# Acoustic Informed Approach:
# Site-Specificity and Choral Composition

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Submitted as part fulfilment for the degree of M.Phil.

2024

Declaration

I hereby declare that this thesis has not been submitted as an exercise for a degree at this or any other University and that it is entirely my own work.

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# Abstract

As we become more distant from the physical and cultural realities of space, it is vital to create site-specific art that reconnects us with the world around us. In comparison to visual art, site-specific music has been far less explored particularly through non-electroacoustic means. The main question of this research is regarding if and how acoustic data can be used to inform a choral composition and how vocal timbre may affect the perception of resonances used. Measurements were taken of two different church sanctuaries and a three minute piece was created for each space and recorded Ambisonically. The anonymous survey results showed a varied response in regards to the perceived resonance of individual notes and chords. Overall this research showed one method of informing choral composition with acoustic measurements along with the architecture and history of the space. However the result is from one person's perspective and can not be expected to accurately portray the space to every person who experiences it.

## Acknowledgements

First, thank you to all of my friends and family who have assisted me during this process, particularly my parents Tanya and Brian Regli. Thank you to my supervisor Professor Jimmy Eadie for guiding and advising me. Thank you to Grace Epiphany Episcopal Church and the Presbyterian Church of Chestnut Hill for allowing me to use their beautiful sanctuaries for acoustic measurements, rehearsals, and recordings as well as allowing me to access church records. Thank you also to everyone who took the time to fill out the survey used to evaluate the project. Another thank you to all the amazing music and choral conductors and educators who have inspired me and given me the experience and skills needed to create such research.

Lastly, I would particularly like to thank the wonderful singers who participated in this process: Luna Dantagnan, Sophia Bollar, Graeme Brown, and Joshua Powell.

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## Media and Repository

"Together in The Bright" Binaural Audio with Scrolling Sheet Music:

https://youtu.be/eUASSKxHRn8

"Find The Light" Binaural Audio with Scrolling Sheet Music:

https://youtu.be/a78C6uNpA8w

Repository of Sheet Music, Audio, and Acoustic Measurements:

https://drive.google.com/file/d/1mdPOcMt1rA0qulQ8wmsl0dStUdxIDZZI/view?usp=sharing

## Chapter I: Introduction

The human sense of identity is inherently tied to our relationship to places and their histories. As we grow and experience life, our sense of place and belonging directly inform how we interact with the people and the environment around us. As we become more distant from these places, uprooting ourselves from specific local cultures, we may lose the ability to locate ourselves. We may lose touch with nature, history, and spirituality along with our own sense of self (Kwon 2002, p. 158). David Harvey in his UCLA Colloquium in 1991 stated that "The elaboration of place-bound identities has become more rather than less important in a world of diminishing spatial barriers to exchange, movement and communication" (p. 156). This growing importance, as Harvey describes, calls artists to create site-specific works to reconnect us with our sense of space, connecting us to our histories and cultures. There is therefore a need to grow and better understand how to create site-specific works that can create this sense of space and identity.

### 1.1 Context

This thesis sits at the cross section of three interdisciplinary fields: site-specificity, room acoustics, and choral composition. In the context of the arts, site-specificity regards works that are designed for a particular space and are therefore inseparable from them. This can include physical properties like the architecture, materials, and acoustics of the space or social cultural properties such as the history, location, and use of the space (Kwon 2002, pp. 3, 11; Lane 2017, p. 27). Acoustics focuses on the study of sound and how it propagates. Particularly, room acoustics works to understand the aspects like the resonances, reflections, and reverberation of sound within a particular space usually through measurements and models (Blesser and Salter 2007, p. 216, 239). Lastly, choral composition refers to music created for a group of voices. In this case, my work builds upon timbral choral compositions of composers such as Caroline Shaw and Meredith Monk.

This combination of fields in research is uncommon. Most of the acoustic based compositions available such as Alvin Lucier's "I Am Sitting in a Room" or Elblaus and Eckel's "Rundgång" and "Clockwork" are electroacoustic in nature using feedback loops and acoustic models to alter the sound. However the *Architexture* series by Professor Ambrose Field in collaboration with Dr Jude Brereton and Dr Helena Daffern from University of York's Audio Lab breaks this pattern. These works are made for voices, similar to my own project, with the goal of using acoustic measurements and models to inform the composition and performance of choral works (Architexture Immersive 2018). All these acoustic based compositions take into account the resonances of the space for which they were made. This thesis seeks to use room resonances found from acoustic measurements to inform a choral composition by taking the methods and advice from these acoustic based compositions and combining them with timbre based composition techniques.

### 1.2 Motivation

By incorporating, even tangentially, music, poetry, literature, and sculpture into our relationship with the world around us, we gain a richness that enhances the quality of our daily lives. Aural architecture also adds its richness, but unlike other art forms, we cannot escape the influence of aural architecture because we live inside it.

– Barry Blesser and Linda-Ruth Salter in *Spaces Speak, Are You Listening?* (p. 364)

When we enter a space like a library, church, or park, our senses help us form an identity of that space. A library might smell of old books and be quietly creaky, while a church may feel like cool stone and sound reverberant. Each space has an aural identity alongside identities regarding sight, touch, smell, and even taste. Our sense of space is crucial to our identity, making it important for the arts to highlight these sensory details. While visual representations of space are common in art, the sound of a space is less frequently used in composition. This thesis is an exploration of one way site-specificity can be incorporated in choral composition through acoustics.

The voice was our first instrument. Singing is a deeply rooted part of the culture of humanity and is one of the many ways we connect to so many moments in our lives whether that be lullabies before bed as a child or scream-singing in the car on the way to work. One of the ways that many people experience the aural identity of a room is by singing or speaking in it. As Barry Blesser and Linda-Ruth Salter in their book *Spaces Speak, Are You Listening?* state: “A singer is an aural detective exploring an environment the way a child explores a toy (p.63).” The reverberant sound and plethora of discrete resonances in a tiled shower prompts even the most shy to sing. Therefore, singers are the perfect medium to connect us to the aural identity of a space through the exploration of acoustic informed composition.

My passion for choral music and acoustics inspired this project. I have sung in choirs for as long as I can remember starting with church choir at a small Episcopalian, stone church. Performing in venues globally in areas such as the United States, Spain, South

Africa, and Ireland showed me how each of these spaces fundamentally changed not only the sound of the music but how I performed. When I was in the Pennsylvania Girlchoir, we performed pieces in the Philadelphia Art museum going from room to room singing choral pieces matching with the time period, style, and location of the art works. This is seared into my memory as one of the first times I understood the connection between space, art, and music. My undergraduate music capstone at Case Western Reserve University explored bedroom music production and how the space of the bedroom or home affects both the music as well as our own mental separation of work, hobbies, and rest. My BSE in Electrical Engineering, with a focus on signal processing, deepened my interest in how sound moves through spaces. Studying acoustics with Jimmy Eadie in my first semester at MMT then further shaped this thesis.

**1.3 Objectives**

This thesis addresses how site-specific choral works can achieve a reconnection between the human experience and historical space using acoustic measurements. Therefore the main question this research seeks to understand is: *How can acoustic data gathered from a particular space inform a site-specific choral composition?* In this project, two 3-minute choral pieces for two different churches were created using acoustic measurements taken inside the sanctuaries of two churches as well as their histories and social contexts. The two churches featured in this project are Grace Epiphany Episcopal Church and The Presbyterian Church of Chestnut Hill both in different neighborhoods of Philadelphia, Pennsylvania in the United States. Each piece was recorded using Ambisonics and rendered into 5.1, binaural, and stereo outputs. A survey was used to evaluate the success of the incorporation of acoustical properties into the piece as well as the quality of the tie between each space and each composition. The main way in which the acoustic data will inform the piece is through obtaining the resonant frequencies of each space. This brings a secondary question: *Does vocal timbre affect the perception of the resonant frequency throughout a composition?* Therefore, sections with different timbres or vowels notated will be incorporated in the compositions to use for comparison in the survey.

**1.4 Methodology**

The methodology of this research can be broken down into three main phases Phase I: Acoustic Measurement, Phase II: Composition, and Phase III: Rehearsal and Recording.

After these phases begins the creation of a survey for the evaluation of the project and the writing of the final paper. In Phase I, the measurements will be taken of each church and analyzed. In Phase II, the piece will be composed based on the history of the church and the data gathered, particularly resonant frequencies. Lastly in Phase III the pieces will be rehearsed and recorded. The recording will be done ambisonically and will be rendered in 5.1, stereo, and binaural. The evaluation of the project will be done through a survey created using the recordings. The goal of this survey is to see if listeners can attach the piece to the space with descriptors and images and to understand their perception of resonance as used throughout the piece.

### 1.5 Overview

There are three main aspects to this thesis project, Site-Specificity, Acoustics, and Choral performance and composition. These will form the overarching sections of the Background research found in Section II. First, the history and background of Site-Specific art and music will be presented. Next, background regarding acoustic measurements and modeling will be addressed as well as current studies on church acoustics. Finally, key aspects of choral singing and composition used in this thesis will be discussed including the history of spatialization in choral composition and vocal timbre. In the Review of Work in Section III, the current compositional research regarding acoustic based composition and timbre based composition will be addressed. Section IV will cover the Methodology of the project and the initial plan for the work. Details regarding the final Implementation of the thesis work is covered in Section V. This will include a detailed record of each step of the process from acoustic measurements to composition and to recording. In the Evaluation found in Section VI, details regarding the survey created for data collection and results will be discussed. Finally in Section VII, conclusions regarding the research questions and success of the project will be drawn and future work will be proposed.

## Chapter II: Background

This chapter will cover background regarding site-specificity, acoustics, and choral composition relevant to this thesis. Chapter I addresses some of the history and background of site-specific art and music upon which this project builds. Chapter II explains key aspects of acoustic data collection and church acoustics used to inform the acoustic measurements and composition of the pieces. Lastly Chapter III addresses spatialization and timbre in choral music. Overall, this section aims to provide the background necessary to contextualize this research within the interdisciplinary context in which it sits.

### 2.1 Site-Specificity: History and Background

Site-specific compositions must pertain to a particular 'space.' However, the idea of space can be inherently blurry as there are both conceptual and physical spaces. Though initial concepts of site-specificity worked with the tangible properties of a site such as its dimensions, materials, lighting, and other distinct physical properties, this idea of space has been questioned going into the 21st century as a site can be anything from a room to a street corner to a magazine page or to an institutional framework (Kwon 2002, pp. 3, 11). Elblaus and Eckel (2020) define a site as "the sum of all the materials, behaviours, circumstances and contexts provided for the piece by its environment" (Elblaus and Eckel 2020, p. 69). This pushes past the understanding of a site as solely the physical properties of a space but the environmental context by which it is surrounded. There can also be a distinction between space and place as something familiar that has value to an individual. It can be argued that site-specific composition attempts to take a space and turn it into a place by making qualities of the social, cultural value of a space apparent through sound (Lane 2017, p. 27). Therefore, providing meaning and drawing attention to physical and social cultural context can be noted as goals of site-specific art.

In the beginnings of site-specific art in the 1960s and 70s, there was a push to view art in tandem with the rooms in which it was presented. As Miwon Kwon (2002) stated "the space of art was no longer perceived as a blank slate, a tabula rasa, but a real place (p. 11)." As artists began to create these site-specific works, they argued that their works were now inseparable from their spaces. When interviewed in 1969 about his wire installations, Robert Barry stated that if they were to be moved, they would inherently be destroyed. Again, Richard Serra with his sculpture Tilted Arc wrote that "to remove the work is to destroy the work" and that "The works become part of the site and restructure both conceptually and perceptually the organization of the site" (Kwon 2002, p. 12). However as site-specific practices have become more common and familiar, there has been a push to continue to redefine the art-site relationship with aspects like mobility.

Starting in the late 1980s, the idea of traveling site-specific art began to gain popularity (Kwon 2002, p. 31). One example of this is Henry Brant's 1984 "Brand(t) aan de Amstel" in which four boats full of flutes floated through the canals of Amsterdam and met multiple ensembles throughout the city on the journey (Harley 1994, p. 222). Lane, in his PhD thesis (2017), created compositions in places of transit and motion including a bridge and river, referred to as "unfixed" places (p. 26). These unfixed locations change the relationships between the audience, site, and performance as each instance will change based on external, uncontrolled factors (p. 25). This is however not dissimilar from more fixed pieces as the perspective of each given audience member inherently affects the way any performance is viewed and experienced. Particularly in terms of site-specific art, the goal is to draw attention to the underlying properties of a place (p. 27). Whether or not these are perceived in the exact way the composer or artist intends, depends on each individual experience which cannot be controlled. These unfixed locations simply add more factors into the possible changes in experience. An appropriate example of a mobile site-specific piece in my opinion is John Cage's 1952 '4'33".' Though it would not have been referred to with such language, this piece called the audience to engage with the sounds around them in any given site. Though the piece itself may not have been designed for a concrete space, it was designed to draw attention to the underlying aspects of a performance space as a larger concept which is the fundamental goal of site-specificity.

## 2.2 Acoustics: Measurements and Churches

This section will discuss the basics of room acoustics and church acoustics essential to this research. First spatial acoustics and measurements will be addressed in terms of the history of the study of acoustics and the current measurement and modeling issues. Church acoustics will then be detailed summarizing key studies regarding the acoustics and architectural features of churches.

### *2.2.1 Spatial Acoustics and Measurements*

The study of musical acoustics focuses on explaining theories of musical sound which can be traced back to Pythagoras, observing the lengths of strings and their relation to intervals of dissonance and consonance. In 1863 Herman Von Helmoltz determined that acoustics was an inherently interdisciplinary field creating experiments that relied on physics, physiology of hearing, and human perception. Then in 1878 Lord Rayleigh created his "Theory of Sound" which serves as the framework for theoretical acoustics. The study of acoustics only grew with the advent of electronic amplifiers, tape recorders, spectrum analyzers and other electroacoustic devices (Sundberg 1977 p. 57-8). In the last half century, the study of spatial acoustics has deepened such that acoustical engineers and architects can design a space with a specific acoustic in mind (Blesser and Salter 2007, p. 215). More complex spatial acoustics, i.e. when a space is not a simple, small, rectangular box, have also not been as thoroughly addressed. As Blesser and Salter (2007) put it: "The science of real acoustics is a messy subject (p. 216)." The study of acoustics is a combination of not only physical science but also perceptual psychology and culture anthropology as our experience of sound boils down to our perspective which is informed by our physiology and historical and cultural experience. The study of acoustics has most developed the physical side with measurement techniques. The more perceptual side, often found in psychoacoustics, has much less clear answers and is therefore difficult to study (p. 216). This can be seen in chapter two during the discussion of timbre which has historically been difficult to define and highly subjective in nature.

Impulse responses are used in fields such as electrical and acoustical engineering in order to completely characterize a system by sending a pulse through said system and finding what changed in comparison to the initial pulse. Impulse responses can be converted to frequency responses which address how each individual frequency behaves in the system. In my case an impulse response was obtained by playing a sine wave sweep from 20 to 20k Hz. When this is played in a room and picked up by a well calibrated measurement microphone, we can find how the room is changing the sound produced from the speaker while it travels to the microphone. However, for these measurements to be theoretically accurate, the system, in this case the room, must be a Linear Time-Invariant (LTI) system (Blesser and Salter 2007, p. 239). Both of these aspects have been questioned when they apply to room acoustics, particularly in the case of larger rooms.

For a system to be linear, multiplying the input by a constant must multiply the output by that same constant (Blesser and Salter 2007, p.239). Impulse responses must be quite loud particularly in larger spaces as they need to overcome background noise levels even as they decay to get accurate reverberation times. However loud, intense sounds, due to the high pressure, make air nonlinear. High intensity pulses also cause intense heat creating a thermal gradient that refracts conic reflection in that area. This led to the use of half or full system sine waves or low level continuous pink noise. Studies have found however that this predominantly works with low-frequencies as high frequency signals are too fragile for thermal waves (p 241). In order for a system to be time-invariant, the response of the system can not vary with time, meaning it is exactly replicable. Aspects like the temperature and humidity of the air can affect the speed of sound in a room changing the measurement depending on those characteristics. One study by Vern Oliver Knudsen (1946) showed that temperature significantly affected room response with fluctuations increasing with higher frequencies and longer paths between the speaker and microphone. He determined that at greater distances, the response would have been completely random (p. 239-40). Though impulse and frequency response measurements are still the key way acoustics are measured, these issues and irregularities are still not fully accounted for. Therefore acoustic measurements of an enclosed space accurately characterize that space only if the space is small, the sound spectrum is limited to low frequencies, and the impulse response is limited to early conic reflection (p. 241).

Because of these issues with larger rooms like concert halls and churches, engineers have worked to create conceptual acoustic models and simulations in which they can conduct measurements. This allows for the control of every aspect of the physical parameters of a space. This does however require a great deal of computing power. In order to truly fully characterize and simulate a typical concert hall with a bandwidth of 20k Hz it would even take a supercomputer days or even years. If the system is limited to smaller bandwidths however, this power can be reduced substantially. But again higher frequencies pose issues when in large spaces over long durations (Blesser and Salter 2007, p. 242-44). Even with the current models and modern computing power it is not possible to completely characterize large rooms.

For this project, measurements were taken of church sanctuaries which are large and can fall into the issues illustrated with linearity and time invariance. Therefore, these measurements are not infallible and must be considered in the context of their current capabilities. Depending on properties like the relative heat and moisture levels, the measurements may change between the measurement day and the recording day and therefore may affect the perception of the resonances used in the compositions.

### *2.2.2 Church Acoustics*

In comparison to concert venues and sound studios, there have been significantly less studies regarding churches within the field of room acoustics until more recently (Girón, Álvarez-Morales, and Zamarreño 2017, p. 378). These studies use room impulse responses to analyze the reverberation times, echoes, coupled volumes and other acoustic characteristics of churches. Acoustic simulations were later introduced by Schroeder et al. in 1962 as a prediction tool for room acoustics for both design and research (p. 380). The origins of church acoustic studies can be traced to the writings of British architect Sir Christopher Wren who designed Saint Paul’s Cathedral and worked on the reconstruction of the churches in London after the great fire in 1666. The first studies however were published in the 1950s and most solely considered reverberation time. Acoustic parameters such as definition, center time, musical clarity, speech intelligibility were established during this time but were widely used only for performance and conference spaces.

Raes and Sacerdote in 1953 worked to locate the echos and other acoustical properties of two famous basilicas in Rome, S. Giovanni in Laterano and S. Paolo Fuori le Mura. Later in 1971, Shankland and Shankland built on this research working with the same basilicas as well as St. Peter's Basilica and Santa Maria Maggiore. They made observations on decay and reverberation using their perception, tape recorders, and stopwatches with a sound source of Koening organ pipes (Girón, Álvarez-Morales, and Zamarreño 2017, p. 381). Lewers and Anderson created new acoustic measurements in 1980 of St. Paul’s Cathedral using new methods with noise generators. They then used Schroeder’s impulse technique which proved more fruitful. They found reverberation data for different frequency bands, created a set of equal sound pressure levels, and found that the space had poor rated speech intelligibility with only 20-30% of words spoken in the center of the nave being understood (p. 382).

Klepper in 1996 worked on the sound reinforcement system of Holy Cross cathedral in Boston which was built in 1875. This work was based on the loudspeaker columns used by Parkin in St Paul's Cathedral, London. He found mid-frequency reverberation times of 3.35 seconds when empty and 2.9 when full. Early to late energy ratios were measured and found that with the correct delay times, amplification could be used to improve speech intelligibility (Girón, Álvarez-Morales, and Zamarreño 2017, p. 382). Girón, Álvarez-Morales, and Zamarreño created a review of research regarding churches globally in 2017 covering studies regarding 20th century Christian churches. Church acoustics as a study has a growing body of work as researchers combine the growth in the study of acoustics with these old church spaces that in many cases are some of the most sonically distinct people experience. This research builds upon these studies through the lens of composition.

**2.3 Choral Music: Spatialization and Timbre**

This section covers the two aspects of choral composition that are key to this project. First the history of spatialization in choral music, particularly in relation to churches, will be discussed. Secondly, vocal timbre will be broken down in order to best understand how vowel choices and individual singer tone may affect the perceived resonance of any particular frequency.

*2.3.1 Spatialization and Choral Music*

The origins of spatialization in western choral music begin with antiphony and choral divisi in church music (Guzik 2020, p.1). Choirs were institutionalized into the Christian church by Pope Gregory the Great leading to choir stalls becoming a fixture of many churches. They were commonly placed either behind the altar or in the transept of cross shaped cathedrals and churches. In Byzantine churches, the choir was placed below the dome in the transept. In Medieval monastic churches, they were closed off behind gates and columns in the main nave. Gothic churches similarly closed off their choirs but with fanciful walls and tall chairs. Renaissance and Baroque churches removed choirs from the central nave as they were seen to distract from the clergy (Girón, Álvarez-Morales, and Zamarreño 2017, p. 379). Polychoral music or *cori spezzati* was introduced as a church music practice in the Renaissance particularly in late 16th century Venice and was most commonly used in masses, motets, and psalms (Guzik 2020, p. 16). This created a sense of dialogue or echo as part of the music and prompted the layout of the ensembles to be chosen based on the acoustic properties of the space (p. 17). One of the most well studied examples of this is St. Mark’s Basilica in Venice. The balconies and transepts created multiple locations for musicians to be placed. As another example, in the Salzburg Cathedral, Leopold Mozart notes the separation of singers into choirs with specific placements. The aspect which made these types of compositions particularly interesting was the physical distance that separated the choirs, incorporating a sense of space into the composition (pp. 18-19).

In the 16th century, there were two significant theorists in the area of polychoral composition: Nicola Vicentino and Gioseffo Zarlino. Vicentino wrote a set of recommendations in his 1555 *L'antica musica ridotta alla moderna prattica* which was centered in Italian traditions from Ferrara, Rome and Venice. Zarlino included guidelines in his 1558 *Le istitutioni harmoniche* before his appointment as *maestri di cappella* at St. Mark's. Both discussed the challenge of distance and timing as with choirs farther apart, it becomes difficult to keep them together musically (Guzik 2020, p. 21-22). Vicentino emphasized the importance of maintaining secure pitch by ensuring the principal choir is centered in references to other choirs. He recommended that for musical continuity, the ending of cadential phrases should overlap with the responding phrase of the other choir (p .23). Both Vicentino and Zarlino point to the importance of a true Bass in the harmonic structure as the clarity of these low frequencies would often become difficult between choirs. Because of the thoughts against dissonance at the time, Zarlino recommended using octaves, unisions, and thirds between bass parts as 5ths could create dissonance between the farthest choirs. Both Zarlino and Giovanni Artusi, another scholar who wrote in 1589, suggest that bass lines should be the same between choirs to give harmonic support to the ensembles (p. 25).

*Sound and Space in Renaissance Venice: Architecture, Music, Acoustics* by Deborah Howard and Linda Moretti addressed the hypothetical positions of singers performing polychoral masses in the Renaissance by assessing 12 churches in Venice through acoustic measurements and audience perception surveys (Guzik 2020, p. 28). They also considered the social norms of the churches including that the ceremonies centered around a central figure, often a priest or member(s) of the aristocracy. Therefore the positioning of these ensembles would serve to emphasize the focus towards this person or group (p.29).

In the post-Reformation of music in Anglican churches, choirs were divided between the two sides of the Chancel. This connected to Antiphonal and Responsorial psalmody which grew from Latin monastic psalmody. The *cantoris* was placed on the north side and the *decani* on the south side. This form was used by Benjamin Britten in *A Hymn to the Virgin* in 1931 for the church of St. John the Evangelist, Lowestoft. This 1853 church was in a cross shape with a 100 ft 6 in long Transept, which is the arms of the cross shape. The church was made of stone with a timbered wood roof and arched ribes and cross braces (pp. 36-7). The choirs sing antiphonally until the final verse of the piece in which they sing together. Choir I leads in English while choir II responds in Latin, presenting a call and response between Latin Catholicism and English Anglicanism. Both the text and spatial difference emphasized the contrasting elements of the piece. It is theorized that the choirs may have been placed on opposite ends of the Transepts. Choir II was intended to be sung by a smaller choir which may point to creating an added sense of distance and echo. In modern performances, the choirs are often positioned with one in front and one behind (pp. 38-9).

Overall through the history of these spatial compositions in churches we see an exploration of space as a fundamental aspect of the composition used to emphasize particular people and ideas and to create contrast. Because of the reverberant nature of churches, the acoustic needed to be well considered in these compositions in order to produce the intended result. Though the compositions made for this research were not polychoral, the recommendations and history of these spatialized choral pieces directly informs my work with singers in church environments. My work intends to deepen this connection between choral composition and acoustics and spatialization.

### *2.3.2 Vocal Timbre*

The voice is an inherently multifaceted instrument uniquely influenced by human physiology and psychology. We can not design this human instrument whereas with a violin or flute, each acoustical property can be considered in the design process. No two vocal instruments are the same since the size and shape of the vocal cavities and resonating chambers, the length and tension of the vocal cords, and the size and shape of the articulators all vary. Moreover, no two people are raised with the same sounds surrounding them or the same vocal training or even the same overall life experience which all fundamentally change the quality of each voice (Eidsheim 2008, p. 2; Daugherty 2001, p. 69). This complexity can be easily seen through the discussions surrounding vocal timbre.

Timbre itself is a complex quality of sound that researchers have attempted to understand and quantify for centuries. Generally speaking, timbre describes the tone quality or personality of a sound. Some have described it as the qualities of a sound that are not fully encapsulated by pitch, loudness, and duration. This research is ever evolving as timbre has been linked to many physical parameters such as spectral and temporal envelope, inharmonicity ratio, synchronicity of partials, as well as onset effects, including ADSR (Attack, Decay, Sustain, and Release) and rise of particles, and steady state effects, including vibrato and pitch instability (Traube 2006, pp. 10-11; Sundberg 1977, p. 69). Authors also note that timbre is a complex musical trait, varying based on the training and history of the listener. For vocal timbre, this is especially relevant as some may find it hard to hear the difference between two cellos, while we as human beings are trained throughout life to distinguish between voices. (Eidsheim 2008, p. 168-9; Traube 2006, p. 6).

Overall, vocal timbre is under researched within the fields of psychoacoustics and voice instruction (Colton Stone and Erickson 2023, p. 2). Vocal timbre depends on many different factors including those of physiological nature and those of a social nature. First there is the biological construction of the vocal instrument or, as some scholars call it, the voice organ. The voice is essentially an oscillator, the vocal folds, and tube resonator created from the vocal tract which is the pharyngeal and buccal cavities. The vocal folds move back and forth due to the air contained in the lungs being released to create the oscillator. This vibration divides the air into pulses which sound somewhat like a buzz. This sound is then transferred into the vocal tract which contains the elements such as the pharynx and mouth cavities and functions as the resonator. This resonator filters in the incoming sound and creates the resulting timbre. Articulation, which is the changing of the shape of the vocal tract in order to make particular sounds, is done by moving the articulators which include features like the tongue, lips, and jaw (Sundberg 2017, p. 169; Sundberg 1977, p. 58). A visual representation of the voice organ can be seen below in figure 2.3.1:

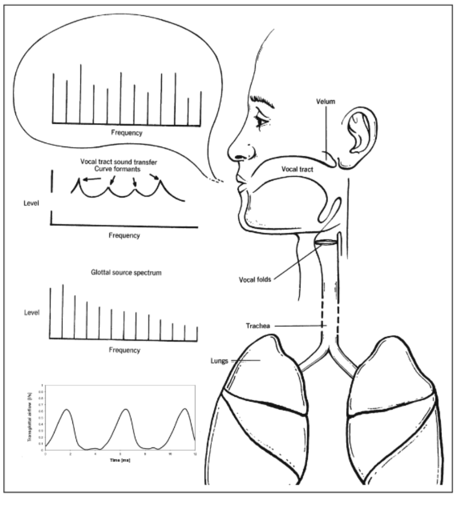


Figure 2.3.1: The Functioning of the Voice Organ (Sundberg 2017, p. 170)

An important aspect of understanding vocal timbre lies in understanding the resonances produced by the vocal tract, commonly referred to as the formants. The vocal tract essentially works like a room in which the size and shape create different reflections and resonances that boost particular frequencies. The vocal tract essentially acts as an adjustable room in which resonances can be changed to create different timbres (Sundberg 2017, p. 169-70). There are four or five particular formants of interest for any particular sound. The two lowest determine most of the vowel quality and the next three tie more to individual voice timbre (p. 171). The length of the vocal tract affects the resonances of this tube which essentially resonates only if the length is an odd multiple of one quarter the wavelength. For the average male with a vocal tract of 17.5 cm, the first three resonances would be 500, 1500, 2500 Hz (Traube 2006, pp. 2, 5; Sundberg 2017, p. 171). Because of the variety of positions and movements the articulators can take, the variety of timbres the voice organ can create is uniquely diverse. The mandible, which forms the lower part of the jaw, is particularly adept in changing the formant frequencies (Sundberg 2017, p. 171).

This is shown through the actions of sopranos when singing high notes. It has been observed that sopranos open their jaws more at higher frequencies and lose vowel definition on these high notes. This particularly affects the frequency of the first formant, essentially changing the first formant's frequency to the fundamental frequency of the pitch they are singing. This change allows for a resonance effect at the frequency of the pitch causing the resulting pitch to be amplified. For example, if a singer sings the note A5 with partials being created at 800, 1760, 2640 and so on on the vowel (u) as in "boot" which has a first formant of 300 Hz without vowel modification, the sung frequency and partials are much higher than the formant, not allowing for any resonance of the formant. With this dropping of the jaw however, the quality of the vowel decreases because of the change in these formats in exchange for an increase in resonance. (Sundberg 1977, pp. 61-3). A visual diagram of this effect and how it changes the formants of the sound can be seen below in figure 2.3.2.

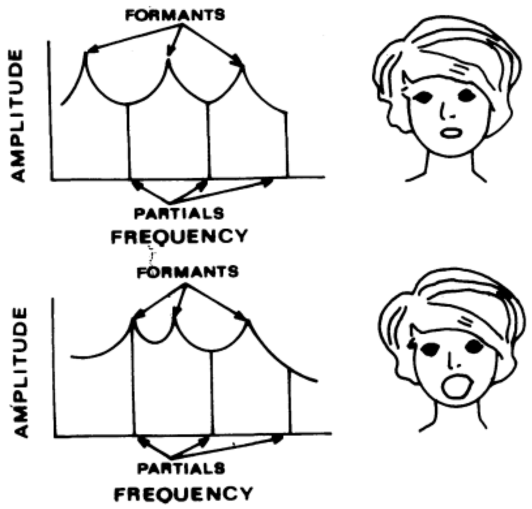


Figure 2.3.2: Change in Formant Frequencies when Dropping Jaw (Sundberg 1977, p. 63)

The second formant of a given sound is sensitive to the tongue shape and the third is sensitive to the size of the cavity that is created between the lower incisors and the tongue tip. An increase in the strength of these two formants reportedly is perceived as a change in placement, described as placing the sound from backward to forward. The fourth and fifth formants have a less direct relationship, however studies show they are connected to the vocal tract length and configuration of the deep pharynx which is why they are less adjustable and more particular to each individual and their biology (Sundberg 2017, p. 171-2). In figures 2.3.3 and 2.3.4 below, two representations of vocal tract adjustments and how they correspond to vowel sounds can be seen. In the first, the positions of the tongue and jaw are shown to be adjusted creating positions labeled front and back which relates to the idea of placement and high and low which pertain to the relative open or closed pace created inside the mouth. In the second, jaw opening and tongue position are used as the x and y axis and circles containing certain vowels are placed on the graph to show the general corresponding positions of the articulators for each vowel. The tongue position is once again listed from forward on the left to backward on the right and the jaw is listed from open towards the bottom and closed at the top.

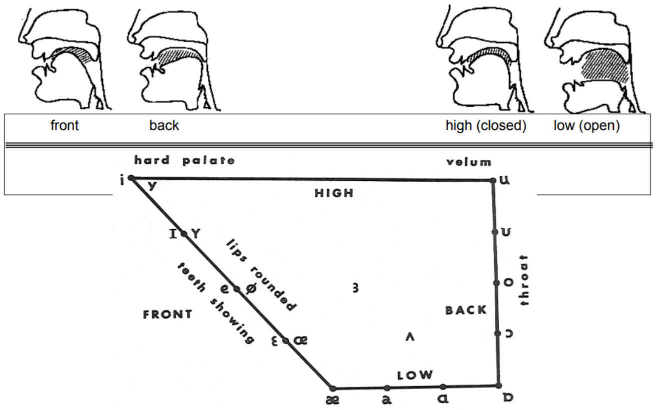


Figure 2.3.3: Depiction of the Effect of Resonators on Vowels I (Traube 2006, p. 2)

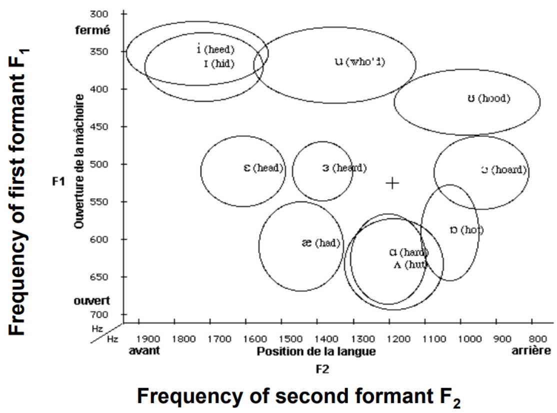


Figure 2.3.4: Depiction of the Effect of Resonators on Vowels II (Traube 2006, p. 3)

Overall, the physiological factors affecting vowel shape are the forward or backward placement of the tongue, the relative open or closed position of the mouth and jaw, the rounding or non-rounding of the lips, and the opening or closing of the passage to the nasal cavity. For consonants, the physiological factors are whether or not it is voiced, meaning whether there is vocal fold vibration, the level of airflow obstruction, the closure or non-closure of the velum, and the surmounting or circumventing the obstruction (Traube 2006, p. 4).

After considering the biological construction of the voice organ, one must address the sociological reasons for the variety of vocal timbres we hear. Vocal timbre is an inherently unique quality of a person. Eidsheim (2008) says "vocal timbre is thought of as something indelible like a fingerprint" but "...unlike a fingerprint, vocal timbre is the sound of a habitual performance that has shaped the physical body" (Eidsheim 2008, p. 1-2). Unless a non-vocal instrument is altered or damaged in some way, the basic timbre of the instrument remains the same. The voice however continually changes with training and socialization. Language, gender, race or ethnicity, and vocal style become important factors in the evolution of vocal timbre.

First we will look at training and vocal styles. As Eidsheim stated in her 2008 PhD thesis, “There are … two bodies: first, there is the body with which we are born, which does not possess any inherent timbral limitations. Second, there is the body that is shaped over time, a body that most likely has been asked to take a form which expresses categories that matter in a given society” (Eidsheim 2008, p. 35). Voice teachers have an inherent effect on the timbre of their students both due to their own voice but also their own societal biases and timbral preferences. It has been found that in different classical conservatories such as that of the French, German, Italian, Nordic, English, etc., there are different timbres taught based on preference. For example French conservatories prefer an onset attack that is very strong created from a powerful inward thrust of the abdomen. This caused the larynx to fix the vocal folds in a single position to deal with this excess airflow. This results in a characteristic “held” sound that is slightly above the given pitch with a sharp phonation in the onset (pp. 36-38). This shows that based on which style one is trained in, different timbral results will occur.

Vocal timbre is not only created from the physiological features of one's body but also the cultural context in which they were raised and trained (Eidsheim 2008, p. 2). Therefore we must consider the features of an individual that affect how they were treated within a social and musical context. In some periods of history, it was believed that those with large noses would have more resonant voices causing some teachers to only accept singers with large noses however studies have disproved this fact. However even though there are no physiological or morphological reasons for the timbre difference based on racial features like noses, people perceive a difference (p. 33). When asked about guiding the development of timbre, voice teachers were found to be concerned with what is healthy and natural to the student and the need to avoid homogenizing the voices of their pupils. These ideas of what is healthy and natural to the voices of each singer often fell on racial and ethnic identities (p. 40). These facts show that a singer's training can be directly affected by how their voice teacher perceives them. The timbre an instructor chooses to foster may be rooted in cultural stereotypes rather than the reality of the initial timbre of the voice.

Gender and sex assigned at birth are also factors in an individual’s physiological and sociological upbringing and therefore their voice. This is particularly interesting when addressing the experiences of young boys and girls prior to the voice change that occurs in many boys that deepens their voice. There is a concept widely believed in church choirs that there is an inherent uniqueness to the young male voice (Welch and Howard 2002, p. 102). In children, the vocal tissue has a less developed structure in which the laryngeal cartilages are less rigid, the membranous portion of the vocal folds makeup less of the total vocal fold length, the mucosa of the vocal folds is thinner but with a higher ratio of mucosa thickness to membranous length than adults, and the overall vocal instrument is smaller. This causes the voices of children to be commonly higher and less complex in terms of acoustic properties (pp. 104-5). The vocal physiological research on children and adolescents indicate much similarity between the sexes prior to puberty (p. 103).

However, studies show that the informed listener can distinguish between the voices of untrained boys and girls closer to the age of puberty (p. 109). In perceptual tests using mixed or single sex choirs, both particular soloists and particular choirs were consistently both misidentified or properly identified. This shows that training of the singers may come into play in regards to the overall perceived sound of a group. Welch and Howard state that “it is clear that some girls, both singly and collectively, are able to produce vocal timbres that are perceived as within a "boy/masculine" category” (p. 114). It is noted that in countries like England, the majority of cathedral choirs keep the boys and girls choirs separate unless there are special occasions. Perceived differences between young male and female voices may be more due to their separation and training than their sex and physiology (p. 102). Overall this shows that prior to puberty related physiological changes caused by sex assigned at birth, gender has an effect on the given training and experience of young singers which affects their timbre as perceived by trained listeners.

This section allowed us to consider how aspects like vowels, training, and physiology affect the perception of timbre of a singer. It is key to this research to consider how timbre affects the pieces composed for this project not only in the perception of resonance depending on vowel but also how each singer’s individual timbre developed through not only their physiology but their training and environment. Each individual singer will have certain formants of their timbre which may affect the perceived resonance of a note. The pieces will also use a variety of vowels in order to see if there are specific brighter or darker timbres that increase perceived loudness or fullness of a note of chord. This background will better inform the survey questions created as well as the results and evaluation of the final works.

## Chapter III: Review of Work

This chapter covers two key areas of composition which informed the final work: acoustic based compositions and timbre based choral composition. A few electroacoustic pieces including Alvin Lucier's "I Am Sitting in a Room," Elblaus and Eckel's "Rundgång" and "Clockwork," and some of Stuart Mellor's PhD portfolio works are discussed. Then the review continues by addressing a set of pieces by Ambrose Field in collaboration with Dr. Jude Brereton and Dr Helena Daffern from University of York's Audio Lab the called "Architexture I," "Architexture II," and "Architexture III" which use choral singers and in some cases technology to create acoustic based compositions. Lastly this section discusses timbre in choral music and one of the compositional inspirations, Caroline Shaw's "Partita for 8 Voices." These works were key to informing my compositional process and to better understanding the current research and context which surrounds my thesis work.

### 3.1 Acoustic Based Composition

Acoustic qualities and models have been used to create site-specific music. However this has predominantly been done with electroacoustic music. One example is Alvin Lucier's 1969 "I Am Sitting in a Room" in which a recorder text of text read by Lucier is repeatedly played back into a particular room. The resonances of the space then slowly change and distort the text over time (ISSUE Project Room, 2021). This is an example of what can be called an "unfixed" site-specific work as each performance of it in a different space changes the piece, making it unique to that particular time and place.

Another example of these acoustically informed, site-specific, electroacoustic compositions can be seen in Elblaus and Eckel's 2020 article which discusses their compositional framework using acoustic modeling to create two site-specific pieces, "Rundgång" and "Clockwork." Both made from acoustic feedback, each piece uses impulse response measurements and real-time convolution to create acoustic models (Elblaus and Eckel 2020, p. 69). "Rundgång," premiered in 2020, is a 20 minute piece designed for the Ligeti Hall in MUMUTH, Graz, during the Elevate Festival (p. 71). Initial recordings for the simulation were taken in Milstein Hall at The Royal College of Music in Stockholm because it was a smaller, less reverberant room. Existing room impulse measurements were used to create a simulation of the room. The performance consisted of a singular microphone, into which a performer could make sound, passing through software developed to filter the incoming sound using the created simulation. This audio then came out of speakers surrounding the microphone to create a feedback loop affected by the acoustics of the space (p. 72). The piece "Clockwork" was created to use two different spaces in the IEM in Graz: the CUBE concert space and a staircase which were connected by a corridor with several doors. Each has microphones and speakers which are connected to the other room such that sound from the concert space travels to the staircase and vice versa. Software was once again placed between the two spaces to alter the sound, creating musical gestures through panning (p. 73).

From their work on these pieces, the authors conclude with three suggestions for site-specific, acoustic informed compositions. First they say to "compose for many vantage points" (Elblaus and Eckel 2020, p. 75). This particularly pertains to understanding the experience of the audience. As with many spatial compositions, depending on the location of the audience member the sound may drastically change in volume or direction. Therefore it is important to consider the possible auditory experiences throughout the space. Next they suggest to "Find new components and relationships in composition" (p. 75). This calls composers to embrace the variability of space based music. Nuance can exist but the piece will greatly differ depending on the particular time and audience. They then suggest to "Employ modelling as a way to work with site" (p. 75). Though models will not be created for this research, the advice saying to look at different perspectives and to embrace the variability of the space was well considered in the process of this project.

Stuart Mellor in his 2022 PhD thesis looked to create a compositional methodology for site specific works expanding on the sculptural practice of Richard Serra with influences from the mindful practices of Pauline Oliveros and Hildegard Westerkamp (Mellor 2022, p. iii). This methodology focuses on the experience of site including analysis of the geometry and architecture, processing of materials, and arrangement of materials (p. 40-1). He breaks his overall processing down into three phases: Activation of Site, Deconstructing the Site, and Being in the Site. The first phase includes the acoustic analysis while the second focuses on developing analysis methods to encompass the shortcomings of these measurements. The last phase deals with direct experience with the space in which the composer becomes the "onsite investigator" (p. 44). Mellor created two to three electroacoustic pieces within the confines of each phase. This allowed him to build upon previous practices, expanding his methodology as he created new works in different spaces (p. 46-8). Mellor's breakdown of methods was particularly interesting to me as it separated the different parts of the aural investigation process during the composition. It is important to look beyond just the acoustics of a space when creating a site-specific work and there are no set methods for the rest of that process. Therefore looking at the methods of various different composers is key to best creating my own approach.

The *Architexture* series is a set of vocal compositions designed to incorporate acoustics into their design. The works are all composed by Professor Ambrose Field with Dr Jude Brereton and Dr Helena Daffern from University of York's Audio Lab working on the acoustic measurements, analysis, and design. Two works have been completed in this series "Architexture I" (2012) and "Architexture II" (2015) while "Architexture III" is currenting in progress. The first composition of the series was created for 10 voices and designed for the York Guildhall (Architexture Immersive 2018). The composition was created in an overlapping, polyphonic style reminiscent of early Renaissance polyphony in which the melodic choices were informed by acoustic analysis of the space. The acoustic analysis came from impulse response measurements similar to my project (Ambrose Field 2012). "Architexture II" was created for six voices and electronics as it was designed not for a currently real space but a previously knocked down building, St Mary's Abbey in York. An acoustic model of the old abbey was created and used in the compositional process (Ambrose Field 2015; Audio Lab 2018). A similar compositional style was used for this piece, feeling most like a choral texture and taking inspiration from early medieval polyphony. The piece was then performed in the ruins of the abbey putting the voices through the acoustic model in order to produce the heard sound of the audience. Field noted that he used a traditional composition method informed by the model rather than a strict mapping of the impulse response data onto the piece (Audio Lab 2018). This process seems in many ways similar to my own. The data from measurements and models is used to inform the composition but does not completely restrict it.

"Architexture III" is planned to be a four voice composition that will be performed live and fed into open back headphones for the audience. This will allow listeners to hear the singers and the virtual acoustic delivered directly to the headphones using binaural audio. The virtual acoustic will be changed throughout the piece changing the space in terms of material, size, and shape. This allows for the malleable acoustic to become a full, changeable instrument within the context of the piece (Audio Lab 2018). This is particularly interesting in terms of future work within this field of acoustic based composition. This no longer becomes a site-specific work necessarily as the fictional space becomes a part of the piece but the piece is not required to be performed or experienced in a particular site. Overall the *Architexture* series is an interesting exploration of acoustics and choral composition.

### 3.2 Timbre Based Choral Composition

Voices are quite unique in the world of instruments due to the malleability and individuality of each sound. Composing with vocal timbre in choral music can be traced back in western music to the 1500s in which musical formats like madrigals used different syllables to portray sounds like birdsong (Hesser Saulle 2019, p. 5). This play was much less prominent during the Baroque and Classical periods as the improvements to non vocal instruments peaked the attention of composers. However, during this time *bel canto* technique for solo operatic singers was developed which aimed to minimize timbral differences between the different registers of the voice (p. 8). In the Romantic period, there was some rise once again in the use of timbre in some choral pieces as the need for emotional expression grew. Western composers in the 19th century began writing completely wordless vocal parts in which voices became inherently timbral instruments. This can be seen in works like Debussy's "Sirénes" (1899) or Puccini's "Madama Butterfly" (1904) (p.12).

Wordless singing became even more popular into the 20th century, used in everything from a cappella music to film scores (Hesser Saulle 2019, p. 10-12). Timbral techniques like *Sprechstimme* which features spoken-like singing were developed and commonly used by composers like Schönberg (p. 12-13). When Berio wrote "Sequenza III" (1965) for solo voice, he worked to develop a detailed notational system for this timbral piece using a combination of text, vowels, notes, and general contours (p. 16). Stockhausen in "Stimmung" (1968) used overtone singing, a technique that continued to grow in popularity explored by composers like David Hykes, Stephen Leek and Stuart Hinds (p.17). During the development of Jazz and Broadway vocal technique, there became more solidified timbral techniques like belting (p. 19-20). Singers like Ella Fitzgerald can be heard using a large variety of vocal timbres in their improvised solos in recordings like her 1960 live in Berlin rendition of "How High The Moon." By the 1980s, a clear tone without vibrato became the preference for choral works (p. 18). This however did not stop the continued exploration of timbre by composers. Meredith Monk is one such composer who worked to develop techniques for specific textures and timbres with her ensemble to use in her intuitive improvisation pieces (p.21).

One of my primary choral inspirations is Caroline Shaw, particularly her *Partita for 8 Voices* which is a 2013 Pulitzer Prize winning choral work of four pieces made for her group Roomful of Teeth. This group has trained in a wide variety of vocal techniques and timbres including Tuvan throat singing, yodeling, Broadway belting, Inuit throat singing, Korean *P'ansori*, Georgian singing, Sardinian *cantu a tenore*, Hindustani music, Persian classical singing, and Death Metal singing. This allows the group to be uniquely suited and expected to sing and create timbral works (Hesser Saulle 2019, p.23). Shaw describes her *Partita for 8 Voices* as: "... a simple piece. Born of a love of surface and structure, of the human voice, of dancing and tired ligaments, of music, and of our basic desire to draw a line from one point to another (The Pulitzer Prizes 2013)." It was inspired by Sol LeWitt's "Wall Drawing 305" (1977) which is an art piece in which one hundred random specific points are placed by a draftsman using the artist's given vocabulary to map the points. At each point descriptions are written using LeWitt's complex terminology to explain how each point was chosen (MASS MoCA 2013). This work is site-specific and can be tied back to the movement calling attention to the physical white walls of an art gallery and their architecture. Though Shaw's composition is not site specific, it uses inspiration from the text and structures of LeWitt's art.

The work uses belting, Tuvan Throat-singing, overtone singing, P'ansori-derived techniques, and Katajjak or Inuit throat singing which do not have standardized notations (Hesser Saulle 2019, p. 69). Though access to even excerpts of the sheet music is limited, there are a few figures below in which the notated timbres can be found. This includes notes indicating vowels and constants using IPA and notes indicating when to use chest or head voice. Figure 3.2.1 shows in particular how she notated Katajjak. Overall this piece as well as research into other timbral choral works have inspired my work and informed my approach for my compositions and research.

Figure 3.2.1: Partita for 8 Voices: III. Courante, Bars 12-15


Figure 3.2.2: Partita for 8 Voices: IV. Passacaglia, Bars 11-30


Figure 3.2.3: Partita for 8 Voices: IV. Passacaglia, Bars 31-38

## Chapter IV: Methodology

In this chapter, the three main phases of the project are discussed including Phase I: Acoustic Measurement, Phase II: Composition, and Phase III: Rehearsal and Recording. The final implementation of this methodology is further shown and analyzed in Section V: Implementation. In order to answer the proposed research questions, two choral compositions informed by the acoustics and history of two different churches were created and evaluated. The two churches used for this research are Grace Epiphany Episcopal Church and The Presbyterian Church Of Chestnut Hill both in Philadelphia, Pennsylvania in the United States. In the first phase of the project, acoustic measurements were obtained from each location. Data from Room EQ Wizard (REW), primarily the Waterfall and Spectrogram plots, was then used to directly inform the choral composition for each space.

In the second phase of the project, the two pieces were composed, each approximately 3 minutes in length. Acoustic data was used throughout the composition to inform note choice and the positions of the singers. As these are site-specific compositions, the historical aspects of the space were also considered along with the acoustical data. Both spaces are churches, which have a long history with choral music. Each church is also of a different denomination, Episcopalian and Presbyterian, which each have different practices and understandings of worship in relation to music. Therefore research was done using the archival history of each church to understand their different musical histories.

The third phase of the project included rehearsing and recording the piece. A group of five voices, a soprano, a mezzo-soprano, an alto, a tenor, and a baritone was obtained. Luna Dantagnan sang soprano, I sang mezzo-soprano, Sophia Bollar sang alto, Graeme Brown sang tenor, and Joshua Powell sang bass. There were two rehearsals of each piece prior to recording. After the first rehearsal, adjustments were made to each score as needed. Each piece was then recorded using a RØDE NT-SF1 microphone which is a first order Ambisonic microphone and a Zoom F8n Pro using the Ambisonic mode. Using the SoundField by RØDE and the Sparta Binauralizer plugins, 5.1, stereo, and binaural renderings were created. The goal of the piece is to use the resonant frequencies of the room. Therefore it is paramount that the singers tune to the initial given pitch center. However singers commonly lose tuning throughout the performance of a piece. Because of this, the recording was not done in a live setting. Multiple takes were performed, checking the tuning after each to ensure we stayed as close as possible to the initial pitch center. However this is an inherent part of much a cappella choral music. The main question of this research is regarding *if* and *how* acoustic data can be used to inform a choral composition. Therefore the difficulties that will be encountered during this process are key to the results of this research.

# Chapter V: Implementation

This chapter is a further breakdown of the final implementation of the initial methodology. In Phase I: Acoustic Measurements, the process of measurements in each church including photographs and diagrams is shown. For Phase II: Composition, the compositional development is shown including the lists and diagrams used and the historical research done for each church used to inform the text, message, and tone of the piece. Phase III: Rehearsal and Recording briefly discusses the rehearsal process along with the recording process including photographs of the recording set up.

## 5.1 Phase I: Acoustic Measurements

Phase I included the process of taking and analyzing the acoustic measurements from each church. This section details the measurement process in both churches and the decisions surrounding placement. First, instruments used and calibration techniques are briefly addressed. Next the measurement process Presbyterian Church of Chestnut Hill (PCCH) is covered followed by that of the Grace Epiphany Episcopal Church (GEEC).

### *5.1.1 Instruments and Calibration*

The measurements were done using a Dbx RTA-M Measurement Microphone, a Scarlett 2i2, a Yamaha HS8 speaker, and the software Room EQ Wizard (REW). A Reed Instruments R8050 Sound Level Meter was also used to measure the Sound Pressure level (SPL). In order to begin measurements, the interface, microphone, and SPL meter must be properly calibrated on REW. First the interface, a Scarlett 2i2, was calibrated using a loopback connection producing a mostly ideal response with a bit of the upper frequencies appearing somewhat obscured. This calibration curve can be found below in figure 5.1.1. The microphone calibration was downloaded and uploaded into the software as well. The same calibration files were used throughout measuring both churches. The SPL meter was then also calibrated. First the Reed Sound Level Meter was calibrated in accordance with the given instructions. Next the SPL meter was opened on REW and adjusted to the settings C weighting and S (slow). The Reed Sound Level Meter was also adjusted to C weighting and S (slow) and held next to the measurement microphone. The REW speaker cal signal was used and the REW SPL meter value was adjusted until equal with that displayed on the Reed Meter. This was done in each new microphone location during measurements in both churches.

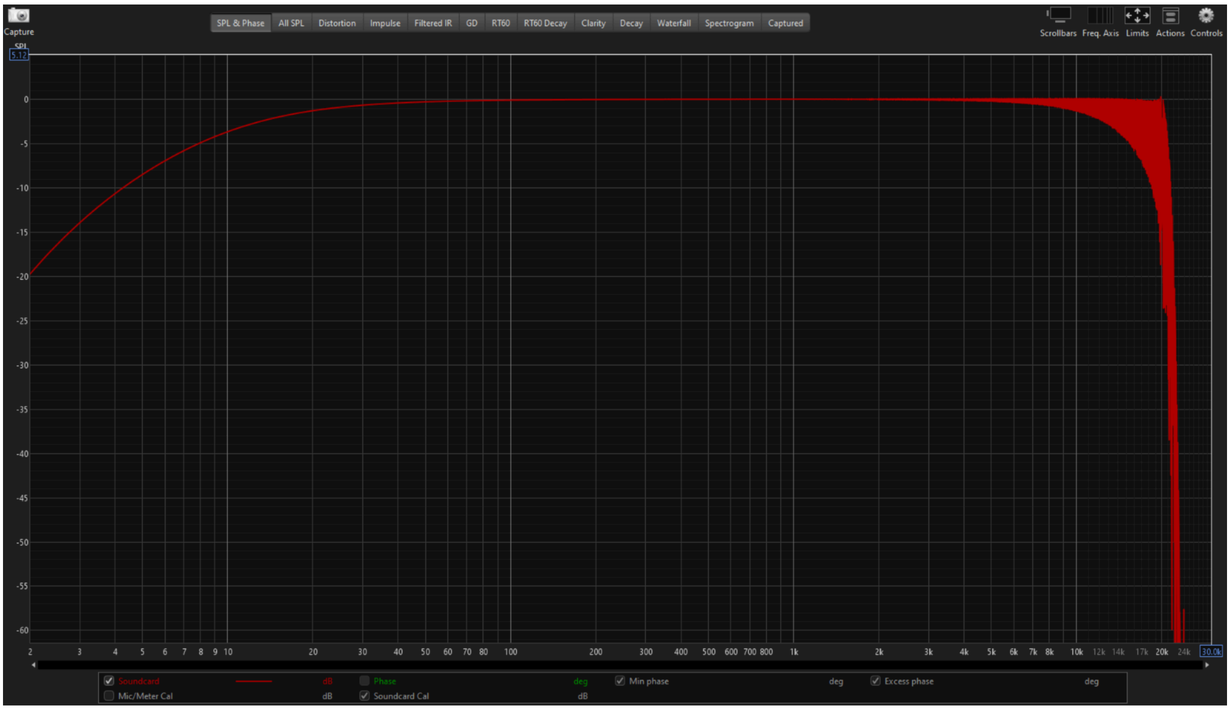


Figure 5.1.1: Scarlett 2i2 Calibration File

*5.1.2 The Presbyterian Church of Chestnut Hill: Measurements*

The measurements of the Presbyterian Church of Chestnut Hill (PCCH) were taken on May 14th. The process began by setting up the speaker and microphone on stands and ensuring everything was properly connected and calibrated. As seen in figure 5.1.2 the space is essentially a long rectangle with a slightly curved ceiling. There is a cut out at the front of the church up a few steps which consists of two concentric cut out areas. This is similar in design to the classical placement of choir stalls in many Catholic and Espicopalian churches however the space is clear except for a table and a few chairs. This area extends to the small pulpits on either side. In the back of the space there is an upper cut out with an organ above the main entrance to the space. Underneath the organ there are a few windows and glass doors that look out to the lobby. This angle can be seen in figures 5.1.3 and 5.1.4. There are 5 large windows on either side. The floors and pews are made of wood and the walls are stone with plaster painted white. There is also a strip of carpet down the center aisle.

Figure 5.1.2: View From Back of PCCH

Figure 5.1.3: View From Front of PCCH 1

Figure 5.1.4: View From Front of PCCH 2

Test measurements were taken in several locations. This space was quite reverberant however sounds in the cut out area did not subjectively sound as reverberant in comparison. Test measurements were taken at the base of the stairs and in the upper cut out area. There were more interesting and distinct spikes in the measurements at the base of the stairs. Because of these tests and my subjective finding of a more reverbant feeling sound in the lower area, the position tested was focused there. In reverberant spaces, it is also important for small groups to be close together in order to stay together rhythmically without a conductor. Therefore a small arch facing slightly inward was decided upon. Measurements were taken in each position along this arch and each spot was marked with a white tape square. These positions can be seen in figures 5.1.5 and 6 below. In this reverberant space, there needed to be a good balance of direct and indirect sound. In order to make sure the small group was clear, the microphone was placed at the first pew. This can be seen in figure 5.1.7 below. The overall speaker placements and microphone position relative to the space including measurements can be seen in figure 5.1.8 and 9.

Figure 5.1.5: Position of Speakers and Microphone from Microphone View for PCCH

Figure 5.1.6: Position of Speakers and Microphone from Speaker View for PCCH

Figure 5.1.7: Position of Measurement Microphone for PCCH

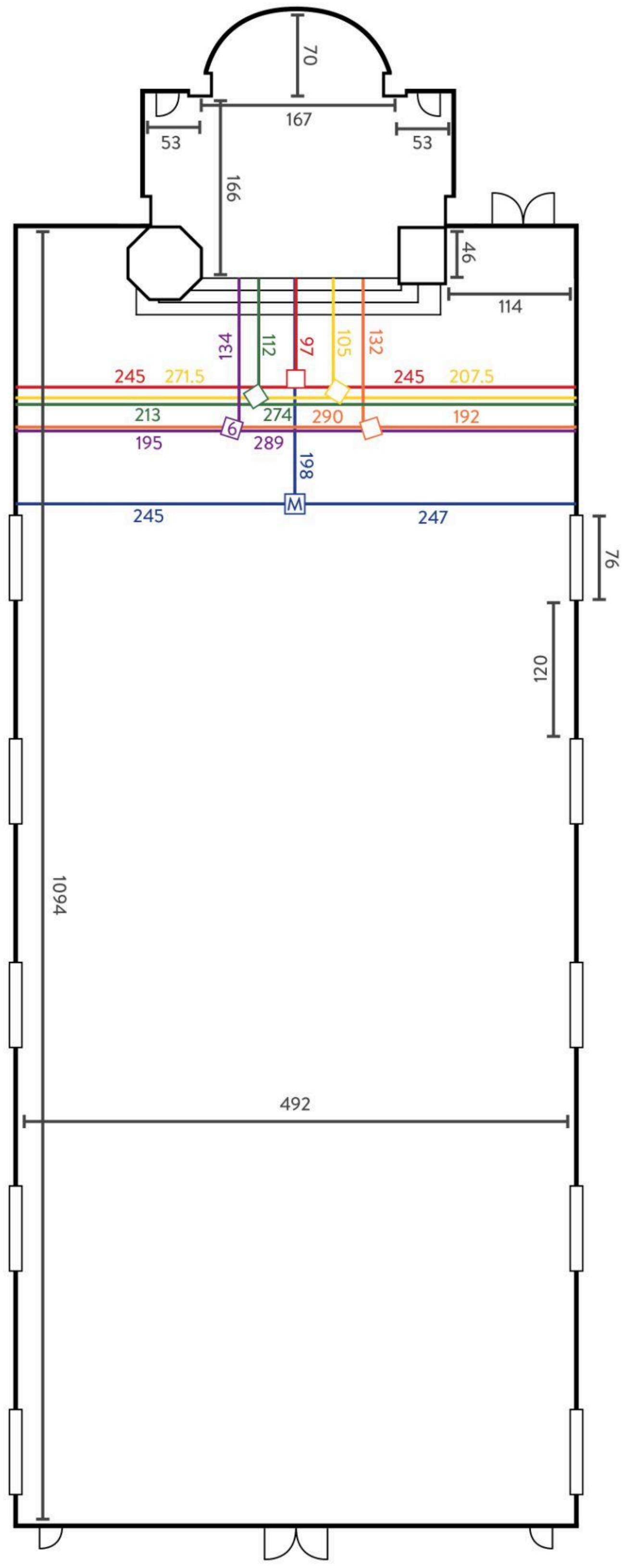


Figure 5.1.8: Diagram of PCCH with Microphone and Speaker Placements

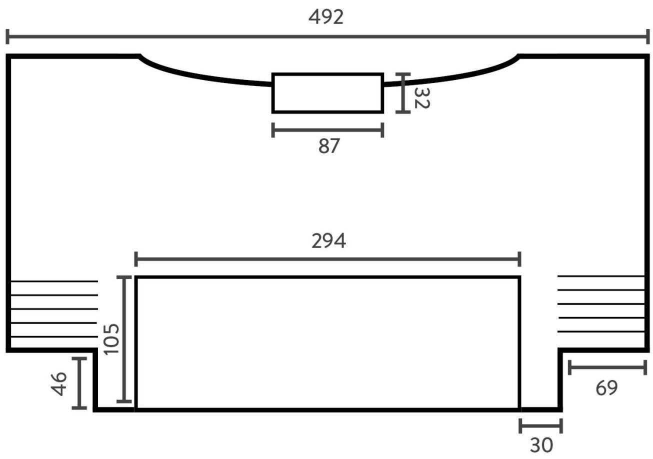


Figure 5.1.9: Diagram of PCCH’s Balcony

In order to view the measurements, each was set to ⅓ octave smoothing. As this project particularly focuses on resonant frequencies, the main data used was obtained from the SPL graphs and Waterfall plots. The combined SPL graph and waterfall plot can be found in figures 5.1.10, 11, 12, 13, 14, and 15. The measurements varied slightly in the different positions but overall showed a number of particularly resonant frequencies with the human vocal range which at its outer limits can reach approximately from 70 to 1200 Hz with some exceptions. For my group, the lowest range was Josh at an F2 (87 Hz) and the highest range was myself at an E6 (1319 Hz).

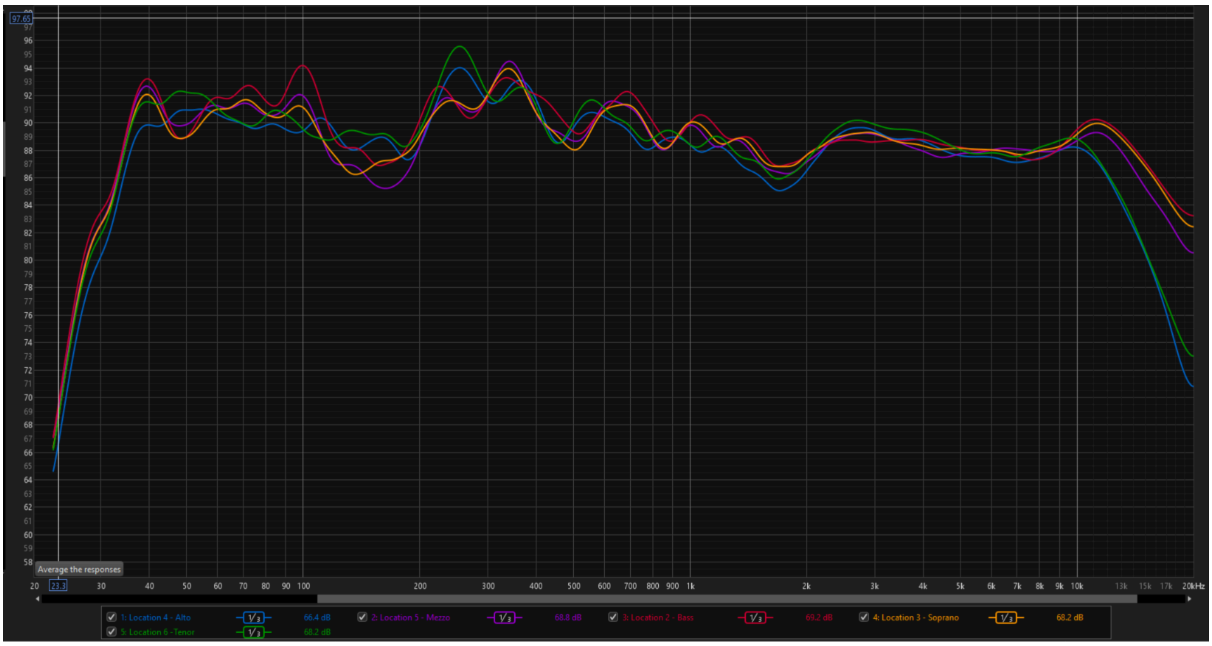


Figure 5.1.10: All SPL from Used Positions

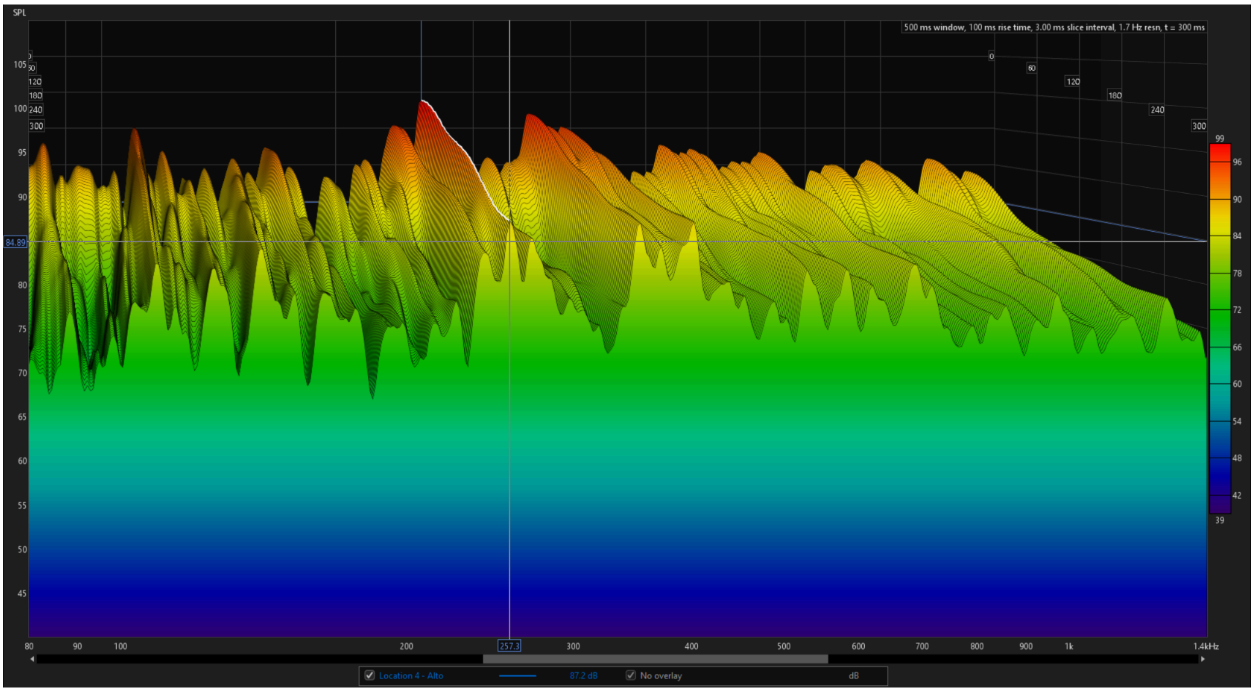

Figure 5.1.11: Waterfall Plot of Position 4 (Alto)

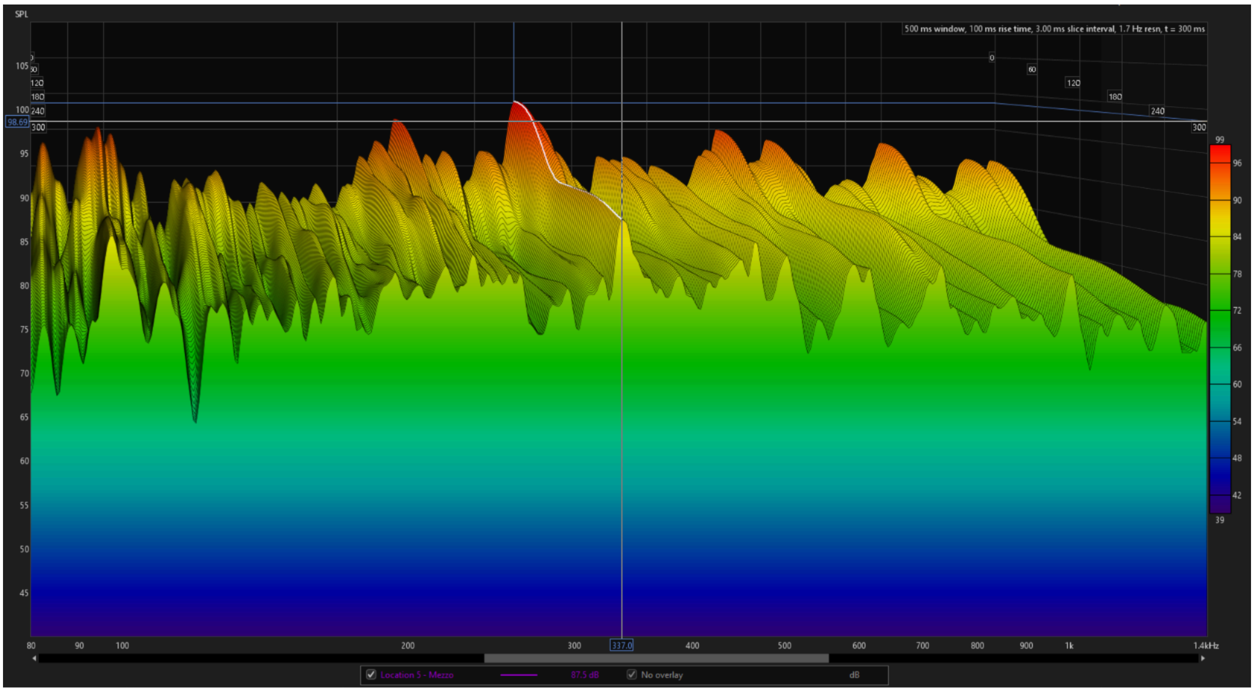

Figure 5.1.12: Waterfall Plot of Position 5 (Mezzo)

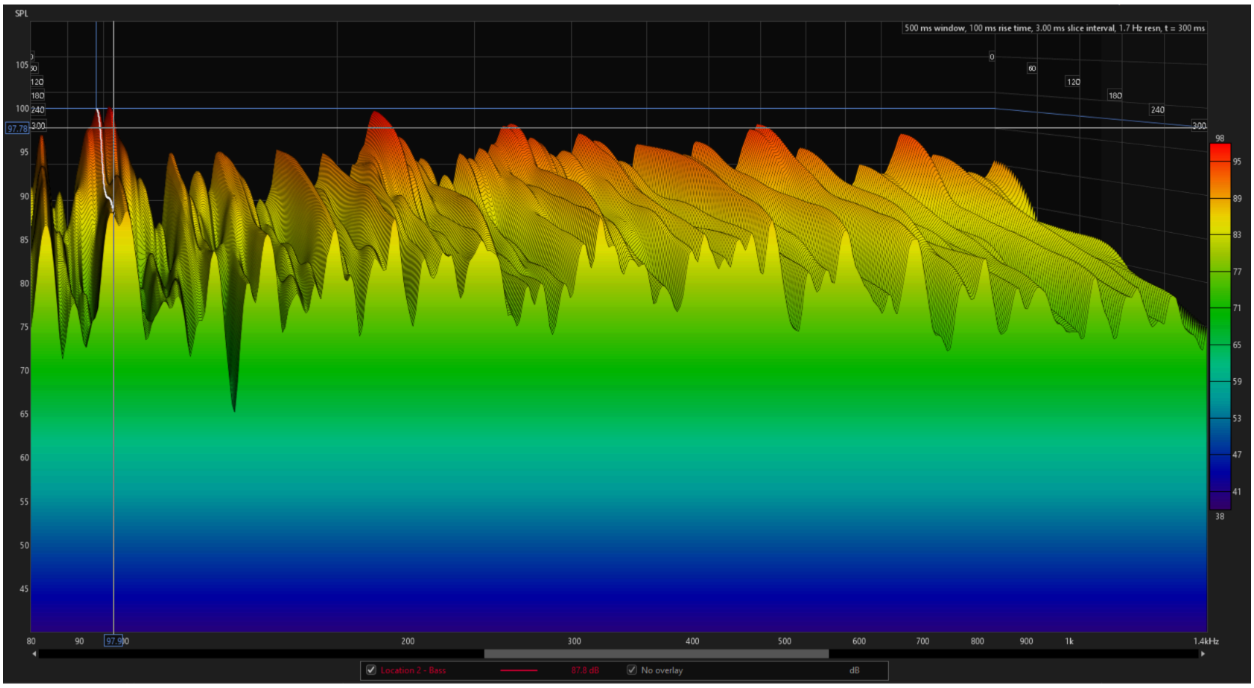


Figure 5.1.13: Waterfall Plot of Position 2 (Bass)

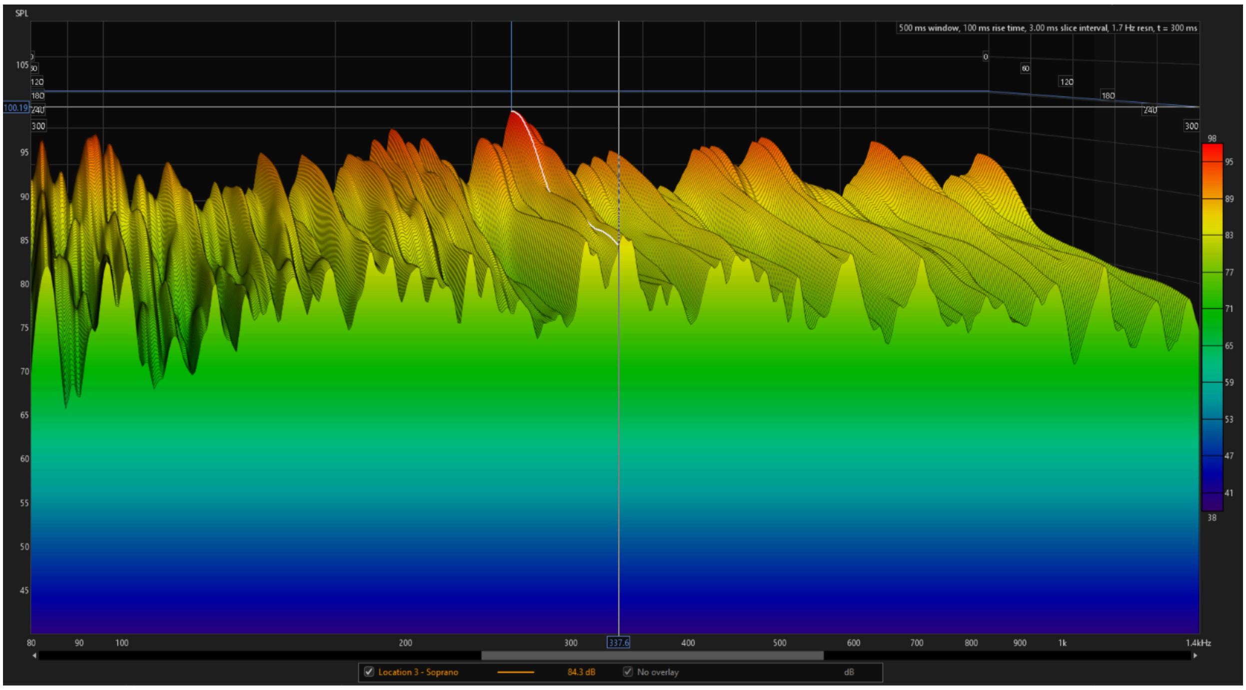


Figure 5.1.14: Waterfall Plot of Position 3 (Soprano)

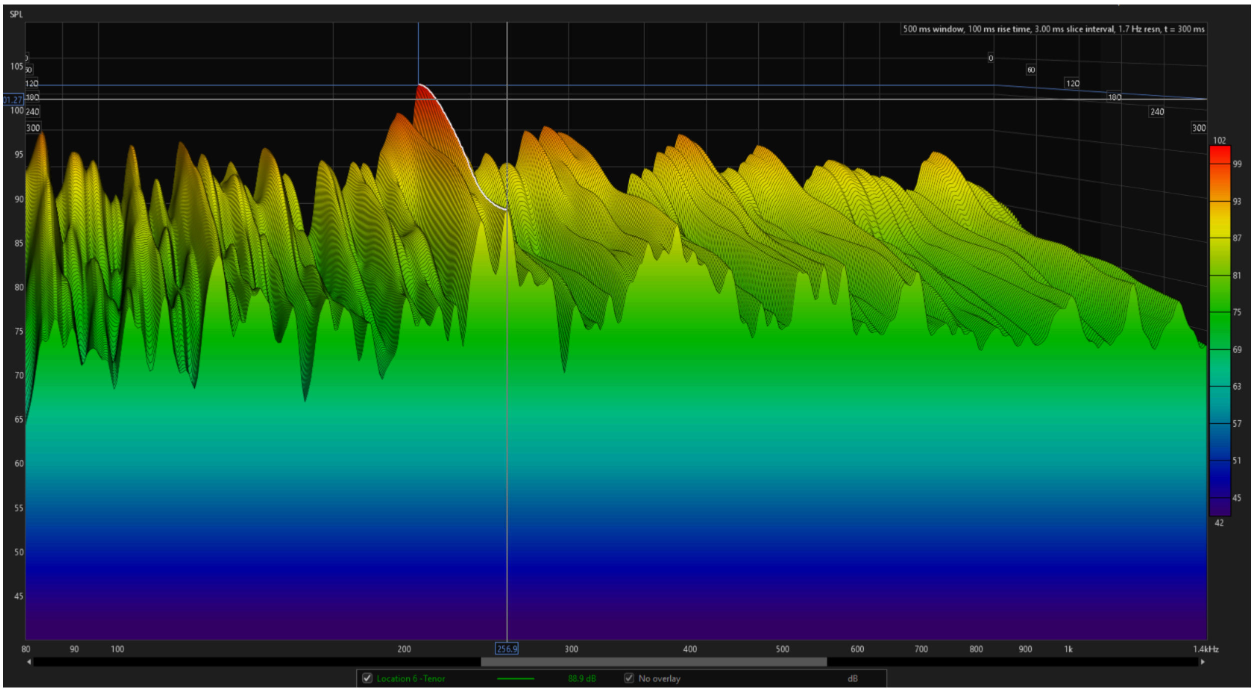

Figure 5.1.15: Waterfall Plot of Position 6 (Tenor)

Using the previously shown waterfall plots, the larger resonances for each position were placed into tables. Tables were created not only with emphasized frequencies but also deemphasized frequencies. These can be found below in tables 5.1.1A and B, 5.1.2A and B, 5.1.3A and B, 5.1.4A and B, and 5.1.5A and B. This tables also include the difference between the Actual Frequency (A) and the Closest Note in equal temperament (CN) as A-CN and the % error as calculated by ((A-CN)/CN)*100. Red highlighted values had the highest SPL and blue had the lowest. Yellow highlighted values are other notable high values and green ones are other notable low values. Within the human vocal range, the main emphasized frequencies from each position were around 256.5 (Position 4), 336.6 (Position 5), 98.2 or 101.5 (Position 2), 332-341 (Position 3), and 257 (Position 6) Hz. This corresponded to the equal temperament tuning of C4, E4, G2 or G#2, E4 to F4, and C4 respectively. In order to determine where to place each singer, vocal ranges were cross referenced with the emphasized frequencies. Singers were asked to self report their approximate vocal range which was placed into table 5.1.6. Based on these values it was determined that the bass should be placed in Position 2, the soprano and mezzo should be in positions 3 and 5, and the alto and tenor should be placed in positions 4 and 6. This allowed for the maximum number of people to sing notes that were emphasized by the space. This created an order of alto, mezzo, bass, soprano, and tenor from left to right around the arch. How these notes are used in the composition will be addressed in Chapter 2 of Implementation.

Table 5.1.1A: Emphasized Frequencies of Position 4

<table>
<tr><th colspan="7">Position 4: Emphasized Frequencies</th><th colspan="2">((A-CN)/CN)*100</th></tr>
<tr><th>Actual Frequency (A)</th><th colspan="2">Closest Note (CN)</th><th colspan="2">CN Frequency</th><th colspan="2">Frequency Diff</th><th colspan="2">% Error</th></tr>
<tr><td>109.8</td><td colspan="2">A2</td><td colspan="2">110</td><td colspan="2">-0.2</td><td colspan="2">0.18</td></tr>
<tr><td>119.1</td><td colspan="2">A#2</td><td colspan="2">117</td><td colspan="2">2.1</td><td colspan="2">1.79</td></tr>
<tr><td>126.3</td><td colspan="2">B2</td><td colspan="2">123</td><td colspan="2">3.3</td><td colspan="2">2.68</td></tr>
<tr><td>147.2</td><td colspan="2">D3</td><td colspan="2">147</td><td colspan="2">0.2</td><td colspan="2">0.13</td></tr>
<tr><td>240.8</td><td>A#3</td><td>B3</td><td>233</td><td>247</td><td>7.8</td><td>-6.2</td><td>3.34</td><td>2.51</td></tr>
<tr><td>256.5</td><td colspan="2">C4</td><td colspan="2">262</td><td colspan="2">-5.5</td><td colspan="2">2.09</td></tr>
<tr><td>352.6</td><td colspan="2">F4</td><td colspan="2">349</td><td colspan="2">3.6</td><td colspan="2">1.03</td></tr>
<tr><td>371.8</td><td colspan="2">F#4</td><td colspan="2">370</td><td colspan="2">1.8</td><td colspan="2">0.48</td></tr>
<tr><td>388.1</td><td colspan="2">G4</td><td colspan="2">392</td><td colspan="2">-3.9</td><td colspan="2">0.99</td></tr>
<tr><td>401.8</td><td>G4</td><td>G#4</td><td>392</td><td>415</td><td>9.8</td><td>-13.2</td><td>2.5</td><td>3.18</td></tr>
<tr><td>521</td><td colspan="2">C5</td><td colspan="2">523</td><td colspan="2">-2</td><td colspan="2">0.38</td></tr>
<tr><td>568</td><td colspan="2">C#5</td><td colspan="2">554</td><td colspan="2">14</td><td colspan="2">2.52</td></tr>
<tr><td>686</td><td colspan="2">F5</td><td colspan="2">698</td><td colspan="2">-12</td><td colspan="2">1.71</td></tr>
<tr><td>697</td><td colspan="2">F5</td><td colspan="2">698</td><td colspan="2">-1</td><td colspan="2">0.14</td></tr>
<tr><td>858</td><td colspan="2">A5</td><td colspan="2">880</td><td colspan="2">-22</td><td colspan="2">2.5</td></tr>
<tr><td>966</td><td colspan="2">B5</td><td colspan="2">988</td><td colspan="2">-22</td><td colspan="2">2.22</td></tr>
</table>

Table 5.1.1B: Deemphasized Frequencies of Position 4

<table>
<tr><th colspan="7">Position 4: Deemphasized Frequencies</th><th colspan="2">((A-CN)/CN)*100</th></tr>
<tr><th>Actual Frequency (A)</th><th colspan="2">Closest Note (CN)</th><th colspan="2">CN Frequency</th><th colspan="2">Frequency Diff</th><th colspan="2">% Error</th></tr>
<tr><td>105</td><td colspan="2">G#2</td><td colspan="2">104</td><td colspan="2">1</td><td colspan="2">0.96</td></tr>
<tr><td>132.4</td><td colspan="2">C3</td><td colspan="2">131</td><td colspan="2">1.4</td><td colspan="2">1.06</td></tr>
<tr><td>155.9</td><td colspan="2">D#3</td><td colspan="2">156</td><td colspan="2">-0.1</td><td colspan="2">0.06</td></tr>
<tr><td>184.3</td><td colspan="2">F#3</td><td colspan="2">185</td><td colspan="2">-0.7</td><td colspan="2">0.37</td></tr>
<tr><td>203.3</td><td>G3</td><td>G#3</td><td>196</td><td>208</td><td>7.3</td><td>-4.7</td><td>3.72</td><td>2.25</td></tr>
<tr><td>221.4</td><td colspan="2">A3</td><td colspan="2">220</td><td colspan="2">1.4</td><td colspan="2">0.63</td></tr>
<tr><td>292.3</td><td colspan="2">D4</td><td colspan="2">294</td><td colspan="2">-1.7</td><td colspan="2">0.57</td></tr>
<tr><td>315.2</td><td colspan="2">D#4</td><td colspan="2">311</td><td colspan="2">4.2</td><td colspan="2">1.35</td></tr>
<tr><td>417.7</td><td colspan="2">G#4</td><td colspan="2">415</td><td colspan="2">2.7</td><td colspan="2">0.65</td></tr>
<tr><td>471</td><td colspan="2">A#4</td><td colspan="2">466</td><td colspan="2">5</td><td colspan="2">1.07</td></tr>
<tr><td>599</td><td colspan="2">D5</td><td colspan="2">587</td><td colspan="2">12</td><td colspan="2">2.04</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| 764 | G5 | 784 | -20 | 2.55 |
| 894 | A5 | 880 | 14 | 1.59 |
| 1023 | C6 | 1047 | -24 | 2.29 |

Table 5.1.2A: Emphasized Frequencies of Position 5

<table>
<tr><th colspan="8">Position 5: Emphasized Frequencies</th><th colspan="2">((A-CN)/CN)*100</th></tr>
<tr><th colspan="2">Actual Frequency (A)</th><th colspan="2">Closest Note (CN)</th><th colspan="2">CN Frequency</th><th colspan="2">Frequency Diff</th><th colspan="2">% Error</th></tr>
<tr><td colspan="2">95.2</td><td>F#2</td><td>G2</td><td>92</td><td>98</td><td>3.2</td><td>-2.8</td><td>3.47</td><td>2.85</td></tr>
<tr><td colspan="2">97.9</td><td colspan="2">G2</td><td colspan="2">98</td><td colspan="2">-0.1</td><td colspan="2">0.1</td></tr>
<tr><td colspan="2">101.7</td><td>G2</td><td>G#2</td><td>98</td><td>104</td><td>3.7</td><td>-2.3</td><td>3.77</td><td>2.21</td></tr>
<tr><td>219.7</td><td>223.8</td><td colspan="2">A3</td><td colspan="2">220</td><td>-0.3</td><td>3.8</td><td>0.13</td><td>1.72</td></tr>
<tr><td>234.5</td><td>236.3</td><td colspan="2">A#3</td><td colspan="2">233</td><td>1.5</td><td>3.3</td><td>0.64</td><td>1.41</td></tr>
<tr><td colspan="2">257.4</td><td colspan="2">C4</td><td colspan="2">262</td><td colspan="2">-4.6</td><td colspan="2">1.75</td></tr>
<tr><td colspan="2">336.6</td><td colspan="2">E4</td><td colspan="2">330</td><td colspan="2">6.6</td><td colspan="2">2</td></tr>
<tr><td colspan="2">433.5</td><td colspan="2">A4</td><td colspan="2">440</td><td colspan="2">-6.5</td><td colspan="2">1.47</td></tr>
<tr><td colspan="2">447.9</td><td colspan="2">A4</td><td colspan="2">440</td><td colspan="2">7.9</td><td colspan="2">1.79</td></tr>
<tr><td colspan="2">465.6</td><td colspan="2">A#4</td><td colspan="2">466</td><td colspan="2">-0.4</td><td colspan="2">0.08</td></tr>
<tr><td colspan="2">503.2</td><td colspan="2">B4</td><td colspan="2">494</td><td colspan="2">9.2</td><td colspan="2">1.86</td></tr>
<tr><td colspan="2">593</td><td colspan="2">D5</td><td colspan="2">587</td><td colspan="2">6</td><td colspan="2">1.02</td></tr>
<tr><td colspan="2">614</td><td colspan="2">D#5</td><td colspan="2">622</td><td colspan="2">-8</td><td colspan="2">1.28</td></tr>
<tr><td colspan="2">712</td><td>F5</td><td>F#5</td><td>698</td><td>740</td><td>14</td><td>-28</td><td>2</td><td>3.78</td></tr>
<tr><td colspan="2">865</td><td colspan="2">A5</td><td colspan="2">880</td><td colspan="2">-15</td><td colspan="2">1.7</td></tr>
<tr><td colspan="2">1002</td><td>B5</td><td>C6</td><td>988</td><td>1047</td><td>14</td><td>-45</td><td>1.41</td><td>4.29</td></tr>
</table>

Table 5.1.2B: Deemphasized Frequencies of Position 5

<table>
<tr><th colspan="7">Position 5: Deemphasized Frequencies</th><th colspan="2">((A-CN)/CN)*100</th></tr>
<tr><th>Actual Frequency (A)</th><th colspan="2">Closest Note (CN)</th><th colspan="2">CN Frequency</th><th colspan="2">Frequency Diff</th><th colspan="2">% Error</th></tr>
<tr><td>119</td><td colspan="2">A#2</td><td colspan="2">117</td><td colspan="2">2</td><td colspan="2">1.7</td></tr>
<tr><td>132</td><td colspan="2">C3</td><td colspan="2">131</td><td colspan="2">1</td><td colspan="2">0.76</td></tr>
<tr><td>149</td><td colspan="2">D3</td><td colspan="2">147</td><td colspan="2">2</td><td colspan="2">1.36</td></tr>
<tr><td>156.5</td><td colspan="2">D#3</td><td colspan="2">156</td><td colspan="2">0.5</td><td colspan="2">0.32</td></tr>
<tr><td>182</td><td colspan="2">F#3</td><td colspan="2">185</td><td colspan="2">-3</td><td colspan="2">1.62</td></tr>
<tr><td>200.4</td><td colspan="2">G3</td><td colspan="2">196</td><td colspan="2">4.4</td><td colspan="2">2.24</td></tr>
<tr><td>211</td><td colspan="2">G#3</td><td colspan="2">208</td><td colspan="2">3</td><td colspan="2">1.44</td></tr>
<tr><td>227.4</td><td>A3</td><td>A#3</td><td>220</td><td>233</td><td>7.4</td><td>-5.6</td><td>3.36</td><td>2.4</td></tr>
<tr><td>302</td><td>D4</td><td>D#4</td><td>294</td><td>311</td><td>8</td><td>-9</td><td>2.72</td><td>2.89</td></tr>
<tr><td>406.8</td><td colspan="2">G#4</td><td colspan="2">415</td><td colspan="2">-8.2</td><td colspan="2">1.97</td></tr>
</table>

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 483 | B4 | | 494 | | -11 | | 2.22 |
| 529 | C5 | | 523 | | 6 | | 1.14 |
| 559 | C#5 | | 554 | | 5 | | 0.9 |
| 641 | D#5 | E5 | 622 | 659 | 19 | -18 | 3.05 | 2.73 |
| 781 | G5 | | 784 | | -3 | | 0.38 |
| 966 | A#2 | B5 | 932 | 988 | 34 | -22 | 3.64 | 2.22 |

Table 5.1.3A: Emphasized Frequencies of Position 2

| **Position 2: Emphasized Frequencies** | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 98.2 | G2 | | 98 | | 0.2 | | 0.2 | |
| 101.5 | G2 | G#2 | 98 | 104 | 3.5 | -2.5 | 3.57 | 2.4 |
| 167.4 | E3 | | 165 | | 2.4 | | 1.45 | |
| 191.5 | F#3 | G3 | 185 | 196 | 6.5 | -4.5 | 3.51 | 2.29 |
| 223.3 | A3 | | 220 | | 3.3 | | 1.5 | |
| 238.8 | A#3 | | 233 | | 5.8 | | 2.48 | |
| 305.8 | D4 | D#4 | 294 | 311 | 11.8 | -5.2 | 4.01 | 1.67 |
| 320.5 | D#4 | E4 | 311 | 330 | 9.5 | -9.5 | 3.05 | 2.87 |
| 331.8 | E4 | | 330 | | 1.8 | | 0.54 | |
| 354.2 | F4 | | 349 | | 5.2 | | 1.48 | |
| 399.5 | G4 | | 392 | | 7.5 | | 1.91 | |
| 408.6 | G#4 | | 415 | | -6.4 | | 1.54 | |
| 462 | A#4 | | 466 | | -4 | | 0.85 | |
| 485 | B4 | | 494 | | -9 | | 1.82 | |
| 577 | D5 | | 587 | | -10 | | 1.7 | |
| 677 | E5 | | 659 | | 18 | | 2.73 | |
| 692 | F5 | | 698 | | -6 | | 0.85 | |
| 785 | G5 | | 784 | | 1 | | 0.12 | |
| 938 | A#5 | | 932 | | 6 | | 0.64 | |
| 1063 | C6 | | 1047 | | 16 | | 1.52 | |

Table 5.1.3B: Deemphasized Frequencies of Position 2

| **Position 2: Deemphasized Frequencies** | | | | ((A-CN)/CN)*100 |
|---|---|---|---|---|
| Actual Frequency (A) | Closest Note (CN) | CN Frequency | Frequency Diff | % Error |
| 105 | G#2 | 104 | 1 | 0.96 |
| 117 | A#2 | 117 | 0 | 0 |
| 131.6 | C3 | 131 | 0.6 | 0.45 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 147.8 | D3 | | 147 | | 0.8 | | 0.54 | |
| 178 | F3 | F#3 | 178 | 185 | 0 | -7 | 0 | 3.78 |
| 202.8 | G3 | G#3 | 196 | 208 | 6.8 | -5.2 | 3.46 | 2.49 |
| 227.4 | A3 | A#3 | 220 | 233 | 7.4 | -5.6 | 3.36 | 2.4 |
| 260.7 | C4 | | 262 | | -1.3 | | 0.49 | |
| 284.1 | C#4 | D4 | 277 | 294 | 7.1 | -9.9 | 2.56 | 3.36 |
| 365.9 | F#4 | | 370 | | -4.1 | | 1.1 | |
| 516 | C5 | | 523 | | -7 | | 1.33 | |
| 636 | D#5 | E5 | 622 | 659 | 14 | -23 | 2.25 | 3.49 |
| 745 | F#5 | | 740 | | 5 | | 0.67 | |
| 849 | G#5 | | 831 | | 18 | | 2.16 | |
| 901 | A5 | A#5 | 880 | 932 | 21 | -31 | 2.38 | 3.32 |
| 997 | B5 | | 988 | | 9 | | 0.91 | |

Table 5.1.4A: Emphasized Frequencies of Position 3

| **Position 3: Emphasized Frequencies** | | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 97 | | G2 | | 98 | | -1 | | 1.02 | |
| 101.9 | | G2 | G#2 | 104 | 98 | -2.1 | 3.9 | 2.01 | 3.97 |
| 159.7 | | D#3 | E3 | 156 | 165 | 3.7 | -5.3 | 2.37 | 3.21 |
| 181.3 | | F3 | F#3 | 175 | 185 | 6.3 | -3.7 | 3.6 | 2 |
| 235 | | A#3 | | 233 | | 2 | | 0.85 | |
| 246.3 | | B3 | | 247 | | -0.7 | | 0.28 | |
| 257.3 | | C4 | | 262 | | -4.7 | | 1.79 | |
| 311 | | D#4 | | 311 | | 0 | | 0 | |
| 332 | 341 | E4 | F4 | 330 | 349 | 2 | -8 | 0.6 | 2.29 |
| 421 | | G#4 | | 415 | | 6 | | 1.44 | |
| 451 | | A4 | | 440 | | 11 | | 2.5 | |
| 579 | | D5 | | 587 | | -8 | | 1.36 | |
| 595 | | D5 | | 587 | | 8 | | 1.36 | |
| 706 | | F5 | | 698 | | 8 | | 1.14 | |
| 988 | | B5 | | 988 | | 0 | | 0 | |
| 1086 | | C#6 | | 1109 | | -23 | | 2.07 | |

Table 5.1.4B: Deemphasized Frequencies of Position 3

| **Position 3: Deemphasized Frequencies** | | | | ((A-CN)/CN)*100 |
|---|---|---|---|---|
| Actual Frequency (A) | Closest Note (CN) | CN Frequency | Frequency Diff | % Error |
| 109 | A2 | 110 | -1 | 0.9 |
| 118 | A#2 | 117 | 1 | 0.85 |
| 132.2 | C3 | 131 | 1.2 | 0.91 |
| 147 | D3 | 147 | 0 | 0 |
| 174 | F3 | 175 | -1 | 0.57 |
| 198.7 | G3 | 196 | 2.7 | 1.37 |
| 228.8 | A#3 | 233 | -4.2 | 1.8 |
| 277 | C#4 | 277 | 0 | 0 |
| 296 | D4 | 294 | 2 | 0.68 |
| 326 | E4 | 330 | -4 | 1.21 |
| 365 | F#4 | 370 | -5 | 1.35 |
| 406 | G#4 | 415 | -9 | 2.16 |
| 540 | C#5 | 554 | -14 | 2.52 |
| 652 | E5 | 659 | -7 | 1.06 |
| 794 | G4 | 784 | 10 | 1.27 |
| 1032 | C6 | 1047 | -15 | 1.43 |

Table 5.1.5A: Emphasized Frequencies of Position 6

| **Position 6: Emphasized Frequencies** | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 109.9 | A2 | | 110 | | -0.1 | | 0.09 | |
| 127.3 | B2 | C3 | 123 | 131 | 4.3 | -3.7 | 3.49 | 2.82 |
| 135.4 | C3 | C#3 | 131 | 139 | 4.4 | -3.6 | 3.35 | 2.58 |
| 162 | E3 | | 165 | | -3 | | 1.81 | |
| 191.5 | G3 | | 196 | | -4.5 | | 2.29 | |
| 240.8 | A#3 | B3 | 233 | 247 | 7.8 | -6.2 | 3.34 | 2.51 |
| 257 | C4 | | 262 | | -5 | | 1.9 | |
| 352.7 | F4 | | 349 | | 3.7 | | 1.06 | |
| 372.7 | F#4 | | 370 | | 2.7 | | 0.72 | |
| 388.3 | G4 | | 392 | | -3.7 | | 0.94 | |
| 521 | C5 | | 523 | | -2 | | 0.38 | |
| 554 | C#5 | | 554 | | 0 | | 0 | |
| 698 | F5 | | 698 | | 0 | | 0 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 828 | G#5 | | 831 | | -3 | | 0.36 | |
| 859 | G#5 | A5 | 831 | 880 | 28 | -21 | 3.36 | 2.38 |
| 932 | A#5 | | 932 | | 0 | | 0 | |

Table 5.1.5B: Deemphasized Frequencies of Position 6

| **Position 6: Deemphasized Frequencies** | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 120.5 | A#2 | B2 | 117 | 123 | 3.5 | -2.5 | 2.99 | 2.03 |
| 148.7 | D3 | | 147 | | 1.7 | | 1.15 | |
| 157.4 | D#3 | | 156 | | 1.4 | | 0.89 | |
| 179.8 | F3 | F#3 | 175 | 185 | 4.8 | -5.2 | 2.74 | 2.81 |
| 189.2 | F#3 | G3 | 185 | 196 | 4.2 | -6.8 | 2.27 | 3.46 |
| 202.4 | G3 | G#3 | 196 | 208 | 6.4 | -5.6 | 3.26 | 2.69 |
| 229.7 | A3 | A#3 | 220 | 233 | 9.7 | -3.3 | 4.4 | 1.41 |
| 249.3 | B3 | | 247 | | 2.3 | | 0.93 | |
| 294.1 | D4 | | 294 | | 0.1 | | 0.03 | |
| 321 | D#4 | E4 | 311 | 330 | 10 | -9 | 3.21 | 2.72 |
| 430 | G#4 | A4 | 415 | 440 | 15 | -10 | 3.61 | 2.27 |
| 464 | A#4 | | 466 | | -2 | | 0.42 | |
| 599 | D5 | | 587 | | 12 | | 2.04 | |
| 716 | F5 | | 698 | | 18 | | 2.57 | |

Table 5.1.6: Self Reported Singer Approximate Vocal Range

| **Singer Approximate Vocal Range** | | | | |
|---|---|---|---|---|
| Singer | True Lowest | Average Lowest | Average Highest | True Highest |
| Luna (Soprano) | E3 | G3 | Ab5 | D6 |
| Andy (Mezzo) | D3 | D#3 | C#6 | E6 |
| Sophia (Alto) | C3 | C3 | C6 | C6 |
| Graeme (Tenor) | E3 | E3 | A4 | B4 |
| Josh (Bass) | F2 | G2 | G4 | G5 |

### *5.1.3 Grace Epiphany Episcopal Church: Measurements*

The measurements of Grace Epiphany Episcopal Church (GEEC) were taken on May 30th. The process began by setting up the speaker and microphone on stands and ensuring everything was properly connected and calibrated. GEEC is a more gothic style church made of stone with wood beams and ceiling. Views from the back and front of the sanctuary can be seen in figures 5.1.16 and 17. The floor of the sanctuary is mostly wood but has a strip of tile down the center of the space. It has a partial cross shape with a long main chamber, upper choir stall area, and left wing with a small chapel space (Figure 5.1.18). However it does not have a right wing making it lack the full cross structure of many churches. There are many stained glass windows throughout the space both on the lower levels on either side of the pews as well as on the upper levels before the wood of the ceiling begins to arch to the center. There are also two large pieces of stained glass on either end of the church and panels in the side chapel area.

Figure 5.1.16: View of GEEC Sanctuary from the Back

Figure 5.1.17: View of GEEC Sanctuary from the Front

Figure 5.1.18: View of GEEC Sanctuary Side Chapel

Test measurements were taken in the choir stall upper area, side chapel, and in the center in front of the altar. When testing sounds in the choir stall area, they sounded a bit duller and less reverberant. Though the side chapel seemed interesting in terms of a spread of musicians, the overall sound as well as the measurements did not seem remarkable. Any resonances from this position seemed to be mostly outside of the vocal range. The center area showed a few interesting harmonics and projected best in the space and was therefore chosen for further tests. This space was not nearly as resonant sounding as the previous space overall. The measurement microphone was placed a bit farther away to get more of the room sound for the final recording. This can be seen in figure 5.1.19. Once again arch positioning was chosen. Measurements were taken in each position along this arch and each spot was marked with a white tape square. These positions can be seen in figure 5.1.20 below. The overall speaker placements and microphone position relative to the space including measurements can be seen in figure 5.1.21.

Figure 5.1.19: Measurement Microphone Placement for GEEC

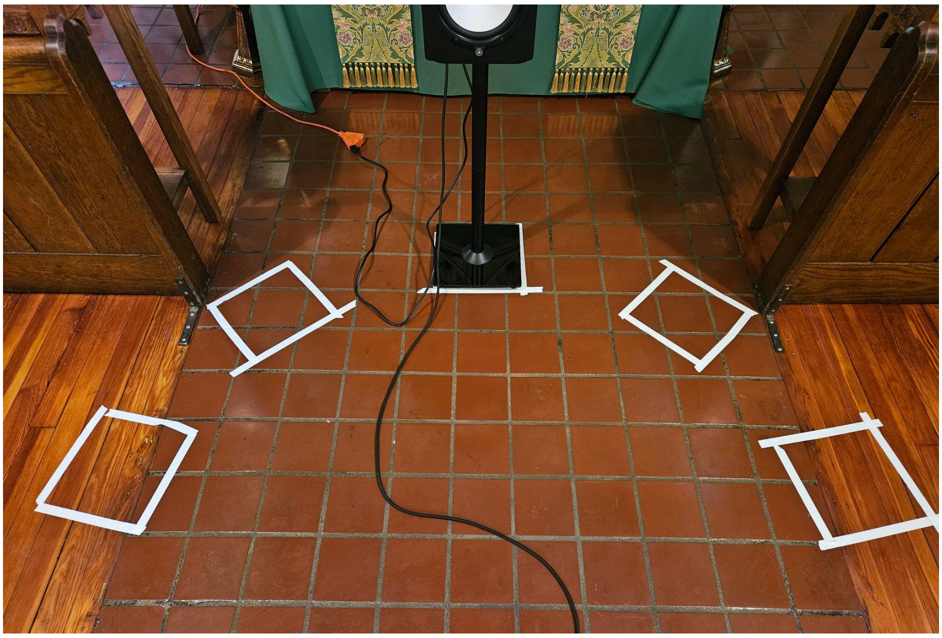

Figure 5.1.20: Final Arch Positions for GEEC

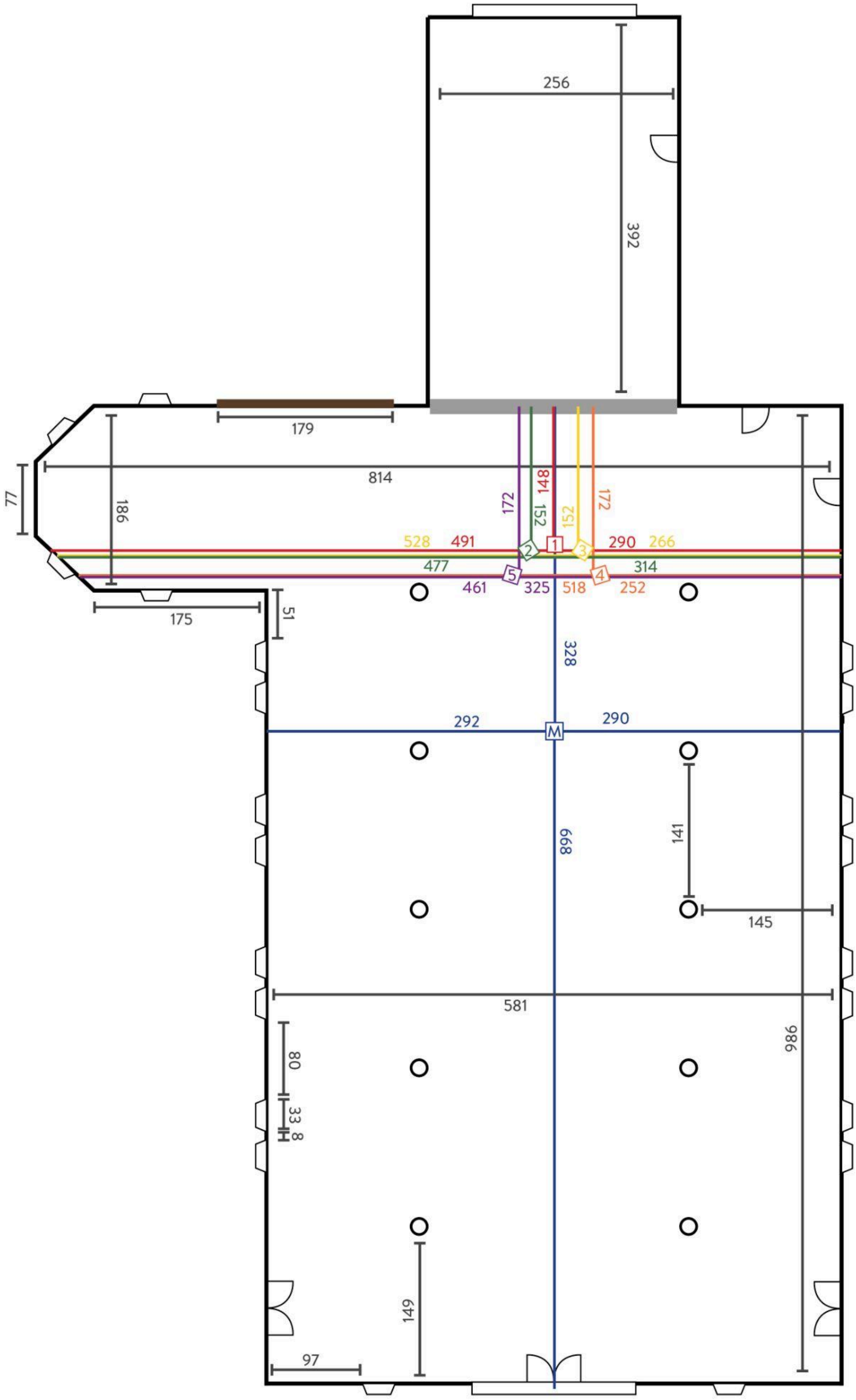


Figure 5.1.21: Diagram of GEEC with Microphone and Speaker Placements

Similarly to the analysis of the PCCH, each measurement was set to ⅓ octave smoothing for viewing. In order to focus on the resonances, the SPL graphs and Waterfall plots were analyzed. The combined SPL graph and waterfall plot can be found in figures 5.1.22, 23, 24, 25, 26, and 27. The measurements varied slightly in the different positions but overall showed a number of particularly resonant frequencies with the human vocal range which at its outer limits can reach approximately from 70 to 1300 Hz with some exceptions. For my group, the lowest range was Josh at an F2 (87 Hz) and the highest range was myself at an E6 (1319 Hz). Unfortunately, the primary resonant frequency of the space appeared to be between 67 and 69 Hz (C#2) which was outside the vocal range of the group however there were plenty of other pitches to work with from the analysis.

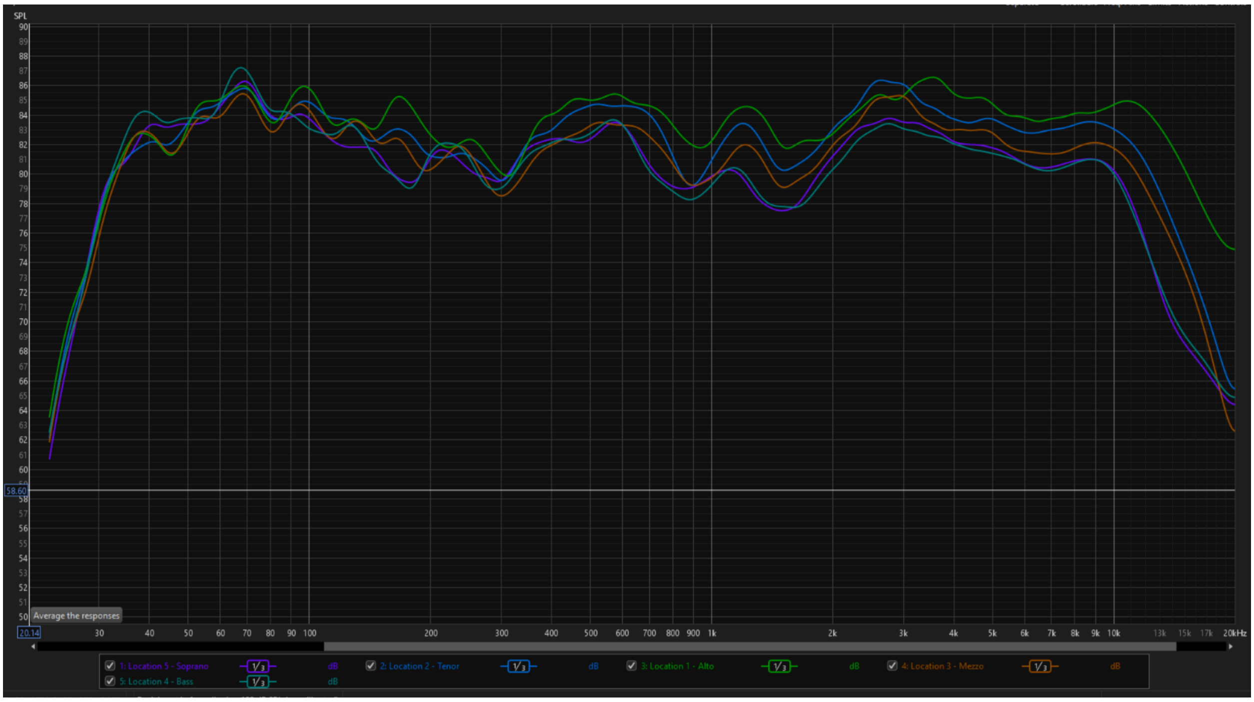


Figure 5.1.22: All SPL from Used Positions

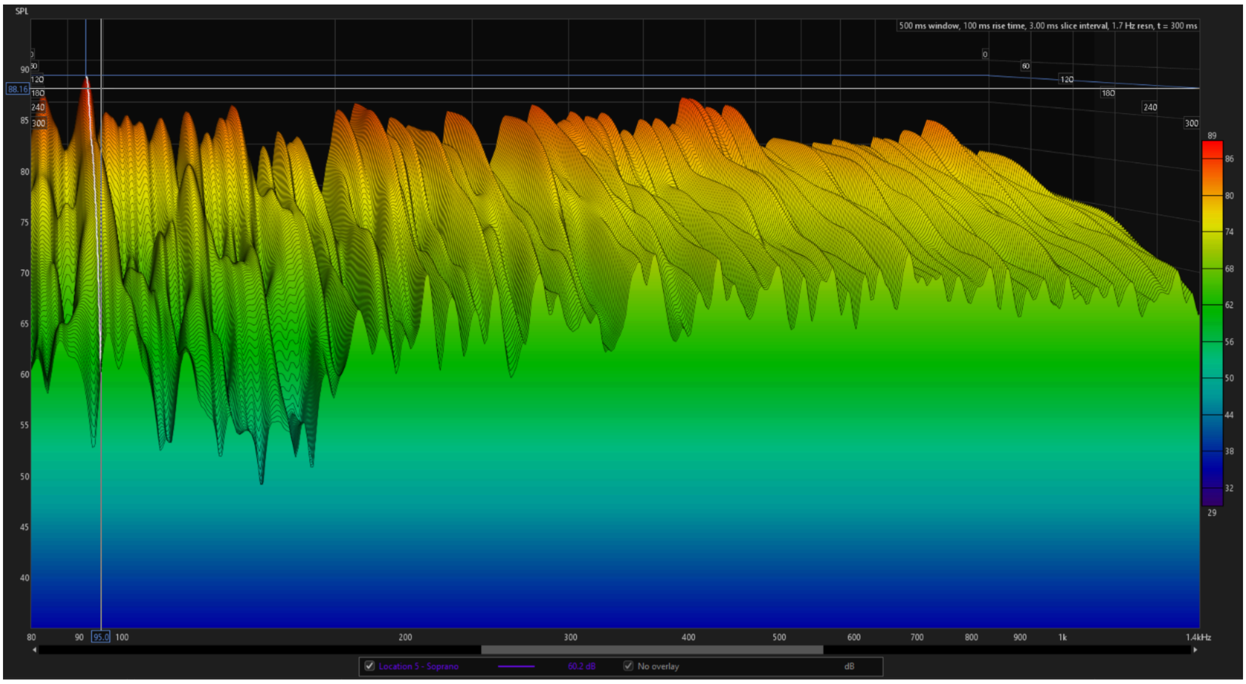


Figure 5.1.23: Waterfall Plot of Position 5 (Soprano)

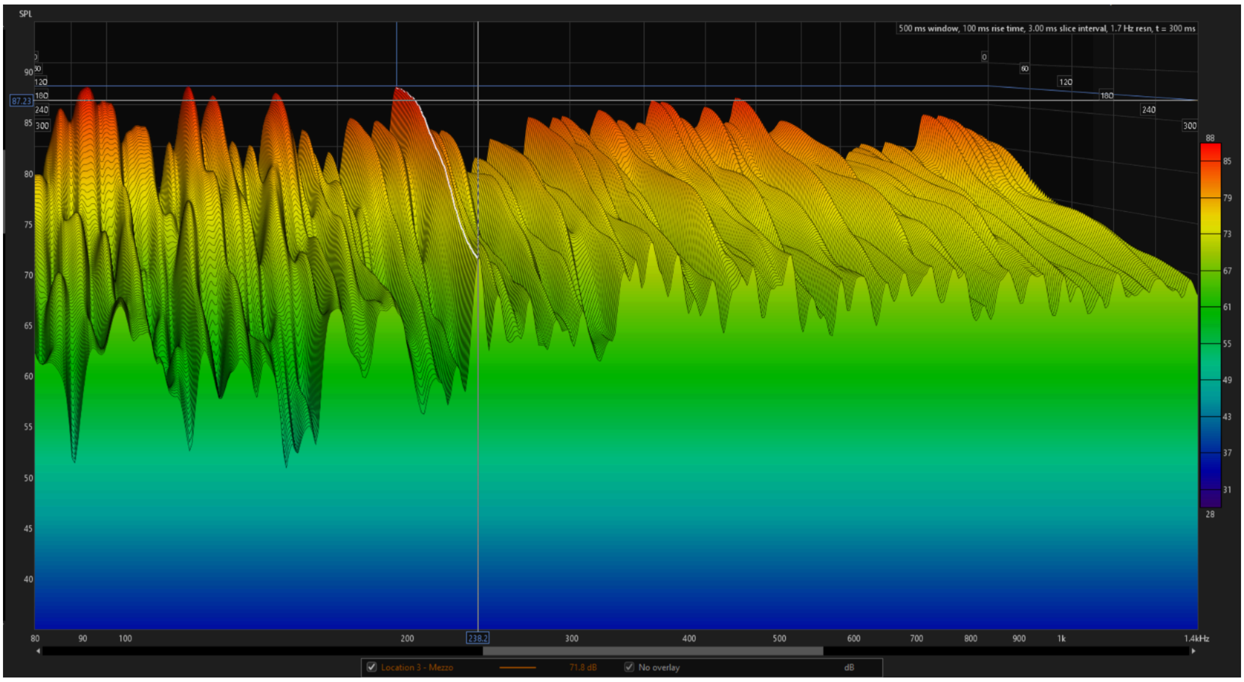


Figure 5.1.24: Waterfall Plot of Position 3 (Mezzo)

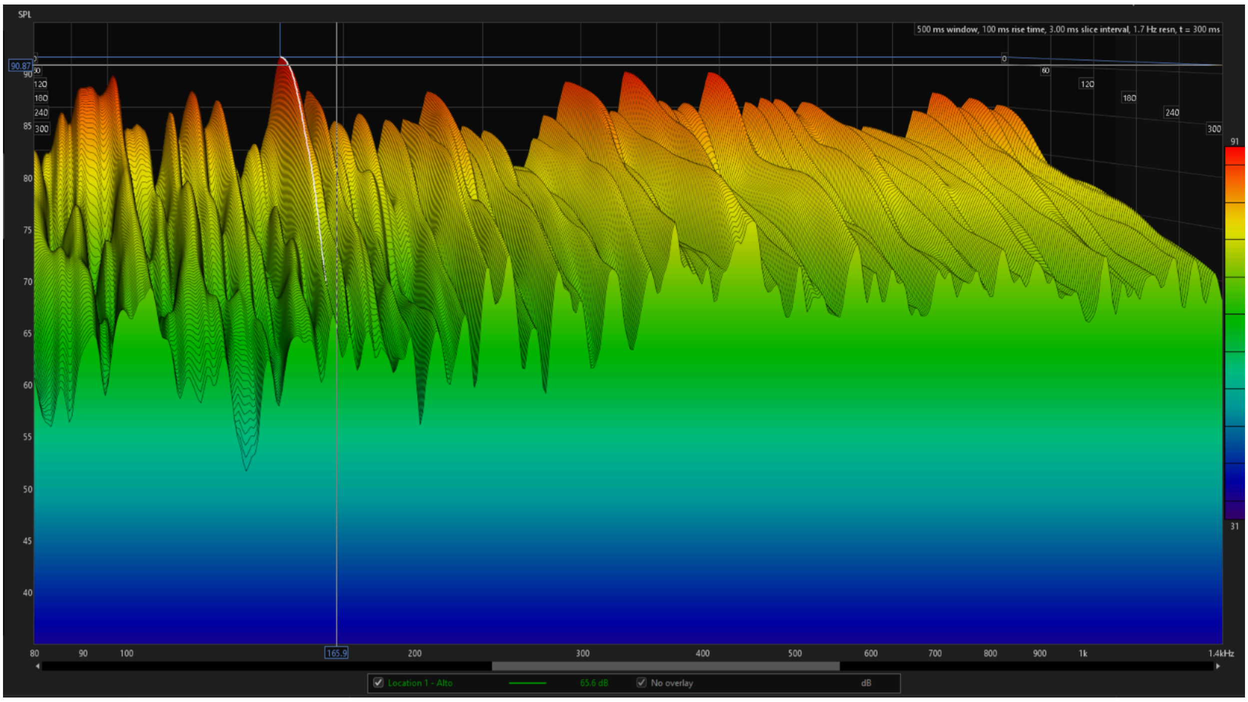

Figure 5.1.25: Waterfall Plot of Position 1 (Alto)

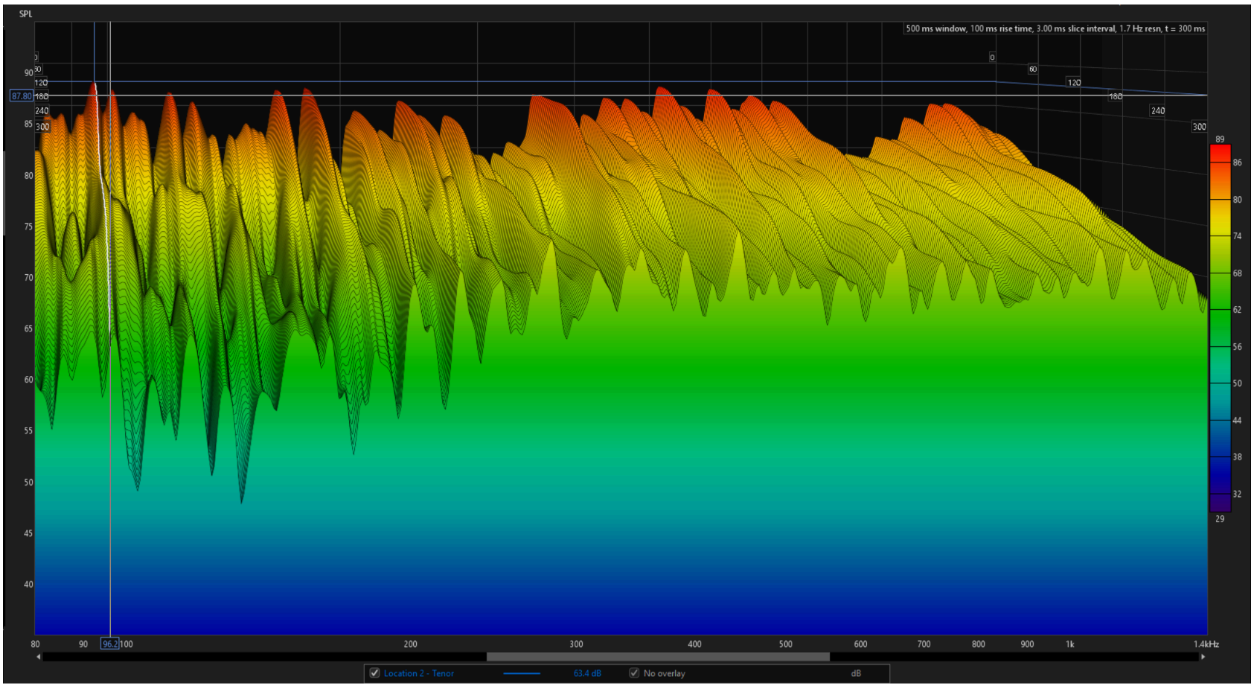

Figure 5.1.26: Waterfall Plot of Position 2 (Tenor)

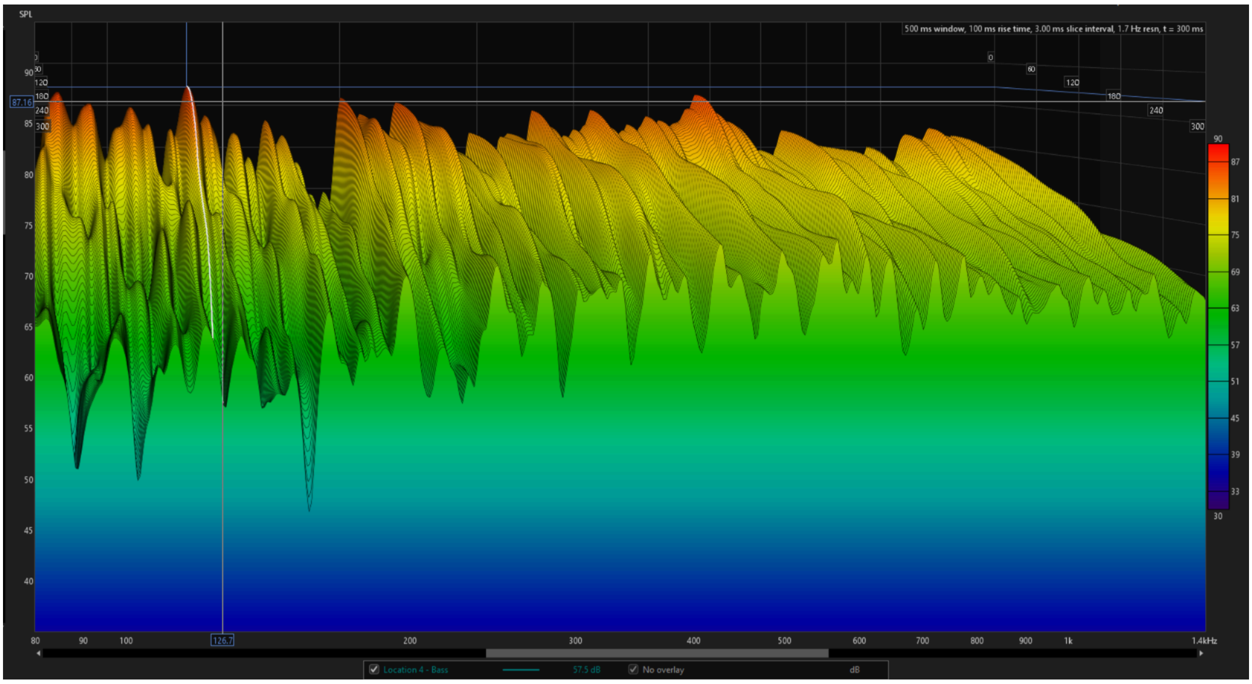

Figure 5.1.27: Waterfall Plot of Position 4 (Bass)

Similarly to the PCCH data, the emphasized and deemphasized frequencies were taken from the waterfall plots and put into tables. These can be found below in tables 5.1.6A and B, 5.1.7A and B, 5.1.8A and B, 5.1.9A and B, and 5.1.10A and B. This tables also include the difference between the Actual Frequency (A) and the Closest Note in equal temperament (CN) as A-CN and the % error as calculated by ((A-CN)/CN)*100. Red highlighted values had the highest SPL and blue had the lowest. Yellow highlighted values are other notable high values and green ones are other notable low values. It is overall notable that for GEEC in comparison to PCCH, there were more equally high peaks shown in the waterfall plots with a more even distribution. Because of this there are many more data points shown in the tables below. Particularly for position 2, there were many equally elevated frequencies therefore there are many more yellow highlighted frequency areas. Within the human vocal range, the main emphasized frequencies from each position were around 94.7 (Position 5), 238.1 (Position 3), 166.1 (Position 1), 95.8 (Position 2), and 126.9 (Position 4) Hz. This corresponded to the equal temperament tuning of F#2 or G2, A#3, E3, F#2, and B2 respectively. Most of these values were fairly low therefore when picking the placement of singers, it was important to look at the distribution overall of more resonant frequencies when selecting their positions. Based on the ranges shown in the previous section in table 5.1.6 and the distribution of emphasized frequencies, it was determined that the soprano and mezzo should be in positions 5 and 3, the alto and tenor should be placed in positions 1 and 2, and the bass should be placed in Position 4. This created an order of soprano, mezzo, alto, tenor, and bass from left to right around the arch. How these notes were used in the composition will be addressed in Section 2 of this Chapter.

Table 5.1.6A: Emphasized Frequencies of Position 5

| **Position 5: Emphasized Frequencies** | | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 77.2 | | D#2 | | 78 | | -0.8 | | 1.02 | |
| 82.4 | | E2 | | 82 | | 0.4 | | 0.48 | |
| 83.7 | 86.2 | E2 | F2 | 82 | 87 | 1.7 | 4.2 | 2.07 | 5.12 |
| 94.7 | | F#2 | G2 | 92 | 98 | 2.7 | -3.3 | 2.93 | 3.36 |
| 102.9 | | G#2 | | 104 | | -1.1 | | 1.05 | |
| 106.8 | | G#2 | | 104 | | 2.8 | | 2.69 | |
| 112.9 | | A2 | | 110 | | 2.9 | | 2.63 | |
| 120.1 | | A#2 | B2 | 117 | 123 | 3.1 | -2.9 | 2.64 | 2.35 |
| 126.6 | | B2 | | 123 | | 3.6 | | 2.92 | |
| 133.2 | | C3 | | 131 | | 2.2 | | 1.67 | |
| 145.4 | | D3 | | 147 | | -1.6 | | 1.08 | |
| 151.7 | | D3 | D#3 | 147 | 156 | 4.7 | -4.3 | 3.19 | 2.75 |
| 159.6 | | D#3 | | 156 | | 3.6 | | 2.3 | |
| 167.6 | | E3 | | 165 | | 2.6 | | 1.57 | |
| 199.5 | | G3 | | 196 | | 3.5 | | 1.78 | |
| 210.2 | | G#3 | | 208 | | 2.2 | | 1.05 | |
| 236.2 | | A#3 | | 233 | | 3.2 | | 1.37 | |
| 248 | | B3 | | 247 | | 1 | | 0.4 | |
| 278.7 | | C#4 | | 277 | | 1.7 | | 0.61 | |
| 293.7 | | D4 | | 294 | | -0.3 | | 0.1 | |
| 321.8 | 327.2 | D#4 | E4 | 311 | 330 | 10.8 | 16.2 | 3.47 | 5.2 |
| 352.5 | | F4 | | 349 | | 3.5 | | 1 | |
| 421.6 | 426.7 | G#4 | | 415 | | 6.6 | 11.7 | 1.59 | 2.81 |
| 495.9 | | B4 | | 494 | | 1.9 | | 0.38 | |
| 561 | 576 | C#5 | D5 | 554 | 587 | 7 | 22 | 1.26 | 3.97 |
| 614 | | D#5 | | 622 | | -8 | | 1.28 | |
| 638 | | D#5 | | 622 | | 16 | | 2.57 | |
| 741 | | F#5 | | 740 | | 1 | | 0.13 | |
| 1074 | | C6 | C#6 | 1047 | 1109 | 27 | -35 | 2.57 | 3.15 |
| 1152 | | D6 | | 1175 | | -23 | | 1.95 | |

Table 5.1.6B: Deemphasized Frequencies of Position 5

| **Position 5: Deemphasized Frequencies** | | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 80.2 | | D#2 | E2 | 78 | 82 | 2.2 | -1.8 | 2.82 | 2.19 |
| 89.2 | | F2 | | 87 | | 2.2 | | 2.52 | |
| 99.4 | | G2 | | 98 | | 1.4 | | 1.42 | |
| 102.9 | | G#2 | | 104 | | -1.1 | | 1.05 | |
| 116 | | A#2 | | 117 | | -1 | | 0.85 | |
| 127.7 | | B2 | C3 | 123 | 131 | 4.7 | -3.3 | 3.82 | 2.51 |
| 139.9 | | C#3 | | 139 | | 0.9 | | 0.64 | |
| 154.3 | 156.6 | D#3 | | 156 | | -1.7 | 0.6 | 1.08 | 0.38 |
| 174.2 | | F3 | | 175 | | -0.8 | | 0.45 | |
| 179.3 | 191.5 | F3 | G3 | 175 | 196 | 4.3 | 16.5 | 2.45 | 9.42 |
| 205.3 | 210.2 | G#3 | | 208 | | -2.7 | 2.2 | 1.29 | 1.05 |
| 227.2 | | A#3 | | 233 | | -5.8 | | 2.48 | |
| 240.6 | | A#3 | B3 | 233 | 247 | 7.6 | -6.4 | 3.26 | 2.59 |
| 262.3 | | C4 | | 262 | | 0.3 | | 0.11 | |
| 287.8 | 290.7 | D4 | | 294 | | -6.2 | -3.3 | 2.1 | 1.12 |
| 312.1 | | D#4 | | 311 | | 1.1 | | 0.35 | |
| 343.7 | | F4 | | 349 | | -5.3 | | 1.51 | |
| 408.3 | | G#4 | | 415 | | -6.7 | | 1.61 | |
| 417.6 | | G#4 | | 415 | | 2.6 | | 0.62 | |
| 465.8 | | A#4 | | 466 | | -0.2 | | 0.04 | |
| 523.4 | | C5 | | 523 | | 0.4 | | 0.07 | |
| 583 | | D5 | | 587 | | -4 | | 0.68 | |
| 670 | | E5 | | 659 | | 11 | | 1.66 | |
| 741 | | F#5 | | 740 | | 1 | | 0.13 | |
| 1110 | | C#6 | | 1109 | | 1 | | 0.09 | |

Table 5.1.7A: Emphasized Frequencies of Position 3

<table>
<tr><th colspan="8">Position 3: Emphasized Frequencies</th><th colspan="2">((A-CN)/CN)*100</th></tr>
<tr><th colspan="2">Actual Frequency (A)</th><th colspan="2">Closest Note (CN)</th><th colspan="2">CN Frequency</th><th colspan="2">Frequency Diff</th><th colspan="2">% Error</th></tr>
<tr><td colspan="2">94.3</td><td colspan="2">F#2</td><td colspan="2">92</td><td colspan="2">2.3</td><td colspan="2">2.5</td></tr>
<tr><td colspan="2">99.5</td><td colspan="2">G2</td><td colspan="2">98</td><td colspan="2">1.5</td><td colspan="2">1.53</td></tr>
<tr><td colspan="2">106.3</td><td>G#2</td><td>A2</td><td>104</td><td>110</td><td>2.3</td><td>-3.7</td><td>2.21</td><td>3.36</td></tr>
<tr><td colspan="2">120.9</td><td>A#2</td><td>B2</td><td>117</td><td>123</td><td>3.9</td><td>-2.1</td><td>3.33</td><td>1.7</td></tr>
<tr><td colspan="2">127.5</td><td>B2</td><td>C3</td><td>123</td><td>131</td><td>4.5</td><td>-3.5</td><td>3.65</td><td>2.67</td></tr>
<tr><td colspan="2">137.4</td><td colspan="2">C#3</td><td colspan="2">139</td><td colspan="2">-1.6</td><td colspan="2">1.15</td></tr>
<tr><td colspan="2">145.6</td><td colspan="2">D3</td><td colspan="2">147</td><td colspan="2">-1.4</td><td colspan="2">0.95</td></tr>
<tr><td colspan="2">153.9</td><td colspan="2">D#3</td><td colspan="2">156</td><td colspan="2">-2.1</td><td colspan="2">1.34</td></tr>
<tr><td colspan="2">166.2</td><td colspan="2">E3</td><td colspan="2">165</td><td colspan="2">1.2</td><td colspan="2">0.72</td></tr>
<tr><td colspan="2">180.1</td><td>F3</td><td>F#3</td><td>175</td><td>185</td><td>5.1</td><td>-4.9</td><td>2.91</td><td>2.64</td></tr>
<tr><td>208.2</td><td>212.9</td><td colspan="2">G#3</td><td colspan="2">208</td><td>0.2</td><td>4.9</td><td>0.09</td><td>2.35</td></tr>
<tr><td colspan="2">223.8</td><td colspan="2">A3</td><td colspan="2">220</td><td colspan="2">3.8</td><td colspan="2">1.72</td></tr>
<tr><td colspan="2">238.1</td><td colspan="2">A#3</td><td colspan="2">223</td><td colspan="2">15.1</td><td colspan="2">6.77</td></tr>
<tr><td colspan="2">251.2</td><td colspan="2">B3</td><td colspan="2">247</td><td colspan="2">4.2</td><td colspan="2">1.7</td></tr>
<tr><td colspan="2">271.8</td><td>C4</td><td>C#4</td><td>262</td><td>277</td><td>9.8</td><td>-5.2</td><td>3.74</td><td>1.87</td></tr>
<tr><td colspan="2">316.7</td><td colspan="2">D#4</td><td colspan="2">311</td><td colspan="2">5.7</td><td colspan="2">1.83</td></tr>
<tr><td>349.7</td><td>353.3</td><td colspan="2">F4</td><td colspan="2">349</td><td>0.7</td><td>4.3</td><td>0.2</td><td>1.23</td></tr>
<tr><td>374.4</td><td>379.8</td><td colspan="2">F#4</td><td colspan="2">370</td><td>4.4</td><td>9.8</td><td>1.18</td><td>2.64</td></tr>
<tr><td colspan="2">391.8</td><td colspan="2">G4</td><td colspan="2">392</td><td colspan="2">-0.2</td><td colspan="2">0.05</td></tr>
<tr><td>437</td><td>447</td><td colspan="2">A4</td><td colspan="2">440</td><td>-3</td><td>7</td><td>0.68</td><td>1.59</td></tr>
<tr><td colspan="2">463</td><td colspan="2">A#4</td><td colspan="2">466</td><td colspan="2">-3</td><td colspan="2">0.64</td></tr>
<tr><td colspan="2">491</td><td colspan="2">B4</td><td colspan="2">494</td><td colspan="2">-3</td><td colspan="2">0.6</td></tr>
<tr><td colspan="2">514</td><td colspan="2">C5</td><td colspan="2">523</td><td colspan="2">-9</td><td colspan="2">1.72</td></tr>
<tr><td colspan="2">529</td><td colspan="2">C5</td><td colspan="2">523</td><td colspan="2">6</td><td colspan="2">1.14</td></tr>
<tr><td colspan="2">559</td><td colspan="2">C#5</td><td colspan="2">554</td><td colspan="2">5</td><td colspan="2">0.9</td></tr>
<tr><td colspan="2">600</td><td>D5</td><td>D#5</td><td>587</td><td>622</td><td>13</td><td>-22</td><td>2.21</td><td>3.53</td></tr>
<tr><td colspan="2">657</td><td colspan="2">E5</td><td colspan="2">659</td><td colspan="2">-2</td><td colspan="2">0.3</td></tr>
<tr><td>737</td><td>761</td><td colspan="2">F#5</td><td colspan="2">740</td><td>-3</td><td>21</td><td>0.4</td><td>2.83</td></tr>
<tr><td colspan="2">928</td><td colspan="2">A#5</td><td colspan="2">932</td><td colspan="2">-4</td><td colspan="2">0.42</td></tr>
<tr><td colspan="2">957</td><td>A#5</td><td>B5</td><td>932</td><td>988</td><td>25</td><td>-31</td><td>2.68</td><td>3.13</td></tr>
<tr><td colspan="2">1029</td><td colspan="2">C6</td><td colspan="2">1047</td><td colspan="2">-18</td><td colspan="2">1.71</td></tr>
<tr><td colspan="2">1155</td><td colspan="2">D6</td><td colspan="2">1175</td><td colspan="2">-20</td><td colspan="2">1.7</td></tr>
<tr><td colspan="2">1209</td><td colspan="2">D6</td><td colspan="2">1175</td><td colspan="2">34</td><td colspan="2">2.89</td></tr>
<tr><td colspan="2">1244</td><td colspan="2">D#6</td><td colspan="2">1245</td><td colspan="2">-1</td><td colspan="2">0.08</td></tr>
</table>

Table 5.1.7B: Deemphasized Frequencies of Position 3

| **Position 3: Deemphasized Frequencies** | | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 88.6 | | F2 | | 87 | | 1.6 | | 1.83 | |
| 102.6 | | G#2 | | 104 | | -1.4 | | 1.34 | |
| 117.1 | | A#2 | | 117 | | 0.1 | | 0.08 | |
| 127.7 | | B2 | C3 | 123 | 131 | 4.7 | -3.3 | 3.82 | 2.51 |
| 137.9 | | C#3 | | 139 | | -1.1 | | 0.79 | |
| 148.5 | | D3 | | 147 | | 1.5 | | 1.02 | |
| 159.7 | | D#3 | | 156 | | 3.7 | | 2.37 | |
| 175.6 | | F3 | | 175 | | 0.6 | | 0.34 | |
| 199.6 | 207.2 | G3 | G#3 | 196 | 208 | 3.6 | 11.2 | 1.83 | 5.71 |
| 217.7 | | A3 | | 220 | | -2.3 | | 1.04 | |
| 230.2 | 244.9 | A#3 | | 233 | | -2.8 | 11.9 | 1.2 | 5.1 |
| 244.9 | | B3 | | 247 | | -2.1 | | 0.85 | |
| 256.8 | | B3 | C4 | 247 | 262 | 9.8 | -5.2 | 3.96 | 1.98 |
| 264.9 | | C4 | | 262 | | 2.9 | | 1.1 | |
| 282.5 | | C#4 | | 277 | | 5.5 | | 1.98 | |
| 297.4 | | D4 | | 294 | | 3.4 | | 1.15 | |
| 321.7 | | D#4 | E4 | 311 | 330 | 10.7 | -8.3 | 3.44 | 2.51 |
| 331.2 | | E4 | | 330 | | 1.2 | | 0.36 | |
| 356 | | F4 | | 349 | | 7 | | 2 | |
| 399.7 | | G4 | | 392 | | 7.7 | | 1.96 | |
| 477 | | A#4 | B4 | 466 | 494 | 11 | -17 | 2.36 | 3.44 |
| 566 | | C#5 | | 554 | | 12 | | 2.16 | |
| 632 | | D#5 | | 622 | | 10 | | 1.6 | |
| 665 | | E5 | | 659 | | 6 | | 0.91 | |
| 810 | | G5 | G#5 | 784 | 831 | 26 | -21 | 3.31 | 2.52 |
| 843 | | G#5 | | 831 | | 12 | | 1.44 | |
| 906 | | A5 | A#5 | 880 | 932 | 26 | -26 | 2.95 | 2.78 |
| 1117 | | C#6 | | 1109 | | 8 | | 0.72 | |
| 1176 | | D6 | | 1175 | | 1 | | 0.08 | |

Table 5.1.8A: Emphasized Frequencies of Position 1

| **Position 1: Emphasized Frequencies** | | | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 92.5 | 95.6 | F#2 | G2 | 92 | 98 | 0.5 | 3.6 | 0.54 | 3.91 |
| 97.6 | | G2 | | 98 | | -0.4 | | 0.4 | |
| 101.6 | | G2 | G#2 | 98 | 104 | 3.6 | -2.4 | 3.67 | 2.3 |
| 108.8 | | A2 | | 110 | | -1.2 | | 1.09 | |
| 120.1 | | A#2 | B2 | 117 | 123 | 3.1 | -2.9 | 2.64 | 2.35 |
| 128.3 | | C3 | | 131 | | -2.7 | | 2.06 | |
| 137.7 | | C#3 | | 139 | | -1.3 | | 0.93 | |
| 166.1 | | E3 | | 165 | | 1.1 | | 0.66 | |
| 179.2 | | F3 | F#3 | 175 | 185 | 4.2 | -5.8 | 2.39 | 3.13 |
| 194.8 | | G3 | | 196 | | -1.2 | | 0.61 | |
| 208.5 | | G#3 | | 208 | | 0.5 | | 0.24 | |
| 226.1 | | A3 | A#3 | 220 | 233 | 6.1 | -6.9 | 2.77 | 2.96 |
| 237.9 | | A#3 | | 233 | | 4.9 | | 2.1 | |
| 251.5 | | B3 | | 247 | | 4.5 | | 1.82 | |
| 254.7 | | B3 | C4 | 247 | 262 | 7.7 | -7.3 | 3.11 | 2.78 |
| 282.6 | | C#4 | | 277 | | 5.6 | | 2.02 | |
| 353 | | F4 | | 349 | | 4 | | 1.14 | |
| 359 | | F4 | F#4 | 349 | 370 | 10 | -11 | 2.86 | 2.97 |
| 374 | | F#4 | | 370 | | 4 | | 1.08 | |
| 382 | | F#4 | G4 | 370 | 392 | 12 | -10 | 3.24 | 2.55 |
| 439 | | A4 | | 440 | | -1 | | 0.22 | |
| 455 | | A4 | A#4 | 440 | 466 | 15 | -11 | 3.4 | 2.36 |
| 504 | | B4 | | 504 | | 0 | | 0 | |
| 546 | | C#5 | | 554 | | -8 | | 1.44 | |
| 580 | | D5 | | 587 | | -7 | | 1.19 | |
| 648 | | E5 | | 659 | | -11 | | 1.66 | |
| 678 | | E5 | F5 | 659 | 698 | 19 | -20 | 2.88 | 2.86 |
| 706 | | F5 | | 698 | | 8 | | 1.14 | |
| 764 | | F#5 | G5 | 740 | 784 | 24 | -20 | 3.24 | 2.55 |
| 1056 | | C6 | | 1047 | | 9 | | 0.85 | |

Table 5.1.8B: Deemphasized Frequencies of Position 1

| **Position 1: Deemphasized Frequencies** | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 95.4 | F#2 | G2 | 92 | 98 | 3.4 | -2.6 | 3.69 | 2.65 |
| 113.8 | A2 | A#2 | 110 | 117 | 3.8 | -3.2 | 3.45 | 2.73 |
| 133.5 | C3 | | 131 | | 2.5 | | 1.9 | |
| 144.4 | D3 | | 147 | | -2.6 | | 1.76 | |
| 159.3 | D#3 | E3 | 156 | 165 | 3.3 | -5.7 | 2.11 | 3.45 |
| 174.1 | F3 | | 175 | | -0.9 | | 0.51 | |
| 189.7 | F#3 | G3 | 185 | 196 | 4.7 | -6.3 | 2.54 | 3.21 |
| 203.1 | G3 | G#3 | 196 | 208 | 7.1 | -4.9 | 3.62 | 2.35 |
| 217.4 | A3 | | 220 | | -2.6 | | 1.18 | |
| 231 | A#3 | | 233 | | -2 | | 0.85 | |
| 244.3 | B3 | | 247 | | -2.7 | | 1.09 | |
| 274.4 | C#4 | | 277 | | -2.6 | | 0.93 | |
| 306.7 | D4 | D#4 | 294 | 311 | 12.7 | -4.3 | 4.31 | 1.38 |
| 337.6 | E4 | | 330 | | 7.6 | | 2.3 | |
| 412 | G#4 | | 415 | | -3 | | 0.72 | |
| 491 | B4 | | 494 | | -3 | | 0.6 | |
| 516 | C5 | | 523 | | -7 | | 1.33 | |
| 556 | C#5 | | 554 | | 2 | | 0.36 | |
| 595 | D5 | | 587 | | 8 | | 1.36 | |
| 619 | D#5 | | 622 | | -3 | | 0.48 | |
| 660 | E5 | | 659 | | 1 | | 0.15 | |
| 684 | F5 | | 698 | | -14 | | 2 | |
| 715 | F5 | F#5 | 698 | 740 | 17 | -25 | 2.43 | 3.37 |
| 737 | F#5 | | 740 | | -3 | | 0.4 | |
| 802 | G5 | G#5 | 784 | 831 | 18 | -29 | 2.29 | 3.48 |
| 843 | G#5 | | 831 | | 12 | | 1.44 | |
| 869 | A5 | | 880 | | -11 | | 1.25 | |
| 921 | A#5 | | 932 | | -11 | | 1.18 | |
| 1009 | B5 | C6 | 988 | 1047 | 21 | -38 | 2.12 | 3.62 |
| 1080 | C6 | C#6 | 1047 | 1109 | 33 | -29 | 3.15 | 2.61 |

Table 5.1.9A: Emphasized Frequencies of Position 2

| **Position 2: Emphasized Frequencies** | | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 95.8 | | F#2 | G2 | 92 | 98 | 3.8 | -2.2 | 4.13 | 2.24 |
| 101.4 | | G2 | G#2 | 98 | 104 | 3.4 | -2.6 | 3.46 | 2.49 |
| 107.8 | | G#2 | A2 | 104 | 110 | 3.8 | -2.2 | 3.65 | 2 |
| 119.9 | | A#2 | B2 | 117 | 123 | 2.9 | -3.1 | 2.47 | 2.52 |
| 128.3 | | B2 | C3 | 123 | 131 | 5.3 | -2.7 | 4.3 | 2.06 |
| 136.9 | | C#3 | | 139 | | -2.1 | | 1.51 | |
| 143.6 | | C#3 | D3 | 139 | 147 | 4.6 | | 3.3 | |
| 150.6 | 157.3 | D3 | D#3 | 147 | 156 | 3.6 | 1.3 | 2.44 | 0.83 |
| 164.8 | | E3 | | 165 | | -0.2 | | 0.12 | |
| 179.8 | | F3 | F#3 | 175 | 185 | 4.8 | -5.2 | 2.74 | 2.81 |
| 202.6 | | G3 | G#3 | 196 | 208 | 6.6 | -5.4 | 3.36 | 2.59 |
| 208.7 | | G#3 | | 208 | | 0.7 | | 0.33 | |
| 225.1 | | A3 | | 220 | | 5.1 | | 2.31 | |
| 237.1 | | A#3 | | 233 | | 4.1 | | 1.75 | |
| 251.5 | | B3 | C4 | 247 | 262 | 4.5 | -10.5 | 1.82 | 4 |
| 271.7 | | C4 | C#4 | 262 | 277 | 9.7 | -5.3 | 3.7 | 1.91 |
| 280.3 | | C#4 | | 277 | | 3.3 | | 1.19 | |
| 350.5 | 353.9 | F4 | | 349 | | 1.5 | 4.9 | 0.42 | 1.4 |
| 410.8 | | G#4 | | 415 | | -4.2 | | 1.01 | |
| 422.5 | | G#4 | | 415 | | 7.5 | | 1.8 | |
| 437 | 445.6 | A4 | | 440 | | -3 | 5.6 | 0.68 | 1.27 |
| 466.1 | | A#4 | | 466 | | 0.1 | | 0.02 | |
| 513.6 | | C5 | | 523 | | -9.4 | | 1.79 | |
| 549.5 | | C#5 | | 554 | | -4.5 | | 0.81 | |
| 573.9 | | D5 | | 587 | | -13.1 | | 2.23 | |
| 595.3 | | D5 | | 587 | | 8.3 | | 1.41 | |
| 612.2 | | D#5 | | 622 | | -9.8 | | 1.57 | |
| 643 | | E5 | | 659 | | -16 | | 2.42 | |
| 662 | | E5 | | 659 | | 3 | | 0.45 | |
| 674 | | E5 | F5 | 659 | 698 | 15 | -24 | 2.27 | 3.43 |
| 723 | | F5 | F#5 | 698 | 740 | 25 | -17 | 3.58 | 2.29 |
| 1068 | | C6 | | 1047 | | 21 | | 2 | |
| 1147 | | D6 | | 1175 | | -28 | | 2.38 | |

Table 5.1.9B: Deemphasized Frequencies of Position 2

<table>
<tr><th colspan="8">Position 2: Deemphasized Frequencies</th><th colspan="2">((A-CN)/CN)*100</th></tr>
<tr><th colspan="2">Actual Frequency (A)</th><th colspan="2">Closest Note (CN)</th><th colspan="2">CN Frequency</th><th colspan="2">Frequency Diff</th><th colspan="2">% Error</th></tr>
<tr><td colspan="2">94.3</td><td colspan="2">F#2</td><td colspan="2">92</td><td colspan="2">2.3</td><td colspan="2">2.5</td></tr>
<tr><td colspan="2">98.4</td><td colspan="2">G2</td><td colspan="2">98</td><td colspan="2">0.4</td><td colspan="2">0.4</td></tr>
<tr><td colspan="2">103.1</td><td colspan="2">G#2</td><td colspan="2">104</td><td colspan="2">-0.9</td><td colspan="2">0.86</td></tr>
<tr><td colspan="2">112.9</td><td colspan="2">A2</td><td colspan="2">110</td><td colspan="2">2.9</td><td colspan="2">2.63</td></tr>
<tr><td colspan="2">123.9</td><td colspan="2">B2</td><td colspan="2">123</td><td colspan="2">0.9</td><td colspan="2">0.73</td></tr>
<tr><td colspan="2">132.7</td><td colspan="2">C3</td><td colspan="2">131</td><td colspan="2">1.7</td><td colspan="2">1.29</td></tr>
<tr><td colspan="2">160.7</td><td>D#3</td><td>E3</td><td>156</td><td>165</td><td>4.7</td><td>-4.3</td><td>3.01</td><td>2.6</td></tr>
<tr><td colspan="2">169.5</td><td>E3</td><td>F3</td><td>165</td><td>175</td><td>4.5</td><td>-5.5</td><td>2.72</td><td>3.14</td></tr>
<tr><td colspan="2">174.1</td><td colspan="2">F3</td><td colspan="2">175</td><td colspan="2">-0.9</td><td colspan="2">0.51</td></tr>
<tr><td colspan="2">194.2</td><td colspan="2">G3</td><td colspan="2">196</td><td colspan="2">-1.8</td><td colspan="2">0.91</td></tr>
<tr><td colspan="2">217.6</td><td colspan="2">A3</td><td colspan="2">220</td><td colspan="2">-2.4</td><td colspan="2">1.09</td></tr>
<tr><td colspan="2">237.5</td><td colspan="2">A#3</td><td colspan="2">233</td><td colspan="2">4.5</td><td colspan="2">1.93</td></tr>
<tr><td>256.2</td><td>262</td><td colspan="2">C4</td><td colspan="2">262</td><td>-5.8</td><td>0</td><td>2.21</td><td>0</td></tr>
<tr><td colspan="2">293.2</td><td colspan="2">D4</td><td colspan="2">294</td><td colspan="2">-0.8</td><td colspan="2">0.27</td></tr>
<tr><td colspan="2">331.3</td><td colspan="2">E4</td><td colspan="2">330</td><td colspan="2">1.3</td><td colspan="2">0.39</td></tr>
<tr><td colspan="2">410.8</td><td colspan="2">G#4</td><td colspan="2">415</td><td colspan="2">-4.2</td><td colspan="2">1.01</td></tr>
<tr><td colspan="2">554.9</td><td colspan="2">C#5</td><td colspan="2">554</td><td colspan="2">0.9</td><td colspan="2">0.16</td></tr>
<tr><td colspan="2">605.4</td><td>D5</td><td>D#5</td><td>587</td><td>622</td><td>18.4</td><td>-16.6</td><td>3.13</td><td>2.66</td></tr>
<tr><td colspan="2">681</td><td colspan="2">F5</td><td colspan="2">698</td><td colspan="2">-17</td><td colspan="2">2.43</td></tr>
<tr><td colspan="2">751</td><td colspan="2">F#5</td><td colspan="2">740</td><td colspan="2">11</td><td colspan="2">1.48</td></tr>
<tr><td colspan="2">1112</td><td colspan="2">C#6</td><td colspan="2">1109</td><td colspan="2">3</td><td colspan="2">0.27</td></tr>
</table>

Table 5.1.10A: Emphasized Frequencies of Position 4

<table>
<tr><th colspan="4">Position 4: Emphasized Frequencies</th><th colspan="2">((A-CN)/CN)*100</th></tr>
<tr><th>Actual Frequency (A)</th><th>Closest Note (CN)</th><th>CN Frequency</th><th>Frequency Diff</th><th colspan="2">% Error</th></tr>
<tr><td>77.3</td><td>D#2</td><td>78</td><td>-0.7</td><td colspan="2">0.89</td></tr>
<tr><td>86.6</td><td>F2</td><td>87</td><td>-0.4</td><td colspan="2">0.45</td></tr>
<tr><td>94.4</td><td>F#2</td><td>92</td><td>2.4</td><td colspan="2">2.6</td></tr>
<tr><td>103.2</td><td>G#2</td><td>104</td><td>-0.8</td><td colspan="2">0.76</td></tr>
<tr><td>107.6</td><td>G#2 | A2</td><td>104 | 110</td><td>3.6 | -2.4</td><td>3.46</td><td>2.18</td></tr>
<tr><td>112.6</td><td>A2</td><td>110</td><td>2.6</td><td colspan="2">2.36</td></tr>
<tr><td>120.8</td><td>B2</td><td>123</td><td>-2.2</td><td colspan="2">1.78</td></tr>
<tr><td>126.9</td><td>B2</td><td>123</td><td>3.9</td><td colspan="2">3.17</td></tr>
<tr><td>133.1</td><td>C3</td><td>131</td><td>2.1</td><td colspan="2">1.6</td></tr>
</table>

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 145.4 | | D3 | | 147 | | -1.6 | | 1.08 | |
| 151.6 | | D3 | D#3 | 147 | 156 | 4.6 | -4.4 | 3.12 | 2.82 |
| 159.9 | 164 | D#3 | E3 | 156 | 165 | 3.9 | -1 | 2.5 | 0.6 |
| 199.5 | | G3 | | 196 | | 3.5 | | 1.78 | |
| 211.4 | | G#3 | | 208 | | 3.4 | | 1.63 | |
| 235.9 | | A#3 | | 233 | | 2.9 | | 1.24 | |
| 250 | | B3 | | 247 | | 3 | | 1.21 | |
| 279.5 | | C#4 | | 277 | | 2.5 | | 0.9 | |
| 293.1 | | D4 | | 294 | | -0.9 | | 0.3 | |
| 321.6 | | D#4 | E4 | 311 | 330 | 10.6 | -8.4 | 3.4 | 2.54 |
| 353.7 | | F4 | | 349 | | 4.7 | | 1.34 | |
| 422.5 | | G#4 | | 415 | | 7.5 | | 1.8 | |
| 495 | | B4 | | 494 | | 1 | | 0.2 | |
| 549 | | C#5 | | 554 | | -5 | | 0.9 | |
| 568 | 577 | C#5 | D5 | 554 | 587 | 14 | -10 | 2.52 | 1.7 |
| 605 | 612 | D5 | D#5 | 587 | 622 | 18 | -10 | 3.06 | 1.6 |
| 643 | | D#5 | E5 | 622 | 659 | 21 | | 3.37 | |
| 743 | | F#5 | | 740 | | 3 | | 0.4 | |
| 1074 | | C6 | C#6 | 1047 | 1109 | 27 | -35 | 2.57 | 3.15 |
| 1175 | | D6 | | 1175 | | 0 | | 0 | |

Table 5.1.10B: Deemphasized Frequencies of Position 4

| **Position 4: Deemphasized Frequencies** | | | | | | | | ((A-CN)/CN)*100 | |
|---|---|---|---|---|---|---|---|---|---|
| Actual Frequency (A) | | Closest Note (CN) | | CN Frequency | | Frequency Diff | | % Error | |
| 80 | | D#2 | E2 | 78 | 82 | 2 | -2 | 2.56 | 2.43 |
| 89.1 | | F2 | F#2 | 87 | 92 | 2.1 | -2.9 | 2.41 | 3.15 |
| 99 | | G2 | | 98 | | 1 | | 1.02 | |
| 103.2 | | G#2 | | 104 | | -0.8 | | 0.76 | |
| 117.1 | | A#2 | | 117 | | 0.1 | | 0.08 | |
| 128.2 | | B2 | C3 | 123 | 131 | 5.2 | -2.8 | 4.22 | 2.13 |
| 140.7 | | C#3 | | 139 | | 1.7 | | 1.22 | |
| 153.5 | 156.7 | D#3 | | 156 | | -2.5 | 0.7 | 1.6 | 0.44 |
| 179.2 | | F3 | F#3 | 175 | 185 | 4.2 | -5.8 | 2.39 | 3.13 |
| 191.5 | | F#3 | G3 | 185 | 196 | 6.5 | -4.5 | 3.51 | 2.29 |
| 211.4 | | G#3 | | 208 | | 3.4 | | 1.63 | |
| 220.8 | | A3 | | 220 | | 0.8 | | 0.36 | |
| 228.7 | | A3 | A#3 | 220 | 233 | 8.7 | -4.3 | 3.95 | 1.84 |

<table>
<tr><td>239.8</td><td>A#3</td><td>B3</td><td>233</td><td>247</td><td>6.8</td><td>-7.2</td><td>2.91</td><td>2.91</td></tr>
<tr><td>262.7</td><td colspan="2">C4</td><td colspan="2">262</td><td colspan="2">0.7</td><td colspan="2">0.26</td></tr>
<tr><td>288.9</td><td>C#4</td><td>D4</td><td>277</td><td>294</td><td>11.9</td><td>-5.1</td><td>4.29</td><td>1.73</td></tr>
<tr><td>307.3</td><td colspan="2">D#4</td><td colspan="2">311</td><td colspan="2">-3.7</td><td colspan="2">1.18</td></tr>
<tr><td>331.8</td><td colspan="2">E4</td><td colspan="2">330</td><td colspan="2">1.8</td><td colspan="2">0.54</td></tr>
<tr><td>343.6</td><td colspan="2">F4</td><td colspan="2">349</td><td colspan="2">-5.4</td><td colspan="2">1.54</td></tr>
<tr><td>408.8</td><td colspan="2">G#4</td><td colspan="2">415</td><td colspan="2">-6.2</td><td colspan="2">1.49</td></tr>
<tr><td>439</td><td colspan="2">A4</td><td colspan="2">440</td><td colspan="2">-1</td><td colspan="2">0.22</td></tr>
<tr><td>465</td><td colspan="2">A#4</td><td colspan="2">466</td><td colspan="2">-1</td><td colspan="2">0.21</td></tr>
<tr><td>526</td><td colspan="2">C5</td><td colspan="2">523</td><td colspan="2">3</td><td colspan="2">0.57</td></tr>
<tr><td>583</td><td colspan="2">D5</td><td colspan="2">587</td><td colspan="2">-4</td><td colspan="2">0.68</td></tr>
<tr><td>626</td><td colspan="2">D#5</td><td colspan="2">622</td><td colspan="2">4</td><td colspan="2">0.64</td></tr>
<tr><td>670</td><td colspan="2">E5</td><td colspan="2">659</td><td colspan="2">11</td><td colspan="2">1.66</td></tr>
<tr><td>1018</td><td colspan="2">C6</td><td colspan="2">1047</td><td colspan="2">-29</td><td colspan="2">2.76</td></tr>
<tr><td>1113</td><td colspan="2">C#6</td><td colspan="2">1109</td><td colspan="2">4</td><td colspan="2">0.36</td></tr>
</table>

## 5.2 Phase II: Composition

After completing the acoustic measurements and creating tables from the data, Phase II of the project commenced. In this phase two pieces approximately 3 minutes in length were composed for each space based on the history of each church and the resonant frequencies from the data gathered. This section addresses the history of each church used in the compositional process as well as the steps taken in creating the individual pieces. This is broken down first into discussing the piece written for The Presbyterian Church of Chestnut Hill entitled "Together in the Bright" followed by a section addressing the piece written for Grace Epiphany Episcopal Church entitled "Find the Light." The same method was used for each piece. First the history of each building and church was researched. Then lyrics, musical themes, and a basic structure were created and the piece was composed. Both pieces used timbral writing. In order to notate this, a mix of mostly IPA with some other vowel writings were used. A list of the vowels and notations used can be found below:

| | | |
|---|---|---|
| mm = hum | uh = u as in cut | eh = e as in pet |
| i: = ee as in week | u: = oo as in boot | dm = dim but close directly to the m |
| ah = a as in hard | ɒ = aw as in shawl | æ = a as in apple |

### *5.2.1 The Presbyterian Church of Chestnut Hill: Together in the Bright*

The original First Presbyterian Church of Chestnut Hill was built in 1853 however the community separated into a second church, Trinity Presbyterian Church in 1889. They rejoined in 1929 becoming The Presbyterian Church of Chestnut Hill. As the church grew, a new, larger space was needed leading to the building of the current church from 1948 to 1950 (The Presbyterian Church of Chestnut Hill 2023a; Chestnut Hill Local 2019). The church building itself was made as a 2 and a half story stone church in the style of the Georgian Revival with center steeple and large pedimented portico. The initial design was created in 1930 to 1931 after the merger (Chestnut Hill Historic District 2019). The organ is one of the most distinct aspects of the sanctuary. The façade carvings are inspired by Psalm 150, St. Francis' "Canticle to the Sun," and the Reformation featuring several instruments, aspects of nature and references to the sacraments of baptism and communion (The Presbyterian Church of Chestnut Hill 2023b). I have a personal history with the church and choral music as I was in Pennsylvania Girlchoir, a group in residence at the church, from age 10 through

18. Having a history of singing in the space gave me an appreciation for the history of music there as well as a better understanding of the acoustic.

Based on the history of the church, I connected with the themes of splitting apart and coming together are reflected in the words "away" and "together" repeated throughout the piece. Not only was this building made as the physical embodiment of a divided church community coming together but it also houses so many different groups and people under one roof. The space itself also played a part as the sanctuary's large, clear windows and bright, white, walls inspired the full lyrics and title of the piece. Two images of the light in the space that served as some of the main inspiration of the piece can be found in figures 5.2.1 and 5.2.2. Throughout the piece the text is extrapolated and layered however the full text used is as follows:

| | |
|---|---|
| *Away* | *Together* |
| *The bright windows open wide* | *With windows open wide* |

*Together in the bright*

Figure 5.2.1: Light in PCCH 1

Figure 5.2.2: Light in PCCH 2

In terms of the musical style, the goal was to create something rather simple and clear feeling with small details peaking through the texture as the piece progresses. This stems from the simple look of the church and the details in areas like the organ. After writing the lyrics, I played with singing and recording different vowels on the resonant frequencies. This helped me to create some themes to use throughout the piece. Vocal slides were used, as one of the key resonant frequencies in the soprano part was between at E4 and an F4 and one of the key frequencies in the tenor and alto part was between A#3 and B3. These in combination with the prominent mezzo E4 and tenor and alto C4 turned into the "away" theme. The "bright" theme was created from the A#3, D#4, and F4, found in the mezzo part and soprano part. Similarly the melody for "windows open wide" was created using F4, D#4, C4, A#3, and A3. The C4, A#3, and A3 are all emphasized in the mezzo part and the F4, D#4, C4, and A#3 are emphasized in the soprano part. The "together" theme was created from the notes A4, G#4 and D#4 as well as G4, F#4, and C4. The first set stems from resonances in the soprano and mezzo positions and the second from the alto and tenor positions.

The composition splits into two main sections "away" and "together." The "away" section introduces themes using the texts of "away," "the bright," and "windows open wide."

This section as a whole represents the time away, feeling misty and a bit lost. It also notes aspects of the space like the windows and brightness as if one is wandering into the space for the first time. First this section starts with a simple texture playing with the key resonances and vowels, later introducing more texture and text building into a larger choir sung together. Then the piece comes back down to play with timbre even more with a droning texture with only the soprano adding bits of the main melody and text. The second section introduces a theme of togetherness which at first feels somewhat out of place and awkward. The theme builds with pieces from the first section until the group comes together on a final line. The tail end of the piece combines the “together” theme with the initial “away” theme using the text and title of the piece “together in the bright.”

In the execution of the piece, the themes and the structure previously chosen were taken and expanded to create the final piece. Key resonances were referenced throughout the piece in both the themes and the background textures. In section A starting in bar 9, an example of this is the small slides in soprano and mezzo parts from at A#3 down and the G4 and A3 “dm” found in the tenor, alto and bass parts. In section B, the mezzo, alto, tenor, and bass parts sing only on their resonant frequencies while altering timbre from a more dark, open ɒ and a brighter æ. Throughout the piece the bass part sings primarily on G2 with some use of G#2 and A3 which are key frequencies in that position. Deemphasized frequencies were also used in the larger choral moments of the piece to assist in crescendos and decrescendos. In bar 21 to 22, every part goes from emphasized frequencies to deemphasized frequencies to aid in the decrescendo. The tenor then returns to singing emphasized frequencies which are brought out of the texture. In bars 50 and 51, the soprano, mezzo, alto, and tenor go from singing deemphasized notes to emphasized ones over a slide to in theory crescendo. The last thing needed for the piece before sending it to my singers on June 3rd, was a program note and cover page. A short summary of the project and the history of the space was created as well as vowel instructions. Then a sketch of the church itself was done to place on the cover. The sheet music for this piece can be found in the appendix.

### *5.2.2 Grace Epiphany Episcopal Church: Find the Light*

Grace Epiphany Church was created from the unification of two churches, Grace Church and The Church of the Epiphany, in 1991, using the previous Grace Church, built in 1889, as the building. The Church of the Epiphany was built just 1.5 miles away in 1902 but burnt down in 1975 leaving only the parish house leading to the eventual merger of the two parishes. Both churches were early adopters of integration. In the 1950's Epiphany was key in integrating the Mount Airy Community with black families being involved in parish life and work. By the mid 1960s, Epiphany was half black and half white. For Grace Church, the first black family joined in 1963 quickly being followed by many other black families. The interior of the church features stained glass not only original to Grace Church but some saved panels from the burnt down Church of the Epiphany (Snyder 1988; Grace Epiphany Church 2024). These panels of color shine differently on the grey, stone walls throughout the day. The church was made in the Gothic Revival style which was commonly favored by the Episcopal church at this time and is made of mostly stone. The vestibule and rood screen were however in the French Gothic style (John Milner Associates 1988). This church is also of personal value to me as my mother is the current Rector of the church. I was able to spend much time sitting in the church and watching the light change throughout the day, initially fearing the space's dark gothic architecture but then growing a fondness for the colorful light it produces.

The historical background of integration and unification prompted me to think about how these groups of people searched for a space of acceptance and unification. The space was also not immediately warm and bright. It is dark and somewhat scary. However if you stay for long enough, you will notice the light and color that fills the space showing the way out of the darkness. Three images of the stain glass used as inspiration for the piece can be seen in figures 5.2.3, 5.2.4, and 5.2.5. These themes lead to the text written for the piece:

*Enter in darkness to find the light*
*The world is dark, the world is grey*
*But here in the light*

*As colors cascade o'er stoney walls*
*The world will bloom in unity*
*To find the light*

Figure 5.2.3: Stained Glass in GEEC 1

Figure 5.2.4: Stained Glass in GEEC 2

Figure 5.2.5: Stained Glass in GEEC 3

For the musical style, the goal was for this piece to feel more ornate and lush with fuller chords that feel both like deep stone and like the vibrant colors of the stained glass. A similar process to that of the first piece was followed, playing with combinations of the resonant frequencies to create musical themes and patterns. Two themes of "light" were created. The first was made on the text "here in the light" using C#4, D#4, A#3, and C4 which uses mostly resonant frequencies found particularly in the alto part. The second was made from a slide between G4 and F#4 which is resonant in the alto part followed by repetitions of C5, which is resonant in the mezzo part and a slide between C#5 and D5 which are resonant in the soprano part. A darkness theme was created with the text "the world is dark" and "the world is grey" using F3, G#3, A#3, and B3 which are resonant in the tenor part. Variations were created for the alto and bass parts using their resonant frequencies as well.

The piece can be broken down into four sections. In the first section, themes of light are introduced but more tenuous, as if stepping into this space for the first time. The following section introduces themes of darkness to represent the gothic and dark nature of the church. This is then followed by an interruption in which the full light theme is introduced, getting stronger and stronger. In the last section, the light bursts out with the completion of the lyrics. This is then brought back to the music from opening but with a more secure, unified feeling. Overall, the story tells of finding a unified space across racial and cultural boundaries in the light when the world seems dark and scary.

When writing the final piece, the initial structure and resonant frequencies were used to create textures and develop the themes. The piece uses chords built on both emphasized and deemphasized frequencies to show uncertainty and to grow dynamics. The first chord of the piece in bar 2 features a D#4, C#4, A3, F#3, and D#3 each of which is relatively deemphasized by the part singing them. This is then followed by a brief solo in the bass part sung only on resonant frequencies on the text "Enter in darkness to find the light." On the word "light," the chord featuring a G#3, B3, E3, F#3, and B is made up of only resonant frequencies. This is the same chord which ends the piece. The chords used in section C starting in bar 32, are all again made up of mostly more resonant frequencies to show that the light feels at home in the space, growing in confidence. The notes of the "here in the light" theme are altered based on the resonances of each part. In bar 56, the chord is made up of F#5, D#5, C#5. B3, and B2 which are all resonant frequencies on the word "bloom," bringing all the parts together on a deeply resonant chord. The sheet music for this piece can be found in the appendix.

### 5.3 Phase III: Rehearsal and Recording

The last phase of the implementation of this research was rehearsing and recording the pieces. The rehearsing and recording process were done in a relatively short amount of time with only two, two hour rehearsals of each piece. The Presbyterian Church of Chestnut Hill (PCCH) unfortunately had limited available hours so we were unable to hold the rehearsals there but we were able to find a time to record there. Rehearsals on the piece occurred on the 7th and 8th of June in Grace Epiphany Episcopal Church (GEEC) with the recording on the 11th of June at PCCH. Rehearsals for the second piece occurred on the 13th and 14th of June with recording on the 15th of June all in GEEC. This section covers both the rehearsal process and the recording including the placement of microphones and any issues that occurred.

#### *5.3.1 The Presbyterian Church of Chestnut Hill: Together in the Bright*

The rehearsals of "Together in the Bright" went smoothly overall. Very few edits were made to the draft of the piece, mostly adding notes to clarify some dynamics and articulations. The timing was the predominant issue worked on during the rehearsals as the piece had some complex cascading parts. The switch to ⅞ in section C bar 40 was also a point of difficulty. As most of my singers came from a more classical choral background, it was difficult to work with slides and timbre changes. After the two rehearsals the singers had the weekend to work on their own so the final recording went rather well musically.

The recording was done Ambisonically with the microphone placed in the same spot as the measurement microphone was for the measurements and the singers in each of their respective spots in the arch. This setup can be seen in figure 5.3.1. There were approximately six full takes recorded. These were then listened to in the Stack B recording studio using the SoundField by RØDE plugin and Sparta Binauralizer in Reaper. 5.1, Stereo, and Binaural renderings were made of the chosen take. All bass management was turned off for rendering. Images of the routing can be seen in figures 5.3.2 and 5.3.3.

Figure 5.3.1: Recording setup in PCCH

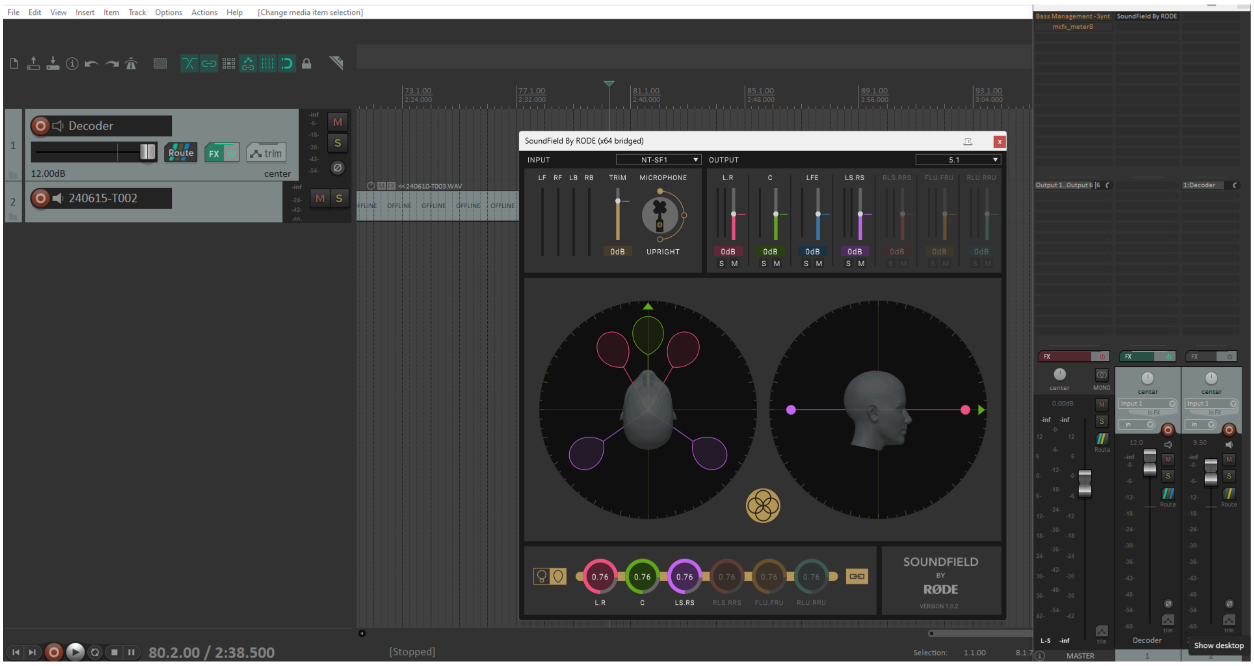


Figure 5.3.2: Reaper Routing with SoundField by RØDE (5.1)


Figure 5.3.3: Reaper Routing with Sparta Binauralizer

### *5.3.2 Grace Epiphany Episcopal Church: Find the Light*

In comparison to the first piece, “Find the Light” proved a bit more difficult to rehearse. The group sometimes struggled with the 5/4 time signature used throughout the piece and particularly with the alternating 5/4 and 6/4 time signatures in sections C and D. There was also difficulty in achieving the dark tone needed for some lines in section B. The hardest part of the piece proved to be section D in which the parts cascade, offset by eighth note entries. A few edits were made for breath marks and intonation marks after the first rehearsal. The group had far less time to work on this piece independently before recording. Therefore the final rendition is not ideal. A photograph from the rehearsals can be seen below in figure 5.3.4.

Figure 5.3.4: Rehearsals in GEEC

Similarly to the piece for PCCH, the piece was recorded Ambisonically with the microphone placed in the same spot as the measurement microphone was for the measurements and the singers in each of their respective spots in the arch as seen in figure 5.3.5. There were approximately eight full takes recorded. Unfortunately due to some older electric issues in the building there was an electric buzz heard in the recording after the 2nd take. Though more was correct in the later takes, it was hard to hear the space and resonances which was key to this project. Therefore the final recording does have a fair amount of errors particularly in sections B and D. One interesting addition to the recordings is that you can hear the birds chirping outside the church. This adds to the sense of place and locational identity of the church as it is in a beautiful area surrounded by nature. Once again these recordings were listened to and rendered in the Stack B recording studio using the SoundField by RØDE plugin and Sparta Binauralizer in Reaper. 5.1, Stereo, and Binaural renderings were made of the chosen take. All bass management was turned off for rendering. The routing was the same as the first piece and can therefore be seen at the end of the previous section.

Figure 5.3.5: Recording setup in PCCH

## Chapter VI: Evaluation

The evaluation of results was done through a survey including the stereo and binaural renderings of the pieces. This research seeks to answer the following questions: How can acoustic data gathered from a particular space inform a site-specific choral composition? and Does timbre (bright/dark tone) affect the perception of the resonant frequency throughout a composition? The survey begins by asking the participants to listen to each recording. It then features questions with clips of the final recordings as references when needed. The goal of this survey is to understand if the acoustic properties of the space can be heard in the composition and to determine if the composition reflects the space.

To start the survey, a basic summary of the project was provided as well as instructions to wear headphones during the survey. Based on the timing of the clips with an allotment of time for answering the questions, the survey totaled to 15 minutes long. The participants are first asked for their consent before proceeding. In total 42 people filled out and consented to participate in the survey. After consenting, the participants are asked "Have you previously heard these pieces and know the spaces for which they were created?" If they respond "yes" this skips over the next section which only applies if you do not know the space or compositions. Three participants answered yes and all others answered no. They are then asked if they have a musical background responding if they are a professional musician, hobbyist, have a little experience, or have no experience. Lastly, they are asked for their choral experience responding if they have extensive, some, or no choral experience. The data regarding musical background and choral experience of the participants can be seen below in figures 6.1 and 6.2. For general musical background, 81% of participants had some musical background with approximately 12% being professional and 43% being hobbyists. In terms of choral background, 61.9% had a choral background with 23.8% having an extensive background. Overall this gives a good amount of diversity in terms of the respondents musical and choral ear.

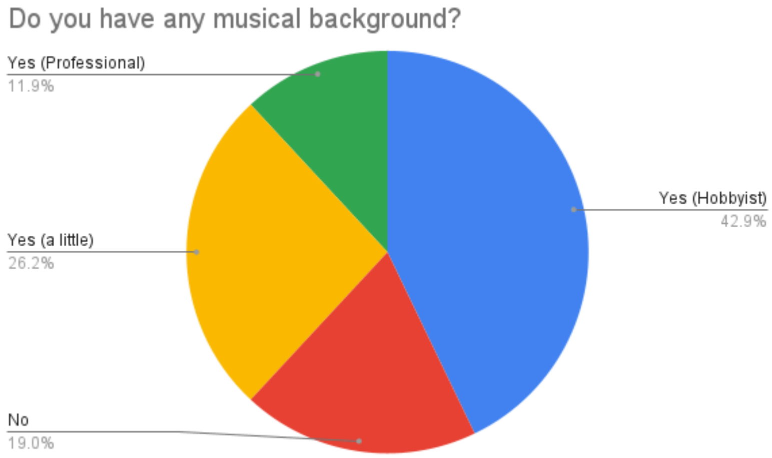


Figure 6.1: Musical Experience of the Participants

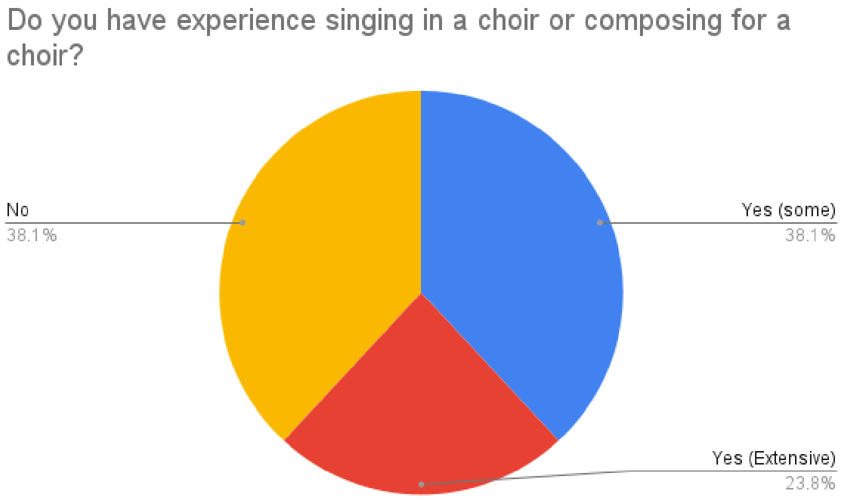


Figure 6.2: Choral Experience of the Participants

The goal of this project is to create a site-specific composition using acoustical and historical data of each space. In order to evaluate this, we need to understand if the qualities of the space can be heard through the composition. This section was skipped if the participant said they knew the space or compositions prior. The participants were asked first without seeing each space what they believe this space looks like including size, materials, and anything else they would like to include. This was then followed by a more specific visual matching in which five images of different churches with different sizes and materials including the two used in the project. Participants will be asked to match one of these images to each piece. These questions allow us to gain insight into how the choices of the composition connect to physical spaces in the minds of others outside of myself as the composer. The picture based question allows for less abstract data to be obtained from listeners.

There was quite a range of responses for the descriptions without pictures for the piece made for the Presbyterian Church of Chestnut Hill (PCCH) with some saying that it seemed like "Dark stone chapel with stained glass windows. Sunlight streaming in as the morning light increases," and a "Smaller setting" and others saying things like "Concrete stairwell of a hospital; a long hallway." Many believed it would be a wood, dark, gothic church while others mentioned white marble or a cool silver/white space. There was also a variety of size descriptions from a large cathedral to a small chapel. One person specifically mentioned they had "a strong sense of Christchurch Cathedral, around half-way down the nave." For Grace Epiphany Episcopal Church (GEEC), responses ranged from "large building with hidden spaces, dark wood, vaulted vaulted ceilings, windows with light that shine in the dark room" to "Medium auditorium as in a school, plaster walls, stage at the front of the room with velvet curtains behind the chorus." Overall many noted it being a dark space lit by stained glass windows or candle light mentioning wood and stone while others thought it was white or pastel colored with carpet. One person described it as "not colorful" and another said "no windows" which is particularly interesting considering the colorful nature of the stained glass in the real space and the lyrics in the piece stating that "colors cascade o'er stoney walls." In terms of size, some described it more as a small chapel while others thought it was large with arched ceilings. One person particularly tied it to the Berkeley Library at Trinity College Dublin and described it as "harsh, angular, heavy material (concrete). High up, light spills in, through multiple windows, gaps, holes. The light travels up and down the inside of the building, creating an expansiveness above."

The set of pictures used for the second question can be seen below in figure 6.3 and the responses of the participants can be seen in figures 6.4 and 6.5. Overall most people (48.7%) believed that the first piece, made for PCCH, was made for option C which is a picture of GEEC. Secondarily, 23.1% picked option E which is a picture of a small Quaker meeting house. Only 10.3% of people picked option A which was a picture of PCCH. Many who picked GEEC for the first piece did so assuming that the space was more resonant from the picture, however in actuality PCCH was much more resonant and GEEC is somewhat dry. For those who picked the Quaker meeting house stated it was because they wanted to pick a small and simple space. One person noted they thought it was the size of E with the architecture of C. One person who picked PCCH correctly said “The piece, for me, invoked images of being outdoors, and this space is the most reminiscent of that. The openness and cavernous quality of the space would also help the more sparse voice parts blend together and flow.” This felt particularly accurate as to what this piece was trying to achieve. Choices for the second piece, made for GEEC, were more split with 30.8% picking C, the picture of GEEC, 28.2% pickling A, the picture of PCCH, and 20.5% picking B, which is somewhat of a halfway point between PCCH and GEEC with stained glass and a similar shape to GEEC but with a carpeted center, white walls and more modern features like PCCH. Those who picked GEEC said it was because the space looked reverberant and large. In contrast those who picked PCCH explained that they thought the space would be square and airy. Those who picked B said it was because the space felt warm, grand, and large. One person who picked GEEC correctly said that “The arrangement and sound of this piece felt more grand, dark, and classical, all of which are qualities this space seems to have. The piece also explores a dynamic range that I believe would suit this space well with its size and apparent cavernous acoustics.” This was the most similar to the goal of this piece. Overall, these results were often surprising after reading the previous descriptions as many who described a white, light church for either piece would then would then pick GEEC which notably looks the darkest. The respondents were influenced by their notions of what a church is in all their responses. A gothic stone church like GEEC is the common image people get when thinking of a church sanctuary which may be why that picture was chosen the most often. Only one picture was also used for each space which makes it more difficult for participants to get an accurate sense of the space, particularly how colorful GEEC can be and how simple and space PCCH is.

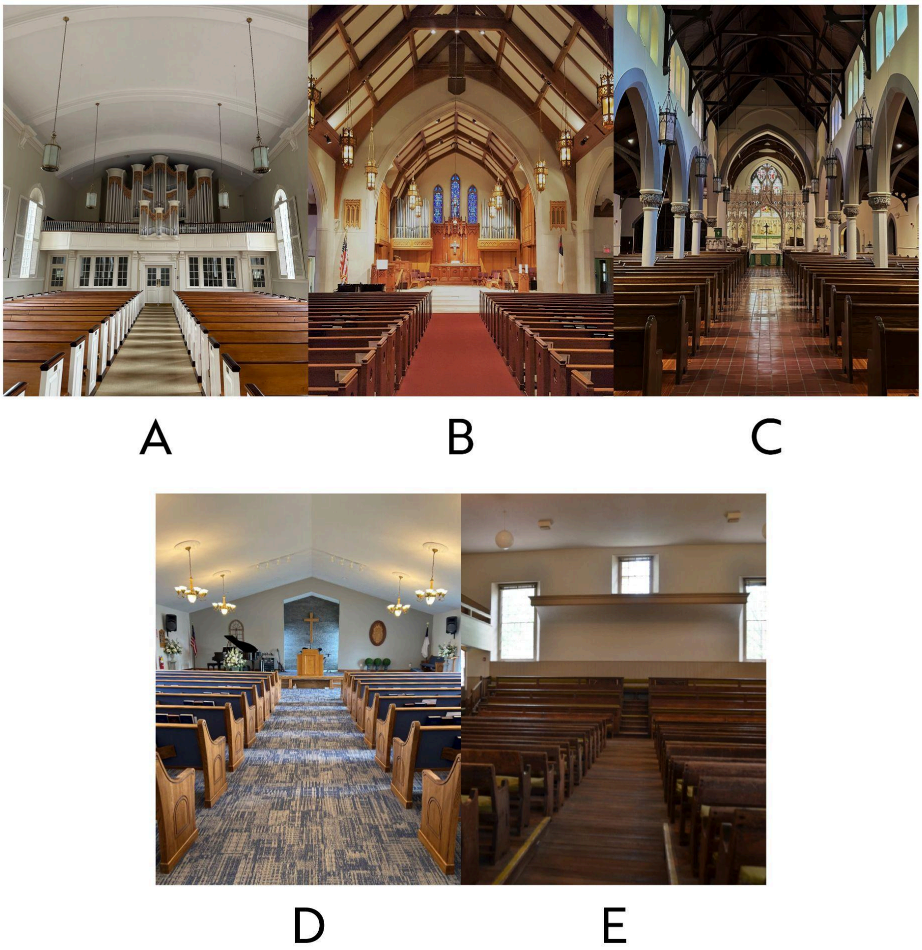


Figure 6.3: Church Pictures Used in Survey

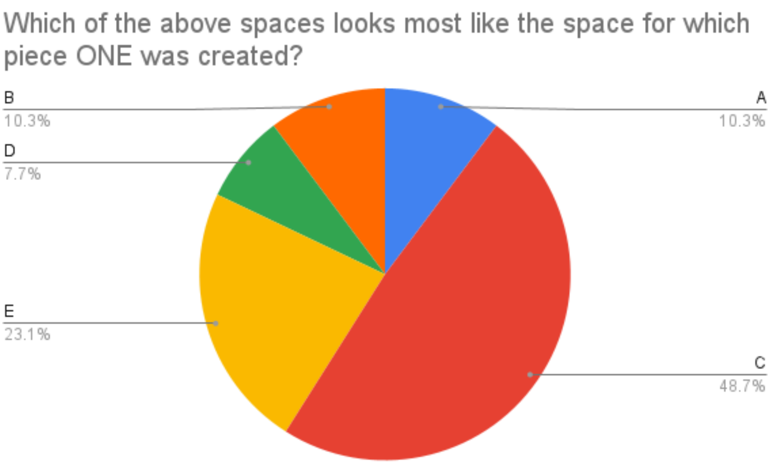


Figure 6.4: Pie Chart of Guesses for Piece I (PCCH)

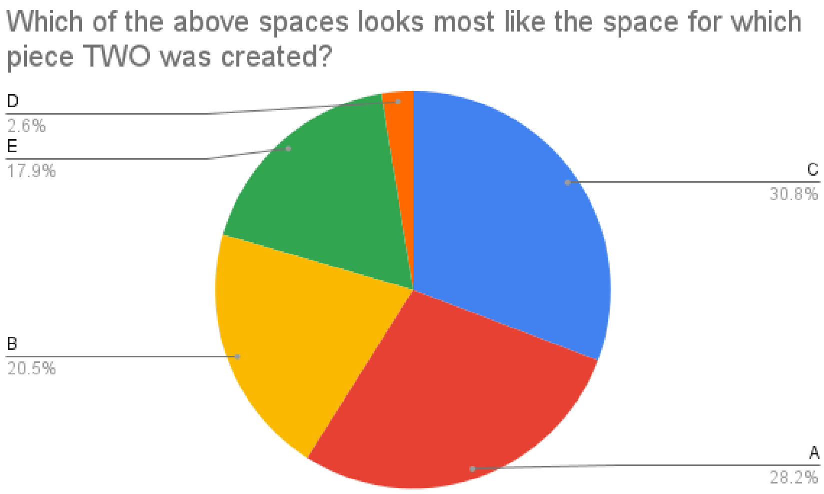


Figure 6.5: Pie Chart of Guesses for Piece II (GEEC)

The next section of the survey focused on vowels and timbre as it shifted during different clips throughout the piece. Participants were asked if one vowel or another vowel appeared more prominent or louder answering with their choice of vowel or no distinction. This is key to the supplemental research question regarding how timbre affects the perception of resonant frequencies. Pie charts of the responses for each question can be seen below in figures 6.6, 7, 8, 9, 10, and 11. While composing, it was assumed that the brighter vowels and the u: vowel would sound the most resonant in the space. For the first two questions regarding clips from the first piece, 54.8% and 57.1% of people picked the darker vowels (eh and ah) as more resonant. The third question, also regarding a clip from the first piece, was more split with 42.9% picking the darker vowel ɒ and 33.3% picking the brighter æ. For the next question regarding a clip from the second piece, 47.6% of participants picked u: as the more resonant vowel and 28.6 picked i:. Once again the next question regarding æ versus ɒ, but regarding its use in the second piece, found a more split response with 35.7% choosing the darker ɒ and 35.7% picking the brighter æ. For the last question using a clip from the second piece, the darker eh had the clear majority of 59.5%. Overall for most of the questions the darker vowel and u: had the majority however never by a great margin. The group was more split on the resonance of æ versus ɒ.

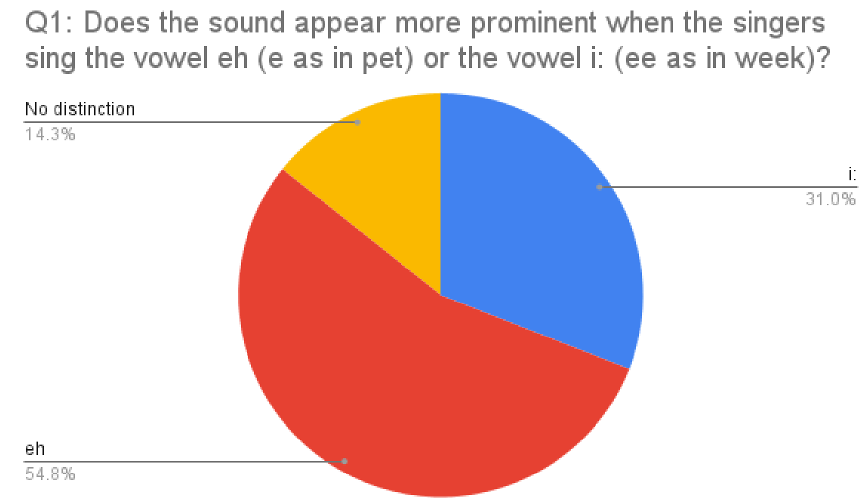


Figure 6.6: Timbre Question 1 Pie Chart

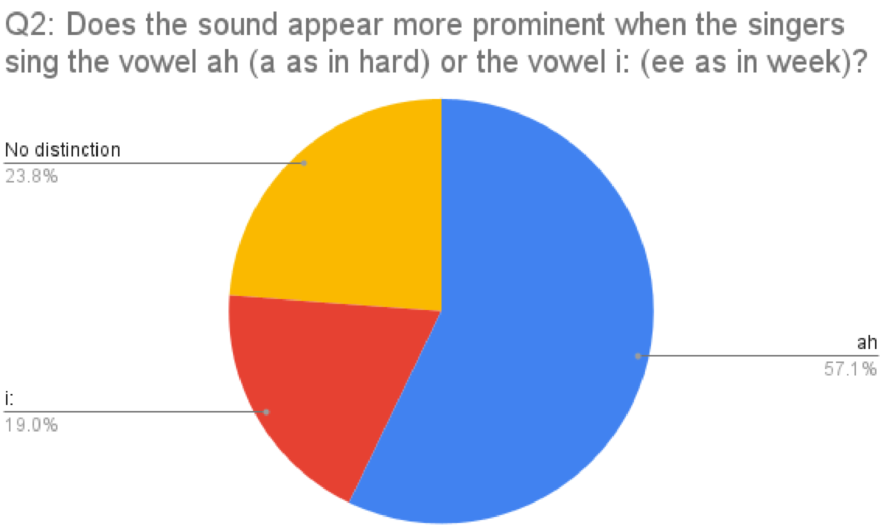


Figure 6.7: Timbre Question 2 Pie Chart

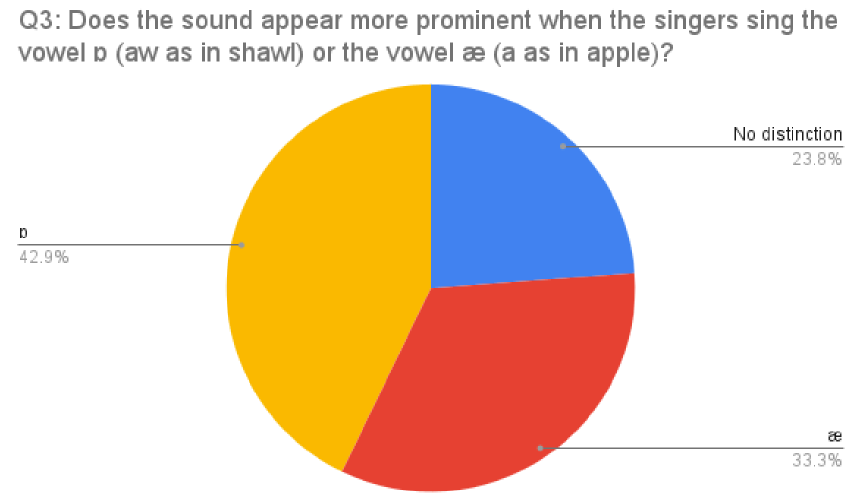


Figure 6.8: Timbre Question 3 Pie Chart

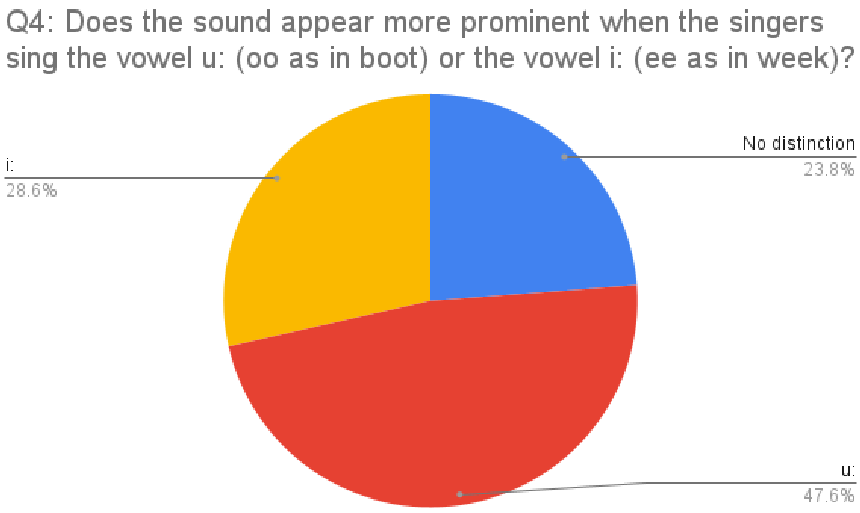


Figure 6.9: Timbre Question 4 Pie Chart

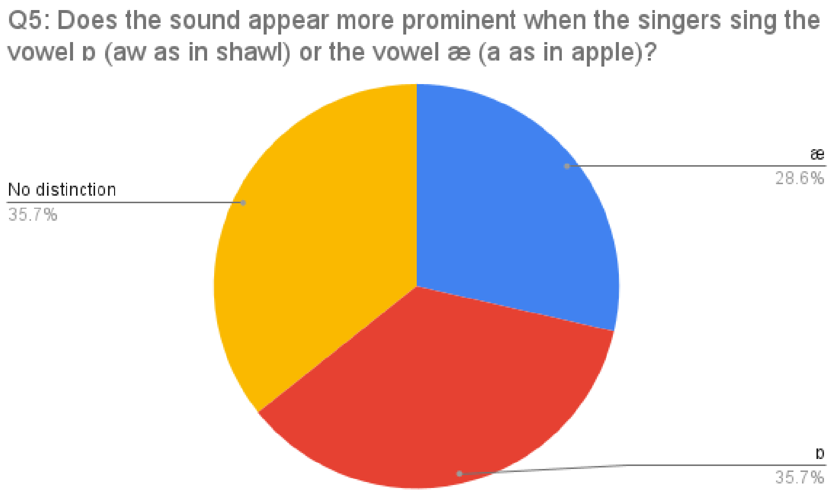


Figure 6.10: Timbre Question 5 Pie Chart

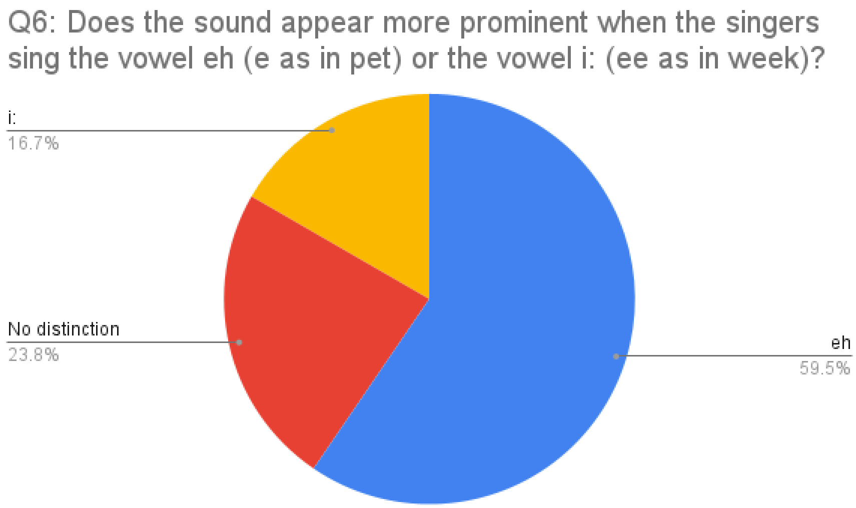


Figure 6.11: Timbre Question 6 Pie Chart

The following section addresses two sets of chords, one from each piece. These came from instances in which a chord was made of deemphasised notes and emphasized notes at the same dynamic marking. Once again participants were asked which chord sounded louder, fuller, or more prominent or if there was no distinction. Pie charts of the responses for each question can be seen below in figures 6.12 and 13. For the first question regarding some of the final chords of piece one, the majority (69%) picked the first chord (A) which was originally designed to be the less resonant chord. This may be because the harmony was closer in structure which allowed for a more tight, intense sound. For the second question regarding some of the opening chords of piece two, the majority (45.2%) picked chord B however this was by much less of a strong margin with chord A at 38.1%. Chord B was the chord designed to be more resonant as it was made up of all key resonant frequencies. It was, however, fairly low in the registers of the singers, particularly the soprano, which may have contributed to the perception of this chord.

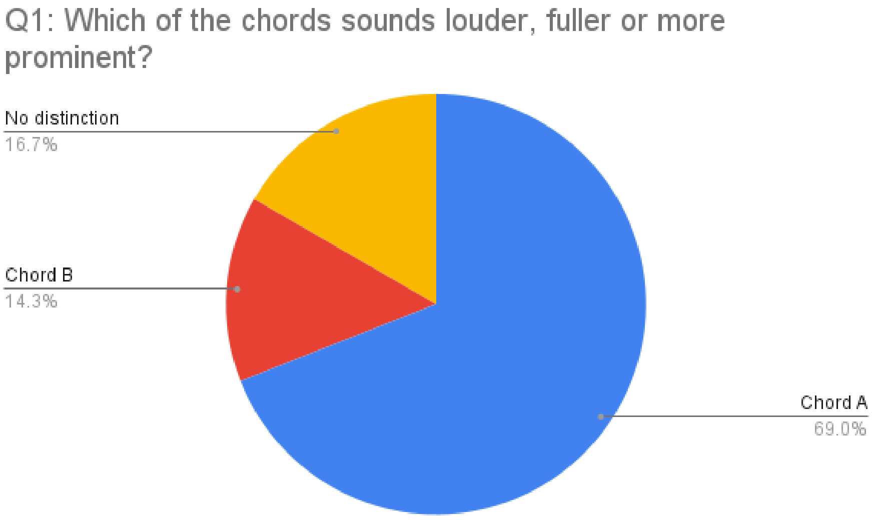


Figure 6.12: Chord Resonance Question 1 Pie Chart

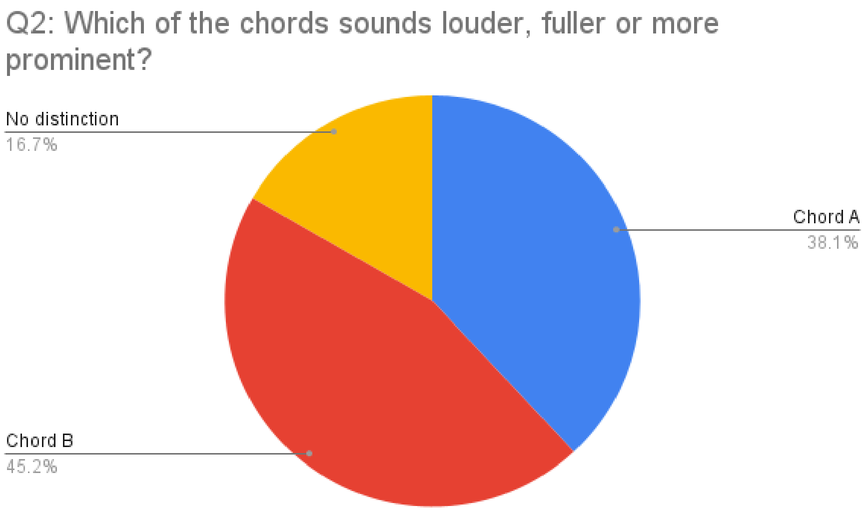


Figure 6.13: Chord Resonance Question 2 Pie Chart

Most of each composition did not feature individual emphasized and deemphasized notes next to each other. However in “Find the Light,” each singer sings their version of “here in the light” some of which occurs on emphasized and others on deemphasized notes. In this section participants were asked which note/word(s) in each phrase sounded louder or more prominent or if there was no distinction. This was heavily affected by the different words and timbres of each voice as well as their own soloistic tendencies with dynamics. Pie charts of the responses for each question can be seen below in figures 6.14, 15, 16, 17, and 18. For the first question in which the alto sings, 73.8% of participants picked D#4 when she sang "in" as the most resonant. It was intended to be C4 on the word "light" which only 2.4% of people selected. Next for the mezzo entrance, it was evenly split between the C#4 sung on "here" and "the," the D#4 sung on "in" and "la," and no distinction. These were both relatively resonant in the space according to the measurement so this split aligns with expectations. For the soprano entrance, 47.6% of people picked F4 on the word "the." Both the F4 and the G4 on "light," which 21.4% of participants chose, were the more resonant notes in the phrase. For the tenor entrance, 52.4% picked the F4 on "light" which was the intention though the C#4 on "here" was also somewhat resonant based on the measurements. The F4 was aided by being the highest note in the phrase and towards the top of the tenor's register overall. Lastly for the bass entrance, 52.4% chose C#4 on the words "here" and "the." The intention was for the G#3 on "light" to be the most resonant however it was the lowest note in the phrase and therefore had a disadvantage. Overall the soloistic nature of this phrase made it difficult to separate the singer's phrasing from the resonance of the pitch. The pitches were also sung on different words rather than one consistent vowel which means that the formants of the vowels may have adjusted the perceived resonance of the notes.

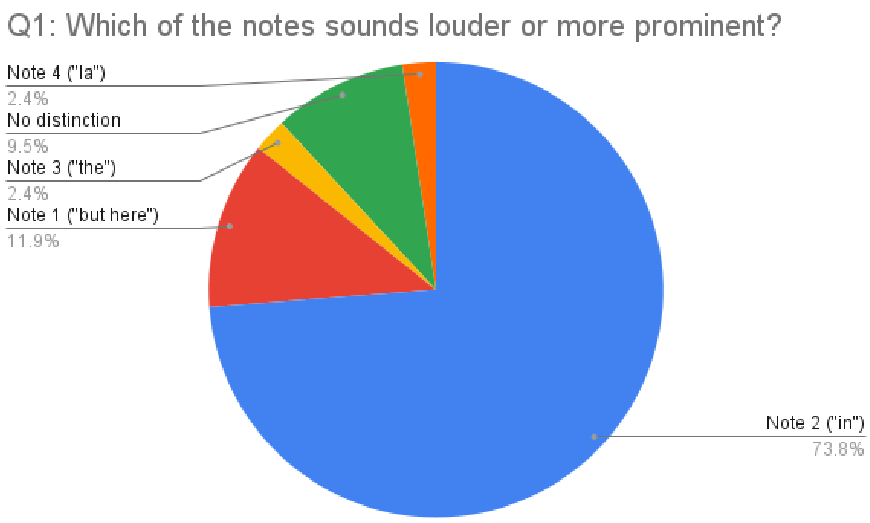


Figure 6.14: Note Resonance Question 1 Pie Chart

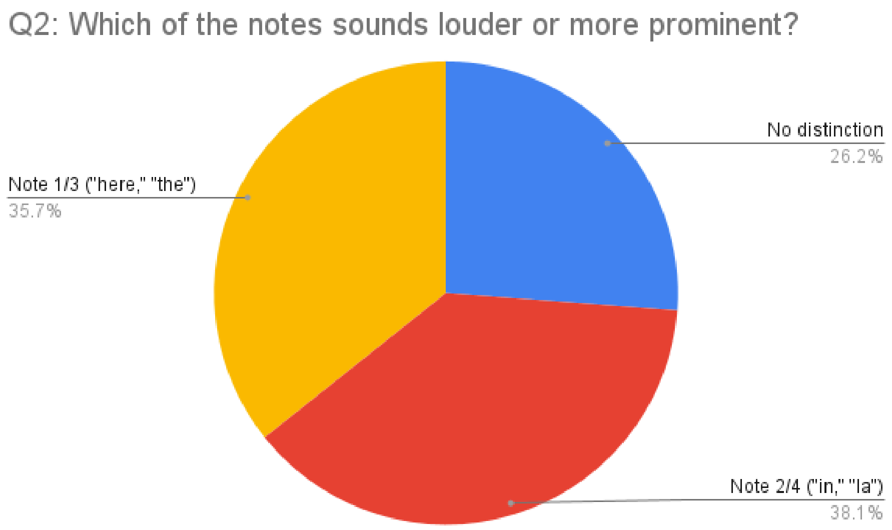


Figure 6.15: Note Resonance Question 2 Pie Chart

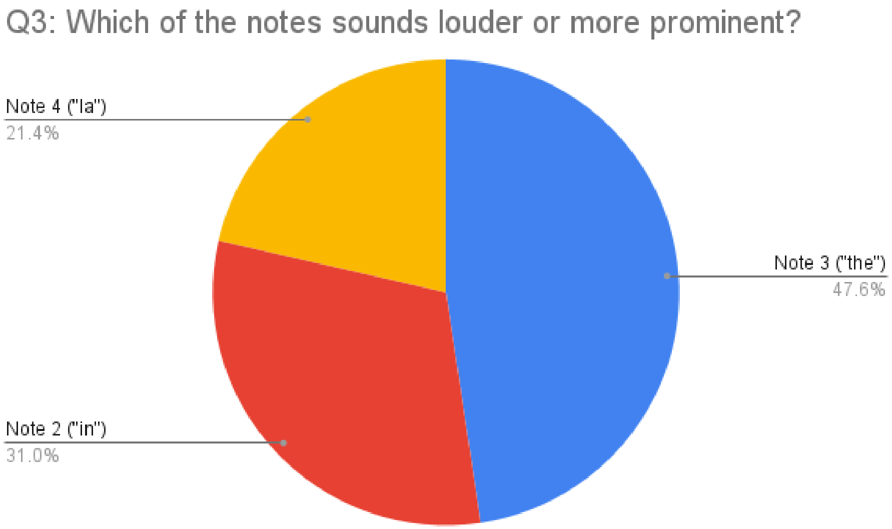


Figure 6.16: Note Resonance Question 3 Pie Chart

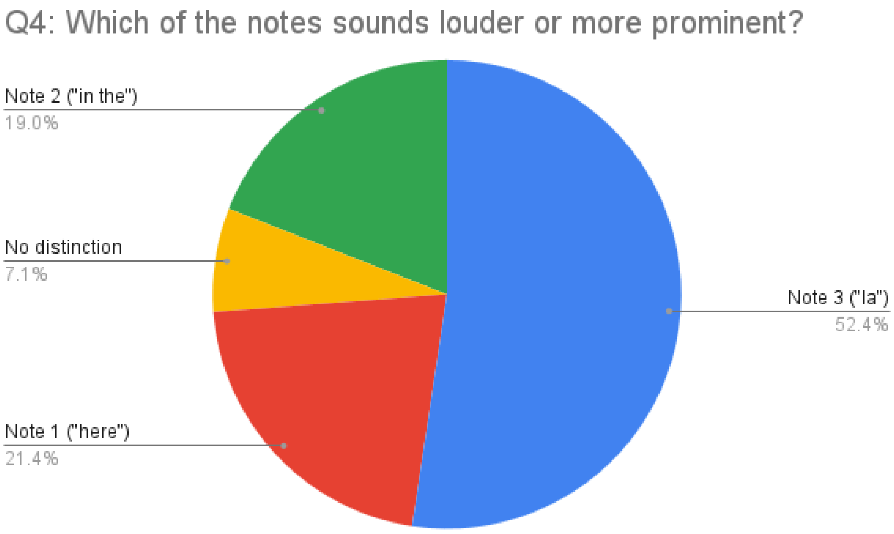


Figure 6.17: Note Resonance Question 4 Pie Chart

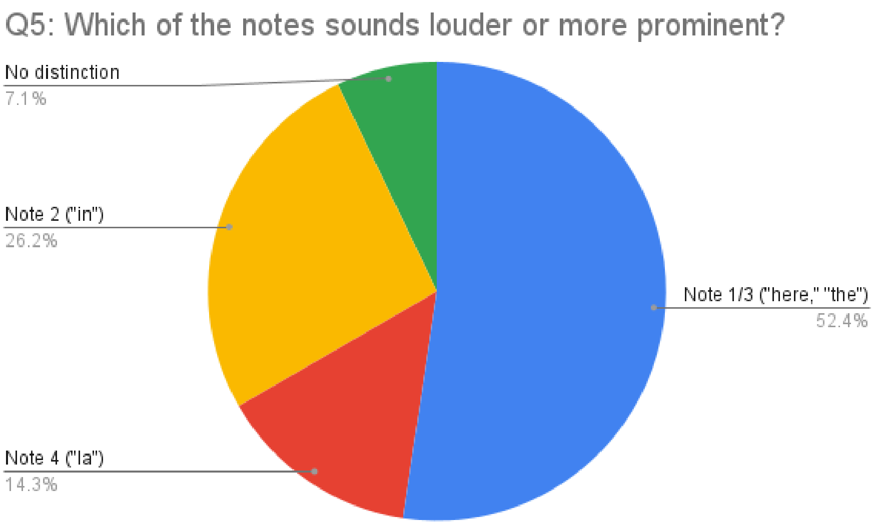


Figure 6.18: Note Resonance Question 5 Pie Chart

In the last section of the survey, 30 second clips from each piece were presented binaurally and in stereo. Participants were asked if they preferred the sound of clip one or two or if there was no distinction. Pie charts of the responses for each question can be seen below in figures 6.19 and 20. For piece one, it was fairly evenly split with 40.5% selecting binaural and 42.95 selecting stereo. Only 16.7% selected no preference. For the second piece, the majority (59.5%) picked binaural over stereo (23.8%) with 16.7% selected with no preference.

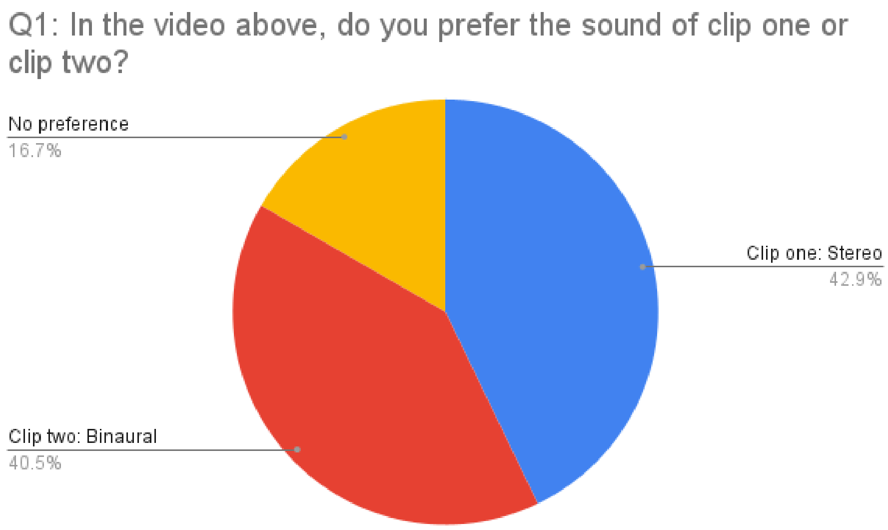


Figure 6.19: Stereo or Binaural for Piece I (PCCH)

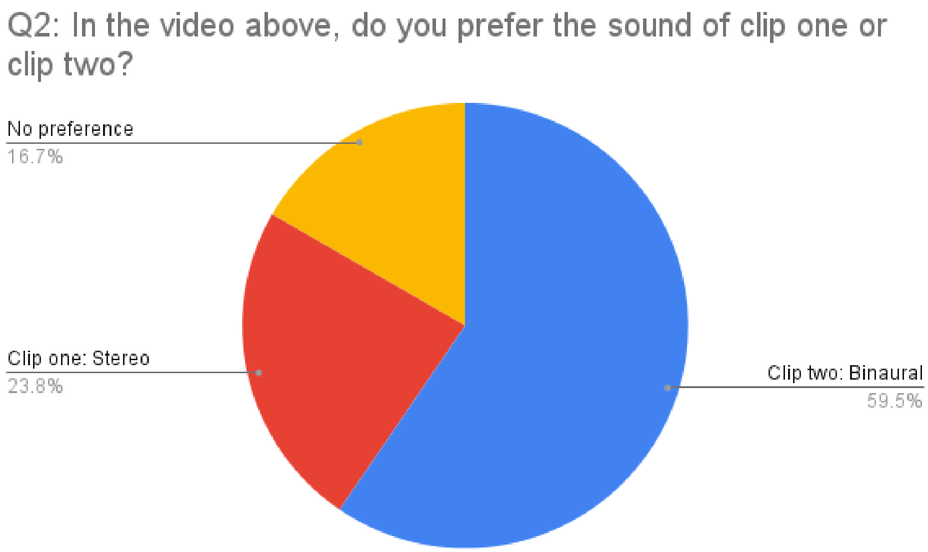


Figure 6.20: Stereo or Binaural for Piece II (GEEC)

Overall the responses to these questions are heavily affected by the background of each person. This is particularly true in terms of the perception of what a church looks and feels like. As discussed in the background section regarding vocal timbre, even the perception of timbre is influenced by the sounds, accents, and voices each of us has heard previously. The singers were also performing soloisticaly and were not singing exact resonant frequencies or even staying exactly on the written pitch throughout the full piece. To answer the research questions with this data, acoustic measurements can certainly be used to inform a composition along with the architecture and history of the space. However that composition is from one person's perspective and can not be expected to accurately portray the space to every person who experiences it. My compositional and musical background influenced the stylistic choices made and not every person listening would have the same opinions or background as me. The participants also did not get to hear the piece live within the space or even see and feel the spaces in person. One picture can only do so much in terms of describing a space. For the timbre questions, it is interesting to note that the darker timbres were generally perceived as more resonant which is not what was initially expected. Overall, these compositions do successfully use acoustics to inform site-specific composition; however my results do not indicate a clear universal connection between the compositional decisions made and the perspective of listeners through a recording.

## Chapter VII: Conclusion

Through this hybrid thesis project, site-specific composition was explored using the lenses of acoustics, choral music, and timbre. The goal was to answer the question: *How can acoustic data gathered from a particular space inform a site-specific choral composition?* and secondarily: *Does vocal timbre affect the perception of the resonant frequency throughout a composition?* In the introduction, we began by discussing the importance of space and how site-specific composition can draw attention to details, histories, and memories of particular spaces. The idea that singers may be a key way to explore space based composition was also introduced. Initial methodology was briefly discussed and an overview of the paper was given. In the background section, the topics of site-specificity, acoustics, and choral music were broken down and defined in terms of this project. First the definition, history, and importance of site-specific art was addressed. Next, research regarding acoustic measurements and church acoustics were discussed. The origins of spatialization in choral music were then shown followed by an introduction to the concept of vocal timbre. In the Review of Work, historical and current acoustic based compositions and timbre based choral compositions were discussed showing key influences for these works.

In the methodology, a summary of the research design was shown including the materials used to complete the project. The implementation section then broke down the three phases of the project: Acoustic Measurements, Composition, and Rehearsal and Recording. This showed each step in the process including any issues that occurred. Lastly the Evaluation section covered the survey creation and results and tied them back to the initial research questions. Overall these results showed that site-specific composition and timbre is subjective and based on prior history and experience. There is not a clear tie between my specific decisions and a collective sense of space though the use of acoustic measurements may have aided me in getting closer to that result.

### *7.1 Critical Analysis*

This project was done on an expedited timeline as this is only a summer thesis. If given more time, the compositions could have been more thoroughly rehearsed which may have improved the results of the recordings. Though the results of the recordings were good, there are many errors that could have been avoided with more practice. If this project was done again, the microphones should be moved further away from the singers. At the time of the measurements and recordings, the goal was for the singers to sound clear and to avoid any measurement distortion that occurs when the impulse response is played too loudly. However it would have been more helpful to get more of the indirect sound particularly of the first church. Compositional research is inherently difficult to evaluate. The survey for evaluation of results was also done virtually therefore the participants did not get to experience the spaces live, only single pictures. Ideally with time, one piece would have been created, rehearsed, and performed live and the audience would have taken the survey in the space. Then a second would be created after the evaluation of the first in order to grow with that feedback. Secondarily the pieces could have been recorded and listened to and the space could have been experienced separately to see if the participants could have tied the two together based on real life experience of the church. In terms of participant background, it would have been valuable to ask questions to better understand the experience and the individuals in regards to churches. Since many respondents described traditional Catholic churches, it would have been good to know if they had mostly been in stone, traditional churches as that would affect the results.

### *7.2 Future Work*

Site-specific composition has only begun to be researched and discussed. Acoustic measurements and modeling need to be further utilized outside of an electroacoustic context. Future research should use acoustic models as a compositional tool and should further explore how to use not only timbre but microtonality. Exploration using string players in which more exact frequencies can be played live would be a valuable contribution to this field. Vocal timbre needs to be further explored with techniques like belting. The group used was not as thoroughly trained in timbral singing as groups like Roomful of Teeth. Therefore a similar project should be done with singers who have training in many different vocal techniques to truly understand how timbre may affect these resonances. Overall this research was a small step within the context of site specific composition and researchers should continue to work with acoustics and singers in order to truly bring a space to life. We exist in so many virtual spaces and live often so disconnected from real space. Site-specific composition is needed to draw us back into the world around us and to better understand our histories and memories through space.

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**Appendix**

*Together in The Bright: Full Score*

# Together in The Bright

Andy Regli

for SSATB voices

*Created for*
*The Presbyterian Church of Chestnut Hill*

# Together in The Bright

Andy Regli

for SSATB voices

*Created for The Presbyterian Church of Chestnut Hill*

## Program Notes:

"Together in the Bright" was inspired by the acoustics and history of The Presbyterian Church of Chestnut Hill. Each singer is placed in a particular location forming a half circle. Acoustic measurements were taken in each spot in reference to a central position in the audience. The parts were made based on the resonant frequencies found in each position.

The themes of the piece were inspired by the history of the church. The original First Presbyterian Church of Chestnut Hill was built in 1853 however the community separated into a second church, Trinity Presbyterian Church in 1889. They rejoined in 1929 becoming The Presbyterian Church of Chestnut Hill. As the church grew, a new, larger space was needed leading to the building of the current church from 1948 to 1950. The themes of splitting apart and coming together are reflected in the words "away" and "together" repeated throughout the piece. The sanctuary features large, clear windows and bright, white, walls which inspired the full lyrics and title of the piece.

This piece was written as part of a Master's thesis for the Music and Media Technology program at Trinity College Dublin. It was composed to explore site-specific composition through the lens of acoustics and choral composition. Timbral writing is used throughout the piece to further explore this research.

## Performance Notes:

Arrows are used to indicate a gradual transition between vowels.
When unclear from vowel markings, full words are indicated in parentheses below the text.
For example, "brah-i:-t" has "(bright)" below it.

Vowels:

| | | |
|---|---|---|
| mm = hum | uh = u as in cut | eh = e as in pet |
| i: = ee as in week | u: = oo as in boot | dm = dim but close directly to the m |
| ah = a as in hard | ɒ = aw as in shawl | æ = a as in apple |

# Together in The Bright

Andy Regli


14
S.
M.
A.
T.
B.
mp
p
close to ns
gliss.
weh → i: (way)
u:
u:
u:
weh → i: (way)
ah → i: (t) win - dows o - pen wide (d) u:
u: weh → i: (way) dm weh → i: i: → u: weh → i: (way)
weh → i: i: → u: dm weh → i: (way)
dm dm dm dm dm dm dm
19
mf
f
like light bursting
the bright the brah (bright) i: (t)
u: dm the brah (bright) i: (t)
dm the brah (bright) i: i: → u:
i: → u: brah (bright) i: uh (away) weh → i:
dm the bright the brah (bright) i: i: → u:


B
24
S.
M.
A.
T.
B.
close to ns
mp
p
win - dows weh → i:
(way)
close to ns
o - pen o -
mp keep jaw in the same position
ɒ → æ → ɒ
31
pen o - pen win - dows weh → i:
(way)
o - pen
ɒ → æ → ɒ → u:
weh → i:
(way)
æ → ɒ → u:
i: → u:


C
♪ = 140 somewhat robotic
38
S.
M.
A.
T.
B.
to-ge - ther
to-ge - ther
wa: → i: (d)
(wide)
to-ge-ther
to-ge-ther
uh
uh
to-ge-
to-ge-ther
uh
gliss.
43
uh u:
uh u:
weh → i: i:
(way)
close to ns
weh → i: i:
(way)
o - pen win - dows o - pen
ther
to-ge - ther
i: → u:
to-ge - ther
to-ge-
to-ge-ther
to-ge-ther
i: → u: i:
uh weh → i: → u:
(away)
uh weh → i: → u:
(away)
mp
p


47
S.
M.
A.
T.
B.
u:
oh o - pen
wide
mp
f
ff
win - dows o - pen win - dows o - pen wide
ther to-ge-ther with win - dows o - pen wide
u: to-ge - ther with win - dows o - pen wide
close to ns
win - dows oh o - pen
wide
D
53
rit.
♪ = 90
p
in the brah ah i: (t)
(bright)
mp freely
to - ge - ther to-ge - ther to-ge-ther
to-ge-ther to-ge-ther
mm

# Find The Light

Andy Regli

for SSATB voices

*Created for*
*Grace Epiphany Episcopal Church*

# Find The Light

## Andy Regli

for SSATB voices

*Created for Grace Epiphany Episcopal Church*

### Program Notes:

"Find The Light" was inspired by the acoustics and history of Grace Epiphany Episcopal Church in Mount Airy, Philadelphia. Each singer is placed in a particular location forming a half circle. Acoustic measurements were taken in each spot in reference to a central position in the audience. The parts were made based on the resonant frequencies found in each position.

Themes for this piece were taken from the history of the church. Grace Epiphany was created from the unification of two churches, Grace Church and The Church of the Epiphany, in 1991 using the previous Grace Church, built in 1889, as the building. The Church of the Epiphany was built just 1.5 miles away in 1902 but burnt down in 1975 leaving only the parish house leading to the later merging of the two parishes. Both churches were early adopters of integration. In the 1950's Epiphany was key in integrating the Mount Airy Community with black families being involved in parish life and work. By the mid 1960s, Epiphany was half black and half white. For Grace Church, the first black family joined in 1963 quickly being followed by many other black families. The interior of the church features stained glass not only original to Grace Church but some saved panels from the burnt down Church of the Epiphany. These panels of color shine differently on the grey, stone walls throughout the day. This contrasts the dark, gothic style of the church interior. This background of integration, unification, and transformation from grey, darkness to color and light lead to a short poem written for the piece:

*Enter in darkness to find the light*
*The world is dark, the world is grey*
*But here in the light*
*As colors cascade o'er stoney walls*
*The world will bloom in unity*
*To find the light*

This piece was written as part of a Master's thesis for the Music and Media Technology program at Trinity College Dublin. It was composed to explore site-specific composition through the lens of acoustics and choral composition. Timbral writing is used throughout the piece to further explore this research.

### Performance Notes:

Arrows are used to indicate a gradual transition between vowels.
When unclear from vowel markings, full words are indicated in parentheses below the text.
For example, "lah-i:-t" has "(light)" below it.

Vowels:

| | | |
|---|---|---|
| mm = hum | uh = u as in cut | eh = e as in pet |
| i: = ee as in week | u: = oo as in boot | dm = dim but close directly to the m |
| ah = a as in hard | ɒ = aw as in shawl | æ = a as in apple |

# Find The Light



Andy Regli


13
S.
light
light
pp
mm
mm
M.
light
pp
mm
mm
A.
the
the
the
the
la → i:
(light)
(t)
T.
→ i:
u: → i:
u: → i:
u:
p
the
no t at end
la → i:
(light)
B.
→ i:
u: → i:
→ u:
B
18
S.
p
mf
dɒ → æ
p
mf
dɒ → æ
mp
dm
M.
mp
dm
p
mf
dɒ → æ
mp
dm
p
mf
dɒ → æ
mp
dm
A.
p
dm dm
æ
mp
dm dm
æ
mp
dark tone, vib.
the world is dark
T.
mp
dark tone, vib.
the world is dark
no vib.
dɒ → æ
B.
no vib.
dɒ → æ → ɒ
dɒ → æ → ɒ


23
S.
M.
A.
T.
B.
p mf
mp
dɒ → æ
dm
dm dɒ → æ
no vib.
dark tone, vib.
æ dm dm
the world is grey
the world is dark
dɒ → æ → ɒ
27
greh → i:
but
greh → i: → eh
(grey)
the world is
the world is grey


32
C
swelling
each time a bit louder
S.
M.
A.
T.
B.
light (t) here
light (t) here in the light (t) light (t)
here in the light (t)
light (t)
light (t) light (t)
light (t)
light (t)
light (t)
light (t)
38
in the light (t) light (t)
light (t)
light (t) light (t)
light (t) light (t)
light (t)
light (t) light (t)
light (t) here in the light (t) light (t)
light (t)
light (t) here
mp
p
mf


♩= 135
44
pp
S.
light (t) light light light
M.
light light light
A.
light light light
T.
light light light
B.
in the light (t) light light light
49
D
f
S.
light as kay wah as
M.
light as col - ors cas - cade o'er stone - y walls
A.
light as kay wah
T.
light as kay wah
B.
light as kay wah


release and grow
53
S.
col-ors cas-cade o'er stone-y walls world will bloom i: in
M.
kay wah bloom i: in
A.
kay wah the world will bloom in u - ni - ty in
T.
kay wah will bloom in u - ni - ty in
B.
kay wah bloom i: in
59
gently
S.
u - ni - ty in u - ni - ty in u - ni - ty to
M.
u - ni - ty in u - ni - ty in u - ni - ty
A.
u - ni - ty in u - ni - ty in u - ni - ty
T.
u - ni - ty in u - ni - ty in u - ni - ty
up the octave if not possible
B.
u - ni - ty in u - ni - ty i:


64
freely, together
pp
p
S.
__ find the__ to__ find the__ light
M.
to find_ the__ to__ find the light
A.
to find the__ to__ find the light
T.
to__ find__ the__ to__ find the light
B.
to find__ the__ to__ find the light