Pratuokng: The Borneo Bamboo Zither of Bidayuh Sarawak

Sinin Hamdan,[a]* Khairul Anwar Mohamad Said,[a] Ahmad Faudzi Musib,[b]
Md Rezaur Rahman,[a] Marini Sawawi,[a] and Aaliyawani Ezzerin Sinin [c]

** Corresponding author: hsinin@unimas.my*

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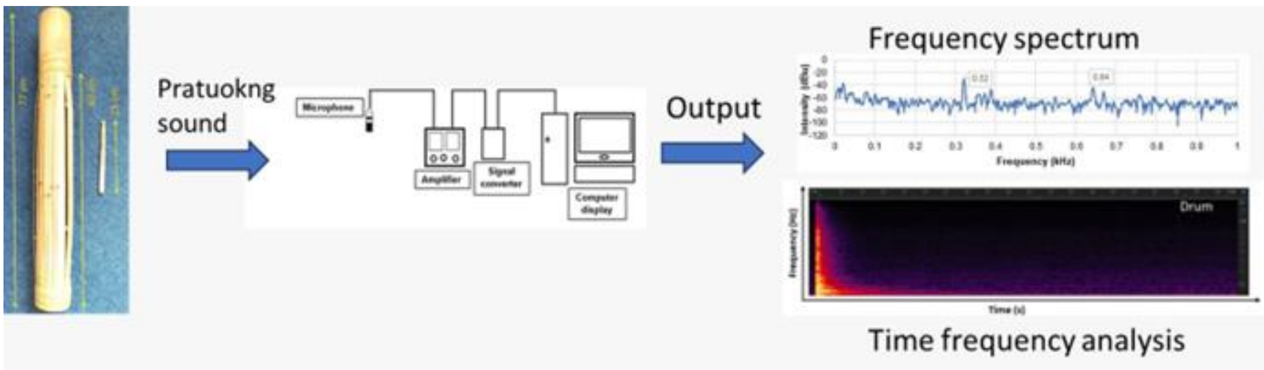
GRAPHICAL ABSTRACT



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The pratuokng is an idiochord tube zither, which is a musical instrument. The Bidayuh Biatah pratuokng bamboo sound radiators of Annah Rais in Padawan, Sarawak, Malaysia are made up of seven strings and one drum. The sound reproduction capabilities are unique and innovative. This study intends to highlight the importance of sound studies in the studio setting. The frequency spectrum was evaluated using a Fast Fourier Transform (FFT) analysis *via* PicoScope oscilloscopes, and the time frequency analysis (TFA) using Adobe Audition that produced the spectrograms. The observations and perceptions offered by the actual meaning of this bamboo tube zither instruments showed that the notes of the pratuokng strings are E, D, F, Ab, B, A#, and B, respectively. The drum note is A. The 1st, 2nd, 3rd(A), 3rd(B), 4th(A), 4th(B), and 5th strings are 320 Hz (E4 = 329.63), 300 Hz (D4 = 293.67), 350 Hz (F4 = 349), 410 Hz (A4b = 415), 490 Hz (B4 = 493), 470 Hz (A4# = 466), and 500 Hz (B4 = 493), respectively, *i.e.*, with note E, D, F, Ab, B, A#, and B, respectively. The drum is 210 Hz (A3 = 220). The signal in the frequency spectrum showed both distinct fundamental and higher partial frequencies. In particular, the first octave are present except for string 4B and 5. The inconsistent number of partials in each string is due to the inconsistent thickness of the raised fiber from the bamboo tube.

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Keywords: Bamboo zither; Bidayuh Biatah; Pratuokng; FFT; TFA; Partial; Annah Rais

*Contact information: a: Faculty of Engineering, Universiti Malaysia Sawarak, 94300 UNIMAS, Kota Samarahan, Sarawak, Malaysia; b: Faculty of Human Ecology, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia; c: Department of Science and Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus, 97008 Bintulu Sarawak Malaysia; * Corresponding author: hsinin@unimas.my*

INTRODUCTION

The development of traditional musical instruments used in Sarawak is seen in terms of the quality and technique of making the instruments. A few examples of the musical instrument are jatung utang, sape, tapi, and pratuokng. The musical instruments are important for certain events or occasions within the community. Every instrument has a role within the society. Unfortunately, tone and tone color, two very important characteristics of the regional musical instrument are rarely discussed. Examining how each sound contributes to the overall auditory experience is crucial when assessing the sound quality of an instrument. The purpose of this study is to examine the tone and tone color of the bamboo zithers that the Bidayuh Biatah community employs.

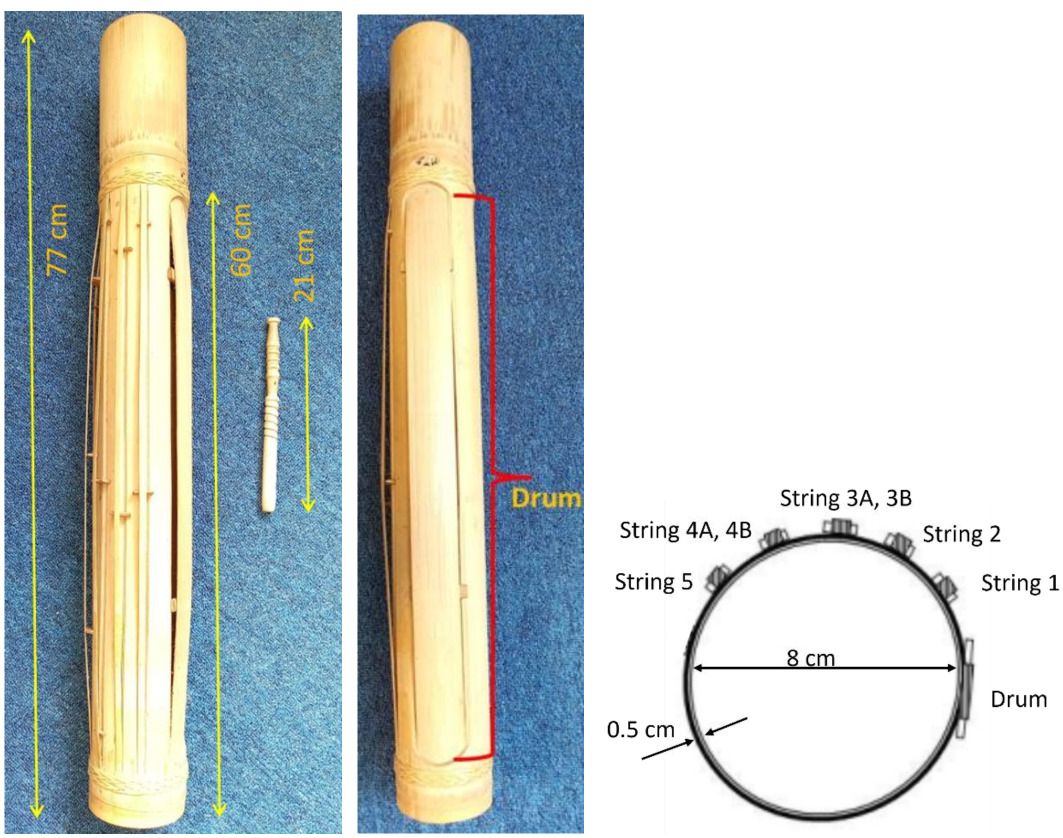
Bamboo is best used as a base material for the manufacture of musical instruments when viewed from the structure of the material. However, bamboo from Sarawak is not widely used for musical purposes. The lack of knowledge on the material and acoustic organology has resulted in a lack of interest by researchers of many musical instruments made of bamboo. In exploring the international reception of traditional bamboo musical instruments from Sarawak, the author initially suggested that a comprehensive study of tone, tone color, and sustain aspects is essential for widespread acceptance. However, it is crucial to acknowledge instances where similar instruments have found favor within the ethnomusicology community without requiring an exhaustive technical analysis. Take, for instance, the instrument, which has garnered appreciation solely for its sound and musicality (see https://www.auralarchipelago.com/auralarchipelago/talempongbotuang). This observation prompts a reconsideration of the earlier assertion, recognizing that the global acclaim for traditional instruments can often transcend stringent analytical criteria, emphasizing the universal enjoyment of their unique sounds.

Many musical instruments produced from bamboo in Sarawak do not consider the density, moisture content, and age of the bamboo. As a novelty of this research, it aims to study the harmonic and overtone spectrogram of the chosen tone, which can serve as a guide for fabricating bamboo pratuokng. Further research is needed to explore the technical and acoustic characteristics of the tube zithers pratuokng. Bamboo is widely known for its use as a material in musical instruments. Bamboo was earlier used as a percussion instrument and later for wind and stringed instruments. The layered structure of fibers of bamboo pipe walls exhibits non-uniform density in the radial direction. Thus, the elastic moduli in the parallel and perpendicular direction to the bamboo fibers are distinct. The hollow form makes bamboo a good choice for a resonator in pratuokng musical instruments. Bamboo was chosen for musical instruments because of its excellent sound applications (Wegst 2008). The studies of bamboo for pratuokng musical instruments are limited. The pratuokng is made of giant bamboo known as pratuokng or betung (von Hornbostel and Sachs 1914). The *Dendrocalamus* bamboo (local name 'betung') is common in Asia. The scientific name is *Dendrocalamus asper* (Wu 1995). Previous works on bamboo were done by the author on a traditional bamboo musical instrument called angklung (Hamdan *et al*. 2022a) and sompoton (Hamdan *et al.* 2022b). The pratuokng is a bamboo tube zither instrument. Researchers on the audio recordings will add a necessary technical dimension to the pratuokng sound elements. The pratuokng sound production is evaluated *via* Picoscope and Adobe audition. The pratuokng is made of bamboo tube with the strings raised from the outer fibers of the tube. The tuning transpires by shifting the location of the supports for tensioning the string, which determines their notes. The pitches retrieval was analyzed *via* Fast Fourier Transform (FFT) to identify the fundamentals and overtones of the individual strings. The sound was measured through studio recordings and scientific assessments of the music features in FFT. The primary aim of this work is to investigate the audio recording from the pratuokng string. The instrument's ability to reproduce sound was considered for each string. The main characteristics in making the pratuokng are the bamboo tube diameter, length between nodes, and thickness of the bamboo (Musib 2014). The length of the bamboo tube in this pratuokng is 60 cm while the mallet length is 21 cm and made of wood.

METHODOLOGY

Material and acoustic organology of bamboo for making basic pitch zither Pratuokng are shown in Fig. 1. There are physically 5 strings made from the trunk of the bamboo. Two strings are divided by a middle peg into 2 parts and make it counted as 7 strings (the 2 strings called as string no 3 and string no 4 are divided by the middle pegs into strings 3A and 3B, and string 4a and 4b, respectively). The strings are played by striking with a small piece of wood. The supports to raise the strings are placed toward the end of the bamboo tube ends. The height of the peg determined the tension in the string.

The PicoScope computer software (Pico Technology, 3000 series, Eaton Socon, UK) was used to view and analyse the time signals from PicoScope oscilloscopes (Pico Technology, 3000 series, Eaton Socon, UK) and data loggers for real time signal acquisition. PicoScope software enables analysis using FFT, a spectrum analyser, voltage-based triggers, and the ability to save/load waveforms to a disc. Figure 2 shows the schematic diagram of experimental setup. The pratuokng was placed to where the sound could be captured with minimum interference. The amplifier (Behringer Powerplay Pro XL, Behringer, Zhongshan, Guangdong, China) ensured the sound capture was loud enough to be detected by the signal converter. The sound spectra are obtained from PicoScope measurements. After the data sound was captured and recorded, the FFT was also analysed using Adobe Audition to obtain dominant frequency for each tone at specific time. Fourier transformation determines fundamentals, harmonics, and subharmonics.



1(a) (b) (c)

Fig. 1. (a) Pratuokng used in this study; (b) The drum (c) Schematic diagram of the bamboo tube with the strings and drum

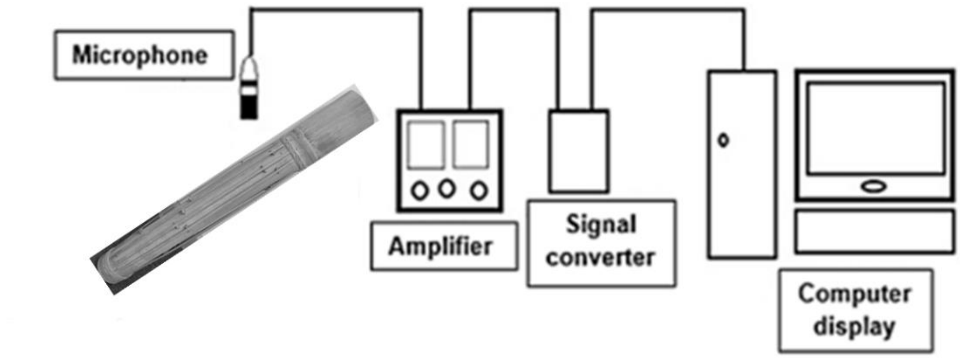
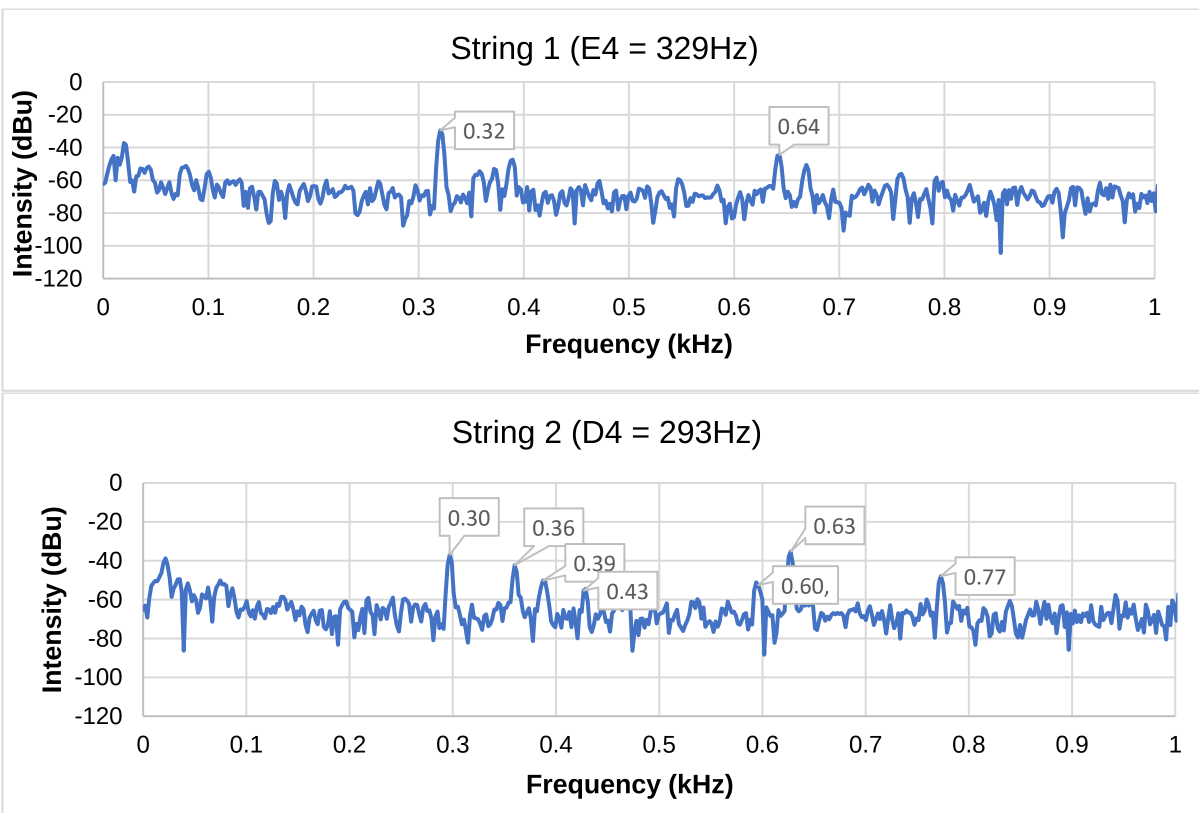
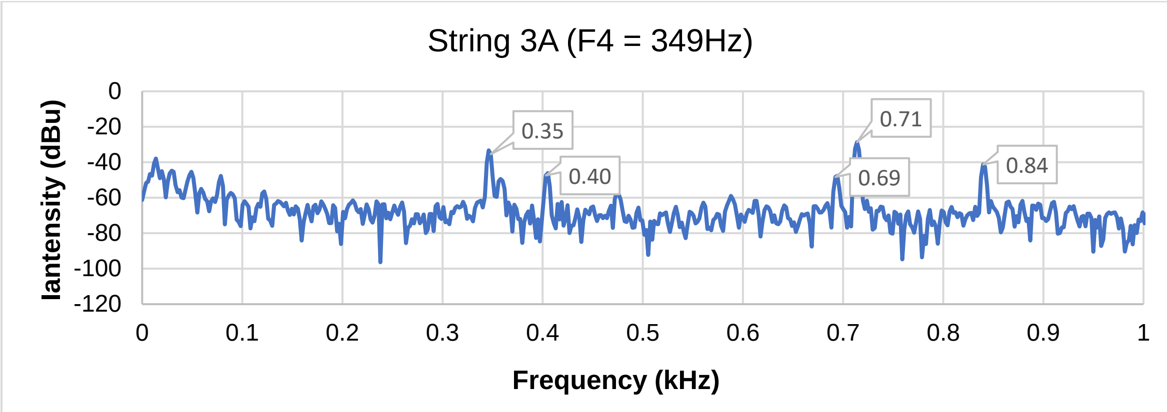


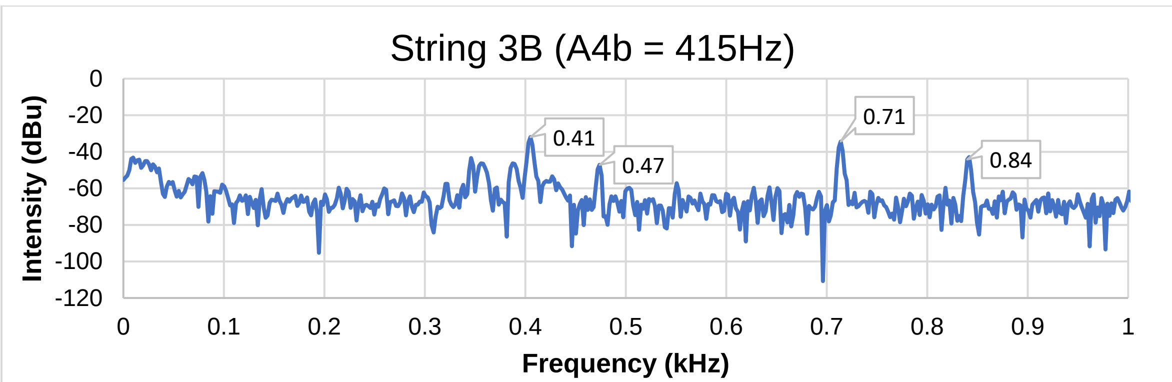
Fig. 2. Schematic diagram of experimental setup

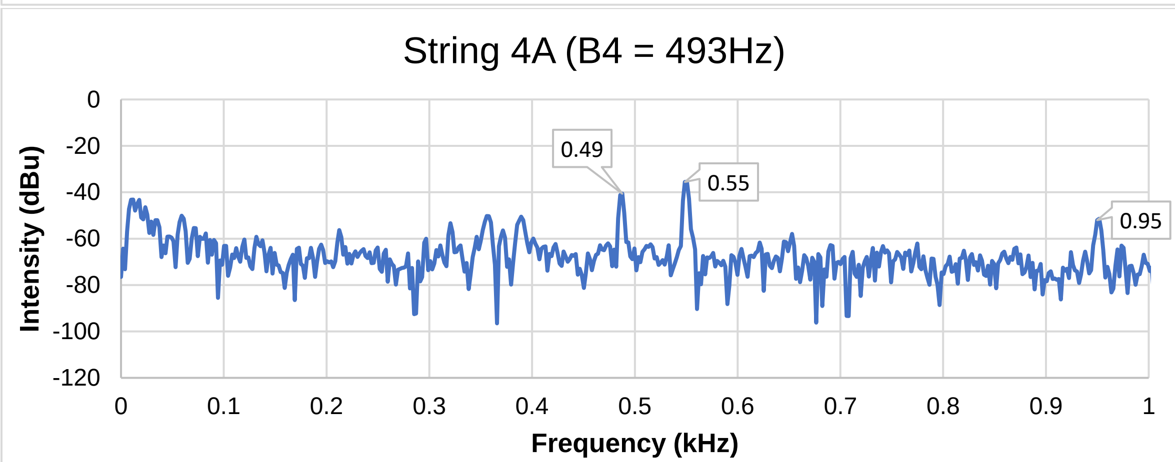
RESULTS AND DISCUSSION

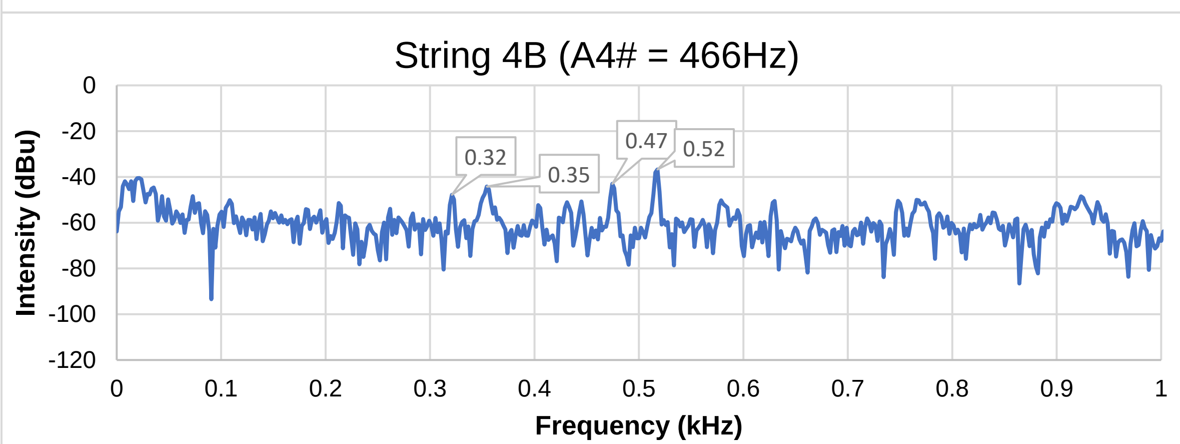
In basic acoustics, fundamentals can be produced by vibrating the entire string length or air column or selecting a higher harmonic. One of the harmonics is fundamental. Harmonic is a set of positive integer multiples of a standard fundamental frequency. A fundamental is also termed a harmonic because it is one time itself (Pierce 2001). The fundamental and the partial frequencies are shown in Fig. 3.




String 3A (F4 = 349Hz)
Iantensity (dBu)
0
-20
-40
-60
-80
-100
-120
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Frequency (kHz)
0.35
0.40
0.71
0.69
0.84


String 3B (A4b = 415Hz)
Intensity (dBu)
0
-20
-40
-60
-80
-100
-120
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Frequency (kHz)
0.41
0.47
0.71
0.84


String 4A (B4 = 493Hz)
Intensity (dBu)
0
-20
-40
-60
-80
-100
-120
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Frequency (kHz)
0.49
0.55
0.95


String 4B (A4# = 466Hz)
Intensity (dBu)
0
-20
-40
-60
-80
-100
-120
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Frequency (kHz)
0.32
0.35
0.47
0.52

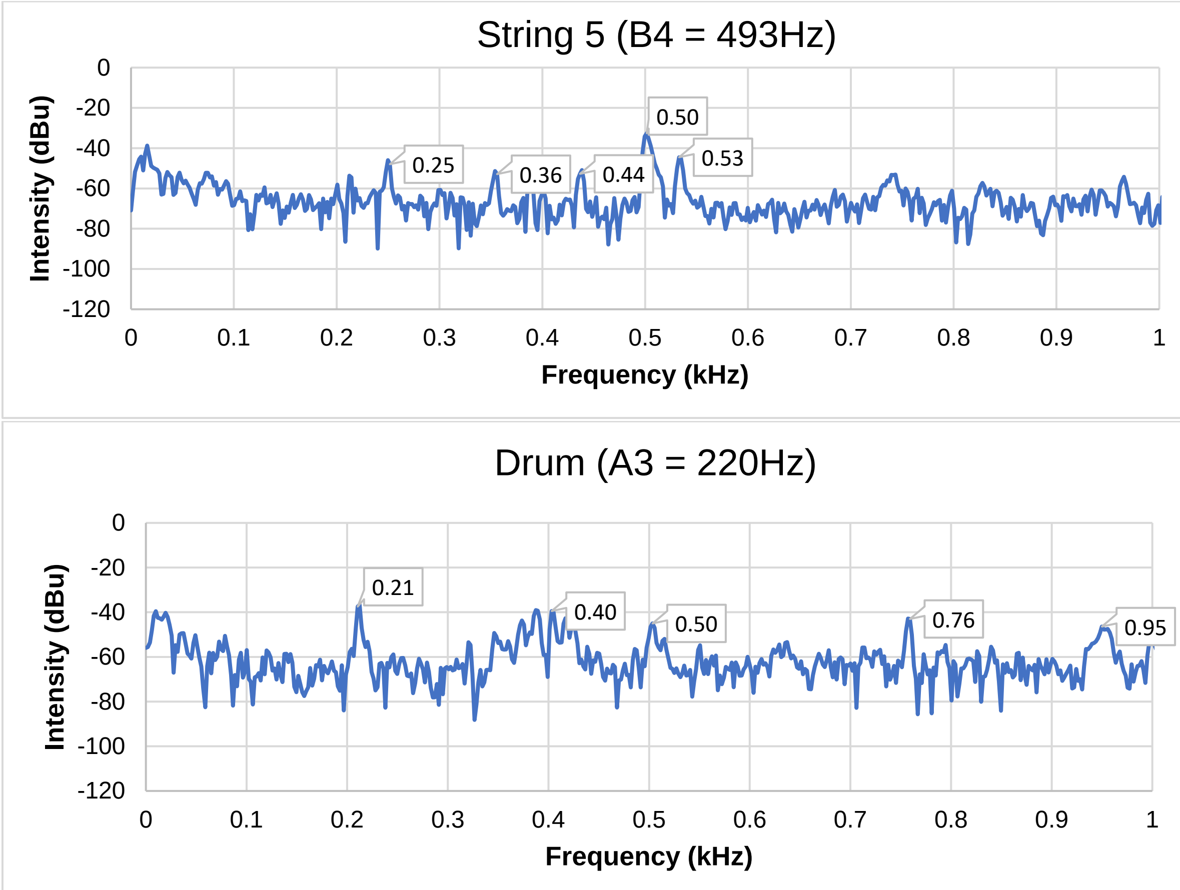


Fig. 3. Frequency spectrum showing the fundamental and partial frequencies of the seven strings and drum

String 1 clearly showed 2 distinct frequencies, namely the fundamental and the first octave. String 2 also clearly showed the distinct fundamental and the first octave with several non-harmonic partials. The intensity of first octave (600 Hz) was lower than the non-harmonic partials (630 Hz). String 3A also clearly showed the distinct fundamental and the first octave with several non-harmonic partials. In string 3A, both the fundamental and the first octave were noticeable in the state of integer multiple compared with the non-harmonic partials. String 3B also clearly showed the distinct fundamental (410 Hz) and the first octave (840 Hz) with only 2 non-harmonic partials. In string 3B the intensity of the first octave (840 Hz) was lower than the non-harmonic partials (710 Hz). This trend was similar with string 2. String 4A clearly showed the distinct fundamental (490 Hz) and the first overtone (950 Hz), which is a non-harmonic partial. String 4(B) clearly showed the distinct fundamental (470 Hz) with 3 non-harmonic partials. String 5 only showed the distinct fundamental (500 Hz) with 1 harmonic partials at one octave lower (250 Hz) and only 3 non-harmonic partials. The drum clearly showed 2 distinct frequencies, namely the fundamental (210 Hz) and the first overtone (400 Hz) with another 3 non-harmonic partials.

The unexpected outcome based on the results of the frequency spectrum analysis is that the pratuokng individual string did not show a similar trend. The intensity of the non-harmonic partial was higher than the first octave in string 2 and 3B. String 5 did not display the first octave frequency but instead displayed partial at one octave lower than the fundamental frequency. It appears that these outcomes may be due to inconsistent thickness of bamboo material fibers of the strings. The mechanical characteristics of bamboo fibers affect their capacity to vibrate at the most typical octave connected to their length and tension when they are strummed. It is audible that the vibrational properties of thicker fibers will differ from those of thinner ones. The material's stiffness, damping, and mass distribution are all thought to play a role in this phenomenon. Playing the bamboo tube zither produces a varied sound when thicker fibers have different inherent frequencies and harmonic characteristics (Aditanoyo *et al*. 2017).

Table 1 showed the fundamental f0, first (f1) and second (f2) partial for strings and the drum. The signal in the frequency spectrum is shown in Table 1 which implies both distinct fundamental and higher partial frequencies, in particular the first octave was present except for string 4B and 5.

Table 1. The Fundamental f0, First (f1), and Second (f2) Partial for String 1 Through 5 and the Drum

	f0	f1	f1/f0	f2	f2/f0	Pitches From FFT
String 1	320(E4)	640	2			E4
String 2	300(D4)	630	2.1	770	2.56	D4
String 3A	350(F4)	710	2.02	840	2.4	F4
String 3B	410(Ab4)	840	2.04			Ab4
String 4A	490(B4)	950	1.93			B4
String 4B	470(A#4)	520				A#4
String 5	500(B4)	530				B4
Drum	210(A3)	400	1.85	500	2.38	A3

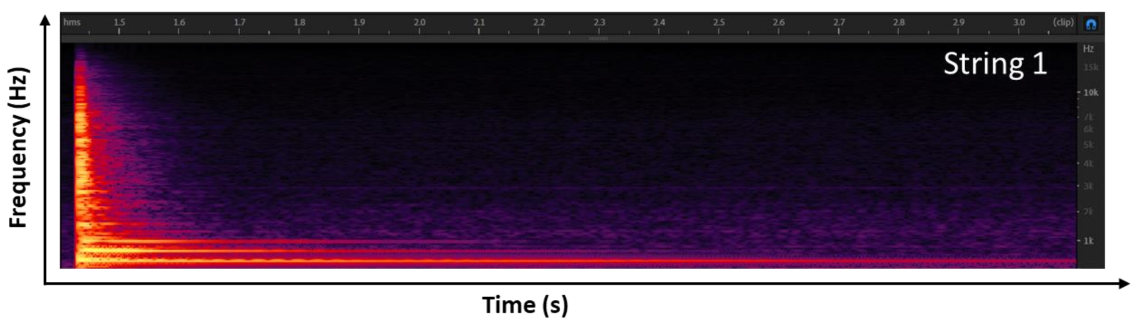
The fundamental for 1st, 2nd, 3rd (A), 3rd (B), 4th (A), 4th (B), and 5th string were 320 Hz (E4 = 329.63), 300 Hz (D4 = 293.67), 350 Hz (F4 = 349), 410 Hz (A4b = 415), 490 Hz (B4 = 493), 470 Hz (A4# = 466), and 500 Hz (B4 = 493), *i.e.*, with note E, D, F, Ab, B, A# and B, respectively. The drum was 210 Hz (A3 = 220). All strings and drum (except string 4B and string 5) displayed the first octave (*i.e.*, f1 = 2f0). The inconsistent number of partials in each string was attributed to the inconsistent thickness of the raised fibre from the bamboo tube. The lack of integration between these two aspects may also be influenced by the distinct playing techniques employed for the string and drum sections. Unlike the strings, which are struck with a beater, the drum section produces its low tonalities through slapping. This difference in playing techniques introduces variations in energy and velocity between the beating of the strings and the slapping of the drum. In theory, one would anticipate a sympathetic support for certain tones and a lack of reinforcement for others, dependent on the energy or velocity disparities between these two distinct methods of sound production within the instrument. In general, the individual tunings vary according to singers or other participating instruments. The typical interval between both strings are critical (Musib 2014). Table 2 shows the sound representation of a single pratuokng and its pitch from Musib (Musib 2014).

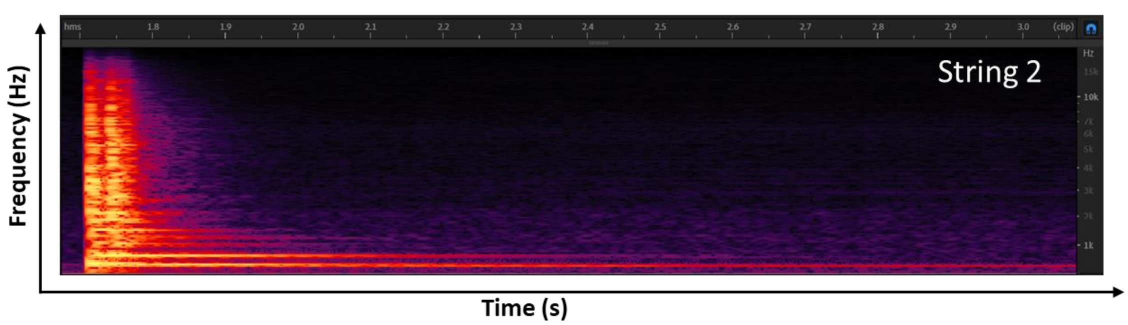
Figure 4 shows the time frequency analysis (TFA) for the seven strings and drum from Adobe. String 3A had the brightest tone colour followed by the string 2 and 3B. String 1, 2, 3A and 5 showed very distinct fundamental frequency. It is evident from the comparison of Musib's (Musib 2014) and the author's performance that the two instruments have similar pitches, namely Ab3 and Ab4. Still, differences emerge in the distinctive pitches that each present.

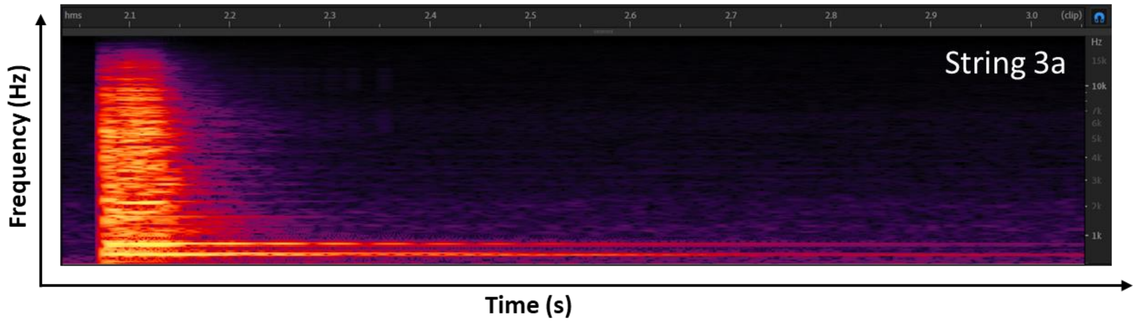
Table 2. The Pratuokng Pitches as Seen in FFT and its Pitches as Heard (Musib 2014)

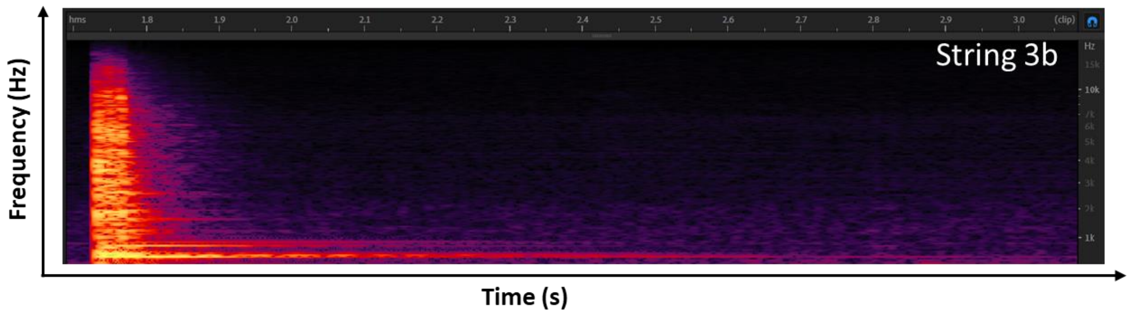
Strings	Pitches as Seen in FFT	Pitches as Heard	Name	Playing Technique	Playing Hand
1	Ab3	G#3	Canang 1	Beater	Right Hand
2	B3	B3	Canang 2	Beater	Right Hand
3	Db3	C#3	Canang 3	Pluck (thumb)	Left Hand
4	Eb3	D#3	Satuk 1	Beater	Right Hand
5	Gb3	F#3	Satuk 2	Beater	Right Hand
6	Ab4	G#4	Tawak 2	Beater	Right Hand
7	Ab3	G#3	Tawak 1	Hand Slap	Left Hand

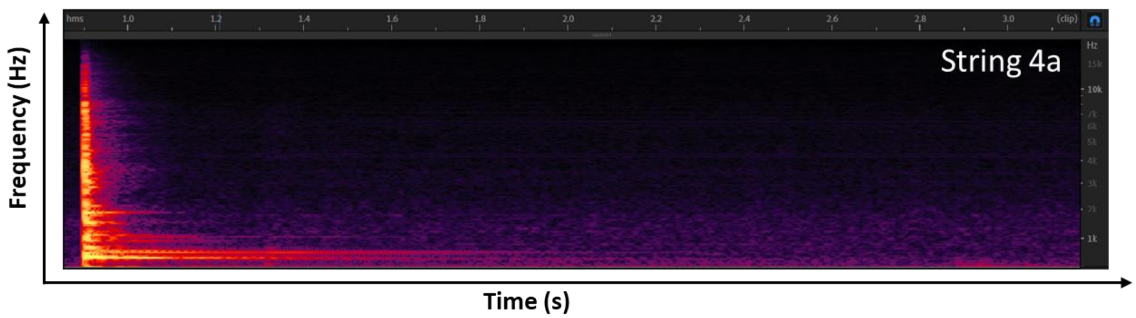
While the author's instrument introduces E4, D4, F4, Ab4, B4, and A#4, Musib's performance includes B3, Db3, Eb3, and Gb3. Pitch ratios such as E4/B3, D4/Db3, F4/Eb3, and Ab4/Gb3 can be examined to gain understanding of the harmonic relationships between these tones. The observed ratios may have an impact on each performance's overall sound and personality, taking into accounts any possible musical consequences. While more complicated ratios may include dissonance, simple ratios frequently produce consonant sounds. The examination of any patterns or distinctive features in the pitch ratios that might affect how scales or enharmonic connections are perceived is also encouraged by this analysis. As a result, this comparative analysis clarifies the harmonic subtleties that exist between Musib's (Musib 2014) and the author's pratuokng, highlighting both characteristics that are similar and those that are particular to each bamboo tube zither's specific tonal profile.

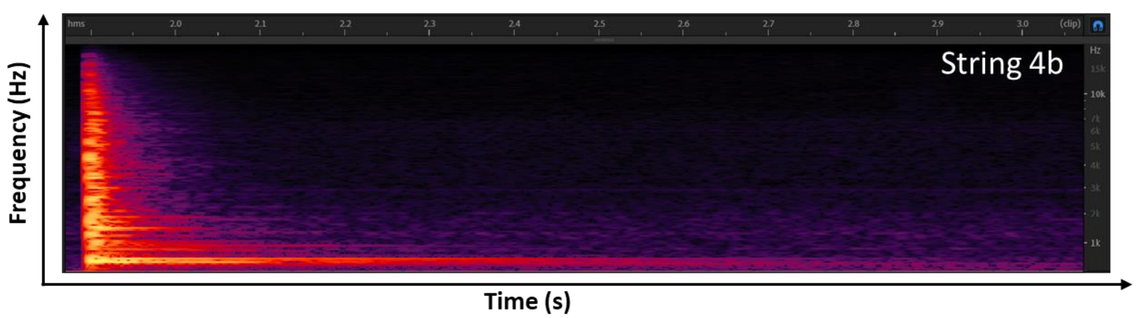


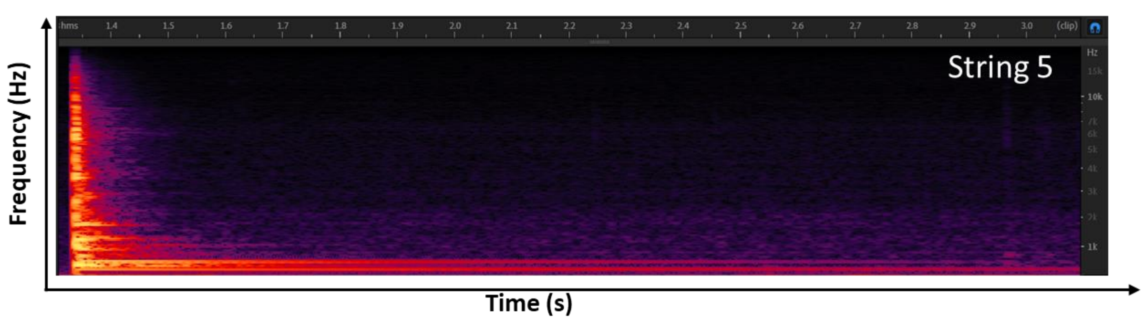



String 3a
Frequency (Hz)
Time (s)


String 3b
Frequency (Hz)
Time (s)


String 4a
Frequency (Hz)
Time (s)


String 4b
Frequency (Hz)
Time (s)


String 5
Frequency (Hz)
Time (s)

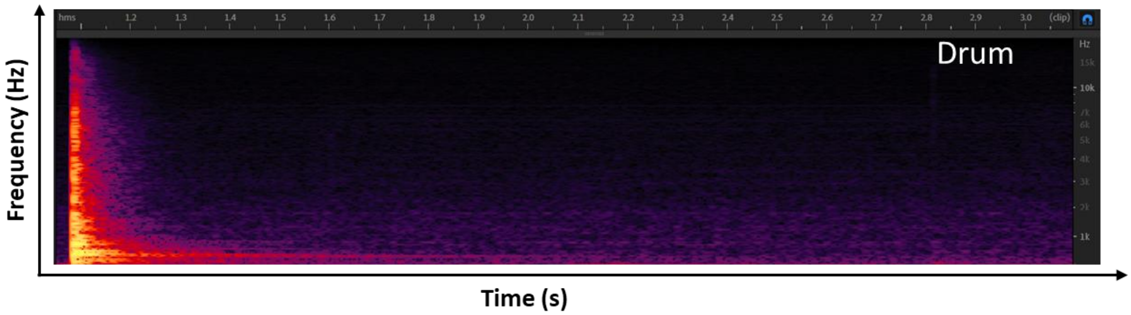


Fig. 4. The time frequency analysis (TFA) for the seven string and drum from adobe

The observed difference in sustain between the drum and the strings on the bamboo tube zither suggests that the drum's tonality is less prolonged compared to the sustained output of the strings. This dissimilarity in sustain emphasizes the relative independence of the string vibrational output from the drum tonality. In practical terms, the shorter sustain of the drum implies a quicker decay of its sound after being struck, creating a perceptual separation between the more sustained tones of the strings and the rapidly diminishing tonalities of the drum. This characteristic contributes to the distinctive and discernible qualities of each component, underscoring the unique contributions of both the strings and the drum to the overall sonic profile of the bamboo tube zither.

The effort to discover the tone and tone color of the bamboo zithers played by the Bidayuh Biatah people is an attempt to safeguard the unique voices and sounds of different civilizations before they change or disappear over time. For example, many indigenous languages and musical traditions are at risk of disappearing as younger generations shift towards more mainstream cultural practices. Through extracting these tones, sounds, and musical traditions, we can help to preserve them for future generations to study and appreciate. In addition to preserving cultural heritage, the study can also help to promote greater understanding and appreciation of diverse perspectives. Through listening to the sounds and voices of different cultures, a deeper appreciation of the richness and diversity of human experience can be developed for better understanding how sound shapes our understanding of the world around us.

CONCLUSIONS

1. From this study the fundamentals for the authors' pratuokng showed that 1st, 2nd, 3rd (A), 3rd (B), 4th (A), 4th (B), and 5th strings are 320 Hz, 300 Hz, 350 Hz, 410 Hz, 490 Hz, 470 Hz, and 500 Hz, *i.e.*, with notes E, D, F, Ab, B, A#, and B, respectively. The drum is 210 Hz (A3 = 220Hz).
2. The signals in the frequency spectrum showed both distinct fundamental notes and had different number of higher partial frequencies; in particular, the first overtones were present except for strings 4B and 5.
3. The inconsistent number of partials in each string was attributed to the inconsistent thickness of the raised fibre from the bamboo tube.

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REFERENCES CITED

Aditanoyo, T., Prasetiyo, I., and Putra, I. B. A. (2017). "Study on vibro-acoustics characteristics of bamboo-based violin," *Procedia Engineering* 170, 286-292. DOI: 10.1016/j.proeng.2017.03.029

Hamdan, S., Rahman, M. R., Zainal Abidin, A. S., and Musib, A. F. (2022a). "Study on vibro-acoustic characteristics of bamboo-based angklung instrument," *BioResources* 17(1), 1670-1679. DOI: 10.15376/biores.17.1.1670-1679

Hamdan, S., Rahman, M. R., Mohamad Said, K. A., Zainal Abidin, A. S., and Musib, A. F. (2022b). "Sompoton: Sabah bamboo mouth organ," *BioResources* 17(3), 5335-5348. DOI: 10.15376/biores.17.3.5335-5348

Musib, A. F. (2014). *Contextual Sound Preservation of the Local String Instruments*, Ph.D. Dissertation, Universiti Putra Malaysia, Selangor, Malaysia.

Pierce, J. R. (2001). *Consonance and Scales. Music, Cognition, and Computerized Sound – An Introduction to Psychacoustics*, P. R. Cook (ed.), MIT Press, Cambridge, MA, USA, pp. 167-186.

von Hornbostel, E. M., and Sachs, C. (1914). "Systematik der Musikinstrumente. Ein Versuch [Systematics of musical instruments. One Try]," *Zeitschrift für Ethnologie (ZfE) [Journal of Social and Cultural Anthropology (JSCA)]* 46(4/5), 553-590.

Wegst, U. G. K. (2008). "Bamboo and wood in musical instruments," *Annual Review of Materials Research* 38, 323-349. DOI: 10.1146/annurev.matsci.38.060407.132459

Wu, S.-M. (1995). "Wood anatomy research," in: *Proceedings of the International Symposium on Tree Anatomy and Wood Formation*, Tianjin, China.

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