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Vibration measurements comparing the contrabass and octobass

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The octobass is the largest and lowest member of the stringed instrument family. First developed in the 1850s by French luthier Jean-Baptiste Vuillaume, the octobass has three strings and measures close to 3.6 meters tall. There are eight known octobasses in the world, with most examples being housed in museum collections. However, the Orchestre symphonique de Montréal (OSM) possesses three octobasses built by French luthier Jean-Jacques Pagès, unique in that they are regularly used in performances. We present recorded bowed notes and bridge admittance measurements of the three OSM octobasses and three contrabasses. The lowest mode frequencies of the contrabasses are 51, 52, and 68 Hz, while the lowest mode frequencies of the octobasses are significantly lower at 34, 35, and 39 Hz. The octobass and contrabass measurements are compared to better understand the advantages and disadvantages of such a colossal instrument.

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1. INTRODUCTION

The octobass is the largest and likely rarest member of the bowed string instrument family. First built around 1851 by French luthier, Jean-Baptiste Vuillaume, the octobass typically measures around 3.6 m tall, compared to an approximate height of 2 m for a full-size double bass (though the more common 3/4 size double basses are closer to 1.8 m tall). The typical soundboard size for an octobass is 2 m tall and 1.1 m wide, and the weight is around 130 kg. Figure 1 shows the size difference between the octobass and a typical 3/4 size contrabass.

The octobass has three 2.18 m long strings, typically made of gut, however, there is no universal tuning. The original tuning of the octobass, according to Hector Berlioz was C_1, G_1, and C_2.[1] The astute bassist may note that C_1 is playable on a contrabass with a low-frequency extension, but extensions were not yet used in the mid 19th century. To extend the range of the octobass, lower tunings are generally used now. The three octobasses studied in this work are tuned to A_0, E_1, and B_1, but tunings as low as C_0, G_0, and C_1 are used, however, this tuning is not practical with gut strings and requires steel strings.

Playing such a colossal instrument is not an easy task and cannot be down with similar technique to a contrabass. The bridge is at a height such that the player needs to stand on a stool to bow the strings. The stool is essentially an integral part of the instrument. It is not possible to reach and finger the strings so a series of capos is used to depress the strings. The capos are controlled by a combination of levers pulled by the left hand and foot pedals. The mechanical mechanisms to connect the levers and pedals to the capos run through the neck.

Only eight octobasses are known by the authors to exist. The first instrument built by Jean-Baptiste Vuillaume in 1851 is held in the collection of the Musée de la Musique in Paris. Two other octobasses exist in the collections of the Kunsthistorisches Museum in Vienna and the Musical Instrument Museum in Phoenix, USA, and two exist in private collections. The Orchestre symphonique de Montréal (OSM) houses the remaining three octobasses.[2]

The Orchestre symphonique de Montréal octobasses are unique in that they are regularly used in performances. The first of the three was built in 2010 by French luthier Jean-Jacques Pagès and is a direct copy of the original 1851 Vuillaume octobass. This octobass uses a fully mechanical pedal and lever system to depress the string capos. The remaining two octobasses were later built by Pagès but with a different capo design. Instead of mechanical capos, they use an electromechanical system with electronically controlled capos. The capos are controlled by a small electric piano-style keyboard mounted on the side of the octobass and controlled with the player's left hand. The keyboard on these two basses can be seen in Figure 2.

The acoustics of the contrabass is relatively little studied compared to the rest of the violin family, but some literature does exist.[3–5] No acoustic studies of the octobass are known by the authors, and most of its mention in the literature focusses on musicological studies.[6–8] The most directly related work is that of Carleen Hutchins on the the extended violin family of instruments.[9–11] While most people will never be lucky enough to experience the sound of an octobass in person, there does exist a sample-based audio plugin made by Soundiron.[12] As an initial study on the acoustics of the octobass, this paper presents admittance measurements as well as bowed and plucked recordings of the three Orchestre symphonique de Montréal octobasses. The octobass measurements are compared to those of three contrabasses.

Figure 1: Two octobasses and one contrabass for scale.

A. THE BASSES

Three octobasses and three contrabasses were measured as part of this study. Table 1 summarizes the six basses. The octobasses are abbreviated as OB1, OB2, and OB3, while the contrabasses are abbreviated as ML, RAG, WB.

The three OSM octobasses were measured (see Figure 2). One is a direct copy of the 1851 Vuillaume octobass (OB3), while the other two (OB1 and OB2) have the same body geometry but use an electromechanical capo system instead of the mechanical levers and pedals. OB1 and OB2 were located in a large rehearsal room in La Maison symphonique de Montréal, the home of the OSM. OB3 was located on a balcony in the main hall of La Maison symphonique de Montréal. This octobass can often be seen on the balcony near the organ in photos taken in La Maison symphonique de Montréal. Due to their large size and weight, the octobasses are only moved when necessary.

Three contrabasses of varied design were measured as a reference for comparison with the octobasses (see Figure 3). Two of the contrabasses are professional instruments, one made in Quebec, Canada by Mario Lamarre (ML) in 2020, and one made in Naples, Italy by brothers Raffaelle and Antonio Gagliano (RAG) in 1850. The third is an intermediate instrument, a copy of a French Gand Bernadel Bass known as Wan Bernadel (WB), made in China in 2007. Basses ML and RAG both have low-frequency extensions on the lowest string while WB does not. The extension on RAG is not original and was retrofitted to meet the demands of modern orchestral repertoire. Both RAG and WB were tuned to the standard E_1, A_1, D_2, and G_2 while ML had solo strings and was tuned to F#$_1$, B_1, E_2, and A_2.

Abbr.	Style	Maker	Year	Origin	Tuning	Notes
OB1	Octobass	Jean-Jacques Pagès	2018-19	Mirecourt, France	A_0, E_1, B_1	Electromechanical capos
OB2	Octobass	Jean-Jacques Pagès	2018-19	Mirecourt, France	A_0, E_1, B_1	Electromechanical capos
OB3	Octobass	Jean-Jacques Pagès	2010	Mirecourt, France	A_0, E_1, B_1	Mechanical capos
ML	Contrabass	Mario Lamarre	2020	Montréal, Canada	$F\#_1$, B_1, E_2, A_2	Has extension, solo strings
RAG	Contrabass	Raffaelle and Antonio Gagliano	1850	Naples, Italy	E_1, B_1, D_2, G_2	Has extension
WB	Contrabass	Wan Bernadel	2007	China	E_1, B_1, D_2, G_2	No extension

Table 1: Summary of the six basses.

Figure 2: The three measured octobasses (OB1, OB2, and OB3 form left to right).

Figure 3: The three measured contrabasses (ML, RAG, and WB from left to right).

2. METHODS

Admittance measurements and playing recordings of bowed notes and plucks were recorded for all six basses. The three octobasses, as well as ML and RAG contrabasses were measured on site at La Maison symphonique de Montréal. OB1, OB2, ML, and RAG were measured in a relatively quiet room, while OB3 was located in the main hall which was not a noise-free environment. WB was measured in an acoustically treated room in a university laboratory so the measurements are much more noise-free. The octobasses were measured standing in their built-in mounts as they cannot be moved. To mimic the mounting of the octobasses, ML and RAG were measured sitting in a bass stand as can be seen in Figure 3. WB was measured standing on the endpin with the instrument held upright by a rope attached to the scroll.

A. ADMITTANCE MEASUREMENTS

Admittance measurements were made on the bass side of the bridge in the direction parallel to the top plate, the general direction of the bow. A force sensing impact hammer (PCB 086E80) was used to input a known force and the resulting velocity was measured with a laser Doppler vibrometer (Polytec PDV-100). The admittance measurement setup with an octobass can be seen in Figure 4. An attempt was made to dampen all the strings with foam. This was difficult with the basses made in situ, so partial string resonances can be observed in the admittance measurements.

Figure 4: Admittance measurement setup for an octobass.

B. AUDIO RECORDINGS

To analyze the instruments in a somewhat natural playing situation, all open strings were both bowed and plucked. The resulting sound was recorded with two microphones, one at approximately 1 m from the bridge, and one approximately 30 cm away from the top plate, just above the treble f-hole. Cardioid condenser microphones (Line Audio CM4) were used instead of omnidirectional measurement microphones to try to minimize noise and reflections since the recordings were not made in ideal conditions. The closer microphone can be seen in Figure 4.

3. RESULTS AND DISCUSSION

All admittance measurements and recordings can be found online at the provided link [1].

A. ADMITTANCE MEASUREMENTS

Admittance measurements for the three contrabasses can be seen in Figure 5 and for the three octobasses in Figure 6. The fundamental frequencies of the open strings are shown as vertical lines. Figure 7 shows a single octobass (OB3) and contrabass (WB), and serves as an instructive comparison.

As could be expected, the octobass admittances favor the low frequencies much more than the contrabass admittances. The lowest resonant frequencies for the octobasses range from 34-39 Hz, while they range from 51-68 Hz for the contrabasses. Table 2 summarizes the lowest resonant frequencies for all basses. In addition to the lowest frequency modes, the octobasses have significant admittance modes around 60-70 Hz, akin to the strong modes around 100-120 Hz present in the contrabasses.

Comparing OB3 with WB as shown in Figure 7 is quite instructive. The modal structure follows a similar pattern with modes around 30-40 Hz lower for the octabass. Notably, the first modes at 39 and 68 Hz, second modes at 61 and 102 Hz, and third modes at 68 and 115 Hz for the WB and OB3, respectively. WB has a very low admittance below the lowest 68 Hz mode which would suggest it has a poor low-frequency response. This bass is owned by the first author, and is confirmed to have a weak response for the lowest few notes on the bass (below 50 Hz). In comparison, ML and RAG have a much higher low-frequency admittance with resonances around 50 Hz.

Low-frequency peaks below 30 Hz can be seen in the admittance measurements. These peaks are likely a result of the non-ideal mounting conditions, not-perfectly damped strings, and non-ideal recording locations.

[1] https://ccrma.stanford.edu/ mrau/projects/Octobass/

It can be confirmed that they are not body resonances of the basses as they are not seen in frequency domain plots of the bowed and plucked note recordings.

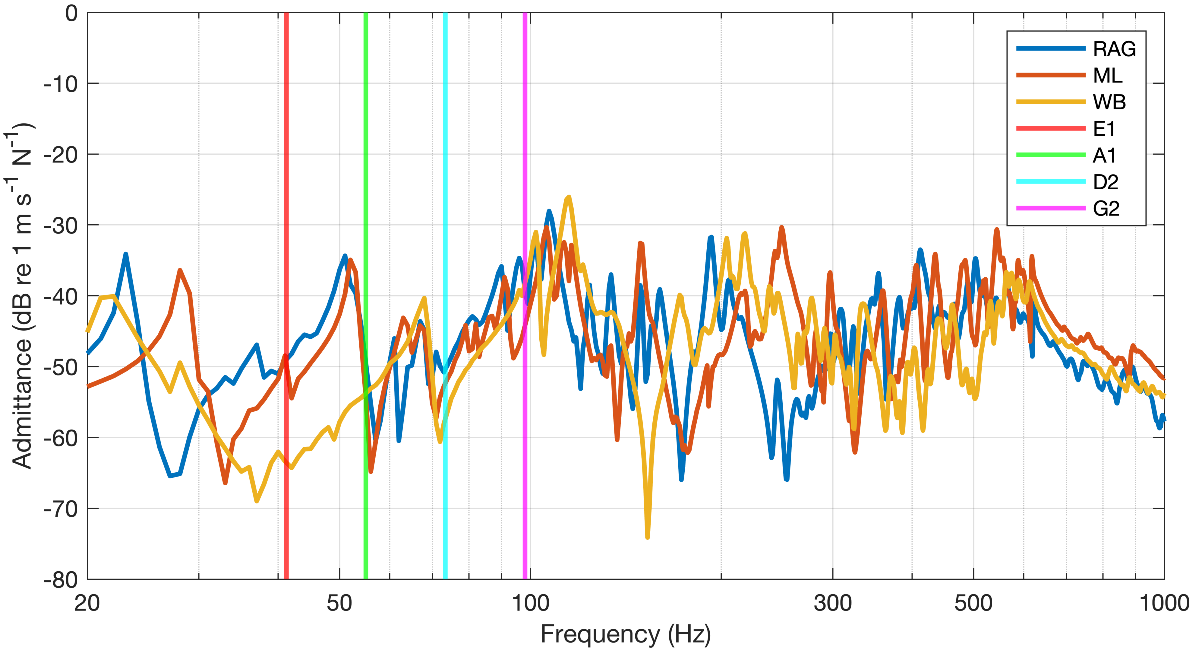

Figure 5: Admittance of all three contrabasses. The fundamental frequencies of the four open strings are shown for reference.

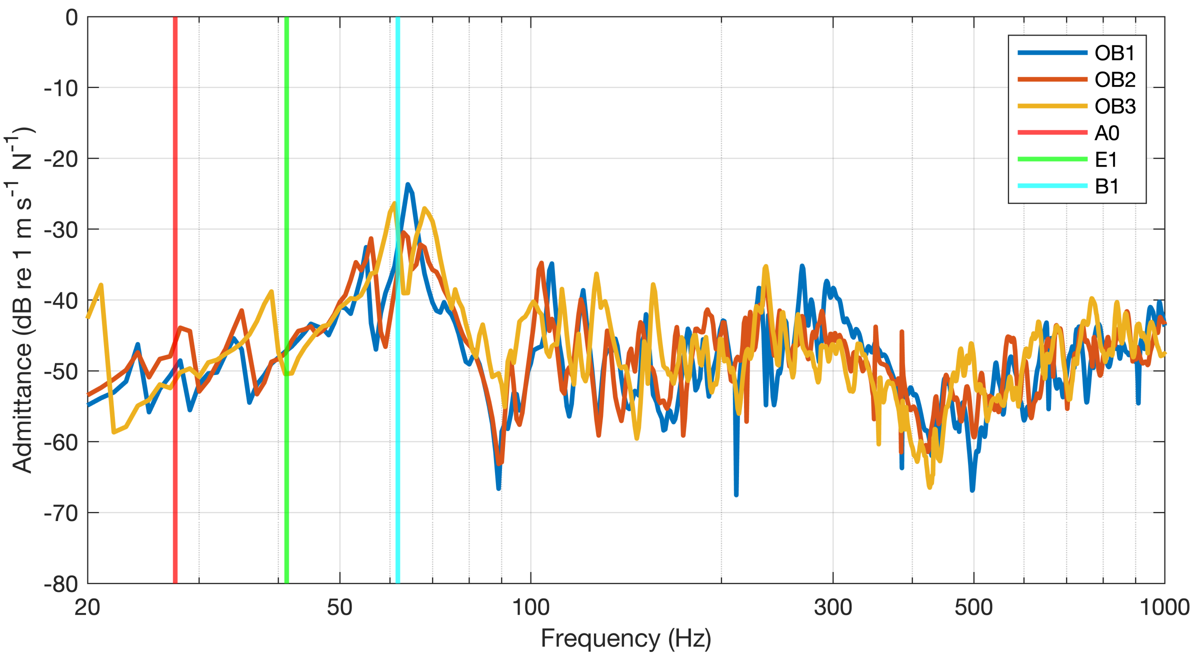

Figure 6: Admittance of all three octobasses. The fundamental frequencies of the three open strings are shown for reference.

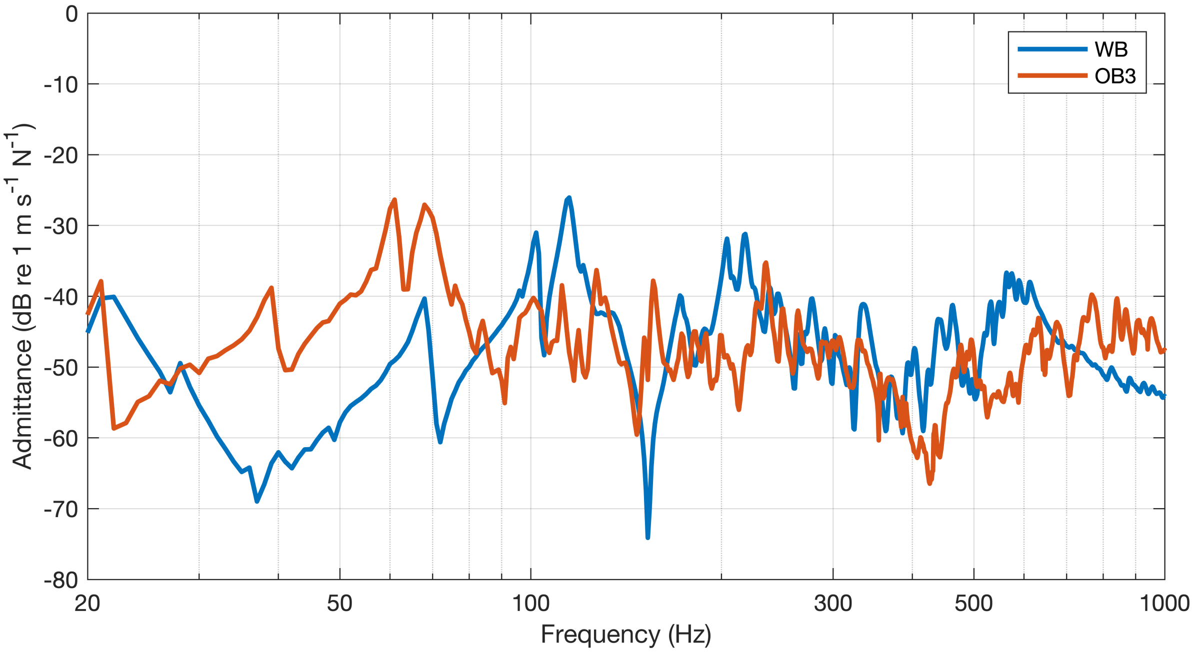

Figure 7: Admittance comparison between one contrabass and one octobass.

Abbr.	OB1	OB2	OB3	ML	RAG	WB
F0 (Hz)	34	35	39	52	51	68

Table 2: Lowest resonant frequency of each bass.

B. AUDIO RECORDINGS

Audio recordings of bowed and plucked notes on the basses are quite informative, as the harmonic structure can be observed and analyzed with relation to the admittance. Since the recordings were made in a natural playing fashion, there is inherent variability. To account for some of the variability, each recording was normalized by its root mean square signal energy.

Figures 8 and 9 show the bowed E1 strings for the contrabasses and octobasses respectively. In each case, one second of the bowed note is displayed with half-second gaps between. The one-second segment is taken from the middle of the steady-state bowed note. It can be observed that the octobasses have significantly more energy at the fundamental frequency of 41.2 Hz than the contrabasses. WB is notably weak at the fundamental, a frequency 27 Hz below its first mode. Figure 10 shows the bowed A0 strings of the octobasses. OB1 and OB2 have significant energy at the fundamental frequency of 27.5 Hz, just below their lowest mode. However, OB3 is rather weak at the fundamental frequency. This could be explained by the higher first resonant frequency of 39 Hz. OB3 has significantly more high-frequency energy than OB1 and OB2. This is likely due to the added resonant structures needed for the mechanical foot pedal and lever capo system. When listening to the audio recordings, the mechanical system is clearly audible.

Figures 11 and 12 show the plucked E1 strings for the contrabasses and octobasses respectively. In each case, four seconds of the plucked note is displayed with half-second gaps between. Again, the octobasses show significantly more energy at the fundamental frequency of 41.2 Hz. It is interesting to note that, while both ML and RAG show an initial high-amplitude fundamental, the energy decays relatively quickly. In contrast, the fundamentals of the octobasses have a long sustain. Figure 13 shows the plucked A0 strings of the octobasses. Again, OB1 and OB2 show a strong fundamental, while it is relatively missing for OB3. OB3 has significantly more high-frequency energy than OB1 and OB2, and it seemingly comes in and out over time. This additional high-frequency energy is likely a result of the vibrating mechanical lever system.

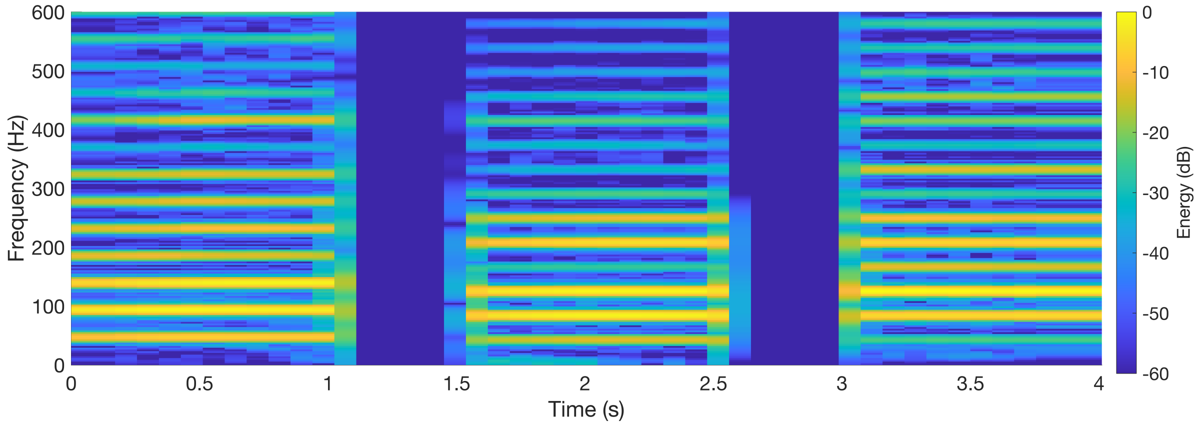

Figure 8: Bowed E1 string on the contrabasses: ML (left), RAG (center), WB (right). Note that the bowed note on the Lamarre is an F#1.

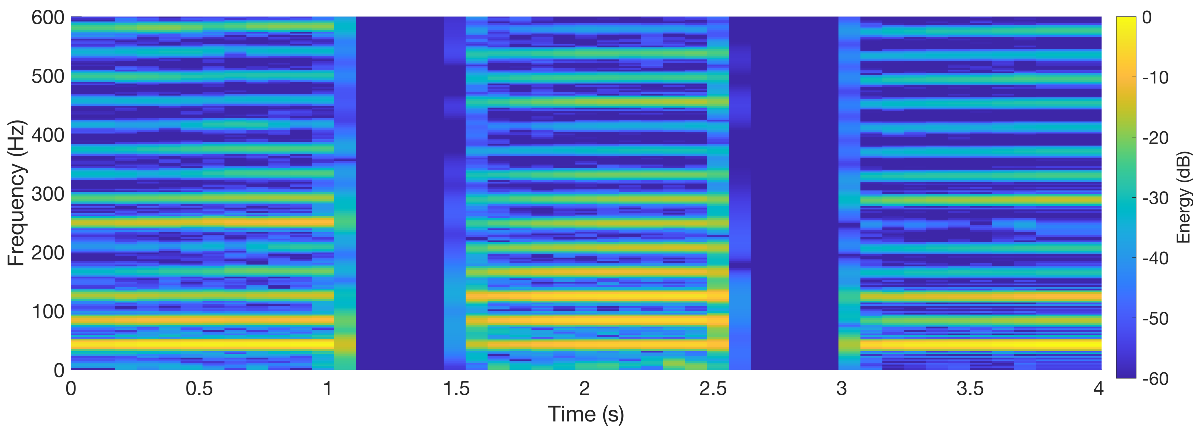

Figure 9: Bowed E1 string on the octobasses: OB1 (left), OB2 (center), OB3 (right).

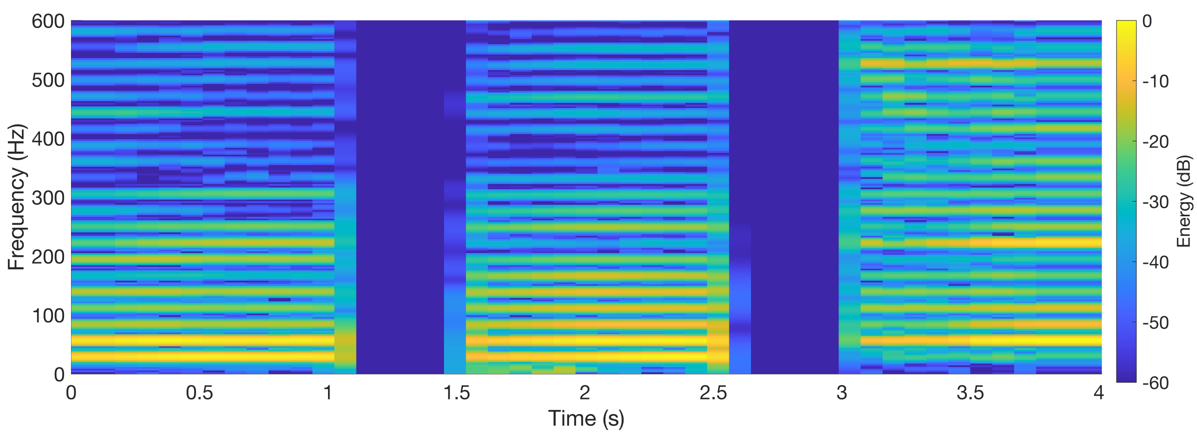

Figure 10: Bowed A0 string on the octobasses: OB1 (left), OB2 (center), OB3 (right).

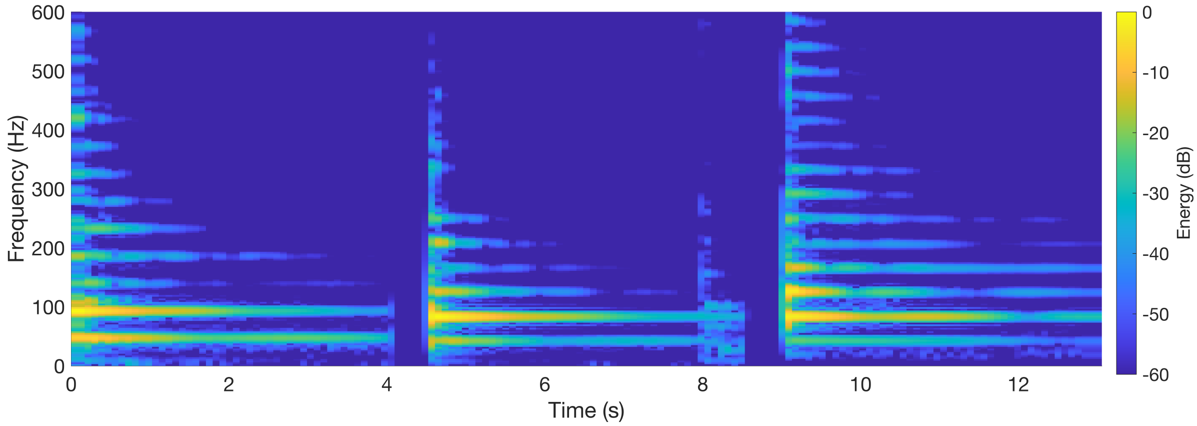

Figure 11: Plucked E1 string on the contrabasses: ML (left), RAG (center), WB (right). Note that the plucked note on the Lamarre is an F#1.

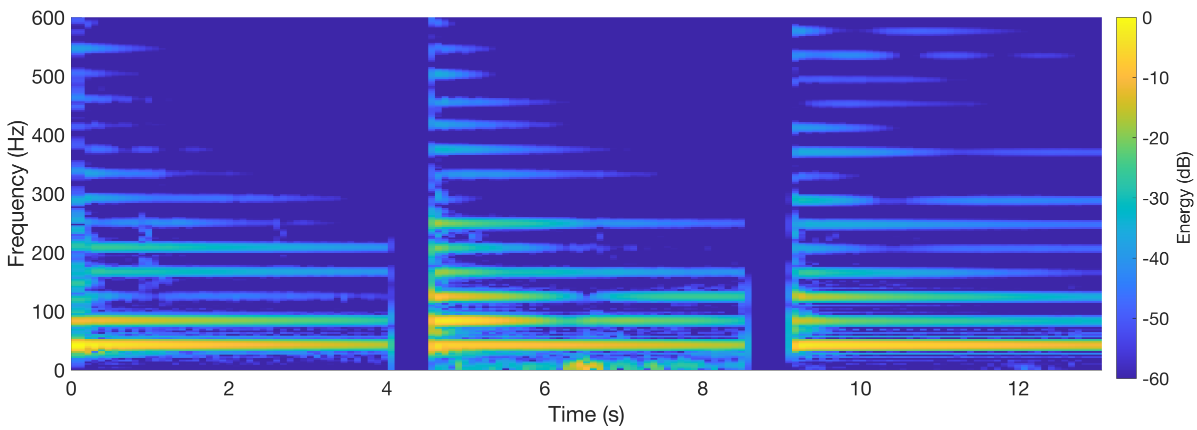

Figure 12: Plucked E1 string on the octobasses: OB1 (left), OB2 (center), OB3 (right).

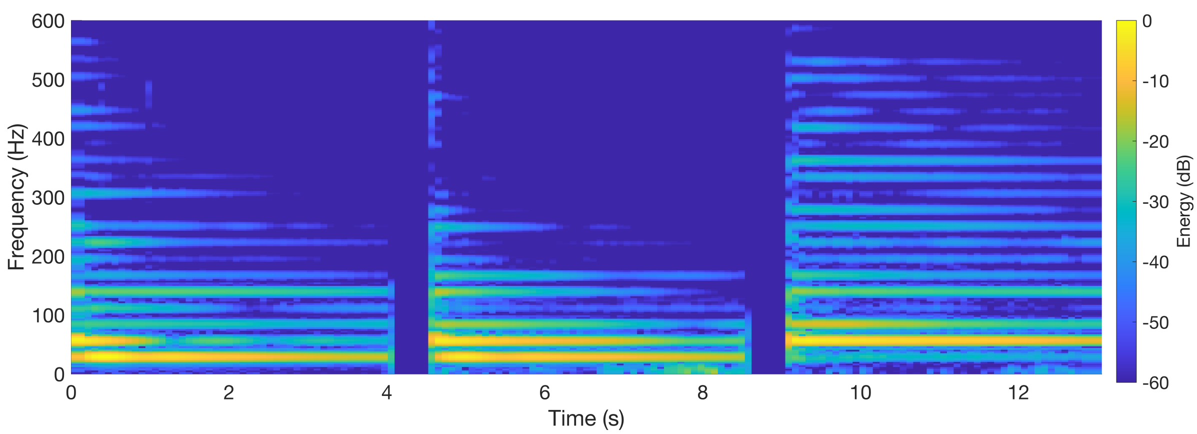

Figure 13: Plucked A0 string on the octobasses: OB1 (left), OB2 (center), OB3 (right).

4. CONCLUSIONS

This paper presented the first known acoustical study of the octobass. Three octobasses were contrasted with three contrabasses, confirming that they have a greater low-frequency response, and do indeed have a place in the expanded string section, even when contrabasses with low-frequency extensions could be used instead. Both admittance measurements and recordings of bowed and plucked notes backed up the findings that the octobass has an improved low-frequency response below 50 Hz.

This study is a good start in understanding the octobass, but there is plenty of room for future work. Ideally, measurements could be performed in a more controlled environment, but this proves difficult with the size and weight constraints of the octobass. Only single-point vibrometer measurements were made, so while the frequency response could be measured, it was not possible to validate the mode shapes of the instrument. Ideally, scanning vibrometer measurements could be made to capture the mode shapes and compare them to the standard mode shapes seen with other bowed string instruments. Additionally, the bowing and pluck responses could be further analyzed to better characterize the relative harmonic amplitudes and decay rates.

In addition to measurements, the development of an octobass synthesis model would benefit its study. With a synthesis model, one would be able to vary parameters such as the resonant frequencies and see how the response of the instrument changes. A synthesis model would also allow for realistic simulation that is paramterizable and more variable than a sample-based synthesizer. This would allow more people to experience the monumental sound of the octobass.

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