sound clarity as provided by Gilford is seen in figure 7:

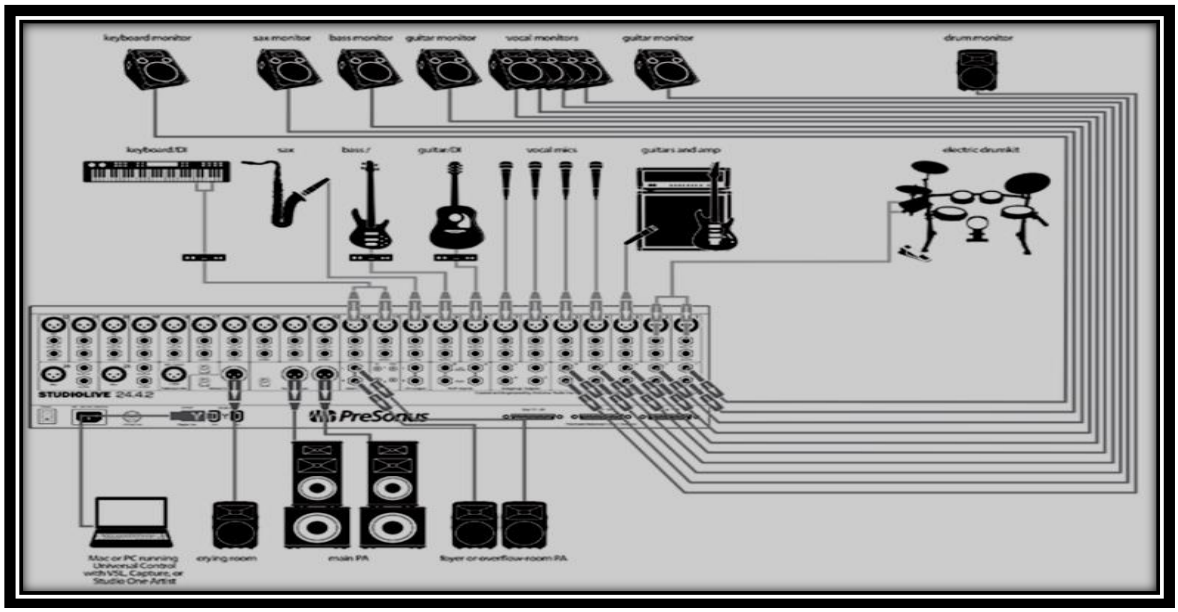


*Figure 7: A typical template sound connection in a worship auditorium (www.soundconektion.com)*(Gilford: 1979, pp. 17-31)

Ingram (2012, p. 26) writes that "sound balance between choir and congregational singing require that the scattered sound around choir area should enhance the balanced singing among choir members". Collective singing between the congregation members is achievable

through a focused control of the sound diffusing panels above the worshippers' ceiling area or sidewalls.

**(c)Church Auditoria Musical Instruments Acoustics and Sound System**

Nagata (2001, p. 47) opines that every surface in a church auditorium has an impact on the quality of musical instruments sound produced within such auditorium. Nagata further comments on how the surface is built, what is on it, and what it is made of, determine how the congregation experience every musical part of a worship service. The acoustics of a room ultimately determines how well such musical sound system works. Buglio (1992, pp. 131-145)opines that growing churches need good musical instruments sound both acoustically and electronically. Buglio is probably expressing the needs for the provision of certain musical instruments and sound amplifying equipment to facilitate musical sound production in church auditoria, more so, musical sound production is a factor that influences full congregants' participation in worship sections in any church service.

Several church auditoria lack the personnel to handle the technical aspects of sound systems, some church auditoria do have members who teach music in colleges; work in broadcasting stations, in electronics shops or even as sound contractors and want to help with the sound system in the church sound unit but, unfortunately the a church auditorium acoustics and the system components used are so different from what these people are familiar with, these limit their ability to help as observed in the Celestial Church of Christ(CCC) Ibadan where the sound engineer is an electronic shop owner and an experienced sound technician. The resultant effect of the above facts leads to poor cable connection and other wrong connections that automatically resulted to loud and rough musical instruments acoustics with no clear sound clarity. It was also noticed that installations of sound system equipment in church auditoria are usually done with no consideration for quality sound system and control of musical sound volume.

**2.7.2 Generation of Musical Instruments' Acoustics in Church Auditoria**

In Nigeria, especially as noticed in the south-western part, church auditoria sound generation are usually meant to impress through large and monumental musical instrument sound

proportions, they are also meant to prompt cohesion between members of the community by amplifying the musical sound and songs as well as the voices of the officiates. This trait has virtually become a phenomenon in church musical instruments' sound production. It was observed in all the selected church auditoria that majority of the congregants don't really have any knowledge about the gravity of the high volume of musical instruments sound perceived during each church worship service and therefore not concerned about the acoustics nature of the church auditorium and the heavy wattage of electronically amplified musical instruments'sounds. In essence, the acoustic of the sound producing environment is very vital to musical sound productions, either amplified or not, these factors are not considered in five of the six selected church auditoria.

Musical instruments' sound productions can be achieved at a desired frequency and volume level. This is possible because every amplifying system has a volume control which could be manoeuvred to get a desired musical sound volume. It is however sad that Nigerians are not sensitive to this area of sound control, this trait was observed in virtually all the church auditoria visited, a situation where every instrumentalist wants to hear his or her musical instrument louder than every other musical instrument within the same sound producing environment. Ideally, good musical instruments' sound production requires balance. Many church auditoriums visited have at least two sound systems, the main house sound system which is the live sound covers the audience, and the monitor sound system which is responsible for feedback at the altar, choir stall and the console cubicle. On the Alter however, balance must be achieved between the various instruments to musically satisfy the lead singer and chorusing backups.

On the harmonious relationship between all the musical instruments' sound generation, a great deal of inharmonious musical sound productions is experienced at every worship sessions of the selected church auditoria, a situation like this was experienced at the Cathedral church of Saint Peter, Ake during the 2016 Annual Harvest Service. In relating this to the selected church auditoria, it was observed that every musical instruments sound produced within any auditorium

has a primary volume generated through the vibration of its body and a secondary volume through the system of amplification. The effects of these musical instruments 'sound production can however be felt in the nature of the sound producing environment. that is, the auditorium and this depend largely on the acoustic nature of the auditorium, the size of the auditorium and the intensity of sound emanation within the auditorium. Moreover, most of the musical instruments such as the guitars, the trumpets and the physical structure of chimes and the trap set drums used in the selected church auditoria were manufactured with initial standing acoustic waves.

**(a)Pitch in Musical Instruments' Acoustics in Church Auditoria**

Pitch in music is considered as the highness or lowness of a musical tone, this is in agreement with its amplitude, length, and colour.Pitch cannot be determined without the frequency and a precise scientific unit of decibel measurement. Gade (1985: p. 112) observes that pitch is equally affected by individual personal opinion that takes into consideration the comparative placement of highness or lowness of musical instruments acoustics within church auditoria especially during a worship service. Olson (1971, p. 13) observes that "pitch is determined by the frequency of sound". However, this could be used in the balancing of musical instruments sounds production in a situation where there is a war of sound or a conflicting emanation of musical instruments' sounds pitch from a live source. The application of pitch analysis in church auditoria will reduce the effects of loud musical sound productions on the congregation and also make clarity of musical sound possible. The traits of conflicting musicalsound production were experienced in virtually all the purposively selected church auditoria case-studying for this research.

My observations on the nature of musical instruments' sound productions in the selected church auditoria signal serious health implications on the congregation especially, young babies whose parents are ignorant of this great health hazards of exposure to amplified music and loud musical sounds. Ameye (2018, pp. 14-16) observes that:

> Long hours of loud sound exposure can result in partial deafness of the instrumentalists and the entire congregation. More often, people in this category

undergo unpleasant hearing sensations and triggered by noise pollution through heavy wattage of musical instruments sound. It is very important to possibly avoid exposing young and old to loud noises especially during worship sessions with loud musical sound productions at church services in order to avoid exposing worshippers to hearing damage that could be permanent al through life times.

This submission attested to research experience in all the selected church auditoria in south-western Nigeria.

**(b)Frequency of Musical Instruments' Acoustics in Church Auditoria**

Frequency of musical instruments' acoustics within the auditoria comprise of compressions, diffractions and refractions of a medium. However, Brown (1992, pp. 1398-1408) comments that in musical instruments' sound productions, the only medium are the musical instruments, using the unit of Hertz (Hz) as frequency measurement, frequencies tend to take up a wider frequency range, because the sound waves excite more ears when the perception of a sound is diminished by a louder sound. In another account, Bruce, (1997, pp. 179-189) writes that higher frequency sounds tend to be more precise in this sense. The graphical demonstration as shown in figures 8 addresses the behaviour of cycle per second movements of sound frequency in musical instruments' acoustics and sound productions as given by Bruce.

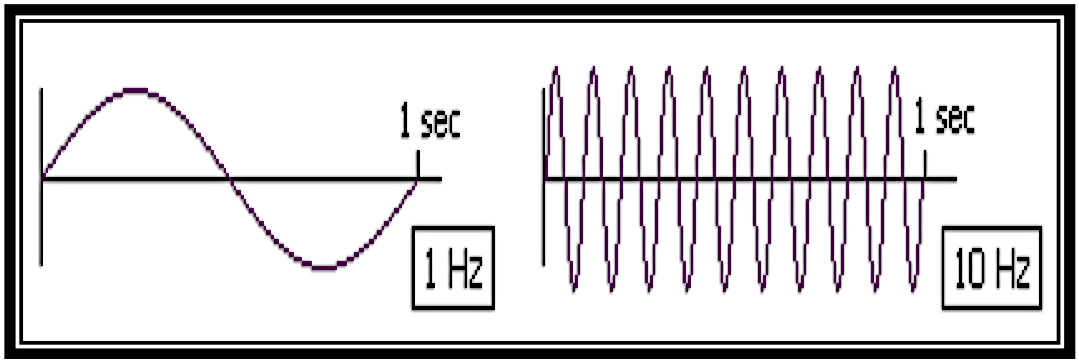



Figure 8: Difference in wave length between 1 Hz and 10 Hz. Bruce, S.W. (1997, p.180)

Relating to musical instruments' production in church auditoria, one will begin to think about the frequency spectrum of each instrument and which musical instrument is masking another musical instrument. This challenge was experienced at the Celestial Church of Christ (CCC), Akobo, Ibadan, where the church sound engineer, due to his lack of experience, put all

the playing musical instruments at the same high and low frequencies resulting into sound production without clarity. It should be noted that the lead guitar has a different frequency from the keyboard, the bass guitar is a low frequency instrument, the saxophone is a high frequency instrument and the trumpet, a high frequency musical instrument, all the musical instruments played at the same frequency cannot make a good musical ensemble. In this context, panning which is a process applied on the console mixer to synthetically proportion each musical instrument's sound in a stereo mix in order to provide a distinctive sound as a way out in order to hear how the frequency spectrum of all the musical instruments sound in the Front of House Speakers (FOHS). For example, if there are two heavily distorted guitars, panning can make them sound apart. The graphical expression of high and low musical instruments is represented in the figure 9:

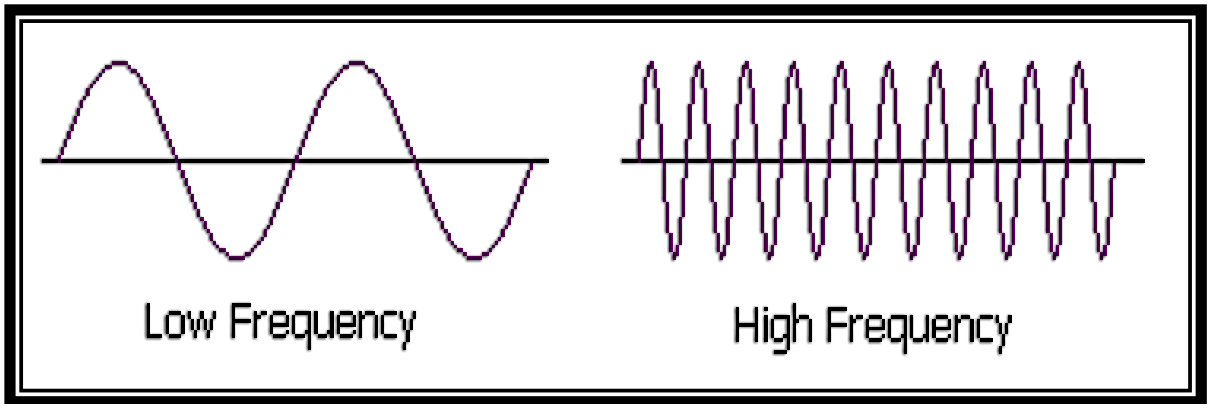



Figure 9: Graphical expression of low and high frequencies of musical instruments

**(c)Musical Instruments Acoustics and Sound Productions in Church Auditoria**

Every musical instrument has its own peculiar acoustic nature which gives the fundamental vibrations to produce sound. Ancient or Modern, African or Western musical instruments are made with certain acoustics considerations. A number of researchers such as Fitch (1999, pp. 1511–1522.), Fitch and Rebv (2001, pp. 1669–1675), Rebv and McComb (2003, pp. 519–530), Hast (1989, pp. 117–121), Riede and Fitch (1999: pp. 2859– 2867) and Fitch (1997, pp. 1213–1222) have studied the sound production techniques of musical instruments. Also, Benade (1976, pp. 1900–1907) and Hutchins (1980, pp. 182–203) have commented on the musical instruments acoustics and sound quality subjectivity in the areas of timbre, loudness and pitch. Recently, large concentrations are directed at the digital process, through the use of

computers, in the production of synthesized musical instrument sound and notational music composition. As a result of the emergence of personnel with training and experience in musical acoustics that are already working in the entertainment industries, in education, in recording and film studios, or in the musical instrument industriesand who are not ready to leave their job for churches'job has left the churches with little percentage of such professionals in church auditoria sound productions and management.

Allard and Atalla's (2009, pp. 243-256) opinion might be right on how the musical instruments produce sound without the process of vibrations but still not addressing how human beings produce sound through the vibration the body. Though, having knowledge of the instinctual foundation of musical instruments sound productions are used in the production of musical notes and sounds, this is required to provide physical criteria in distinguishing between satisfactory instruments from a non-satisfactory musical instruments' sound.

It could have been very necessary to discuss the musical audibility of each class of musical instruments highlighted in this study. However, due to the limitations of the theoreticalframework for this study, it will be very difficult to discuss how each musical instrument produce sound and how each production can be extremely complex and requires the use of other theories outside the thesis' theoretical framework. For example, Turbulence theory of irregularity and unpredictability by Ricardo (1999) as cited by Zwinglio (2008, p. 112) which is needed to describe the fluctuation in the movement of air production of certain Aerophones musical instruments.

### 2.7.3 Elements of Musical Instruments Acoustics in Church Auditoria

Richard (1888, p. 315) opines that musical instruments' acoustics in church auditoria is a reflection and expression of the individual's mind that are subjective to how individual perceives musical sound. In his assertion, Richard (ibid) states that:

> "Music has an estimable ability to deliver and act for the mind, more intuitively than any other sensual mean, the very standing, rising and falling, the very steps and inflections every way, the turns and varieties of all passions whereunto the mind is subject; yea so to

imitate them, that, whether it resembles unto us the same state wherein our minds already are, or a clean contrary, we are not more contentedly by the one confirmed, than changed and led away by the other. In harmony, the very image and character even of virtue and vice is perceived, the mind delighted with their resemblances, and brought by having them often iterated into a love of the things themselves. For which cause, there is nothing more contagious and pestilent than some kinds of harmony; nothing more strong and potent unto good".

Richard's opinion further states that musical activities in church auditoria should be of the highest quality. It should be as a rule, especially for Church worship to pass desired messages and also meaningful to the worship participants. Much of musical activities as practiced and perceived in the selected church auditoria are distant in agreeing with Richard's attestation. Musical activities in many cases amount to noise pollution and noise scandal. Making music in church auditoria could been seemingly analogised to a story book with spelling mistakes in every page yet, musical instruments with unbearable high wattage of volume are still allowed and accepted and even tolerated as a result of ignorance on the part of Church administrators and worshippers alike.

### 2.7.4 Musical Instruments as Sources of Amplification

Regarding musical instruments as sources for sound amplification, rely will be onBongers' (2006, p. 1890) category. Bongers argues that "even though the Hornbostel-Sachs organology that examines how musical instruments actually produce sound through categorization into idiophones, membranophones, aerophones and chordophones, was extended with the term 'electrophones". Bongers further states that "this does not adequately distinguish between electric and electronic instruments, let alone instruments utilising digital technology". Almost all digital musical instruments are electronically manufactured and this resulted from the transition of the analogue to digital technology which to allow for all digitally preserved sound or digital processed sound to be clearly audible. Bongers referred to these 'digital electronic' based on his divisions which are made with reference to technological developmental stages.

These include, according to Bongers, objects like“drums, passive mechanical (reeds, horns, stringed instruments), active mechanical likechurch organ, electric guitars and pianos, analogue electronic such Theremin, Moog Synths and digital electronic with examples such as Samplers and digital synthesiser such as the Yamaha DX-7”, all these musical instruments produce musical sound without secondary amplification.

White and White (1990, pp. 380-392) write that “generally, electronic technology differs from electric technology in that an electronic device can exert change on an electric signal; an electric device (dynamo, guitar pick-up, light bulb) can (merely) induce or transport a current”. In this case, White and White state that “an additional computer stage can be added; computers can run many music technology processes (recording, analysing, synthesising, spectral and dynamic processing) but again they are dependent on electronic technology to be heard”. Also, that“the important difference between acomputer and other digital technology is that it can be programmed to perform different tasks as specified in that program (the software)”. Martellota (2008, p. 134) givesa contemporary example in what he refers to as “live coding”this is a situation when a performer can programme his music live on stage.In a complimentary comment, Barron (1995, p. 134) states that “the code is often displayed on an overhead display and often with additionally generated visual displays, that program is executed and amended on the spot, giving the performing musician freedom to ‘instantly compose’, improvise and show off virtuosity in coding skills”.

Olson (1967, p. 188) corroborates this that “most instruments combine (successive) technologies” as explained by Bongers from the perspectives of the “electric guitar”. Olson (1967, p. 186) further states that “it is a passive mechanical instrument and the coil that picks up the vibrations of the string is electric or mechanoelectric as coined by and the amplifier is electronic, an external analogue or digital effects processor can be connected to further enhance (or distort) the guitar sound to the performer’s taste”. Also, from the perspective of electronic amplification, Rigden (1977, p. 121) suggest two types of sound amplification sources as “acoustic sources that need a microphone to transduce its sound into an electric signal and

electric instruments that use electro-magnetic induction or capacitance to transduce vibrations in a (metal) sounding string or body and that can be ‘Directly Injected’ (DI)” with no need of a microphone injection into an instrument amplifier or sound system.The two sources of sound amplification expressed by Rigden are specially designed for non-electronic musical instruments but only depend on the use of pickup devices for sound amplification.

### 2.7.5 Amplification Channel for Musical Instruments’ Sound Productions

Power failure in a performance situation offers a good test for the importance musical sound amplification. Failure of power in any case would probably leave the vocals and other amplified musical instruments out of clear audibility; this suggests when any musical instrument’s sound is amplified, it doubles the acoustic nature of such musical instrument, this is an addition to the acoustic sounds operating in its own channel. Moles (1966, p. 35) while discussing the approaches to music and its variousmodes of productions at different spatial and temporal channels, Moles holds a position that “these approaches should be used to get music from a studio to the consumer”. Another author Irmgard (1994, p. 108) examines the involvement ofintensified musical sound in a concert hall and uses moles’ concept of a “technical transmission channel” as a way to describe intensified musical sound at concerts halls, in this way, Irmgard (1994, p. 110) opines that “live musical representation is communicated to the listeners through a natural channel (that is, the auditorium in which music is performed) with all its specific qualities that affect this communication in terms of musical instruments sound production and auditorium acoustics”. Musical instruments’ sound and its amplified intensity is therefore regarded as either “an artificial channel or a technical transmission chain” which includes various microphone gadgets, mixing-console desk, sleeve amplifying engine and loudspeakers at both high and low frequencies. It is inadmissible to treat as equivalent music sound transmitted by technical channels and musical instruments’ sound that aretransmittedwithout amplification, because doing this suggests a process of dishonouring the due process of transmission which could readily results from technical interactions.

Blaukopf (1992, pp.45-56) refers to this transformation as ‘Metamorphosis’. Inappropriately, Blaukopf could not offer any reasonable solution to how an amplified musical instrument’s sound could be controlled from his perspective. Balukoff (1992, p. 56) suggests a “process rather than a binary opposition”, in this sense, musical instruments’ soundand its amplification basically depend on sound pressure level (SPL) from soft to loud. Blaukopf argument fails to emphasis the reciprocal relation between the two (Technical and Direct musical sound production) especially in concerts that are contemporary in nature with high volume of musical instruments’ acoustics that are often higher than the room volume. This has been a regular practice even, with aesthetic attractions but not technically applicable. In this connection, Michel (1999, p. 163) makes some interesting, stereotypical, but unsubstantiated observations as follows that:

> the sound volume more or less consciously desired by the listener is reversely relative to the real sound volume from the sound source; andgreater percentage of musical instruments sound produced do not sufficiently get to the hearers directly but through loudspeaker amplification system

From the observations as stated above, it is a very clear warning on the possibility of losing the potentials of good hearing, which has been experienced and still being experienced as a result of amplified musical instruments’ sound. Moreover, Michel’s (1999, p. 163) submission aligns with the Place theory of sound perception that sound pressure level (SPL) desired by listeners should be proportional to the volume of the space where such sound is produced to avoid hearing loss. The process of sound from the source which depends on the loudness concept that runs through the human ear sensitivity to allow for judgement creation on sound intensity and its eventual decibels as received by the human ear.

### 2.7.6 The Sensation of Loudness

The human ear has a limited power to musical instruments sound reception in terms of loudness and volume level. Barron (2005, pp. 576-578) writes on the "sensation of hearing" that:

> When pressure fluctuations reach the human ear, this occurs in a certain frequency region, and do not fall below a minimum sound level. The lowest frequency for which a vibration process is still perceived as a tone is approximately 16 Hz. This corresponds to a $C_o$ which is included in the 320 register of some large organs. For yet lower frequencies, the ear can already follow the temporal process of the vibrations, so that a unique tonal impression can no longer be formed.

From the above submission, Barron's position is clearly understood that it is likely that hearers of musical sound can lose tonal registration and impression if certain musical sound is higher in volume than the human threshold of hearing. In this context, Sessler, Schultz and Watters (1991, p. 885) submit that:

> This so-called threshold of hearing depends in large measure on frequency. The ear responds with most sensitivity to tones in the frequency range between 2,000 and 5,000 Hz. In this range, the minimum required sound level is the lowest. For higher frequencies, but even more so for lower frequencies, the sensitivity of the human ear is reduced, so that in these regions significantly, higher sound pressure levels are required for a musical tone to become audible.

Watter's position is slightly different from Rigden, If the"threshold of hearing"is depended on the on the measurement of sound regular occurrence, the ear will respond to the most sensitive sound is a generalised statement and of course, is not binding on all sound hearers. Hearing musical sound, either at low, middle or high frequencies, it will affect the threshold of hearing if the volume is grater or higher that what the human hear can tolerate.

Patynen (2009, pp. 876-878) in his submission categorically states that:

> The same tendency is evident when at higher intensity of tones of different frequencies are compared in relation to their impression of loudness. The sound pressure level as an objective measure of existing physical excitation is by no means equivalent to the loudness as a subjective measure of sensation.

From Patynen submission, it is deduced that objectivity and subjectivity factors in musical sound perception cannot be ruled out. The impression of musical sound loudness is not a general concept, what is loud to 'A' might not be loud to 'B' in terms of musical instruments sound productions.

In a supportive argument, Ikibe (2010, p. 207) views the sensation of loudness of musical instruments soundas experienced in worship auditoriumfrom a different position to Sessler, Schultz and Watters (1991, ibid) and Patynen (ibid, 2009). Ikibe argues that the high level of musical acoustics in church auditoria could be likened to a musical sound in a disco hall. Ikibe's opinion was based on his experience at the Redeem Christian Church of God, Kwara Provincial Council. The level of loudness of the musical production was high and this triggered the secularization of the dance steps of the choir which made the ladies to shake their buttocks in the manner of a disco hall dance as observed at Winners' Chapel, Ilorin and Saint Peter's Cathedral Church, Ake, Abeokuta.

### 2.7.7 Features of Musical Instruments Sound in Church Auditoria

The attributes or features of musical instruments sound in church auditoria are considered fundamental concerns in the generation, production, propagation and reception of musical sounds within church auditoria. These features include frequency, pitch, timbre and sound amplitude.

**(a) Frequency**

Jacko (2009, p. 231) defines the musical instruments sound frequency as a process of reoccurring musical sound. These musical instruments sound are however measured in units of decibel. Cavanaugh and Wilkes (1999, pp. 346-349) give further explanation that:

The decibel scale of sound measurement depends on the power on which the base number is raised in accordance with the logarithm of the ratio of the pressure of sound and in connection with audibility threshold, while the regular occurrence of sound with its waves is measured in Hertz (HZ), this process is refereed to “cycles per second” and then arranged in continuous eight successive musical notes.

In complement to the above, Binggeli and Greichen (2011, pp. 435-446) submit that the octave band acuteness of the human ear lies in-between 1000hz and 4000hz and therefore give a recommendation of a table of band limits for musical instruments acoustics in any sound producing environment as table 8.

Table 3: Frequency of Octave Band

| Octave Band | Approximate band limits (HZ) |
|---|---|
| 22-24 | 31.5 |
| 44-48 | 63 |
| 88-175 | 125 |
| 175-350 | 250 |
| 350-700 | 500 |
| 700-1400 | 1000 |
| 1400-2800 | 2000 |
| 2800-5600 | 4000 |
| 560-11,200 | 8000 |

(Binggeli and Greichen (2011, p. 438: Architectural Graphics Standard)

However, in frequency distribution and the response of the human ear, the sensitivity of the ear varies substantially over this range, as shown by the equal loudness contours in figure 10.

**(b) Pitch**

Distinguishing between pitch and timbre as separate musical variables is very important, though both are determined entirely by sound frequency. Timbre is considered colour of a sound, the distribution of harmonics and how it evolves while pitch is supposed to capture a sense of what note is being played. Thus, the concept of pitch is defined by reference

to the sound produced by an individual musical instrument (or, in the case of a piano, independently vibrating part of a polyphonic musical instrument). In a situation where musical sounds are produced by an ensemble of musical instruments in a particular category with different pitch and timbre, the combination of these musical instruments can produce a well blended and good harmony of sound. Barron (2009, p. 481) writes that "Pitch as the subjective response of human hearing mechanism to changing frequency. All musical instruments produce complex sounds which are made up of several frequencies, although the lowest is normally determined by the pitch which is the perceived frequency". Pitch is the property of sound that is perceived as highness and lowness. A difference in the frequency at which a sound wave vibrates is caused by changes in the pitch, measured in cycles per second (cps).Barron further gives four examples of musical notes with four different pitches as seen figure 10:

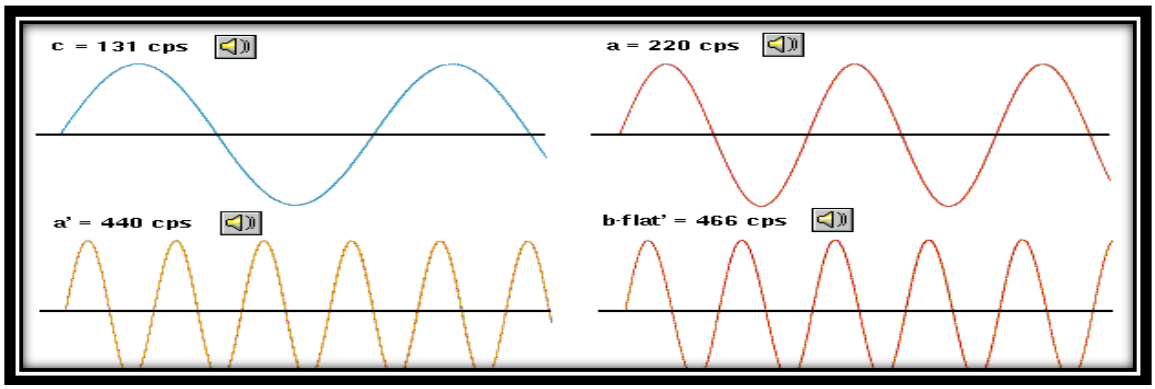


Figure 10: a screen shot of pitch measurement (Baron (2009, p. 481)

The above graphical example of pitches in wave length as provided by Barron indicates that there is an increase in the pitch and sound frequency simultaneously. Salvi, Levine, Nam, Oron, and Melcher (1998, pp. 11-15) write that it is possible to have natural pitch detection ability to determine different musical instruments tones pitch but, majority of church worshippers are not endowed with inborn ability of pitch detection and are also found in the musical arena, these set of people are greater in percentage than those with inborn ability. The trait of singing out of pitch is very common to most choristers as observed in the selected church auditoria. The problems of singing and playing of musical instruments always generate high volume of sound if not consciously controlled by the sound engineer.

**(c) Timbre**

The identification of timbre rests largely of two factors as argued by Berkhout (1993, pp. 2768-2778) that:

> Waveform of the steady part of the tone, and the way the spectrum changes with time, particularly at the onset or attack. Once knowledge to identify a particular timbre and recognition is possible even if the pitch is changed or if parts of the spectrum are filtered out. Timbre, also called tone colour, it is the characteristic quality of a sound produced by a particular musical instrument,independent of pitch or loudness of course, which can be regulated by the sound engineer without distorting and iota of sound propagations.

Timbre is an interconnection of many different musical attributes. The American National Standards Institute (1973, p. 20) states that"Timbre is that attribute of auditory sensation in terms of which a listener can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar".

In summary, Platt and Racine (1985, pp. 543-553), Melara and Marks (1990, pp. 169-178) and Caruso and Balaban (2014, pp. 865-870) define timbre "as all the sound attributes, except pitch, loudness, and duration, which allow distinguishing and recognizing that two sounds are dissimilar". However, Grey (1975, p. 145) gives a contrary opinion that "timbre, pitch, and loudness can interfere in the auditory sensation".

**(d) Sound Amplitude**

Musical instruments sound amplitude is by nature not static but full of free dynamism; this is contrary to the scientific measures of amplitude as applied to physics. Dynamics describe the perceived loudness of music and musical instruments sound. Musical sound amplitude travels in waves with regular pitched tone that suggests information on the propagated musical sound. Figure 11 reflects the wavelength and amplitude where the wave is progressing from left to right and the amplitude travelling in a straight direction.

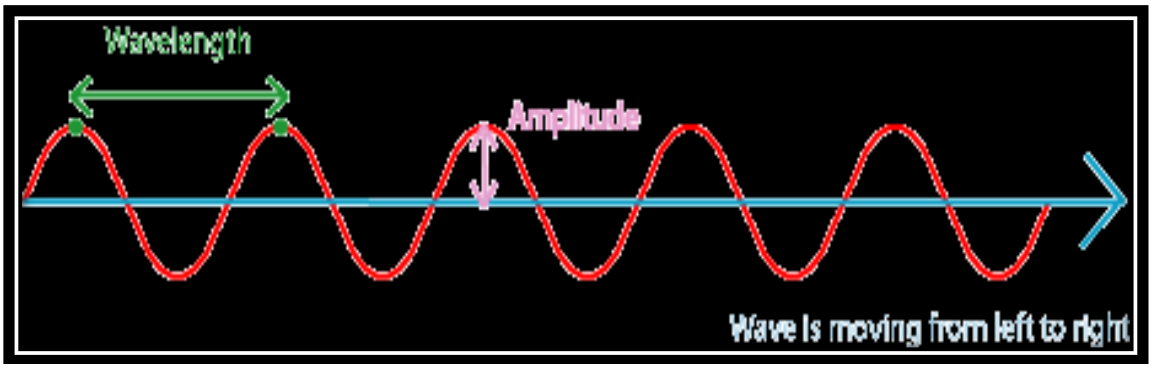


Figure 11: Wavelength and Amplitude

From the above illustration, the sound amplitude is moving at a straight line in-between the undulating wavelength at higher and lower degrees of volume. It is also noticed from the above illustration that an "increase in wave frequency causes a decrease in wavelength while the wave speed remains constant".

Barron (2000, pp. 152-157) defines the loudness of musical instruments' sound as "perceived volume", this referred to as the "maximum travelling displacement of a wave from the normal or zero position" as shown in figure 11. Which describes the corresponding amount of motion of molecules of a waves in the air. The human ear can accommodate sound in this position without constituting any negative effect. In the same argument, Barron (2003, pp. 354-366) writes that:

> as the level of motion in the molecules increases, its strike the ear drums with greater force progressively and as a result causes the ear to react to a louder sound. The amplitude of a sound wave is ascertained by the magnitude of the pressure fluctuation. Therefore, it is taken that the greater the amplitude of the wave, the harder the molecules strikes the human eardrum and the louder the sound that is perceived.

However, Blauert (1983, pp. 67-78) opines that "the range of pressure to which human ears can react to exceeds a ratio of one to million and response is not linear".Barron (ibid, pp. 354-366) position on how musical sound amplitude strikes the ear to cause discomfort the human ear is a one of the major objectives of this study as it relates to musical sound production, propagation and reception within church auditoria. The emphasis of the Place theory was concerned with this aspect of sound production.

### 2.7.8 Structure of Musical Instruments sound in Church Auditoria

Structurally, every single propagated musical instruments tone in the church auditorium in placed in the human ear. This is the position of the Place Theory of Sound Perception (PTSP). The human ear therefore perceives the sound and interprets same. Musical sounds are perceived in a pitch and tone colour except if the musical statement or tone is invigorated with vibration and other musical embellishments. Furthermore, there are certain emergence of rising and falling in the sound pressure level (SPL) in terms of loudness. Finally, it is possible to arrive at a submission on the structure of musical instruments acoustics vis-a-vis the volume of the room. Rauschecker (1995, pp. 34-38) gives two physical factors to help in resolving acoustics phenomenon in any sound producing environment especially, in church auditoria. In his comment, he opines that:

> There is a certain difficulty posed by the circumstance that the individual characteristics perceived are not each determined by only a single physical quantity, but come about by the cooperation of several components. The problem of finding an association between objective acoustical data and tonal impressions on the basis of practical experiences should not be overestimated.

Also Jones, Dell'Anna, Molmari, Rausell, and Hashlkawa (1995, pp. 153-l70) submit that:

> The starting transient which is the portion of time during which the tone is developed from complete rest to its final state, the stationary condition, which is the portion of time during which the tone is practically not subjected to change and the decay, which is the portion of time during which the tone, after completion of the excitation dies out to complete silence.

Kang (2002, pp. 4553-4565) finally expresses that:

> The decay process plays a special role for plucked and percussion instruments, since in the absence of continuing excitation there is no stationary or quasistationary state, yet, also for other instruments, it has certain significance for convincing connections between tones in flowing musical passages.

The understanding of the three positions above indicates that the travelling of sound from the point of production to point of decay is perceived by different experiences as depended on different musical instruments sound productions.

### 2.7.9 The Human Ear as Sound Analyzer and Measuring Instrument

When musical instruments are played to accompany vocal sessions at church services, more especially, when such musical tunes and the instrumentations are familiar, there is a natural flow of the congregation to be fully participative in such musical activity. The human ear and the human brain function at the best analysis of perceived musical instrument sound. The place theory of sound perception (PTSP) emphasises on the importance of the human ear to perceive musical sounds and analyse same as good or bad, loud or not loud. Burris-Meyer, and Cole (1959, pp. 23-28) write that "Perceived sound is a function of the ear canal where all these sounds are mixed together and how the human ear succeed in separating them". Drawing an analogy, Stevens and Warshofsky (1965, p. 564) write that:

> Sound propagation as a ship is affected by the sea surface and might be disturbed by many wave systems due to local wind from a distant storm, and several waves from passing vessels; this is essentially what the ear is constantly doing with complex sound waves.

It is not a gainsaying that there is an existing gap between objective and subjective opinion of perceived musical instruments sound because individual perceives musical sound differently. The human ear as an analyser determines what is perceived by each person. The objectivity and subjectivity syndrome has become a pattern of judgement of the perception of aural musical instruments in African society, and worshippers in church auditoria are not left out.

## 2.8 Musical Instruments Sound and Noise in Church Auditoria

The human experience of sound production especially in terms of musical instruments and other sound sources from the environment are common because these are partly endowed with our living in African and particularly Nigeria. Musical instruments sound emanation from church auditoria has become a menace to the society because churches are built within the

environment where people live and church services hold in form of Bible study, prayer meeting and other crusades from Monday through Sunday; these are usually accompanied with variant of musical noises that constitute a nuisance to the society. The nonchalant attitude and insensitivity of the church musicians due to lack in musical experiences and other technicalities involved in playing musical instruments might have been responsible for this. Every musician need to possess the musical skill to play musical instruments at the minimal volume level especially, if such musical instrument is amplified, this is required to avoid evidential productions of musical sound and noise simultaneously. Everest (1986, pp. 50-59) submits that:

> Musical sounds are extremely variable in their complexity and can range from a near sine-wave form of a single instrument or voice to the highly complex mixed sounds of a performing dance band. Each instrument has a different tonal texture for each note produced.

Sivian, Dunn, and White (1931, pp. 360-361) provide the peak power of various selected musical instruments found in church auditoria in the in Table 10. Table 4: Peak Power of Musical Sound Sources:

Table 4: Peak Power of musical Instruments (As measured by the researcher)

| Musical Instrument | Peak Power Watts (Db) |
|---|---|
| Bass Drum | 22 |
| Snare Drum | 25 |
| Pipe Organ | 8 |
| Electronic Keyboard | 10-15 |
| Cymbals | 10 |
| Trumpet | 1.3 |
| Saxophone | 0.3 |
| Conga Drum | 5-7 |
| Talking Drum | 16-20 |
| Omele Drum | 5 |

The above table compares the frequency range of the various musical instruments found in the selected church auditoria. In Sivian, Dunn, and White (1931, p. 361) conclude that the immediate volume level of sound determines the activeness and relations to the sound energy which could be perceived as either music or noise.It is comprehended that noise cannot be exonerated from musical instruments sound especially in church auditoria because it is considered as a means of communication and domination of space. However, Gaver (1989,

pp.67-94) comments on the nature of the process in which a "decaying band of noise" gives information based on the acoustical quality of the sound producing environment. Gaver (1989, p. 93) further expresses that:

> There are types of noise that are undesirable and sometimes it is difficult to tell whether it is the unpleasant musical sound or noise or only a carrier of information. The noise of an automobile conveys considerable information on how well it is running. A particular musical sound, even if noisy to one might be another one else's communication. A high-fidelity system can produce some beautiful sounds deemed very desirable by the sound producer, but to a neighbour this might not be considered beautiful at all. Sometimes it isn't easy to distinguish between information and noise.

In this connection, Gracyk (1996, pp.34-45) opines that a particular musical sound is likened to the enharmonic position of a black musical sound on the organ or piano to have two names.Likewise, a particular sound can be informative, communicative and be noisy. The determinationof this sound is based on individual perception of such sound as subjective or objective.

### 2.8.1 Effects of Loud Musical Sound on Human Health

One of the specific objectives of this study is to examine the effects of loud sound on human health. Over the years now, little consideration is given to how much of loud sound we have caused damage to our system and how it has eventually affected our overall health especially in Africa and Nigeria in particular. Several concerns have been expressed about noise and its adverse impact on human health and the environment. These concerns have also been expressed scholarly by many experts such as Brown (1992, p. 1398), Bruce (1997, p. 189) and Greenwood(1990, p. 2598) in the musical and medical studies as measures to reduce and or control the health hazards of noise as it affects human existence and life sustenance. However, the impacts of noise as it relates to loud musical instruments' sound on human health are not presumably to reduce until certain corrective measures are applied. This practice of societal

disturbances has brought noticeable and constant state of worries to numerous people around the loud sound producing environment.

Pollution of the environment through excessive musical sound productions inside or outside church auditoria is often an ignored as a one of the environmental challenges that are dangerous to human health and existence. In the United States of America and according to (AJPM online: p. 56), it is estimated that about “One hundred (100) million people are exposed to unhealthy levels of noise; typically, from automobile and aircraft traffic but also include everything from leaf blowers and lawnmowers to loud music can equally contribute to noise pollution situation”(USEPA Mag. 2015, p. 24). Writes that:

> In the 1970s, the United States Environmental Protection Agency (USEPA) set a recommended noise exposure limit of 55 decibels in a 24-hour period, with nighttime’s noise weighted more heavily because it can interfere with sleep. For comparison, a quiet suburb has a decibel level of about 50, while freeway traffic is closer to 70 and a chain saw is 120 decibels.

However, if the issue of noise could be handled by the federal, state and local governments’ level, how it is also suggested that an individual should also be able to handle the issue of noise to avert health challenges. This suggestion was established by Hartmann (1996, pp. 2457-2483) that:

> once you know the volume and duration of sound you are exposed to, it is a matter of calculating how much attenuation(reduction of volume) is necessary to ensure you are not being overexposed. This will guide you in your selection of the appropriate hearing protection device

In another comment on the dangers of loud musical sound, Trevor and D'Antonio (2009, pp. 2243-2257) write that “exposure to loud sound can overload the hearing system which may results in symptoms of hearing loss and/or tinnitus”. This could be retrieved with twelve hours, provided the contact with the heavy wattage of sound is discontinued but, if the contact persists,

the destruction of the inner ear may result in everlasting injury to the human hearing process may not be sensitive to any treatment.

Noise pollution through musical activities is likely toupsurge human possibility to have lost of hearing, stressful feelings, disturbances of sleep and possible attack on the human heart. According to a new analytical research conducted on environmental assessment of the United States noise pollution, Environ Health Perspectives (2007, pp. A536–A537) observes that "cardiovascular health hazard has resulted through loud musical instruments' volume". The analysis suggests that "a 5 decibel noise reduction would reduce the prevalence of high blood pressure by 1.4 percent and coronary heart disease by 1.8 percent". Theodor (2012, pp. 132-145) writes complimentarily that "noise exposure levels in 2013 were the same as those assessed in 1981, however, as urbanization has increased it is likely these are underestimates and reductions in noise may impact even more people than the study suggested".

Ochuko (2013, pp. 470-476) in his research writes that

> long-term exposure to traffic noise may account for approximately 3 percent of coronary heart disease deaths (or about 210,000 deaths in Nigeria each year. But, how, exactly, does noise harm human heart? One of the key ways is by elevating stress hormones such as cortisol, adrenaline, and noradrenaline, which, over time, can lead to high blood pressure, stroke and heart failure.

From Ochuko's submission, it is very clear that Ochuko suggestion is not applicable in the environment like Nigeria where the research was carried out because there is no such medical equipment to elevate stress hormones in our national and state hospitals.

Anomohanran, Oghenerhoro, Iwegbue&Egbai (2008, pp. 292-297) write that "arousal associated with night-time noise exposure increased blood and saliva concentrations of these hormones even during sleep". Expressing the same view, Ighoroje, Marchie andNwobodo (2004; pp. 9-14) state that:

many people become habituated to noise over time. The biological effects of are imperceptible, so that even as you become accustomed to the noise, adverse physiological changes are nevertheless taking place, with potentially serious consequences on human health.Taken together, recent epidemiologic data show us that noise is a major stressor that can influence health through the endocrine, immune, and cardiovascular systems. The impact can be significant.

It was also observed by Zannin, Ferrera & Szeremetta (2006: pp. 423-433) that:

> chronic noise exposure increased the risk of cardiovascular mortality by 80 percent, also chronic noise exposure leads to health risks beyond human heart, such as hearing loss, diminished productivity, sleep disruption, impaired learning, and more.

Ijaiya(2014: pp. 1-6) opines that "noise-induced hearing loss (NIHL) can occur from continuous exposure to loud musical sounds which eventually translate to noise over time affects about 54 percent of Nigerians"(Ijaiya: 2014: p. 4) further states that that "sound is measured in units called decibels. Sounds of less than 75 decibels, even after long exposure, are unlikely to cause hearing loss". In the same connection, Schessel (1992: pp. 233-235)stresses the need to consider some loudness/time facts using decibel as a unit of measurement as expressed in the table below:

Table 5: Schessel's Loudness and Time Measurements in Units of Decibel

| **Decibel Rate (dBR)** | **Effects of Exposure per Day (EED)** |
|---|---|
| At 95 dB | the damage will occur after four hours of exposure per day |
| At 100 dB | the damage will occur after two hours of exposure per day |
| At 105 dB | the damage will occur after one hour of exposure per day |
| At 110 dB | the damage will occur after 30 minutes of exposure per day |
| At 115 dB | the damage will occur after 15 minutes of exposure per day |
| At 120-plus dB | the damage occurs almost immediately |

Schessel (1992: p. 234)

Beyond human heart, excessive musical instruments production can be harmful in many other ways that could lead loss of hearing. For example, Gehring, Tamburic, Sbihi, Davies & Brauer (2014: pp. 343-352) writes that "exposure to loud musical sounds may lead to lower birth weight". In another research, Tzivian, Winkler, Dlugaj, Schikowski, Vossoughi, Fuks, Weinmayr

and Hoffmann (2015: pp. 13-30) also suggest “long-term exposure to noise pollution may have an effect on cognitive development in children and cognitive and psychological functions in adults”, although more researches are needed in this area of study.

There is also the issue of disruption and denial of sleep and this accounts for the reason why night time musical sound production is more disturbing than the daytime. If one cannot sleep as a result of excessive loud musical sounds.Dzhambov and Dimitrova (2015: pp. 39-46) write that:

> Chronic psychological distress can cause suppression of the hypothalamic-pituitary-testicular axis and thus lead to male hypogonadism [a condition in which the body doesn’t produce enough testosterone], which is associated with psycho-social dysfunction, chronic diseases, and as a result, considerable economic costs.Conversely, noise is a prototypal environmental stressor of growing importance, already linked to birth outcomes and diabetes. However, its effects on male testosterone levels have been paid little attention … Research on humans is highly warranted, especially given the steady trend in Western societies for increasing the burden of both male hypogonadism and noise pollution.

Minimizing or total control of excessive or loud musical instruments sound production in church auditoria, it is very imperative to think about the addition of acoustic tiles and other sound absorbing materials to buffer all excessive generation of noise during all worship services.

## 2.9 Theoretical Frameworks

In order to critically examine the congregants’ perception of musical instruments acoustics in the selected church auditoria, this research, is premised on the Place Theory of Sound Perception (PTSP).This theory is applicable in the study of sound perception and sound hearing especially, in a close acoustic like the church auditoria.

### i. The Place Theory of Pitch Perception (PTPP)

The place theory of sound perception was developed by Georg von Bekesy in 1928. According to Yolanda (2016, p.6) this theorystates that:

> One's perception of sound depends on the place where each component frequency produces vibrations along the basilar membrane, in this situation;different parts of the cochlea are activated by different frequencies. it further discusses the ability of the human ear to process musical instrument sound as it passes through the human hearing process and interprets by the human sense of thought and feeling. (http://www.alleydog.com).

The place theory of sound perception is used to explain how soft and loud musical instruments sounds are distinguished when perceived via the human ear and as detected by the human brain with regards to the pitch as depended on the placement of ear cells in the process of sound transmission.In order to understand the purpose of place theory of sound perception (PTSP), a good understanding of the basic knowledge about the structure of the ear is required. Figure 12depicts the different parts of the human ear and how sound frequency relates to sound behavioural pattern when it is in contact with the human ear.

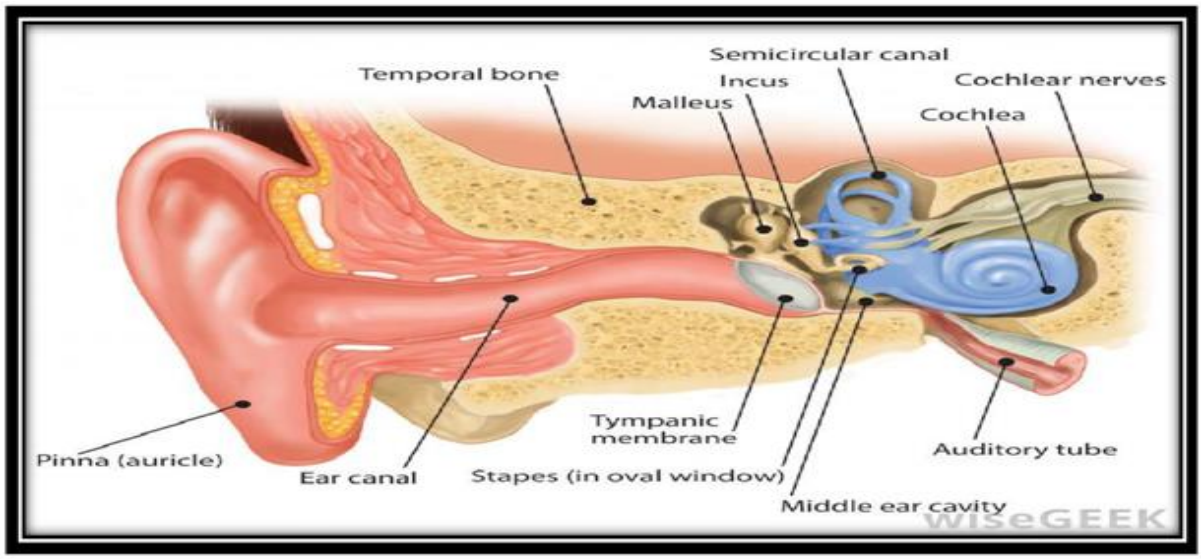



Figure 12: Place Theory of Sound Perception (PTSP) (assessed on (http://www.alleydog.com/glossary/definition.php?term=Frequency%20Theory#ixzz3odZfeQx assessed May 14, 2015).

Other studies on auditory perception of musical instruments acoustics has provided several of the persuasive proofs of how the human ear perceives and analysis musical sound. Bess, Dodd-Murphy and Parker (1988, pp. 334-345) writes that

> An initial dichotic listening study with infants between the ages of 22 and 140 days yielded a right-ear advantage (REA) for detection of transitions between consonants, for example, ma/ to /da/), and a left-ear advantage (LEA) for transitions in musical timbre, for example, cello to bassoon

Bess, Dodd-Murphy and Parker's position here is an affirmation of the Place theory that the human ear has a place for different (musical and speech) sounds as it comes to human hearing.

In another study in line with the Place theory of Pitch Perception (PTPP), Josh,McDermott and Andrew (2008, pp. 452–463) write that:

> The perception of music depends on many culture-specific factors, but is also constrained by properties of the auditory system. This has been best characterized for those aspects of music that involve pitch. Pitch sequences are heard in terms of relative, as well as absolute, pitch. Pitch combinations give rise to emergent properties not present in the component notes. This has given the basic auditory mechanisms to contribute to perceptual effects in music.

From the above submission, it is understood that perception of music is always affected by the process of the auditory mechanism which decodes and encodes musical instruments acoustic information.Also, the perceptive ability in encoding musical instruments acoustics pitch as related to intervals is related tohow tonal structure is perceived.

Further study by Stefanos, Vassiliki, Vassiliki, Stergios, Konstantinos, and George (2004) observe that:

> Perception of complex sound is a process carried out in everyday life situations and contributes in the way one perceives reality. Both nature sounds and sounds in most everyday situations are complex sounds composed of basic sounds. Basic

> sounds are most often produced and heard in laboratory situations. Attempting to explain sound perception is complicated. Sound has a physical and a psychological component.

The implication of the above submission by Stefanos, Vassiliki, Vassiliki, Stergios, Konstantin and George put it that the effects of musical sound perception in human psychology and physiology seem complicated. An attempt to expatiate musical instruments acoustic perception could only be easier if such perception is trimmed to the fundamental and relative hearingincitement. This perception of auditory signals can only be "analysed by the science of psychoacoustics".

On the perception of loudness and lowness of musical instruments acoustics as located in the place theory, Serpanos and Gravel(2017) write that:

> Loudness is an attribute for a sound that places perception on a scale ranging from inaudible/quiet to loud/uncomfortable, in response to change in sound pressure level (intensity). The same goes for low intensity of sound. It all depends on where and how such sound is perceived.

From all the studies highlighted above, it has established that the Place Theory of Pitch Perception (PTPP) will drive home the set objectives of this study It should however, be emphasised here that congregants' perception of musical instruments acoustics than the traits of this theoretical framework because it hasestablish a foundation to achieve the set objectives at probing into the congregation's perception of sound within the church auditoria, establish what represent good and bad sound production in church auditoria and to measure the volume of sound produced vis-a-vis the size of the worship auditorium.

# CHAPTER THREE
# PERCEPTION OF MUSICAL INSTRUMENTS'ACOUSTICSIN THE SELECTED CHURCH AUDITORIA

## 3.0 Introduction

The musical instruments'acoustics of the selected church auditoria in South-Western Nigeria have become a social phenomenon at every worship service. The effects of this are not limited to worshippers alone, but also extend to residents around the church auditoria immediate environment. Due to rapid growth in the development of technology and its application in the area of musical production and propagation currently advancing in developing countries like Nigeria, the musical and liturgical style of most churches have changed, even without considering the acoustic nature and status of the existing church auditorium. This chapter therefore examines the musical instruments' acoustics of selected church auditoria in south-western Nigeria with particular attention to reflection, reverberation, absorption and transmission of musical instruments in order to enhance the hearing and perception of musical sounds emanation within such auditoria. The musical ensemble of the various musical instruments as used in these selected church auditoria were also examined in this chapter.

## 3.1 Historical Perspective and Acoustic Effects of Selected Church Auditoria

On the historical perspectives and acoustic effects of the selected church auditoria, the study examines the historical development of the churches, the various musical instruments available in each church auditorium and the church acoustic structure and parameters. The placement of the organ and other musical instruments such as trap set drums, bass guitar, rhythm guitar, saxophone, talking drum, trumpet, wood block and conga drums in connection with musical instruments sound production, propagation, receptionand perception within each church auditorium and how they are characteristically influenced by usage, function and contribution to the entire musical instruments acoustics during each worship session.

**(a) Saint Peters Cathedral, Ake, Abeokuta**

The city of Abeokuta is capital of Ogun State, is located in the Southwestern part of Nigeria. Abeokuta is situated on the eastern part of the Ogun River. The city derives its name from the very big Olumo Rock which served as the vantage place for the Egba warriors during the Kunrunmi-Ijaye war. The city of Abeokuta shares boundary in the north with Ibadan, the capital of the Oyo state)(www.saintpetersake.org. Figure 13 is the Map of Abeokuta, the location of Saint Peters Cathedral Church.




*Figure 13: Map of Ake (www.map.data.com)*

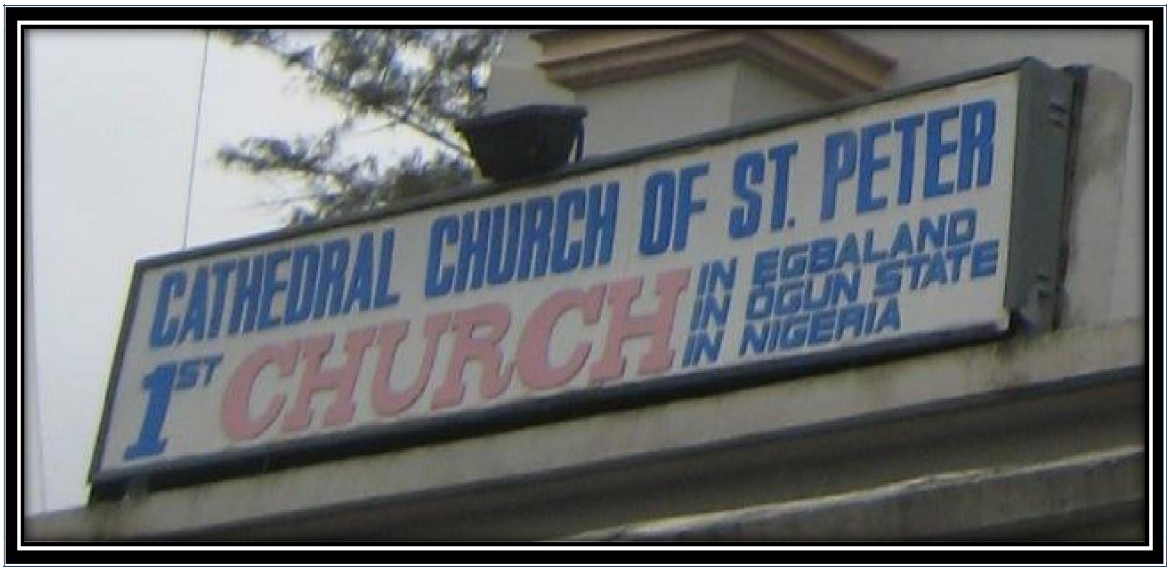



*Figure 14: The Signpost of Cathedral Church of Saint Peter, Ake. Abeokuta (Photograph taken by the researcher on January 3, 2016)*



Figure 15: Cathedral Church of Saint Peter, Ake. Abeokuta
*(Photograph taken by the researcher on January 3, 2016)*

**(b) Musical Instruments Sound at Saint Peter's Cathedral, Abeokuta**

From various observations and experiences as a church musician, I have discovered that churches are not just built but, are built in line with church doctrinal values which are premised on the structural styles of the auditoria where worshippers gather to worship. Resulting from study of history, when places of worship were built by believers for the purpose of physical and symbolic reasons, for example, the acclaimed first church (Cathedral Church of Saint Peters) in Nigeria built in 1899 in Abeokuta as replaced with a new church building as a result of the desire to express symbolic form with modern building. This symbolic reason, at the same,reproduces the particular mission, nature aspirations of the congregation, this is coupled with establishing a referential point to the general characteristics of the worship auditorium.

On musical and acoustic effects of the church, the following observations were made inside the church auditorium. There are various musical instruments available for use in the auditorium, these include pipe organ, electronic keyboard, rhythm guitar, bass guitar, trumpet, saxophone, trap set drum, conga, gong and wood block. Figure 16 shows the set of musical instruments or praise singing at the Cathedral Church of Saint Peters, Abeokuta.



Figure 16; Praise band musical instruments at the Cathedral, Abeokuta *(Photograph taken by theresearcher on January 3, 2016)*

The three-manual Pipe Organ at the Saint Peter's Cathedral Church Ake, Abeokuta is placed at the front right side of the church auditorium; the pipe organ which was built by Reservolt was purchased and installed in 2010. The pipes of the organ were separately installed directly opposite the organ side close to the pulpit. The pipe organ was built with two octaves pedal notes. Figure 17 is the pipe organ as found at the Cathedral church Ake, Abeokuta.



Figure 17: The Three-manual pipe organ at the Saint Peter's Cathedral church Ake, Abeokuta with Yemi Odediran on the organ console in one of the church worship services. *(Photograph taken by theResearcher on January 3, 2016)*



Figure 18: Pipes of the Organ at the Saint Peters' Cathedral Church, Ake, Abeokuta.


Figure 19: *The amplifying system console at the Cathedral Church of Saint Peters, Ake, Abeokuta (Picture taken by the Researcher on January 3, 2016)*

The musical sound amplifying equipment at the Cathedral church, Ake is just a simple installation. The reason for this was provided by the Clergy-in Charge that much emphasis is not laid on the amplified instruments but only on the pipe organ sound which is the basic instrumental accompaniment for hymnal songs that are mostly used during each worship service in the Anglican Communion. Although, the praise band also function in the church during worship services but for only a period of fifteen (15) minutes slated forthe offering and thanksgiving. Figure 19 above is the simple sound equipment at the Cathedral church auditorium.

**(c) Our Saviours' Church, Ikenne**

The city of Ikenne is a major town in Ogun State which became highly influential as a result of the political emergence of Late Chief Obafemi Awolowo during the struggle for Nigeria independence in the late 50s. Our Saviours' Church, Ikenne was built by Chief Obafemi Awolowo but now in the control of the Christian Mission Society (CMS) of Nigeria. (www.saintpetersake.org). Figure 20 is the Map of Ikenne, the location of Our Saviours' Church, Ikenne.

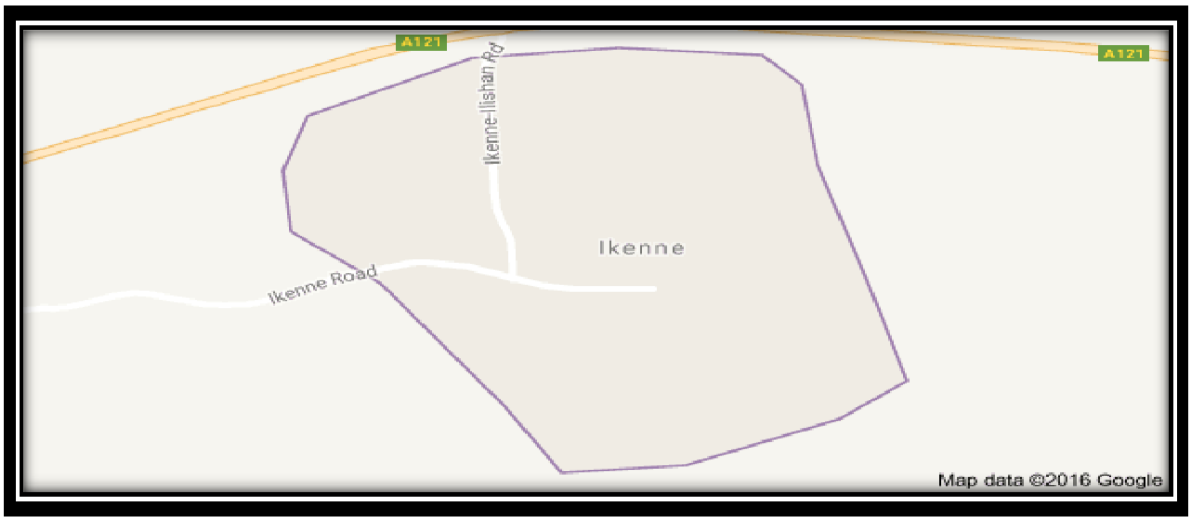



*Figure 20: Map of Ikenne (www.map data.com) (Accessed on March 8, 2017*




Figure 21: The signpost of Our Saviour's Church, Ikenne (Photograph taken by the researcher on March 5, 2016

**(d) Musical Instruments Sound of Our Saviour's Church, Ikenne**

The musical instruments ensemble available at Our Saviours church, Ikenne include pipe organ, electronic keyboard, rhythm guitar, bass guitar, trumpet, saxophone, trap set drum, conga, gong and wood block. The position of the organ in the church is at the left front side (caged) of the auditorium facing the church Altar as seen in figure 22. The pipes of the organ were installed separately from the main organ console; the pipes are located at the back side and to the south entrance door of the auditorium which makes the organ sound to radiate round the entire auditorium. Figure 22 reflects the position of pipes of the organ at OurSaviours Church, Ikenne



Figure 22: Electronic Organ at Our Saviours church, Ikenne. ((*Photograph taken by theresearcher on March 5, 2016)*



Figure 23: Pipes of the organ at Our Saviours church, Ikenne. ((*Photograph taken by theresearcher on March 5, 2016)*

The installed equipment for sound production and propagation in this auditorium is too large in capacity when compared with the size of the auditorium. This notwithstanding, the sound production in the auditorium is very clear. It was also discovered the useof condenser microphones are also available in the auditorium, besides this, the vicar uses pin-up microphone in the celebration of services, the microphone is usually clipped to clergy robe around the neck area of the cassock. Figure 24 and 25 are the sound consoles as found in the auditorium.



Figure 24: The sound equipment



Figure 25: The Mixer Console

*(Photograph taken by the researcher at* Our Saviour's Church, Ikenne *on March 5, 2016)*

**(e) Celestial Church of Christ, Akobo, Ibadan**

The city of Ibadan is the OyoState's capital, in the South-western, Nigeria. The city shares boundary Omi-Adio and Ikire. (www.saintpetersake.org). Figure 26 is the Map of Akobo, the location of the Celestial Church of Christ, Oluwaseun Parish, one of the selected church auditoria for this study.



Figure 26: Map of Akobo, Ibadan (*www.mapdate.com*) *(Accessed on August 5, 2016)*

**(f) Musical Instruments Sound atthe Celestial Church of Christ, Akobo Ibadan**

The musical instruments ensemble available at the Celestial Church of Christ, Oluwaseun Parish, Akobo Ibadan include a Yamaha PSR 940 electronic keyboard, two rhythm guitars, one bass guitar, three trumpets, four saxophones, one trap set drum, one conga, one gong, three Talking drums, one Omele drum and one wood block. The position of the musical instruments in the church is at the left side in the front of the auditorium. The positioning arena of the musical instruments was not rugged but with a terrazzo with no sound absorber which generates several soundreflections. This arena also has other reflective materials such as the floor surface, unpadded walls and plastic chairs that contribute to severe sound reverberations and dullness of musical instruments 'acoustics. Figure 27 is the praise band position at the Celestial Church of Christ, Akobo Ibadan.


Figure 27: Musical Instruments available at Celestial Church of Christ, Akobo. ((*Photograph taken by theresearcher on August 6, 2016)*

**(g) The Redeemed Christian Church of God, Mega Parish Ilesa**

The Redeemed Christian Church of God, Mega Parish Ilesa was situated in Ilesa, South western Nigeria. Figure 28 is the map of the location of the Redeem Christian Church of God (RCCG), Ilesa Mega Parish.




Figure 28: Map of Ilesa (*www.mapdate.com*) *(Accessed on April 7, 2019)*




Figure 29:Main entrance of the Redeem Christian Church of God, Ilesa. (Picture by the researcher on April 7, 2019)

In the auditorium are several sound reflective materials such plastic chairs, tilled floors, block pillars, PVC ceiling and other non-absorbent materials. Figure 30 reflects the picture of the internal features of the main church auditorium.



Figure 30: The inner view of the RCCG Mega Parish, Ilesha. (Picture by the researcher on April 7, 2019)

**(h) Musical Instruments Sound at theRedeem Christian Church of God, Ilesa.**

The musical instruments ensemble found at the Redeem Christian Church of God, Ilesa include a Yamaha PSR 940 Series Model electronic keyboard, two rhythm guitars, one bass guitar, two trumpets, three saxophones, one clarinet, two talking drums, one Omele drum, one Conga drum, and one gong. The choir plays a vital role during each worship service because the choir controls and directs all musical activities during services thus: the choir and the position of the musical instruments in the church are at the same location, just to the left side of the Altar when observed from the main entrance of the church auditorium through the west door.

**(i) Iyeru Okin African Church, Offa**

The city of Offa is one of the ancient cities in Kwara State. it is located some kilometres from Ilorin, Kwara State capital in the North-Central part of Nigeria. Figure 30 is the Map of Offa, the location of Iyeru Okin African Church, one of the selected church auditoria for this study.



Figure 31: Map of Offa (*www.mapdate.com*) *(Accessed on March 28, 2019)*



**Figure 32:** The main entrance of Iyeru Okin African Church, Offa. (Picture by the researcher on April 7, 2019)

**(j)Musical Instruments Sound at African Church, Offa**

The musical instruments ensemble available at Iyeru Okin African Church, Offa include a four manual electronic organ with two octaves pedals scales, electronic keyboard, rhythm guitar, bass guitar, saxophone, trap set drum, conga, gong and wood block. The position of the organ in the church is at he let side in the front of the auditorium, just immediately at the back of the choir seat. Figure 32 is the four manual electronic keyboards found at the Iyeru Okin African Church, Offa.



Figure 33: The Four-manual electronic keyboard atIyeru Okin African Church, Offa. (Picture by the researcher on April 7, 2019)



**Figure 34:**The inner view of Iyeru Okin African Church, Offa (Picture by the researcher on April 7, 2019)

The city of Ile-Ife is situated in the State of Osun; precisely it is located in the Ife Central Local Government Area in south-western Nigeria. Gospel Faith Mission International, Dominion Center is one of the selected church auditoria for this study, it is located along Ife/Ibadan Express

way, opposite Adesanmi Bus stops, Ile-ife. Figure 33 is the map of Ife Central Local Government Area.

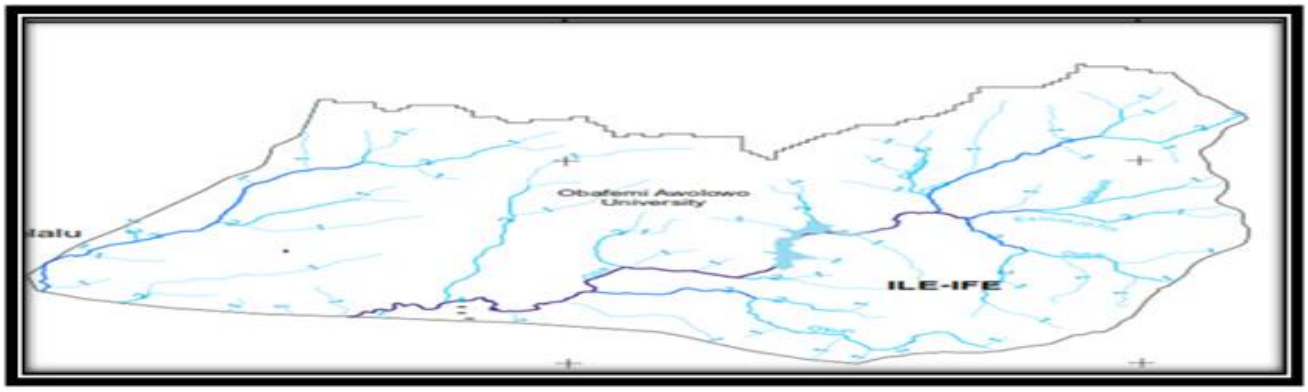



Figure 35: Map of the Location Dominion Center Church, Ile-ife (*www.mapdate.com*) *(Accessed on March 28, 2019)*




Figure 36: Dominion Center Church Signpost (Picture by the researcher on May 9, 2017

**(l) Musical Instruments Sound at Dominion Center Church, Ile-Ife**

The musical instruments ensemble found at the Dominion Center Church, Ile-ife include Yamaha PSR 940 Series Model electronic keyboard, 2 rhythm guitars, a bass guitar, saxophone, trap set drum, conga and a gong. The position of the musical instruments in the church is at the same with choir seats, just to the right side of the auditorium Altar. The floor of the choir stall was tilled with only the drum placed on a rectangular colour red rug, to prevent drum shift while playing and also to dampen any excessive vibrations from the drum. Figure 35 is the electronic keyboard found at the Dominion Center Church, Ile-ife.



Figure 37: The inner view of the Dominion Centre Church (picture by the researcher on April 7, 2019)

### 3.2 Location of the Choir and Instrumentalists in the Selected Church Auditoria

The choir and the instrumentalists are identified and valued because of the functions performed at every worship service and as a result, the choir and the instrumentalists have to be positioned in a vantage arena within the church auditorium. The location of the choir as observed in the two gothic structured church auditoria; Saint Peters Cathedral church Ake, Abeokuta and Our Savour's church, Ikenne is on both sides of the sub-alter region, just a step to the altar, that is one at the organ side and the other at the pulpit side, however, this choir location is peculiar to most orthodox churches. The choir seats are made of wooden pews with installed conference type dynamic microphones positioned at the interval of five feet to one another. Other musical instruments used like the bass guitar, rhythm guitar, trap set drums, trumpets, saxophones, conga, gong and woodblock are positioned at the space behind the pulpit. The location of the choir at the Redeem Christian Church of God (RCCG) Ilesha follows the contemporary church settings, the choir and the instrumentalist are place in the same arena, that is, at the right side of the alter. The singers are placed in the front with separate cushioned chair for each chorister while the instrumentalists are positioned behind the choir. There are about eight cable dynamic microphones placed on microphone stands and two pairs of dynamic wireless microphones. The lead singer has

a separate multi-dimensional wireless microphone which allows for liberty to move freely around the auditorium during praise singing.

Location of the choir and instruments differs and depends on church design. Some churches design can place the choir and the instrumentalists on the gallery while others locate the choir and the band in the front side, very close to the Altar as observed in all the three selected churches. Other determining factors may include the identification of certain unchangeable situations based on liturgical understandings and on the number of musical instruments available for use in each church auditorium. The position of the pipe organ is usually fixed at the Pulpit side as observed at the Saint Peters Cathedral Church Ake, Abeokuta and Our Saviours' Church, Ikenne and the reason for this is rigorous time it requires to relocate the pipe organ from one place to another without affecting the position of the pipes which are responsible for it sound production.

Based on observation atthe Redeem Christian Church of God (RCCG) Ilesha,it was concluded that Pentecostal church auditoria suffer acoustically treated structure in addition to the under-use of sound-absorbing carpeting which contribute to adverse acoustic effects on musical instruments' acoustics quality. Consequently, the use of non-calibrated amplifying sound systems, as observed in virtually all the three selected church auditoria sound amplifying set up, results into excessive amplification of musical instruments acoustics resulting in displeasure of sound perception within church auditoria.

There are several musical instruments available as observed in the selected church auditoria, these include pipe organ as discussed in the earlier part of this chapter, and others are guitars (rhythm and bass), trap set drums, saxophone, trumpet, conga drums, wood block and gong. Each of these musical instruments has particular musical and acoustic contributions to the overall musical production, propagation, receptionand perception within each church auditorium. The musical and acoustic characteristics of each musical instrument as observed in these church auditoria would be briefly discussed, however, this discussion is based on the classification of each into a particular category as used in the selected church auditoria.

### 3.2.1 Musical Instruments Sound Propagation in the Selected Church Auditoria

The acoustic properties of an auditorium directly dictate the sound quality in that environment and which directly affect musical sound propagation from the source of sound to receiver's perception coupled with the awkward bending sound round the auditorium and put the worshippers' ear to a very limited extent of good musical instruments perception. This singular factor puts the perception of musical instruments acoustics as a useful ability to appreciate, to inform and to communicate a difficult issue. Observations of musical acoustics in these church auditoria reflect that propagated sound lack proper clarity as a result of the acoustic nature provided in these auditoria. Moreover, musical instruments sound as observed in all the three selected church auditoria hit the wall and as a result, part of the sound is engrossed, part dispersed and the rest reproduced, in this process, fundamental sound energy is misplaced, or partially distributed in space and the left less sound energy propagated faintly or weakly to the entire congregation.

Based on participant observation at the Saint Peters Cathedral church Ake and Our Saviour's church, Ikenne, it was also observed that the performance space for musical activities is one major factor in musical sound propagation in church auditoria because of the tonalcolouration nd reverberation provided by such room in order to make musical sound pleasing and attractive but not dead. Realistically, reflections from the auditorium of walls in the selected church affect the total propagated sound in these auditoria. It was also observed that the amount of sound scattering depends on the volume and frequency of sound wave and the available reflecting constituents with the church auditoria.

### 3.2.2 Musical Instruments with Vibrating Strings Acoustics

Various musical instruments in the strings family have has a reservedposition in musical performances for several years. Agren(1986, pp. 213-226) posits that"these string instruments form the backbone of the symphony orchestra and are widely used as solo instruments in chamber music as well". Alonso (1984, pp. 91-98) equally states that "bowed or plucked string instruments have been the objects of considerable scientific study; even so, their acoustical behavior is just

beginning to be understood". Hutchins (1983, pp. 182-203) has attempted the historical values of violin in hisresearch from "Pythagoras (sixth century B.C.) to the present". Hutchins (ibid: p. 200) states that "Scientific understanding of vibrating strings began with Galileo Galilei (1564-1642) and Marin Mersenne (1588-1648) as cited by Stephen, Firth, Jack, and Alan (1974, pp. 600-604). Marshal (1985, pp. 1437-1442)". These scholars discuss the values of stringed instruments and indicates the human perception of minimal four overtones as established in the musical instruments' sound of all vibrating strings instruments.

Felix Savart (1791-1841) as cited by Miller (1987, pp. 211-221) recalls some of this studies in a joint research with "Jean Baptiste Vuillaume (1798-1875), a renowned violin maker". According to Raman (1976: p. 1222) in Fletcher (1976, pp. 1566–1569) write that "Vuillume constructed experimental instruments and expressed the inharmonic musical oscillatorswhich resulted in the development of a"12-foot octo basse". Savart (1978, pp. 5923-5928) also write on the "vibrations of top and back plates on Stradivarius and Guarnerius violins loaned to him by Vuillaume, and by careful experiments correctly deduced the function of the sound post".

Another string musical instrument relevant to this study is the guitar because it is commonly used in all church worship sessions especially, as observed in all the purposively selected church auditoria for this study. The coming into existence of the guitar cannot be without the link with the "sixteenth-century Spanish vihuela, which has its roots in antiquity". Allen and Arnold (1976, pp. 125-136)also establishes that "Boccherini and other composers of the eighteenth century included the guitar in some of their chamber music,the establishment of the guitar as a concert instrument took place largely in the nineteenth century". Fletcher and Rossing (1988, p. 432) write on the nature of guitar wood as"usually a hardwood, such as rosewood, mahogany, or maple, both the top and back plates are braced, thebracing of the top plate being one of the critical design parameters". However, Martin(2009, pp. 46-56) opines that:

> acoustic guitars generally fall into one of four families of design: classical, flamenco, flat top (or folk), and arch top. Classical and flamenco guitars have

nylon strings; flat top and arch top guitars have steel strings. Steel string guitars usually have a steel rod embedded inside the neck, and their soundboardsare provided with crossed bracing

The relevance of this pictorial expression is that guitars are mostly used in church auditoria and even serve both as the song accompaniment to the keyboard and a solo instrument with the role playing the interlude to most songs. It is to affirm the fact that guitar, like every other musical instrument, are manufactured with a fundamental acoustic. The guitar has its own acoustic and produces sound such through the sound hole, even when not amplified, will still produce musical sounds.

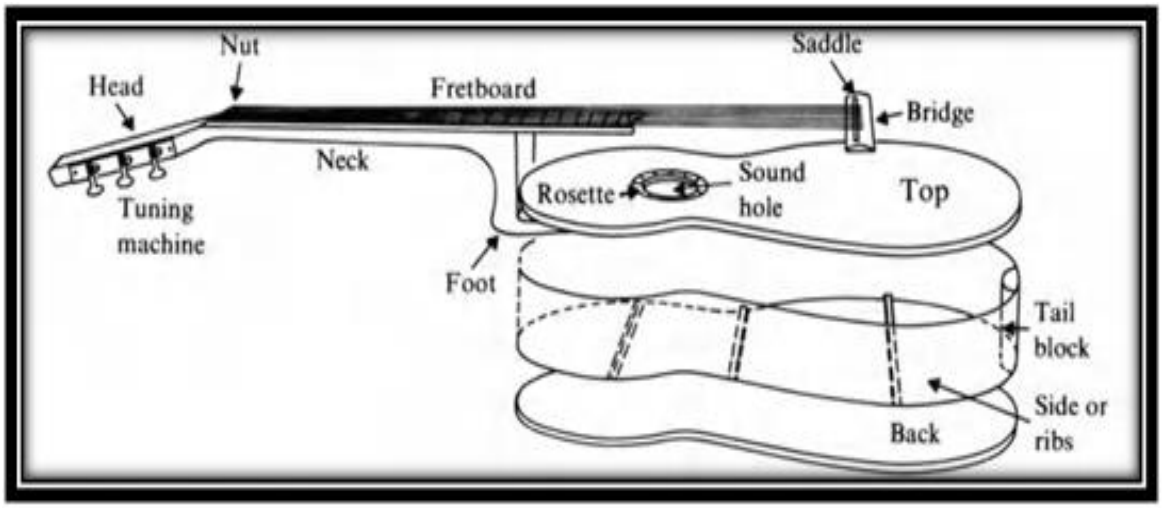



Figure 38: Martin's exploded view of a guitar construction (Martin: 2009, p. 44)

Congregants' perception of the guitar in the selected church auditoria is basically as a musical instrument with all its beautiful tones in spite of certain observed certain inter-connected effects of sound distortion from the guitar especially, when amplified as noted by the researcher the selected church auditoria.

**(a) Resonances of a Guitar Body**

Caldersmith (1978, pp. 1566-1575.) observes that:

> the frequency response of a guitar is characterized by a series of resonances and anti-resonances. In order to determine the vibrational configuration of the instrument at each of its major resonances, it is usually driven sinusoidally at one or more points, and its motion observed optically, acoustically, electrically, or mechanically.

Buttressing Caldersmith's opinion, Stetson, (1981, pp. 67-73) wrote that "optical sensing techniques include holographic interferometry and laser velocimetry are required for the playing of guitar in order to achieve a better sound result". Boullosa, (1981, pp. 344-348) equally compliments that "acoustical detection techniques have included using an array of microphones and scanning with a single microphone". In his own opinion, Ross and Rossini (1979, pp. 657-678), write that "electrical pickup relies on variation in capacitance as the instrument vibrates, and a mechanical pickup consists of an accelerometer or a velocity transducer of very small mass such as a phonograph cartridge".

Arnold & Weinreich (1982, pp. 1739-1746), writes that

> the configuration of a guitar at one of its resonances is often called a mode of vibration, but it is not necessarily a normal mode of the system. A resonance may result from exciting two or more normal modes. Only when the spacing of the normal modes is large compared with their natural widths does the vibration pattern at a resonance closely resemble that of a normal mode of vibration

Very limited numbers of studies with regards to the acousticnature of a guitar have been made known, for example, Firth (1977, pp, 12-24) writes on the measurement ofthe guitar quality and its credibility, Firth states that this occurs "at thetreble end of the bridge and the radiated sound level 1metre away".Firth then connects"the peak at 132 Hz with the "Helmholtz air mode" which is the action of the air pressure on the fundamental mode of a musical instrumentand thepeaks at "304, 395, and 602 Hz with resonances in the top plate". The graphical expression below shows the Sound Pressure Level of Guitar see figure 39.

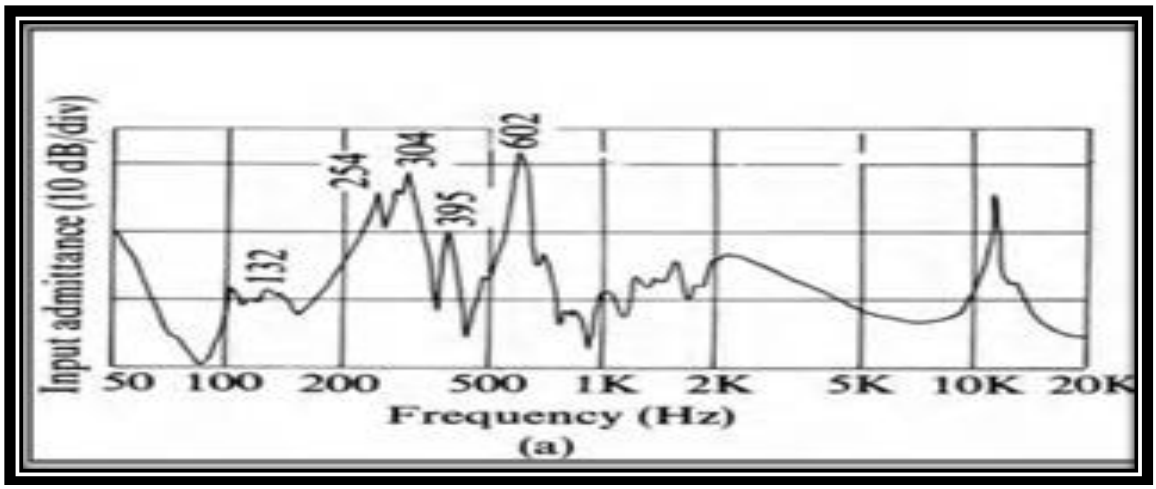


Figure 39: Guitar Sound Pressure Level (SPL).

**(b) Timbre vibratos**

Carse (1965, p. 139) definesvibrato is the "periodic fluctuation in pitch, amplitude and timbre of a musical tone". Most strings instruments players always apply vibrato effects, just as singers and in some cases, it is also applied by the wind instrumentalists for the purpose of colouring a particular musical sound. Researches on vibrato havebeen directed mainly to the conventional features which have formed a practice that is mostly seen in "sinusoidal" which was defined by Carse (1965, p. 137) "as a signal made of the sum of several periodic signals and displayed in its perceived central pitch, the mean or median of pitch fluctuation". Shonle & Horan (1996, pp. 1728-1735) write that:

> the conscious or unconscious control of vibrato features by professional violinists have been a point of debate while string instruments are generally found to be able to control vibrato rate and extent, singers are said to have very limitedconsciousness to no control, or to have only some control over vibrato extent

According to Shonle and Horan (1996, p. 1730) "the portion of the forces of musical sound being exert on the strings' bridge is a very strong function of frequency, as a result of the many resonances in the body.Shonle and Horanalso buttressed this that when a note is played "with a particular frequency, some but not all of the harmonics coincide with resonances, some are strongly transmitted in the output sound, while others are weakly transmitted". Violin and guitar belong to the strings family, bridge and bodyresonances of violin and guitar producetimbre vibrato

which is considered a source of fundamental sound productions. The use of violin and guitar are noticed in the selected church auditoria.

### 3.2.3Musical Instruments with Vibrating Body (Idiophones)

Musical instruments in the idiophone family possess the ability to produce independentmusical sounds. Ibagere (1994, p. 91), defines idiophone "as a group of self-sounding instruments which produce sound when they are struck, scratched, or shaken". Cook (2004, pp. 315–320) was of the opinion that although, the musical instruments with vibrating body are found inmusical ensembles throughout the worldyet, has little functional significance in churches in this century. The reason for this has been attributed to several factors such as the non-amplification nature of most of these musical instruments. In this connection, Le Guin (2006, pp. 122-134) cited few examples of the family of these musical instruments such as the Glockenspiels and orchestra bells which are considered as percussion family in an orchestra though are categorised as Idiophones in the Sachs-Hornbostel system of musical instruments classifications. Other musical instrument in this category includes Xylophone, Ekele or Akpata, Oponda, agogo, ogene, ekwe and une.

According to Blades (1970, pp. 267-279),one of the commonly used idiophone musical instruments in Nigeria is the local xylophone although, not commonly used in church auditoria especially, in the selected church auditoria.Ibagere(1994, p. 93) write that:

> most of the instruments are made of cow horns. Ibagere further states that because of the hard wooden or metal materials used, which is struck or beaten, it becomes difficult (if not out rightly impossible) to use the hand, rather, well carved sticks (some of which the beating area is covered with synthetic material) are used to beat or strike the wood or metal to produce sound.

Figure 38 is an example of the gong as captured at the Saint Peters' Cathedral Church, Ake, Abeokuta



Figure 40: A typical Gong (Picture by the researcher at Saint Peter's Cathedral, Ake)

Musical instruments like the gong are noticeably used at the Saint Peter's Cathedral churchAke, Abeokuta with the main function to keep the metronome especially when native airs are sung.

Also observed, because of the amount of noise generation, is the crash cymbal, one of the parts of a trap set drums. Benade, (1976, p.233) writes that:

> Cymbals are among the oldest of musical instruments and have had bothreligious and military use in a number of cultures. Many different types ofcymbals are used in orchestras, marching bands, concert bands, and jazzbands. Orchestral cymbals are often designated as French, Viennese, andGermanic in order of increasing thickness. Jazz drummers use cymbals designatedby such onomatopoeic terms as crash, ride, swish, splash, ping, and pang.

Blades (1970, p. 312), in his description of the crash cymbals, submits that:

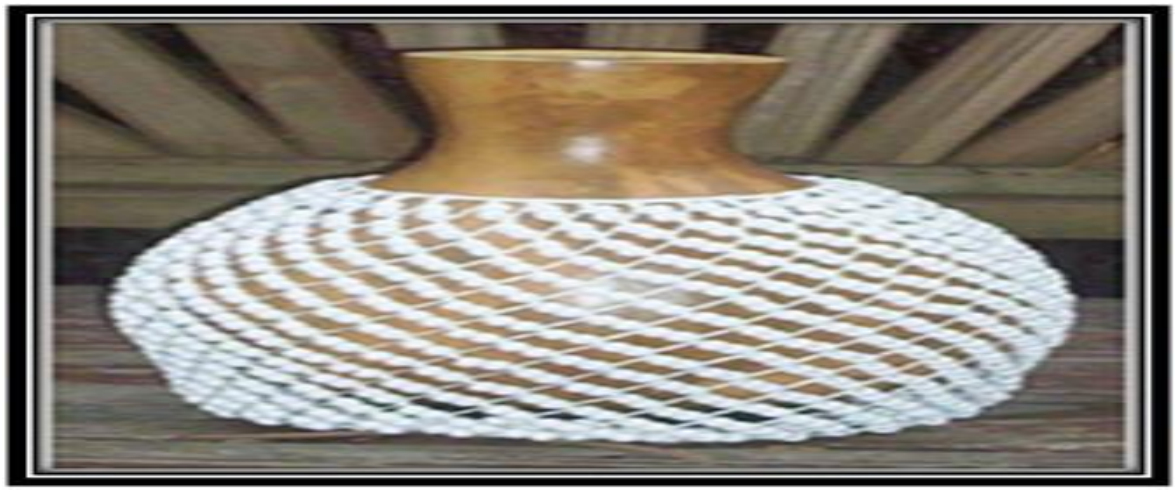
> cymbals are normally made of bronze, and they range from 20 cm to 74 cm in diameter. The Turkish cymbals generally used in orchestras and bands are saucer shaped with a small spherical dome in the centre, in contrast to Chinese cymbals, which have a flattened dome and a turned-up edge.

Figure 41 expresses the picture of most Turkish cymbals as discussed by Blades and as found in most church auditoria and Brigade Bands within the church musical performance groups.



Figure 41: A typical Cymbal (Picture by the researcher at Dominion Centre, Ile-Ife)

Also observed in this category is the maraca which was used as the rhythm controller in musical instruments sound production in all the selected church auditoria. Figure 42 is a typical example of Maracas as captured by the researcher at Dominion Center, Ile-Ife.


Figure 42: A Maraca as captured by the researcher at Dominion Center, Ile-ife

Congregants' perception of self-sounding musical instruments especially, the gong and the crash cymbals is loud. Though, these musical instruments are considered as metronomes yet, the sound override other musical instruments when amplified and full of discordant if not properly played in consonance with the existing rhythm in an ensemble.

### 3.2.4 Musical Instruments with Vibrating Membrane (Membranophones)

Membranophones are musical instruments that produce musical sounds by anexpandedthin layer of animal tissue, examples of such are drums. Membranophones instruments as observed in all the selected churches include the Trap set Drums, Conga Drums and the Talking Drums.

Membranophone instruments have been as old as history can write about them. Blades (1970, p. 275) writes that:

> drums are practically as old as the human race but, with the exception of the human voice, they are our oldest musical instruments. The earliest drums were probably chunks of wood or stone placed over holes in the earth.

Cook (2004, p. 218), in his submission writes that

> the discovery of more sounds as obtained from hollow tree trunks by the ancestors of our contemporary log drums. No one knows where the first membrane drum was made, but some ancient drums are at least 5000 years old. Skins of animals or fish were stretched across hollow tree trunks, and the drums were probably struck with the bare hands. Later progress in skin drums led to bowls or shells with special shapes and various means for applying tension to the drum heads. Drums acquired religious as well as musical importance, and drum making became an important ritual in several cultures.

Drums are found to be very important in the musical instruments' ensemble in all the selected church auditoria in south-western Nigeria and equally form avital aspect of worship especially in praise singing.Drums are manufactured in various shapes and patterns.Baines (1992, pp. 213-225) expresses that:

> the two basic shapes for shells are bowls and tubes. In his expression, it was opined that the most familiar bowl-shaped drums in Western music are kettledrums, also known as timpani. Tubular drums may be taller than they are wide, such as conga drums, or shorter than they are wide. Short drums, also known as shallow drums, are the most common tubular drums used in Western music. Shallow drums include snare drums, tenor drums, and bass drums.

Other types of drums found in Nigeria are Talking drum, Bata drum, *Omele*, *Kudi*, Conga and *Iya Ilu*.Among the several examples of drums given above, the most commonly used, as observed in the selected church auditoria, are the talking drum and the Conga drum. The use of these two Membranophone musical instruments are noticed at the Saint Peter's Cathedral church Ake,

Abeokuta, Our Saviours' church Ikenne and especially, Celestial Christian Church, Ibadan where it is profoundly used because of the nature of high praise singing style of the church. Figures 43 and 44 are the talking drum and conga drums as found at the Celestial Christian Church, Ibadan.



Figure 43: Talking drum



Figure 44: Conga Drums

(Pictures taken by the researcher at Dominion Centre church, Ile-Ife)

Drums produce musical sound by either hand-beaten or struck-beaten and this has the general sound producing feature of drums. Bonfoey (1986, p. 123) argues that"some membranophones have the vibrating membrane set into motion by sound waves coming from a human voice or from another musical instrument", example of such drums are the snare drums.

**(a) Bass Drums**

The kick drum, also known as the bass drum is one of the sets of drums in a trap set drums. It is a loud musical instrument and often perform the function of maintaining the rhythm with the gong in musical instrument ensemble. Rossing (1982, pp. 192-208), observes that:

> the bass drum is capable of radiating the most power of all the instruments in the orchestra, at theacoustical peak power of above 20wtsA concert bass drum usually has a diameter of 80-100 cm (32-40 in.), although smaller drums (50-75 cm or 20-30 in.) are popular in marching bands. Most bass drums have two heads, set at different tensions, but single headed "gong" drums are widely used when a more defined pitch is appropriately required and of which heads has a thickness of 0.010 in. (0.25 mm) are widely used, although calfskin heads are preferred by some percussionists for large concert bass drums.

In tuning the bass drums, Rigden (1977, p. 121) writes that

> most drummers tune the batteror beating head to a greater tension than the carryor resonating head; some percussionists suggest that the difference be as much as 75% (giving an interval of about a fourth. Rigden further recommends that tuning the carry head higher than the batter head for orchestral music but lower than the batter head in solo or small ensemble playing.

Rossing (1987, pp. 121-132) compliments that:

> a distinctive timbre results from setting both heads at the same tension, but the prominent partials in the 70-300-Hz range appear to be stronger (initially) and to decay faster when the carry head is tuned below the batter head. Frequencies of the (01), (11), (21), (31), and (41) modes fall surprisingly near a harmonic series, and if their partials were the only ones heard, the bass drum sound would be expected to have a rather definite pitch. Inthe frequency range above 200 Hz, however, there are many inharmonic partials that sound louder since the ear discriminates against sounds of low frequency.

In the calculation of the number of partial in the frequency range of the bass drum, Fletcher and Bassett (1978, p. 57) found “160 partials in the frequency range 200-1100 Hz”. Table 6 for the “modal frequencies of an 82-cm-diameter bass drum”as experimented by Rossing (1978, p. 53). Figure 45 is a typical Bass Drum commonly used as observed in the selected church auditoria:




Figure 45: Common Bass Drum used in church auditoria (Picture taken by the researcher on April 9, 2017)

The Bass Drum has its specific modal frequencies fathomed on the drum venom head; this decides the sound production based on the intensity of sound produced. These modal frequencies are highlighted by Rossing (1987, p. 53)

Table 6: Modal frequencies in the bass drum head

| Mode | Carry Head at lower Tension | Heads at the same Tension |
|---|---|---|
| **01** | 39 | 44.104 |
| **11** | 80 | 76. 82 |
| **21** | 121 | 120 |
| **31** | 162 | 160 |
| **41** | 204 | 198 |
| **51** | 248 | 240 |

Rossing (1987, p. 53)

It could be observed from the above tablethat carrying head of the drum "at a lower tension" produces the same head at the high tension. The lower the carrying head gives the higher tension when played.Rossing (1987, p. 53) further opines that:

> when the two heads were at the same tension, for example, it was observed that a pair of (0l) modes at 44 and 104 Hz and a pair of (11) modes at 76 and 82 Hz. The (01) pair are the modes of a simple two-mass oscillator whose frequencies are given as $f1{=}f1\ and\ f1$

**(b) Snare Drum**

Snare drum is also one of the several parts of the trap set drums in the membranophone category of musical instruments.Rigden (1977, p. 121) writes that:

> the orchestral snare drum is a two-headed instrument about 35 cm (14 in.) in diameter and 13-20 cm (5-8 in.) deep. Strands or cables of wire or gut are stretched across the lower or snarehead. When the upper or batterhead is struck, the lower head vibrates against the snares. Alternatively, the snares can be moved away from the lower head. The modern side drum is a descendent of a long line of military drums.

Patterson (1994, pp. 1409–1418) submits that

snares were probably added about the time it appeared in jazz bands and dance orchestras. Variants of the side drum include the parade drum and the tenor drum, which are considerably deeper than the snare drum (30-50 cm). The parade drum is equipped with snares, but the tenor drum normally is not.

Figure 46 is a typical example of a snare drum.



Figure 46: A typical snare drum as observed at Redeem Christian Church of God, Ilesha. (Picture taken by the researcher on June 11, 2017)

### 3.2.5 Musical Instruments with Vibrating Column of Air (Aerophones)

Musical instruments in the wind category produce musical sound through of air into hollowed holes at the mouth piece. Musical instruments in this category include, as observed in the selected church auditoria, trumpets and saxophones. Benade (1976, pp. 489-504), observes that:

> those in which the blowing pressure tends to force the reed valve open (the human larynx, buzzing lips in brass instruments, and harmonium reeds) and those in which the blowing pressure tends to force the reed valve closed (clarinets, oboes and related woodwinds, and organ reed pipes). The first type can act as a sound generator over only a very narrow fundamental frequency range just above the resonance frequency of the reed, and can do so in some cases even without the aid of a resonant pipe.

Based on the observations of how worshipper perceived the musical tones of the drums, it was established that the loud output of the snare drum was considered as always very noisy. The

loudness is largely dependent of the styles of play by different drummers through their strokes on the snare without proper control despite the amplification of the drum sets. It was discovered that as the tempo of the drums increase, there was an equal pressure on the overall loudness of the drum sound. Most congregants condemned this attitude of high sound pressure during worship services.

### 3.2.5(a)Reed Driven Musical Instruments

Reed support in the sound generation of certain areophone musical instruments such as saxophone, clarinet, bassoon and oboe cannot be ignored. Nakamura (2004, pp. 417-420) submits that "vibrating reed generator is basically a pressure-controlled valve".Schumacher's (1981, pp. 151-153) development of "a physical model of the clarinet where the reed is regarded as a spring-mass system with one degree of freedom, and a reflection function calculated from the shape of an actual instrument is used".Sommerfeldt, Sawada and Sakaba (1981, pp. 1790-1794) and Miyachi and Takasawa, (2000, pp. 3–10) argue that:

> considering the resonance of the player's vocal tract, the former investigates the influence of the vocal tract on the quality of the generated sound. The latter successfully explains mechanisms of shifting pitch by the position of holding the reed betweenthe lips and by the thickness of the reed. In the double-reed instrument, pressure acting on thereed (*pr)* is different from pressure at the entrance of the instrument (*p)*, since the reed and the instrument are not connected directly but via a narrow tube

Meyer(1978, pp. 151-153) writes that "the former is due to turbulence and the latter is to re-attachment of theflow to the tube wall. Experimental and theoretical analysis on this phenomenon has not been completed yet". Recently, Vergez, Almeida, Causse, and. Rodet (2003, pp. 964–973) suggest a modelwith a parameter which relates to the generation of sound pressure "in the cross-sectional area of the narrow tube" which Copley and Strong (1996, pp. 1219-1226) see as applicable in"function for the double-reed instrument as differs from that for the single-reed instrument".

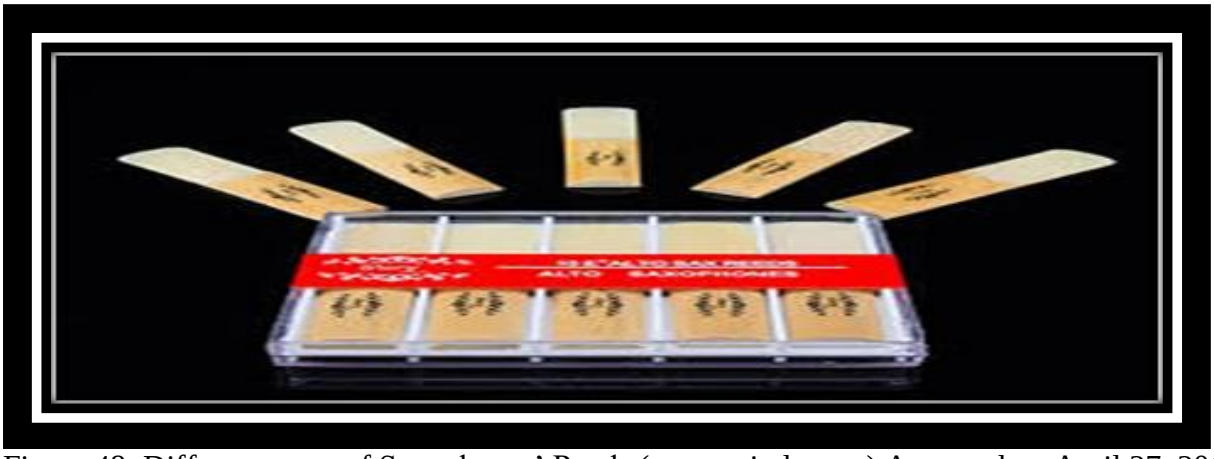
**(b) The Saxophone**

Benade (1986, p. 494) gives an account on how the saxophone was enlarged and upgraded with the giant step taken by "Adolph Sax in themid-nineteenth century" which put the saxophone in the direct contrast to the Bassoonas seen in figure 47.Benade&Kouzoupis (1988, pp. 292-304) also submit that "the saxophones when played to the octave will produce a spectrum with all harmonics present than what the bassoon will produce". In this regard, Benade and Lutgen (1988, pp. 1900-1907) submit that

> the lattice cut off frequency is relatively high, but the broad bell mouth radiates well, so that there is a strong fundamental component and strong radiation damping for higher partials. The tone is thus loud and full, though some playing techniques favour a raucous rather than a mellow sound



Figure 47: A set of the saxophone family (www.winds.com) Accessed on April 27, 2017)


Figure 48: Different types of Saxophones' Reeds (www.winds.com) Accessed on April 27, 2017)

Saxophone is perceived by the selected church congregants' as a musical instrument with high frequencies which described the saxophone sound as bright and sonorous. The sound of the saxophone by the congregants' is good and well appreciable as not loud when compared to the sound of the trumpet.

**(c)The Lip Driven Musical Instruments**

These category of musical instruments depend solely on the lipsound generating technique, this fact was complimented by (Carse: 1939, p. 206) "as a pressure-controlled system that functions best when working into a very high impedance in the minor range". Baines (1967, p. 131) puts it that "the development of these early instruments took two different paths in medieval times, both aimed at producing more flexible melodic possibilities".

The other line of development, according to Ancell (1960, p. 32) was "to increase greatly the length of the instrument and to narrow its bore so that the closely spaced upper modes became available for melodic use. Early military trumpets and bugles went some way in this direction using modes from the third to the sixth to produce familiar musical signals for camp life". Backus (1985, pp. 17-20), in his contribution,writes that:

> ceremonial trumpets used a greater mode range for their fanfares, and the coiled natural horns had available to them modes up to about the sixteenth and were thus able to produce an octave of complete diatonic scale, which, because of their considerable length, lay at a musically useful pitch.

Among other musical instruments in the lip driven sound generating techniques are the trumpet, trombone, euphonium, tuba, recorder French horn and cornet.

**(d) Trumpet**

Hirschberg Gilbert,Ponthus and Petiot (1998, pp. 1627–1632) give the historical account of the trumpet to have dated back to"the 1820s Heinrich Stölzel (1777–1844) who made a trumpet

in the true bass range, and Eb' tunings and was adopted by military bands. Today the genuine trumpet (in F') is manufactured by the firm of Thein in Bremen, Germany". To corroborate this, Miller, (1990, pp. 161-171) submits that "in 1828 the German instrument maker Heinrich Stölzel became the first to feature a trumpet in (low) Bb in his catalogue". Adachi and Sato (1995, p. 3850–3861) write that:

> the trumpet was described as a tenor trumpet in Bb, which was in fact its true register. Richard Wagner used this low-pitched trumpet in his *Ring of the Nibelung* to symbolize the fortitude and dominance of his heroes ("sword motif"). The trumpet in C consists of the trumpet tube and bell, the mouth pipe with detachable mouthpiece, three valves and the tuning slide, with which the overall tuning of the instrument can be altered. The tuning slide has a water key.

Pratt, Elliott, and Bowsher (1977, pp. 236-245) conclude that:

> in many cases, all three valves have valve slides which can be pulled out with a trigger to correct the intonation of individual notes. A number of models can be re-tuned from C to Bb by means of an extended tuning slide or an additional piece of tubing.



*Figure 49: A typical example of a Bb trumpet (www.brass.com)* Accessed on April 30, 2017)

Writing on the historical development of sound generation in trumpet, Sundberg and Lindqvist (1973, pp. 922-929) submit that "sound production in trumpet has the natural harmonic series which are actually playable beginning with the 2nd natural (C4) and rises to the 8th natural (C6). Highly proficient trumpeters can reach the 11th natural (F6), but this note is not called for in

orchestral compositions. On the musical application of trumpet particularly in jazz". Fletcher, (1979a, pp. 123-146) opines that:

> there are no limits as to how high the regular scales can go, many jazz trumpeters try to produce ever higher notes on the instrument and even to reach the heights of the fourth octave above middle C. With the valves, the trumpet's range of naturals can be lowered by a total of six half tones to F#3. Figures 50 and 51 are the musical notation of the trumpet's natural harmonic series and fingering as applied to the 2nd harmonics.

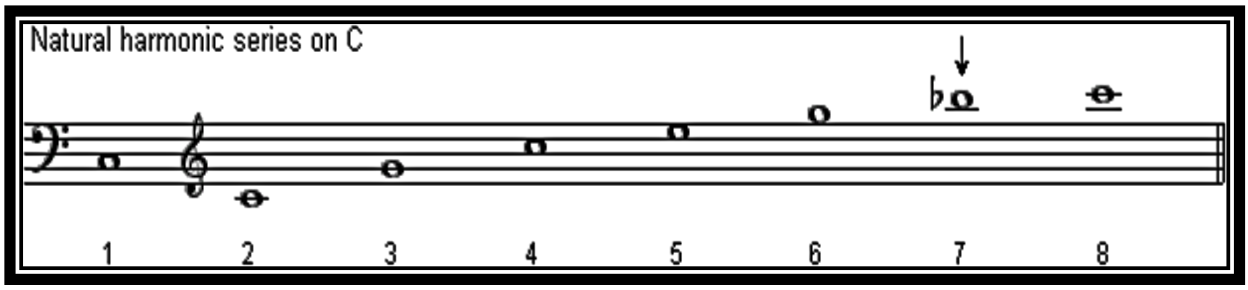



*Figure 50: Natural harmonic series on C (Score by the researcher)*

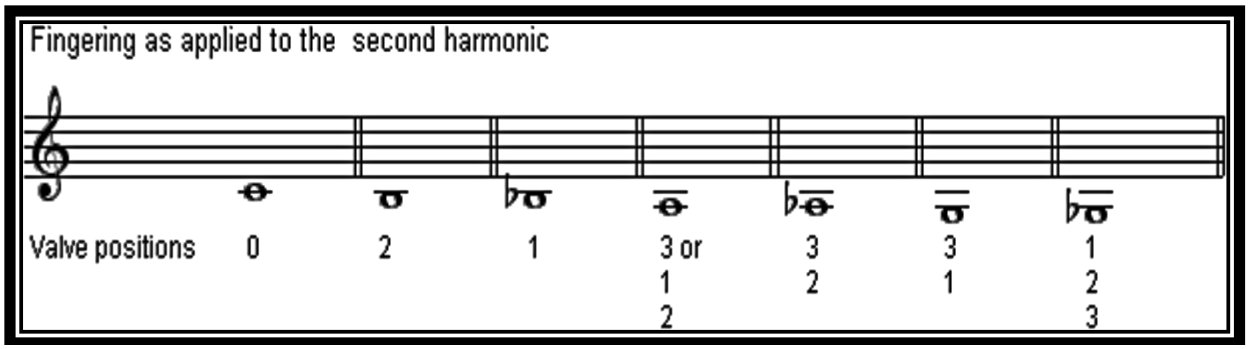



*Figure51: Fingering as applied to the second harmonic (Score by the researcher)*

As a trumpeter, I have observed over time that the trumpet's fingering skills increases the trumpet's tube and the results to playing the trumpet at a pitch lower than the original pitch. Backus and Hundley (1971, pp. 509-519) compliment that

> the horn's tubing is lengthened from about 386 cm to 550 cm at its lowest pitch. Of course this also means that a column of air has to be vibrated to about 550 cm long. So the trumpet has a relatively consistent tone quality in all registers.

On the sound characteristics of the trumpet, Luce and Clark (1967, pp. 1232-1243) describe the trumpet's sound "as metallic, bright (but also dark in the lower register), intense, brilliant, powerful and stately. Trumpetprojects best between G3 and G5, but drawing a direct comparison between the C and Bb trumpets, which are the two most commonly used today". Fletcher (1979b, pp. 155-159) comments that the "C trumpet sounds brighter, more reserved and soberer while the B♭ has a softer and more rounded sound". According to Adachi and Sato (1996, pp. 1200–1209), "differences in the registers are relatively hard to locate and depend on the individual instrument and the mouthpiece used". Ehara, Nagai and Mizutani (2003, pp. 541–549) gives a division of the tone registration of trumpet into three main orders as:

i. **Lower register:** The lower register of the trumpet is between F#3 & F#4. Ehara, Nagai andMizutani (2003, pp. 541–549) write that:

> his register "is not as rich in overtones in the upper register because the sound is fairly dark and rounded.In its low register the trumpet is well-suited as a metallic, dark, precise and agile middle voice in the orchestra and as such offers an effective contrast to the soft horns in the same register. The lowest notes down to C4 are prominent, assertive, and dark.

Bateye (2011, pp. 141-154) concludes thatthese"lower register effects are often used for battle scenes in dramatic works to create a moody scenario".

**i.** **Middle register:** The middle register of the trumpet is between G4 – F#5 and the "instrument's sound comes into its own: brilliant, full, rounded, magnificent". Olatunji (2008, pp. 63–72) states that "this is a metallic brilliance sound of the trumpet pervades the entire orchestra and cannot be achieved by any other instrument". Adachiand Sato (2003, pp. 3850–3861) also give a conclusive submission on the bright nature of the trumpet's middle register sound that "the ease of its playability makes it ideally suited

for thematic tasks and solos, even when played piano, which is still clearly audible even in *tutti* passages".

ii. **Upper Register:** The upper register of the trumpet is between G5 – C6. This is bright, shrill, penetrating and vivid. Feit(2003, pp. 125-137) regards this as homogeneous continuations of "the middle register, although no longer so prominent. The notes above this range are sound piercing and develop a particular quality appreciated especially by jazz musicians".

Figure 52 is the expression of Ehara, Nagai and Mizutani's categorization of the trumpet sound registration as scored by the researcher.

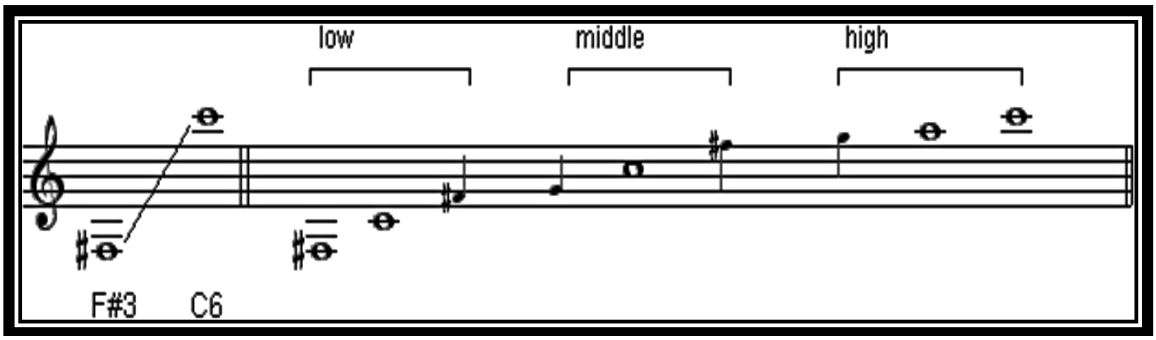



*Figure 52: The lower, middle and upper ranges of the trumpet (Score by the researcher)*

The trumpet id perceived as a loud musical instruments even, when not amplified. The trumpet when played at the high registration and amplified at the same time becomes a nuisance to the congregants as observed in the selected church auditoria.

### 3.2.6 Musical Instruments Controlled by Keyboard and other Electronic Devices

Nolle, (1983, p. 121) writes that:

> the pipe organ was known to the Romans and Greeks nearly 2000 years ago and began to develop toward its modern form in the late middle ages, the organ in Winchester Cathedral in the tenth century already having 400 pipes and a compass of 40 notes. By the seventeenth and early eighteenth centuries,

According to Lottermoser, (1983, pp. 135-137) that the "art of organ building in Europe had reached an artistic and technical peak, particularly in Germany, and some of the greatest music of

all time, particularly that of Bach, was strongly influenced by the style and structure of organs of this Baroque period".Lottermoser, (1983, p. 132) further states that "with the rise in popularity of the orchestra in the Classical and Romantic periods, the organ suffered an artistic decline because of a desire on the part of its builders to imitate orchestral sounds, though many fine organs continued to be built for cathedrals and halls throughout the world". Boner (1988, pp. 32-40) writes that the "workmanship of many early organs was excellent, and some large eighteenth century instruments have survived nearly unaltered to the present day".In his own observation, Sharp (1973, pp.70-80) submits that

> historically, inthe past 50 years, there has been a return to the organ as an instrument in its own right, and organs being built today for churches and concert halls have largely returned to the principles that guided the master builders of the eighteenth century. Even the mechanical technology of the organ mechanism has largely returned to its eighteenth century "*form-for good*" reason.

Many books on the organ for example, Andersen (1969, p. 65), Sumner(1973, p. 43), Lottermoser (1983, 132) have been written for both technical and historical purposes. Mahrenholz (1975, p. 231),**in his** contributionon further development of the organ, writesthat

> theintroduction of stops to turn off the air to particular ranks was usually accomplished by means of a wooden lath,known as a slider, with holes in it at positions corresponding to each pipe of the rank. This was done in registration with the pipes, to allow free access of air to thatrank from any key that was pressed, but when slightly withdrawn, the solidsections of slider were opposed to each pipe and air access to ranks would be blocked.

Another development came along with the emergence of the native techniques in the 19$^{th}$century which werenaturally applied to the organ mechanism. Nolle, (1983, p. 136) writes that:

> the first were pneumaticlevers that enabled the manuals to be coupled to each other and to the pedalswithout requiring extra playing force on the keys. Pneumatic action was thenextended to the primary mechanism as well, so that the only force required onthe key

was that necessary to open a small valve and allow a pneumaticbellows motor to collapse. With the advent of reliable electrical supplies,key actions using electromagnets were also introduced.

Rossing (1982, p. 142) opines that:

> this is either in conjunctionwith a pneumatic action or as a direct valve actuator for each pipe. Alongwith these innovations came electro-pneumatic (or now even microprocessorcontrolled)stop actions, with combination buttons to select particular sets ofstops, and many other devices.

Adachi (2003, p. 3859) comments that "some of these have become standard on modern organs, even those with mechanical tracker action, and some of them have faded into oblivion".On the subject of sound radiation from stopped pipes, Pollard (1978, pp. 65-74) opines that:

> a relatively a simplematter, since there is only a single radiating source at the pipe mouth which is very small compared with the pipe length, and therefore with the wavelength of the fundamental, the radiation pattern of the lower harmonics of the sound is nearly isotropic. For higher harmonics, when the wavelength becomes less than a few times the width of the mouth, the radiation pattern becomesconcentrated to the front of the pipe with a large angular spread in the vertical plane and a smaller spread in the horizontal plane. Much more significant is the radiation pattern for an open pipe, for then we have two coherent sources, at the mouth and open end respectively,which are acoustically in phase for odd harmonics and out of phase for even harmonics.

Pollard (1978, pp. 75-85) writes that "this is not immediately clear that the strength of these two sources is the same, for the area of the mouth is typically less than one fifth of the area of the open end, and the flow of the jet must also be considered".Coltman (1969, p. 477) concludes that"it is expected that the strengths of the two sources to be exactly equal"

How organ pipes produce different sounds depend on the great many sizes and shapes of organ pipes. The distinctive sound of each pipe voice is determined by its unique style and design. Boner (1983, pp. 32~40) writes that the sound quality (timbre) of an organ is influenced by

several factors which include the aspect ratio of the air column (generally length to width), its shape, the position and shape of the air stream at the mouth of a flue pipe, or the design of the shallot and tongue in reed pipes, the materials of construction, and whether the top end of the pipe is open or is closed in some way. Figure 53 reflects the various shapes of the organ air column:

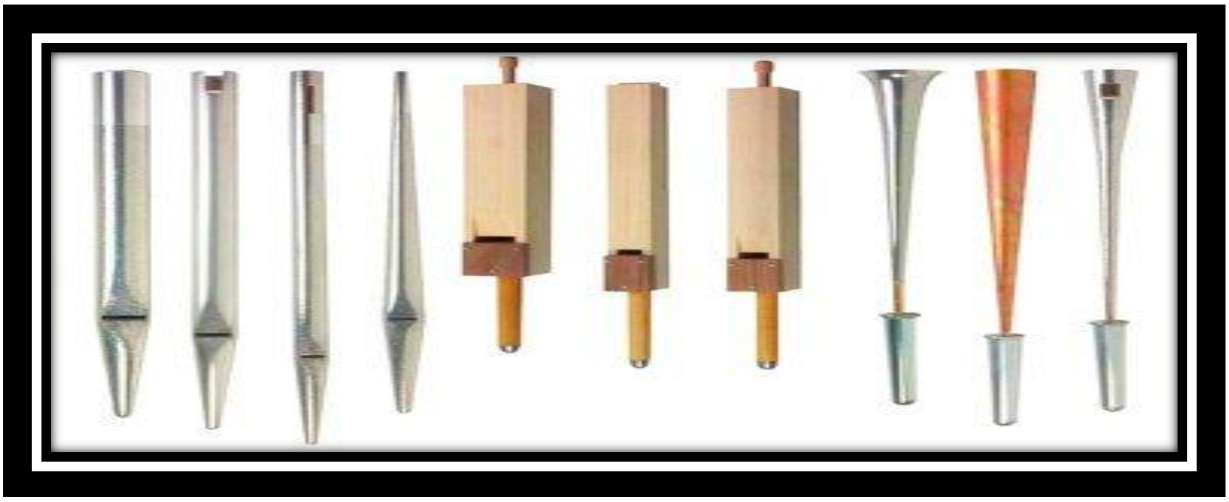


Figure 53: Various shapes of the organ air column (www.piprorgancolomns.org) assessed on April 20, 2017)

Lottermoser (1983, p. 131) writes that "these factors collectively determine the number and relative intensity of the harmonics added to the fundamental pitch of the pipe".Lottermoser further givesexamples that "long skinny pipes can suggest the sound of strings, while fat pipes whose aspect ratio is very low produce a much more mellow sound that begins to approach a pure tone with few harmonics adding to the fundamental pitch".Mahrenholz (1975, p. 235) in his illustration of the organ pipes which was described to be in the same shape as whistles gave the illustration as seen in figure 54:

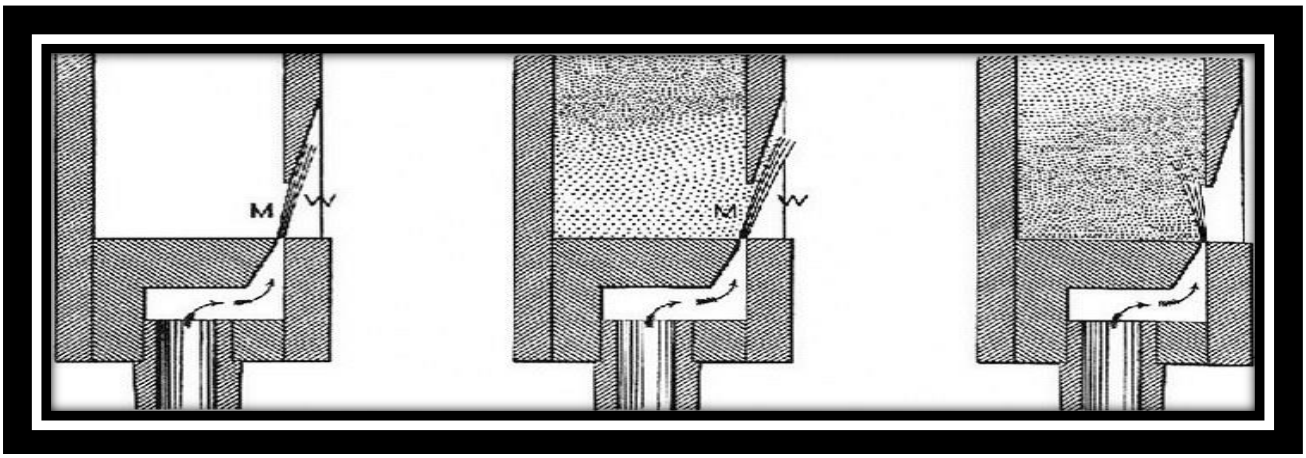



Figure 54: Organ Flue Pipes (www.piprorgancolomns.org, assessed on April 20, 2017)

### 3.2.7 Musical Instruments and Auditorium Tonality

Musical instruments and the auditorium where music is played need to agree on a tonal understanding. This is determined for the purpose of consonance between the two elements. In this regard, Ingerslev and Frobenius (1974, pp. 1 - 44) write that:

> an organ is so much a part of the building in which it is played, thatis, it is impossible to separate musical tonal point from architecture tonal design. An organ for a large cathedral with a reverberation time approaching 12 s will need to be entirely different from an organ in a concert hall with a reverberation time of 3 s or from a small organ for chamber musicMuch has been written about this subject, about different national traditions in organ building, and about individual organ specifications.

Andersen (1969, p. 65) and Sumner(1973, p. 43) were of the opinion that"the organ is an instrument in its own right; it is not a substitute for an orchestra therefore, a satisfying organ must have, as a first requirement, asatisfying main chorus built from properly scaled diapason ranks, if possible including a mixture". Also, Lottermoser (1983, p. 133) cautions on any attempt "to take short cuts, for example by using electric action to borrow higher pipes from an extended rank to produce nominal4-ft, 2-ft, and even mixture pitches produces a characteristic theatre organ sound.For most music, a balancing smaller chorus of softer diapasons or even flutes is required, and this is best located on a second manual to give flexibility".

Plomp (1976, p. 176) opines that:

> even in contrapuntal music which requires an equally independent pedal divisionwith its own chorus of voices, certain requirements were met for centuries on German organs but typically given scant attention in small English-style organs until comparatively recently.With an increase in organ size

In his contribution, Pollard (1978, pp. 75-85) submits that:

> chorus reed ranks are added, then solo ranks of various types and contrasting choruses on different keyboards are added which gave rise to national traditions with German organs concentrating on bright flue pipes, mixtures, and mutations, Spanish organs providing ceremonial trumpet stops, and English organs concentrating on full, rich choruses with an

emphasis on enclosed divisions.Modern large organs attempt to combine the best of many of these traditions so that there are several effective instruments in one, the player being able to select just that range and distribution of ranks required for theperformance of each particular piece of music, complimenting this development

Sharp (1973, p. 78) providesa suitable model of the "organ in the Sydney Opera House, which was completed in 1970, the design of which has been described by its builder. It has some 10,000 pipes in 205 ranks grouped into 127 stops that are distributed over 5 manual keyboards and apedal board". Pollard and Jansson(1982, pp. 162-171) compliment that"Organs of this type attempt to blend tradition with the best of modern scholarship, insight, and technology to perpetuate a noble instrument".

### 3.2.8 Musical Instruments Sound and Acoustical Phenomena of an Enclosed Space

Nowadays, very vital musical concerts in church auditoriaalways hold within the auditorium with waves of sound reflecting back and front as a result of walls, ceilings and other reflective material around the church auditorium and which usually leads to echo generation problem. Farina (2007, pp. 1-31) writes that "objective classification is achieved with acoustical parameters extracted from the impulse response of a particular space or room". Thus, as commented by Hidaka and Beranek (2000, pp. 89-96) that "accurate impulse response measurements already regulated by the International Organization for Standardization" (ISO, 2009, pp.3382-3383) standard which provides "specifications, guidelines or characteristics" to apply in order to reduce and ascertain the processing ofacoustic parameters that are fit for that particular use.

Barron (2009, pp. 45-53) observes that "the reverberation time (RT) is the basic indicator of acoustical behaviour and it is the time required for the early decay time (EDT) to decay by 60dB". However, it could be examined on minor active level than 60 dB and then generalise it to a 60dB fade off period and arranged in such order. Stewart and Sandler (2007, pp. 59–62) write that "if Reverberation Time (RT) is derived from the average slope of the decay in the range

between 5 dB and 25 dB below the initial level, it is accordingly labelled, if the range is between 5 dB and 35 dB, then the corresponding time is equally labelled". Kahrs and Brandenburg (2009, pp. 136-148) describe the "early decay time (EDT) as the reverberation time computed by the slope of the decay in the range between 0 and –10 dB on the early decay time".

### 3.2.9 Basic Requirements Musical Instruments Sound Productions in Worship Auditoria

Every musical instrument sound produced in a church auditorium is for the purpose of worshipping God. Olive, Schuck, Sally, and Bonneville (1994. pp. 651–669) write that:

> church auditoria that have very "live" acoustics are good for music but distort speech. Since people must be able to hear what is said at any congregational service, it's better to have a "dry" or "tight" sound in a church auditorium so people can hear what is said

Schuck, Olive, Ryan, Toole, Sally, Bonneville, Verreault, and Momtohan (1993.pp. 49–73,) also opine that "a room designed to deaden all sounds is doomed to kill liturgical participation". In this argument, Naylor (1987, pp. 231-239) writes that:

> it is possible to hear the singers in a "lively" and "reverberant" church that makes the organ, choir, and other musicians sound beautiful. The use of technology is more beneficial to use to enhance the clarity of solo voices than to "quiet a room down" and, thereby, dampen the corporate voice of the entire congregation.

Moreover, Stephenson (1990, pp. 35–72) observes that "in a dead room with the acoustics of a sound studio, all the imperfections of the musicians, no matter how accomplished they may be, come to the surface". Stephenson's observation was noticed at the Saint Peter'sCathedral Church Ake, Abeokuta. Despite the high technological position of the musical equipment installations available, the choir musical sound suffers great reflective and reverberant problems. The church is big with no acoustics treatment, with tiled floors and ceramic pulpits for preaching and Bible reading. The choir vestry and the Alter are all tiled with no sound absorbents. Even with the best sound reinforcement system in terms of using a "Public Address" (PA) System, this situation may not provide adequate hearing for some worshipper as a result of the above stated observations.

Discussing the availability of acoustics materials in all the selected church auditoria, the study discovers that there are virtual absences of acoustics materials like sound absorbers, sound diffusers, and noise breakers but only noticeable are sound reflectors. The study's observations show that sound absorbers like"acoustics foam panels, white paintable acoustical wall panels, fabric wrapped panels, acoustical wall coverings, ceiling tiles, baffles and banners for ceiling and fibre glass blankets and rolls" are all missing. Most of the church auditoria visited are laced with floor tiles, plastic chairs and glass windows.

**(a) Sound Absorbers**

The primary purposes of sound absorbers are to absorb excessive sound and prevent same from bouncing around the auditorium. Sound absorbers also prevent transmission lost and guide other transmission restrictions like"absorption coefficient, scattering coefficient and flow resistance". A typical example of a sound absorber is provided in figure 55:

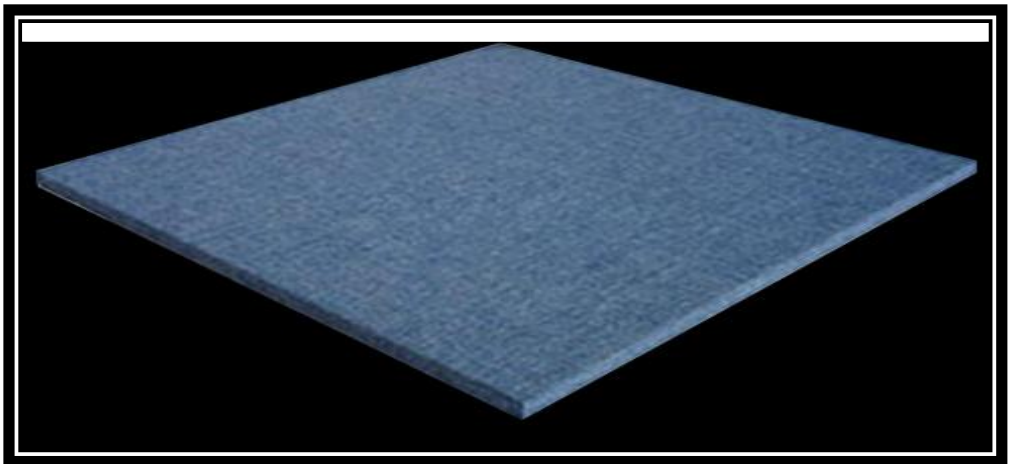


Figure 55: Typical example of a sound absorber (www.controlnoise.com)

**(b) Sound Diffusers**

To diffuse musical instruments' sound, there is the need to project a means to breakupprobable waves of the sound in and around the auditorium. This step will assist to manage excessive sound generation and also allow for good functioning of the sound equipment especially in a musical concert.



Figure 56: Typical example of a sound diffuser (www.controlnoise.com)

**3.2.9(c) Acoustical Wall Coverings**

These are acoustic materials that reduce the level of sound reverberations in an auditorium. It is required to allow for balance sound propagation and communication within such auditorium. Figure 55 is a typical example of acoustic wall coverings

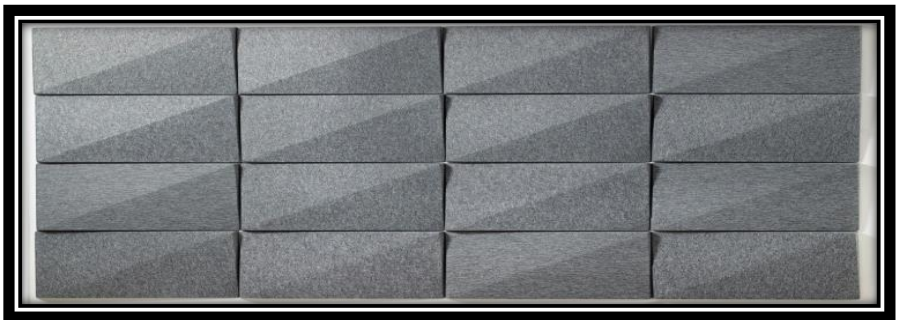


Figure 57: Acoustical Wall Coverings (https://acousticalsolutions.com/product-category/acoustic-panels)

The resultant effect reflects all overthe generation, propagation and reception of the mechanical waves and vibrations is shown in figure 58

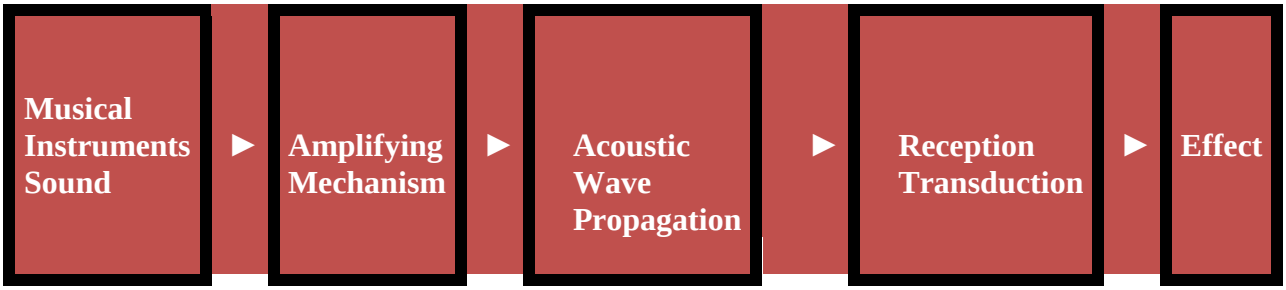



Figure 58: Sound propagation and reception table (Researcher's expression)

Recommending a suitable acousticsenvironment, a worship auditorium with regards to good musical instruments' sound and worshippers' better comprehension of all musical activities, such recommendations should address some major stakeholders in any all church auditoria during any worship service, these include the pastors, the choristers and the congregation. Reacting to

setting of appropriate acoustical conditions for church auditoria, D'Antonio (1986, pp. 23-34) gives the following basic requirements that:

> lively natural acoustics that support and enhance the spoken and sung responses of the assembly; an acoustic environment that gives an audible impression of the presence of others, clearly conveying the experience of public worship, suitable locations and spatial configurations for the primary sound sources, good sound isolation to prevent the intrusion of distracting sounds during worship or meditation and to allow privacy and confidentiality where needed, adequate control of noise produced by building systems within the church such as HVAC, plumbing, and lighting; and a high-quality sound reinforcement system.

The above basic obligations are completely absent in all the church auditoria selected for this study. An investigation for the reasons for these absences, as stated by the vicars-in-charge is that these church auditoria were built without any consideration for good musical sound but specifically concerned with the issue of evangelization and preaching the message of Christ. D'Antonio (1986, p. 33), further opines that "meeting these requirements is most effectively and economically accomplished if they are an integral part of the architectural design from the earliest design phases before construction", this is a practice lacking value as far as church auditoria construction is concerned in most Nigerian church auditoria. Barron; 1993, pp. 345-350) writes that

> every structure has its own natural acoustics which are referred to as to 'the way an architectural space responds to sound without sound reinforcement or electronic enhancement' The natural acoustical qualities of a church must serve speech and music, provide an aural awareness of the presence of the assembly, support the social and communal elements of the faith gathering, foster a sense of the sacredness of the worship space, and help people feel involved and become involved in the liturgical action.

Orlowski (1999, pp. 1749-1752) writes that the "architecture of a worship space can most effectively support good natural acoustics by providing beneficial reflections of sound, and it must do this without introducing acoustical faults such as echoes and focusing of sound". Beranek (2003, pp. 619-623), suggests that:

> most commonly occur; they are a relatively short reverberation that allows clearly intelligible speech but which tends to frustrate and repress music and congregational response; a medium or compromise reverberation that serves all types of speech and music acceptably but usually serves none exceptionally; a long reverberation that imparts a glorious and resounding character for spoken and sung responses of the congregation, pipe organ and traditional choir yet, if excessive, can render speech virtually incomprehensible and reduce contemporary and folk music groups to muddled noise. These three conditions actually represent three ranges of reverberation conditions.

### 3.3 Acoustics Parameters of the Selected Church Auditoria

Church auditoria are places of regular gathering of people especially, worshippers with the aim to sing, dance and pray to God. Such a public place is usually large to accommodate a greater percentage of worshippers as established in the all the selected church auditoria. Consequent to this, such auditoria require high musical instruments sound qualitywith tonal tones and clarity of perceivable musical instruments sound for every congregant in the auditoria.Greater percentage of the selected church auditoria were constructed with no acoustic considerations, these auditoria were built and decorated with sets of perimeter walls, sound reflecting ceilings and tiled floors that scatter musical instruments sound wave and its reflections around the worship auditoria.As a result of deficient auditoria acoustics which are generated by lack of absorption and existence of echoes, musical instruments perception in all these church auditoria have hampered in one way or the other.

#### (a) Saint Peters' Cathedral Church, Ake, Abeokuta

On the acoustics parameters of the Saint Peters' Cathedral Church, Ake, Abeokuta, it was observed that the use of wooden pews in the church for the choir and the congregation have

helped to reduce sound reverberation and overtones generations. Wooden pews are as good sound absorbers, though, the auditorium floor was tilled, yet the provision of other sound absorbers like curtain drops, the roofing sheets and the foamed chairs at the Alter contribute to a fairly acceptable acoustic treatment within the church auditorium. Figure 59is the picture of the wooden pews as observed at the Saint Peters' Cathedral Church, Ake, Abeokuta.



Figure 59: The wooden pews as observed at the Saint Peters' Cathedral Church, Ake, Abeokuta.
*(Photographtaken by the researcher on January 3, 2016)*

**(b) Our Saviour's Church, Ikenne**

Our Saviour's Church, Ikenne auditorium has no special treatment but, the use of wooden pews has assisted in the suspension of sound echo. The wooden roofing sheets materials used also absorbs excessive musical instruments sound generation and reception within the auditorium. Sound clarity is equally good in this auditorium as a result of the presence of several sound absorbing materials in the auditorium. Figure 60 is the inner view of the church auditorium and the cross section of the choir as captured by the researcher.



*Figure 60: The inner view of Our Saviours Church, Ikenne.* (*(Photograph taken by the researcher on March 5, 2016)*

**(c) Celestial Church of God, Ibadan**

Celestial Church of God, Akobo Ibadanisnot acoustically treated at all. The auditorium Alter is not rugged to protect sound scattering and refraction. The ceiling used for the auditorium also contributes to bad sound production. The choir and the congregation seat in the auditorium are single plastic chairs, these chairs, apart from accommodating and giving comfort to the worshippers also contribute to excessive musical sound transmission within the auditorium which constitute nuisance to good musical instruments sound. Figure 61is the arrangements of chairs at the Celestial Church of God.



*Figure 61: The arrangements of plastic chairs on a terrazzo floorat the Celestial Church of Christ, Ibadan (Photograph taken by the researcher on March 5, 2016)*

The altar of the church auditorium is not sound protected by any sound absorbing materials to preventexcessive sound echo. Figure 62 is the observed altar as recorded by the researcher.




Figure 62: The Altar at the *Celestial Church of Christ, Ibadan (*Photograph *taken by the researcher on March 5, 2016)*

The roofing materials used at the Winners' Chapel has also aided good musical instruments sound perception because of the availability of sound diffusers. Though, the sound production at the Winners' Chapel is so high, right above 60Db, yet the auditorium is fairly treated in terms of acoustics parameters.Figure 63is the roofing materials as observed by the researcher.



Figure 63: The ceiling view of the*Celestial Church of Christ, Ibadan*. ((Photograph taken by the researcher on March 5, 2016)

**(d) Iyeru Okin African Church, Offa**

The acoustics parameter at the Iyeru Okin African is endowed with several sound reflectors, these include floor tiles and ceramic pulpits for lay readers and sermon. The church

auditorium volume is very high with several sound echoes. Although, the wooden pews available in the auditorium have helped in the reduction of excessive sound generation yet, the musical instruments sound lacks clarity. Figure 64 is the picture of the church auditorium with all the observable acoustics parameters.



Figure 64: Iyeru Okin African Church auditorium (Photograph by the Researcher on April 8, 2019)

The church altar is also decorated with sound reflectors which have cause negative influence of the musical instruments sound productions. Figure 65 is the Altar of Iyeru Okin African Church, Offa.



Figure 65: The well-padded Altar at Iyeru Okin African Church, Offa (Photograph by the researcher on April 8, 2019)

**(e) Redeem Christian Church of God, Ilesa**

The acoustics preference at Redeem Christian Church of God, Ilesais sub-standard, the auditorium is big with no acoustic parameters. The wrong placement of the Front of House speakers (FOH) negatively affects musical instruments sound production. It was observed that the speakers are wrongly mounted and this has been responsible for excessive noise generation and

high level of musical instruments sound echoes. Figure 66 is the church auditorium with all the acoustics parameters therein.



Figure 66: Redeem Christian Church of God, Ilesa (Photo by the researcher on May 11, 2017)

The available cushioned chairs in the church auditorium serve as sound absorbers which protect musical instruments acoustics from bouncing around the church auditorium. There is also the sound clarity in the auditorium which has made the perception of musical sound very fairly perceivable with the church auditorium.Moreover, the semi-cushioned chairs are sparsely arranged in the auditorium, this arrangement has given way to musical sound escape. The main auditorium is equally decorated with several sound reflectors which constitute to bad musical instruments acoustics. Figure 67is the observable plastic chairs in the auditorium.



Figure 67: Semi- Cushioned chairs at the Redeem Christian Church of God Ilesa. (Photograph by the researcher on May 11, 2017)

The '*Polyvinyl chloride'* (PVC) roofing materials used for the church auditorium is another conductor of sound production because it makes musical instruments sound to vibrate very rapidly to produce a higher pitch (teacherinstitute.yale.edu). the use of PVC has affected the musical instruments sound perception in the church auditorium. Figure 68is the ceiling of the Deeper Life Church auditorium, Osere, Ilorin.



Figure 68: The PVC roofing materials at the Redeem Christian Church of God, Ilesa (Photograph by the researcher on May 11, 2017)

**(f) Dominion Centre Gospel Faith Mission Church, Ile-Ife**

Observable acoustics parameters at the Dominion Centre are mostly sound reflectors. The floor tiles and the plastic chairs (though with few cushioned chairs at the front seats of the auditorium) coupled with glass windows are responsible for the excessive musical instruments sound echoes and high reverberations. These have made the perceptions of musical instruments acoustics muddy and devoid of clarity. Figure 67 is the church auditorium with observable materials



Figure 69: Dominion Centre of the Gospel Faith Mission, Ile-ife (Photograph by the Researcher on April 2, 2019)

Another acoustics parameter observed at the Dominion Centre Church, Ile-ife is the floor tiles in the auditorium; these floor tiles are basically sound reflectors, though with semi-cushioned

and white plastic chairs and the set of glass windows have adverse effectson musical instruments acoustics and sound production during worship services with grievous effect on the congregational perception of good and bad musical sound. Figure 70is the observable floor condition of the Dominion Centre Church, Ile-ife.



Figure 70: Dominion Centre of the Gospel Faith Mission, Ile-ife (Photograph by the Researcher on April 2, 2019)

Also, the Altar of the church auditorium is laced with floor tiles and wooden pulpit coupled with wooden backdrop. These wooden materials are responsible for the little breaking of excessive sound in the church auditorium. The tiles also allow the musical instruments acoustics to bounce round the auditorium especially when the volume of sound production is excessively loud.Figure 70is the Altar as observed.



Figure 71: The Altar at the Dominion Centre Church, Ile-ife.(Photograph by the Researcher on April 2, 2019)

The ceiling materials at the church auditorium are the only observable sound absorbers. These roofing materials are placed to cover the entire auditorium. These ceiling materials have helped in the reduction of sound reverberations of musical sound in the entire church auditorium. Figure 72is the picture of the auditorium ceiling materials as captured by the researcher.



Figure 72: Dominion Centre auditorium ceiling(Photograph by the Researcher on April 2, 2019)

### 3.4 Musical Instruments Sound on Acoustics Parameters in Church Auditoria

Kleiner, Klepper and Torres (2010. pp. 205-269) write on the beginning of the digital age ($19^{th}$ -$21^{st}$ century), that

> the main focus of church auditorium has been to quantify the physical parameters that determine the ear response to sound, in order to apply this information to the design process with special emphasis on the architecture for music performances. However, at around the same time, acoustic studies of places of worship were initiated in all faiths, following the same metric procedures established and agreed for music venues.

Due to the interconnected features of church auditoria as a result of formal approaches to issues on general sound productions during worship services, Some researchers such as Galindo (1999, pp. 1-16); Sendra, Zamarreno, Ando and Navarro (1999, pp. 1-5); Sant'Ana and Zannin (2001, pp. 511-517); Cirillo and Martellotta, (2003, pp. 271-288); Magriniand Ricciardi, (2004, pp. 5-8) through researches on worship auditorium acoustics have concluded that "it is common to see results regarding the room's sound field, without considering the use of sound reinforcement

system". Furthermore, other researchers like Lencastre (2000, pp.7-14) and Soeta ((2012, pp. 1206-1220) have studied the "influence of Sound Reinforcement System (SRS) on speech intelligibility, the information about these systems and its relations to worship spaces are still insufficient".

Most current studies on musical instruments' acoustics in church auditoria examine acoustic dimensionsof different sound sources and sound routes. For example, Soeta, Ito, Shimokura, Sato, Ohsawa, and Ando (2012, pp. 1206-1220) note that "the effects of the style of liturgy on the acoustic characteristics within churches" while Kosala (2011, pp.: 1144-1152) andBerardi (2012, pp. 521-528) "propose a synthetic way to summarize the acoustics of churches for both music and speech, by means of the calculation of synthetic indexes".

On the design of a church auditorium, which must meet high requirements as regards acoustic quality, it is important to model sound propagation from a sound source to listeners. Modelling of musical sound is supposed to be one of the fundamental considerations in the planning of a church auditorium. Kuttruff (2000, pp. 211-218) writes that during the design of such, subjective opinions can turn out to be unreliable, in this sense, Kuttruff argues that there are defined objective parameters, which can be calculated numerically with the use of geometrical methods. Apart from the room parameters definition, it is necessary to determine sound source parameters like acoustic power level and directivity pattern which could not be observed in all the selected church auditoria in South western Nigeria. On this note, Holters, Corbach and Zolzer (2009, pp. 1-5) put it that "the sound source can be assumed as Omni–directional point source". However, it doesn't reflect the most of real-live sources precisely. Gołas, Suder-Debska and Filipek (2010, pp. 62-65) conducted an experiment to check how directivity pattern can influence the musical acoustics parameters distributions in a selected worship auditorium where simulations were carried out for three types of sound sources, which had the same "sound power level of 81 Db", with placement of the same in front of the alter and on auditorium centre. Sound sources had different directivity patterns, multi directional sources and an omni-directional source as provided in figure 73.

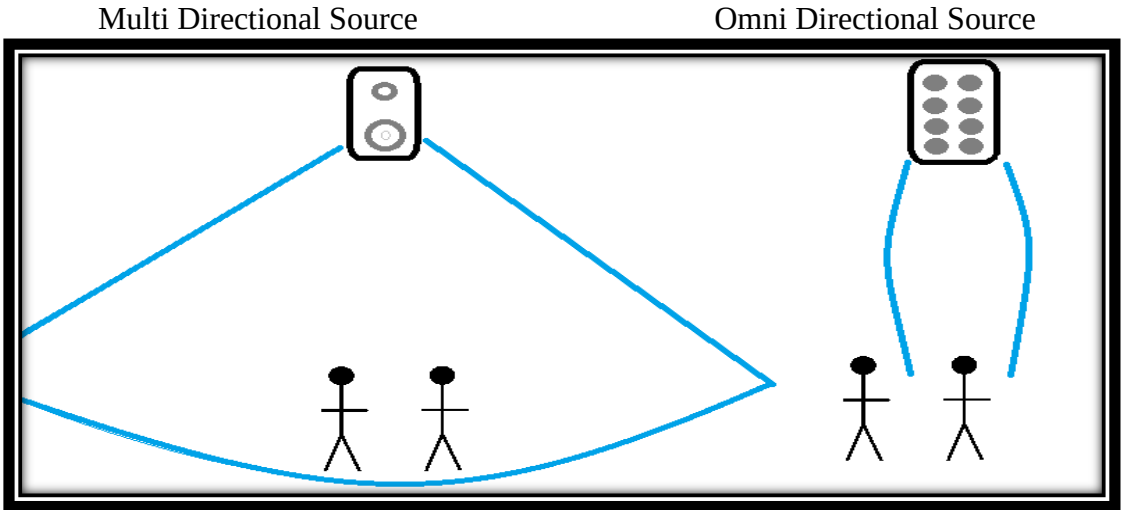



Figure 73: Multi directional sources and an omni-directional source. (Sketch by the researcher)

The two sources of sound in figure 2 above are reflections of how musical sounds are received in an auditorium. The blue lines are the demarcation of sound emission and reception by individual.

### 3.5 Musical Instruments Sound and Amplifying System in Selected Church Auditoria

The multifaceted nature of a sound system equally makes it so complicating. The consideration of four vital elements was done for this study. These elements aremicrophones, these are considered as input devices, mixer console which is considered as the central processing sound unit,poweramplifier which is considered as the amplification power for front of house (FOH) and subwoofer speakers and Speakers, these assist in the final sound out-put to make the musical instruments' sound well audible.

**(a) Microphones**

Microphones are patterned to generate fundamental sound from the source, they are also regarded to be the primary connection in the audio sequence. There are varieties of microphones available in the market with specific range and function application. Typically, from observation, dynamic Cardioids microphones are mostly used for Nigerian music concerts, especially for backup

singers. Recently, microphones manufacturers have seen the need to produce various microphones because of great and increasing demands for the use in vocal musical activities. Examples of identified microphones in the selected church auditoria are pickup microphones which are specifically designed for musical instrument. Some of these microphones are expressed in figures 74: Vocal microphones mesh and figure 75 is instrument microphone mesh



Figures 74: Circular mesh balls



Figure 75: Flat grills

Causse (1992, p. 152) describes “a pickup pattern as the microphone’s response to the angle of sound incidence”. Chanan (1994, pp. 550-551) writes that “cardioids pickup is the most common for live applications”. Chanan further stresses that this is a “unidirectional pickup microphones with optimum response from the front of the microphone and a somewhat reduced response from the sides”. Condenser Cardioids microphones may be considered for use if only the auditorium has very good acoustics. Condenser microphones may be used. Dillner (2012, p. 520) suggests that Cardioidsmicrophones “for instruments like the guitar that produces sharp sound pulses and have lower sound pressure levels”. This recommendation for the guitar might have been as a result of its “Transient Response” quickvibrations of musical sound. The installation and usage of the above types of vocal and instruments microphones were identified in all the selected church auditoria. These were used according to application specification for vocals and instruments especially for Trap set and Konga drums. Other microphones identified in these church auditoria include those used for saxophones and trumpets however, the use of pickup microphone was observably used for Alto saxophone at The Redeemed Christian Church of God, Mega Parish, Ilesha. In this connection, Ashrae. (1991, p. 65) submits that “vocal microphones

though, come in a wide array of forms, are differentiated by three primary characteristics".These characteristics include:

**(b) Operating Principle**

Ballou (2005, p. 89) defines this as "transducer driving microphone, turning the sound waves into a small electrical voltage". Ashrae. (1991, p. 65) writes that:

> in meetings and conferences, almost all microphones are either dynamic or condenser type". Dynamic microphones are rugged and reliable, relatively economical while condenser microphones are more complex in design and typically more sensitive to quiet sounds.

It was further started by Ballou (2005, p. 90) that "both have the advantage of being easier to design with flat frequency response, and can be made very small without significant loss of performance". Figures 76 and 77 reflect the different diaphragm in dynamic and condenser microphones:

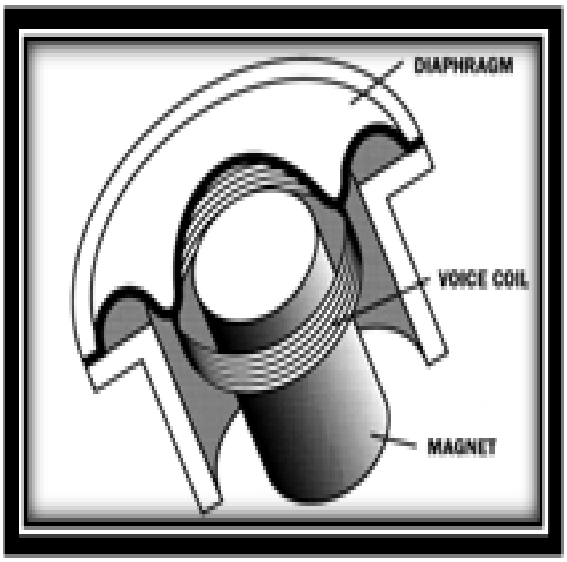



Figure 76: Dynamic Microphone

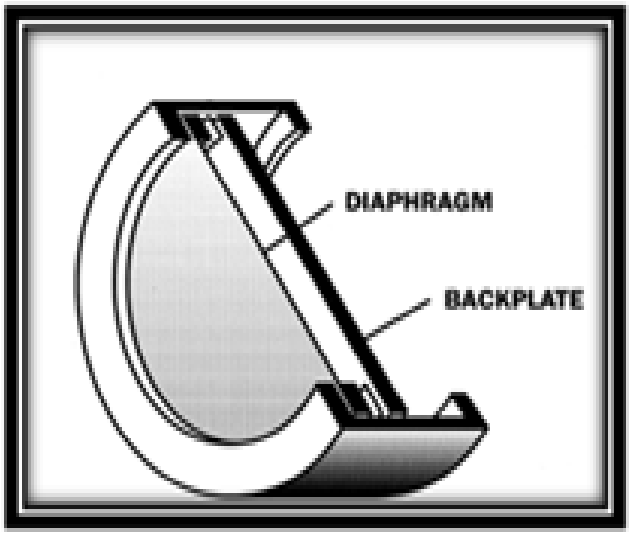



Figure 77: Condenser Microphone

**(c) Principle of Frequency Response**

Alton (2001, pp. 79-82) notes that:

> this is an inherently deceptive microphone metric, because a good response graph is nearly impossible to identify, while equal response at all frequencies as a flat or uncoloured response would seem to be an obvious goal, that sort of microphone is

better suited to wide-range musical instruments like pianos. Vocal microphones are usually designed with a shaped, or tailored, response.

Fry (pp. 139-142) writes that "the idea behind a shaped response is to enhance the sound by smoothly emphasizing the desired frequencies (in our case, the upper midrange for vocals) while minimizing frequencies outside the vocal range".Figure 78& 79 are the graphical expressions of the two frequency responses discussed above.

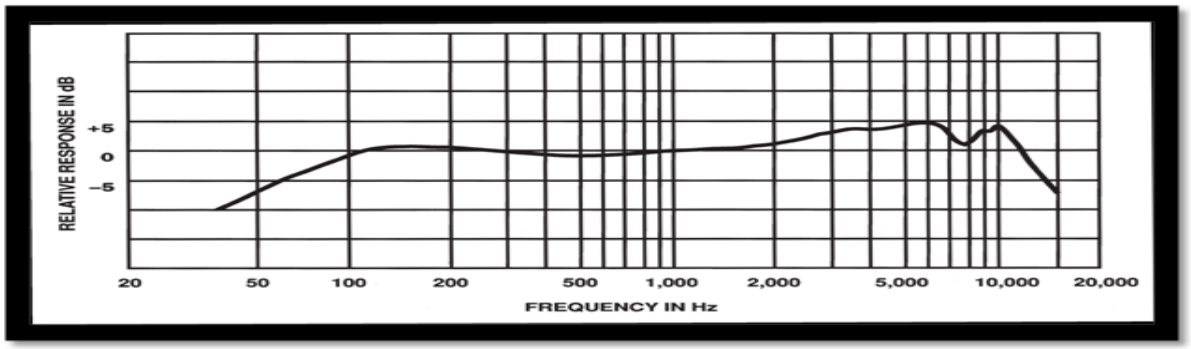



Figure 78: Flat frequency response Fry (139-142).

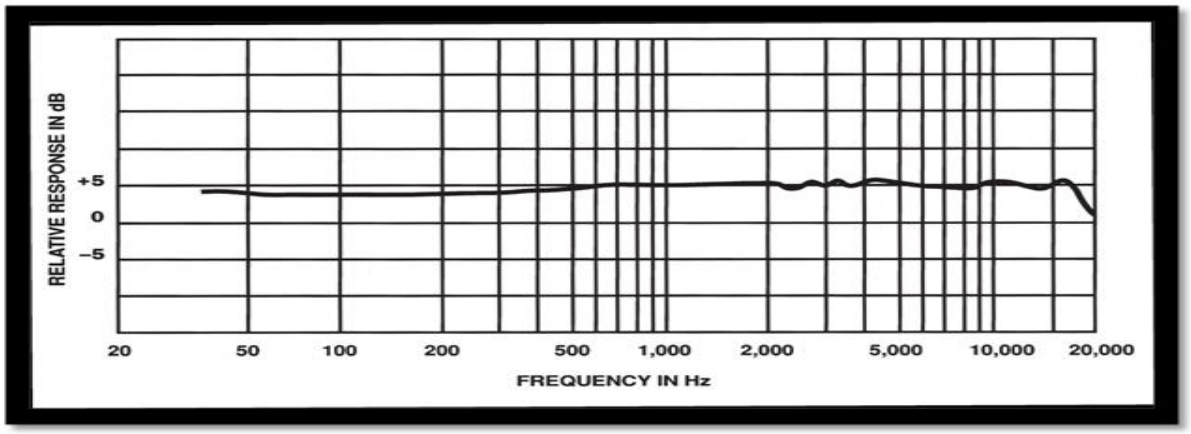



Figure 79: Shaped frequency response Fry (139-142).

**(d) Directionality**

The response of microphones to diverse musical sound from varioussound processing units is referred to as its "polar response" which forms an inseparable element in the reinforcement of sound. Thèberge (1997, pp. 67-85) gives the two main types of microphones as "omnidirectional" ("Omni") which picks musical or vocal sound from within the "360 degrees' circumference" and "unidirectional" ("uni"), which picks only musical or vocal sound from one direction as desired by the sound engineer. These types of microphones were observed at Saint Peters' Cathedral Church Ake, Abeokuta during a Communion service as used by the Lay reader purposely for Bible reading and for backup singers. Significantly, Steeneken and Houtgast (1980, pp. 318–

326)complimentarily assert that“there is also an angle of minimum sensitivity, called the null point”.

Several makes of dynamic microphones were seen and applicably used in all the selected church auditoria, these varieties of “unidirectional microphones”had no progressive functions because they were less functional to what could bring good and clear audibility to worshippers at different sitting positions within the church auditoria. This types of microphoneswere observed at the Redeemed Christian Church of God (RCCG), Ilesha Mega Parish as used only by the choir as surroundsmicrophone for secondary backups, the purpose of the use is to pick lighter voices as differ from the main songs backup singers. Providing information on the existence of other microphones, complimenting the poor function nature of dynamic microphones, Anderton (1978, pp.28-40) writes that:

> bi-directional microphones also exist, but are rarely used in meeting scenarios and large gatherings, these are microphones used mainly in the recording studiosby pointing it directly at the desired sound source, a unidirectional microphone picks up more of the intended sound and less unwanted ambient sound.

In his comments, Allen (1980, p. 143) writes that:

> a well-planned microphone positioning can minimize the pickup of unwanted sound sources (other presenters, rustling papers, loudspeakers, etc.), thus enhancing musical and speech sound productions. In any case, the other microphone specifications should be just as carefully chosen to satisfy the basic acoustic and musical requirements of the application. Ultimately, all five characteristics must be properly specified to yield the best results.

Figures80 (a-d) are examples of other specification of microphones found in the selected in selected church auditoria in South western Nigeria.




80 (a) observed in all churches
GM-939-E, Dynamic microphone PTT
• Dynamic microphone, symmetric, 200 Ω




80 (b) observed in all churches
SM-58, Dynamic microphone
Dynamic microphone, symmetric, 200 Ω




80(c) observed only in Winners' Chapel
ME-64, Condenser microphone
Condenser microphone, symmetric, 200 Ω



80(d) observed in Saint Peters' Cathedral, Ake
ES-Serie, Condenser microphone
Condenser microphones, symmetric, 200 Ω

Figures 9 (a-d): Different microphones used in worship auditoria

**(e) Mixing Console**

Sound mixing console is the central sound processing unit (CSPU) and most unfriendly especially, if there are no sufficient ad-hoc equipment to rely on.There are three main operating components on the mixing console, these include:

(i) The Pre-amplifierincreases either a microphone signal or a Line signal to set the appropriate Gain structure. Usually, there is a switch to determine a microphone or a Line signal. Consoles may be labelled with Low Impedance for 3-pin XLR microphone inputs and High Impedance for ¼ inch Line inputs.

(ii) The Equalizer(EQ)helps to achieve tonal balance of each microphone and each musical instrument in order to make the sound more pleasing and intelligible.

(iii) The Mixeradds the equalized signals from different microphones and musical instruments together.

Chion (1994, pp.7-18) writes that “a balanced mix of musical sound is the key to good overall sound”. Beck. (1998, pp. 15-25) compliments that “the amount of amplification achieved at the Pre-amplifier stage is called “Gain” and it is a very critical parameter”. This is process of controlling each individual musical instrument’s acousticsto generate a better musical sound.The challenge of imbalance in the musical sound production in church auditoria is as a result of sound checking of voices and musical instrument before the start of a worship service. On this note, Cremer (1989, pp. 1213-1225) give a strong warning to be aware of the fact that

> the presence of the audience or congregation will change the acoustical characteristics of any auditorium and as a result, the Gain settings need to be further fine-tuned as the concert begins. Optimal Gain setting minimizes the feedback and reduces the system noise. Any distortions are indicated by small red lights called LEDs (Light Emitting Diodes), attenuate (reduction in the volume) the Gain to eliminate any distortions.

This trait of sound distortion was experienced in all the selected church auditoria; the culture of high volume of musical sound is very common to all the churches. The sound engineers however, lack good knowledge on the functions of the different buttons on the mixer console so, if sound propagation, production and transmission are not well grounded, then there will be problem with such sound reception because when the foundation is destroyed, what can the righteous do? (Psalms 11:3 KJV) A typical mixing console is provided in figure 81.



Figure 81: (picture by the researcher on April 11, 2017)

**(f) Amplifying Engine**

The Amplifying engineenhances sound signal in the driving of musical sound into the mixing console. This is done to further process the amplified sound through the central processing unit (spu) in order to be powered by console into the front of house (FOH) speakers and the low frequency sub hoovers.Dorman (1995, pp. 2403-2411) writes that “the higher the power amplifier, lesser the distortion. The power amplifier requirement depends on the size of the auditorium and numerical strength of members”. Approximately according to Davies (2006, pp. 991–999), gives two types of sound amplifier “as“linear amplifier” which responds to different frequency components independently, and does not generate harmonic distortion or inter modulation distortion contrary to a nonlinear amplifier which generates distortion”, and two, “a “wide band amplifier” with a precise amplification factor over a wide range of frequencies, and is often used to boost signals for relay in communications systems”.

In essence, Davies argument states that “the power rating and the impedance of the amplifier must match that of the speakers” in consonance with the musical sound producing room. It is possible to have a power mixer, a situation where both the mixer and the amplifier are built in one casing. Figure 82 is the common power amplifier found in most church auditorium in Nigeria especially in the selected church auditoria for this study.



Figure 82: Power mixer amplifier(picture by the researcher on April 11, 2017)




Figure 83: Common power amplifier(picture by the researcher on April 11, 2017)

**(g) Speakers**

Speakers are regarded as the final production stage to make all amplified musical sound heard by listeners. Commenting on this, Bies and Hansen (1996, p.344) put it that "the most important parameter is impedance matching which is the resistance to the alternative current (AC)supply". The retrogress performance of sound amplifier and the connecting cables need to be taken care of in order of the speaker to function as desired. However, live sounds in a church auditorium are amplified through two types of speakers; the front of house (FOH) and the sub woofers. Figures 84 and 85 respectively:



Figure 84: Front of house (FOH) speakers(picture by the researcher on April 11, 2017)

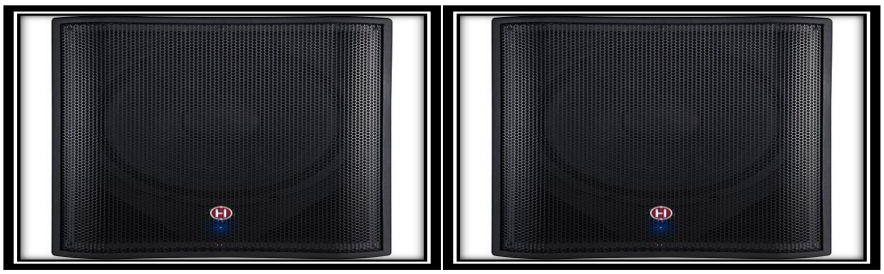


Figure85: Sub-woofer speakers(picture by the researcher on April 11, 2017)

Monitor speaker are not usually a full range speaker because the function is just to provide a feedback purpose of sound from the live source. Monitor speakers are mainly for the choir and the preacher which are usually placed very close to the choir stall and the Altar and they must sound as pure as possible to avoid sound distortion. Dorman (2003, p. 240) suggests that "to achieve this musical parlance, the speaker specification must have a flat, that is, uniform frequency response for true sound". This is also referred to as a "Feedback speakers". Most types of monitor speakers observed in the selected church auditoria are provided in figure 86:



Figure 86: Most common monitor speakers used in church auditoria(picture by the researcher on May 9, 2017)

However, all the speakers used for sound production are not assembled in a particular corner in the church auditorium, but sparsely positioned within the auditorium with the formation and the location within the sound system positioning as provided in figure 87.

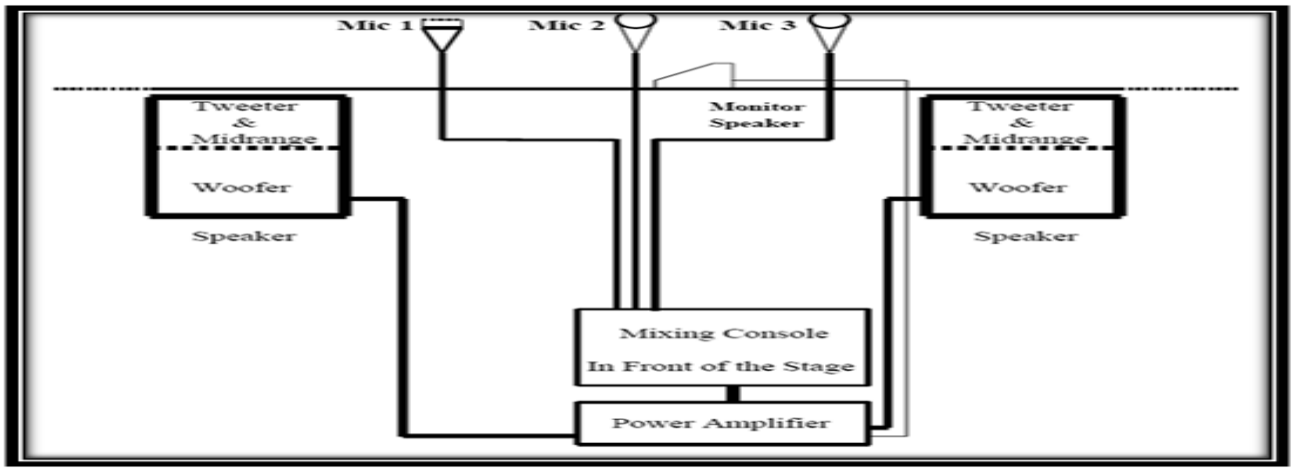



Figure 87: Formation of sound positioning in a worship auditorium.

The ideal graphical settings above are lacking in all the visited church auditoria and this is perhaps the fundamental challenge to good musical acoustics in Nigerian, especially in south-western and north central regions church auditoria.

### 3.6 Reverberation and Time Response

Several definitions have been given to examine and provide a judgement on reverberation and time response of auditoriums. In spite of his, "reverberation time" has continued to be a strong measuring element of acoustics' parameters. Horvat, Jambrosic and Domitrovic (2007, p. 405) submit that in the "professional work of an acoustician, it is often required to measure the reverberation time in auditorium with very different sizes, shapes and intended purposes". Moreover, Blesser (2007, p. 39) opines that "a number of different methods for measuring the reverberation time has been developed and implemented".Bonebright (2001, p. 151) equally submits that "the integrated impulse response method and the method of recording the room response to an impulsive source and the burst method" would be fairly adequate for the measurement of "reverberation time". Horvat, Jambrosic and Domitrovic (2007, p. 407) have suggested that "the integrated impulse response method and the method of recording the room response to an impulsive source could be the most suitable ones to be used in field measurements", so the emphasis in this thesis has been made on "Smaart v7 Impulse Response

Measurement" methods which adapts conveniently with the Place theory of sound perception for reverberation and time response of musical acoustics in the selected church auditoria.

However, certain "requirements and parameters" are needed in "reverberation time response" measurement. Schroeder (1965, pp. 409–412) suggests two requirements that "the source, either a loudspeaker or, if nothing else is available, an impulsive source of some kind, should have an omni-directional radiation pattern" and "the sound pressure level must be high enough to provide a minimum required dynamic range to perform a reverberation time measurement, to be more precise, at least 45 dB for methods that do not apply synchronous averaging few decibels to the required dynamic range and lowering the demands on the sound source at the same time".

Another technique was suggested by Farina (2007, pp. 27-31), that:

> the interrupted noise method basically uses a portion of pink noise with a duration of several seconds that ends abruptly and the response of the room to this noise signal, that is, the reverberation, is recorded as a wave, file and then imported in audio measurement and analysis software for further analysis. The method which utilizes an impulsive source of some kind by recording the response of the room to it is actually quite similar to the interrupted noise method. The procedure is described above, while the only difference is the source of excitation. Unlike the interrupted noise method, which uses a loudspeaker.

Hidaka and Beranek's (2000, pp. 368-383) method allow "for a wide variety of impulsive-like sources, like air-filled balloons, firecrackers, pistol shots, hand clap, two pieces of board clapped together". Hidaka and Beranek's method was adopted in the measurement of low, mid and high time responses at the Celestial Church of Christ, Akobo, Ibadan where the results showed that the method is not ideal for measurement of sound echoes generations and its equivalent overtones in all the levels of sound productions.

### 3.7 Musical Instruments sound and Directional Hearing in Church Auditoria

When musical instruments'' sound intrudes the human ear from all sound directional waves, there is always a smallarrival point difference that distinguishes the period of perception

from one listener to another. This musical instruments' sound points of perception according to Fry (1979, pp. 139-142) "is evaluated by the nervous system to determine the direction of incidence of the sound. In this context". Reichardt (1968, p. 119) submits that:

> the extremely short time span of 0.03 ms is sufficient to evoke a sensation of directional change; this corresponds to a sound path difference between the human ears of about 1 cm. Thus, the ears are able to detect a departure of only 3° from the frontal sound incidence direction. For incidence from the side, orientation resolution with this procedure would drop to 7.5°, furthermore, confusion with sound incidence from the rear would be possible if additional information based on directional characteristics of the human ear were not available for these angular regions.

Reichardt's submission therefore concludes that musical instruments' can only be heard from one side of the human ears at a point in time because the two human ears cannot hear musical instruments' sound intensity at the rate and at the same time. For example, Hoeg (1972, pp. 453-556) observes that "only one sound source located between the original sources is perceived when in comparison with a move in the tonal point which often cause a change that doesn't go beyond 3ms". The running time as asserted by Hoeg with differences of not more than 3ms is solely attainable on the basis that the source of the musical instruments' soundsituated on the directional waves way of the sound indicator. Haas (1951, p. 257) in his own submission opines that "the running time differences is likely to increase to between 5 and 30 ms, this level difference can amount to up to 10 dB without influencing the localization of the sound source in relation to the direction of incidence from the first source". This phenomenon, according to Takahashi (1997. p. 146) is labelled as "the precedence effect". Blauert (1974, p. 415) categorically states that "frequency contributions below 600 Hz as well as those from about 3,000 to 6,000 Hz support the direction". The ''front'' is components "between 800 and 1,800 Hz as well as above 10,000 Hz", and the direction ''back'', and components around 8,000 Hz the "upper direction"

### 3.8 The Sensation of Loudness

Barron (2005, pp. 576-578) writes on the “sensation of hearing which arises when pressure fluctuations reach the human ear”, this “sensation of hearing” strikes at a particular intensity range but, not always go beneath the required smallest sound level of sound occurrence to allow for sound pulsation. Lokki (2011, p. 229) argues that“for younger persons, the upper limit of hearing lies in the range of 20,000 Hz”. In this sense, Lokki’s position is that the smallest musical instrument’s sound level required that humanears cannot perceive musical tones all at the time and period. In this context, Sessler, Schultz and Watters (1991, p. 885) write that:

> this is an interesting result and noted that this so-called threshold of hearing depends in large measure on frequency. One notes that the ear responds with most sensitivity to tones in the frequency range between 2,000 and 5,000 Hz. In this range, the minimum required sound level is the lowest. For higher frequencies, but even more so for lower frequencies, the sensitivity of the human ear is reduced, so that in these regions significantly, higher sound pressure levels are required for a musical tone to become audible.

Patynen (2009, pp. 876-878) categorically states that “the same tendency is evident when at higher intensity of tones of different frequencies are compared in relation to their impression of loudness. The sound pressure level as an objective measure of existing physical excitation is by no means equivalent to the loudness as a subjective measure of sensation”. In a contrary argument, Ikibe (2010, p. 207) posits a different position from Sessler, Schultz and Watters (ibid, 1991) and Patynen (ibid, 2009). Ikibe argues that the high level of musical acoustics in church auditoria could be liked to a musical sound in a disco hall in loudness. Ikibe’s opinion was based on his experience at the Redeem Christian Church of God, Kwara Provincial Council. The level of loudness of the musical production was high and this triggered the secularization of the dance steps of the choir which made the ladies to shake their buttocks in the manner of a disco hall dance.

Establishing a relationship amid these schools of thoughts regarding the sensation of loudness, Bradley (1991, pp. 442-453) introduces the unit of a phon for the measurement of loudness level and narrates this as

> the decibel (dB) scale for sound pressure level and the phon scale for loudness level to coincide at 1,000 Hz. When tones of different frequency are compared to a tone of 1,000 Hz, the so called equal loudness curves are obtained which represent the relationship between the objective sound pressure level and the loudness level as determined by the sensitivity of the human ear.

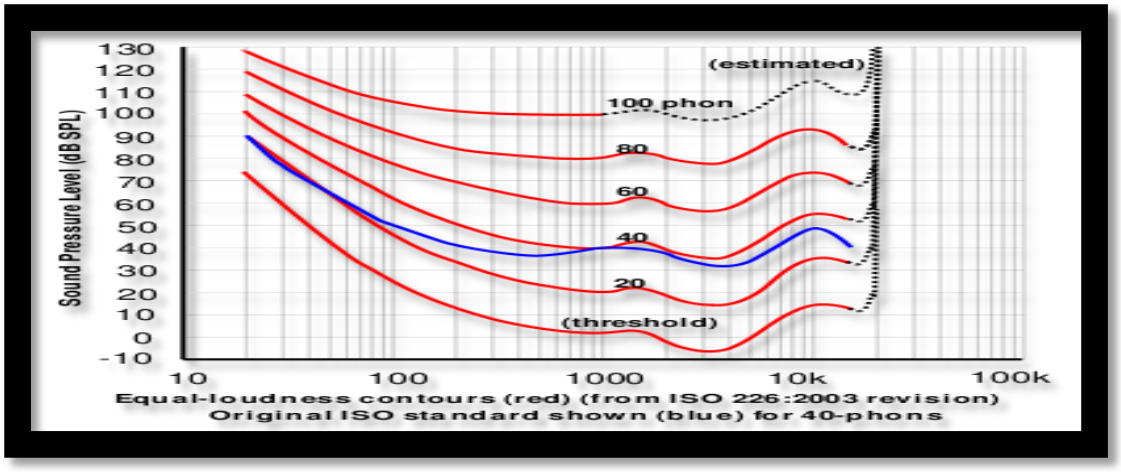



Figure 88: Equal loudness curve Fletcher (1999, p. 59)

When sensation of loudness is reached in musical acoustics, it turns to “threshold of pain”, this denotes that the levels of “hearing sensation” has becomes painful. Reichardt (1968, p. 395) submits that

> at this point, a safety measure goes into effect in the middle ear, which protects the inner ear from a damaging overload, so that it no longer transmits the full vibration amplitude. However, even below this threshold of pain there are some loudness levels which in a musical context.

Reichardt’s position was observed at the Celestial Church of Christ, Akobo, Ibadan and Saint Peter’s Cathedral Church, Ake, Abeokuta, where loud musical instruments’ sound were “not

considered to be beautiful, but rather annoying". This loud sound irritation limit nevertheless, provides a signal for "sound pressure levels" (SPL)that is put within the "threshold of human hearing" as stipulated by the Place theory of sound perception (PTSP).

### 3.9 Perception of Musical Instruments Acoustics

Features of musical instruments acoustics are tones with regulated highness and lowness sound quality. The musical instruments'sounds are produced through the nature of musical instruments and amplified by the sound system with the mixing console as the main sound processing unit (SPU) through regulated "periodic vibrations" the sound engineer within the range of the perception of the human ear.

Jacko (2009, p. 231) defines the "frequency of a sound waves as simply the number of complete vibrations occurring per unit of time which is measured in decibels". Cavanaugh and Wilkes (1999, pp. 346-349) give further explanation that

> the decibel scale is a logarithmic scale based on the logarithm of the ratio of a sound pressure to a reference sound pressure within the threshold of audibility, while the frequency of sound waves is measured in Hertz (HZ) which is also known as cycles per second (cps), these are grouped into octaves (an octave band is labelled by its geometric centre frequency).

Binggeli and Greichen (2011, pp. 435-446) submit that "human hearing is most acute in the 1000 to 4000 HZ octave bands and therefore recommend central frequencies and the band limits of eight octave bands" which are commonly used in musical sound production as seen in table 7.

Table 7:Frequency Band in Octave

| Octave Band | Approximate band limits (Hz) |
|---|---|
| **22-24** | 31.5 |
| **44-48** | 63 |
| **88-175** | 125 |
| **175-350** | 250 |
| **350-700** | 500 |
| **700-1400** | 1000 |
| **1400-2800** | 2000 |
| **2800-5600** | 4000 |

| | |
|---|---|
| **5600-11,200** | 8000 |

(Binggeli and Greichen (2011, p. 438: Architectural Graphics Standard)

However, in frequency distribution and the response of the human ear, Gazanfar, Turesson, Maier, Dinther, Patterson, and Logothetis (2006, p. 289) submit that "the human ear is capable of detecting sound over a wide range of frequencies in ideal listening conditions for a healthy young adult with normal hearing, the lower limit is around 50Hz and the upper limit approaches 20 kHz". Figure 8 shows the sensitivity of the ear as varies substantially over the range of "20kHz". Fletcher and Munson ((1953, pp. 2635-2645) first measured equal-loudness contours using headphones to test human hearing and listening "to pure tones at various frequencies and over 10 dB increments in stimulus intensity".

However, frequency perceptions of musical instruments' acoustics in the selected church auditoria are at variance because of the different acoustic parameters available in each of the church auditorium and also as a result of subjective reactions to musical sound frequencies. Frequency cannot be stand alone without the attributes from timbre. Stephen and Bruno (2008: p. 73) posit that

> Timbre is a misleadingly simple and vague word encompassing a very complex set of auditory attributes, as well as a plethora of psychological and musical issues. It covers many parameters of perception that are not accounted for by pitch, loudness, spatial position, duration, and various environmental characteristics such as room reverberation. This leaves a wealth of possibilities that have been explored over the last 40 years or so.

From Stephen and Bruno (2008: p. 73) submission, it clearly understood that perception of musical instruments frequency can only be depended of the sound pitch and its quality in the high, middle and low frequencies. All these attributes could not be found in the perceptual views of the selected church congregants in line with what represent a good or a bad musical instruments acoustics. As worshippers, every musical sound from the loudspeaker is a good one as long as it satisfies their worship and praise emotions, not minding the loudness or otherwise nature of such musical sound.

### 3.9.1 Musical Sound Waves

Crandell (2005, p.184) defines sound “as the vibration of air particles, which travels to your ears from the vibration of the object making the sound”. Connecting Crandell’s definition to the process by which musical instruments produce sound, for example, the strings of a plucked guitar only produces sound as a result of an interaction with the “soundboard”, this presents a “sound wave” that travels through the atmosphere. The difference between various sound production rests on the waveforms of the two different sounds from two different sources. The observable difference and similarity in the two waveforms as submitted by Crandell (2005, p.184) is that “these waveforms make the same transition from loud to soft as the first, but otherwise are quite different”.

The fundamental element to hear and understandthe features of musical instruments’ sound according to Diament (1986, pp. 450-451) is the “physics of waves”. Elert (2004, p. 65) equally opines that “sound is a wave that is created by vibrating objects and propagated through a medium from one location to another”. A wave, according to Bradley (2002, pp. 243-256) is a “disturbance that travels through a medium, transporting energy from one location to another location. The medium is simply the material through which the disturbance is moving; it can be thought of as a series of interacting particles”. Poletti (1991, p. 211) gives the” example of a slinky wave as often used to illustrate the nature of a wave” as thus:

> A disturbance is typically created within the slinky by the back and forth movement of the first coil of the slinky. The first coil becomes disturbed and begins to push or pull on the second coil. This push or pull on the second coil will displace the second coil from its equilibrium position. As the second coil becomes displaced, it begins to push or pull on the third coil; the push or pull on the third coil displaces it from its equilibrium position. As the third coil becomes displaced, it begins to push or pull on the fourth coil.

Poletti’s position here is understood that this process continues in consecutive fashion, with each distinct sound steam substituting to shift the nextmusical steam. Poletti illustrates this graceful process as seen in figure 88

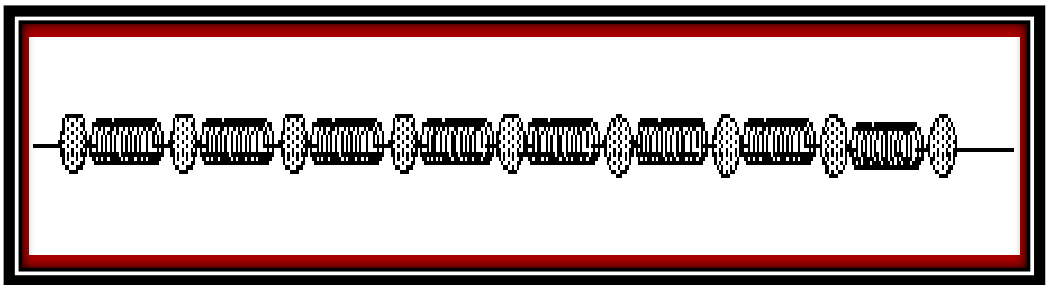


Figure 88: Poletti's slinky wave's illustration

Resulting from the general overview of various sound waves as illustrated by different scholars and as observed in the sound propagation in the selected church auditoria, it is pertinent to establish that a sound wave is similar in nature to a "slinky wave" for three obvious reasons which Poletti states as (i) "there is a medium that carries the disturbance from one location to another. Typically, this medium is air, though it could be any material such as water or steel. The medium is simply a series of interconnected and interacting particles". (ii)" here is an original source of the wave, some vibrating object capable of disturbing the first particle of the medium. The disturbance could be created by the vibrating vocal cords of a person, the vibrating string and soundboard of a guitar or violin, the vibrating tines of a tuning fork, or the vibrating diaphragm of a radio speaker" and (iii) "the sound wave is transported from one location to another by means of particle-to-particle interaction. If the sound wave is moving through air, then as one air particle is displaced from its equilibrium position, it exerts a push or pull on its nearest neighbours, causing them to be displaced from their equilibrium position. This particle interaction continues throughout the entire medium, with each particle interacting and causing a disturbance of its nearest neighbours".

In a complimentary statement, Giancoli (2009, pp. 324-326) writes that "since a sound wave is a disturbance that is transported through a medium via the mechanism of particle-to-particle interaction, a sound wave is characterized as a mechanical wave", that is, an oscillation of matter, and therefore transfers energy through a medium.The sound output therefore suggests the rate at whicha loud musical instruments' is sound produced. The illustration in figure 89 is a description of how sound wave travels through wavelength from amplitude through compression and refraction to the ambient pressure as provided by Giancoli (ibid, p. 325)

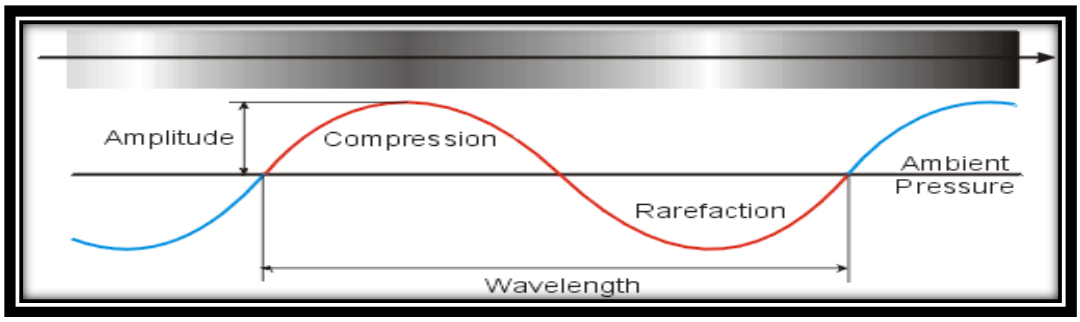


Figure 89: Travelling wave Giancoli (2009, p. 325)

### 3.9.2 Pitch

Distinguish between pitch and timbre as separate musical variables is very important, though both are determined entirely by the "frequency content of the sound". Timbre is relative to "colour" of a sound, the distribution of harmonics and how it evolves while pitch is supposed to capture a sense of what note is being played. Thus, the concept of pitch is defined by reference to the sound produced by an individual musical instrument (or, in the case of a piano, independently vibrating part of a polyphonic musical instrument). In the case of sound produced by an ensemble and separate out pitch versus timbre, because certain combinations of instruments in harmony can blend into a sound that mimics a single instrument with a complex timbre.

In this connection, Barron (2009, p. 481) defines pitch as

> the subjective response of human hearing mechanism to changing frequency. All musical instruments produce complex sounds which are made up of several frequencies, although the lowest is normally determined by the pitch which is the perceived frequency. Pitch is the property of sound that is perceived as highness and lowness.

Salvi, Levine, Nam, Oron, and Melcher (1998, pp. 11-15) write that "some people have the inborn ability, known as perfect pitch to recognize or sing a given note without reference to any other pitch", this position cannot be said to all correct because those that are not endowed with inborn ability of pitch detection are also found in the musical arena.

In fact, these set of people are greater in percentage than those with inborn ability. The trait of singing out of pitch is very common to most choristers as observed in the selected church

auditoria. The problem pitch detection is not only peculiar to singers alone; most instrumentalists are also affected by this pitch lost syndrome. It was observed during a wedding service at the cathedral church of Saint Peter, Ake where the lead praise singer, within the short period of praise singing, unintentionally modulated to three different keys. Figure 90 illustrates "different pitches measured in cycles per second (cps)" as given by Baron (2009, p. 481)

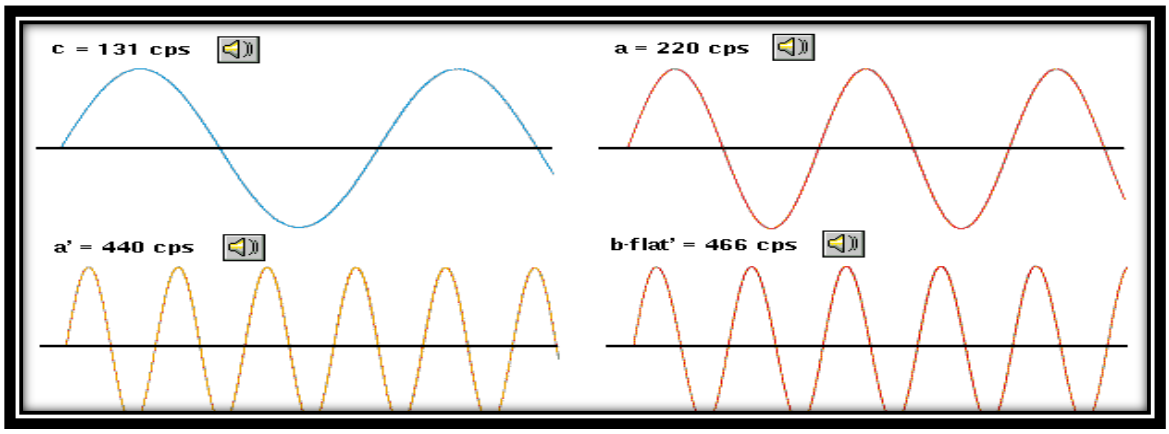



Figure 90: Illustration of different pitches measured in cycles per second (cps) Baron (2009, p. 481)

### 3.9.3 Timbre

One of the complexities in musical instruments' sound production characteristics is the "timbre", which results mainly as from the sound "harmonics, vibrato and the attack and decay of a sound". This is as opposed to Poletti's (1991, p. 211) "travelling wave pattern". In a comment, Auslander (2003, p. 161) opines that:

> the regular repetitive sound of the standing vibration is perceived as more pleasing than irregular vibrations in which recognition of similar sounds in aspects other than pitch and loudness is not concerned with, but it is an ability that everyone seems to share.

Berkhout (1993, pp. 2768-2778) argues that:

> Once knowledge to identify a particular timbre and recognition is possible even if the pitch is changed or if parts of the spectrum are filtered out. Timbre, also

called tone colour, it is the characteristic quality of a sound produced by a particular musical instrument, independent of pitch or loudness.

Berkhout's (1993, pp. 2768-2778) position of course,suggest that timbre can be regulated by the sound engineer without distorting any iota of sound productions and propagations. Other researchers such as Krumhansl (1989, pp. 43-53) and Smalley (1994, pp. 35-48) have also defined "timbre as a complex and multidimensional attribute of sound". In addition, one of well accepted excellent definitions of "timbre" commonly referred to in academic articles is the one suggested by the"American National Standards Institute" (1973, p. 20) that "Timbre is that attribute of auditory sensation in terms of which a listener can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar". In summary, Platt and Racine (1985, pp. 543-553), Melara and Marks (1990, pp. 169-178) and Caruso and Balaban (2014, pp. 865-870) define "timbre as all the sound attributes, except pitch, loudness, and duration, which allow distinguishing and recognizing that two sounds are dissimilar". However, Grey (1975, p. 145) adds to thesedefinitional meanings of "timbre" that "timbre, pitch, and loudness can interfere in the auditory sensation".

### 3.9.4 Congregants' Perception of musical Instruments Acoustics

Congregants' perception of musical instruments acoustics in the selected church auditoria could be considered to perceive musical instruments' acoustics inthe fundamental,the harmonicsand the residual perceptions. However, these three areas of musical instruments'acoustics' perception are largely dependent of the congregants' sitting position within the church auditorium. There are four sitting positions in any church auditorium; these are the Altar, the front seats in the auditorium, the middle seats in the auditorium and the rear seats in the auditorium.

Perception of the original musical instruments sound is only perceived by the congregants sitting at the rear position of the church auditorium especially where the amplifying speaker systems are raised on sky folds. The musical instruments sound travels above the heads of the

front rows of seats to the back and perceived by these sets of congregants. Perception of the harmonics sound is perceived by the middle seats congregants as it flows from the original sound. The perception of harmonics is less heavy than the fundamental musical acoustics while the residual sounds are theovertones of the fundamental sounds, the sound are perceived when the original and harmonics fade off. This also affirms the observation made by Birdsall(2012, pp. 232-245) that musical instruments sound requires long reverberations to allow for the "perception of the residual sounds".

Congregants' perception of musical instruments acoustics in the selected church auditoria differ from one another. Study experience showed that congregants have different understandings of the musical instruments acoustics as it applied to their diverse emotion for example, congregants at the Saint Peters' Church Cathedral, Ake Abeokuta perceived musical instruments acoustics as worship tools and not really concerned about the sound intensity or volume of sound since it could satisfy their emotion curiosity. Congregants at Our Saviour's Church, Ikenne perceived musical instruments acoustics as main part of the worship service which could not be taken away from the worship processes. Musical instruments acoustics was seen as a drive to total worship mood. At the Iyeru Okin African Church, congregants perceived musical acoustics as the main factor in service because you can only get closer to God in worship through music especially, through indigenous musical practices. The case was a different one at the Daystar Church, Lagos where congregants perceived musical acoustics as a communication factor between the worshippers and the creator. Congregants in this churchperceived musical acoustics as means to connect with God and reach a level divine interaction with God. Congregants at the Celestial Church of Christ, Akobo, Ibadan perceived musical instruments acoustics as a tool for praising the divine God, not only this, it was also perceived as a drive to a high level of spiritual attainment that culminates in prophesying and vision revealing to members of the congregation while at the Dominion Centre, the perception of musical instruments acoustics by the congregants was basically a spiritual necessity which could only be achieved through spiritual state of being at any worship service.

# CHAPTER FOUR

# ANALYSIS OF MUSICAL INSTRUMENTS' ACOUSTICS IN THE SELECTED CHURCH AUDITORIA

## 4.0 Introduction

Musical instruments acoustics and production quality in a church auditorium is vital to the provision of best overall sound outcome for singers and worshipers as parts of worship services. Musical sound qualities and quantities in the selected church auditoria in south-western Nigeria were examined without or favour. These bias free quantitieswere envisaged by many acoustic limits and bias filled examination which wereadjudged through probing of worshippers, pastors, choristers and sound engineers on preference of musical instruments' acoustics' limit as perceived during a worship service. In this connection, Bradley and Soulodre (1995, pp. 45-56) write that:

> Subjective evaluation of room musical acoustic measure depends solely on individual sense of musical perception which is equally based on several acoustic measurements parameters that are found to have strong correlation with each subjective rating. Objective evaluations were performed with several acoustic parameters that are obtainable through computational analyses.

The overall average of musical instruments acoustics at each limit within the selected church auditorium were likened to the seats at each closeness from the front auditorium arena, the middle auditorium arena and the rear auditorium arena of the selected church auditoria. There are more than a few applicable methods to examine musical instruments' acoustics in an auditorium. Each method requires the need to analyse one or more acoustical limits to arrive at an objective or a subjective conclusion. In connection with the scope limit of this study, church musical instruments' acoustics sound production in the area of loudness,

clarity, ensemble, frequency, pitch and reverberation were discussed as observed in the selected church auditoriums in south-western Nigeria.

### 4.1 The setting parameters used for measurement for this study

Table 8: The operational Levels of Parameters used for Measurement

**Settings of Limit Used for Musical Instruments' Acoustics Measurement**

| Limits | Operational Level |
|---|---|
| **Tempo fall-off speed** | 100 ms |
| | |
| **Usualintermissionamid quantity** | 15mins |
| | |
| **Specimen speed** | High |
| | |
| **Weighting** | A |
| | |
| **Automatic Gain Control** | By-passed |
| | |
| **Factory Made Device Microphone** | Enabled |
| | |
| **Measurement device** | Techno DPR 7 Tablet |
| | |

#### 4.1.1 Method of Data Collection

This study adopted descriptive research method using the quantitative and qualitative designs to achieve the set objectives. The tool for data collection were participant-observation, oral interviews and questionnaires on church congregants, pastors, choristers and sound engineers. The study population comprised of eleven interviewees, and 959 questionnaires six churches. A simple percentile was adopted in the analysis of the collected data. The sound measurement was done with A4DaTuner to measure the sound pressure level in each church auditorium. The Place Theory of Sound Perception (PTSP) by Bekesy (1928) was applied in the study as the theoretical framework.

The sound measurement software applications; the 'A4 Da Tuna' was installed on a Techno DPR7 Android Tablet phone and used to measure musical instruments' acoustics in all the selected church auditoria in south-western Nigeria. The periods of measurement were divided into three

sections of hymnal, worship and praise singing between 10am-12pm on each research day. Readings of average musical acoustics sound pressure level (SPL) were measured with the Techno DPR7 Tablet mobile phone for each measurement carried in this research study.

However, the sound pressure level (SPL) for hymnal singing, worship singing and praise singing were measured at different dates with differently generated results in each of the selected church auditoria. Moreover, acoustics of each church auditorium were observed to arrive at suggestions and recommendations for this study in order to solve certain acoustics problems in any of the selected church auditorium. The average of the musical instruments' acoustics' ensemble was calculated to arrive at the total number of the generated musical sound decibels in each and in all the selected church auditoria using the International Organisation for Standardization (ISO) 3382 Standard for the measurement of musical instruments vis-a-vis auditorium acoustics.

### 4.1.2 Analysis of Data

The collected data for this study was analysed in accordance with the tested variables as reflected in the applied questionnaire which entails reverberation time, frequency, pitch, clarity and ensemble of musical acoustics as perceived by the worshippers (the pastors/clergy, the choir and the congregation) in the selected church auditoria. The data analysis is divided into three categories as collected in each of the six purposively church auditoria in south-western Nigeria: Saint Peter's Cathedral Church, Ake, Abeokuta, Our Saviour's Church, Ikenne, Celestial Church of Christ, Akobo, Iyeru Okin African Church, Offa, Redeem Christian Church of God, Mega Parish, Ilesha and Dominion Centre Church, Ile-Ife.

### 4.1.3 Quantitative Analysis of Results of Musical Instruments' Acoustics in the Selected Church Auditoria.

The respondents in this section are the church congregation and the choir. One hundred and twenty questionnaires were distributed to the respondents. But one hundred were received fully filled and found useful are therefore used for data analysis.

### 4.1.4 Analysis of Questionnaires

A total of 959 questionnaires were distributed to respondents in all the six selected church auditoria in south-western Nigeria but, only 825 were completed and retrieved as seen in table 9:

**Table 9: Respondents per church auditorium**

| Church Auditoria | Male Respondents | Female Respondents | Total Respondents |
|---|---|---|---|
| Saint Peters' Cathedral Church, Ake | 60 | 100 | 160 |
| Our Saviour's Church, Ikenne | 50 | 80 | 130 |
| Iyeru Okin African Church, Offa | 50 | 70 | 120 |
| Celestial Church of Christ, Akobo, Ibadan | 60 | 90 | 150 |
| Redeem Christian Church of God Mega Parish, Ilesa | 45 | 100 | 145 |
| Dominion Centre Church, Ile-Ife. | 40 | 80 | 120 |
| Cumulative Number of Respondents. | 305 | 520 | 825 |

The figures in table 9 were computed for the results analysis. Six hundred and eighty three (683) questionnaires were completed by the congregants and the choir, fifteen (15) questionnaires were completed by the organists, choirmasters and music directors, fifteen (15) questionnaires were completed by the clergy men and twelve (12) by the sound engineers giving the total of retrieved questionnaire to be 825 leaving one hundred and three (103) questionnaireswere unattended to and which were subsequently discarded from the administered Nine hundred and fifty nine applied questionnaires (959). The percentage of the analysed is therefore put at 91.4% while the lost data is put at 8.5% and are not part of the study results analysis.

The collection of data through the application of questionnaires, was subjected to "frequency counts" with responses for each question summed up in order of appearance to arrive at the "highest frequency of occurrences" which were quantified and presented on percentile basis. This analysis is presented in tabular form with one "variable or combined two to three variables" in a table. The category of respondents in this analysis include the church congregation, organists and choirmasters, clergymen and sound engineers in all the selected church auditoria in south-western Nigeria.

## 4.2 Personal Data of Respondents

Table 10: Respondents' Sex

| Sex | Frequency | Percentage | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|
| Female | 800 | 56% | 285 | 56% |
| Male | 800 | 32% | 825 | 36% |
| Invalid | 25 | 8.2% | 25 | 8.2% |

Source: Field survey results**,** 2017

**Interpretation**

It is observed that most of the respondents are females with 56% and males with 36%

Table 11: Respondents' Marital Status

| Variable | Frequency | Percentage | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|
| Single | 572 | 69% | 572 | 69% |
| Married | 242 | 29% | 242 | 29% |
| Widower | 6 | 0.72% | 6 | 0.72% |

Source: Field survey results**,** 2017

It is observed that 69% of the respondents are single, 29% married, 15% widower and 0.72% of this section was left unanswered.

### 4.2.1 Respondents' Educational Qualification

Table 12:Educational Qualification of Respondents

| Variables | Frequency | Percentage | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|
| SSCE | 825 | 43% | 825 | 100% |
| First Degree | 825 | 30% | 825 | 100% |
| Master's Degree | 825 | 18% | 825 | 100% |
| Ph.D | 825 | 7% | 825 | 100% |
| Other Qualifications | 825 | 2% | 825 | 100% |

Source: Field survey results**,** 2017

It is observed that all the respondents have Senior School Certificate in Education (SSCE), with 2% for other qualifications.

### 4.2.2 Related Questions to the Respondents

Table 13: Do you consider musical instruments volume very high during worship Session.

| Variable | Response | Frequency | Percentage | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|---|
| A-Loud enough | Yes | 745 | 90% | 745 | 90% |
| B-Too loud | Yes | 40 | 4.8% | 40 | 4.8% |
| C-Very loud | Yes | 20 | 50% | 20 | 2.4% |
| D-Disturbingly loud | No | 20 | 2.4% | 20 | 2.4% |

Source: Field survey results**,** 2017

**Interpretation**

The results in table 13 reflects that higher percentage of the respondents is 90%, this indicates that the musical instruments acoustics is loud enough during each worship session in the selected church auditoria, 4.8% of the respondents assert that musical instruments acoustics is too loud, 2.4% also agree that it is very loud while 2.4% agree to it too disturbingly loud.

Table 14: Are you in anyway affected by the Loud Musical Sound?

| Variable | Response | Frequency | Percentage | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|---|
| A-Yes | Yes | 745 | 90% | 745 | 90% |
| B-No | No | 60 | 7.2% | 60 | 7.2% |
| C-I don't know | I don't know | 20 | 2.4% | 20 | 2.8% |

Source: Field survey results**,** 2017

**Interpretation**

From the table 14, highest number of the respondents (90%) agreed to have been affected by the loud musical sound, 7.2% are not affected while 2.8% did not notice any effect of loud musical sound during worship sessions. The implication of this result is the most congregants are used to loud musical instruments acoustics during worship service and are no longer disturbed by

the heavy wattage of sound. Most of the congregants' ears are accustomed to this noisy worship environment.

Table 15: Which aspects of the worship session do you experience high volume of sound

| Variable | Response | Frequency | Percentage | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|---|
| Hymnal | Hymnal | 105 | 12.7% | 105 | 12.7% |
| Worship | Worship | 110 | 13.1% | 110 | 13.1% |
| Praises | Praises | 610 | 73.9% | 610 | 73.9% |

Source: Field survey results**,** 2017

**Interpretation**

From table 15, 12.7% of the total respondents enjoy the hymnal section of the worship service, 13.1% enjoy the worship section while 73.9% are interested in the praise aspect of musical instruments acoustics in all the selected church auditoria. The implication of this result is that few congregants of about 12.7% and 13.1% respectively are conscious of the effects of loud musical sound on human health while most congregants do not have any understanding of the effects of high volume of musical instruments' sound on their wellbeing. The implication of this result centres on the congregant's inability to define good and bad music objectively but has allowed what is considered as choice and preferences to influence their understandings of loud and soft or good or bad music though their subjective biases.

**Table 16: How would you rate your musical instruments acoustics vis-vis auditorium acoustics?**

| Variable | Response | Frequency | Percentage | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|---|
| A-Bad | Bad | 85 | 10.3% | 85 | 10.3% |
| B-Good | Good | 600 | 72.7% | 600 | 72.7% |
| C-Not sure | Not sure | 50 | 6% | 50 | 6% |
| D- Don't understand | Don't understand | 90 | 11% | 90 | 11% |

Source: Field survey results**,** 2017

**Interpretation**

From table 16, 10.3% of all the respondents considered musical instruments acoustics in all the selected auditoria as 'bad', 72.7% considered it as 'good', 6% not sure while 11% have zero knowledge about musical instruments sound perception. It is implied as a result that most congregants have zero knowledge about musical instruments acoustics and auditoria volume, generating about 72.7% of the congregants accepting music to be good when such do not conform to the room volume is a serious challenge to church congregants in this century.A broad result of the analysis of various variables observed and measured in all the selected church auditoria are presented below

### 4.3 QualitativeAnalysis of Variables in all the Selected Church Auditoria: Day One

Qualitative analyses of musical instruments sound as measured in all the selected church auditoria Day One are expressed in the table below:

Table 17: Results of Day One measurement of Musical Instruments Acoustics

| S/N | Church Auditorium | Measured Variables | Measurement Day and Date | Measurement Time | Measurement Results in Decibels (d |
|---|---|---|---|---|---|
| 1. | Saint Peters' Cathedral, Ake, Abeokuta | Hymns | February 5, 2017 | 10.20am | 65dB |
| | | Worship | February 5, 2017 | 11.10am | 95dB |
| | | Praises | February 5, 2017 | 11.20am | 110.8 dB |
| 2. | Our Saviour's Church, Ikenne | Hymns | March 5,2017 | 9.40am | 61 dB |
| | | Worship | March 5,2017 | 10.10am | 85.3 dB |
| | | Praises | March 5,2017 | 11.55am | 95 dB |
| 3. | Iyeru Okin African Church, Offa | Hymns | March 31, 2019 | 10.10am | 72 dB |
| | | Worship | March 31, 2019 | 10.40am | 97 dB |
| | | Praises | March 31, 2019 | 11.15am | 99.53 dB |
| 4. | Celestial Church of Christ, Akobo, Ibadan | Hymns/Worship | July 14, 2019 | 11.30am | 100.07 dB |
| | | Praises | July 14, 2019 | 12.40pm | 118.29 dB |
| 5. | Redeem Christian | Hymns/Worship | July 21, 2019 | 8.20am | 85 dB |

| | | | | | |
|---|---|---|---|---|---|
| | Church of God, Mega Parish, Ilesa. | Praises | | 9.30am | 92 dB |
| 6. | Dominion Centre Church, Ile-Ife | Hymns/Worship | May 6. 2017 | 9.40am | 92 dB |
| | | Praises | May 6. 2017 | 10.30am | 98 dB |
| **Total No. of Decibels in Each Church Auditoria per Service** | | | | | |
| 1 | Saint Peters' Cathedral, Ake, Abeokuta | | | | 270 dB |
| 2 | Our Saviour's Church, Ikenne | | | | 241.3 dB |
| 3 | Iyeru Okin African Church, Offa | | | | 268.53 dB |
| 4 | Celestial Church of Christ, Akobo, Ibadan | | | | 218 dB |
| 5 | Redeem Christian Church of God, Mega Parish, Ilesa. | | | | 177 dB |
| 6 | Dominion Centre Church, Ile-Ife | | | | 190 dB |
| **Minimum *L*Aeq,T in All the Selected Church Auditoria** | | | | | **177 dB** |
| **Maximum *L*Aeq,T in all the Selected Church Auditoria** | | | | | **270 dB** |
| **Cumulative Average *L*Aeq in all the Selected Church Auditoria** | | | | | **227.47 dB** |

### 4.3.1 Analysis of Variables in the Selected Church Auditoria: Day Two

Qualitative analyses of musical instruments sound as measured in all the selected church auditoria Day Two as expressed in the table below:

Table 18: Results of Day Two measurement of Musical Instruments Acoustics

| S/N | Church Auditorium | Measured Variables | Measurement Day and Date | Measurement Time | Measurement Results in Decibels |
|---|---|---|---|---|---|
| 1. | Saint Peters' Cathedral, Ake, Abeokuta | Hymns | April 9, 2017 | 10.25am | 62 dB |
| | | Worship | April 9, 2017 | 11.00am | 92 dB |
| | | Praises | April 9, 2017 | 11.30am | 103.8 dB |
| 2. | Our Saviour's Church, Ikenne | Hymns | April 16, 2017 | 9.43am | 60 dB |
| | | Worship | April 16, 2017 | 10.15am | 81 dB |
| | | Praises | April 16, 2017 | 11.55am | 95 dB |
| 3. | Iyeru Okin African Church, Offa | Hymns | April 7, 2019 | 10.13am | 77 dB |
| | | Worship | April 7, 2019 | 10.40am | 92 dB |
| | | Praises | April 7, 2019 | 11.15am | 97 dB |
| 4. | Celestial Church of Christ, Akobo, Ibadan | Hymns/Worship | June 2, 2019 | 7.38am | 103.07 dB |
| | | Praises | June 2, 2019 | 9.45am | 115.30 dB |
| 5. | Redeem Christian Church of God, Mega | Hymns/Worship | May 12, 2019 | 8.10am | 63 dB |

| | | | | | |
|---|---|---|---|---|---|
| | Parish, Ilesa. | Praises | May 11, 2019 | 9.25am | 65 dB |
| 6. | Dominion Centre Church, Ile-ife | Hymns/Worship | May 26. 2019 | 9.44am | 90 dB |
| | | Praises | May 26. 2019 | 10.32am | 95 dB |
| **Total No. of Decibels in Each Church Auditoria per Service** | | | | | |
| 1 | Saint Peters' Cathedral, Ake, Abeokuta | | | | 257.08 dB |
| 2 | Our Saviour's Church, Ikenne | | | | 236 dB |
| 3 | Iyeru Okin African Church, Offa | | | | 266 dB |
| 4 | Celestial Church of Christ, Akobo, Ibadan | | | | 219 dB |
| 5 | Redeem Christian Church of God, Mega Parish, Ilesa. | | | | 128 dB |
| 6 | Dominion Centre Church, Ile-Ife | | | | 185 dB |
| **Minimum *L*Aeq,T in All the Selected Church Auditoria** | | | | | 128 dB |
| **Maximum *L*Aeq,T in all the Selected Church Auditoria** | | | | | 266 dB |
| **Cumulative Average *L*Aeq in all the Selected Church Auditoria** | | | | | 215.18 dB |

### 4.3.2 Analysis of Variables in the Selected Church Auditoria: Day Three

Qualitative analyses of musical instruments sound as measured in all the selected church auditoria Day Two are expressed in table 19:

Table 19: Results of Day Three measurement of Musical Instruments Acoustics

| S/N | Church Auditorium | Measured Variables | Measurement Day and Date | Measurement Time | Measurement Results in Decibels |
|---|---|---|---|---|---|
| 1. | Saint Peters' Cathedral, Ake, Abeokuta | Hymns | June 4, 2017 | 10.20am | 64 dB |
| | | Worship | June 4, 2017 | 11.10am | 97 dB |
| | | Praises | June 4, 2017 | 11.15am | 116 dB |
| 2. | Our Saviour's Church, Ikenne | Hymns | May 5 2017 | 9.45am | 62 dB |
| | | Worship | May 5 2017 | 10.10am | 85 dB |
| | | Praises | May 5 2017 | 11.50am | 99.4 dB |
| 3. | Iyeru Okin African Church, Offa | Hymns | April 15, 2019 | 10.08am | 86 dB |
| | | Worship | April 15, 2019 | 10.45am | 98 dB |
| | | Praises | April 15, 2019 | 11.21am | 102 dB |
| 4. | Celestial Church of Christ, Akobo, Ibadan | Hymns/Worship | July 9, 2017 | 7.37am | 101.01 dB |
| | | Praises | July 9, 2017 | 9.30am | 113.29 dB |
| 5. | Redeem Christian | Hymns/Worship | May 19, 2019 | 8.11am | 68 dB |

| | | | | | |
|---|---|---|---|---|---|
| | Church of God, Mega Parish, Ilesa | Praises | May 19, 2019 | 9.42am | 84 dB |
| 6. | Dominion Centre Church, Ile-Ife | Hymns/Worship | May 23. 2019 | 9.46am | 99 dB |
| | | Praises | May 23. 2019 | 10.45am | 101 dB |
| **Total No. of Decibels in Each Church Auditoria per Service** | | | | | |
| **1** | Saint Peters' Cathedral, Ake, Abeokuta | | | | 227.08 dB |
| 2 | Our Saviour's Church, Ikenne | | | | 246.4 dB |
| 3 | Iyeru Okin African Church, Offa | | | | 286 dB |
| 4 | Celestial Church of Christ, Akobo, Ibadan | | | | 214.39 dB |
| 5 | Redeem Christian Church of God, Mega Parish, Ilesa. | | | | 152 dB |
| 6 | Dominion Centre Church, Ile-Ife | | | | 200 dB |
| **Minimum *L*Aeq,T in All the Selected Church Auditoria** | | | | | **152 dB** |
| **Maximum *L*Aeq,T in all the Selected Church Auditoria** | | | | | **286 dB** |
| **Cumulative Average *L*Aeq in all the Selected Church Auditoria** | | | | | **221 dB** |

### 4.3.3 Cumulative Volume Level and loudness of Musical Instruments Acoustics

Table 20: Cumulative results of measurement of musical instruments acoustics (Day One)

| Day 1 | Decibel | Level of volume and Loudness |
|---|---|---|
| Hymn | 79.1 dB | None Perceptible |
| Worship | 92.39 dB | Clearly Noticeable |
| Praises | 102.27 dB | Much Louder |

Table 21: Cumulative results of measurement of musical instruments acoustics (Day Two)

| Day 2 | Decibel | Level of volume and Loudness |
|---|---|---|
| Hymn | 75.85 dB | None Perceptible |
| Worship | 86.84 dB | Clearly Noticeable |
| Praises | 95.18 dB | Much Louder |

Table 22: Cumulative results of measurement of musical instruments acoustics (Day Three)

| Day 3 | Decibel | Level of volume and Loudness |
|---|---|---|
| Hymn | 80.01 dB | None Perceptible |
| Worship | 91.01 dB | Clearly Noticeable |
| Praises | 102-5 dB | Much Louder |

## 4.4 Analysis of Musical Instruments Acoustics in selected Auditoria

Analysis of musical instruments acoustics in each of the selected church auditoria are as stated below:

### 4.4 (a) Saint Peter's Cathedral Church Ake, Abeokuta

Saint Peter'sCathedral church is an Orthodox Church of the Christian Missionary Society (CMS) located in Abeokuta, Ogun State, Nigeria. The musical acoustics as observed and measured in this church auditorium are categorised into three main divisions; the hymnal singing, worship singing and praise singing which were done at three different days for three

different worship services. However, in this observations and measurements, five different variables such as sound reverberation, sound clarity, pitch, sound frequency and sound volume decibel were considered as connected with musical productions, transmission, reception and perception by the worshippers within the acoustics nature of the auditorium. Table 23 is the result of the musical acoustics measurement as obtained at Saint Peter's Cathedral church, Ake, Abeokuta.

Table 23: Musical Acoustics measurement of Saint Peter's Cathedral church, Ake, Abeokuta **Musical Acoustics results of the Saint Peter's Cathedral church, Ake**

| Variable Measured | Hymns | Worships | Praises |
|---|---|---|---|
| Measurement Day 1 | February 5,2017 | | |
| Time of Measurement | 10.20am | 11.10am | 11.20am |
| Measurement Results | 65dB | 95dB | 110.8dB |
| Measurement Day 2 | April 9, 2017 | | |
| Time of Measurement | 10.25am | 11.00am | 11.30am |
| Measurement Results | 62dB | 92dB | 103dB |
| Measurement Day 3 | June 4, 2017 | | |
| Time of Measurement | 10.20am | 11.10am | 11.15 |
| Measurement Results | 64dB | 97dB | 116dB |
| **Total No. of decibels** | 191dB | 284dB | 329.8dB |
| **Average Decibels** | 63.67dB | 94.67dB | 109.9dB |
| **Cumulative Average** | **Minimum *L*Aeq,T** | | **Maximum *L*Aeq,T** |
| | **63.67dB** | | **109.9dB** |

### 4.4 (b) Analysis of Results for the Cathedral Church, Ake, Abeokuta

The results of musical acoustics as found at the Saint Peter's Cathedral church, Ake, Abeokuta was categorized into three different sections of Hymn, worship and praise singing which are accompanied by musical instruments. Among the musical instruments used during each worship service are the Pipe Organ which is used specifically to accompany hymns, others are the rhythm guitar, bass guitar, 2 trumpets, 3 saxophones, a set of trap set drum, Conga drums, maracas, gong, wood block and tambourine. Musical acoustics measurement was conducted at three different times and dates. The first measurement was conducted on February

5, 2017 which was the first Sunday of the month and thanksgiving Sunday. The hymn number 243 from *'Iwé Orin Mímọ'* (IOM) was used for the service only with pipe organ accompaniment for the choir and the congregation. The sound volume level (SVL) for the hymn was measured at 10.20am with 65Db of sound volume, worship songs accompanied by electronic keyboard and other musical instruments as seen table 3 was measured at 11.10am with 95Db result and praises accompanied with electronic keyboard and other musical instruments as seen table 3 at 11.20am with 110.8dB result.

The second measurement was conducted on April 9, 2017 with emphasis on hymn, worship and praise singing. The hymn number 132 from 'IwéOrin Mímọ' (IOM) was used with only the pipe organ accompaniment for the choir and the congregation. The pressure volumelevel for the hymn was measured at 10.25am with 62dB of sound volume, worship songsaccompanied by electronic keyboard and other musical instruments as seen table 3 was measured at 11.00am with 92dB result and praises accompanied with electronic keyboard and other musical instruments as seen table 3 at 11.30am with 103dB result while the third measurement was conducted on June 4, 2017. The hymn number 320 from '*ÌwéOrin Mímọ'* (IOM) was used for the service only with the pipe organ accompaniment for the choir and the congregation. The "sound pressure level" (SPL) for the hymn was measured at 10.20am with 64dB of sound volume, worship songs accompanied by electronic keyboard and other musical instruments as seen table 3 was measured at 11.10am with 97dB result and praises accompanied with electronic keyboard and other musical instruments as seen table 23 at 11.15am with 116dB result. Table 24 provides the musical instruments' analysis and results of the number of worshippers per service and per measurement. The table equally provides information on the acoustic conditions of the auditorium as observed during the period of study.

Table 24: Identified musical instruments at the Saint Peter's Cathedral Church, Ake,

| Activity | Musical Instruments Accompanying | No. of participants | |
|---|---|---|---|
| | | Choir Average | Congregation Average |
| Hymn | Pipe Organ | 62 | 250 |
| Worship | 1 Electronic Keyboard | 77 | 250 |
| | 1 rhythm Guitar | | |
| | 1 bass Guitar | | |
| | 2 trumpets | | |
| | 3 saxophones | | |
| | 1 trap Set Drums | | |
| | 1 conga Drum | | |
| | 3 maracas | | |
| | 1 small Gong | | |
| | I wood Block | | |
| | Tambourines (with congregational | | |
| | participation) | | |
| | | | |
| Praises | 1 Electronic Keyboard | 78 | 250 |
| | 1 rhythm Guitar | | |
| | 1 bass Guitar | | |
| | 2 trumpets | | |
| | 3 saxophones | | |
| | 1 trap Set Drums | | |
| | 1conga Drum | | |
| | 3maracas | | |
| | 1small Gong | | |
| | 1wood Block | | |

**4.4 (c) Analysis of Variables at the Saint Peter's Cathedral Church, Ake, Abeokuta**

There are five variables on which the results of musical instruments acoustics are analysed based on qualitative and quantitative observations in the selected church auditoria, these variables include:

**(i)Reverberation Time**

The sound source, as observed at the Cathedral Church of Peters, Ake is placed at the front arena of the auditorium where the Clergy or the pastor and the choir can project both the speech and musical sounds. The Cathedral church of Saint Peters, Ake is gloomy structured and very depressing in musical instruments acoustics because of the excessive generation of sound echo within the auditorium, the auditorium is not ideal for praise songs but notadaptable Western musical repertoire and Gregorian Chants, but does not work for contemporary Gospel music like

the Pentecostal churches. The sound source, for a speaking voice or a singing voice or a musical instrument as played acoustically or amplified is relatively directed and oriented towards the congregation. The lower frequency of sound production was measured to be below 500Hz which is omnidirectional and with higher frequencies to be above 2000Hz when directionally perceived by the congregation. This then provides the understanding on the reason why lower frequencies can sometimes create some levels of problems if not controlled by putting certain acoustics parameters and treatments in place to curtail musical instruments' acoustic's refraction. Musical instruments acoustics are disseminated into the church auditorium through the sound source which often bounce back as a result of several sound reflectors within the church auditorium and this action alone is considered as an obstacle for a higher frequency of 2000Hz. In this situation, musical instruments with high frequency as observed in thisauditorium reflects that there is a bounce of sound from the stone column of pillars and the church pews which are equally sound reflectors but the lower frequency of the musical instruments go around the obstacle to create diffractions.

On the church acoustics especially, as connected to its reverberation time (RT), Cathedral Church of Saint Peter's, Ake is not acoustically sound proofed in any ramification. Observably, most of the musical instruments acoustics reflecting against the central pillars and the walls creates features of reverberation which makes the musical instruments acoustics to sound bigger than the live sound within the auditorium. Reverberation time (RT) at its best supposed to have a good proportional ratio of direct and indirect sounds that could be obtained with a mixture of regular and irregular types and apparent physical textures that embedded in gothic structured church auditoria with such elements such as pews, benches and lecterns offer a variety of sound reflections and absorptions. It was observed that the numeric strength of about two hundred and fifty (250) worshippers on the average for the Cathedral Church of Saint Peters' Ake, Abeokuta has helped to reduce sound reverberation which may have seemed difficult to control when the church is empty. The "best reverb time for a space in which music is played depends on the size of the space and the type of music". The reverberation time (RT) for the Cathedral church of

Saint Pater could be seen as fairly alright because of the type of music such as hymnal, Gregorian chants and more of classical music played within the auditorium, also the total figure of worshippers is"related by ratio" to the size of the auditorium during congregational hymnal singing but not ideal for praise singing because the fast tempo rhythm that usually accompany praises.

**(ii) Sound Clarity**

Cathedral church of Saint Peters, Ake has an in-house speaker system with a collection of sixteen (16) speakers which are concealed in the auditorium ceiling, these speakers are built in four-in-one (4 in 1) together with six (6) Front of House Speakers (FOH) which are suspended to the right and left sides of the church auditorium with four (4) sub-wolvers of two (2) cones in each casing, this equals to eight (8) speakers in all. The cable and wiring connections of the right and left speakers' channels are laid in a parallel direction with the four (4) ceiling speakers in the front left zone and the right zone as well. The quality of the tonal sensibility of musical instruments acoustics emanating from the auditorium height speakers are importantly distinct from the quality of the tonal sensibility of the right and left front of house Speakers' (FOH)channels. Figure 91is the setup of the mixer console room at the Saint Peters' Cathedral Church Ake, Abeokuta.



Figure 91: The console room setup at the Saint Peters' Cathedral Church Ake, Abeokuta.
*(Picture taken by the researcher on June 4, 2017)*

It was observed that the ceiling speakers are basically sound twitters with more treble that the middle and low frequencies which is really not ideal for good for musical instruments

acoustics because the large number of sound origins which provide lack clarity and brightness of the sound.It is believed that “clarity”, “intelligibility” (ability to clearly understand each word), “punch” (bass response), “edge” (high frequency response), and “directionality” (direction you hear the sound coming from) could be wellimprovedthrough the use of the “front of house” (FOH) of the right and left channels alone rather than the use of the ceiling speakers for Church services and “concert type programs”. Figure 92 is a sample of the ceiling speakers observed at the Cathedral church of Saint Peter, Ake.



Figure 92: Sample of the ceiling speakers found at the Cathedral Church, Ake, Abeokuta *(Picture taken by the researcher on June 4, 2017)*

There are two (2) floor speakers that served as “monitor speakers”, these weredirectly facing the Altar. Apart from the malfunctioning condition of these floor speakers, they do not provide enough coverage feedbacks for the choir and the ministers. The speakers are also positioned too far from the Altar which created quiet spot at the center of the Alter. However, the sub-wolvers speakers in the auditorium provided sufficient low frequency sound to soften the high frequency from the ceiling speakers.

**(iii) Sound Frequencies**

Sound frequency at the Cathedral church of Saint Peters, Ake, Abeokuta faces some little challenges from the auditorium as the sound producing environment to the worshippers, microphones positioning and the mixer console settings. It was discovered that the acoustics of the church auditorium was not considered during the building of the church. The hard surfaces, tilled floor, glass window, ceramic pulpit and the metal roof are all reflective materials and aid to

sound reflections at high frequency, moreover, with the modern worship band style and the useof trap set drums, electric guitars, and floor monitors contributed to this highly reflective Cathedral auditorium.These factors make thecontrol of frequency difficult and since the auditorium is not acoustically treated, it is not ideal for the contemporised praise band in the Cathedral style of worship. The sound frequency as observed and measured reflects the level of musical instruments sound emanating from the auditorium with average volume of 109.9dB.

**(iv) Volume and Loudness**

Volume and loudness of musical acoustics observed at the Saint Peter's Cathedral church, Ake is very high with cumulative average of 109.9dBof sound volume. The musical instruments' acoustics' measurement observed in the auditorium therefore put the hymnal singing volume at a cumulative of 63dB, worship signing at 94.67dB and praises at 109.9dB which are out rightly above the recommended decibel of loudness that the human ear can perceive. Resulting from the responses of the applied questionnaire, it was established that loudness and volume perception among worshippers are either objective, subjective and relative. The worshippers agreed that the volume was high but it has no effect on them because they are used to such volume of loudness at every worship service. Table 25, 26, and 27 are the summary of volume and loudness of sound as noticeably present at the Saint Peters Cathedral church of, Ake, Abeokuta.

**(v) Musical Ensemble**

Musical ensemble at the Saint Peters Cathedral church, Ake, Abeokuta is relatively large comprising all male as members with twenty-three (23) soprano singers, seventeen (17) alto singers, ten (10) tenor singers and ten (10) bass singers, for the hymnal singing, same for worship and praise singing with additional instrumentalists as provided below to put the total number of participant at seventy-eight (78):

1Electronic Keyboard

1 Rhythm Guitar

1 Bass Guitar

2 Trumpets

3 Saxophones

1 Trap Set Drums

1 Talking Drum

1 Conga Drum

3 Maracas

1 Small Gong

I wood Block

The musical ensemble observed at the Cathedral church of Saint Peters, Ake auditorium lacks clarity of sound. All the musical instruments are played at the same relative high volume level which made it difficult to hear the lead singer and the backups voice during the praise session. The depth effect given to the talking drum and the bass guitar made the sound production too heavy because the two low frequency musical instruments covered the high and the middle frequencies of the entire sound production. The electric keyboard and the lead guitar also dominated the entirehigh frequencyof the entire sound production which resulted intocacophony of sound production. The overall assessment of the musical instruments ensemble in the church lacked good musical instruments' quality with no sound balancing form the sound engineer with no formal knowledge of sound engineering and mixing but a sound equipment technician and a repairer of public address system (PAS). Tables 25, 26, and 27 is a reflection of musical instruments' acoustics as measured at the Cathedral church of Saint Peters Ake, Abeokuta.

Table 25: Musical Acoustics measurement at Saint Peter's Cathedral church Ake, Abeokuta.

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 65dB | Just Perceptible |
| Worship | 95dB | Clearly Noticeable |
| Praises | 110.8dB | Much Louder |

Table 26: Table 22: Musical Acoustics measurement at Our Saviours' church, Ikenne

| **Day 2** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 62 dB | Just Perceptible |
| Worship | 92Db | Clearly Noticeable |

| | | |
|---|---|---|
| Praises | 97 dB | Much Louder |

Table 27: Level of volume and loudness on the third day measurement

| Day 3 | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 110.8 dB | Just Perceptible |
| Worship | 103 dB | Clearly Noticeable |
| Praises | 116 dB | Much Louder |

With this analysis as expressed in tables 25, 26 and 27, it is submitted that musical instruments' acoustics at the Saint Peter's Cathedral Church Ake, Abeokuta is louder than the church auditorium volume because in all the measurement,the volume of sound emanating from the auditorium is much higher than the prescribed 60Db by the World Health Organisation (WHO) for normal human ear to perceive.

### 4.4 (b) Our Saviour's Church, Ikenne

Our Saviour's church, is an Orthodox Church of the Christian Missionary Society (CMS) located in Ikenne, Ogun State, Nigeria. The musical instruments' acoustics observed and measured in this church auditorium are categorised into three main sections; the hymnal singing, worship singing and praise singing which were done at three different days for three different worship services. However, in these observations and measurements, five different variables; sound reverberation, sound clarity, pitch, sound frequency and sound volume were considered as connected with musical productions, transmission, reception and perception by the worshippers within the acoustics nature of the church auditorium.

Table 28: Musical Acoustics measurement of Our Saviour's Church, Ikenne **Musical Acoustics results of Our Saviour's Church, Ikenne**

| Variable Measured | Hymns | Worships | Praises |
|---|---|---|---|
| Measurement Day 1 | March 5, 2017 | | |
| Time of Measurement | 9.40am | 10.10am | 10.50am |
| Measurement Results | 61dB | 85.3dB | 98 dB |
| Measurement Day 2 | April 16, 2017 | | |
| Time of Measurement | 9.43am | 10.15am | 11.55am |
| Measurement Results | 60dB | 81dB | 95dB |
| Measurement Day 3 | May 5, 2017 | | |
| Time of Measurement | 9. 45am | 10.10am | 11.50am |

| | | | |
|---|---|---|---|
| Measurement Results | 62dB | 85dB | 99.4dB |
| Total No. of decibels | 183dB | 251dB | 292dB |
| Decibels Average | 61dB | 83.66dB | 97.33dB |
| **Cumulative Average** | **Minimum** *L*Aeq,T | | **Maximum** *L*Aeq,T |
| | 54dB | | 82.33dB |

**4.4 (c)Analyses of Results**

The results of musical acoustics at Our Saviour's church, Ikenne were categorized into three different sections of Hymn, worship and praise singing. Among several musical instruments used during each worship service are the Pipe Organ which is used specifically to accompany hymnal songs, others are the rhythm guitar, bass guitar, a set of trap set drum, 1 set of conga drums, 1Talking Drum, maracas, gong used in the accompaniment of the worship and praise songs. Musical instruments' acoustics measurementswere conducted at three different times and dates. The first measurement was conducted on March 5, 2017 which was the first Sunday of the month and thanksgiving Sunday. The hymn number 303 (*Igbagbo)* from '*IwéOrin Mimọ'* (IOM) was used for the service only with the pipe organ accompaniment for the choir and the congregation. The volume of the musical instruments' acoustics for the hymn was measured at 9.40am with the result arrived at 58dB of sound volume, worship songs was accompanied by electronic keyboard and other musical instruments were measured at 11.10am with 60dB result and praises accompanied with electronic keyboard and other musical instruments as seen table 28 at 10.50am with 86dB result.

The second measurement was conducted on April 16, 2017 with emphasis on hymn, worship and praise singing. The hymn number 57 from *'IwéOrin Mimọ'* (IOM) was used with only the pipe organ accompaniment for the choir and the congregation. The "sound pressure level" (SPL) for the hymn was measured at 9.43am with 549dB of sound volume, worship songs accompanied by electronic keyboard and other musical instruments as seen table 29 was measured at 10.15am with 67dB result and praises accompanied with electronic keyboard and other musical instruments as seen table 29 at 11.55am with 82dB result while the third measurement was conducted on May 5, 2017. The hymn number 256 from *'IwéOrin Mimọ'* (IOM) was used for the service only with the pipe organ accompaniment for the choir and the

congregation. The "sound pressure level" (SPL) for the hymn was measured at 9.45am with 55dB of sound volume,worship songs accompanied by electronic keyboard and other musical instruments as seen table 29 was measured at 10.10am with 67dB result and praises accompanied with electronic keyboard and other musical instruments as seen table 29 at 11.50am with 85dB result. Table 29 is the analysis results of the available musical instruments used and the number of worshippers per measurement per worship service at Our Saviours' Church, Ikenne.

Table 29: Musical instrument used as observed at Our Saviour's Church, Ikenne.

| Activity | Musical Instruments Accompanying | No. of participants | |
|---|---|---|---|
| | | Choir Average | Congregation Average |
| Hymn | Pipe Organ | 27 | 105 |
| Worship | 1 Electronic Keyboard<br>1 Rhythm Guitar<br>1 Bass Guitar<br>1 Trap Set Drums<br>1 Conga Drum<br>1Maracas<br>1 Small Gong<br>Tambourines (with congregational participation) | 27 | 105 |
| Praises | 1 Electronic Keyboard<br>1 Rhythm Guitar<br>1 Bass Guitar<br>1 Trap Set Drums<br>1 Talking Drum<br>1 Conga Drum<br>1 Maracas<br>1 Small Gong<br>Tambourines (with congregational participation) | 27 | 105 |

### 4.4 (d) Analysis of Variables at Our Saviour's Church Ikenne

There are five variables on which the results of musical instruments' acoustics were analysed based onqualitative and qualitative observations, these variables include;

**(a) Reverberation**

Church acoustics and its reverberation time (RT60 or T60) with connection to Our Saviour's church, Ikenne, reflected a non-sound proofed auditorium.There were several noise interferences in terms of acoustics parameters which make the musical instruments' acoustics production to scatter around the auditorium. Reverberation at Our Saviours' Church Ikenne sound productions energy always reflect against the walls, the same situation as observed at the

Cathedral Church of Saint Peters Ake, Abeokuta. Reverberation of musical instruments' acoustics at Our Saviours' Church auditorium make musical sound seems deceptive because the emanated musical sound is bigger than what the auditorium volume could accommodate and this creates an experience of reverbs through the feedback speakers. The church auditorium structure and other sound filtering elements such as pews, benches, lecterns and statues that are used in the beautification of the auditorium offer a variety of shapes (regular and irregular) as well as surfaces, which does not favour an ideal reverberation in terms of sound production. The numeric strength of one hundred and thirty-two (132) (ministers, choir and the congregation) on the average for the church, this has not assistedto reduce the auditorium "reverberation time" (RT). An ideal 'reverberation time' for a worship auditorium where musical instruments are played rests largely on the auditorium volume. The reverberation time (RT) for Our Saviours' Church Ikenne is considered to be fairly better because of the type of music such as hymnal, Gregorian chants and more of classical music played within the auditorium.

**(b) Sound Clarity**

Our Saviour's church, Ikenne has a house speaker system of eight (8) Front of House speakers (FOH) placed atboth sides of the church auditorium, these are complimented with four (4) sub-wolvers of one (1) cone in each speaker casing to make a pillar of speakers. The right Front of House Speaker (FOH) is wired in the same distance to the left Front of House Speakers (FOH) to powerthe two (2) speakers'channels simultaneously with each of the channel associated to a stereo side of the power amplifier to provide an amplitude of about "185W RMS" per channel. This method of sound amplification connection is to improve the splitting of the sound direction and production on the four (4) monitor speakers placed at the Altar, two (2) speakers for the choir and the other two (2) speakers for the priest to serve as feedback. These speakers' setup has not produced any clarity of musical instruments' acoustics. The auditorium lacks acoustic treatments and this allows musical sound to bounce round the auditorium. The presence of ceramic pulpit for the preachers and lay readers did not help the sound clarity in any sense.

**(c) Sound Frequency**

Sound frequency at Our Saviour's church, Ikenne suffers a serious problem of professionalism in the setting and handling of the installed sound system. Apart from the challenges of sound reflections from the auditorium, the microphones positioning and the mixer console settings were a secondary issue. It was observed that the acoustics of the church auditorium was not considered during the building of the church, this trait which, of course is common to all the old Anglican churches in Nigeria. The hard surfaces, tilled floor, glass window, ceramic pulpit and the metal roof are all reflective materials that allow musical sound to bounce round the auditorium and aided sound refractions at high frequency within the auditorium. Moreover, with the modern worship band style with the use trap set drums, electric guitars, saxophones, trumpets and other musical instruments playing in an ensemble has resulted into highly reflective musical instruments' sound. This situation made the control of musical sound frequency difficult because the auditorium is not acoustically treated, it not suitable for praise band style of worship because of the several musical instruments involved. The sound frequency as observed and measured at Our Saviours' Church Ikenne reflects the level of musical instruments sound emanating from the auditorium with average volume of 97.33dB.

**(d) Volume and Loudness**

Volume and loudness of musical acoustics as observed at Our Saviour's Church, Ikenne is equally on the high side with cumulative average of 97.33dB sound volume. The musical instruments' acoustic measurement in the auditorium put the hymnal singing volume at a cumulative of 61dB, worship signing at 83dB and praises at 97.33dB which areabove the recommended decibel of sound perception that the human ear can accommodate. Resulting from the responses of the questionnaire, it was established that loudness and volume perception among worshippers are objective, subjective and relative. The worshippers agreed that the volume was high but it has no effect on them because they are used to such volume of loudness at every worship service. There was a case of a particular worshipper who insisted that musical sound has to be loud enough for her to dance and praise God with all her spirit, body and soul.

**(e) Musical Ensemble**

The musical ensemble at Our Saviour's Church, Ikenne is relatively small, it comprised of seventeen (17) males and ten (10) females as members with ten (10) soprano singers, seven (7) alto singers, four (4) tenor singers and four (4) bass singers, one (1) choir master and one (1) organist for the hymnal singing, same for worship and praise singing with additional instrumentalists as given below to put the total number of choir participants at twenty-seven (27). The list of the praise band members' summary is provided below:

1 Electronic Keyboard

1 Rhythm Guitar

1 Bass Guitar

1 Trap Set Drums

1 Talking Drum

1 Conga Drum

1 Maraca and 1 Small Gong

All these musical instruments played at the same relative high volume level even, with the almost empty auditoriumwhich has made the control of sound volume very difficult. Virtually, the depth effect given to the pipe organ during the hymnal singing was too heavy and the vibration of the pedal tones was so glaring which caused ripples in the human. Also during the praise singing, the talking drum and the bass guitar were put at the same low frequency volume which equally produced a heavy low frequency that made sound production obscured. The bass drum of the trap set was also set at a very deep low frequency; this created a conflict with the bass guitar sound production. The microphones positioning at the choir stall were too close the singers and this has resulted into the babbling of voice production as a result of the vibration from the singers' lips, this puts the overall assessment of the musical instruments ensemble at Our Saviours' Church to lack good musical sound quality with no balancing from the sound engineer.

Table 30: Cumulative results of measurement of musical instruments acoustics (Day One)

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|

| | | |
|---|---|---|
| Hymn | 61dB | Just Perceptible |
| Worship | 85 dB | Clearly Noticeable |
| Praises | 98 dB | Much Louder |

Table 31: Cumulative results of measurement of musical instruments acoustics (Day Two)

| **Day 2** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 60 dB | Just Perceptible |
| Worship | 81 dB | Clearly Noticeable |
| Praises | 95 dB | Much Louder |

Table 32: Cumulative results of measurement of musical instruments acoustics (Day Three)

| **Day 3** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 62 dB | Just Perceptible |
| Worship | 85 dB | Clearly Noticeable |
| Praises | 97.33 dB | Much Louder |

With this analysis as expressed in tables 30, 31 and 32, it could be submitted that the musical acoustics at Our Saviour's Church, Ikenne is loud because in all the measurement, the volume sound emanating from the auditorium is much higher than the prescribed 60dB by the World Health Organisation (WHO) for normal human perception

### 4.4 (e) Celestial Church of Christ, Akobo, Ibadan

Celestial Church of Christ (CCC), Ibadan is a Pentecostal church situated on Akobo road I,Akobo, with different doctrinal values from the first two churches discussed earlier. The observable musical instruments' acoustics measured in this church auditorium are categorised into two main divisions; the Hymnal/worship and praise singing,measurements of musical instruments' acoustics were done at three different days for the three different worship services. However, in this observations and measurements, five different variables such as sound reverberation, sound clarity, pitch, sound frequency and sound volume decibel were considered as connected with musical productions, transmission, reception and perception by the worshippers within the acoustics nature of the auditorium.

Table 33: Musical Acoustics measurement of Celestial Church of Christ, Akobo, Ibadan

| **Musical Acoustics results of Celestial Church of Christ, Ibadan** | | |
|---|---|---|
| Variable Measured | Hymns/Worships | Praises |
| Measurement Day 1 | April 2, 2017 | |

| | | |
|---|---|---|
| Time of Measurement | 7.35-8.05am | 9.40am |
| Measurement Results | 100.07Db | 118.29Db |
| Measurement Day 2 | June 11, 2017 | |
| Time of Measurement | 7.37 -8.10am | 9.35am |
| Measurement Results | 100.23Db | 114.20Db |
| Measurement Day 3 | July 2,2017 | |
| Time of Measurement | 7.31-8.05am | 9.30am |
| Measurement Results | 100.10Db | 113.29Db |
| Total No. of decibels | 300.04Db | 345.78Db |
| Average Decibels | 100.13Db | 115.26Db |
| **Cumulative Average** | **Minimum** *L*Aeq,T | **Maximum** *L*Aeq,T |
| | 100.13Db | 115.26Db |

The results of musical acoustics as found at Celestial church of Christ, Akobo, Ibadan were categorized into two different sections of Hymn/worship and praise singing which are accompanied by different musical instruments. Among the musical instruments used during each worship service is the electronic keyboard, the rhythm guitar, bass guitar, a trap set drum, one set of conga drums, twoTalkingDrums, one Omele drum, maracas, gong and many tambourines use by the congregants. Musical instruments' acoustics' measurement was conducted at three different days and dates. The first measurement was conducted on April 2, 2017 which was the first Sunday of the month and a thanksgiving Sunday. The "sound pressure level" (SPL) for the hymn/worship measurement was taken around 7.30am with the result of 100.07dB of sound volume, hymn/worship songs were accompanied by electronic keyboard and other musical instruments as seen table 34 and praises accompanied with electronic keyboard and other musical instruments with decibels point at 118.29dB.

The second measurement was conducted on June 11, 2017 with emphasis on hymn/ worship and praise singing. The "sound pressure level" (SPL) for the hymn/worship was taken at about 7.37am with 100.10dB of sound volume accompanied by electronic keyboard and other musical instruments as seen table 34. Praises were accompanied by electronic keyboard and other musical instruments as seen table 34 was measured at 9.35am with 114.20dB result while the third measurement was conducted on July 2, 2017 with 100.13dB result for

hymn/worship and 113.26dB result for praises. Table 34 provides the available musical instrument acoustics and the number of worshippers per measurement during worship services.

Table 34: Musical instrument used as observed at Celestial Church of Christ, Akobo, Ibadan

| **Activity** | **Musical Instruments** | **No. of participants** | |
|---|---|---|---|
| | Accompanying | Choir Average | Congregation Average |
| Hymn/ Worship | 2 Electronic Keyboard | 64 | 245 |
| | 2Rhythm Guitar | | |
| | 1Bass Guitar | | |
| | 3Trumpets | | |
| | 4 Saxophones | | |
| | 1 Trap Set Drums | | |
| | 1 Talking Drum | | |
| | 1 Conga Drum | | |
| | 1 Maracas | | |
| | 1 Small Gong | | |
| | I wood Block | | |
| | Tambourines (with congregational participation) | | |
| | | | |
| Praises | 2 Electronic Keyboards | 64 | 245 |
| | 2 Rhythm Guitars | | |
| | 1Bass Guitar | | |
| | 3Trumpets | | |
| | 4 Saxophones | | |
| | | | |
| | 1Trap Set Drums | | |
| | 1 Conga Drum | | |
| | 3 Maracas | | |

| | | | | |
|---|---|---|---|---|
| | 1 Small Gong | | | |
| | I wood Block | | | |
| | Tambourines (with congregational participation) | | | |

**4.4 (f). Analysis of Variables at Celestial Church of Christ, Akobo, Ibadan**

There are five variables on which the results of musical acoustics are analysed based on qualitative and quantitative observations, these variables include:

**(a) Reverberation**

The reverberation time (RT60) at the Celestial Church of Christ, Akobo Ibadan is not ideal because the auditorium is not acoustically treated which makes the sound production to be filter around theauditorium which caused ripples in the congregation's ear. The auditorium is very big with no sound proof materials in the ceiling and around the Alter. The chairs are not cushioned with foam material and are arranged in a row of ten chairs. Reverberation of sound in this auditorium makes musical sound not perfect and this has led to harsh production of musical instruments' sound during the worship services, this coupled with the high degree of volume of musical instruments' sound. The volume was clearly noticeable because of the lack of auditorium acoustics treatment and the average number of worshippers of about two hundred and forty-five (245) (ministers, choir and the congregation) could not absorb the effects of the high wattage of sound in the auditorium. This factor has further helped to increase the auditorium reverberation and has equally made the sound production within the auditorium to be hard and harsh in nature. The volume of the musical instruments' acoustics in the auditorium is on the high side with 118.29dB, 114.20dB and 113.29dB decibels on the three different times for conduct of sound measurements, the average of which for worship and praises are 100.03dB and 115.26dB decibels respectively.

**(b) Sound Clarity**

As at the time of this research, Celestial Church of Christ, Akobo, Ibadan has “front of house speakers” (FOH) whichcomprise of an arrangement of twelve (12) loud speakers with two cones in each speaker case which were hung in two pillars to the left and right of the auditorium with six (6) sub-wolvers of two (2) cones in each case. The left front of house (FOH) speakers are wired in equal distance to the right Front of House (FOH) speakers. Each of the speaker pillars are connected the stereo amplifier providing amplification for both sides with a Hybrid Church Sound System. There are three (3) monitor speakers placed at the Altar and four (4) monitor speakers for the choir for feedback purposes. It was observed that even with these numbers of speakers and volume of amplification of the musical instruments’ acoustics, the clarity of sound was not achieved. The musical instruments’ acoustics and production wererough and meaningless.

**(c) Sound Frequency**

Celestial Church of Christ, Akobo, Ibadanhas a sharp sound frequency response which makes its sound production to be bad. It was discovered that the acoustics of the church auditorium was not considered during the building of the church, a trait which is of course, very common to other selected churches in south-western Nigeria. The hard surfaces, non-rugged floor, glass windows, lectern and the PVC roof are all sound reflectors rather than sound absorbent materials that allow musical sound to bouncearound the auditorium, moreover, with the Hybrid sound system available in the auditorium, the modern worship style for the church with the large number of musical instruments and the amplifying equipment used by the praise band, the sound frequency was put beyond control since the auditorium is not acoustically treated and not well suitable for praise band style of worship. The measured sound frequency reflects the high level volume of musical instruments sound emanating from the church auditorium to be an average of 115.26dB. This is really on the high side and was clearly noticeable.

**(d) Volume and Loudness**

Volume and loudness of musical instruments' acoustics as observed at the Celestial Church of God, Akobo, Ibadan is equally on the high side with a cumulative average of 115.26dB of sound volume. The musical instruments' acoustics' measurement as observed in the auditorium put the average of hymnal/worship singing volume at 100.13dB and praises at 115.26dB, these decibels are far above the recommended decibel of loudness to be perceived by normal human ear. Resulting from the responses of the applied questionnaire, it was established that loudness and volume musical instruments' acoustics among the congregation are objective, subjective and relative. The worshippers agreed that the volume was high but, it has no effect on them because they are used to such volume of loudness at every worship service. One of the worshippers confided in me that Celestial Church of Christ, Akobo, Ibadanmembers are used to high praises which requires high volume of musical sound to provide sufficient inspirations to praise God.

**(e) Musical Ensemble**

The musical ensemble at the Celestial Church of Christ, Akobo, Ibadanis relatively large comprising of twenty-four (24) soprano singers; fourteen (14) females and five (10) males, thirteen (13) alto singers; eight (8) males and five (5) females, and eight (8) tenor singers; all male, one (1) choir master, one (1) voice conductor, one (1) musical instrument conductor, two (2) keyboardists, two (2) rhythm guitarist, one (1) Bass guitarist, three (3) trumpeters, four (4) saxophonists, one (1) trap set drummer, one (1) conga drummer, one (1) Small Gong player and one (1) wood block player for the hymnal/worship and praise singing as given below to put the total number of participant at twenty-seven (64):

2 Electronic Keyboards

1 Rhythm Guitars

1 Bass Guitar

2 Trumpets

4 Saxophones

2 1 Trap Set Drums

3 1 Conga Drum

4 3 Maracas

5 1 Small Gong & I wood Block

The musical ensemble at Celestial Church of Christ, Akobo, Ibadan is relatively large with the voice parts harmony divided into four; Soprano, Alto, Tenor and Bass. This four parts harmony is not a common trend in virtually all the Pentecostal churches in the southwest Nigeria, because most Pentecostal churches. The musical ensemble in this auditorium is balanced with good sound mixing and better auditorium acoustics. Despite the good sound production at Celestial Church of Christ, Akobo, Ibadan. it was observed that the overall measured volume of sound is very high, even when compared with other churches selected for this study. The overall measurement of decibel of musical acoustics is provided in tables 35, 36 and 37 below:

Table 35:Cumulative results of measurement of musical instruments acoustics

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/ Worship | 100.07dB | Clearly Noticeable |
| Praises | 118.29dB | Much Louder |

Table 36: Cumulative results of measurement of musical instruments acoustics

| **Day 2** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/ Worship | 100.23dB | Clearly Noticeable |
| Praises | 114.20dB | Much Louder |

Table 37: Cumulative results of measurement of musical instruments acoustics

| **Day 3** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/ Worship | 100.13dB | Clearly Noticeable |
| Praises | 115.26dB | Much Louder |

With this analysis as expressed in tables 35, 36 and 37, it could be submitted that the musical acoustics at Celestial Church of Christ, Akobo, Ibadanis very loud because in all the volume of sound measurements, sound emanating from the auditorium is much higher than the prescribed 60dB by the World Health Organisation (WHO) for normal human perception.

**4.4 (g)Analysis of Variables at Iyeru Okin African Church, Offa**

There are five variables on which the results of musical instruments acoustics are analysed based on qualitative and quantitative observations in the selected church auditoria, these variables include:

**(a) Reverberation**

The reverberation time (RT60) at the Iyeru Okin African Church, Offa is within the perceptible range of the normal human hearing because the auditorium has several installed sound absorbers to diffuse excessive musical instruments' sound. The auditorium is very big with high roof which allows for free travelling of musical instruments' sound. Reverberation of sound in this auditorium makes musical sound good and soft but with a little degree of high volume which may not be noticeable because of the auditorium acoustics sound absorbers and the high number of worshippers of about One hundred and eighty (180), this number includes the ministers, the choir and the congregation. The volume of musical instruments sound emanating from the auditorium is on the high side with 99.53dB even with all the acoustic treatments therein.

**(b) Sound Clarity**

The arrangements of the amplified speakers at Iyeru Okin African church, Offa have both the Front of House Speaker's (FOH) and Back of House (BOH) speaker's systems which consist of an array of four (4) speakers with two cones in each case at the front and four (4) speakers with one cone in each case at the Back of House (BOH). These were hung against the two pillars at the back side of the auditorium, there are six sub-hovers in all the speaker arrangements. The left house speakers were connected in an equal distance to the right speakers, each of the speaker zones are connected to the stereo line of the amplifying systems. There are two (2) monitor speakers placed at the Altar and two (2) monitor speakers for the choir. There are also several microphones paced at the choir stall in an arrangement of about five (5) microphones in each pew, these are arranged on both sides of the space next to the Altar. At the Alter for the Vicar is the Lapel Microphone pinned to the cassock. There were also series of other wireless microphone used by the lead singer and the backups

**(c) Sound Frequencies**

Iyeru Okin African Church, Offa has a sharp sound frequency response which makes its sound to move around the auditorium just like the other two Gothic structured (Cathedral church, Ake and Our Saviour's Church, Ikenne) worship auditoria. It was observed that the auditorium has certain acoustics parameters such as the pews, the wooden roof and the rug (sound absorbers) used in the auditorium, a trait that is common to orthodox churches in Nigeria. The available musical instruments in the auditorium includean electronic pipe organ, one bass guitar, one rhythm guitar, a pair of conga drums, two talking drums, one wood block and a set of Trap set drums. The sound frequency as measured reveals that the level of musical instruments' sound emanating from the church auditorium to a cumulative average volume of 89.3dB.

**(d) Volume and Loudness**

Volume and loudness of musical instruments' acoustics observed at Iyeru Okin African Church, Offa is measured a higher than what the normal human ear of 60dB could perceive. The musical instruments' acoustics' measurement observed in the auditorium put the average of hymnal/worship singing volume at 72dB and praises at 97dB; this is out rightly above the recommended decibel of loudness perceivable by the normal human ear. Responses from the questionnaire established that loudness and volume perception among worshippers is objective, subjective and relative because many of the congregants claimed not to enjoy a low volume of musical instruments loudness when singing praises to God.On interactions with some of the congregants, it was confided in me thatloud musical instruments' sound transits them into a higher spiritual and psychologically realms of worshipping God.

**(e) Musical Ensemble**

The choir and musical instruments''ensemble at Iyeru Okin African Church, Offa is not really large, it comprises of twenty (20) soprano, fifteen (15) alto, ten (10) tenor and eight(8) bass one choirmaster, one conductor, one organist, one (1) keyboardists, one (1) rhythm

guitarist, one (1) Bass guitarist, one (1) trap set drummer, one (1) conga drummer, one (1) Small Gong player and one (1) wood block

1 Electronic Keyboards

1 Rhythm Guitars

1 Bass Guitar

1 Trap Set Drums

1 Conga Drum

1 Small Gong & I wood Block

Table 38: Level of volume and loudness on the first day measurement

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 72dB | Noticeable |
| Worship | 97dB | Clearly Noticeable |
| Praises | 99.53dB | Much Louder |

Table 39: Level of volume and loudness on the second day measurement

| **Day 2** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 86dB | Noticeable |
| Worship | 98dB | Clearly Noticeable |
| Praises | 102dB | Much Louder |

Table 40: Level of volume and loudness on the third day measurement

| **Day 3** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn | 77dB | Noticeable |
| Worship | 92dB | Clearly Noticeable |
| Praises | 97dB | Much Louder |

### 4.4 (h)Analysis of Variables at Redeem Christian Church of God, Mega Parish, Ilesa

There are five variables on which the results of musical instruments' acoustics are analysed based on qualitative and quantitative observations in the selected church auditoria, these variables include:

**(a) Reverberation**

The reverberation time (RT60) at Redeem Christian Church of God, Mega Parish, Ilesais very high; the auditorium size is perhaps responsible for this high reverberation time (RT).The auditorium is relatively big with several musical instruments sound reflectors, the use of plastic chairs, PVC roofing materials, wings and angular shape of the auditorium, the position of the amplified speakers and the distance between the console and sound producing

environment. The low roofing style of the auditorium also contributes to the existing high reverberation of musical instrument sound. The average volume of musical instruments' sound emanating from the auditorium is on the high side of76dB.

**(b) Sound Clarity**

The arrangements of the amplified speakers at Redeem Christian Church of God, Mega Parish, Ilesahave both the Front of House Speaker (FOH) and Middle of House (MOH) speaker and Back of House (BOH) speaker systems. These consist of an array of six (6) speakers with two cones in each case, these are placed indiscriminately around the church auditoriumwith two sub-hovers to each pillar of upright speakers. The speaker connection is mono, which can only produce musical instrument sound from one source to all the speakers in the auditorium. This process of amplifying sound will produce a faint and non-audible sound which lacks clarity. There are two (2) monitor speakers placed at the Altar and two (2) monitor speakers for the choir. The use of wireless microphones was very prominently in the for sound projection within the church auditorium.

**(c) Sound Frequencies**

Redeem Christian Church of God, Mega Parish, Ilesha auditoriumhas a very dull sound frequency response; this affects the production of musical instruments'acoustics within the auditorium during worship services. The movement of sound in the auditorium always generate excessive noise that resulted into bad and unclear sound productions.Observations shows that the auditorium has no presence ofacoustic parameters that could have absorbedmusical instruments' sound rather, the use of plastic chairs in the auditorium were responsible for sound reflections and generations of sound echoes in the auditorium. There are glass windows and existence of other smaller auditorium within the main one with direct link with the main auditorium which equally responsible for all sorts of musical instruments' sound escapes.The sound frequency observed and measured revealed that the level of musical instruments' acousticsin the auditorium was at an average volume of 76dB.

**(d) Volume and Loudness**

Volume and loudness of musical acoustics as observed at Redeem Christian Church of God, Mega Parish, Ilesa is very loud because the big auditorium is fortified with sufficient amplifying system with no sound absorbing materials, the maximal number of loud speakers in the auditorium has not made the musical instruments acoustics to be well audible. Several complains of inaudibility of sound production has affected the perception of sound in the auditorium. This high volume of musical instruments acoustics has always resulted in severe noise generation through series of sound reverberations and reflections. Another observable trait in the auditorium is the wrong placement of the front of house (FOH) speakers, the speakers are placed at a lower level in the auditorium, and this position could not allow musical sound to travel far into the congregation because of certain concrete blockages such as wells and other reflective parameters such as the auditorium pillars and the tilled floor.

**(e) Musical Ensemble**

The musical instruments' ensemble at the Redeem Christian Church of God, Mega Parish, Ileshais fairly large. The available musical instruments are the electronic keyboard, guitars (rhythm and bass) alto saxophones, trumpets,clarinet, trap set drums, conga and the talking drums used during praise and hymnal songs accompaniments.

Table 41: Level of volume and loudness on the first day measurement

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/worship | 85dB | Noticeable |
| Praise | 92dB | Clearly Noticeable |

Table 42: Level of volume and loudness on the second day measurement

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/worship | 68dB | Noticeable |
| Praise | 84dB | Clearly Noticeable |

Table 43: Level of volume and loudness on the third day measurement

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/worship | 63dB | Noticeable |
| Praise | 65dB | Clearly Noticeable |

**4.9Analysis of Variables at the Dominion Centre Church, Ile-Ife.**

There are five variables on which the results of musical instruments acoustics are analysed based on qualitative and quantitative observations in the selected church auditoria, these variables include:

**(a) Reverberation**

The reverberation time (RT60) at the Dominion Centre Church, Ile-Ife isvery high; the auditorium size is perhaps responsible for this high reverberation time (RT).The auditorium is relatively big with several musical instruments sound reflectors, the use of plastic chairs mixed with sets of cushioned chairs reduce the sound escapes a little. The roofing materials and the glass windows, the position of the amplified speakers and the distance between the console and congregation could not give the sound engineer to monitor live sound, thereby driving the console volume higher than what the auditorium volume could accommodate. The high roofing style of the auditorium allows for sound escapes which prevents the musical instruments sound from bouncing back and front with the auditorium. The average volume of musical instruments' acoustics in the auditorium is95.6dB.

**(b) Sound Clarity**

The arrangement of the amplifying speakers at the Dominion Centre Church, Ile-Ife, has only two Front of House Speakers (FOH) which are arranged into channels 'A' and 'B', Sub-hover speakers were mounted right under the front of house speakers. Each casing of the front of house speakers has two cones while the sub speaker case has one cone each, making the entire number of speakers in the auditorium to consist of an array of four (6) speakers with two monitor speakers on the Altar and two for the choir as monitors. The speaker connection is stereo which produce musical instrument sound from the two channel sources to all the speakers in the auditorium.

**(c) Sound Frequencies**

Dominion Centre Church, Ile-Ife has a very dull sound frequency response; this has not only made perception of sound difficult but, has also made musical instruments sound non-adaptable within the auditorium. The musical instruments'acoustics in the auditorium is full of

excessive noise and makes clarity of sound productions non-achievable.Observations reflects that though, the auditorium has no acoustic parameters that absorb sound, except the few cushioned chairs placed at the front seats of the auditorium to diffuse excessive musical sound generation and distribute same around the entire auditorium. The sound frequency as observed and measured revealed that the level of musical instruments' acousticsin the church auditorium is within an average volume of 95.8dB.

**(d) Volume and Loudness**

Volume and loudness of musical instruments' acoustics as observed at the Dominion Centre Church, Ile-Ife is very loud when placed in comparison with auditorium volume because of the presence of over- fortified and over-sufficient amplifying system, the number of loud speakers in the auditorium can serve a double size of the church auditorium. Several complains of over-audibility of sound production has affected the perception of sound in the auditorium. The volume of musical instruments' acoustics in the auditorium is noticeably loud, this results from theexcessive driving of the main volume control on the mixer console by the sound engineer. This number of speakers and their positioning in the auditorium has over powered the room volume hence; there is noise generation of musical instruments' acoustics with the auditorium during every worship service. The highest decibel of musical instruments' acoustics measured in the auditorium is 101dB

Table 44: Level of volume and loudness on the first day measurement

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/worship | 99dB | Noticeable |
| Praise | 101dB | Clearly Noticeable |

Table 45: Level of volume and loudness on the second day measurement

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/worship | 92dB | Noticeable |
| Praise | 98dB | Clearly Noticeable |

Table 46: Level of volume and loudness on the third day measurement

| **Day 1** | **Decibel** | **Level of volume and Loudness** |
|---|---|---|
| Hymn/worship | 90dB | Noticeable |
| Praise | 95dB | Clearly Noticeable |

**(e) Musical Ensemble**

The choir ensemble at Dominion Centre Church, Ile-ife is fairly minimal. The available musical instruments are as follows:

1 Electronic keyboard (Yamaha PSR 940 Series)

I Trap Set Drum

1 Conga Drum

1 Bass Guitar

1 Rhythm Guitar

1 Trumpet

2 Saxophones

2 Talking Drums

1 Gong

## 4.5 Congregations' Perception of Musical Instruments Acoustics in Church Auditoria

Congregations' perception of musical instruments' acoustics in the selected church auditoria is premised on the provision of certain acoustics' parameters. It was observed that the congregational understandings of the perceptions of musical instruments' acoustics were based on subjective rather than objective judgements, these judgements were arrived at from the observations of the worshippers' ignorance of the dangers of high and heavy volume of musical instruments' sound on human health. This lack of knowledge is responsible for the severalmistaken ideas on "musical instruments'acoustics" in terms of "production, propagation, transmission, reception and perception" particularly, in the purposively selected church auditoria in South Western Nigeria. However, several limiting factors were responsible for this shortcoming in the general musical instruments' acoustics' perception by the worshippers as applicable to the selected church auditoria and as observed from the response to the applied questionnaire. Musical instruments perception is established and categorised into three areas, these include the following:

**(a) Perception of the Original Musical Instruments' Acoustics**

Original sound of musical instruments' acoustics exists first in the slow, meek and flowing low tempo sound, this is peculiar to the nature of hymnal and worship songs,these sounds are mostly used in the solemn section of any worship service in church auditoria. The original musical instruments acoustic sound is only perceived when played at a lower volume with no sound reverberation. The aural perceptions of the original musical instruments acoustics sound depend greatly on the available acoustics parameters available in such church auditorium and equally depend on the knowledge of acoustics of available musical instruments.

In essence, perceptions of musical instruments' acoustics original sound in the selected church auditoria as established through participant observation, is achievable at the one-third (⅓) of the sitting arrangements in the auditorium where there are back of house (BOH) speakers but perceived at the half (½), that is, the middle sitting arena of the auditorium with only the front of house (FOH) speakers, as observed in the purposively selected auditoria in south-western Nigeria.

**(b) Perception of the Harmonics of Musical Instrument's Acoustics**

Harmonics sound of musical instruments is perceived bythe physical properties of musical instruments'acoustics as controlled through the use of 'Gain' button on the mixer console. The manoeuvring of the high, mid and the low buttons also dictate what volume of musical instruments' sound to produce. The reason for this harmonics effect is to create and bring closer to the congregation, other non-available musical instruments sound that could be found in the original sound productions. This is to specifically allow for possible perception of the physical properties of these musical instruments especially,during worship services within the church auditoria.

**(c) Perception of the Residual of Musical Instrument's Acoustics**

The residual sounds are theovertones from the fundamental sounds, the sound are perceived when the original and harmonics fade off at a reverberation time (RT) of seven

seconds (7secs) for musical instruments' acoustics. Residual soundsare mostly heard where there are no monitor speakers available for music instruments' acoustics.

# CHAPTER FIVE

# SUMMARY, FINDINGS, CONCLUSION AND RECOMMENDATIONS

## 5.0 Summary

The main aim of this research is the study of musical instruments' acoustics in the purposively selected church auditoria in south-western Nigeria in order to achieve the following set objectives The objectives of the study were to: (i) examine the congregants' perception of musical sound in selected church auditoria in South-western Nigeria; (ii) establish the factors that determine good and bad musical sound; (iii) measure the volume of musical sound in relation to the church auditoria; (iv) investigate the acoustic parameters of each church auditorium; (v) assess the level of sound decibel (dB) perceived at each worship service; and (vi) evaluate the acoustical treatment of the various church auditoria. The study was divided into five chapters as follows:

Chapter one is the background information to the study which provides an introduction to the study. The chapter also discusses the statement of research problems and the need for the study. It equally justifies this need, aim and objectives of the study. Moreover, the study discusses the operational definition of terms to prevent ambiguous and complication of terms as used in the thesis.

Chapter two is the review of existing related literature in terms of books on musical instruments' acoustics and music productions. Also, reviewed in this chapter are articles in journals, magazines, periodicals and newspaper reports. The chapter also discusses the human ear as sound analyser and measuring instrument, it considers the human ear and the human brain as functional at the best analysis of perceived musical instruments' sound premised on the Place Theory of Sound Perception (PTSP) as theoretical framework by Von Bekesy (1938) which emphasises on the importance of the human ear to perceive musical sounds and analyse same as good or bad, loud or not loud within the human ear domain.

Chapter three dwells on the perception of musical instruments and acoustic parameters in the selected church auditoria. The chapter outlines the historical perspectives of each of the

selected church auditoria and the available musical instruments' acoustics observed in all the selected church auditoria. The chapter also discusses the location of musical instruments and the choir in each auditorium and how musical instruments' sound is propagated in these church auditoria. The chapter further categorises the available musical instruments in the selected auditoria into the following:

a. Musical Instruments with Vibrating Strings Acoustics
b. Musical Instruments with Vibrating Body (Idiophones)
c. Musical Instruments with Vibrating Membrane (Membranophones)
d. Musical Instruments with Vibrating Column of Air (Aerophones)
e. Musical Instruments Controlled by Keyboard and other Electronic Devices

This chapter further discusses the musical instruments sound and acoustical phenomena of an enclosed space using the International Organization for Standardization standard as specifications as guidelines. The chapter concludes with discussions on acoustics parameters such as sound absorbers, sound reflectors and sound diffusers as observed in each selected church auditorium.

Chapter four discusses the experimental results and analysis of musical instruments' acoustics of the selected church auditoria using a set parameter for measurement. The chapter explains the methodological approach to data collection by applying sound measurement software applications; the 'A4 Da Tuna' and 'Decibel dB' sound measurement software installed on a Tecno DPR7 Android Tablet phone and used same to measure musical acoustics in the selected church auditoria. This chapter also analyses the measured musical instrument's acoustics using qualitative and quantitative analytical approaches.

Chapter five is the concluding chapter which provides the summary of the study, findings of the study, conclusion of the study and recommendations for solutions to the study problems. This chapter also suggests the needs for further studied on the research work, it also enumerates the research's contribution to knowledge in the area of musicological studies.

## 5.1 Research Findings

The following findings resulted from the study of musical instruments' acoustics in the selected church auditoria in south-western Nigeria. These findings are answers to the study's research questions and the set objectives:

On the probe into how the congregation perception of musical instruments' acoustics, the research finds out that congregation perceived musical instruments' acoustics as a tool for praising and worshipping God. It was discovered that the worshippers are used to loud musical instruments' acoustics, this has continued to be the attitude of worship to take them into the realm of true worship. The study takes into cognizance, various worship attitudes of churches with regards to musical instruments' acoustics' production as that which constitute a nuisance to the community in terms excessive musical instruments' sound productions that emanate from these church auditoria. The study observed that church administrators are not really concerned about the effects of this excessive sound on the community where the church is located but rather interested in the evangelical message for the people.

On what actually represents a good and bad musical instruments'acoustics, the study observes that, establishing a direct relationship between good and bad musical instruments' acoustics requires a multi-disciplinary research over several years within different climatic and cultural zones, this study finds out thatthe representation of good or bad musical instruments' acoustics is90% subjective, 7.2% objective and 2.4% relative. Discussing the issue of the representation of good and bad musical instruments' acoustics, the study further finds out that perception of pitch in musical instruments' acoustics is subjective because, some worshippers perceived pitch differently, this depends on what is perceived to be good music or what is not, it was also noted that pitch responsiveness of the human ear differs in the audio perception of musical instruments' frequency and loudness. The issue of perception as applicable to worshippers in the selected church auditoria are equally depended on the directional pattern of

musical instruments' acoustics and influence on the acoustics parameter distribution. However, it is evident that the absence of acoustics parameters in most of the selected church auditoria hasbeen responsible for the ambiguousmisunderstandings of musical instruments' acoustics in most of the selected church auditoria even, with the installations of good sound reinforcement system as observed at Saint Peter's Cathedral Church Ake, Abeokuta, Our Saviour's church, Ikenne, Celestial church of Christ, Akobo, Ibadan, The Redeemed Christian Church of God, Mega Parish, Ilesha and Dominion Centre Church, Ile-Ife.

Further findings revealed that musical instruments' acoustics are not perceivedby either the attributes of the music or the behavioural responses of the listeners, but rather by the communication between the music, the listeners and the church auditoria which was premised on how individual worshipper receives, perceives and interprets the musical instruments' sound. This study finds out that most worshippersare more concerned about the beauty of musical rhythm and the lyrics than the wattage of musical instruments'acoustics' volume.It was further discovered that most worshippers lacked the knowledge of high or low number of decibels of sound they are exposed to during each worship service. Thisis equally applicable to church administrators, clergymen, pastors and the choir. With this zero knowledge about sound pressure level (SPL) and the auditorium volume, it was discovered that many church auditoria especially, the selected ones produced high musical instruments' acoustics' volume with no absorbing acoustics parameters to avertthe heavy wattage of sound of the availablemusical instrumentsin the auditorium, in this case, it is the human body that absorbs the excessive volume with a dint.

On the musical instruments' acoustics' volume and the auditoria volume, the study finds out that there is no consonance between the wattage of musical instruments' acoustics' volume and the auditoria volume. Resulting from participant observation in all the selected church auditoria, it was found out that the performance space for musical activities is a major factor in musical instruments' acoustics and sound propagation because of the tonal colouration and reverberation provided by the selected church auditoria. Realistically, reflections from the solid flat areas of walls in the selected church auditoria affect the total propagation of sound in these

auditoria. It was also discovered that the amount of sound scattering depended on the rate of occurrence of the waves of sound and the reflective materials and at the same time, the lower rate of sound occurrence is also likened to the dimension of the sound reflective objects, this suggest that the musical instruments' sound does not only reflect from the flat walls, but also experienced refraction as the musical instruments sound waves increases in length and changed in its directional propagation in a non-complete and curving round the reflective objects within the church auditorium.

The gothic architecture of the Saint Peter'sCathedral Church Ake, Abeokuta, Our Saviour's church, Ikenne and Iyeru Okin African Church, Offa are endowed with physical elements such as pews, statues, ceramic pulpits and lecterns presented such conditions to create musical instruments' acoustics' reflections although, these internal materials favour a good reverberation for hymnal music. It was observed that the presence of a high numerical size of worshippers in these church auditoria during each worship service has also helped to reduce excessive sound generation that might have been an impediment to good musical instruments' acoustics in these concerned church auditoria. The situation at Redeem Christian Church of God, Mega Parish, Ilesha, Celestial Church of God, Akobo, Ibadan and Dominion Centre Church, Ile-Ifeis not different from the other three Gothic structure churches.Due to the large sizes of these church auditoria, the sanctuary presented acoustic challenges of delay which placed the choirs at Saint Peter's Cathedral church, Ake and Our Saviour's church Ikenne especially, when the organist also doubles as the choirmaster as observed in the above stated churches.

Another observable trait in the three gothic church auditoria, these include Saint Peters' Cathedral Church Ake, Abeokuta andOur Saviours' Church, Ikenne is the vertical emphasis of the structure with height clearance, this outward aspect is further improved by the building design and the attractive items around the auditoria with several pillars in the building, the long narrow windows as observed at the Cathedrals church, Ake, while Our Saviour's Church, Ikenne have upright decorations at the doors and symbolic sculpture of the Saints which has emphasized

the sense of antiquity, all these attributes contribute in no small gravity to the bouncing of musical instruments' acoustics around the church auditoria during each worship service.

Contrarily, the situation at the Iyeru Okin African Church, Offa was designed and decorated with good acoustic parameters,the wooden roof and the beautiful floor lines that are laced with smooth arrangements and transparent window sills to allow for good illumination. The window is embellishedwith frames which add to the aesthetic quality of the entire auditorium. The auditorium has better acoustics parameters like rugged alter, cushioned chairsfor worshippers, non-sound reflecting ceilings and a large of number of worshippers which sufficiently absorbed excessive musical instrument acoustics to balance for the auditorium volume. On the acoustic treatment of the selected church auditoria, the study finds out that only Iyeru Okin African Church, Offa was acoustically treated; other selected church auditoria were not.

On the measured sound decibel in the selected church auditoria, the study finds out thatthere were different three musical instruments acoustics perception per each worship service, the three main divisions are the hymnal singing, worship singing and praise singing which were done at three different days for three different worship services. However, in this observations and measurements, five different variables such as sound reverberation, sound clarity, pitch, sound frequency and sound volume were considered as connected with musical instruments' acoustics in its transmission, reception and perception by the worshippers within the acoustic nature of the selected auditoria.The Place Theory of Sound Perception (PTSP) emphasised how human ear perceives and interprets sound. It is on this theoretical framework that this study looks at the perceived number of decibels in the selected church auditoria to be on the minimum of 86.54dB and maximum of 92.32dB and the average of 90.29dB.

Qualitative results of the measurement of musical instruments sound in all the selected church auditoria are summarised in the table below:

Table 47: The qualitative results of musical instruments sound volume in all the selected church auditoria

| **Analysis of Sound Decibel Generation in the Selected Church Auditoria** | | | |
|---|---|---|---|
| **Auditorium** | Average Decibel Day One | Average Decibel Day Two | Average Decibel Day Three |

| | | | |
|---|---|---|---|
| Saint Peters' Cathedral, Ake, Abeokuta | 90 dB | 85.93dB | 93.33 dB |
| Our Saviour's Church, Ikenne | 80.43dB | 78.66dB | 82.13 dB |
| Iyeru Okin African Church, Offa | 89.51dB | 88.66 Db | 95.33 dB |
| Celestial Church of Christ, Akobo. Ibadan | 109.18dB | 109.50dB | 107.15 dB |
| Redeem Christian Church of God, Mega Parish. Ilesa | 88.50dB | 64dB | 76 dB |
| Dominion Centre Church, Ile-ife | 95dB | 92.50 dB | 100 dB |
| Average Musical Instruments Acoustics Volume | **Day One** | **Day Two** | **Day Three** |
| | 92.03dB | **86.54dB** | **92.32dB** |
| Average of Noise Level in All the Selected Church Auditoria | **Minimum** *L*Aeq,T | **Maximum** *L*Aeq,T | **Average *L*Aeq,T** |
| | **86.54dB** | **92.32dB** | **90.29dB** |

From the summary above, Maximum *L*Aeq, T, of 92.32 dB was obtained in all the selected church auditoria for the three days' measurement while the minimum value *L*Aeq, Tof 86.54dB was obtained for the same period of measurement.The average musical instruments' acoustic in all the six selected church auditoria to be 90.29dB.

## 5.2 Recommendations

Owing to the increasing noise levels occasioned by very loud musical instruments' acoustics in church auditoria, the time has come to begin legislation on noise control although,

this step has been championed by the Oyo State Government with the passage of a bill by the Oyo State House of Assembly as published by the Punch Newspaper of October 19, 2017, this prohibits noise pollution in churches and mosques in Oyo State. This study therefore suggests that an acceptable and most desirable level of musical instruments acoustics volume and sound production, either in close or open acoustics be legally established and applied to control excessive musical instruments sound productions in church auditoria and other religious worship centres in other regions in Nigeria, this is to effectively minimize the effects of heavy wattage of musical instruments' acoustics and other sources of loud musical instruments' sound productions on the Nigerian citizenry.

Moreover, the National Orientation Agency (NOA) should be mandated, through the passage of a bill by the National Assembly (NASS) to set up a committee to oversee the need to create and embark on awareness and advocacy campaign programmes with the mandate to educate, inform, and acquaint the citizenry on the health risk of loud musical instruments' acoustics which often transmute to noise. Due to the ignorance of Nigerians about the existing intimate connection between ideal musical instruments' volume and what could be regarded as noise pollution, butminimal or zero concentrations are directedto the management of loud and heavy wattage of musical instruments sound volume especially, in church auditoria probably as a result of the doctrinal and cultural values attached to religious sentimentality in Nigeria. The implementation and execution of the laws with regard to environmental pollution through excessive musical instruments acoustics in church auditoria during worship services has never been effectively applied in any part of the Nigerian nation.

This study hereby suggests that the primary viewpoints and steps to reduce noise generation, pollution and contamination of the society through musical instruments' acoustics emanating from church auditoria is for the Nigerian government to introduce heavy taxation on churches and mosques with musical instruments' sound above the World Health Organisation (WHO) specified sixty decibels (60dB) as the musical instruments soundvolume limit. The study also recommends that government should set up a Sound Production Monitoring Unit (SPMU) in

each local government area of all the states in Nigeria for proper implementations of these laws. Moreover, a maximum volume level of sound production in the public should be prescribed in order to maintain a particular sound volume which will commensurate with the ideal sound level expected.However, New York Times (2015, p. 27) confirmatively reports that “long or repeated exposure to loud musical sounds at or above 85dB can cause hearing loss”. Meanwhile, highest generated decibel of musical instruments’acoustics in the selected church auditoria was 109.dB which are far higher than the normal decibel of sounds the human ear can perceive and accommodate.

It is therefore essentialthat environmental noise through the musical instruments acoustics in worship services of churches around the living arena needs a critical and urgent attention. From the findings of this study, it has been established that church attendants are really ignorant of the resultant effects of loud musical instruments sound as related to their health status in the selected church auditoria.

## 5.3 Suggestions for Further Studies

Resulting from the findings of this research, it is therefore suggested that further studies be carried out on musical instruments’ acoustics in other worship auditoria like mosques and other religion centres in south-eastern and north central Nigeria because of the concentration of large Christian Islamic religions’ worshippers in these parts of the country. Efforts should also be made to examine and analyse the vocal and instrumental structures of musical performances and practices in selected church, mosque and lecture auditoria in our Universities and other public places in the south-eastern and north-central Nigeria respectively. A heightened awareness campaign and understanding the effects loud volume musical instruments’ acousticswill help in the protection of the physical, mental, and spiritual health and vitality of worshippers in these geographical zones.

## 5.4 Contribution to Knowledge

Findings have been made on the generation, propagation, reception and interpretation of musical instruments’ acousticsas related to pitch, sound clarity, sound frequencies, sound

reverberation, sound volume and loudness and musical ensemble in all the selected church auditoria in south-western Nigeria. The study further discussed the regular recurrence of beat and other acoustic inconsistencies on pitch, musical amplitude, intensity, frequency, loudness and loudness phenomena as obtained in the performance of music in contemporary church auditoria in south-western Nigeria.

In the analytical approaches to amplified musical instruments' acoustics, the study examined amplified sound as a channel for musical sound productions in connection with the fundamental physical principles of acoustics and the performance of music within an enclosed space. Also established in this study, are some factors to aid variables such as sound pressure, sound particle velocity, sound power, sound frequency, sound reverberation and sound time response as applicable to musical instruments' acoustics in worship places especially, in south-western Nigeria.

**5.5 Conclusion**

This study on musical instruments' acoustics in selected church auditoria in south-western Nigeria was conducted within the ambience of church musical instruments' acoustics in terms of its generation, transmission, reception and perception of musical sound in selected church auditoria in south-western Nigeria. This study has applied the "Place Theory of Sound Perception" (PTSP) by Von Bekessy (1938). The theory was concerned with "how sound is perceived and analysed by the human ear".

Serious attention has been drawn to an emerging and important area of discourse in the arts; humanities and the environment, within the ambience of musical instruments' acoustics in selected church auditoria in south-western Nigeriaespecially, with regards to musical sound productions, propagation and perception and the nature of acoustics parameters of the selected church auditoria. The study takes into cognisance the various worship musical attitudes of churches with regards to available musical instruments in each church auditorium. The study further investigated how worshippers perceive musical instruments' acoustics in each of the

selected church auditoria in relation to sound production in order to establish who perceives what at a particular seat location within the church auditorium.

The study also perused and established what represented good and bad musical instruments' acoustics in all the selected church auditoria to the representation of good or bad musical sound {factors being Sound Clarity(SC), "Sound Pressure Level" (SPL) and "Reverberation Time" (RT) and "Auditorium Acoustic Parameter" (AAP) is 90% subjective, 7.2% objective and 2.8% relative. Moreover, church administrators are not really concerned or bothered about the effects of this excessive loud musical instruments' sound on the community where the church is located.

The study also submitted that electrical or electronic equipment used for sound production and re-enforcement in the selected church auditoria could also cause severe health hazards through some forms of sound radiations if the acoustics parameters of such auditorium is not well treated or rightly paddedto control the volume of sound production inside and outside the worship spaces. It is not unlikely that available musical instruments used within any church auditorium may be operating on a double acoustic standard, especially when amplified with the musical instruments' fundamental acoustics nature. Although,to establish a straitconnection between musical instruments' acoustics and noise requires a multi-disciplinary research over years and in several understandings of climatic and cultural zones.This study established that loud musical sounds coming out from church auditoria are subtle agents to reducing the life span of those who are religiously or culturally, coupled with ignorance, attached to loud musical instruments' acoustics and its amplified productions from which are likely to suffer great consequences. The study further observed that loud musical instruments' acoustics in form of "noise pollution" from such church auditorium has been ignored and has made our society to become very noisy.

This study therefore concluded that musical instruments' acoustics and its amplified sound produced in the selected church auditoria were actually more than the recommended sixty decibels (60dB)by the World Health Organisation (WHO) for a normal human ear.

**References**


Abel S.M. (2001). Duration discrimination of noise and tone bursts. *Journal of AcousticsSociety of America, .51*, 1219–1223.

Adachi, S. & Sato, M. (2003). Time-domain simulation of sound production in the brass instrument, Journal *of Acoustics Society of America*, (67), 3850–3861.

Adachi, S. & Sato, M., (1996). Trumpet sound simulation using a two-dimensional lip vibration model,'' *Journal of Acoustics Society of America*, (99), 1200–1209.

Adesiya, M. (2005). *An introduction to music management*. South Africa: Dolly Publishers Limited.

Adrignola, R. (2009). *The science and applications of acoustics.* Heidelberg: Springer Verlag

Alison, R (2009). *Different functions for different medial temporal lobe structures? Learning and Memory*. Germany: Verlag

Aldred, J. (1978). Manual of Sound Recording. *Journal of Audio Engineering Society*, 25(1), 60-78.

Aldred, J. (1972). Manual of Sound Recording, London: Am I Too Loud?*Journal of Audio Engineering*Soc, Fountain Press, (25), 126.

Allen, J.D. (2005). *Rhythmic instrument: A guide to the making and using of simply rhythmic Instrument.* University of Illinois at Urbana-Champaign.

Allen, W. A. (1980). Music stage design. *Journal of Sound Vibrations, 69,* 143.

Allison, W. (1974) Human Temporary Threshold Shift (TTS) and Damage Risk. *Acoustical Society of America, 90(1*), 314-319.

Alton E. F. (2001). *Master Handbook of Acoustics*. McGraw-Hill, Two Penn Plaza, NY, USA, 4th edition. America, 104(1), 221-231.

Ancell, J.E. (1960). Sound pressure spectra of a muted cornet. *Journal of Acoustics Society of America.* (3), 32,

Andersen, P-G. (1969). *Organ Building and Design*. George Allen and Uniwin, London.

Anderton, Craig. (1978). *Home Recording for Musicians*. New York: Amsco Publications.

Ando, Y. (1985) *Concert Hall Acoustics*. Springer, Berlin.

Anomohanran, O., Iwegbue, C.M.A. Oghenerhoro &I.O, Egbai I.J.C. (2008). Investigation of Environmental noise pollution level of Abraka in Delta State, Nigeria. *Trends in Applied Sciences Research*, 3(4), 292-29.

Anon (2008, March 18) ***Science & Music.*** Retrieved May 27, 2017, from Anon2008Science & Music Nature Web Focus. http://www.nature.com/nature/focus/scienceandmusic/.

Arlene L. B. (2015, April 8). ***The Increase in Noise Pollution: What are the Health Effects and the Harmful of Noise?*** Retrieved august 15, 2016.http://www.findarticles.com.

Armstrong, J. (2017) *The Routledge Companion to Embodied Music Interaction.*Ed. Pieter-Jan Maes, Marc.

Arthur, M. N. (2002). Auditorium Acoustics. *Journal of the American Society forInformation Science and Technology, 64(3), 600–610.*

Ashrae, Paul (1991). Sound and Vibration Control. In *ASHRAE System Guide and Data Handbook* (pp. 56-68). PYC: Atlanta. Associates, Inc.

Attali, J. (1985). Noise: The Political Economy of Music. Manchester University Press, Manchester.

Auslander, P.B. (2012). Reverberation time and maximum background noise level for classroom from a comparative study of speech intelligibility metric. Journal of *Acoustical Society of America, 100(1), 408-427.*

Ayers, R. D. (1998). ***New perspective on the brass instruments***,'' Proc. Int. Symp. Musical Acoustics, Leavenworth, USA.

Backus, J. (1961). Vibrations of the reed and air column in the clarinet. *Journal of Acoustics Society of America*, (4), 806-809.

Backus, J. (1977). ***The Acoustical Foundations of Music***, 2nd ed., Chap. 12. Norton, New York.

Backus, J. (1985). The effect of the player's vocal tract on woodwind instrument tone. *Journal of Acoustics Society of America.* (78), 17-20.

Backus, J., & Hundley, T.C. (1971). Harmonic generation in the trumpet. *Journal ofAcoustics Society of America.* 49, 509-519.

Bagenal, H & Wood, A. (1931). ***Planning for Good Acoustics***. London: Methuen and Co Ltd.

Baines, A, (1978). ***The Oxford Companion to Musical Instruments***. *New* York: Oxford University Press.

Baines, A. (1967). ***Woodwind Instruments and their History***. Faber and Faber, London.

Ballagh, D. (1994). Evaluation of stage acoustics in Seoul Arts Center Concert Hall by measuring stage support. *Journal of Acoustics Society of America 117(2),* 667.

Ballon, G.M. (2000). ***A sound engineer's guide to audio test and measurement***: United Kingdom, Elsevier's science and technology Ltd, pp. 45-65.

Ballou, G. M. (2005). ***Handbook for Sound Engineers***, Elsevier science and technology Ltd.

Barron, G.M. (1988, January). Subjective study of British symphony concert halls. *Acoustica, Vol. 66(4),* 1-14.

Barron, G.M. (1993). ***Auditorium Acoustics and Architectural Design 1***. E&FN Spon. USA.

Barron, G. M. (2005). ***Auditorium Acoustics and Architectural Design 2***. Taylor & Francis, London.

Barron, G.M. (2004). Precedents in Concert Hall Form. *Proceedings of the institute ofAcoustics, 14(2),* 147-156. *Journal of Acoustical Society of America, 46,* 34-45.

Barron, G.M. (2009) The Gulbenkian great hall, lisbon, ii; an acoustic study of a concert hall with variable stage. *Journal of Sound Vibrations, 59,* 481.

Barron, G.M. (2010). Subjective study of British symphony concert halls. *Acoustica, 66(4),* 87-99.

Barron, G. M. (2009), Energy relations in concert auditoriums I, *Journal of the Acoustical Society of America, 4(8),* 45-53.

Bartolozzi, B. (1981). ***New Sounds for Woodwinds***. 2nd ed. Oxford Univ. Press, London.

Bassuet, L. (2004) Predicted and experimental results of acoustic parameters in the new Symphony Hall in Pamplona, Spain, *Applied Acoustics, 67(1),* 2582-2593.

Bate, P. (1966). ***The Trumpet and Trombone***. Norton, New York.

Bateye, B.O (2011) Dancing with the Spirit: A Sociological Investigation of Sound, Female Leadership and Ritual Performance in Water from the Rock (A.K.A. Faith Covenant Church) Ile-Ife. *Nigerian Music Review, Obafemi Awolowo University, Ile-Ife, (11) 141-154.*

Baumann, R.B., & C.L. Briggs. (2000). Genre, Intertextuality, and Social Power. *African Journal ofLinguistic Anthropology* 2 (2) p. 243.

Bayer, M. (1998) Using the standard on objective measures for concert auditoria, ISO 3382, to give reliable results. *Journal Acoustical Science and Technology, 26(2),* 147-155.

Bazin, G. (1967). ***The Museum Age***. Universe Books.

Beck, A. (1998). Point-of-listening in radio plays. *Sound Journal* 1(1), 15-25.

Benade, A.H. (1976). ***Fundamentals of Musical Acoustics 2***," pp. 489-504. Oxford Univ. Press, London and New York.

Benade, A.H. (1990).***Fundamentals of Musical Acoustics 1.*** Oxford University Press; Oxford.

Benade, A.H. &Gans, D.J. (1986). ***Sound production in wind instruments***. Ann. New. York.

Benade, A.H. &Kouzoupis, S.N. (1988). The clarinet spectrum: Theory and experiment. *Journal of Acoustics Society of America*. (83), 292-304.

Benade, A.H., and Lutgen, S.J. (1988). The saxophone spectrum. *Journal of AcousticsSociety of America.* (83), 1900-1907.

Beranek, L. (2008). ***Music, Acoustics and Architecture***. Krieger Publishing Company, New York.

Berard, U. (2014). Simulation of acoustical parameters in rectangular churches. *Journal of Building Performance Simulation,* 7(1), 1-16.

Berg, E. & Stock, D. G (1986).***The Physics of Sound***: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, U.S.A.

Berkhout, H. (1993).***Electronic reverberation equipment in the Stockholm Concert Hall***. Oxford, Oxford University Press.

Bernamou, M, (2010). ***Rasa effect and intuition in Javanese musical aesthetics***: Oxford, Oxford University Press.

Berry, R. & Kinzey, B. Y. (1954). ***Planning for sound in church worship.*** Oxford University Press.

Bies, D.& Hansen, C. (1996).***Theory Engineering Noise Control and Practice***. London: E & FN Spon Press.

Binggeli, C &Greichen, P. (1999). ***Interior Graphic Standards*****.** New Jersey: John Wiley & Sons Inc.

Birdsall, G. (2012). Calculating Virtual Pitch", *Hearing Research Journal 1*, 232-245.

Blades, J. (1970). ***Percussion Instruments and Their History***. Faber and Faber Pub. Chicago

Blauert, J. (1983). ***Spatial Hearing***. Cambridge, MA: MIT Press.

Blaukopf, M.J. (1992). The objective effects of first reflections in concert halls – the need for lateral reflections. *Journal of Sound Vibrations, 14(4),* 45-56.

Bode, G.H. (1984).***The Complete Luthier's Library. A Useful International Criteria*** Florenus Edizioni. Bologna.

Boner, C.P. (1988). Acoustic spectra of organ pipes: *Journal of Acoustics Society of America.* 10, 32~40.

Bongers, M. G. (2006). The processing of temporal and non-temporal information in the remembering of event durations and musical structure. *Journal of ExperimentalPsychology: Human Perception and Performance, 24,* 1087-1104.

Borwick, J. (2001). ***Loudspeaker and Headphone Handbook***. London. Reed Education & Professional Publishing Ltd.

Bouhuys, A. (1985). Sound-power production in wind instruments: *Journal of Acoustics Society of America. (*37), 453-456.

Boulos, L. (1966). Conserving Biodiversity Outside Protected Areas: The Role of Magnetism, *Rev. Geophys, 13(5), 284–296.*

Boyd, M. (2006).Impulse response measurement techniques and their applicability in the real world,*Proceedings of the 12th International Conference on Digital AudioEffects (DAF '09),* (163-195) Como, Italy.

Bradley, J. (2002). Relationships among measures of speech intelligibility in rooms: *Journalof. Audio Engineers Society, 46(5),* 243-256.

Brown, S.D (1992). Time-domain simulation of sound production in the brass instrument.

Bruce, S.W. (1997). Pitch discrimination of diotic and dichotic tone complexes: harmonic resolvability or harmonic number? *Journal of Acoustics Society of America, 11(3), 179-189.*

Bruel, Kjaer&Naerum (1986).*Sound Analysis and Noise Control*: Van Nostrandreinhold, 115 Fifth Avenue, New York, 10003.

Buglio, D. (1992, April 28). ***Why is church sound so confusing?*** Retrieved November 15, 2016 from website JdB Sound, Acoustic. Lab. http://www.jdbsound.com/art/art509.htm. Canada: John Wiley & Son, Inc.

Canby, M. (1995). The relationship of choir and orchestra in concert halls. *Proc. Inst. Acoust. 10(1),* 479.

Caruso, V. C. and, Balaban E. (2014). Pitch and timbre interfere when both are parametrically varied, Plus *one, 9(1),* 865-870.

Carvalho, A.P.O. & Silva, P.M.A. (2010). Sound, Noise and Speech at the 9000-Seat Holy Trinity Church in Fatima, *Portugal. Archives of Acoustics*, 35(2), 145-156.

Causse, J (1992). ***Understanding Microphone Sensitivity***.Retrieved November 15, 2016 from website JdB Sound, Acoustic. Lab. http://www.jdbsound.com/art/art509.htm. Canada: John Wiley & Son, Inc.

Cavanaugh, W and Wilkes, J. (1999). Architectural Acoustics: Principles and Practice. *Journal of Acoustics Society America, 19(7), pp. 1398-1408.*

Cavour-Aramayo, E. (2003). ***DiccionarioEnciclopedico de musicales losinstrumentosde Boliva*. CIMA Producciones**. *Century Ethnography*, Literature, and Art. Cambridge MA: Harvard Univ. Press.

Chanan, M. (1994). ***MusicaPractica: The Social Practice of Western Music from Gregorian Chant to Post Modernism***.Verso Publisher, London

Chedd, G. (1970).*Sound: from communication ton Noise pollution. Journal of Acoustics Society of America*, (99), 1333–1348

Chion, M. (1994). ***Audio-Vision: Sound on Screen.*** **Columbia** University Press.

Clements, P. (1999). **Reflections on an ideal: tradition and change of the grosser** Musikvereinssaal, Vienna. Acoustics. Bull, Heft.

Chen, F.C. & Weinreich, G. (1996). Nature of the lip reed. *Journal of Acoustics Societyof America,* (99), 1227–1233

Cirillo E. &Martellotta F. (2003). An improved model to predict energy-based acoustic parameters in Apulian-Romanesque churches", *Applied Acoustics, 64, 55-76.*

Clifford, J. (1988). *On Collecting Art & Culture. In* Predicament of Culture. Ed. Peter James, Verso Publisher, London

Collins, J.D. (2014). The relationship of choir and orchestra in concert halls. *Proc. Inst.*

Coltman, W. (1969). Sound radiation from the mouth of an organ pipe. *Journal of Acoustics Society of America, (*46), 477

Copley, D. C & Strong, W. J. (1996). A stroboscopic study of lip vibrations in a trombone,'' *Journal of Acoustics Society of America,* (99), 1219–1226

Cox T. J. & Antonio, P. (1996). ***Acoustic absorbers and diffusers: theory, design and application*.** Spon Press, London and New York.

Craig, J.F. (1990).***Computer calculated initial reverberation time of some open air musical theatres.***Kongr. Ber. FASE '79, Dubrovnik, 14(9), PP. 79-100

Crandell, T. (2005).***Exploration of pressure field around the human head during speech***. New York Times Bestseller

Cremer, L. (1989). ***Early Lateral Reflections in Some Modern Halls***. Acoustical Publisher.

Crillo, E &Martellotta F. (2003). ***Acoustics of Apulian-Romanesque Churches: An Experimental Survey***. Sinauer Associates, Inc.

Cusick, S. (2007). Soundscapes of Captivity in the "Global War on Terror". *Society for Ethnomusicology conference seminar.* (pp. 12-28). Columbus, Ohio.

D'Antonio, P. (1986 December). Acoustical control of worship spaces. Technologies for Magazine: Sound, Acoustic. Lab. D180-, Boeing Aerospace Co, 19(7). 19061-19063

D'Antonio, P. (2005). Acoustical control of worship spaces. Technologies for Worship Magazine [On line] Available from URL: http://www.jdbsound.com/art/art521.html, (December, 2002). JdB Sound, Acoustic. Lab.

Dabh A. H (1966). A note on the importance of room cross-section in concert halls. *Journalof Sound Vibrations. 5, S. 100, p. 108.*

Davies J.F. (2006).***The residue and the mechanism of hearing.****ProcKon Aka Wetenschap.*

Davis, W. &Patronis, H (2006) Electronic reverberation equipment in the Stockholm Concert Hall. *Journal of Audio Engineers Society*, 22, 627.

Dillner, L. (2012). Effect of material on flute tone quality. *Journal of Acoustics Society of America. 49*, 520.

Dorman, M. (2003). ***Speech intelligibility as afunction of the number***. John Wiley & Son, Inc. Dover; New York.

Dzhambov, G.D & Dimitrova, G. H. (2015, March 16) *Acoustical control of worship spaces***.** Retrieved from Technologies for Worship Magazine December 20, 2016). Retrieved from: http://www.jdbsound.com/art/art521.html.

Ehara, K. N. &Mizutani, K. (2003). Analysis of two dimensional vibrations of lips in an

artificial brass-playing system using optical measurements and numerical calculations,' *Journal of Acoustics Society of Japan*. (59), 541–549.

Elert, G. (2004, August 27). *Frequency Range of Human Hearing*. In Physic Factbook, p. 65

Elliott, S.J.,Bowsher, J. & Watkinson, J. (1982). Input and transfer response of brass wind instruments. *Journal of Acoustics Society of America* (72), 1747-1760.

Ellison, S & Poletti M, (2004). Control of Room Acoustic Parameters by the Variable Room Acoustics System (VRAS).*Proceedings of the Institute of Acoustics*, 120-132.

Ellison, S & Poletti M, (2005).*Control of Room Acoustic Parameters by the Variables* London Books.

Emielu, A. (2013). ***Nigerian highlife music*:** Nigeria, Centre for Black and African Arts and Civilization (CBAAC).

Emmerson, J.R. (2007). Multiple Channel amplification of Reverberation, *Proceedings of the Institute of Acoustics*, Edinburgh.

Emmerson, U. (2007). ***Sound and Its Phenomena, Sunderland***. Massachusetts: Sinauer

Enendu, O. O. (eds.) (2007). ***The sight of sound***: Ibadan: Kraft Books.

Everest, A. (1986).***Master Handbook of Acoustics***, McGraw-Hill, Two Penn Plaza, NY, USA, 4th edition.

Engel, Z. & Kosala K. (2005). Acoustic properties of the selected churches in Poland.

Environ Health Perspectives. (2007, November). pp. 36-37.

Farina, A (2007). Impulse response measurements,*Proceedings of the 23rd Nordic Sound Symposium Training and Information Seminar for Audio People*, 1–31.

Farmer Williams (1931).***The Organ in Western Culture***, Retrieved from Technologies for Worship Magazine December 20, 2016). Retrieved from: http://www.jdbsound.com/art/art521.html.

Farrell R.J. &Booth J.M. (1975). ***Design Handbook for Imagery Interpretation Equipment***, D180-19063-1, Boeing Aerospace Co.

Feld, S. & A. Fox. (1994). Music and Language. Annual Review of Anthropology.

Fielding, J (1980). ***Survey of Audiology: Fundamentals for Audiologists and Health Professional***. Boston: Pearson Education, Inc.

Fiedler, G.H. (2007). The acoustics of the new chamber music hall in Berlin. *Proc. Inst.*

Filipek, H.K &Wiciak, E.F. (2008). Exploration of pressure field around the human head during speech. *Journal of Acoustics Society of America*. 10, 184.

Finegold, L.S., Harris, C.S. & von Gierke, H.E. (1994). Community Annoyance and Sleep Disturbance; Updated Criteria for Assessing the Impact of General Transportation Noise on People. *Noise Control Engineering Journal, 42*, 25-30.

Fletcher N.H & Rossing T. D (1998). ***The physics of musical instruments***. Springer Verlag; New York.

Fletcher, N. H. (1976). Analysis of the design and performance of Clarinet. *Acustica* (37), 139

Fletcher, N. H. & Munson, J.D. (1953). *Speech and Hearing in Communication*. D. van Nostrand Publisher.

Fletcher, N.H. (1979, December 18). Air flow and sound generation in musical wind instruments. Annual. Report on Fluid Mechanism. Retrieved from http//: www.musicawind.com.

Fletcher, N.H. (1979). Excitation mechanisms in woodwind and brass instruments. *Acustica (*43), 63-72; erratum (1982) (50), 155-159.

Fletcher, N.H., &Thwaites, S. (1983). The physics of organ pipes. *Scientific Journal of America.* 248 (1), 94-103.

Forsyth, H. (1985). Causes of Hearing Damage: Occupational Health and Safetyfraction and apparent source width in concert halls.*Journal of Acoustics Society of America, (4) 124-136.*

Gade, A.C (1985). Musicians ideas about room acoustic qualities" Technical University of Denmark Report No. 1. Retrieved from http//:www.gadeac.org.

Gaver, W. W. (1993). How do we hear in the world?*Explorations in ecological*

*acoustics, Ecological Psychology*, Los Angelis p. 285-313.

Gehring, U., Tamburic, L. Sbihi, H. Davies, HW, &Brauer, M. (2014). Impact of Noise on Ear. Journal of Acoustics Society of America, 47(1) 343-352.

Georg von Békésy (1938). ***Audiology and the cochlea***: Mayo Clin. Proc.

Gilbert, A. &Soulodre, B. S. (1998) Subjective evaluation of new room. *Journal of Acoustics Society of America, (98), 45-54.*

Gilbert, J., K. &Ngoya, E. (1989). Calculation of the steady-state oscillations of a clarinet using the harmonic balance technique. *Journal of Acoustics Society ofAmerica*, (86), 35-41.

Gilford, C.L.S. (1979). The Acoustic Design of Talks Studios and Listening Rooms. *Journalof Audio Engineering Society, 27(1), 17-31.*

Gilford, C.L.S. (1979). The acoustic design of talks studios and listening rooms. *Journal of Audio Engineering Society,* Vol. 27, No. 1. pp. 17-31.

Gomery, D.K. (1995).***Noise control in buildings: a guide for Architects and Engineers***. New York: McGraw-Hill, Inc.

Governar, J.F. (2008). The perceptual onset of musical tones. *Journal onPerceptionof musical sounds* 43, 991–999. 67–94.

Gracyk, M.I. (1996). On The Audience Induced Background Noise Level in Auditoria.*Journal onPerceptionof musical sounds* 43, 991–999. 101–109.

Greene, D. P., & Porcello, T. (2005).***Wired for sound*: *Engineering and technologies in Sonic Cultures,*** Middletown Connecticut, John Willey & Sons, Inc.

Greenwood, A.C. Musicians ideas about room acoustic qualities. University of Denmark Report. (2009, January 15). Retrieved from University of Denmark website: www.universityofdenmark.com.

Grey, J. M., (1975). *An exploration of musical timbre*. Ph.D. dissertation, Stanford University.

Griesinger, D. (2011, January 16). ***The audibility of direct sound as a key to measuring the***

***clarity of speech and music.*** Retrieved November 15, 2016, from 162nd ASA meeting, SanDiego website:http://www.akutek.info/Papers/DG_Audibility_Direct_Sound.pdf

Groh, H.O. (1974). Experiences in concert auditoria. *Acoustica, 24(3),* 759-799.

Hansler, E., & Schmidt, G. (2004) ***Acoustic Echo and Noise Control: A practical approach***. Middletown Connecticut, John Willey & Sons, Inc.

Haraway, Donald (1991). ***Percussion Instruments and Their History***. Faber and Faber, London.

Harris, H.A. (1999). Experiences in concert auditoria. *Acoustica, 24,* 236-250

Hartmann, W. M. (1996). Pitch, Periodicity and the Brain. *Journal of Acoustical Society of America, 94(A), 2457-2483.*

Hidaka, T., Beranek L., Mauda, S., Nishihara, N., & Okano, T. (2000, January). Acoustical design of the Tokyo Opera City (TOC) concert hall, Japan, *Journal of Acoustics Societyof Japan. Vol. 107(1),* 89-96.

Hirschberg, J., Gilbert, D, Ponthus, S & Petiot, F. ((1998). Artificial buzzing lips and brass instruments: Experimental results,'' *Journal of Acoustics Society of America*, (104), 1627–1632.

*Holy Bible* (KJV) Chapter 4; 21.***Holy Bible,*** **King James Version**, 3rdEdition.

Howard, R. (2009).Noise Induced Hearing Loss. Philadelphia, Pa: Elsevier Science & Technology Ltd. http://www.jdbsound.com/art/art509.htm, (November, 2002) *Journal of Sound, Acoustics.*

Ighoroje A.D.A, Marchie. C &Nwobodo E.D, (2004). Noise Induced Hearing Impairment as an Occupational Risk Factor among Nigerian Traders, *Nigerian Journal ofPhysiological Sciences 9(1-2),* 9-14.

Ihde, Don, (2007). ***Listening and Voices: Phenomenology of Sound***, 2nd Edition. State University of New York Press.

Ijaiya H. (2016, February 24). ***The legal regime of noise pollution in Nigeria***. Beijing Law Review. Retrieved from http://dx.doi.org/10.4236/blr.51001

Ikibe, S. & Babarinde (2013). Religious transformation: Critical issues in the secularization of

Gospel music in Nigeria. A paper presented at the crossroads in African StudiesConference (Brazilafrica) at the department of *African studies and Anthropologycentre of West African Studies, University of Birmingham, United Kingdom*.

Ingerslev, F., & Frobenius, W. (1974). ***Some measurements of the end-corrections andacoustic spectra of cylindrical open flue organ pipes*.** Trans. Dan Acad. Tech. Sci.

Ingram, D. (2012, August 25). Acoustics in Worship Spaces. American Guild of Organists

Ingram, D., Barnes, E., Hampton, C., Klepper, D., &Noehren, R. (2008). Acoustics in Worship Spaces: American Guild of Organists (pamphlet available from AGO, 815, 2ndAve, New York, NY 10017)

Irmgard, F. J (1994). ***Mass media and new types of youth music, methodological and terminological problems*.** New York: John Willey and Sons, Inc.

ISO 3382:1997, *Acoustics Measurement of the reverberation time of rooms with reference to other acoustic parameters*, (1997).Retrieved December 15, 2016 from*www.instituteofacoustics.com.*

ISO 3382-3383:2009(E). *Acoustics-Measurement of room acoustic parameters, Part 1: Performance spac**es,*** International Organization for Standardization, Geneva, SwitzerlandRetrieved December 15, 2016 from *(www.instituteofacoustics.com.*Italy.

Jacko, R. (2009). ***Environmental Health and Safety for Municipal Infrastructure, Land Use And Planning, And Industry***. *USA*. John Wiley & Sons Inc.

Jarzabkowski, M. (2002). The role of acoustics in preliminary sanctuary design: Church Business, Build-in Sound. *Journal of American Acoustics Society. 13(2), 248-259.*

Johnson, R. (1990). ***Reflection on the acoustical design of halls for Music Performance in Japan*.** Japan National Press.

Johnston, R., Clinch, P.G., and Troup, G.J. (1986). The role of vocal tract resonance in clarinet playing. *Acoustics Australia* (14), 67-69.

Jurgen, M. (2009) The acoustics of the singing voice. *Sci. Am. 23(6),* 82.

Kahrs, M. & Brandenburg, K. (1998) *Applications of Digital Signal Processing to Audioand*

*Acoustics*, Kluwer Academic Publishers, Norwell, Mass, USA,

Kang, J. (2002). ***Acoustics of Long Spaces*: *Theory and Design Practice***. London: Thomas Telford Ltd.

Kartomi, M.J (2001). ***On Concepts and Classifications of Musical Instruments2***, Chicago Publishers:

Kartomi, M.J. (1994). ***On Concepts and Classifications of Musical Instruments***. Chicago Publisher.

Keefe, D.H. (1982). Theory of the single woodwind tone hole. *Journal of Acoustics Societyof America*, (72), 676-687.

Kjellgren, Eric. (2000). Musical *Instruments of Oceania*." In Heilbrunn Timeline of Art History. New York: The Metropolitan Museum of Art, p. 46-62 http://www.metmuseum.org/toah/hd/muoc/hd_muoc.htm accessed March, 2017) Kongreßber. 5. ICA, Liege.

Kosała K. & Engel Z.W. (2013). Assessing the acoustic properties of Roman Catholic churches: A new approach. Journal of *Applied Acoustics, 74(12), pp. 1144-1152*.Krieger Publishing Company: New York.

Krug, R. W. (1993, June 20). ***Dosimeter standards, Europe & America, what difference does it make?*** Retrieved August 22, 2016, from Proc AIHCE

Krumhansl, C. L. (1989). Why is musical timbre so hard to understand? *Structure and perception of electroacoustic sound and music, 9,* 43–53.

Ku¨hnelt, B. (2004). Simulating the sound generation in flutes and flue pipes with the Lattice-Boltzmann-Method. *Proc. Int. Symp. Musical Acoustics*, Nara, Japan, p. 251–254.

Kuttruff, H. (2000). ***Room Acoustics***. Elsevier Sciences Publishers Ltd. New York.

Lab Carse, A. (1939). ***Musical Wind Instruments***. Macmillan, London. Reprinted by Da Capo Press, New York.

Lam, J. & Hodgson, R. (1990). ***Acoustics of Long Spaces: Theory and Design Practice***Oxford Univ. Press.

Latour, B. (2005). ***Reassembling the Social: Introduction to Actor Network Theory***. Oxford Univ. Press.

Lehman, P.R. (2007). Harmonic structure of the tone of the bassoon. *Journal of Acoustics Society of America*, (36), 1649-1653.

Levine, H. & Schwinger, 1. (1984). On the radiation of sound from an unflanged circular pipe. *Phys. Rev. (*73), 383~406.

Lokki, A.H., Parkin, P. H.& Morgan, K. (2011) ***Assisted Resonance« in the Royal Festival*** Thomas Telford Ltd, London

Lottermoser, W. (1983). ***Orgeln, Kirchen und Akustik***. Verlag Erwin Bochinsky.

Mahrenholz, C. (1975). ***The Calculation of Organ Pipe Scales from the Middle Ages to the Mid-nineteenth Century.***Positif Press, Oxford.

Louden, F. (1981). Panel Absorber. *Journal of Sound Vibration, 48(10),* 101-104.

Mackenzie, W. (2005). *Noise Control Management*. New York, Van Nostrand Reinhold. Magazine of Acoustics [On line] Available from URL: http://www.jdbsound.com/art/art521.html, (December, 2002). JdB Sound, Acoustic. Lab. Magnetism, Rev. Geophys, 13(5), 284–296,

Małecki, P. (2014). Auralization of Several Churches and Listening Comparison Using Multidimensional Scaling Approach, Proceedings of the EAA. (pp.151-155). Joint Symposium on Auralization and Ambisonics, Berlin.

Manniche, A.H. (1991).***Room acoustics* 3**. Aufl. London.

Martellota, R. D. (2008). New perspective on the brass instruments. *Proceedings ofInternational Symposium on Musical Acoustic,* (pp. 29–34)

McAdams, S. &. Bregman, A. (1979). Hearing musical streams. *Computer Music Journal3 (4), pp. 26- 60.*

Meddis, R. & Hewitt, M. J. (1991). Virtual pitch and phase sensitivity of a computer model of the auditory periphery II: Phase sensitivity. *Journal of Acoustics. Society of America, 1(2), pp. 2883-2894.*

Mendel, K., David L. K & Rendell, R. T(2010). ***Worship Space Acoustics***, J Ross Publishing United States.

Mereni, A. (2014). ***Theorising Practice and Practising Theory: A Phenomenology of Music in Nigeria***, University of Lagos Inaugural Lecture Series,

Meyer, J (1986). Preferred Problems of mutual hearing of musicians. *Journal of Sound Perception, America, 12(12), 33-38*

Meyer, J. (1978). ***Acoustics and the Performance of Music***. Verlag das Musikinstrument, Frankfurt am Main.

Michael R. H., &Andrew, N. N (2016). Musical concepts and acoustics in concert halls. *Journal of the Acoustical Society of America* (13)9, pp. 3229.

Miller, D. (1987). ***Material Culture and Mass Consumption***. Oxford: Blackwell.

Moles S. (1966). *The Theory and Practice of Amplified Sound*. London, Macmillan

Miller, D.C. (1990). The influence of the material of wind-instruments on the tone quality. *Scientific Journal (*29), 161-171.

Michel, A. (1999). ***Controlling sound transmission through concrete block walls; Instate for research in construction.*** National Research Council, construction technology update 13.Retrieved February 10, 2015 from: http://www.nrc-cnrc.gc.ca/eng/ibp/irc/ctus-n 13. html 08 June, 2011.

Millard, H (2004). A preliminary study on the directional characteristics of room resonance perceived by solo performers. (p.255). *Proceeding of International Symposium onMusical Acoustics*. Tokyo.

Montagu, J. (2007), *Origins and Development of Musical Instruments*, The Scarecrow Press.

Moore, B.C.J. (1986). *Frequency selectivity in hearing*, London: Academic, BF251.

Nagata, M, (2001, March 26). Church Acoustics. Nagata Acoustics News, p. 43-48 New Jersey, USA. Wiley Publishers, pp. 1433–1451

Nisbett, A. (1972). *The Technique of the Sound studio for Radio, Television and Film*.

noise pollution in Makurdi Metropolis, Nigeria''. *Journal of Pure Applied Science, 6(2),* 134-138.

Nolle, A.W. (1983). ***Flue organ pipes: Adjustments affecting steady waveform***. New York Publisher, USA, 4th edition.

Noxon, A. M. (1991). Understanding church acoustics channels of stimulation for signal processor using sine-wave and noise-band outputs. *Journal of Acoustical society ofAmerica, 102(4),* 2403-2411.

Ochuko, A. (2013). Evaluation of environmental noise pollution in Abuja, the capital city of Nigeria. *IJRRAS, 14(4), 470-476.*

Olaniyan, Y. (2008). Yoruba Dundun Musical Practice, *Nigerian Music Review. SpecialEdition, (2) 32-47.*

Olatunji, M.O. (2008). The Indigenization of Military Music in Nigeria: Issues and Perspectives, *International Journal of African Culture, Politics and Development*, (2), 63 -72.

Olson, H. F. (1998).***Modern Sound Reproduction,*** Van Nostrand Reinhold 2. Aufl. New York.

Orlowski, J. (1999). ***$Na^+/H^+$Exchangers: Molecular Diversity and Relevance to Heart***. Annals of the New York Academy of Sciences,

Oyedepo, S.O. & Saadu, A.A. (2010). Evaluation and analysis of noise levels in Ilorin Metropolis. Nigeria Environmental, Monitoring and Assessment, 16(2), 563-577 Pamphlet, pp. 21-35.

Patterson, R.D. &Allerhand M. G. C. (2015). Time-domain modeling of Peripheral Auditory Processing: A Modular Architecture and a Software Platform. *Journal of Acoustics. Society of America*. 98(2), 48-64.

Patynen, L. (2009).***Subjective reverberation time and its relation to sound decay*.**New York Academy of Sciences

Paul, J. (1991). Sound and Vibration Control. In *ASHRAE System Guide and Data Handbook* (pp. 56-68). PYC: Atlanta

Pawel, J. (1996). ***Neurophysiologic Approach to Tinnitus Patients***. American Feit Publisher

Perrin, G.H and Swallowe, A.F (2003).*Optimum reverberation for an auditorium*. Physics Publisher, Japan

Platt, J. R. & Racine, R. J. (1985). Effect of frequency, timbre, experience, and feedback on musical tuning skills. *Perception & Psychophysics, vol. 38(6),* 543– 553.

Plomp, R. (1976). ***Aspects of Tone Sensation***. Academic Press, London.

Pollard, H.F. (1978). Loudness of pipe organ sounds I. *Plenum combinations. Acustica* 41, 65-74.

Pollard, H.F. (1978). Loudness of pipe organ sounds II. Single notes. Acustica *(41),* 75-85

Porter, G. (1998).***The Science and Applications of Acoustics***. New York: Springer Science and Business Media, Inc.

Potter, H & Sorrell, H. (2012).***Halls for Music Performance: Two decades of experience1962-1982.***New York: Institute of Physic. Proc. Vancouver Symposium, 33-38.Published N.Y. Doubleday, 1970, New York.

Quartieri, J., D'Ambrosio, S., Guarnaccia, C. &Iannone, G. (2009).Experiments in Room Acoustics: Modelling of a Church Sound Field and Reverberation Time Measurements. *WSEAS Transactions on Signal Processing.* Issue 3, Vol.5, pp. 126-135, ISSN: 1799-5022

Rault, C (2000, April, 2001).***Religious Architecture***. Accessed 25-01-2017. Http//:www.churchbuildings.com

Rault, C. (2000). Religious Architecture. Http, (Accessed 25-01-2017) p. 110-122 Reby, D. (2003). Anatomical constraints generate honesty: Acoustic cues to Age and weight in roars of red deer stags. *Journal of Animal. Behaviour*, 65(5), 18-32.

Reybrouck, M. (2010). Music cognition and real-time listening: denotation, cue abstraction, *Journal of American Acoustics.* (8) 132-142.

Richard, H. (1888).***The Works of Richard Hooker***, vol. 1, Richard Hooker Press, London.

Riedel, R. ((2007, November). Acoustics in the worship space. Diapason Magazine, Environ

Health Perspectives. pp. 24-28

Riedel, R. (1983, July 26). Acoustics in the worship space. Diapason Magazine, p. 26

Rienstra, R. (1955). *Church design for music, Architectural Record*, pp. 193-194 Rigden, J. (1977). *Physics and the Sound of Music*. Wiley Press, Auckland.

Room Acoustics System (VRAS)", (pp. 443-455) *Proceedings of the Institute of Acoustics.* Rossing, T. D. (1982). Science of Percussion Instruments. Singapore. (pp. 192-208). *River Edge,* N.J.: World Scientific.

Rossing, T.D (2001). ***The Compact Disc Digital Audio System***. The Physics Teacher Pub.

Rossing, T.D. (1982). ***The Science of Sound***. Addison-Wesley, Reading, Massachusetts.

Rossing, T. D. (1982). Acoustics of bar percussion instruments. *Percussive Notes 19(3),*

Sandell, G. J. (1995). Roles for spectral centroid and other factors in determining blended Instrument pairings in orchestration. *Music Perception 13(2), 209-246.*

Schaffer, A.H, (1997) Noise and its effects: *Administrative Conference of the United States Journal* (ACUSJO) 4 (2), 47-55.

Schessel, D.A. (1992). Recurrence rates of acoustic neuronal in hearing preservation surgery. *American Journal Ontological Studies. 13(3), 233-235.*

Schroeder, M. R. (1975). Binaural dissimilarity and optimum ceilings for concert halls. *Journal of Acoustics Society of America, Vol. 43, pp. 113–201.*

Schumacher, J. (1981*).* ***Acoustics and the Performance of Music***, Verlag das Musikinstrument, Frankfurt am Main, Springer Verlag, Heidelberg.

Senturia, B.H., Marcus, M.D, and Lucente F.E. (2012). ***Diseases of the External Ear-An Otologic-Dermatologic Manual***. New York: Grune& Stratton Press.

Shapira L. I, Stone L (2008). ***Perception of musical consonance and dissonance: anoutcome of neural synchronization*.** J. Roy Interface Press. Atlanta.

Sharp, R. (1973). The grand organ in the Sydney Opera House. *Journal of Proc. Roy. Soc. NSW* (106), 70-80.

Shepherd, G. (2010). ***Neurobiology***. New York: Oxford University Press

Smith, C.A & L.W. Morris, (1966). Effects of simulative and seductive music on cognitive and emotional components of anxiety, Psychological Reports 38. Retrieved from *http//:www.psychologia.com*

Smith, C.A. (1987). Effects of simulative and seductive music on cognitive and emotional components of anxiety, Psychological Reports 38, 75–93.

Smith, J. D. (1997). The place of musical novices in music science. *American Journal ofMusic Perception 14(3), 227-262.*

Smith, RA., and Mercer, D.M.A., (1994). Possible causes of woodwind tone colour, *Journalof Sound Vibrations.* 32, 347-358

Soeta Y, Ito K, Shimokura R, Sato S, Ohsawa T &Ando Y (2012). Effects of sound source location and direction on acoustic parameters in Japanese churches; *Journal of AcousticsSociety of America. 131(2):1206-1220. doi: 10.1121/1.3676697.*

Steeneken, H. & Houtgast, T. (1980). A physical method for measuring speech-transmission quality. *Journal of Acoustics Society of America. 67(1), 318–326.*

Stephen McAdams & Bruno L. Giordano (2008) The perception of musical timbre https://www.researchgate.net/publication/224012550

Stevens, S. &Warshofsky, F. (1965). ***Sound and Hearing*, Time-Life Books**, NY Sudnow, D. (1979). *Talk'sBody: A Meditation Between Two Keyboards*. New York: Knopf.

Sumner, W.L. (1973). ***The Organ: It's Evolution, Principles of Construction and Use***. MacDonald and Jane's, London.

Stewart, R & Sandler, M. (2007). Statistical measures of early reflections of room impulse responses. *Proceedings of the 10th International Conference on Digital Audio Effects(DAF '07) Bordeaux, France.* 116-130.

Strube, H.A. (1980). Experimental study on the evaluation of stage acoustics by musicians using a 6-channel sound simulation system", *Acoust. Sci. & Tech. 24(3),* 453-459.

Sundberg, J. and Lindqvist, J. (1973). Musical octaves and pitch. *Journal of Acoustics Societyof America. (*54), 922-929.

Takahashi, G. (1977). Timbre of steady sounds – a factorial investigation of its verbal attributes. *Acustica 30*, 146.

Ternström, S. (1989).**Long-time average spectrum characteristics of different choirs' in different rooms**. Quarterly Progress and States Report 3/89 des Speech Transmission Laboratory der KTH Stockholm, 15.

Ternström, S. (1993). Perceptual evaluations of voice scatter in unison choir sounds. *Journalof Voice 7*, 129-141.

Ternström, S., &Sundberg, J. (1986). ***Acoustics for singing*:** Sweden. Acoustics for Choir and Orchestra, Royal Swedish Academy of Music.

Thèberge, P. (1999). ***Any sound you can imagine**:* Making Music /Consuming technology: Middletown Connecticut, Wesleyan University Press.

Theodore C. G. (2012) Folk Music; *Journal of America's Ethnic Music, p. 132-145*

Thomas, N. (1991). ***Entangled Objects: Exchange, Material Culture, and Colonialism in the Pacific***. Cambridge MA: Harvard Univ. Press.

Toole, F.E. (1994). In-Head Localization of Acoustic Images," *Journal of Acoustics Societyof America, 48*, 112–118.

Trevor J. C., & D'Antonio, P. (2009). **Acoustic absorbers and diffusers**:***Theory, design and application.*** (pp. 2243-2257). Taylor & Francis, London, N.Y.

Tzivian, H.D., Winkler, N. G, & Hoffmann, J.H. (2015). Physics and Music. *Saunders College. Journal of psychoacoustics*, 5(1), 13-30.

Ugwuanyi, J. U, Ahemen, I, & Agbendeh, A.A, (2004) ''Assessment of environmental United States Environmental Protection Agency Magazine. 2015, p. 24 Univ. Press.

Urry, J. (2002). ***The Tourist Gaze***. Sage Publications, London.

Vercoe, B. L. (1997). ***Computational auditory pathways to music understanding inPerception and Cognition of Music***, I. Deliège and J. Sloboda, ed. London,Psychology Press.

Vorländer M. (2008). ***Auralization, fundamentals of acoustics, modeling, simulation, algorithms and acoustic virtual reality***: Berlin, Springer-Verlag.

Waksman, S. (2003). ***Electric Guitar and the shaping of musical experience***. Harvard University Press, Cambridge, London

Wang, G. &Vigeant, R. (2009). ***Optimum reverberation for an auditorium***. Phys. Rev. Press

Waterhouse, W. (1999) ***Controlling the transmission of impact sound through floors. In state for research in construction***, National Research Council, construction technology updates 15.Retrieved April 18, 2016 from: http://www.nrc-cnrc.gc.ca/eng/ibp/irc/ctus/ctus-n35.html, 16 June, 2016.

Westrup David (1972).***Music Theory from Zarlino to Schenker: A Bibliography and Guide***. Retrieved April 18, 2016 from: http://www.nrc-cnrc.gc.ca/eng/ibp/irc/ctus/ctus-n35.html,

Wever, E.G. (1965) ***Theory of hearing***, New York: Wiley (reprint of 1986 edition) QP461.

White, H. E. & White, D. H. (1990). ***Physics and Music***, Saunders College Press.

Wikipedia (Eds.), ***The Free Encyclopedia***. Retrieved April 10, 2017 From http://hypertextbook.com/facts/2003/ChrisDAmbrose.shtml.

Worman H.L.F. (1971) In On the sensations of tone, (pp. 132-145). *Ellis AJ, translator*.

Yoichi A. & Dennis N. (1995). ***Music and concert hall acoustics***: San Diego, Academic Press. Harcourt Brace & Company.

Zannin, P.H.T., Ferrera, A.M.C. &Szerametta, B. (2009). Evaluation of Noise Pollution in Urban Parks. *Environmental Monitoring Assessment, 11(8)*, 423-433.

Zatorrel, P. (2001). ***The Biological Foundations of Music***. Ann N Y Academic Science.

Zwicker, E. &Fastl, H. (1990). ***Psychoacoustic: facts, and models***, Berlin; Springer-Verlag, QP461.

**Oral Interviews**

Mr Yemi Odediran-Organist, Cathedral church of Saint Peters Ake, Abeokuta

Mr. Kayode Oni-Organist, Our Saviour's church, Ikenne

Mr. JareAdefemi-Choir Director, Winners' chapel, Ilorin

Mr. SegunGbadebo, Sound engineer, Cathedral church of Saint Peters Ake, Abeokuta

Mr. TaiwoAwolesi, Sound engineer, Our Saviour' church, Ikenne

Mr. Gideon Lawremce Sound engineer, Winners' chapel, Ilorin

Prof. A.A. Amusa, Professor of Ear, Nose and Throat (ENT), Obafemi Awolowo University, Ife.

Prof. H.B. Olaniyi, Professor of Physics, Obafemi Awolowo University, Ife.

Emeritus Prof. O.O. Awolesi, Peoples' Warden, Our Saviour's Church, Ikenne, Ogun State.

**Appendix I**

**QUESTIONNAIRE ON CHURCH AUDITORIA MUSICAL ACOUSTICS**

**DEPARTMENT OF THE PERFORMING ARTS**

**FACULTY OF ARTS**

**UNIVERSITY OF ILORIN, KWARA STATE**

**QUESTIONNAIRE ON MUSICAL ACOUSTICS IN SLECTED CHURCH AUDITORIA IN SOUTHWESTERN AND NOTH CENTRAL IGERIA**

My name is Adekogbe Olatunbosun Samuel, a PhD student in the Performing Arts Department, University of Ilorin. I am carrying out a study on Musical Instruments Acoustics in Selected Church Auditoria in South -Western Nigeria. However, your church is one of the three purposively selected churches. You are requested in this questionnaire to objectively provide answers to the following questions. In this survey, approximately 150 members (Pastors, choristers, sound engineers and members of the congregation) are expected to complete a survey that asks questions on perception of musical instruments acoustics during worship services. It will take approximately 15-20minutes to complete the questionnaire.

The questionnaire is divided into five categories to sample opinions from the congregation, Pastor/clergymen, choristers, organists/choirmasters/choir directors and sound engineers. Section A (Bio data) is compulsory for all the respondents, section B in others are as stated for each group of other congregants. Please, kindly respond as applicable.

Your participation in this study is completely voluntary and your responses are considered confidential and helpful in this research on the study of musical acoustics in church auditoria. Thank you very much for your time, support and understandings.

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**SECTION A**

**Tick the answers that appropriately suit your opinion**

1. What is your sex? Male [ ] Female [ ]
2. What is your marital status? Married [ ] Single [ ] Widow [ ] Widower [ ]
3. What is your highest educational qualification SSCE [ ] B.A, B.Sc, LL.B, [ ] Post graduate degree [ ]

**SECTION B: Congregation (including choristers)**

1 How long have you been worshipping in this church?

1-3 years [ ] 4-6 years [ ] 7-10 years [ ] 11 years and above [ ]

2. What is the numerical size of your church members?

100-150 [ ] 160-200 [ ] 210-260 [ ]

3. Which of the musical sessions of the service do enjoy most?

4. Give reason/s for your choice in 3 above in the provided space below

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5. Which of the musical sessions of the service do you hate most?

6. Give reason/s for your choice in 5 above in the provided space below

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7. Do you consider any of the musical sessions of your church service noisy?

8. Give reason/s for your choice in 7 above in the provided space below

---

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9. What is the assessment of musical sound in your church during worship services in terms of clarity?

   Fairly audible [ ] Not audible [ ] clumsily audible [ ] disturbingly audible [ ]

10 What is your assessment of musical sound volume of your church? Loud enough [ ] Too Loud [ ] Very loud [ ] Disturbingly loud [ ]

11. What is your reaction to loud musical instruments sound during any worship service in your church?

    Sharp reaction [ ] soft reaction [ ] No reaction [ ]

12, Does loud musical sound affect you in any way?

Yes [ ] no [ ] do not know [ ]

13. If yes, how does it affect you? ----------

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14. If no, how do you cope with loud musical sound? ----------

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**Appendix II**

**QUESTIONNAIRE ON CHURCH AUDITORIA MUSICAL ACOUSTICS**

**DEPARTMENT OF THE PERFORMING ARTS**

**FACULTY OF ARTS**

**UNIVERSITY OF ILORIN, KWARA STATE**

**QUESTIONNAIRE ON MUSICAL ACOUSTICS IN SLECTED CHURCH AUDITORIA IN SOUTHWESTERN AND NOTH CENTRAL IGERIA**

My name is Adekogbe Olatunbosun Samuel, a PhD student in the Performing Arts Department, University of Ilorin. I am carrying out a study onMusical Instruments Acoustics in Selected Church Auditoria in South -Western Nigeria. However, your church is one of the three purposively selected churches. You are requested in this questionnaire to objectively provide answers to the following questions. In this survey, approximately 100 members (Pastors, choristers, sound engineers and members of the congregation) are expected to complete a survey that asks questions on musical sound production during worship services. It will take approximately 10 minutes to complete the questionnaire.

The questionnaire is divided into five sections of A, B, C, D and E. Section A is compulsory for all respondents, section B is for members of congregation, C is for organist/choirmaster/choir director, D is for pastor/reverend and E for the sound engineer. Please, kindly respond as applicable.

Your participation in this study is completely voluntary and your responses are considered confidential and helpful in this research on the study of musical acoustics in church auditoria. Thank you very much for your time, support and understandings.

**SECTION A**

**Tick the answers that appropriately suit your opinion**

1. What is your sex? Male [ ] Female [ ]
2. What is your marital status? Married [ ] Single [ ] Widow [ ] Widower [ ]
3. What is your highest educational qualification SSCE [ ] B.A, B.Sc, LL.B, [ ] Post graduate degree [ ]

**SECTION B (For Organists, choirmasters and choir directors)**

1 How long have you been the organist/choirmaster/choir director in this church? -----

2 What is your experience in respect of musical sound in the church during a worship service? ----------

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3 Do you consider your church musical instruments acoustics clear and audible?

Yes [ ] no [ ]

4. If yes, give three reasons for your judgment

i. ----------

ii. ----------

iii. ----------

5. If no, give three reasons for your judgment

i. ----------

Ii ----------

iii, ----------

6. How would you describe the musical ensemble of your choir? Please, give your comment in the space provided below:

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7. How would you describe the reverberation time of your church auditorium? Give your comment in the space provided below:

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8 How would you aaaaa (high or low) the musical instruments sound volume of hymnal, praise and worship musical sessions during services in yourchurch?

Hymnal sound volume: ----------
Praise sound volume: ----------
Worship sound volume: ----------

9 Do you and your choir hear sufficient feedback of musical sound during worship

Services? Yes [ ] no [ ]

10 Give reasons for your judgments in 23 above

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**Appendix III**

**QUESTIONNAIRE ON CHURCH AUDITORIA MUSICAL ACOUSTICS**

**DEPARTMENT OF THE PERFORMING ARTS**

**FACULTY OF ARTS**

**UNIVERSITY OF ILORIN, KWARA STATE**

**QUESTIONNAIRE ON MUSICAL INSTRUMENTS ACOUSTICS IN SLECTED CHURCH AUDITORIA IN SOUTHWESTERN AND NOTH CENTRAL IGERIA**

My name is Adekogbe Olatunbosun Samuel, a PhD student in the Performing Arts Department, University of Ilorin. I am carrying out a study on Musical Instruments Acoustics in Selected Church Auditoria in South -Western Nigeria. However, your church is one of the three purposively selected churches. You are requested in this questionnaire to objectively provide answers to the following questions. In this survey, approximately 100 members (Pastors, choristers, sound engineers and members of the congregation) are expected to complete a survey that asks questions on musical sound production during worship services. It will take approximately 10 minutes to complete the questionnaire.

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**SECTION A**

**Tick the answers that appropriately suit your opinion**

1. What is your sex? Male [ ] Female [ ]
2. What is your marital status? Married [ ] Single [ ] Widow [ ] Widower [ ]
3. What is your highest educational qualification SSCE [ ] B.A, B.Sc., LL.B, [ ] Post graduate degree [ ]

**Section B: Pastor/Reverend**

1. How would you describe your church musical instruments acoustics?

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2. How would you describe your church musical instruments sound volume volume?Loud enough [ ] Too Loud [ ] Very loud [ ]

3. Are members of the church always complaining of your

   musical instrumentssounding too loud?

   Yes [ ] No [ ]

4. Have you ever experienced a situation of high volume of musical sound during any Worship service? Yes [ ] No [ ]

5. If yes, can you describe your experience? ----------

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6. What measure/s have you taken to avert a repetition of such high volume of musical instruments acoustics? Please, provide your comment in the space provided below:

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   ---

7. How would rate your church auditorium acoustics?

   Bad [ ] good [ ] not sure [ ] I do not understand [ ]

8. Do you ever consider acoustics factor of church auditorium as related musical sound Production? Yes [ ] No [ ]

9. If no, why? ----------

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**Appendix IV**

**QUESTIONNAIRE ON CHURCH AUDITORIA MUSICAL ACOUSTICS**

**DEPARTMENT OF THE PERFORMING ARTS**

**FACULTY OF ARTS**

**UNIVERSITY OF ILORIN, KWARA STATE**

**QUESTIONNAIRE ON MUSICAL INSTRUMENTS ACOUSTICS IN SLECTED CHURCH AUDITORIA IN SOUTHWESTERN AND NOTH CENTRAL IGERIA**

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The questionnaire is divided into five sections of A, B, C, D and E. Section A is compulsory for all respondents, section B is for members of congregation, C is for organist/choirmaster/choir director, D is for pastor/reverend and E for the sound engineer. Please, kindly respond as applicable.

Your participation in this study is completely voluntary and your responses are considered confidential and helpful in this research on the study of musical acoustics in church auditoria. Thank you very much for your time, support and understandings

**SECTION A**
**Tick the answers that appropriately suit your opinion**

1. What is your sex? Male [ ] Female [ ]
2. What is your marital status? Married [ ] Single [ ] Widow [ ] Widower [ ]
3. What is your highest educational qualification SSCE [ ] B.A, B.Sc., LL.B, [ ] Post graduate degree [ ]

**Section B: Sound Engineers**

1 How would you assess your church sound productions? Provide your assessment in the provided space below:

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2 What are your challenges in the area of musical instruments sound productions as peculiar to your church sound?

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3 How would rate your church auditorium acoustics? Give your comments in the provided space below:

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4 How would you describe your sound volume vis-à-vis your church auditorium volume?

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5 How would rate your musical instruments acoustics ensemble during worship services?

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6 Have you at any point in time, considered your church musical instruments sound too loud?

Yes [ ] No [ ]

7 If yes, what did observe as reasons for this loudness?

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8 Have you ever had a disagreement with the Reverend/Pastor/Choir Director/Members of the choir in terms of insufficient sound volume or volume too loud? Give instances of this situation n in the provided space below;

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