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Recording the Classical Tuba

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Recording the Classical Tuba

Larry Dine

Research project submitted to the College of Creative Arts
at West Virginia University

in partial fulfillment of the requirements for the degree of

Doctor of Musical Arts in

Tuba Performance

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ABSTRACT

Recording the Classical Tuba

Larry Dine

Many musicians find it difficult to capture the sound of their instrument in a recording. Often times the trouble is getting a recording to sound natural, or true to life. This is no different for the classical tuba, especially due to the way its sound is produced. This paper focuses on some of the broad variables that go into realistically reproducing the tuba's sound, which has received very little, if any, academic study.

Within this study, microphone selection and placement is considered, interpreted, and discussed via objective and subjective methods. More specifically, this includes direct and indirect microphone placements, as well as condenser and dynamic microphones containing both small and large diaphragms. Each microphone placement and microphone type is compared and contrasted with each other. Objective data was collected via spectrographs and analyzed; subjective methods include appraisal of audio playback.

Based on the results collected, the author includes a suggestion for how to capture the best tuba sound via recording. The author also offers input on areas that still require further study.

Table of Contents

Acknowledgement	iv
Chapter 1. Introduction	1
<i>Why study this?.....</i>	<i>1</i>
<i>Objectives</i>	<i>3</i>
<i>Terms, Definitions, and Other Considerations</i>	<i>4</i>
<i>Anticipated Conclusions</i>	<i>10</i>
Chapter 2. Methodology	12
<i>Acoustical environment.....</i>	<i>12</i>
<i>Equipment used for recording</i>	<i>12</i>
<i>More on Microphones</i>	<i>13</i>
<i>Microphone Placements</i>	<i>16</i>
<i>Recordings.....</i>	<i>17</i>
<i>Recording Analysis</i>	<i>18</i>
Chapter 3. Analysis of Recordings	20
<i>Direct Placements - SM57.....</i>	<i>20</i>
<i>Indirect Placements - SM57.....</i>	<i>23</i>
<i>Direct Placements - AT2035, EV RE20, MD 421-II, SM7b</i>	<i>25</i>
<i>Indirect Placements - AT2035, EV RE20, MD 421-II, SM7b.....</i>	<i>29</i>
Chapter 4. Conclusions	31
<i>Above Bell Microphone Placements</i>	<i>31</i>
<i>Under Bell Microphone Placements</i>	<i>32</i>
<i>Indirect Microphone Placements</i>	<i>33</i>
<i>Areas for Continued Study.....</i>	<i>34</i>
<i>Final Thoughts: Recommendations for Recording the Classical Tuba ..</i>	<i>38</i>
Works Cited	40

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Chapter 1. Introduction

Why study this?

Though there is much written on the topic of recording, almost nothing is written specifically related to recording the tuba. In most writings on recording techniques, the tuba is a peripheral matter, in which it is either lumped in with a short paragraph on general brass recording techniques, or mentioned in passing. Somewhat often, the topic of recording brass instruments is left out entirely.

In order to showcase the lack of writing time the tuba gets in documents on recording, let us look at some examples. The 2004 magazine article, *Brass Tactics*, from the well-known recording magazine *Electronic Musician*, only mentions the tuba in passing. “Although there are many instruments in the brass family—including trumpet, cornet, trombone, French horn, euphonium, and tuba—I’ll concentrate on trumpet and trombone because they’re the ones you’ll most frequently encounter” (Summer 74). Given that the article was not titled “Trumpet and Trombone Tactics,” I may have expected an overview on all instruments of the brass family, and not just trumpet and trombone. A similar situation can be found in Lynn Fuston’s 2004 *EQ Magazine* article, *Miking Brass—Getting Down to Brass Tracks*, where the only brass instruments discussed are saxophones (a reeded woodwind instrument that happens to be made of brass), trumpets, and trombones (Fuston). A 2005 article from *Mix Magazine* includes information about trumpet, horns, trombones, and (again, technically not a brass instrument) saxophone (Becka). The tuba finally gets a mention in the periodical, *Connections*, where David Sebald gives a quick suggestion on recording techniques for

many classical instruments. “Tuba tones are quite diffuse and don't have high overtones. A dynamic mic at 3 or more feet away catches the sound just fine. If you want the realism of breathing and key clicks, a little closer” (Sebald, *What Every Musician Needs to Know About Microphones Part 4* 10). This “suggestion” offers very little detail, and does not mention if he means for the audio engineer to put a microphone three feet above the bell or three feet in front of the performer. Steve Savage recommends the same trick for all brass in his book, *The Art of Digital Audio Recording*, “...a basic miking technique will serve well for all brass: the mic is placed opposite the bell (the large opening at the end of the instrument). The mic can be placed closer or farther from the horn, depending upon [the microphone’s ability to handle high volume]...” (Savage 112). He goes on to suggest placing a microphone about 18-24 inches from the bell for a tuba. While more descriptive than other information one can dig up about recording, this final recommendation does not offer a whole lot of insight. Though this is all just a general overview of what can be found on recording brass (and the tuba), it should be pretty clear from these snippets of published works that there is hardly anything written about recording the tuba in specific.

Now that it has been established that this topic has received little to no formal study, the question of why it is an important topic comes up. Nearly all instrumentalists face difficulty in reproducing the natural, life-like sound of their instrument via a recording. This applies to the tuba without a doubt. Due to the shape of the classical tuba, the tuba is arguably one of the most difficult instruments to record accurately (“accurately” in this case means close to the sound of what an audience member hears when in the same room as a tuba performer). The bell of the tuba points upward, rather

than outward (like on neighboring trumpets and trombones), meaning sound heard by the audience is mostly due to reverberated sound waves. These waves can pose a difficult situation in the recording process, where traditional close-miking techniques (such as putting a microphone straight into an instrument's sound source — the tuba's bell — to capture direct sound) result in a completely different sound quality than what an audience member would experience in a live performance at a music hall — mostly indirect sound. Unfortunately, capturing sound indirectly with a microphone can introduce many complications to the resulting recording. With these ideas in mind, the topic of recording the tuba can get rather murky, and it can become quite difficult for a recording engineer to best capture the tuba's sound.

Throughout my own experience recording the tuba, I have found that it is easy for tuba recordings to fall into two sound categories: 1) that of a direct bell sound, which introduces unique sound artifacts and results in a harsh and punchy sound (typically the opposite of what a classical musician is looking for), and 2) that of an echo-y room, where the tuba can sound thin, dull, distant, and lifeless. It is anticipated that this study will produce a better understanding on what yields the aforementioned results, and subsequently open the door to new ideas that can capture the tuba's sound more accurately.

Objectives

Various genres of music which use the tuba (New Orleans Brass Band, Banda, Funk, to name a few) champion certain sound characteristics in regard to the tuba. I have found that many of these sound concepts do not lend themselves well to the tuba

in a classical context. While musicians on online forums may find it suitable to throw a microphone down the bell and call it a day, the resulting audio recordings typically are not suitable for the classical genre. Therefore, while the information in this document will be of use to all types of tuba players, the goal set forth in this study is to better understand the recording the tuba specifically in the classical setting. This will be done by exploring various microphone types and microphone placement techniques and looking closer into the effects of each. It is hoped that this document will be a valuable resource to those desiring familiarity with recording the tuba.

Because of the complicated nature of recording, this study had to be limited in its scope. There are simply too many variables that affect recording quality to allow for an exhaustive analysis of each. This paper will discuss a few single-microphone placements, using a limited number of microphone types.

Terms, Definitions, and Other Considerations

The following is a compilation of information that may be a useful reference in looking at topics located within this document.

Three Categories of Microphone:

Dynamic—does not require a power source. Can typically handle the highest volume levels (Sound Pressure Level, or SPL) and will be most likely to survive being dropped (Lau 60). These microphones are frequently used in live situations because of their durability, willingness to accept high volume, and better reduction of feedback (Gallant 50). Dynamic microphones are not as accurate as

other microphone types (such as condenser microphones). They often make the sound source “warmer” and “rounder” in character (Savage 112). This means that, depending on the microphone, they could make an instrument sound a bit darker than a more neutral microphone.

Condenser—requires a power source, or “phantom power,” at 48 volts. The power source often allows these microphones to transmit sound more evenly across the frequency spectrum. For this reason, condensers are often regarded as being more detailed (Savage 22). Condenser microphones are usually known for being more neutral (less colored) and for reproducing sound more accurately, especially in the higher frequency range (Gallant 50). In addition, they are generally more sensitive (Sebald, *What Every Musician Needs to Know About Microphones Part 4* 9). They sometimes can sound more bright as well (Savage 112).

Ribbon—less common than the other two categories of microphone. The diaphragm is made up of a ribbon (a thin, stretched piece of metal – also known as a filament) (Gallant 50). The pickup pattern of the ribbon includes a node on either side, resulting in a figure-eight, or bi-directional pickup pattern (Fuston). The bi-directional design of ribbon microphones often allow it to pick up more ambient, or room, noise (Summer 74). The ribbons in these microphones can be quite fragile, especially in older models, and therefore cannot always handle as much in the way of sound pressure level, or SPL. Newer models can handle

higher SPLs. Many believe ribbon microphones to be “smoother” sounding due to the way they pick up transients. They can often be brighter in sound than dynamic microphones, but are usually not as bright as condensers. As Steve Savage puts it in *The Art of Digital Audio Recording*, ribbon microphones are a good balance between “the warmth of a dynamic mic and the detail of a condenser” (Savage 21). This may be in part due to the fact that ribbons respond more quickly to transients than dynamic microphones. A ribbon microphone’s filament has less mass than dynamic microphone diaphragms, which allows it to react to sound waves more easily (Edstrom 70). These microphones are much less accessible (due to lack of commonality as well as due to price) than dynamic and condenser microphones (Savage 112-113), and for that reason were not used in this study.

Microphone Pickup Pattern: This describes the shape around a microphone’s diaphragm in which sound is picked up. Nodes in a pickup pattern denote a dead spot in the pickup pattern; sound coming from that direction cannot be detected in this particular part of the microphone (Gallant 51). All microphones in this study are cardioid microphones. These microphones pick up the most sound in the front, less sound on the side, and have a node in the rear (Sebald, *What Every Musician Needs to Know About Microphones Part 3* 10). This node can become helpful in rejecting unwanted noise while using direct microphone placements, such as instrument keys clacking or loud breathing.

Four Typical Pickup Patterns of Microphones:

Cardioid

Hypercardioid

Figure-8 or Bi-directional

Omnidirectional (Gallant 51)

Proximity effect: An increase in low frequency information the closer a microphone is to a sound source. This effect is noticed most in directional microphones, such as cardioids, and is worse in some microphones than others (White 312).

Transient: A non-repeating part of a sound wave which typically occurs in the articulation, or “attack,” of musical instruments and in speech consonants (White 404). This can also be described as “a short attack in the audio signal” (Kefauver and Patschke 67). This part of the sound wave is often much higher in amplitude than a sustained tone from a voice or instrument (White 404).

Considerations about close-miking techniques:

Pros—Captures the direct sound of the instrument. Reduces background noise such as from a ventilation system or performance sounds (like foot tapping).

When recording several instruments at once, close miking reduces noise from other instruments in the room, allowing for better control over each individual instrument’s volume, equalization, and other sound processing (such as artificial reverb) done in the post-recording process (Savage 22). Depending on the

microphone used, this technique contains more low frequency information due to the proximity effect, which can be either good or bad depending on the timbre desired (White 312). Reduces reverberated sound (also known as room sound), allowing for more control over this later (Savage 22-23).

Cons—Close miking does not always produce the same sound as what an audience member will experience. As Steve Savage says in *The Art of Digital Audio Recording*, “sometimes room ambience plays an integral role in the sound and is best captured in the initial recording” (Savage 22). “Room ambience” may very well play an integral role in the sound of a tuba due to its sound source (the bell) pointing upward, reflecting the sound throughout the room, rather than at an audience directly. Close miking would not capture room ambience. The close miking technique can also introduce unwanted sound artifacts (keys or valves clacking, a wind instrument player’s breaths, a bow scraping against a string, etc.). Additionally, with a microphone close to an instrument, the sound can drastically change if the musician likes to move their body and/or instrument during performance. Direct microphones often contain more low frequency information due to the proximity effect, possibly resulting in “muddiness” or a loss of clarity (Savage 22-23).

Considerations about room miking techniques:

Pros—the existence of acoustical reverberations can sound closer to what audiences hear. This could highlight good acoustics if done properly.

Microphones further from the source may additionally pick up less unwanted noise, such as breathing, key clacking, etc. (Savage 22).

Cons—The recording engineer cannot manipulate the room sound or artificial reverb after recording as easily after the recording has been made. This can highlight poor acoustics (Savage 22-23). Lack of bass frequency boost from the proximity effect could cause the recording to lack depth.

Diaphragm: The microphone diaphragm is what picks up sound vibration (say, from a tuba) and turns it into mechanical energy. The moving of a diaphragm is then converted into electrical current (Kefauver 16). This electrical current can be sent to a powered speaker (in live music settings) or to a computer/tape recorder for playback at a later time. Condenser microphones use a diaphragm that vibrates close to a back plate, while dynamic microphones use a diaphragm connected to a moving coil (Savage 19; Lau 60). There are two main diaphragm sizes: small and large. Small diaphragms are associated with being able to pick up all frequencies relatively evenly. Small diaphragms typically handle transients most accurately. Large diaphragms are associated with picking up low frequencies better than high frequencies since their higher mass (theoretically) makes them more difficult to be moved by higher frequencies (Savage 19). Though less accurate, some recording engineers take advantage of larger diaphragms to add “warmth” to a recording. Transients are often smoothed out in a large diaphragm

microphone as they do not react as quickly as small diaphragm microphones (Edstrom 70-71).

Anticipated Conclusions

It is my hypothesis that recordings from microphones positioned closer to the tuba will possess more low-frequency information due to the proximity effect. I believe that these closer placements may not sound natural or realistic since audience members do not hear the tuba's sound so closely, but rather from the seats of a music hall, which is often ten or more (up to several hundred) feet away. Because the sound of the classical tuba is not normally heard directly by audience members (as well as due to personal experience), I also believe that placements that are able to capture more direct sound from the tuba will contain more high-frequency artifacts, which for the purposes of this document I will refer to as "bell fuzz."¹ Microphones in indirect placements may not provide enough of the low end of the frequency spectrum to sound natural either, as the tuba's voice tends to be deep in such a way that one can often feel its resonance throughout the body, similarly to the feeling of a subwoofer in a loud movie theater or from a car's loud stereo passing by on the street. Without enough of the lower frequencies, the recorded tuba can sound thin and distant. This is likely to happen with the microphone placements that are the furthest from the tuba. Additionally, microphones placed further away will introduce a new element: acoustics. A decent acoustic can often be pleasing when a human is listening to a sound source live, but can often cause headaches and complications when a microphone captures many

¹ The term "bell fuzz" was first used by Carson McTeer in a personal conversation with me. This term seems uniquely fitting and so I have decided to use it for more easy referral of this phenomenon within this document.

sound reflections.

With these considerations in mind, I believe that a microphone placement somewhat removed from the tuba (giving the tuba sound a chance to fill up the room), without receiving too much direct sound from the bell, will give the most balanced response. Additionally, I hypothesize that one microphone alone may not be able to record an adequate representation of a tuba's sound. Instead it is my belief that a blend of microphone placements (allowing for the capture of multiple aspects of the tuba's sound) may be needed in order to in order to recreate what an audience member experiences when listening to a live tuba.

Chapter 2. Methodology

This study needed to be limited in scope in order to maintain focus on a few areas of interest. These areas of interest include a look into single microphone placements (as opposed to blending multiple microphones and placements together), microphone diaphragm types (small versus large), and two categories of microphones: dynamic and condenser. Ribbon microphones were left out due to expense and lack of availability, as well as to keep the study more simple in nature.

Acoustical environment

The acoustical environment in which a recording takes place can greatly impact the final result of a musical recording. A space with a lot of reverberation, or “echo,” will color the sound of a recording—for better or for worse. The recordings were made in West Virginia University’s Falbo Hall. This was done in attempt to eliminate extra sound coloring from the acoustical environment in each microphone placement. In addition to being a fairly large space, Falbo Hall is the “deadest” space available on West Virginia University’s campus—that is to say it has the least amount of reverberation. Because the space is relatively large, reverberated sound must travel farther in order to reach a microphone than in a smaller space. For the reasons stated above, it is hoped that this hall was the most acoustically neutral space available.

Equipment used for recording

MacBook Pro, Early 2011 model

Behringer U-Phoria UMC404HD (usb audio interface)

Logic Pro X (Digital Audio Workstation, or DAW – recording software)

XLR Cables

Cloud Lifter (used only on Electro Voice RE20 and Shure SM7b microphones)

Microphones:

Audio Technica AT2035

Electro Voice RE20

Sennheiser MD 421-II

Shure SM57

Shure SM7B

More on Microphones

Constant group: Shure SM57

The **SM57**, the instrumental counterpart to the SM58, is the “industry standard” instrumental microphone for live sound and recording (Gallant 50; Lau 60). Its rugged, dynamic design allows it to handle high SPLs in addition to standing up to rough use. This microphone is being used as a control for two main reasons: it’s affordability and its commonality (most sound technicians will have at least a few of these on hand). The fact that it is such a common microphone makes it a good candidate to use in comparing to other microphones.

Another reason for using this microphone is that I had access to three Shure SM57s for this study. This allowed me to record three separate microphone placements in the same take. Because of this, in each of the three microphone's respective recordings, I am able to completely eliminate discrepancies that can arguably exist across different takes/performances — thus eliminating human error.

Unfortunately, with other microphones, I only had access to one of each model. This required me to record many different takes, moving the microphone between each one. Though slight, this could introduce variations between recordings that would not be the result of the placement, but rather of the performer.

Additional microphones:

Audio Technica AT2035

Electro Voice RE20

Sennheiser MD 421-II

Shure SM7B

Each one of these microphones were chosen with a particular reason in mind, in addition to the fact that each was available for use in this study (either from my own collection or rented through WVU's music technology program). Among all of them, they contain diaphragms on the larger end. In theory, this can result in an overall smoother sound with greater presence from low frequencies. More can be read about this in the section of this document titled "Terms, Definitions, and Other Considerations." In my own experience, the classical tuba can frequently come across as rather harsh and

overly bright in amateur or otherwise rudimentary recordings. The fact that larger diaphragms are described as producing a smoother, warmer sound made this type of microphone diaphragm seem important to analyze more closely.

The **Audio Technica AT2035** has a large diaphragm and was chosen as the only condenser microphone in the study. This theoretically makes it a more accurate choice in reproducing the full frequency spectrum (without “coloration” of the sound).

The **Electrovoice RE20** and **Shure SM7B** are among the most common microphones used by radio and podcast hosts (Sebald, *What Every Musician Needs to Know About Microphones Part 4* 9) as well as for singers (Savage 22). In the same way they provide a warm, smooth sound for radio broadcasters, it was hoped that they provide warmth and smoothness on the tuba as well, accentuating the tuba’s characteristically deep sound. Additionally, I have seen both of these models come up on the internet (in social media and in tuba forums) as being used with success on the tuba. Though they both fit similar characteristics (large diaphragm, dynamic microphones used frequently for the voice), these two microphones appeared to be the most promising for the tuba after research on various microphone types.

The **Sennheiser MD 421-II** was chosen mostly to add variety to the microphone selection, as well as due to its frequent use on instrumental applications. It contains a diaphragm that is somewhere between small and large in size. *It is important to note that this was also the only microphone used with a bass roll off function engaged.* This can reduce proximity effect in a recording. For better or for worse, this adds further variety to the spectrum of microphones used in this study.

Microphone Placements

There are two overarching placement types of interest in this study: **direct** and **indirect**. These are of interest due to the unique way the classical tuba produces and projects sound into an audience, with the sound directed toward the ceiling, allowing the audience to hear *mostly* reverberated sound, rather than sound directly from the bell. It should be noted that audio engineers are known to mix both direct and indirect microphone recordings for the best of both worlds. This study's separation of these two placement types will help to detect (and understand!) the difference in sound between each.

Within direct placement, two subcategories exist: placements above the tuba's bell and placements below the bell. Placements above the bell will look at the effect of distance above the bell, as well as the effect of placements along bell's axis—in the center of the bell versus near the edge of the bell. Placements below the bell also look at direct microphone placement (less acoustical information, more low frequency information), but will additionally allow us to compare how much bell fuzz is present below the bell.

Direct Placements used:

- One, two, and three feet above the bell (at the center of the bell)
- Above the bell: Center, edge, and between the center and edge of the bell (all one foot above the bell). With each of these, the microphone diaphragms were approximately parallel to the bell

-Below the bell: three inches below the bell's edge (with microphone approximately parallel to the bell), three inches away from the biggest part of the bell flare with the microphone diaphragm pointed at the flare (where the bell has the widest bend as it expands outward), and a foot from the bell flare with the microphone diaphragm pointed at the flare.

Indirect Placements used:

-five, ten, and fifteen feet away from the bell (in the direction of the hall's audience seating), approximately four feet above the ground, with the microphone diaphragms pointed at the performer.

Recordings

Each recording contains a total of nine tones from the tuba. First, three C2s, second, three C3's, and finally, three C4s. These tones are each an octave apart, and give a look into the most commonly used two octaves of the instrument. The repetition of each tone is meant to provide multiple choices for analysis later. The best (meaning the most natural and steady sounding) of each set of three tones can be chosen for analysis. The pitch class, C, was used because the recording was done with a CC tuba, meaning these tones could all be produced without any valves.

Recording Analysis

The analysis is done in two ways: comparison of spectrum graphs for quantifiable data that depicts the strength of presence of each frequency in the recording, as well as with aural comparison between recordings.

Spectrum graphs were synthesized with two types of visualization software: Sonic Visualiser and Logic Pro X's Multimeter tool. Sonic Visualiser provides a more traditional frequency spectrum snapshot, while Logic Pro X's Multimeter tool provides a 61-band level meter of the frequency range. A benefit of the Multimeter tool is that it can simultaneously show two levels within the same image—the peak of each frequency during the articulation and also the level of each frequency in the middle of a long tone.

Each take was normalized in Logic X. This process finds the peak volume of each recording, and sets it to the same level. For microphones different distances away from the tuba, this adjusts the volume to be the same for the sake of comparison. For example: a microphone five feet away from the performer will pick up sound at a much greater volume than a microphone fifteen feet away from the performer. Normalizing the recordings helps ensure that the audio from both microphones are at the same level before being analyzed.

First, three (out of the nine total) tones were selected from each recording: one C2, one C3, and one C4. The most steady example of each tone is the one that is selected. Then, the recordings are put into both Logic Pro X and Sonic Visualiser. A snapshot is taken from the middle of the recording, a little after the articulation of each tone, allowing for the sound to settle after articulation. In recordings of the same take,

the snapshot is taken at the exact same part of the recording to allow for better comparison.

For example: in a single recording take that uses three SM57s (simultaneously) at three different heights above the bell, the snapshot of each spectral analyzer is taken at exactly the same amount of time after the articulation. In these instances we can rule out any fluctuation of sound waves during a single tone.

Chapter 3. Analysis of Recordings

Note to reader: use the appendix and recordings with this section. All images and track numbers correspond to each other. Image 1.1a and 1.1b are visual representations of track 1.1.

An important first note to make about the spectral graphs is the fact that the lowest octave C recorded included the most frequency information. That is to say that this octave contained more overtones. This gives us the most information about frequency response of each microphone and placement due to the existence of a wider variety of frequencies. With this in mind, it makes most sense for the discussion around the analysis to include the lowest octave recordings, eliminating the need to analyze the recordings of the C3 and C4 octaves.

A second note to make is that sound characteristics are most impacted by the ratio of frequencies to each other rather than by volume itself. Therefore, a look will be taken at frequency presence in relation to each the frequencies that surround it rather than by sheer decibel count alone.

The most important place to begin with analysis of the recordings is with the SM57 microphone takes. Because the microphone type is the same, we can most easily assess effects that microphone placement has on the resulting recording.

Direct Placements - SM57

Height Above the Bell (in the center of the bell):

First is a look into direct microphone placements. Because the sound of the tuba comes from the bell, this seems a natural place to start. In images 1.1a-1.3a, we see a snapshot of the frequencies picked up by an SM57 when a C2 is played on the tuba. Fairly little difference is seen between the three heights (1, 2, and 3 feet, respectively). The most easy difference to spot is a slight change in ratio between the lowest two frequencies present (around 62 Hz and 125 Hz). There is a smaller gap between these two frequencies with the SM57 1' above the bell than in the other two placements. This suggests a higher ratio of the 62 Hz frequency compared to the frequency shown in the 125 Hz band. With the microphone 1' above the bell, there is approximately 14 dB difference between the two frequencies, while the microphone 3' from the bell there is about 16 or 17 dB between these two frequencies. This may likely be due to proximity effect making the presence of lower frequencies more strong.

In listening to the audio of the SM57s at each height above the bell (tracks 1.1-1.9), a general trend is that the further the microphone is from the bell, the less of the low frequencies can be heard. This trend is coupled by a slight increase in higher overtones, giving a more nasal quality. All of these recordings had a harsh, fuzzy quality (bell fuzz) in the higher frequency range that made them sound inauthentic.

Above the Bell, Center vs. Edge of Bell:

In looking at the effects of the bell axis (whether one places the microphone closer to the center or edge of the bell), the most apparent difference in spectral graphs is in the high frequency content. Image 2.1a (showing the recording of C2 at the edge of the bell) shows frequencies dropping off entirely about halfway between one and two

kHz. The peak frequencies, shown in yellow lines (which would have given the frequency at the articulation of the note), also show a drop after about 3 kHz. If we compare this to image 2.3 (the recording of C2 made in the center of the bell), we see that the high frequency range does not drop off until 2 kHz, while the peak frequency shows presence up to 4 kHz (with 8 kHz present, though it is hard to say if this is an artifact found in the recording – its presence is very faint).

In listening to tracks 2.1-2.9 (especially those made of the C2 octave, 2.1-2.3), we can hear bell fuzz: a nasal, uncharacteristic quality that is similar to the Take 1 recordings (tracks 1.1-1.9). This fuzzy-sounding quality is a bit more subdued the further the microphone is from the center of the bell. This can be heard in tracks 2.1-2.3, where track 2.3 (center of bell) sounds more fuzzy than either tracks 2.1 or 2.2.

Under the Bell:

Compared to the recordings made above the bell, those recorded below the bell have decently reduced high frequency information. Images 3.1a-3.3a show the C2 overtones all but entirely dropping off the chart by about 1 kHz, with 3.2a (microphone pointed at bell flare) dropping off just before 1 kHz. Even the peak frequency shows nothing above 2 kHz, while the recordings taken above the bell mostly have peak frequencies apparent up to about 4 kHz or even above. Furthermore, each of these recordings shows a much steeper roll-off of high frequencies. This can be seen rather well if we look at the 250 Hz band compared to the 1 kHz band. In images 3.1a-3.3a, we can see about a 30 dB difference in volume between these frequencies, while in images

1.1a-1.3a, we see sometimes only a 10 dB change. This is a rather drastic roll-off of the higher frequencies.

Among the three SM57s placed under the bell, very little difference can be seen between the spectral charts. The most noteworthy difference is that the microphone 1' from the bell flare had large dip around 800-900 Hz (image 3.3a), while the other microphones did not. The microphone 3" from the bell flare (image 3.2a) did not detect any frequencies above 1 kHz, while the other two microphones (images 3.1a and 3.3a) did barely include frequencies above the 1kHz band.

Among all recordings made with the SM57 microphones, Take 3 tracks (tracks 3.1-3.9) have the least amount of high frequency artifacts or fuzz when listening. Due to how unnatural sounding the bell fuzz was in Take 1 and Take 2 (all above the bell), recordings under the bell seem a lot more promising for making natural sounding recordings. They do, however, sound slightly "muffled," or "muddy." This could be a potential drawback of this type of placement.

Indirect Placements - SM57

Distances Away From the Performer (in the direction of the audience):

In looking at 5, 10 and 15 foot distances from the performer in the C2 recordings, there is a bit less consistency among spectral graphs. Not only are these microphone placements five feet apart from one another (rather than several inches), but another factor has been added as well: acoustics. For example, with the C2 recording made ten feet away from the performer, we see a small spike in the frequency band just below 1 kHz, at approximately 900 Hz or so (image 4.2a). We do not see this five feet (image

4.1a) or fifteen feet (image 4.3a) away from the performer. For that reason, this spike would not seem to have to do with any correlation between distance away from the performer and presence of this frequency. Rather, it could be due to the specific acoustics of the space.

Because acoustics add another complication (which may be impacting the spectral graphs), it could be more helpful instead to consider more general trends. For example, in images 1.1a-1.3a we can generally see a plateau in frequencies from about 250-500 Hz, with a small, but steady drop off until a little after 1 kHz, where we see a steep decline in frequencies. By contrast, in images 4.1a-4.3a, we see strong, but unsteady presence in the 250-500 Hz range, with a greater decline from 500 Hz to 1 kHz, which continues until no higher frequencies can be detected. So in these placements further from the performer, the frequencies above 500 Hz begin to decline more rapidly, dropping off entirely by 1.5 kHz. By contrast, some of the placements above the bell still show presence of frequencies around 2 kHz, such as in image 2.2a, showing C2 a foot above the bell, between the edge and center of the bell.

A trend noticed in playback of recordings with the SM57s placed in front of the performer (tracks 4.1-4.9) is that the closer the microphone is to the performer, the more low frequencies are salient. Unlike the recordings made from above the bell, there is not anywhere near as much in the way of fuzziness, nasal quality, or artifacts in the higher frequency range. Additionally, unlike the recordings made below the bell, the placements further away from the performer do not have a muffled quality. It would seem that allowing the sound some distance from the sound source (the bell) reduces the nasal quality that can be captured directly above the bell. Potentially the biggest

drawback of these placements away from the performer is the lack of lower frequencies. The middle to higher frequencies sound quite a bit more natural than in the recordings of direct microphone placements, which could be in part due to the acoustics adding some “liveliness” to what the microphones are able to pick up. Yet, the low frequency content is rather lacking compared to what it sounds like to listen to a live tuba in a recital hall.

Direct Placements - AT2035, EV RE20, MD 421-II, SM7b

Above Bell, In Between Center and Edge of Bell:

The same high frequency artifacts that were heard above the bell in the SM57 recordings can also be heard in the AT2035, RE20, MD 421-II, and SM7b. However, there is a bit of variance in how much this nasality is heard. For example, the Sennheiser MD 421-II has even more of this quality than the SM57. This is likely perceived as being even greater due to the fact that the bass roll-off function was engaged on this microphone during recording, making low frequencies sound much weaker than middle and high frequencies. To put it rather bluntly, the MD 421-II (with bass roll-off) sounded terrible above the bell due to how bright it is. It would hardly pass as sounding like a tuba at all – disengaging the bass roll-off function could change this. Among the large diaphragm microphones (AT2035, RE20, and SM7b), the AT2035 had the greatest amount of clarity (which makes sense as it is a condenser microphone—often increasing high frequency range, or at least possessing a more “level” frequency response in the high range), while still possessing a great deal of low frequency substance. The RE20 and SM7b, on the other hand, are a bit more rounded out. They

contain less high frequency fuzz than the AT2035, and sound more deep and rich. The SM7b may sound slightly more clear than the RE20, or at least when comparing them aurally side-by-side, the SM7b seems to have slightly more mid-high and high frequencies.

If we look at the spectrographs, we can see all of the same trends that are heard in these recordings. Image 5.1a shows that the AT2035 has about a 15 dB drop from around 200 Hz to 1 kHz, while the RE20 has about a 21 dB drop in image 5.2a. The SM7b in image 5.4a shows about a 17 dB drop in the same frequency range, showing that the AT2035 has the greatest high frequency response, with the SM7b being slightly more “clear” sounding than the RE20. The MD 421-II (image 5.3a) only has about 8 dB drop off in the same range, giving it by far the greatest ratio of middle and high frequencies. This data accounts for how bright this microphone sounded. Looking back to Image 2.2a, showing the SM57 in the same relation to the bell of the tuba, we see a 16 dB drop across this frequency range, showing possibly a bit more high frequency information than all of the large diaphragm microphones (except for the AT2035, which is a condenser microphone).

If we take a look at the low frequencies, we see a 19 dB difference from 62 Hz up to about 200 Hz in the MD 421-II recording (image 5.3a), while the AT2035 (image 5.1a) shows about a 11 dB difference. In the same comparison, the RE20 (image 5.2a) shows a 15 dB difference, and the SM7b (5.4a) shows approximately 12 dB between the same frequencies. This is consistent in finding the MD 421-II to lack a significant deal of low frequency material. The 11dB difference in the AT2035 explains why the recording it made of the C2 octave still had a full low end response, despite the harsher sounding

upper frequency range. In looking at how the small diaphragm SM57 compares to these larger microphones (like in image 2.2a, which was made in the same placement), it has a 15 dB difference between 62 Hz and 200 Hz, which is similar to the RE20. The RE20, however, had a quicker drop off in the high frequency range than the SM57, perhaps due to differences in diaphragm size.

Under Bell, About 1' Away:

The most stark difference among all of the microphones under the bell comes from the Sennheiser MD 421-II. The counteraction of the proximity effect – created by the engagement of its bass roll-off switch – reduces low frequency presence significantly. This results in a much brighter, or at least less dark and muddy, recording, without the harshness found above the bell. By contrast with the MD 421-II (track 6.3), the AT2035 (track 6.1), RE20 (track 6.2), and SM7b (track 6.4) sound a bit boomy and deep. Unfortunately, the MD 421-II is likely too bright. It lacks so much low frequency content that it loses its natural depth that can be perceived in listening to a tuba live.

In spectrograph images 3.3a and 6.1a-6.4a, above the fundamental pitch (around 62 Hz on the Logic-made spectrograph), the two overtones (approximately 125 Hz and 200 Hz, respectively) show a difference of about 10 and 13 dB in the AT2035, 15 and 18 dB in the RE20, 15 and 21 dB in the MD 421-II, 13 and 14 dB in the SM7b, and 14 and 15 dB in the SM57. It is surprising to see that the RE20 sounds almost as boomy as the AT2035 and SM7b, despite being the closest match to the MD 421-II as far as the relationship of the lowest frequencies to each other.

The MD 421-II was the brightest of the microphones in the under bell placement. This is represented in the data by a bigger difference between the fundamental pitch and the first two overtones. However, considering that the RE20 has a similar reading to the MD 421-II in this lower range (as mentioned in the previous paragraph), this suggests that perhaps the darkness of sound is determinant upon the relation of these lowest frequencies with the higher overtones. For example, from the fundamental (about 62 Hz) to the 250-350 Hz range, we see a difference of approximately 9 dB in the AT2035, 14 dB in the RE20, 20 dB in the MD 421-II, 11 dB in the SM7b, and 11 dB in the SM57. This additional comparison aids in showing why the MD 421-II has a greater bias towards having a brighter result than the RE20. This difference indicates that the middle frequencies shine through more in the MD 421-II than in the RE20. Similarly, the MD 421-II shows a near plateau in frequency response in the 200-350 Hz range, while the other microphones show a bit more clear downward trend in the same range. The increased presence of the MD 421-II in this range may very well be an added factor in its apparent brightness.

It is important to note that in every recording made under the bell there was an absence of bell fuzz. This bell fuzz has been a salient characteristic in every recording made *above* the bell. This means that among all of the direct microphone placements, placements below the bell seem to be the most usable for the classical tubist. Though the MD 421-II lacked enough low frequency presence, its bass roll-off setting was maxed out. Perhaps using a lower setting could yield beneficial results that are neither boomy nor bright. Better yet, bass roll-off could be achieved after recording via audio equalization, allowing the recording engineer to do it to taste.

Indirect Placements - AT2035, EV RE20, MD 421-II, SM7b

Distances Away From the Performer (in the direction of the audience):

Similarly to the SM57, the AT2035, EV RE20, MD 421-II, and Shure SM7b all contained less presence of low frequencies with microphone placements further from the bell than the direct placements. For example, with the AT2035 at 10 and 15 feet away, we see around a 20 dB drop off from just under 250 Hz to around 60 Hz (Image 8.1a and 9.1a). By comparison, in image 5.1a (AT2035 1' above the bell, between the center of the bell and the edge of the bell), there is only about 11 dB difference between those two frequencies. Additionally in image 6.1a (AT2035 about 1' under bell flare), there is about 13 dB of difference between the above frequencies. In image 7.1a, which is 5' away from the performer with the AT2035, we have about 15 dB of difference between around 250 and 60 Hz. With these numbers in mind, it is easy to see that placements that are further away from the bell can rather significantly reduce low frequency presence.

Additionally, these placements allow for more capture of upper frequencies better than with direct placements. Compared with direct placements above the bell, the high frequencies are able exist without the added harshness of the bell fuzz. As for the under bell placements, microphones several feet away from the performer contain more upper frequencies, making them sound less dull. This can be seen in images 6.1a-6.4a (below bell placement) as frequencies cease to be detected above 1 or 1.5 kHz, while away from the bell, frequencies are detected up to almost 2 kHz – especially for the SM7B at five and fifteen feet away (images 7.4a and 9.4a). Additionally, there is an essence to

the indirect placements, especially in the higher frequencies, that make them sound a bit more natural, possibly due to the acoustics of the room as well as the absence of bell fuzz.

In many of the recordings below the bell, a significant drop in middle to high frequencies is found – mostly steady from about 400 Hz to 1 kHz or higher, seen in images 6.1a-6.4a. On the other hand, five feet away from the performer, there is a steady presence from about 5-600 Hz to a bit over 1 kHz (see images 7.1a-7.4a). This can be observed to a certain extent in placements ten and fifteen feet away, such as with the AT2035 (image 8.1a and 9.1a), RE20 (image 9.2a), MD 421-II (image 8.3a and to a certain extent 9.3a), and Shure SM7B (image 8.4a and 9.4a). This shows that placements away from the performer do a better job of capturing mid to high frequencies than under bell placements.

The frequency ranges extend even higher with indirect placements as well. For example, in image 6.1a we do not see any detected frequencies above 1 kHz for the AT2035, while indirect placements of the same microphone show frequencies reaching around 1.5 Hz (images 7.1a, 8.1a, and 9.1a). Additionally, with indirect placements, peak frequencies that indicate the volume of the note start, or articulation, extend to about 4 kHz (7.1a-7.4a, 8.1a-8.4a, and 9.1a-9.4a), while direct placements under the bell show peak frequencies only to about 2 kHz (images 6.1a-6.4a).

Chapter 4. Conclusions

It seems apparent that the greatest factor in the sound of a recording is due to the placement of the microphones. While there are appreciable differences between each type of microphone (condenser vs. dynamic, small diaphragm vs. large diaphragm), the trends shown across all microphone placements are both relatively consistent (no matter the microphone) and often of greater significance than the differences between specific microphones. For example, no matter the microphone type, bell fuzz was detected in every microphone placed above the bell. In a similar manner, when looking at indirect microphone placements, all microphones that were tested lacked the bass response to stand alone as a good representative of the tuba's sound. Therefore, I believe the greatest takeaway from this study is what was learned about the effects of each microphone placement.

Above Bell Microphone Placements

As already mentioned, all microphones that were placed above the bell contained a harsh artifacts in the upper frequency range, which has been deemed "bell fuzz" in this document. For this reason, recordings made with these placements, while containing a wide spectrum of frequencies, are practically useless for the classical tubist. Bell fuzz is incredibly distracting, and out of the character for how the classical tubist would hope to sound. The axis of a placement (center of bell versus edge of bell), as well as the height of the placement, did make an appreciable difference in recording, however the presence of bell fuzz rendered all above-bell placements unusable for the classical tubist.

As a side note on placements above the bell: an over-bell placement may often be acceptable in other genres of music, such as jazz, funk, or rock. With this type of placement, the presence of the low end of the frequency spectrum, due to proximity effect in many directional microphones, adds great weight and depth to the sound of the tuba. Meanwhile, the added presence of high frequencies above the bell could potentially allow the tuba to punch through in a rock or funk mix. In these more popular genres of music, mid to low frequencies can become rather saturated as they are shared by so many different instruments. In these instances, the presence of bell fuzz could potentially help the tuba to stand out, just as the higher overtones of a “slapped” electric bass jump out in a recording. While the subtlety found in classical music would likely be ruined by bell fuzz, this may not be much of an issue in types of music that are often already made up of distorted guitar, bass, and/or drum kits. Others may prefer the way in which a microphone above the bell includes more of the high overtones of the tuba, giving the tuba a more clear articulation.

Under Bell Microphone Placements

Direct microphone placements that were under the bell had the benefits associated with direct miking: less environmental and acoustical sound interference, while still maintaining a characteristic tuba sound in general. Lack of bell fuzz was a huge benefit of recordings made under the bell. A downside with this was that sometimes recordings sounded slightly muffled, with the low frequencies on the boomy or muddy side of things.

In both looking at the spectral graphs and in hearing the audio files, it would seem that the high frequencies were lost a bit under the bell. This makes sense due to the directionality of higher frequencies. Lower frequencies, especially sub-bass frequencies, are usually non-directional, and therefore not as reliant upon having a direct “line of sight” between the sound source and the microphone in order to be detected. Despite a slight loss of the highest frequencies, these recordings were rather characteristic of the classical tuba’s sound, albeit slightly boomy at times. This is most probably due to the proximity effect, and could potentially be remedied by a few things: equalization during post-production of a recording, utilizing different microphones (such as those with omni directional pickup patterns that are less prone to proximity effect, or microphones with bass roll-off settings), or even pulling the microphone away from the underside of the bell another foot or two—reducing proximity will attenuate the proximity effect.

A potential concern with under bell placements that was not looked at closely in this study is extraneous noises, such as the performer’s breathing and valve noise. On the other hand, some purists in the audio world would insist that these noises add life and a sense of realism to recordings, mimicking the sounds likely to be heard in a live performance. Yet, even if one were to subscribe to this “realist” argument, too much of a good thing could easily become distracting in the context of a classical recording.

Indirect Microphone Placements

Microphones that were further away from the performer (at 5’, 10’, and 15’) had a certain natural quality, especially in the middle and high frequency ranges. The

downside to this was that they usually lacked so much in the low frequency range that the timbre would seem too “thin” sounding. Compared to the sound heard when one is listening to a live tuba (even if relatively far away from the performer), these recordings lacked in depth of sound. A live tuba player fills the room with their sound, and one can usually *feel* the lowest frequencies in their abdomen. Although a recording will not create a physical sensation (unless played back at extreme levels), microphones too far from the performer simply lack the low frequency content to give the impression of a full tuba sound.

The greatest benefit of the indirect placements is the ability to capture a wider range of high frequency information without the added bell fuzz. The possible downside to this is the addition of another variable: the room’s acoustics. If the room’s acoustics are an element that is disliked in a specific microphone’s recording, there is nothing that can be done to take the acoustic information away without excluding that microphone’s recording from the final product.

Another benefit of indirect microphone placements is the absence of muddiness or boominess. Of course, the downside to this, as previously discussed, is a fairly severe lack of low frequency information (depending on how far away microphones are placed).

Areas for Continued Study

After considering the above discussion of benefits and weaknesses among various types of microphone placements, new questions about recording the tuba come to mind. This study had to be limited in scope in order to maintain focus on a

complicated topic that appears to have had no previous formal or published study. Therefore, the scope of this one study alone is not enough to cover the infinite number of variables that can be looked at when exploring the complicated topic of recording the tuba. This section of this document will discuss other areas that would be useful to study further in order to better understand tuba recording.

Considering that all of the microphone placements had a perceivable (and measurable) benefit and weakness, it would be conceivable that mixing two microphone placements could yield a beneficial result. Though mixing signals between several microphones was not specifically looked at in this study, it would seem possible that mixing the signal of a microphone under the bell with that of a microphone placed far away could lead the recorder to capture the best of both worlds: the low frequency depth of an under bell placement in addition to a natural sounding high frequency range of an indirect (or “room”) microphone. These signal levels could be mixed and matched to taste in the post-recording production. If the final result has too much low frequency content, the recording engineer could simply turn down the track that contains the microphone placed under the bell. Conversely, if there is too much high frequency and/or acoustical information in the final result (or if the room’s acoustics do not lend themselves well to the recording), the recording engineer could turn down the track containing the microphone that was placed 10’ (or more) from the performer.

Another area that could be studied in greater depth is a wider array of microphone placements. This study was mostly able to record a few categories of placements (e.g. direct vs. indirect, under bell vs. over bell), but microphone placement options are infinite in number. For example, only three placements under the bell were

tested. What if three feet away from the bell flare was less boomy than one foot away from the bell flare? I would even be curious to know what a microphone 10' directly above the bell would sound like (should a microphone stand that tall exist). Or, for another example, if one foot underneath the bell is too boomy, and five feet from the performer may not contain enough perceived depth, what about two, three, or even four feet from the performer? There could be a sweet spot that captures the best of both worlds with just one microphone. Another question arises from this idea as well: would the height of the microphone from the ground matter if the microphone were just two or three feet away from the performer? Three or four feet from the ground would still be under the bell of the tuba, while five or six feet from the ground could theoretically pick up some direct tuba sound above the bell in an oblique fashion. Would that introduce bell fuzz? Or does the bell fuzz only come from immediately above the bell? Would a microphone that is six feet above the ground and three feet away from the performer be able to capture more high frequencies? Would that make it sound significantly different from a microphone that is only three feet above the ground (but still three feet away from the performer)? There are still many worthwhile questions about microphone placements that could only be answered with further study.

Other placement possibilities could take into consideration the less desired noises heard from a performer: breathing, valve noise, and foot tapping. The design of this study could not account for these noises, as a five to ten second long tone does not require breathing in the middle, toe tapping to keep time, or changes in valves. It is worth noting that breathing and/or valve noise may be more subjective since these are arguably “natural” and “human” imperfections that would be heard during live

performance. One way in which this could be studied is by using directionality of microphone (and the nodes in their pickup patterns) to try to block out valve clatter, breathing, and even toe tapping.

Types of microphone is another area for continued study for a few reasons. For one, ribbon microphones were not looked at in this study. While they are typically less accessible (financially as well as in quantity compared to condenser and dynamic microphones), I have found several anecdotes among colleagues and in informal internet discussions about ribbon microphones working well on brass instruments due to their ability to pick up more detail than a dynamic microphone, while not getting quite as overly harsh as can sometimes happen with a condenser microphone. It is said that sound transients are typically smoothed by use of a ribbon microphone. This may be an additional reason for ribbon microphones to be able to record brass without introducing harshness into the sound.

Another area needing study relating to a ribbon microphone has been touched on above, but is worth revisiting: the figure-eight pickup pattern of a ribbon microphone could be used as an advantage when trying to mask valve clatter and breathing. The nodes in either side of this figure-eight pattern effectively block out sound. Pointing one of these nodes at either the mouth of the musician or the valves of the tuba (or since there are two nodes — one on each side — perhaps one node could be pointed in the vicinity of the mouth of the performer, while the other could be pointed near the valves) would prevent breathing and valve noise from being picked up by the ribbon filament.

Furthermore, only cardioid microphones were used in this study. Omnidirectional microphones, in contrast to more directional microphones, typically do not pick up

extended bass from the proximity effect. Using an omnidirectional microphone under the bell could aid in taking out the heaviness of bass frequencies that were found in this study. While one microphone in this study did take advantage of its bass roll-off function (the Sennheiser MD 421-II), the study did not look at the same microphone's results with the roll-off switch disengaged. Therefore, a closer look at the effects of the roll-off switch is an additional area for possible study.

Final Thoughts: Recommendations for Recording the Classical Tuba

There are still plenty of questions regarding the topic of recording the tuba. With that said, the information that has been learned as a result of this study leads me to a broad recommendation in recording the tuba. I would recommend recording the direct sound of the tuba under the bell in addition to a stereo pair further away from the performer. The sound captured under the bell will provide depth and clarity without any acoustical information “bleeding” into the recording. The stereo pair can act as a “room microphone” to help pick up more of the middle and high frequencies (which can be lost a bit under the bell), as well as to give some natural reverberation. The use of a stereo pair will add a three-dimensional quality as well, mirroring what two ears are able to pick up in a live performance. The two signal types, stereo and direct, can then be mixed and matched to taste after the recording is made in a digital audio workstation (DAW), effectively combining the best of both worlds. Information collected from this study would suggest that neither of these microphone placements would pick up bell fuzz, which is seemingly half the battle in creating a realistic-sounding classical tuba recording.

If time allows, a few placement options could be experimented with before a recording is made. For the microphone under the bell, one could try placing the microphone further from the tuba to reduce proximity effect. One could also use a microphone with a bass roll-off switch (or an omni-directional microphone) to accomplish a similar result. The stereo pair could also be tried in a few different locations, both closer to and further away from the tuba. Closer to the tuba would likely pick up greater low frequency content, while placing the pair further away will capture more acoustical content.

After the recording has been made, a few other things could be done to help the sound quality via a DAW. If too much proximity effect results from the microphone under the bell, one could use an equalizer to attenuate the low frequencies. If the recording sounds dead and lifeless from a lack of natural reverberation, artificial reverb could be added to give the listener a sense of being in the room with the tuba.

Admittedly these recommendations for recording the classical tuba are not a simple checklist for how to capture the best sound. There are many variables in play, many of which were not able to be looked at more closely in this study. Yet, the recommendations provided are far more descriptive than what has been traditionally written on the subject, and therefore these suggestions should provide an excellent jumping off point in the recording process.

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Recording the Classical Tuba

D.M.A. Research Project — Appendix

Larry Dine

Table of Contents

A Note On The Appendix3

Shure SM57 Only4

Different Heights Above Bell4

Axis Above Bell.....10

Under Bell.....16

Distances Away From Performer22

Array of Mics: AT2035, RE20, 421-II, SM7b28

Above Bell28

Below Bell.....36

Distances Away From Performer: 5’44

Distances Away From Performer: 10’52

Distances Away From Performer: 15’60

A Note On The Appendix

This section contains visual spectral graphs from the research study. It is hoped that these visuals aid in understanding the differences between each microphone and each microphone placement. Due to the volume of data recorded, I have chosen to only include visuals from the C2 octave recordings. Among the three octaves/notes recorded – C2, C3, and C4 – this octave contained the widest array of frequencies to be measured, and is therefore the most useful for the purposes of comparison.

An added reason for excluding the C3 and C4 octaves is for ease of use by the reader. The addition of these extra octaves would yield over 100 additional pages, making this appendix rather cumbersome to sift through.

Also noteworthy in using the appendix is the fact that the image numbers correspond to the numbers found on recordings. For example, Track 1.1 correlates to both Image 1.1a and 1.1b. The images are visual representations of the frequencies found in the middle of the recording. The middle of the recording was used for making the spectral graphs in order to allow time for the tuba's sound to settle, as well as due to the desire for consistency. It is difficult to get all articulations to be exactly the same, and therefore making comparisons based on the articulation only, rather than the core tone, could potentially yield less consistent results.

Shure SM57 Only

Different Heights Above Bell

Image 1.1a

Shure SM57

1' Above Bell

C2

Logic Multimeter Tool

Image 1.1b
Shure SM57
1' Above Bell
C2
Sonic Visualiser

Image 1.2a
Shure SM57
2' Above Bell
C2
Logic Multimeter Tool

Image 1.2b
Shure SM57
2' Above Bell
C2
Sonic Visualiser

Image 1.3a
Shure SM57
3' Above Bell
C2
Logic Multimeter Tool

Image 1.3b
Shure SM57
3' Above Bell
C2
Sonic Visualiser

Axis Above Bell

Image 2.1a

Shure SM57

Edge of Bell, 1' Above

C2

Logic Multimeter Tool

Image 2.1b
Shure SM57
Edge of Bell, 1' Above
C2
Sonic Visualiser

Image 2.2a
Shure SM57
Between Center and Edge of Bell, 1' Above
C2
Logic Multimeter Tool

Image 2.2b
Shure SM57
Between Center and Edge of Bell, 1' Above
C2
Sonic Visualiser

Image 2.3a
Shure SM57
Center of Bell, 1' Above
C2
Logic Multimeter Tool

Image 2.3b
Shure SM57
Center of Bell, 1' Above
C2
Sonic Visualiser

Under Bell

Image 3.1a

Shure SM57

3" Under Edge of Bell

C2

Logic Multimeter Tool

Image 3.1b
Shure SM57
3" Under Edge of Bell
C2
Sonic Visualiser

Image 3.2a
Shure SM57
3" from Bell Flare
C2
Logic Multimeter Tool

Image 3.2b
Shure SM57
3" from Bell Flare
C2
Sonic Visualiser

Image 3.3a
Shure SM57
1' From Bell Flare, Pointed at Flare
C2
Logic Multimeter Tool

Image 3.3b
Shure SM57
1' From Bell Flare, Pointed at Flare
C2
Sonic Visualiser

Distances Away From Performer

Image 4.1a

Shure SM57

5' Away From Performer

C2

Logic Multimeter Tool

Image 4.1b
Shure SM57
5' Away From Performer
C2
Sonic Visualiser

Image 4.2a
Shure SM57
10' Away From Performer
C2
Logic Multimeter Tool

Image 4.2b
Shure SM57
10' Away From Performer
C2
Sonic Visualiser

Image 4.3a
Shure SM57
15' Away From Performer
C2
Logic Multimeter Tool

Image 4.3b
Shure SM57
15' Away From Performer
C2
Sonic Visualiser

Array of Mics: AT2035, RE20, MD 421-II, SM7b

Above Bell

Image 5.1a

Audio Technica AT2035

1' Above Bell, between center and edge

C2

Logic Multimeter Tool

Image 5.1b

Audio Technica AT2035

1' Above Bell, between center and edge

C2

Logic Multimeter Tool

Image 5.2a
EV RE20
1' Above Bell, between center and edge
C2
Logic Multimeter Tool

Image 5.2b

EV RE20

1' Above Bell, between center and edge

C2

Sonic Visualiser

Image 5.3a
Sennheiser MD 421-II
1' Above Bell, between center and edge
C2
Logic Multimeter Tool

Image 5.3b
Sennheiser MD 421-II
1' Above Bell, between center and edge
C2
Sonic Visualiser

Image 5.4a
Shure SM7b
1' Above Bell, between center and edge
C2
Logic Multimeter Tool

Image 5.4b
Shure SM7b
1' Above Bell, between center and edge
C2
Sonic Visualiser

Below Bell

Image 6.1a

Audio Technica AT2035

Under Bell, 1' From Bell Flare

C2

Logic Multimeter Tool

Image 6.1b
Audio Technica AT2035
Under Bell, 1' From Bell Flare
C2
Sonic Visualiser

Image 6.2a
EV RE20
Under Bell, 1' From Bell Flare
C2
Logic Multimeter Tool

Image 6.2b
EV RE20
Under Bell, 1' From Bell Flare
C2
Sonic Visualiser

Image 6.3a
Sennheiser MD 421-II
Under Bell, 1' From Bell Flare
C2
Logic Multimeter Tool

Image 6.3b
Sennheiser MD 421-II
Under Bell, 1' From Bell Flare
C2
Sonic Visualiser

Image 6.4a
Shure SM7b
Under Bell, 1' From Bell Flare
C2
Logic Multimeter Tool

Image 6.4b
Shure SM7b
Under Bell, 1' From Bell Flare
C2
Sonic Visualiser

Distances Away From Performer: 5'

Image 7.1a

Audio Technica AT2035

5' Away From Performer

C2

Logic Multimeter Tool

Image 7.1b
Audio Technica AT2035
5' Away From Performer
C2
Sonic Visualiser

Image 7.2a
EV RE20
5' Away From Performer
C2
Logic Multimeter Tool

Image 7.2b
EV RE20
5' Away From Performer
C2
Sonic Visualiser

Image 7.3a
Sennheiser MD 421-II
5' Away From Performer
C2
Logic Multimeter Tool

Image 7.3b
Sennheiser MD 421-II
5' Away From Performer
C2
Sonic Visualiser

Image 7.4a
Shure SM7b
5' Away From Performer
C2
Logic Multimeter Tool

Image 7.4b
Shure SM7b
5' Away From Performer
C2
Sonic Visualiser

Distances Away From Performer: 10'

Image 8.1a

Audio Technica AT2035

10' Away From Performer

C2

Logic Multimeter Tool

Image 8.1b
Audio Technica AT2035
10' Away From Performer
C2
Sonic Visualiser

Image 8.2a
EV RE20
10' Away From Performer
C2
Logic Multimeter Tool

Image 8.2b
EV RE20
10' Away From Performer
C2
Sonic Visualiser

Image 8.3a
Sennheiser MD 421-II
10' Away From Performer
C2
Logic Multimeter Tool

Image 8.3b
Sennheiser MD 421-II
10' Away From Performer
C2
Sonic Visualiser

Image 8.4a
Shure SM7b
10' Away From Performer
C2
Logic Multimeter Tool

Image 8.4b
Shure SM7b
10' Away From Performer
C2
Sonic Visualiser

Distances Away From Performer: 15'

Image 9.1a

Audio Technica AT2035

15' Away From Performer

C2

Logic Multimeter Tool

Image 9.1b
Audio Technica AT2035
15' Away From Performer
C2
Sonic Visualiser

Image 9.2a
EV RE20
15' Away From Performer
C2
Logic Multimeter Tool

Image 9.2b
EV RE20
15' Away From Performer
C2
Sonic Visualiser

Image 9.3a
Sennheiser MD 421-II
15' Away From Performer
C2
Logic Multimeter Tool

Image 9.3b
Sennheiser MD 421-II
15' Away From Performer
C2
Sonic Visualiser

Image 9.4a
Shure SM7b
15' Away From Performer
C2
Logic Multimeter Tool

Image 9.4b
Shure SM7b
15' Away From Performer
C2
Sonic Visualiser