

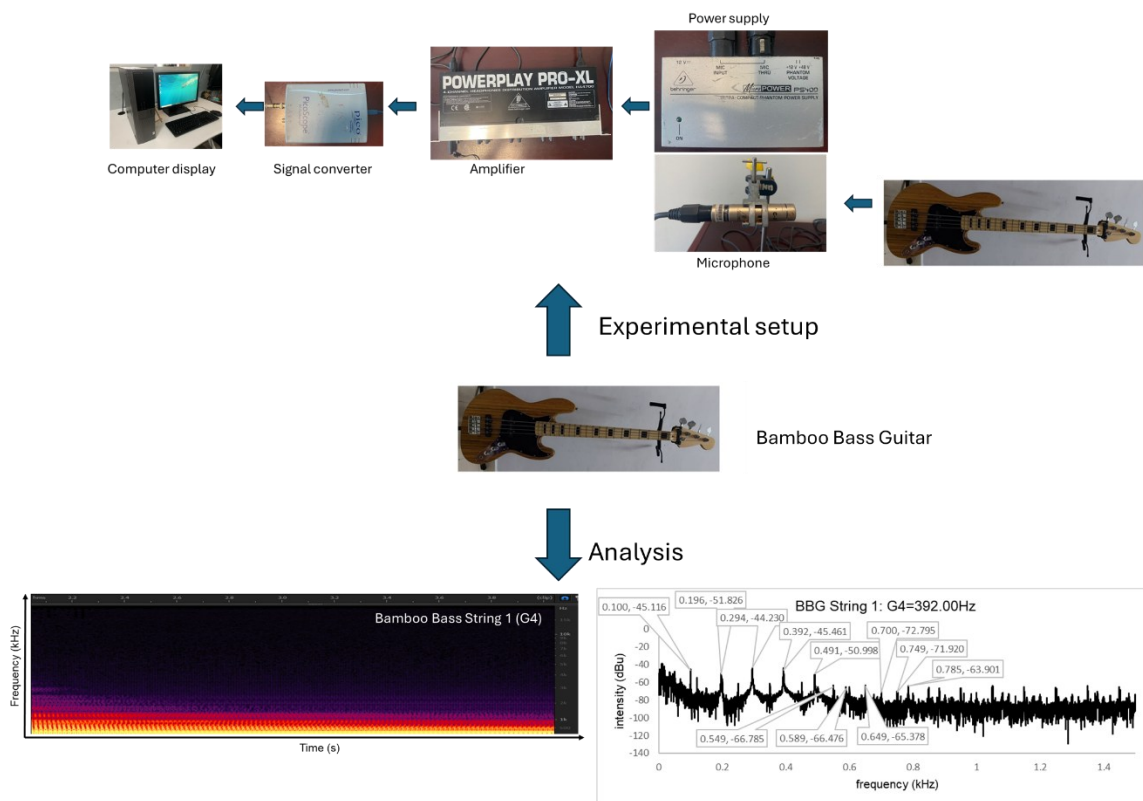
A Case Study on Sonic Heritage and Acoustic Profiling of the Bamboo Bass Guitar

Ahmad Faudzi Musib,^{a,*} Aaliyawani E. Sinin,^b Sinin Hamdan,^c Khairul A. M. Said,^c and Khairil A. Dean Kamarudin^d

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GRAPHICAL ABSTRACT



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The acoustic properties of a custom-built bamboo bass guitar (BBG) were examined in this study as a sustainable substitute for traditional wooden instruments. To evaluate tonal and harmonic behavior, the BBG which was made completely of bamboo components was contrasted with the Fender Jazz Bass '70s (FJB70s). While spectrograms from Adobe Audition offered visual insight into overtone distribution, frequency spectrum data were recorded using a PicoScope oscilloscope and subjected to Fast Fourier transform (FFT) analysis. Although the BBG's pitch and harmonic series matched those of the FJB70s, its timbre was noticeably different, with less radiation and more damping. Throughout the spectrum, its overtone amplitudes gradually decreased, while the FJB70s' harmonic presence remained increasingly distinct and steady. In the BBG signal, random partials that show up in between harmonic peaks indicate variations in structural resonance. These results lend credence to bamboo's potential as an acoustic material for bass instruments, providing unique sound textures and encouraging environmental sustainability.

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Keywords: Bamboo bass guitar (BBG); Fender Jazz Bass 70s (FJB70s) guitar; Fast Fourier Transform (FFT)

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INTRODUCTION

A lot of bamboo is grown in Malaysia. Bamboo has been widely used by the locals, particularly to make a wide variety of musical instruments. Because of its quick development, bamboo is expected to be used as an economical alternative in the future. Locals created the bamboo bass guitar (BBG) utilized in this study to substitute for the wood components of the instrument. The body was constructed from a 14 cm diameter pressed bamboo tube. Even when their melodies are comparable, bamboo guitars generally have a different feel from wooden guitars (Sinin *et al.* 2025a). Three more chordophones (string instruments) that use bamboo are the pratuokng (Hamdan *et al.* 2024), tongkungon (Hamdan *et al.* 2025), and gendang kecap (Sinin *et al.* 2025b). When compared to other common materials, bamboo is thought to be an appropriate soundboard material (Wegst 2008). The materials used for soundboards and back plates have a similar high sound radiation coefficient. The characteristic impedance of the material and the thickness of the soundboard are connected to the impedance. As a result, the impedance of the soundboard

and strings can be carefully adjusted. Thus, bamboo can be used in place of a guitar body. Kusumaningtyas *et al.* (2016) used bonded bamboo board to create a guitar soundboard. The guitar sound spectra obtained by many researchers, including Jansson (1983), Meyer (1983a,b), Ross and Rossing (1979), and Ross (1979), show individual variances. According to Rossing (2010), they all show a variety of peaks over 1.5 kHz, several peaks in the 400 to 700 Hz region, and notable peaks around 100 and 200 Hz. These sound spectra demonstrate the volume of sound produced when a sinusoidal force perpendicular to the bridge is applied with a constant amplitude. The notable peaks at 100, 200, and 400 Hz, which are brought on by resonances in the guitar body, primarily define the low-frequency tonal qualities of the instrument. Meyer (1983a,b) found a substantial relationship between the peak strength of the resonance at 400 Hz and the listeners' evaluation of the guitar's quality. This study examines the acoustics of a BBG using PicoScope's Fast Fourier Transform (FFT) and Adobe Audition's spectrogram. The fundamental frequency and overtones determine the impression of pitch and timbre.

Frequencies that are integer multiples of fundamental frequency are also referred to as harmonics. The fundamental frequency is also called the first harmonic. Non-harmonic in music refers to having nothing to do with harmony or a harmonic. Musical tones that exist above the fundamental frequency are called overtones. Undertones in the undertone series might be referred to as undertones in music. The fundamental partial, which is the lowest frequency and significantly influences the perceived pitch, is one of the partials that contribute to the overall sound. Partial can be either inharmonic (frequencies without simple ratios) or harmonic (whole number multiples of the fundamental). Frequencies below a sound's fundamental frequency are known as subharmonics. A subharmonic is a component of a periodic wave having a frequency that is an integral submultiple of the fundamental frequency. The subharmonic having half the fundamental frequency is the second subharmonic. Subharmonic frequencies are frequencies below the fundamental frequency of an oscillator in a ratio of $1/n$, with n being a positive integer. For example, if the fundamental frequency of an oscillator is 440 Hz, sub-harmonics include 220 Hz ($1/2$), ~ 146.6 Hz ($1/3$), and 110 Hz ($1/4$).

A wooden Fender guitar with the model number Jazz Bass 70s served as the project's reference model. It is known to produce a clear, bright, well-balanced tone with good projection and resonance. The Fender Jazz Bass 70s (FJB70s) can be regarded as a typical mid-range bass guitar. It is a good point of comparison because of its playability, excellent sound quality, and well-made design. When compared to other guitars in this range, including models from Yamaha, Guild, Epiphone, Eastman, Godin, Gretsch, Heritage, Gibson, and Ibanez, the FJB70s performs brilliantly. Thus, it makes sense to use it as a reference in this work. The FJB70s was selected as the reference model due to its dual single-coil pickup configuration, which offers a broader frequency response and clearer articulation compared to the split single-coil pickup of the Precision Bass. These characteristics made it more suitable for detailed spectral comparison with the BBG. Additionally, the BBG's pickup placement and body contouring were modeled after the FJB70s, ensuring consistency in electronic and structural design. This made it possible in this work to isolate and better evaluate the impact of the bamboo body material on tonal characteristics, without significant interference from differing pickup types or body shapes.

The Fender Precision Bass, also referred to as the P-Bass, is an electric bass guitar model manufactured by Fender Musical Instruments Corporation. A solid-bodied, four-stringed instrument with a single split-coil humbucking pickup and a one-piece, 20-fret maple neck with a maple or rosewood fingerboard is the standard Precision Bass model

after 1957. (Shop Fender at <https://www.fender.com> for electric guitars, acoustics, bass, amps, and more). The prototype was designed by Leo Fender in 1950 and went on sale for the first time in 1951. It was the first to become widely known and utilized. As one of the most copied electric bass guitars, it has had a significant impact on popular music's sound (Shop Fender).

The type of wood used determines the mechanical, acoustical, and vibrational properties of a musical instrument (Haines 1979; Ono *et al.* 1983; Barlow 1997; Bucur 2006). The characteristic impedance, sound radiation coefficient, loss coefficient, and sound speed for different types of wood have all been covered in a number of studies (Wegst 2006; Bremaud 2012). These pieces imply that certain wood species are superior to others for certain types of musical instruments and parts. Numerous scientists have explored the acoustic and vibrational qualities of wood-stringed musical instruments (Wright 1996; Bollousa 2002; French 2008; Paiva and Dos Santos 2014). While acoustic guitar wood takes 30 to 40 years to grow, bamboo may be harvested after three to five years.

This study aimed to investigate the acoustic characteristics of a locally constructed BBG made from *Gigantochloa scortechinii* (Semantan bamboo) by comparing its tonal and spectral properties with those of a standard wooden FJB70s guitar. The research specifically sought to analyze the frequency spectrum and timbre of the BBG using Fast Fourier Transform (FFT) and spectrogram analysis through PicoScope and Adobe Audition software. Additionally, it evaluated the impact of bamboo material on the guitar body's sound radiation, tonal clarity, and harmonic structure in comparison to the FJB70s, which utilizes traditional tone woods such as alder and maple. This study also assesses the viability of laminated bamboo as a substitute for conventional wood in the manufacturing of musical instruments, particularly bass guitars, based on measurable acoustic performance and sound quality. Ultimately, the findings aim to provide a valuable comparative reference for local instrument makers and researchers interested in adopting bamboo as a sustainable and accessible alternative material in musical instrument construction.

EXPERIMENTAL

Bamboo can be split or used in its natural cylindrical form. According to Wegst (2008), bamboo is the only material in the world for which the mechanical and acoustical profile can simultaneously satisfy the design and functional requirements for all classes of musical instruments. Few studies have investigated how bamboo specifically influences soundboard characteristics. In this study, a BBG was constructed using Semantan bamboo (*Gigantochloa scortechinii* Gamble) as the primary material (see Fig. 1). While the body was made entirely of laminated bamboo, the neck and fingerboard were constructed from maple and rosewood materials, respectively, similar to the commercial benchmark model, the FJB70s bass guitar. Semantan bamboo features erect culms that grow up to 20 m tall in wet tropical environments. The leaves are lanceolate with a hairy underside and a petiole-like connection to the culm. The laminated bamboo plank used in this study exhibited a modulus of rupture (MOR) of 146.8 MPa, compressive strength of 71.3 MPa, and a hardness of 4.5 kN (Ong *et al.* 2023). These characteristics suggest that Semantan bamboo is mechanically and acoustically suited for musical instrument construction.



Fig. 1. The ‘Semantan’ bamboo (*Gigantochloa scortechinii* Gamble)

The process of drying and gluing bamboo into slabs was carried out at Bio-Composite Sendirian Berhad in Gerik, Kedah, Malaysia. Fresh, green Semantan bamboo was collected from the forests around Gerik and cut into small blades measuring around 10 to 13 mm wide. The bamboo blade was soaked in hot water for 24 h. This soaking process (without using any chemicals) removed the gum components in the bamboo stem. The purpose of removing these gums is to prevent them from being attacked by termites and to ensure even moisture before drying. After 24 h in hot water immersion, these bamboo blades were subjected to a drying process using the kiln-dry drying technique (dried ~50 °C) for 4 days. Once the bamboo had cooled, the process of levelling the surface using a planer machine was carried out before it was glued using epoxy. The bamboo plank was 1.5 cm thick, 7.5 to 10 cm wide, and 90 to 120 cm long. Twelve of these slabs were arranged in up to 3 layers in 4 rows. For the finishing process, clear aerosol spray was used. This finishing process was done using the matte finishing technique. Later, smoothing was done using the wet sanding technique before being dried and polished.

The dimensions and features of the BBG were closely modeled on the FJB70s bass guitar. Figure 2 illustrates the upper and lower bouts of the BBG. The overall length measured approximately 1296 mm, with the body length around 432 mm and the neck extending 864 mm. The dimension is indicated in Fig. 2. The strings were from Ernie Ball with gauge size 0.45, 0.60, 0.80, and 1.00 mm. The tuning range was from the lowest, E3, to A3, D4, and G4 (highest). To ensure accurate and repeatable sound production, a skilled bassist performed the plucking on both the BBG and FJB70s guitars. Consistency was ensured by maintaining the same technique, plucking angle, and force for each attempt. Prior to recording, the bassist rehearsed the precise motions multiple times to minimize human variability and enhance the reliability of the sound comparison. The plucked notes were G4 (392 Hz), D4 (294 Hz), A3 (220 Hz), and E3 (165 Hz), corresponding to strings 1 through 4.

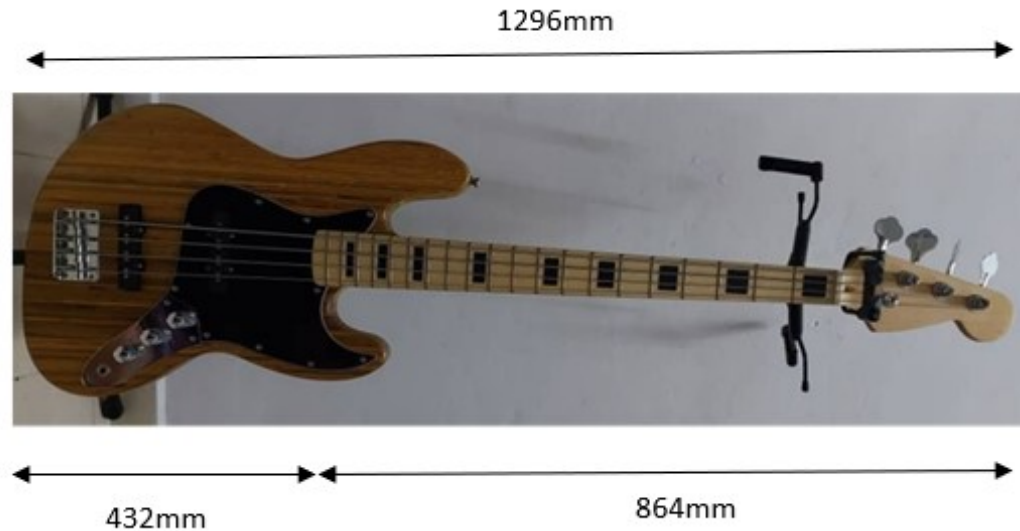


Fig. 2. The bamboo bass guitar (BBG)

All recordings were conducted in an anechoic chamber to eliminate external sound reflections. An omnidirectional polar pattern microphone was positioned 20 cm above the instrument to capture the radiated sound. Both instruments were played in a conventional seated position to replicate typical playing conditions and ensure optimal sound resonance. The sound signals were captured in real time using a PicoScope 3000 series oscilloscope and accompanying data recorder (Pico Technology, Eaton Socon, UK). The PicoScope software enabled waveform viewing, Fast Fourier Transform (FFT) analysis, spectrum visualization, and voltage-based triggering. A schematic diagram of the experimental setup is provided in Fig. 3.

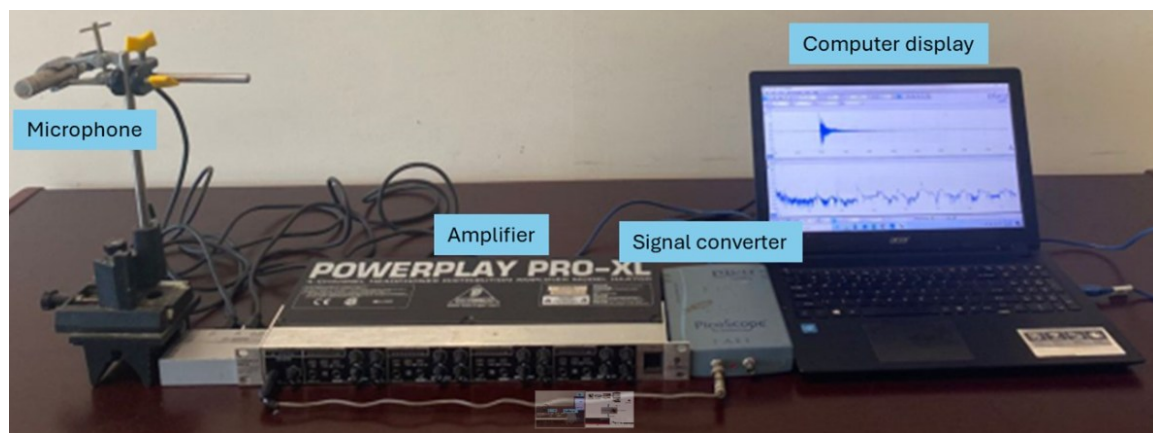


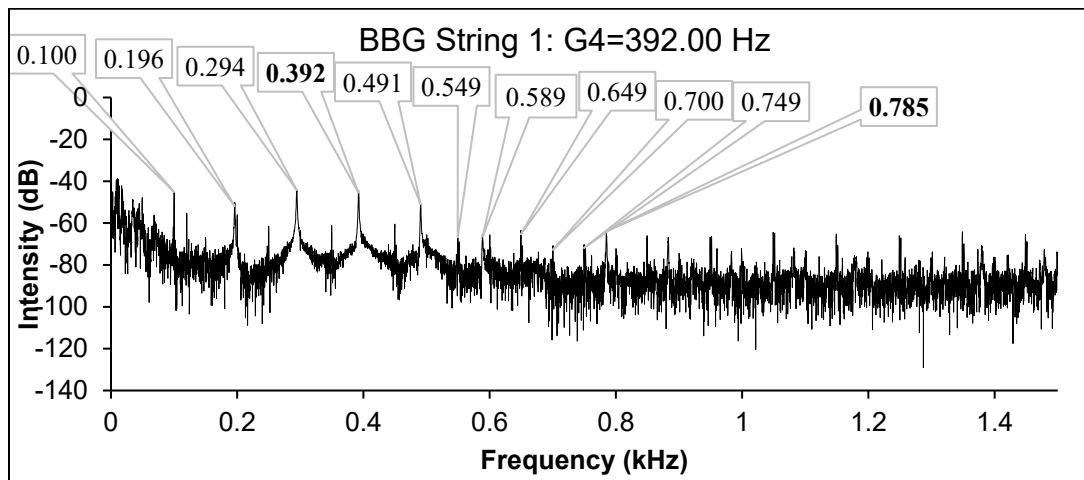
Fig. 3. Schematic diagram of the experimental setup

To prevent distortion or bias, both guitars were recorded under identical conditions, including fixed microphone position and orientation. The signal was amplified using a Behringer Powerplay Pro XL amplifier (Zhongshan, Guangdong, China) before being processed by the PicoScope. The resulting sound spectra were analyzed in Adobe Audition, where FFT analysis was used to extract dominant frequencies and evaluate tonal characteristics. The Fourier transform technique enabled identification of fundamentals, harmonics, and subharmonics in the recorded waveforms. The FJB70s, a reputable mid-

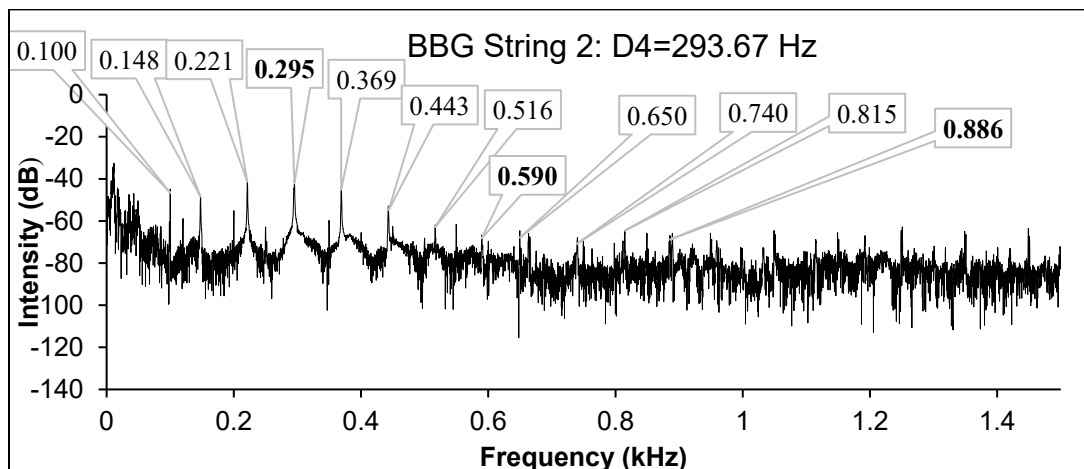
range bass guitar, was selected as a reference model due to its recognized tonal reliability and construction quality. Sound data from both the BBG and FJB70s were collected in multiple trials. Each iteration was recorded under the same conditions, and the resulting waveforms were averaged to reduce variability and noise. This approach ensured a robust and meaningful acoustic comparison between the two instruments. By employing controlled plucking, consistent recording parameters, and multiple rounds of measurement with averaged data, the methodology ensures a clear, accurate, and scientifically valid comparison of the acoustic performance of the bamboo-based BBG and the commercial FJB70s bass guitar.

RESULTS AND DISCUSSION

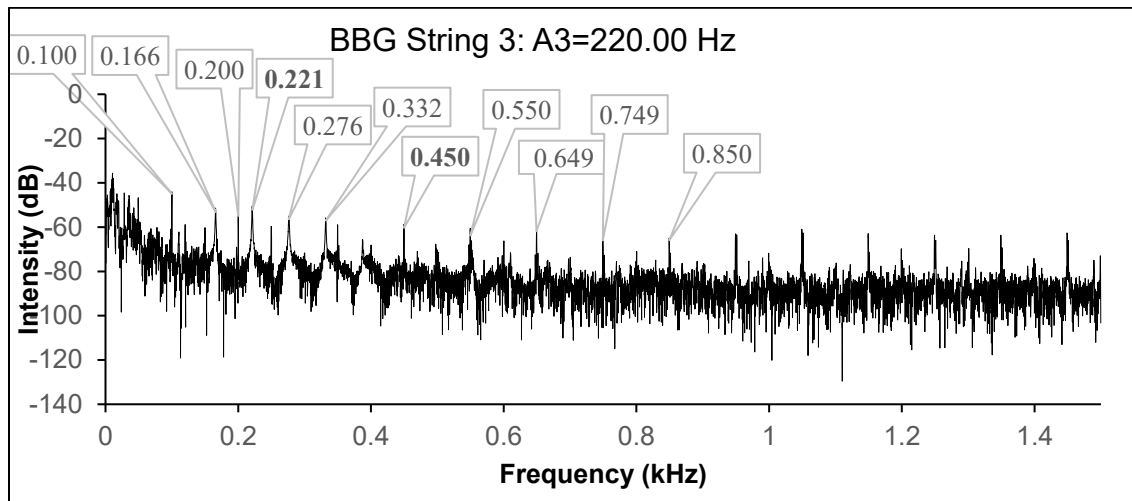
In a periodic wave, the fundamental frequency is the lowest frequency present. It is the base frequency around which other frequencies are defined. Periodic waves can be expressed as a sum of sine waves, including the fundamental and its harmonics and subharmonics. Harmonics are integer multiples of the fundamental frequency ($1f_0$, $2f_0$, $3f_0$, *etc.*). Subharmonics are frequencies that are integer submultiples of the fundamental frequency ($1/2(f_0)$, $1/3(f_0)$, $1/4(f_0)$, *etc.*).



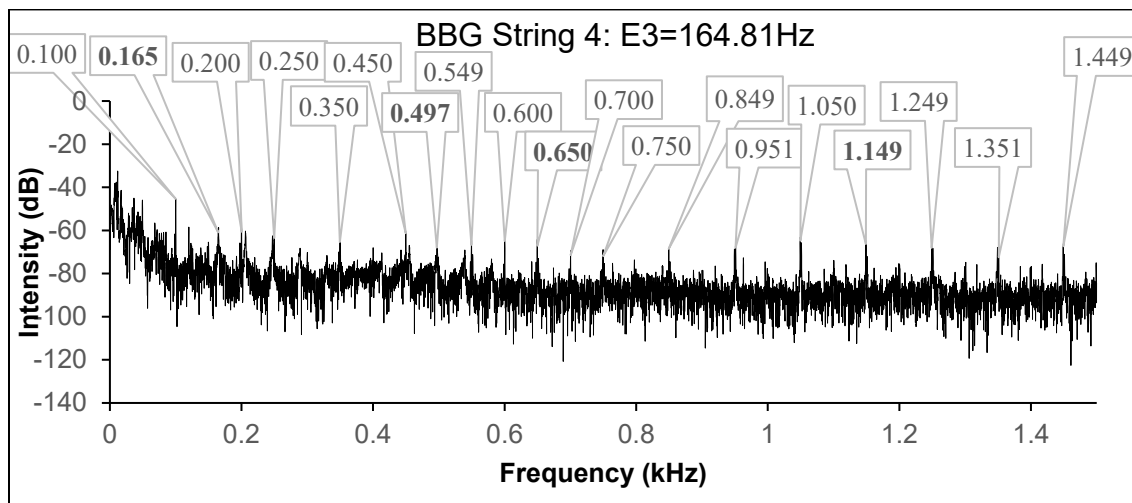
(a) String 1



(b) String 2



(c) String 3



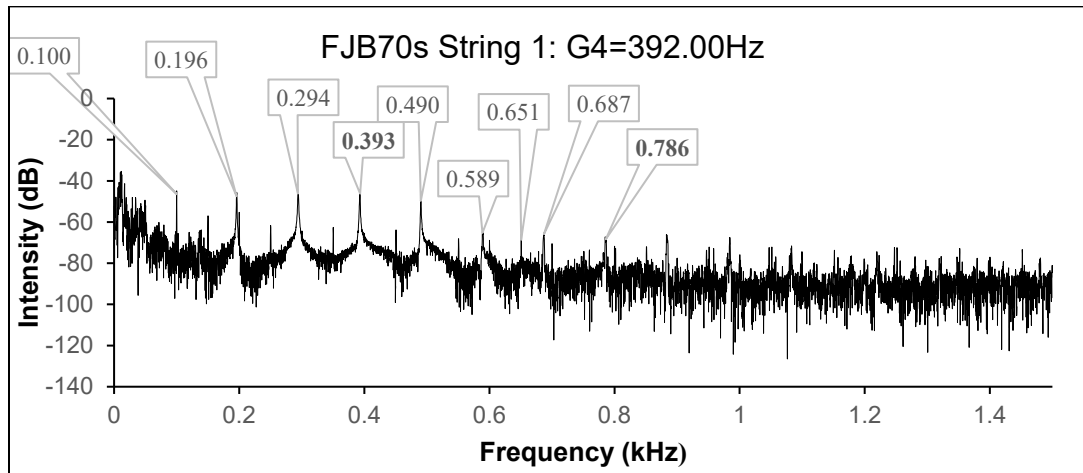
(d) String 4

Fig. 4. FFT spectra from strings 1 to 4 (G4 (392 Hz), D3 (148Hz), A3 (220 Hz), and E3 (165 Hz)) for BBG. Harmonic peaks are the peak frequencies in bold font

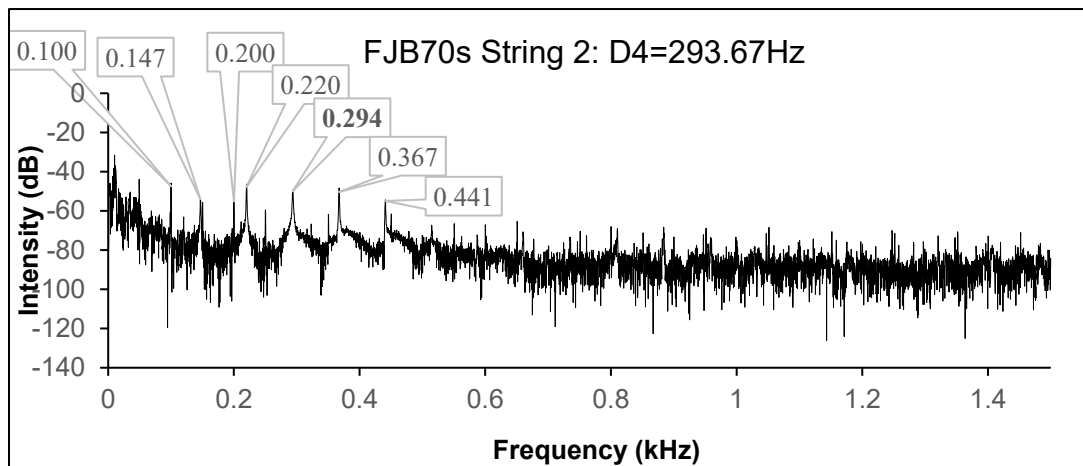
While harmonics are higher frequencies than the fundamental, subharmonics are lower frequencies than the fundamental. The second subharmonic is the one with half the fundamental frequency. The FFT spectra for BBG are displayed in Fig. 4 for strings 1 through 4 (G4 (392.00 Hz), D4 (293.67 Hz), A3 (220.00 Hz), and E3 (164.81 Hz)). Harmonic peaks are displayed in bold font.

String 1 had the 1st and 2nd second harmonics at 0.392 and 0.785 kHz, respectively with 6 non-harmonics at 0.491, 0.549, 0.589, 0.649, 0.700, and 0.749 kHz. The note G4 (0.392 kHz) was very significant with 3 subharmonics at 0.100 kHz (0.25f₀), 0.196 kHz (0.5f₀), and 0.294 kHz (0.75f₀). Although the string was tuned to G4 (0.392 kHz), the subharmonics D4 (0.294 kHz) was also significant. Strings 2 had 3 harmonics at 0.295, 0.590, and 0.886 kHz with 6 non-harmonics at 0.369, 0.443, 0.516, 0.650, 0.740, and 0.815 kHz. The D4 (0.295 kHz) was very significant with 3 subharmonics at 0.100, 0.148(0.5f₀), and 0.221(0.75f₀) kHz. Although the string was tuned to D4 (0.294 kHz), the subharmonics A3 (0.221 kHz) were also significant. Strings 3 had 4 harmonics at 0.221, 0.450, 0.649, and 0.850 kHz and 4 with non-harmonics at 0.276, 0.332, 0.550, and 0.749 kHz. The

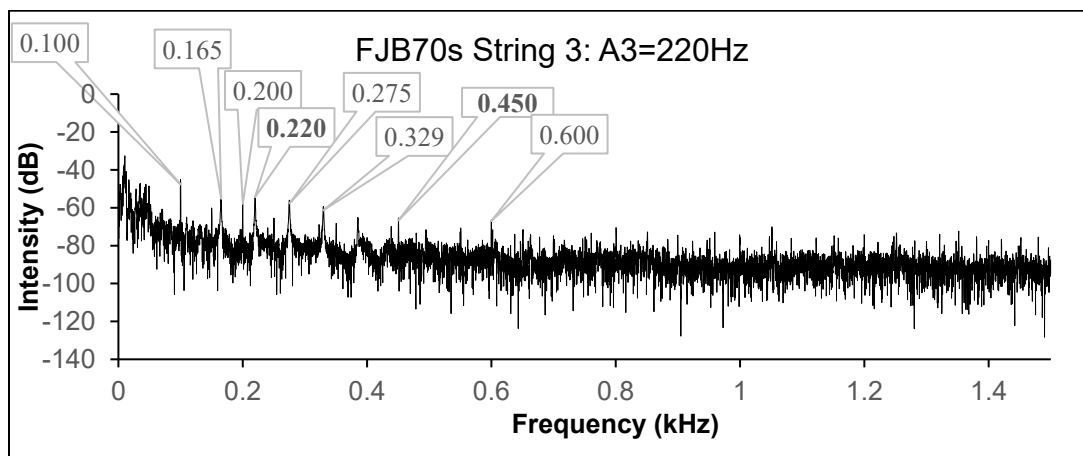
fundamental A3 (0.221 kHz) was very distinct. The 3 subharmonics at 0.100, 0.166 (0.75 f_0), and 0.200 kHz were very significant. Although the string was tuned to A3 (0.221 kHz), the subharmonics E3 (0.166 kHz) were also significant. Strings 4 had 5 harmonics at 0.165, 0.350, 0.495, 0.650, and 0.849 kHz and 8 non-harmonics at 0.200, 0.250, 0.450, 0.497, 0.549, 0.600, 0.700, and 0.750 kHz. The intensity of E3 (0.165 kHz) was lower than the subharmonics (0.100 kHz) and overtone (0.200 kHz).



(a) String 1



(b) String 2



(c) String 3

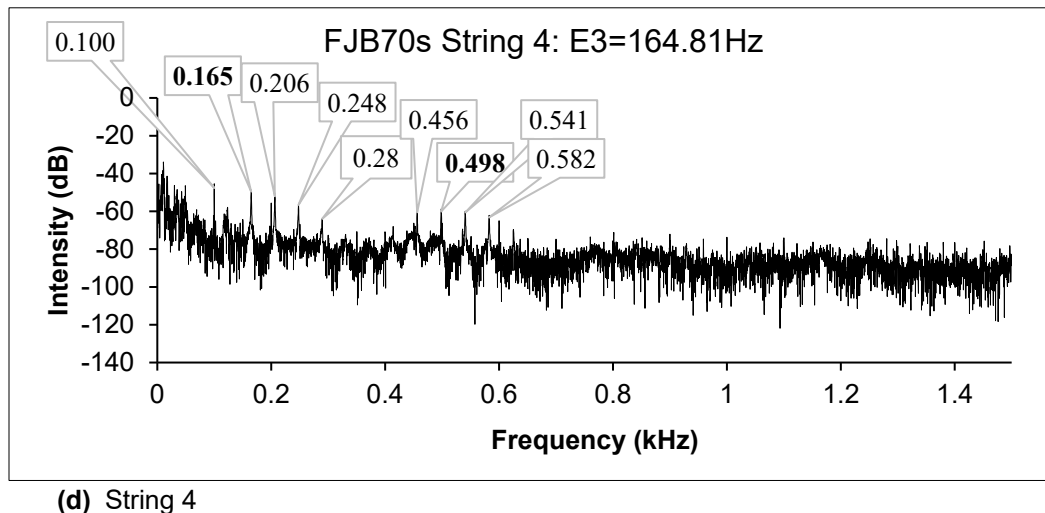


Fig. 5. FFT spectra from strings 1 to 4 (G4 (0.392 kHz), D4 (0.293 kHz), A3 (0.220 kHz), and E3 (0.165 kHz)) for FJB70s guitar. Harmonic peaks are the peak frequencies in bold font.

The guitar's low-frequency tonal characteristics were mostly determined by the significant peaks at 0.100, 0.200, and 0.400 kHz, which are caused by resonances in the guitar body (Rossing 2010). The FFT spectra for the FJB70s guitar are displayed in Fig. 5 for strings 1 through 4 (G4 (392.00 Hz), D4 (293.67 Hz), A3 (220.00 Hz), and E3 (164.81 Hz)). Harmonic peaks are displayed in bold font.

String 1 in FJB70s guitar had the 1st and 2nd second harmonics at 0.393 and 0.786 kHz, respectively with 4 non-harmonics at 0.490, 0.589, 0.651, and 0.687 kHz. The note G4 (0.393 kHz) was very significant with 3 subharmonics at 0.100 (0.25f₀), 0.196 (0.5f₀), 0.294 (0.75f₀) kHz. Although the string was tuned to G4 (0.393 kHz), the subharmonics D4 (0.294 kHz) were also significant. String 2 had harmonic at 0.294 kHz only. The subharmonics also occurred at 0.147 (0.5f₀) and 0.220 (0.75f₀) kHz and surprisingly appeared at a significantly high intensity in string 2. Although the string was tuned to D4 (0.294 kHz), the subharmonic A3 (0.220 kHz) was also significant. String 3 had harmonics at 0.220 kHz and 0.450 kHz. Overtones occurred at 0.275, 0.329, and 0.600 kHz. Three subharmonics also occurred at 0.165 kHz (0.75f₀). Although the string was tuned to A3 (0.220 kHz), the subharmonics E3 (0.165 kHz) were also significant. String 4 had a harmonic at 0.165 (E3) kHz only. The higher partials occurred at 0.206, 0.248, 0.289, 0.456, 0.498, 0.541, and 0.582 kHz. Table 1 displays the partials frequency and the ratio between the partials with respect to the fundamental for BBG and FJB70s. The guitar's low-frequency tonal characteristics were mostly determined by the significant peaks at 0.100, 0.200, and 0.400 kHz, which are caused by resonances in the guitar body (Rossing 2010).

Variance is a statistical measurement that indicates the spread of numbers in a dataset with respect to the average value or mean. It is calculated as the average of the squared deviations from the mean, reflecting the variability of the dataset. Variance is also defined as the square of the standard deviation, providing insight into the dispersion of data points. In the present findings, the data were similar for every run. Therefore, the statistical variance was zero.

Table 1a. The Partial Frequency and the Ratio between the Partial with respect to the Fundamental for BBG

String 1 (G4)		String 2 (D4)		String 3 (A3)		String 4 (E3)	
Hz	ratio	Hz	ratio	Hz	ratio	Hz	ratio
100	0.25	100	0.33	100	0.45	100	0.60
196	0.5	148	0.50	166	0.75	165	1
294	0.75	221	0.74	200	0.90	200	1.21
392	1	295	1	221	1	250	1.51
491	1.25	369	1.25	276	1.24	350	2.12
549	1.40	443	1.50	332	1.50	450	2.72
589	1.50	516	1.74	450	2	497	3
649	1.65	590	2	550	2.48	549	3.32
700	1.78	650	2.20	649	2.93	600	3.63
749	1.91	740	2.50	749	3.38	650	4
785	2	815	2.76	850	3.84	700	4.24
		886	3.00			750	4.54
						849	5.14
						951	5.76
						1050	6.36
						1149	7
						1249	7.56
						1351	8.18
						1449	8.78

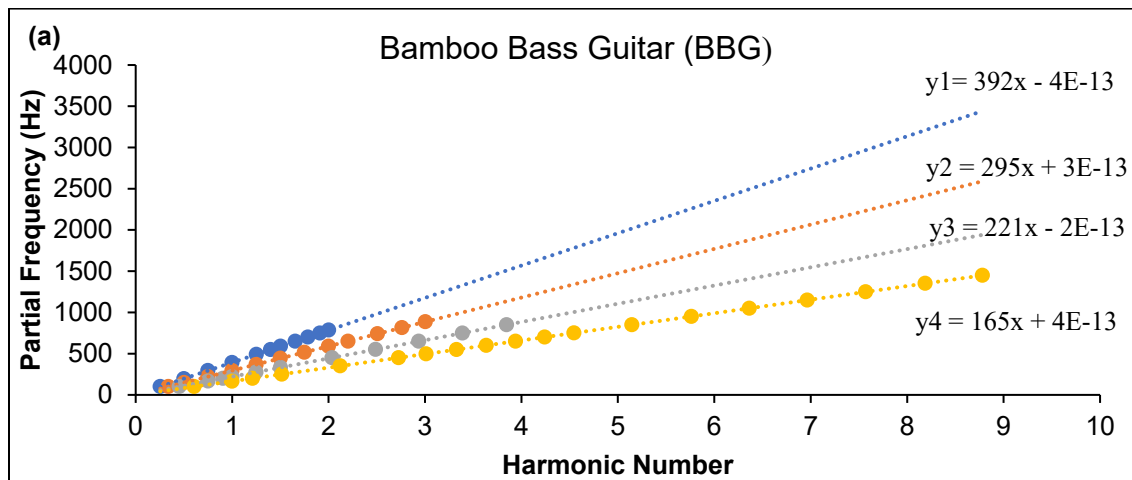
Note: Bold font indicates harmonics ratio.

Table 1b. The Partial Frequency and the Ratio between the Partial with respect to the Fundamental for FJB70S Guitar

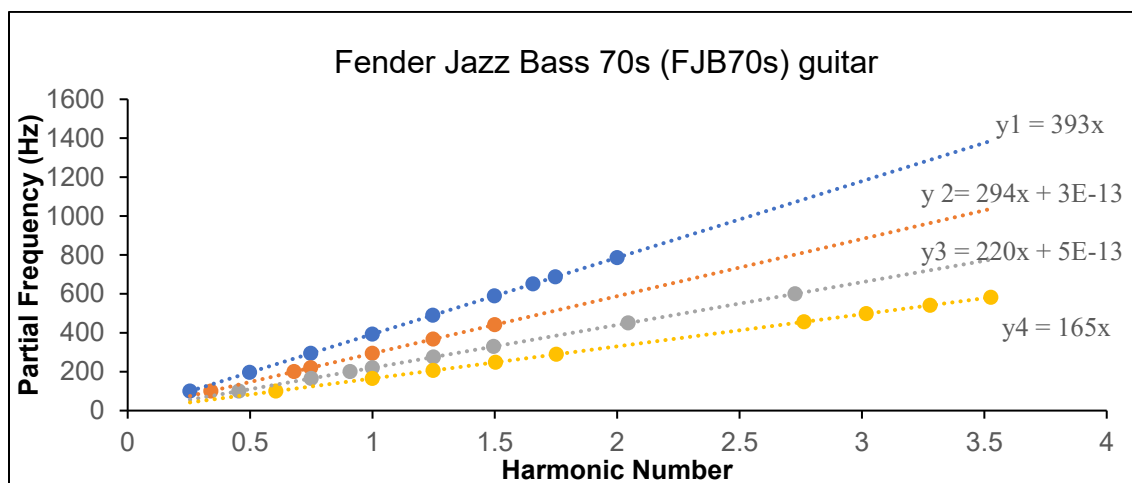
String 1 (G4)		String 2 (D4)		String 3 (A3)		String 4 (E3)	
Hz	ratio	Hz	ratio	Hz	ratio	Hz	ratio
100	0.25	100	0.34	100	0.45	100	0.60
196	0.49	200	0.68	165	0.75	165	1
294	0.74	220	0.74	200	0.90	206	1.24
393	1	294	1	220	1	248	1.50
490	1.24	367	1.24	275	1.25	289	1.75
589	1.49	441	1.5	329	1.49	456	2.76
651	1.65			450	2	498	3
687	1.74			600	2.72	541	3.27
786	2					582	3.52

Note: Bold font indicates harmonics ratio.

The data were always consistent regardless of how many experiments were conducted. Therefore, the mean values were well reproduced. From Table 1, the FFT spectra data shows that the BBG had more partials compared to the FJB70s. String 4 shows a regular signal from the BBG up to 7th harmonics. String 2 from FJB70s had the least partials with only one harmonic. Strings 1, 2, and 3 showed 3 subharmonics whereas string 4 showed only 1 subharmonic for both guitars. The FJB70s guitar showed less partials at low pitch. In contrast, BBG displayed the highest number of partials at low pitch. FJB70s displayed a recognizable pattern, whereas the BBG showed an irregular pattern with more significant overtones. Figure 6 displays the partials frequency *versus* the harmonic number for both guitars.



(a) Bamboo Bass Guitar (BBG)



(b) Fender Jazz Bass 70s (FJB70S) guitar.

Fig. 6. The partials frequency *versus* the harmonic number for (a) Bamboo Bass Guitar (BBG) and (b) Fender Jazz Bass 70s (FJB70S) guitar

From Fig. 6, although both guitars showed similar equations for string 4, BBG showed lower intensity than FJB70s (see Figs. 4 and 5). The string's sound can be immediately reflected onto the guitar body. The FJB70s radiated more due to the wood's hardness. In contrast, the sound of the BBG progressively faded laterally. Because the bamboo lateral characteristics are lower than its longitudinal ones, it has more lateral flexibility, which causes it to fade laterally. The body in BBG is composed of a single piece of laminate, as opposed to a single piece of solid wood in the case of the FJB70s guitar. Compared to the FJB70s guitar, the BBG's frequency response function is typically composed of a greater number of partials that are not an integer of the fundamental. Despite having the same body thickness, the FJB70s displayed a greater radiation coefficient than the BBG. The FJB70s has a smaller loss coefficient than the BBG because the impact of the loss coefficient is less noticeable at high frequencies. Because the bamboo absorbed more sound, the BBG's frequency response function is more damped. Numerous arbitrary partials between the BBG's harmonics are displayed in Fig. 4. The FJB70s guitar's lack of partials may be because wood has a greater radiation coefficient.

According to Table 1, the fundamental frequencies of the BBG and FJB70s emitted the same pitch, and the 1st and 2nd partials of each string on both instruments matched. As the pitch changed, so did the number of partials. The normal sound quality of both guitars was confirmed by the overtone partials. In comparison to the BBG, the FJB70s exhibited fewer partials. As shown in Fig. 4, the BBG revealed a different timbre from the FJB70s, although having a comparable pitch and sounding. The spectra in Fig. 5 demonstrated that the FJB70s guitar sounded brighter than the BBG. Both guitars exhibited varying overtone intensities, which might result in a varied timbre. The body is the main source of the timbre difference because the two materials' components are so dissimilar.

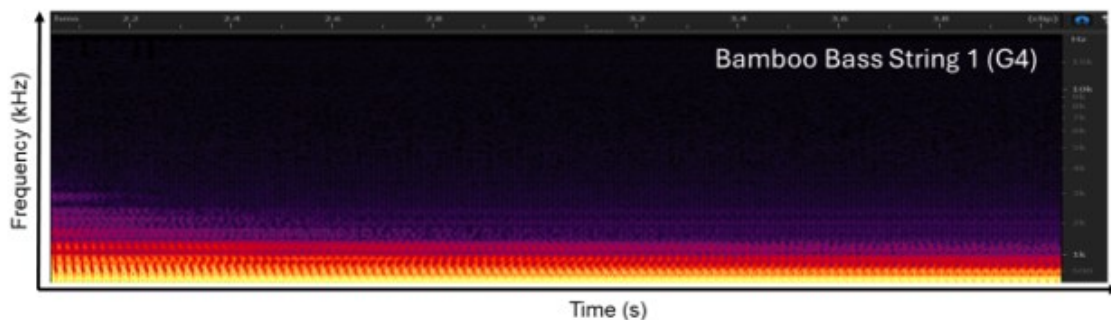
The subjective measures of sound quality in this study included using listener assessments and psychoacoustic testing. A talented bassist performed using both the FJB70s and the locally constructed BBG in a controlled environment. Expert listeners evaluated the sound's playability, timbre, projection, and resonance. Based on the evaluations, qualitative data regarding the perceived sound characteristics of each instrument was acquired. The human ear's perception of each guitar's sound was also investigated through psycho-acoustic study. This method was used to assess loudness, pitch perception, and sound quality metrics such as sharpness and fluctuation strength. The technical information from the FFT spectra and spectrogram data were integrated with the outcomes of these subjective assessments and psycho-acoustic tests to allow for a thorough comparison of the perceived sound quality and acoustic qualities of both guitars.

Subjective listener evaluation was conducted using a basic structured approach to gather perceptual feedback on the BBG in comparison to the FJB70s. A group of 10 listeners including musicians, sound engineers, and music students evaluated audio samples of both instruments in a controlled listening environment. Listeners rated specific tonal attributes such as warmth, brightness, clarity, and overall tonal balance using a 5-point Likert scale (1 = very poor, 5 = excellent). No formal psychoacoustic testing protocol was employed in this initial phase. There was no structured rubric, blind testing, or statistical analysis applied (*e.g.*, Wilcoxon Signed-Rank Test). Future work will incorporate a more rigorous psychoacoustic evaluation design, including a larger listener panel, defined assessment parameters, and statistical treatment of the data to strengthen the findings.

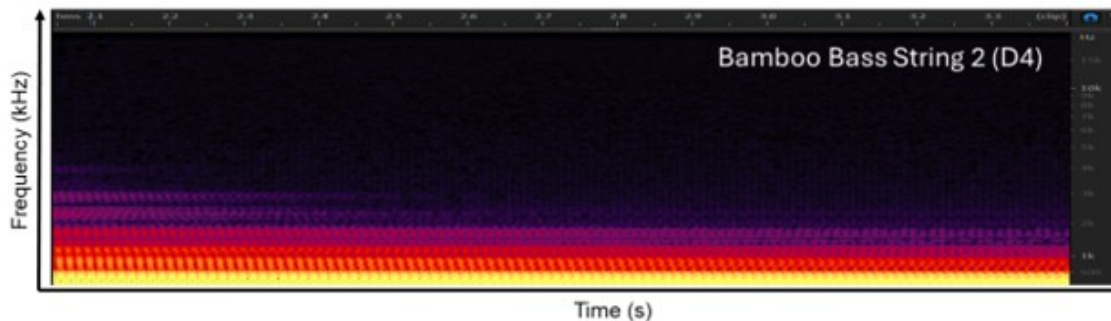
The FJB70s' well-balanced neck and faultless fretboard make it a joy to play. It can be played right away without worrying about making any last-minute tweaks because the motion is typically flawless right out of the box. Long practice sessions are easy because of its pleasant and playable design. Undoubtedly, though BBG has some differences from the FJB70s, BBG has its own distinct vibe. The timbre is less rich even if the fundamental harmonics are the same. The less obvious sustain and notes that fall short of their entire range of sound affect the overall timbre of each string. In contrast to the dazzling projection of FJB70s's solid wood construction, the BBG tends to generate a more subdued sound because it is made of connected bamboo pieces. A subdued sound is one that is not very loud or intense, often described as quiet, hushed, or muted. In the context of sound means that the sound is not strong, loud, or intense. As a result, even though it was judged to be fun to play both guitars, the FJB70s sounds was judged to be deeper and more resonant. Figure 7 shows the spectrogram from Adobe Audition for BBG and FJB70s. The bassy sound was reflected by the dark black spectrogram of both guitars. The term "bassy" was used to describe the sound, based on visual analysis of the spectrogram, where darker and more prominent intensities appeared in the lower frequency range (typically between 40 and 250 Hz). These dark bands indicated stronger energy concentration in the low-end

spectrum, commonly associated with a bassy tonal character. The Adobe Audition spectrogram uses a brightness scale in which darker regions reflect higher amplitude across that frequency band. Sounds that are robust in the lower frequency band and frequently have a deep, resonant, and forceful tone are referred to as bassy sounds. Usually, these noises fall between 20 and 300 Hz. The bass area of the audio spectrum is another name for this range of frequencies. Low frequencies, or sound waves with a longer wavelength and a slower rate of vibration, are what define bassy sounds. Bass sounds are deep and resonant because of this slower vibration. Bass sounds can be felt as well as heard. This is due to the fact that the lower frequencies have the ability to generate a visceral sensation by vibrating the body. In music, bassy sounds are essential because they serve as the basis for rhythm, harmony, and depth. They are frequently produced by electronic synthesizers, bass drums, and bass guitars. The bass tones in music and other media can be noticed and enjoyed because the human ear is especially sensitive to lower frequencies.

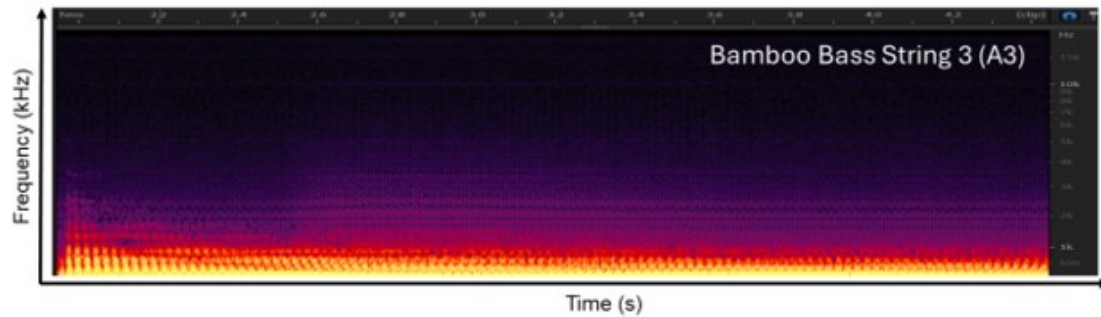
The first string of both guitars displayed sharp and clearly defined spectrum due to the high pitch of the first string. String 2 of BBG showed more bassy sound than the FJB70s. Strings 3 and 4 clearly show indistinct frequency spectrum due to the very low pitch from both guitars. In general, the FJB70s displayed a clear distinct spectrogram compared to the BBG.



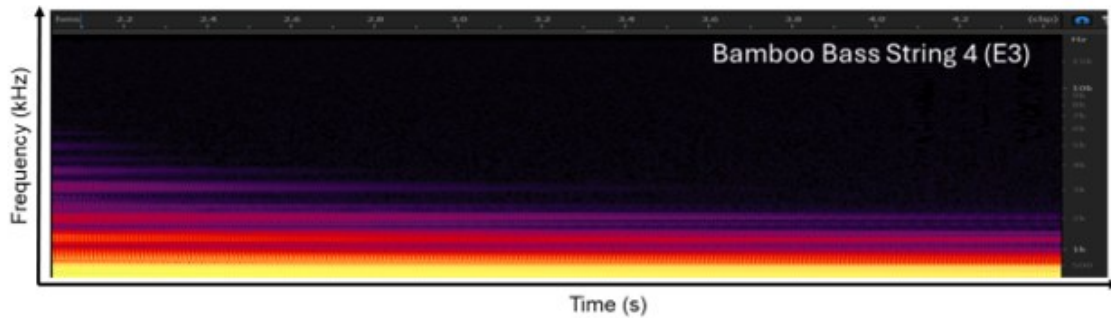
(i) String 1



(ii) String 2

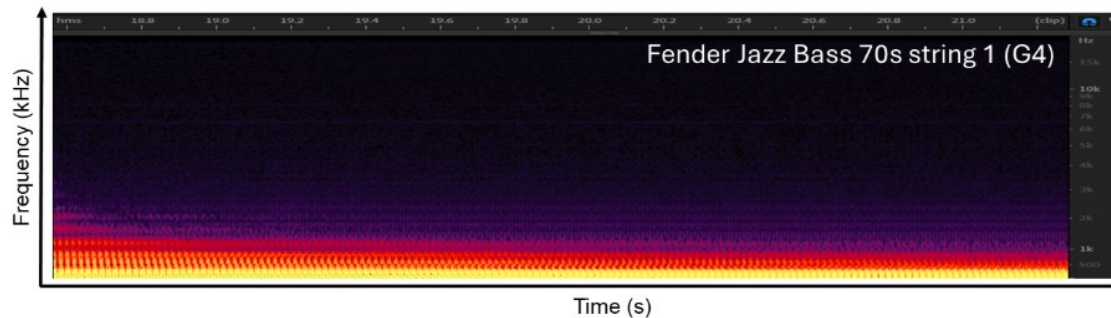


(iii) String 3

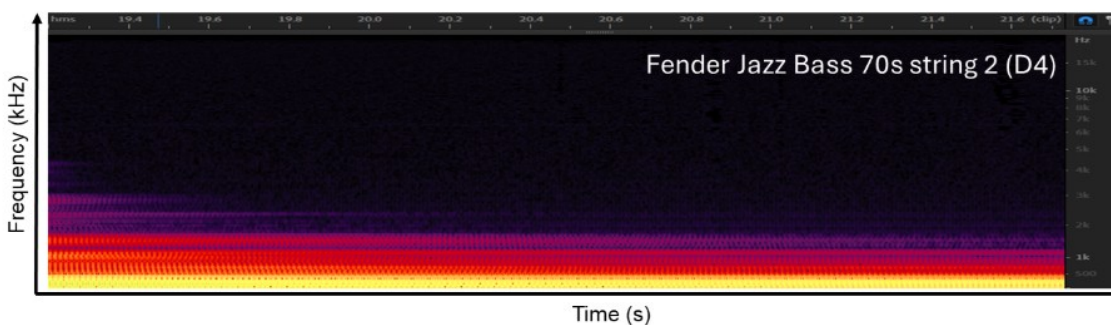


(iv) String 4

Fig. 7a. The spectrogram from Adobe Audition for string 1 (G4), 2 (D4), 3 (A3), and 4 (E3) from bamboo bass guitar (BBG). Recording conditions; the input from the microphone and amplifier was connected to a computer and analyze with Adobe Audition under multitrack function. Yellow indicates the low frequency spectrum, red indicates the medium frequency spectrum and violet indicates the high frequency spectrum. This is bass guitar therefore the low frequency domain is dominant as expected from bass guitar.



(v) String 1



(vi) String 2

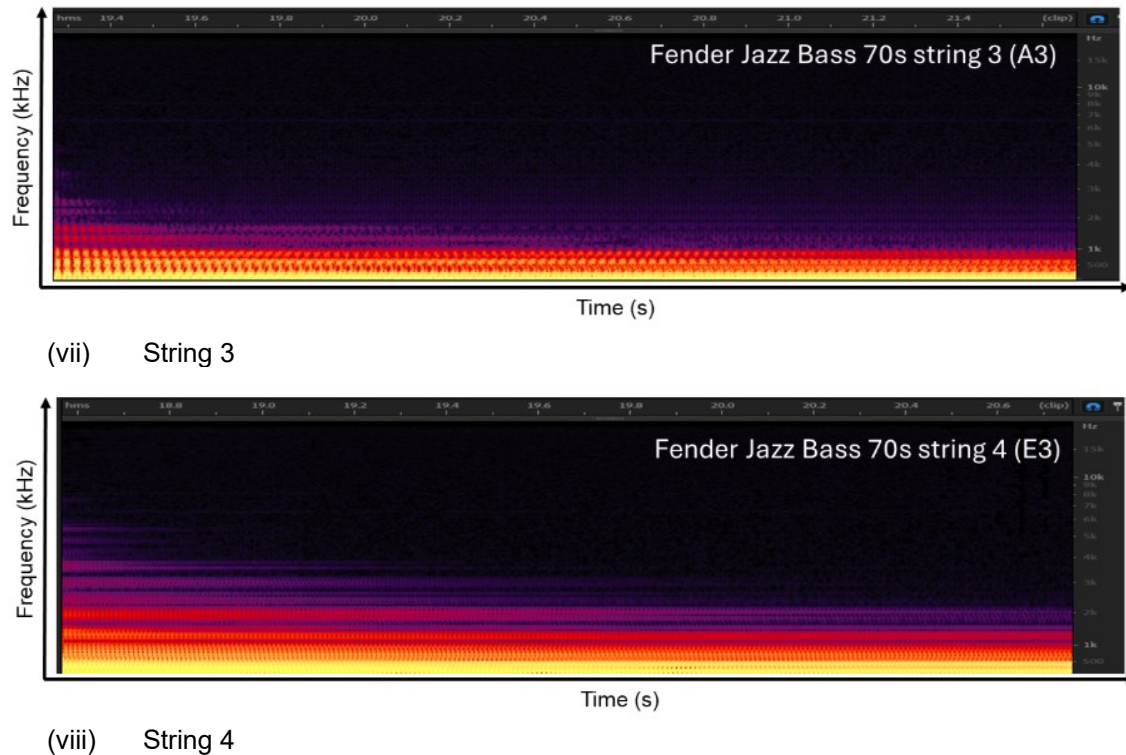


Fig. 7b. The spectrogram from Adobe Audition for string 1 (G4), 2 (D4), 3 (A3), and 4 (E3) from Fender Jazz Bass 70s (FJB70s) guitar. Recording conditions; the input from the microphone and amplifier was connected to a computer and analyze with Adobe Audition under multitrack function. Yellow indicates the low frequency spectrum, red indicates the medium frequency spectrum and violet indicates the high frequency spectrum. This is bass guitar therefore the low frequency domain is dominant as expected from bass guitar.

Because of its stunning wood texture and high-quality sound, Fender bass guitars, including the popular Precision and Jazz Bass models, commonly feature bodies made of wood materials such as alder, ash, or occasionally poplar or basswood. Alder is a popular choice for its balanced, warm tone, particularly for Fender's Stratocasters, Jaguars, Jazz masters, and Jazz Basses. Ash is known for its powerful sound and fast response, though it can sound drier and less balanced than alder. Poplar and basswood are also used in some Fender basses, particularly in the lower price ranges. Fender often uses maple for necks, not bodies. Some Fender basses might feature other woods such as mahogany or even exotic woods for specific models or custom builds. These woods are not accessible in Malaysia. As a result, Malaysian guitar makers looked for a substitute material. The locally made BBG can be evaluated by contrasting it with a reliable and recognizable standard, such as the FJB70s. This decision guarantees that the analogy makes sense and is pertinent to the guitar community as well as knowledgeable listeners.

Incorporating psychoacoustic descriptors such as warmth, brightness, and transient clarity would enhance the interpretive value of our findings. This include a qualitative comparison based on listening tests involving five experienced musicians and audio engineers. Terms such as warmth (referring to the low-mid tonal balance), brightness (related to the high-frequency clarity), and transient clarity (attack definition and response speed) are now used to describe the perceptual differences between the BBG and FJB70s.

These descriptors were drawn from both subjective impressions and spectral observations, particularly in the 200 Hz to 5 kHz range.

CONCLUSIONS

1. In this study, the FJB70s guitar has been used to compare the pitch and timbre of BBG. Despite having identical pitch and harmonic characteristics, the BBG's timbre differs from that of the FJB70s guitar. The BBG's fundamental, 1st and 2nd overtone frequencies which are harmonics (but not timbre) are the only output that can be compared to the FJB70s guitar.
2. Both guitars' bodies utilized the longitudinal grain direction. The BBG body is constructed from split bamboo that is bonded together, which contributed to variances. By contrast, the FJB70s guitar utilized only one piece of wood (rather than being bonded from split wood), and it displayed a higher radiation coefficient. The BBG body exhibited more damping and less radiative characteristics. Additionally, the integer overtones on the BBG exhibited diminishing intensities, although it produced the same harmonic frequencies with the FJB70s guitar. Compared to the FJB70s guitar, the BBG body exhibited an odd pattern of partials intensities.
3. Future research directions or practical applications of the findings will incorporate a more rigorous psychoacoustic evaluation design, including a larger listener panel, defined assessment parameters, and statistical treatment of the data to strengthen the findings.

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