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A Consideration on the Sound Radiation Pattern of Violin

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ABSTRACT

The Violin is the musical instrument in the stringed instruments family and is usually considered as the most important instruments in classical music. When the violin is played, it radiates sound waves in various directions. The sound that we hear includes the sound played from the violin, and the sound that has reflected from the hard surfaces from around us.

In order to study the sound radiation pattern accurately, we will set up a 42 channel spherical microphone array on a human sized Icosahedron in the Anechoic Chamber to prevent any sound reflection. A violinist will be playing in the middle of the spherical microphone array to record and analyze the spatial radiation pattern of the sound which is an important factor affecting our hearing of the violin sound.

Keywords: spatial radiation pattern, violin, microphone-array.

INTRODUCTION

The violin is a string instrument. Amongst the string family, it has the highest pitch. The violin body constitute by a large number of parts. Figure 1 shows the detail of violin parts [1]. The quote given below is from homepage on “Violin wizard” about major violin parts [2].

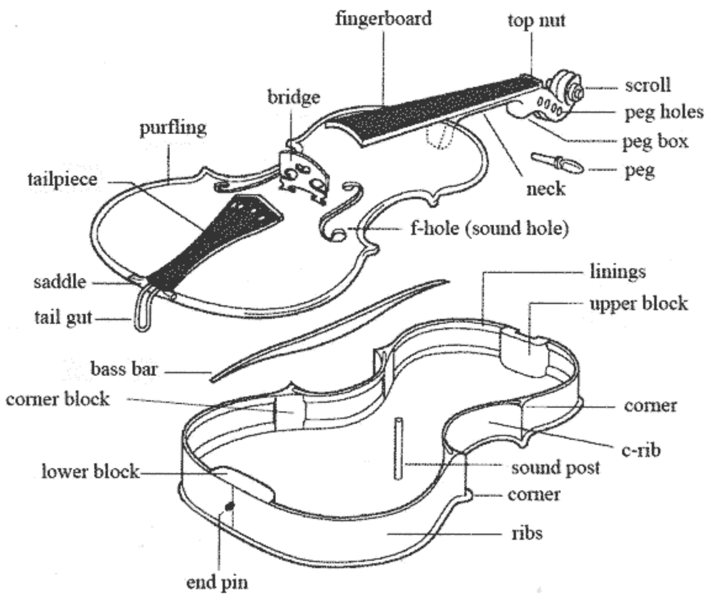

Figure1. *Schematic view of the violin.*

Violin body consists of the top plate also called the belly, back plate, ribs, which connect the top and bottom plate at the side and the neck. The back plate, ribs and neck are made of maple or sycamore

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whereas spruce is generally used for the belly. Added to this, the violin typically has four strings tuned in perfect fifths. The pitches of open strings (without any finger stopping) on a violin G3-D4-A4-E5 is used for most violin music.

Bridge

The bridge supports the strings above the fingerboard from the nut, over the bridge to the tailpiece. Bridges are usually made of maple as they have the ability to withstand the pressure caused due to tightening of the strings. Some bridges have an insert of ebony where the E-string will go to prevent its digging into the bridge.

Finger Board

The fingerboard is the piece of wood that is laminated on top of the neck of violin and above which the strings run. A violin's fingerboard is traditionally made of ebony. The player presses strings down to it in order to change their vibrating lengths, causing changes in pitch.

Bass Bar

Bass bar is a thin, about 265 mm long wooden strip attached to the interior of the belly underneath bass side of the bridge. It is almost parallel to the strings. The bass bar helps it to transfer the sound vibrations to a larger area of the belly.

Sound Post

The sound post is a cylindrical piece of wood, which is fitted to the interior of the instrument underneath the treble side of the bridge between the back plate and front of violin. It is made of spruce. Tight violin strings which push the bridge down provide a pressure from the top to the bottom plate, and the sound post is held on this pressure. The main function of sound plate is to transfer the sound energy from the top plate to the back plate of the instrument. The accurate positioning of the sound post is very important as it critically affects the quality and timbre of sound and the playability of violin.

There are many parts of the violin that determines the sound that it makes. As mentioned above, the sound post and bridge are the most important parts of the violin. The sound post is a piece of wood connecting the top and bottom plate of the violin, and the bridge is also piece of wood. A bridge that supports the strings on a stringed musical instrument and transmits the vibration of those strings to some other structural component of the instrument, typically a soundboard, such as the top of a violin, which transfers the sound to the surrounding air as shown in Figure 2. By alternating these important parts placement, length, thickness, or wood used, the sound will be greatly influenced. These give us an important starting point for further studies.

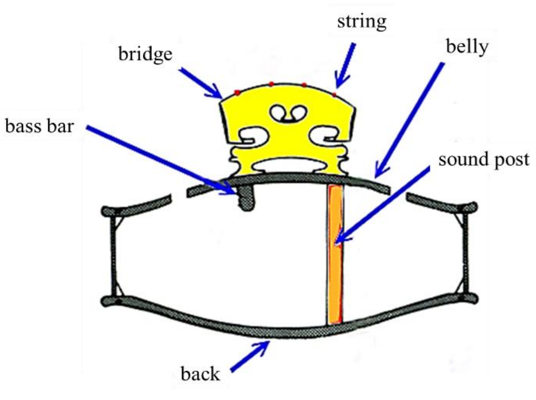

Figure2. *General view of violin.*

The violin can produce sound in two ways. “Plucking” and “Drawing a bow across the strings”. Plucking creates a sound different when bowing the violin. There are different types of plucking. The standard way of plucking uses the flesh of the finger of the bowing hand. Plucking can also be done using the fingernails. The different ways of plucking creates different specific types of sounds.

In this work, create a three dimensional model of the sound radiation pattern of the violin. The icosahedron created in MATLAB will be used for illustration purposes, to show where the microphones will be placed during recording of the violin sound.

A life-sized icosahedron will be built for setting up the 42 channel microphone array. The icosahedron is built big enough for the violinist to be able to stand in it and play the violin with bow across for recording.

EXPERIMENTAL SETUP

By setting up a spherical microphone array with 42 channels in an anechoic chamber around a violinist, the sound radiation pattern can be recorded and analyzed. We built icosahedron, the skeleton is made out of thin (ϕ =8 mm) metal pipes, because of prevent the sound reflection and tied up together with steel wires to provide a strong base. one side length of which is 1 m as shown in Figure 3. The distance from the center of icosahedron to the each microphone are 80 cm. The icosahedron is a polyhedron. Polyhedrons are made up of flat polygonal faces, straight edges, and sharp vertices. There are two types of icosahedrons, the convex regular icosahedron and the great icosahedron. The icosahedron has 20 flat polygonal faces, thus making 30 straight edges and 12 sharp vertices. We setup the 42 channels microphone around icosahedron to the 12 apexes and 30 edges, located to become the equal density.

Sound radiation from violin was recorded by omni-directional condenser microphone "CX-500" located 80 cm away from the center. The microphone specifications shown in Table 1.

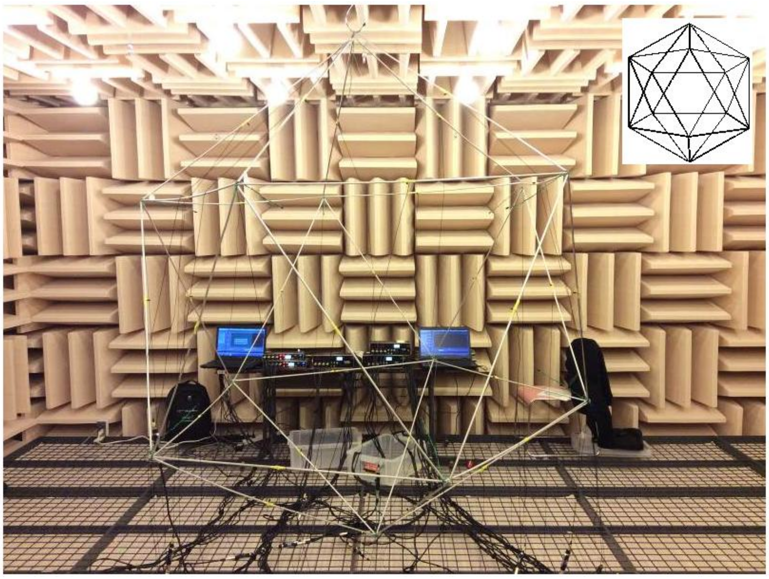

Figure3. *Experiment setup.*

Table1. *The Microphone Specifications*

Microphone type	Omni-directional condenser
Frequency Response	20 to 20,000 Hz
Max.SPL for 1% T.H.D.	130dB
Signal-to-Noise Ratio	68dB
Weight	6.5 grams(including cable)
Dimensions	ϕ 6mm(W)*13mm(H)

Figure4. *An apex of the icosahedron.*

Figure 4 shows the microphone being attached to an apex of the icosahedron, 22cm away from the apex and directed in the center direction. It was attached there using green metallic wires that are coiled around the microphone wires. The other eleven apexes were done in the same way.

Figure 5 shows the microphone attached to an edge of the icosahedron. The microphone was attached using yellow masking tape and directed in the center direction. The other 29 edges have microphones attached in the same way.

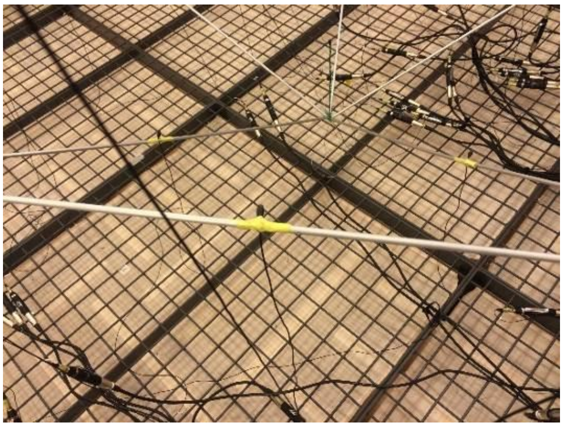

Figure5. *An edge of the icosahedron.*

MEASUREMENT AND RESULTS

Measurement

The recording is done by violinist while he plays a music ascending scale from note G3 till C6, each sound keep playing for 10 seconds and recording the sample levels in A-weighted sound pressure level. Since each sound has a different frequency, the sample data will have different readings across the sounds. Table 2 shown the playing sounds by violin and frequency and the measurement was performed in the Anechoic Chamber as shown in Figure 6.

The violinist paid close attention equally to play and without vibrato. The experiment is repeated 3 times to generate an average data in order to obtain an accurate result.

Table2. *Playing Sounds and Frequency*

Pitch names	G3	A3	B3	C4	D4	E4	F4	G4	A4
Frequancy [Hz]	196	221	248	262	294	331	350	393	442
Pitch names	B4	C5	D5	E5	F5	G5	A5	B5	C6
Frequancy [Hz]	496	525	589	662	701	787	884	992	1051

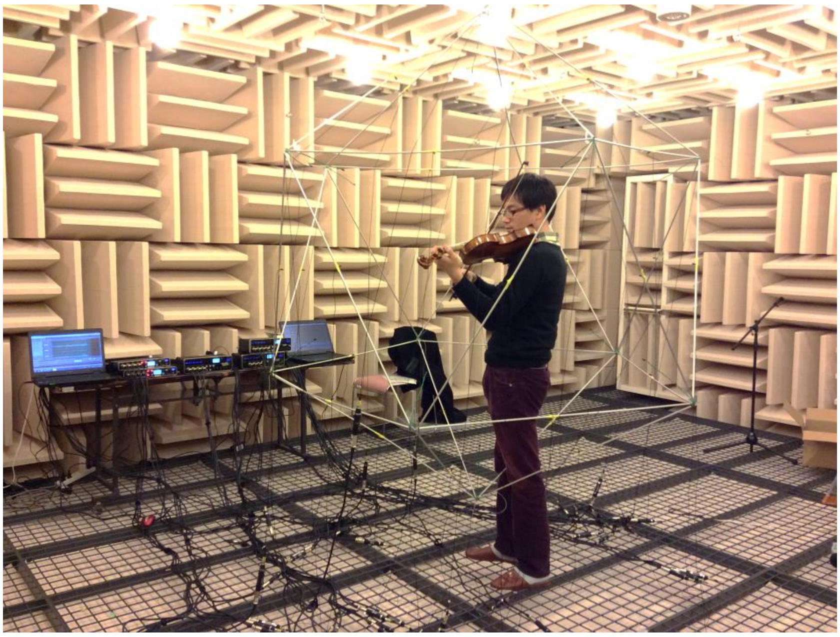

Figure6. *Situation of the measurement.*

After all of the recordings, each sample data was input into a real time analyser. It generates the values of the A-weighted sound pressure level and store it into a csv file. After that we create a function to find out the average sound pressure level of the 3 recorded data on a new csv file. Then, the each average data is normalized by using the formula

$$x = \frac{(n - \min n)}{(\max n - \min n)} \tag{1}$$

where n represents a data on any column, and min n and max n represents the minimum and maximum values of the same column. The normalized data is then used to draw the vector arrows on the 3D icosahedron model to represent the sound radiation pattern and direction.

RESULTS

The results are shown in Figure 7-10. The direction of the front face is yellow triangle, that is, the tip of the violin facing center of yellow triangle. We selected the representative musical notes of open strings G3-D4-A4-E5, and the red arrows shown the top 7 direction of sound pressure level. By doing this way, we can easy to understand about characteristic of sound radiation pattern.

These figure indicates that, each sound radiation pattern has the strong normal vector direction of belly. These figures prove clearly that vibration occurs across the entire belly and back plate by bridge and sound post. As mentioned above, the accurate positioning of the sound post is very important as it critically affects the quality and timbre of sound and the playability of violin. It is generally agreed that things, but it is not always understood why this should be so [3]. H.Weisshaar and M. Shipman studied the correlation of timbre and sound post [4], but it leaves unanswered the question of correlated position of bridge and sound post. This should serve as an example for our future research strategies.

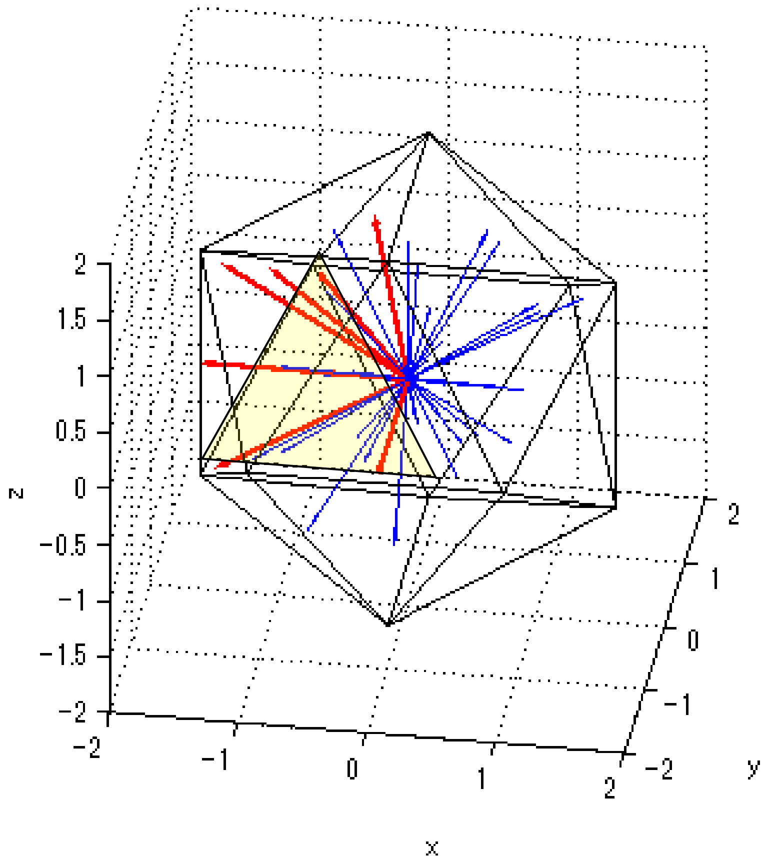

Figure7. *Situation as G3 (196Hz) in G string*

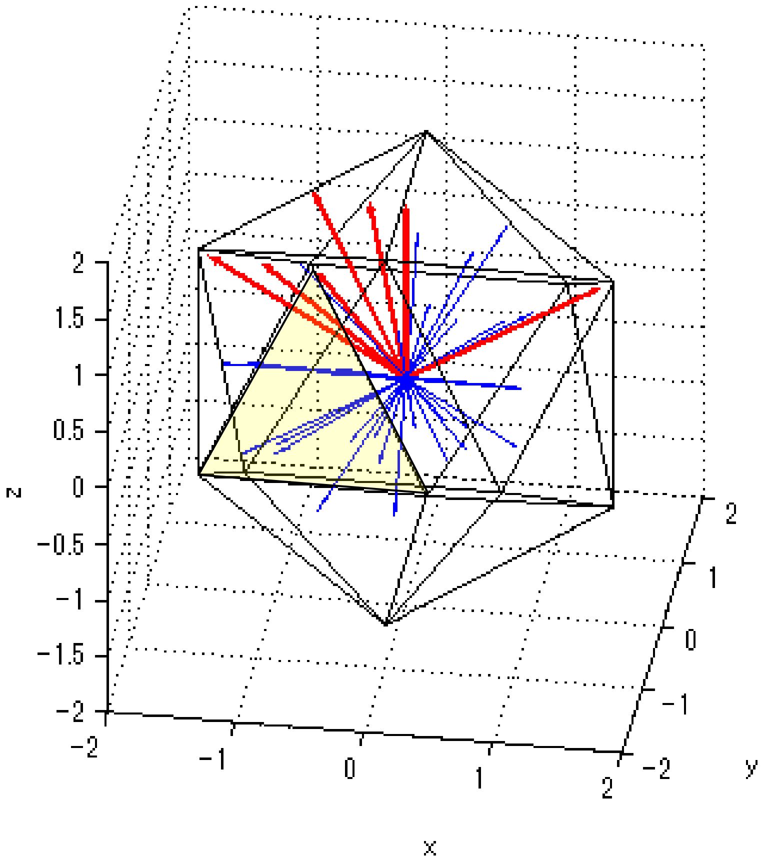

Figure8. *Situation as D4 (294Hz) in D string*

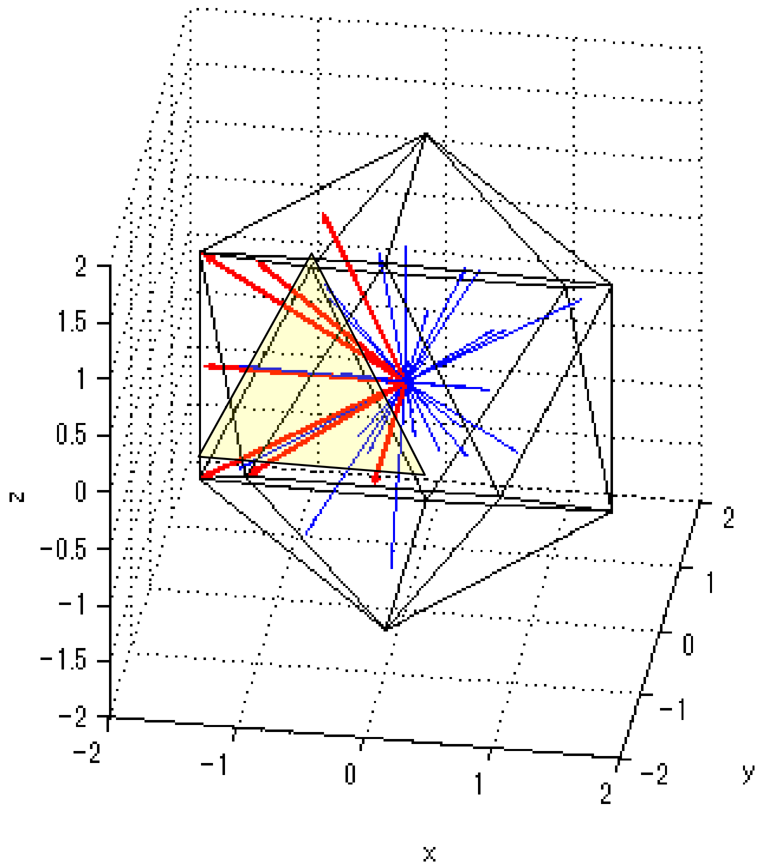

Figure9. *Situation as A4 (442Hz) in A string*

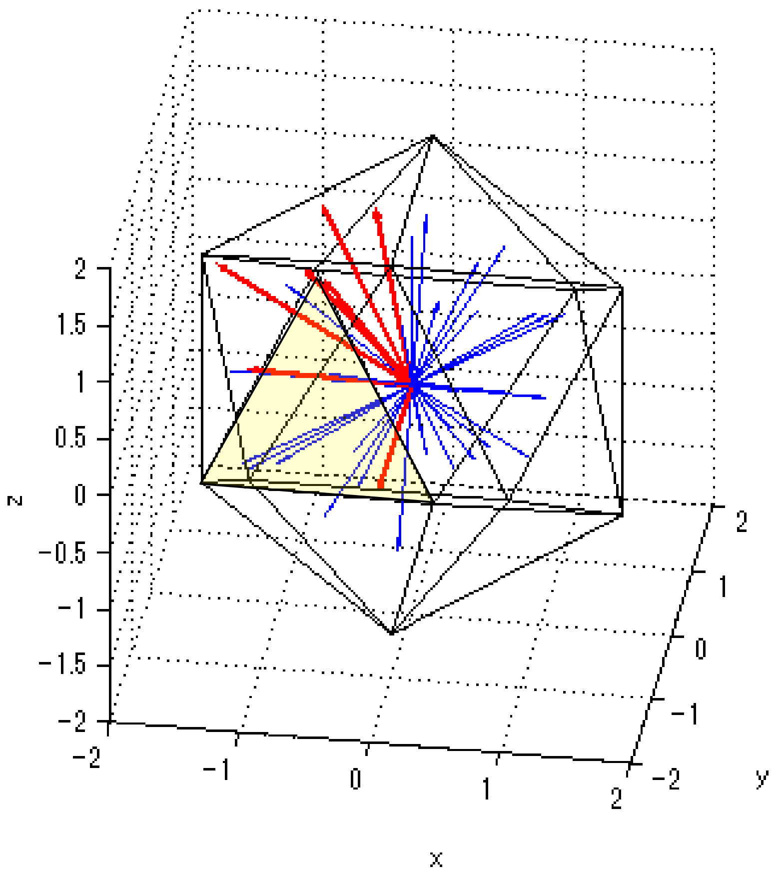

Figure10. *Situation as E5 (662Hz) in E string*

CONCLUSION

In this work, to examine the sound radiation pattern of violin. By setting up a spherical microphone array with 42 channels in an anechoic chamber around a violinist, and recorded. We obtain the accurate sound radiation pattern.

Of course these are just a few examples and consideration. A subsequent study, we should find a way out of the question of correlated position of bridge and sound post.

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