Gambus Hadhramaut: The Malaysian Malay Lute Tuning Retrieval

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Hamdan Sinin
University Malaysia Sarawak

Khairul anwar Mohamad said
University Malaysia Sarawak

Mohammed M. Rahman
King Abdulaziz University

Aaliyawani Ezzerin Sinin
Universiti Putra Malaysia Bintulu Campus

Gambus Hadhramaut: The Malaysian Malay Lute Tuning Retrieval

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

This study identified elements in a simple homemade gambus from a local crafter using a scientific approach. The gambus was made from geronggang wood (*Cratoxylum arborescens*), a light Malaysian hardwood with pink sapwood, distinct from the heartwood with brick-red or deep pink. The sound was processed to generate fast Fourier transform (FFT) and time-frequency analysis (TFA) using PicoScope and Adobe Audition software, respectively. The gambus A 1st string (note C4#) displayed a harmonic overtone at the 1st and 2nd octave. The 2nd string (note A3) showed harmonic overtone at the 1st, 2nd, and 3rd octave. The 3rd string (note D3#) showed a significant fundamental peak and harmonic overtone at the 1st, 2nd, 3rd, 4th, and 5th octave. The 4th string (note A2#) displayed consistent harmonic overtones at the 1st, 2nd, 3rd, 4th, and 5th octave. The 5th string (note E2) had a harmonic overtone at the 5th octave. Gambus A showed an inconsistent signal in the 6th string (note D2#) with inharmonic overtone at 3.35th and 6.79th overtones. The gambus A 1st to 6th strings are C4#, A3, D3#, A2#, E2, and D2#, respectively. The gambus B 1st to 6th strings are C4, G3, D3, A3, E3, and B2, respectively.

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Contact information: a: Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia; b: Department of Science and Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus, 97008 Bintulu Sarawak Malaysia;
** Corresponding author: rmrezaur@unimas.my*

INTRODUCTION

The name gambus (Malay lute) is applied to structurally related lutes resembling the rebab of Northwest Africa (Picken 1975). The gambus is one of the national instruments of Malaysia. It is made from geronggang wood (*Cratoxylum arborescens*). Geronggang is a light Malaysian hardwood with pink sapwood, distinct from the heartwood with brick-red or deep pink. It has a very lustrous surface when planed. The tree rarely exceeds 60 feet in height with a diameter up to 3 feet. The grain is interlocked with moderately coarse but even texture. It is easy to cut with density ranging from 432 to 608 kg/m³. The average commercial parcels are about 544 kg/m³ when dried.

The acoustic properties of tropical wood species suitable for manufacturing musical instruments are determined by the specific dynamic Young's modulus (E/γ), internal friction (Q^{-1}), and acoustic conversion efficiency (ACE) of several tropical wood species (Sedik 2010). The determination of suitability of tropical wood species for making musical instruments is conducted dominantly based on trial and error or experience of manufacturer. Therefore, the tropical wood species that have been selected by manufacturers in making musical instrument are very limited, such as *Intsia palembanica* (Merbau) and *Artocarpus champeden* Spreng (Cempedak), although there are a lot of other wood species available in Malaysia (Chong 2000). The determination of suitable wood for manufacturing musical instruments is scientifically done based on the acoustic properties of wood. Since then, studies have been conducted on acoustic properties of substitute woods and woods that have been used for manufacturing musical instruments. However, only a few tropical wood species have been used so far, such as *Dialium* species and *Agathis borneensis* (Chong 2000).

The gambus has a variety of forms, different in shape, size, and the number of strings. Figure 1 shows the gambus hadhramaut (A) and (B) used in this study. It has a deep arched-back body with a fretless fingerboard and a short neck. It has an almost sickle-shaped reverse or back-bent peg-box. The gambus has 11 lateral pegs with only 11 (5x2+1) nylon strings normally used for fishing line. The 1st to the 5th is double string followed by 6th single string. The gambus is tuned in fourths. The actual tuning is C5, G4, D4, A3, E3, and B2 (Kartomi 1984).

(A) (B)


Fig. 1. Gambus Hadhramaut (A) and (B)

In Malaysia, not all the instruments are tuned to a standard reference scale, thus producing many different tunings. It is tuned for its orchestral purposes relative to a single ensemble. Therefore, the tuning differs in intonation, tone, and feelings. The different tunings are due to differences between the spectra. Therefore, the tunings present an intriguing challenge. Gambus music consists of harmonic and in-harmonic spectra. The extraction process is characterized by Fast Fourier Transform-FFT with PicoScope. This FFT showed a range of frequencies after the plucking. Several studies were also done using the Adobe Analyzer. The adobe analyzer displayed the frequency changes with time.

The gambus A was borrowed from the owner Haji Kipli Haji Zaini (76-year-old man) who crafted it 40 years ago and gambus B from Haji Yahya Haji Mohamad (70-year-old man) who bought it many years ago. Figures 2 and 3 show gambus A and gambus B used in this study, respectively.

Fig. 2. Gambus A used in this study

Fig. 3. Gambus B used in this study

Fourier transformation was used to determine the fundamentals, harmonics, and subharmonics for each instrument's characteristics. The motivations of the studies were as follows. First, it is noted that the theory of tuning is relatively easy to understand but very difficult to put into practice. It is common to copy the tuning of some well-known instrument. The maker tunes the instrument to a pitch or intervallic structure, and these were not standardized in the olden days. This study aims to contribute to tuning and to all facets of sound as research data of gambus musical instruments. This will clarify the role of the musical acoustician to the tuning of gambus. This work retrieved the gambus tuning by observing the different tones and intonations of these instruments.

The octave of one gambus is not necessarily similar to another gambus. Two sets of measurements of gambus A and B were studied by recording the fundamentals and all higher partials. The tuning was done using the player's natural hearing. The information regarding timbre (spectra) identifies the sound produced for making scales. This study aimed to obtain harmonic contents through audio signal retrieval. This research attempted to recognize tunings and scales of a gambus. Previous work only measured the fundamental frequency and not the harmonics and sub-harmonics.

EXPERIMENTAL

The gambus A wind chest maximum width was 44.5 cm with the length up to the neck of 59 cm. The length of the neck was 18.5 cm. The diameters of the big and small openings on the front were 13.5 cm and 8 cm respectively. The gambus B wind chest maximum width was 34.5 cm with the length up to the neck of 57 cm. The length of the neck was 15 cm. The diameter of the opening on the front was 6.5 cm. The string of the gambus is from a monofilament fishing line, *i.e.*, the most basic and most common fishing line made from nylon extruded in a single, continuous filament. The 1st, 2nd, 3rd, 4th, and 5th strings were double, and the 6th string was single.

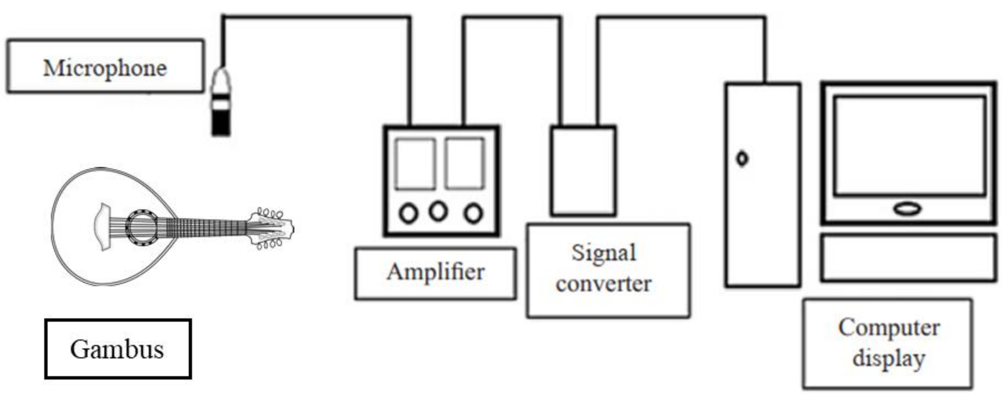


Fig. 4. Diagram of the experimental setup

The frequency was measured at the studio hall of Universiti Malaysia Sarawak (UNIMAS). The acoustic spectra were captured using PicoScope oscilloscopes which display the fundamental and overtone frequencies. The microphone was held above the top surface along the axis of symmetry at 20 cm. The audio signal derived from the plucking was recorded. The audio signal was recorded in mono, at 24-bit resolution, and 48 kHz sampling rate. The signal was calibrated using a 1 kHz sine wave. The signal was recorded using the Steinberg UR22mkII (audio interface), Audio-Technica AT4050 (microphone) and XLR cable (balance). The microphone was placed 20 cm above the gambus with minimum interference. The time signals which produced FFT spectrum were viewed and analyzed using PicoScope. FFT determines fundamentals, harmonics, and subharmonics.

Figure 4 shows the experimental setup. The data sound was also analyzed using Adobe Audition to yield the frequency for every tone. Each instrument is characterized by the intensity and harmonics/subharmonics. These characteristics were used to distinguish the difference between the two gambus instruments.

RESULTS AND DISCUSSION

The typical captured spectrum of gambus A string 1 from PicoScope screen is shown in Figure 5. Figure 6 shows one typical example to determine the overtone from string 1 of gambus A.

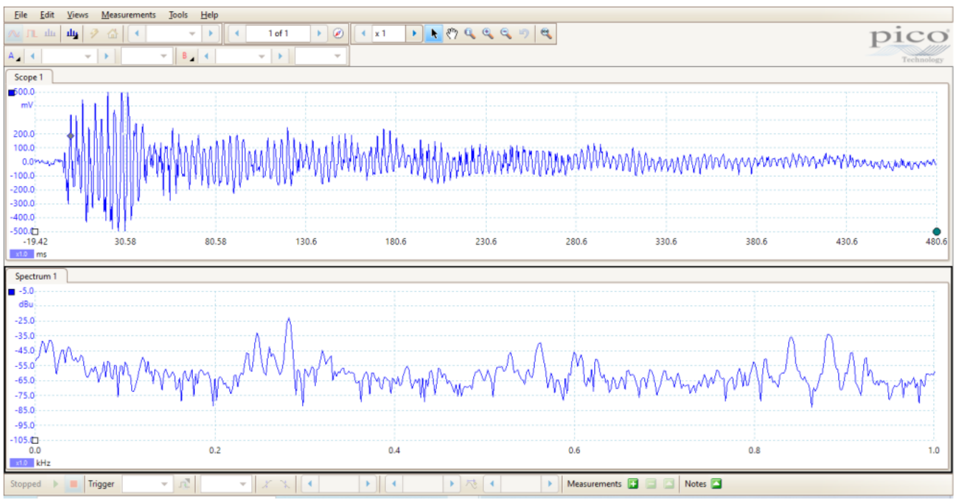


Fig. 5. Typical captured spectrum displayed directly from PicoScope screen for string 1 of gambus A

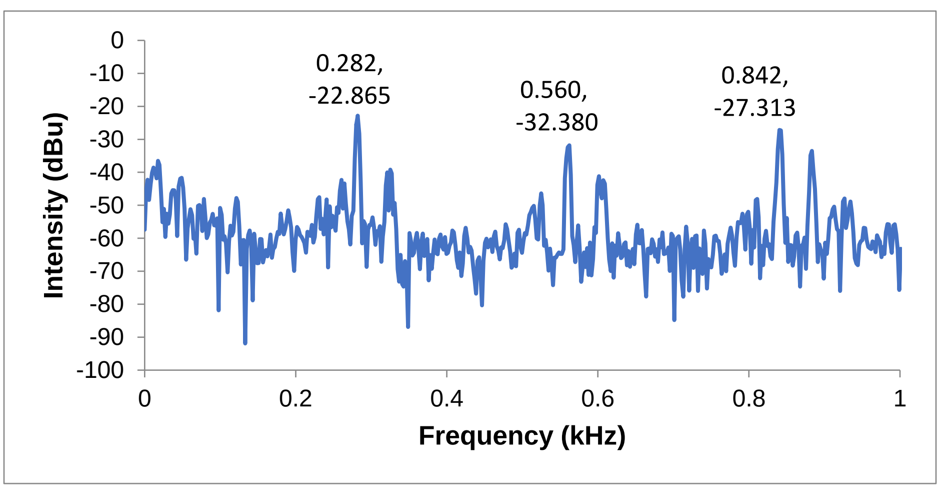


Fig. 6. The detailed analysis of FFT by plotting data from Picoscope into an excel spread sheet to determine the overtone from string 1 of gambus A.

The overtone analysis was determined by plotting data from Picoscope into an excel spread sheet (not just using the eye to approximate). Figure 6 shows one typical example to determine the overtone from string 1 of gambus A. The detailed analysis of FFT is carried out by choosing the first highest peak as the fundamental frequency (282 Hz), followed by the second highest peak as the first octave frequency (560 Hz) and the third highest peak as the second octave frequency (842 Hz). The octave is calculated as follows: fundamental frequency=282 Hz, the first octave 560/282=1.98, and the second octave 842/282=2.98.

The fundamental and overtone frequency from PicoScope for gambus A string 1 to 6 are shown in Table 1. The 1^{st} string (equivalent to note C4#) displayed 2 harmonic overtones at 1^{st} and 2^{nd} octave (*i.e.*, 560 and 842 hertz respectively) and 1 inharmonic overtone at 3.13^{th} ratio (*i.e.*, 885 hertz). The 2^{nd} string (equivalent to note A3) displayed 3 harmonic overtones at 1^{st}, 2^{nd}, and 3^{rd} octave (*i.e.*, at 429, 646, and 859 hertz, respectively) and 4 inharmonic overtones at 1.33^{rd}, 1.47^{th}, 3.31^{st}, and 4.33^{rd} ratio (*i.e.*, at 286, 317, 713, and 932 hertz, respectively). The 3^{rd} string (equivalent to note D3#) exhibited all 5 harmonic overtones, which were quite consistent at 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} octaves. The 4^{th} string (equivalent to note A2#) displayed a regular pattern with the presence of 5 harmonic overtones at 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} octaves (*i.e.*, at 238, 356, 475, 595, and 715 hertz respectively) and 2 inharmonic overtones at 2.56^{th} and 5.11^{th} ratio (*i.e.*, at 305 and 609 hertz respectively). The 5^{th} string at 80 hertz (equivalent to note E2) had the harmonic overtone at 5^{th} octave and inharmonic overtone at 1.48^{th} and 4.5^{th} ratio. The gambus A lowest frequency was shown by the 6^{th} string, *i.e.*, at 78 hertz (equivalent to note D2#). The inharmonic overtone at 3.35^{th} and 6.79^{th} ratio occurred at 262 and 530 hertz respectively. Both 5^{th} string and 6^{th} string showed only 3 and 2 overtone peaks respectively. The peaks from the 6^{th} string were less distinct compared to the 5^{th} string (with additional harmonic overtones at 5^{th} octave). The most harmonic overtone frequency occurred for 3^{rd} string (equivalent to note D3#), whereas the 6^{th} string did not produce any harmonic overtones. Of all the strings, only the 2^{nd} string displayed regular harmonic and inharmonic overtones with less noise frequencies, although it was not very harmonics as in the 3^{rd} string. In general, both the 3^{rd} and 4^{th} strings displayed 5 harmonic overtones at 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} octaves. The 2^{nd} strings displayed 3 harmonic overtones at 1^{st}, 2^{nd} and 3^{rd} octaves only (distinct harmonic overtone with sharp peaks). Although the 1^{st} string harmonic overtones obviously occurred at 1^{st} and 2^{nd} octaves, the inharmonic overtone at 3.13^{rd} ratio was very significant. The 3^{rd} string (equivalent to note D3#) overtones were theoretically harmonics. In general, although the overtones for the 3^{rd} string are theoretically harmonics, the ripples of noise frequencies were very significant because the signals did not show regular pattern *i.e.*, with a distinct harmonic overtone. The fundamental and overtone frequency from PicoScope for gambus B string 1 to 6 are shown in Table 2.

Gambus B displayed more harmonic overtones. The 1^{st} string showed 4 harmonic overtones at 1.92(~2), 2.87(~3), 3.79(~4), and 4.82(~5) overtones. The 2^{nd} string showed 11 harmonic overtones at 3.9(~4), 4.91(~5), 6.01(~6), 6.93(~7), 7.94(~8), 8.91(~9), 9.92(~10), 10.97(~11), 13.03(~13), 14, and 15.09(~15) overtone. The 3^{rd} string showed 3 harmonic overtones at 2.2(~2), 3.1(~3) and 4.21(~4) overtones. The 4^{th} string showed 2 harmonic overtones at 1.94(~2) and 3.02(~3) overtones. The 5^{th} string showed 3 harmonic overtones at 2.01(~2), 3.08(~3) and 8.01(~8) overtones. The 6^{th} string did not display any harmonic overtones.

Table 1. The Frequency (hertz) and Octave for Gambus A String 1 to 6

	String 1 C4# (277.18)		String 2 A3 (220.00)		String 3 D3# (155.56)		String 4 A2# (116.54)		String 5 E2 (82.407)		String 6 D2# (77.78)	
Over-tone	frequency	ratio	frequency	ratio	frequency	ratio	frequency	ratio	frequency	ratio	frequency	ratio
Fundamental	282	1	215	1	155	1	119	1	80	1	78	1
first	560	1.98	286	1.33	309	1.99	238	2	119	1.48	262	3.35
second	842	2.98	317	1.47	474	3.05	305	2.56	360	4.5	530	6.79
third	885	3.13	429	1.99	613	3.95	356	2.99	480	6		
fourth			646	3.00	764	4.92	475	3.99				
fifth			713	3.31	919	5.92	595	5				
sixth			859	3.99			609	5.11				
seventh			932	4.33			715	6.00				

Table 2. The Frequency (hertz) and Octave for Gambus B String 1 to 6

	String 1 C4 (261)		String 2 G3 (196)		String 3 D3(146)		String 4 A3(220)		String 5 E3(164)		String 6 B2(123)	
overtone	freq	ratio	freq	ratio	freq	ratio	freq	ratio	freq	ratio	freq	ratio
fundamental	276	1	199	1	146	1	222	1	160	1	122	1
first	531	1.92	778	3.9	322	2.2	338	1.52	323	2.01	199	1.63
second	793	2.87	979	4.91	454	3.1	431	1.94	493	3.08	323	2.64
third	1048	3.79	1196	6.01	616	4.21	547	2.46	919	5.74	702	5.75
fourth	1333	4.82	1381	6.93	771	5.28	671	3.02	1283	8.01	1082	8.86
fifth	2399	8.69	1582	7.94	917	6.28	764	3.44	1655	10.34	1268	10.39
sixth	2646	9.58	1775	8.91	1064	7.28	980	4.41				
seventh	2908	10.53	1976	9.92	1373	9.4						
eight	3448	12.49	2185	10.97	1543	10.56						
ninth	3726	13.5	2594	13.03	1706	11.68						
tenth	4545	16.46	2787	14								
eleventh	4807	17.41	3004	15.09								

Note: The actual tuning is C5, G4, D4, A3, E3, and B2 (Kartomi 1984)

Figure 7 shows the frequency *versus* ratio from PicoScope for gambus A string 1 to 6. Some strings did not have the exact octave (with harmonic and inharmonic overtone). Figure 8 shows the frequency *versus* ratio from PicoScope for gambus B string 1 to 6. All strings displayed up to the 2nd overtone only. Only the 2nd, 3rd, and 4th strings displayed the 4th and 5th overtones, whereas only the 2nd and 4th strings displayed the 6th and 7th overtones.

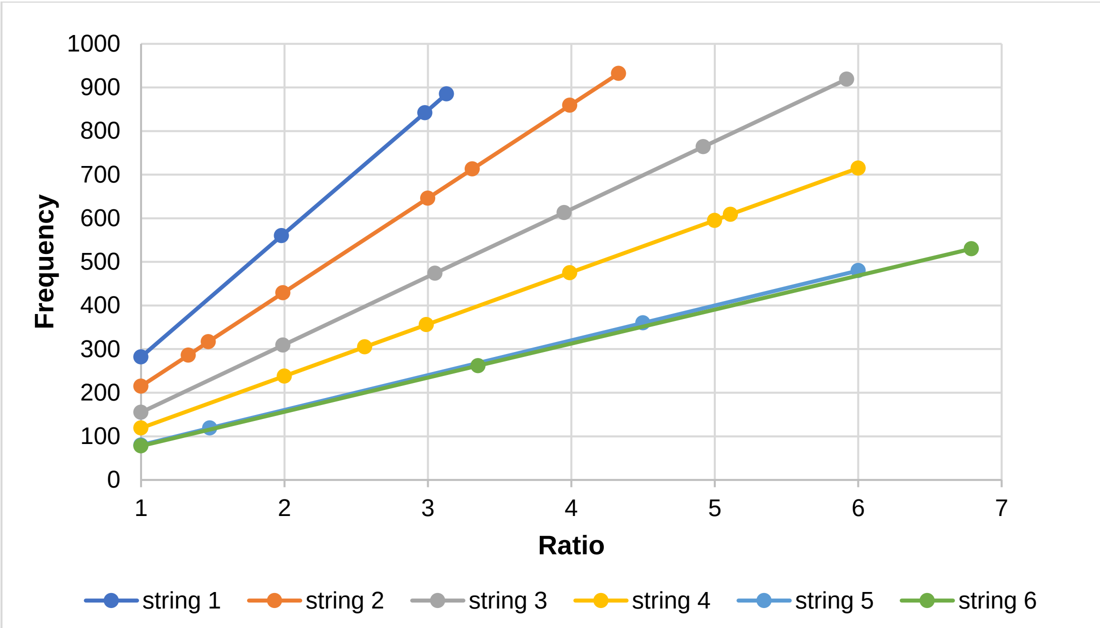


Fig. 7. Frequency versus the ratio of gambus A string from PicoScope for string 1 to 6

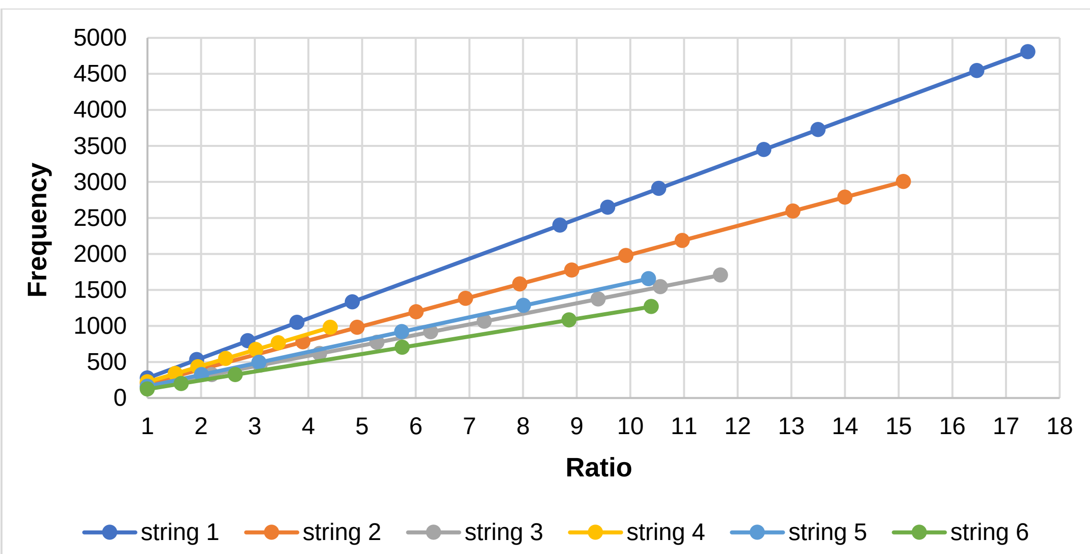
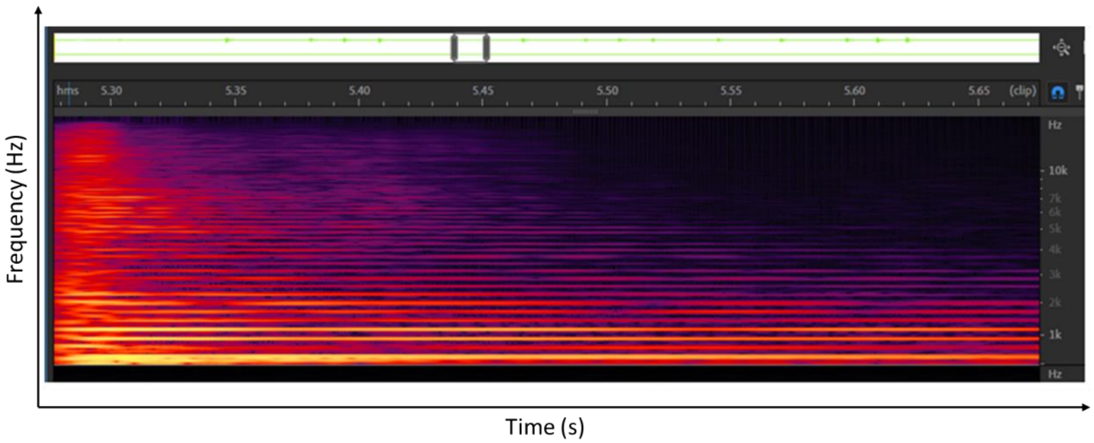
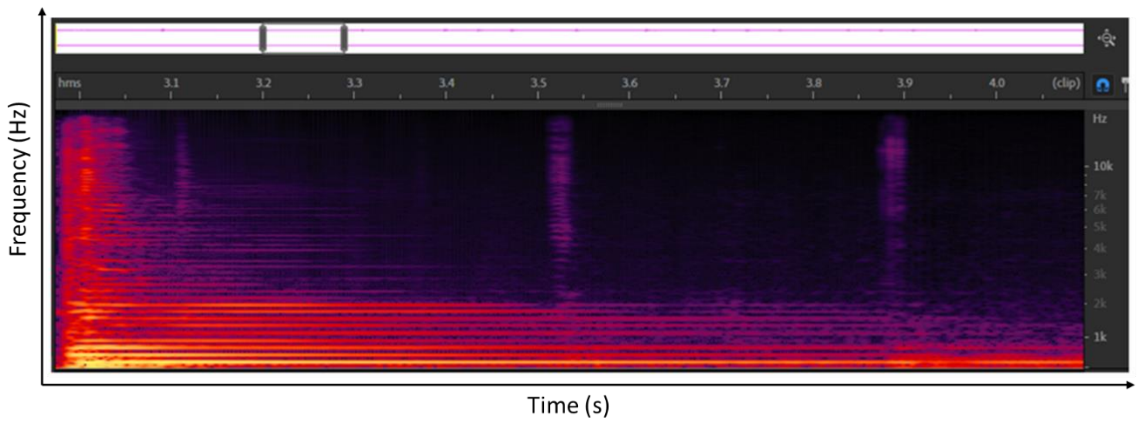


Fig. 8. Frequency versus the ratio of gambus B string from PicoScope for string 1 to 6

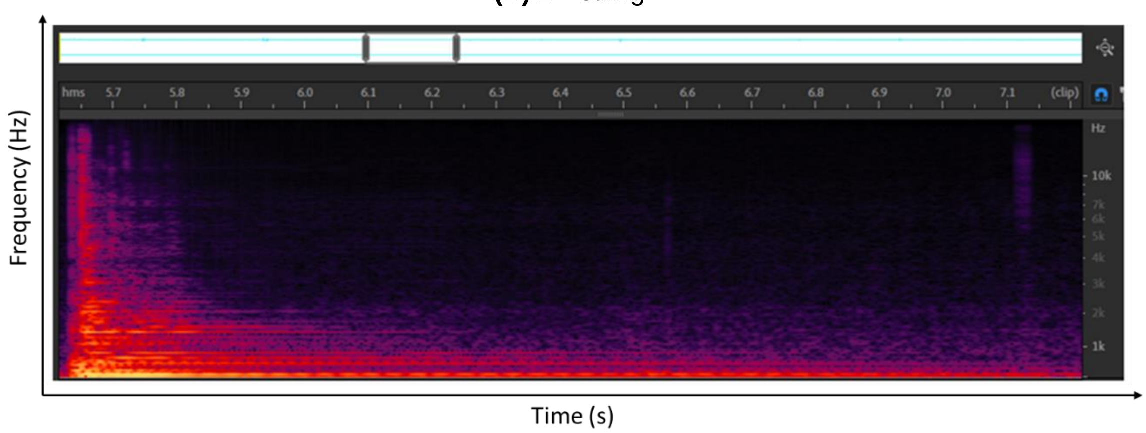
The human ear cannot distinguish the individual harmonics from a complex tone. Therefore, individual harmonics are not easily distinguished. The partials are impossible to identify by listening to tones (Plomp 1976). Figure 9 showed the TFA for gambus A string 1 to 6. The TFA displays the intensity at the frequency range stated on the vertical axis with the yellow and red part. Since the partial are nearly impossible to identify when listening, the frequencies present are easily identified and give information about time localization. This gives the dominant frequency for each tone at a specific time.



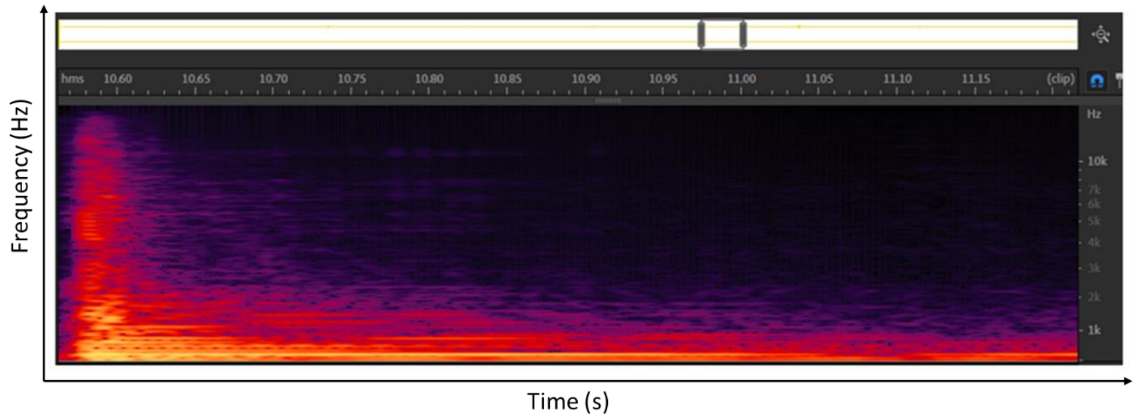
(A) 1st string



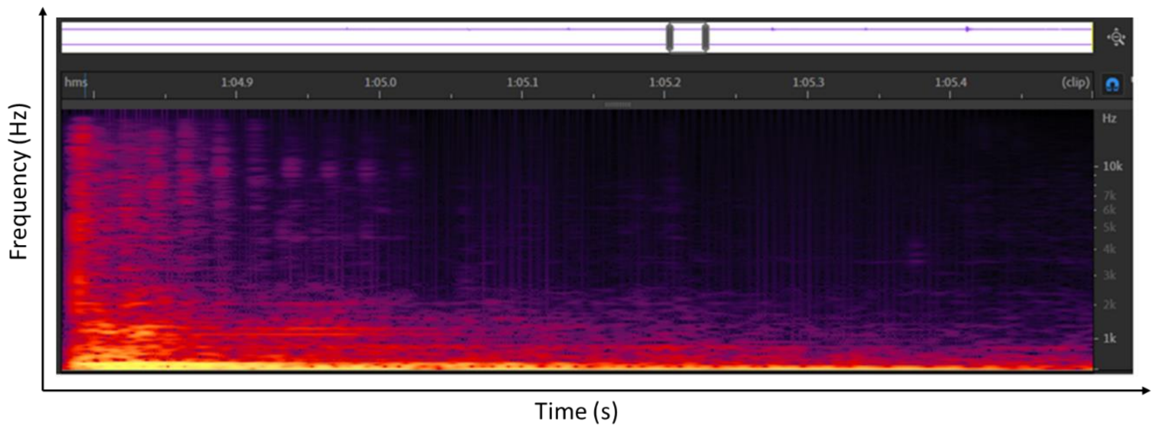
(B) 2nd string



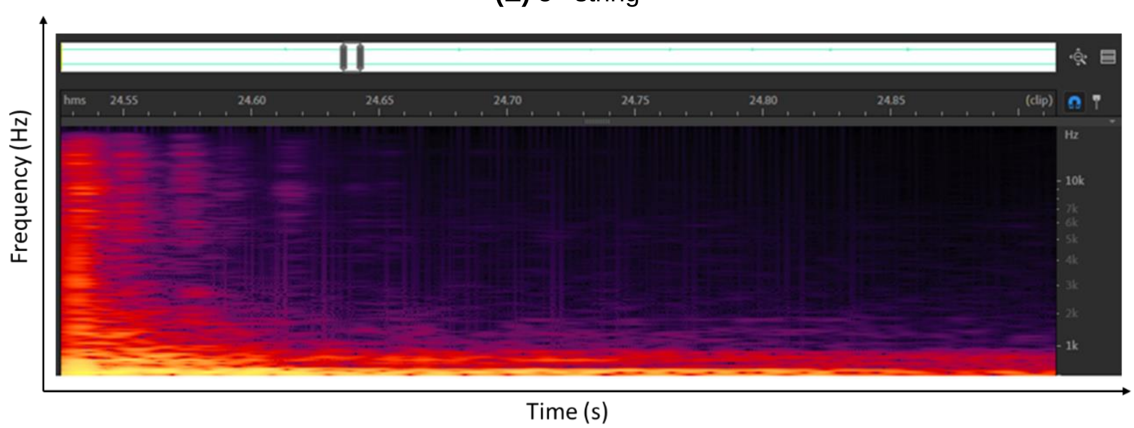
(C) 3rd string



(D) 4th string



(E) 5th string



(F) 6th string

Fig. 9. Time Frequency Analysis (TFA) from Adobe Audition for gambus A string 1 to 6

Figure 9 shows that the 1st and 2nd strings displayed many peaks in TFA although the 1st string did not display a distinct peak in PicoScope spectrum. Although the PicoScope spectrum displayed regular harmonic and inharmonic overtones for the 2nd string, the intensity was not significant in TFA from Adobe Audition compared to the 1st string. Although the 1st string harmonic overtones obviously occurred only at the 1st and 2nd octaves with the inharmonic overtone at the 3.13th overtone very significant from PicoScope, the TFA from Adobe Audition displayed all the ranges of overtones significantly. The 3rd and 4th string showed the fundamental frequency distinctly, but the 5th and 6th string did not display a distinct peak. This study attempted to retrieve the intuitive hearing of the gambus crafter/player and examined it using Fourier spectra (using PicoScope). PicoScope data provided the intensity of the fundamental and overtone frequencies of the whole signals. These findings showed that the gambus tone and intonation depended on the gambus crafter/player. The tuning was done by the gambus crafter/player based on his hearing. From the PicoScope, the gambus strings content complex tone and their fundamental equivalent to the equal tempered scale (ETS). Although its frequency accuracy was nearly similar, the sound characteristic sense as shown in Table 1 differed in tone and intonation characteristics. The sense allows the crafter/player himself to craft a specific tone through sound characteristics of a particular gambus. Table 3 shows the comparison between Gambus A and Gambus B fundamental frequency with the equal tempered scale.

Table 3. Comparison between Gambus A and Gambas B Fundamental Frequency with the Equal Tempered Scale

String	Gambus A Fundamental Frequency (Hertz)	Equal Tempered Scale	Gambus B Fundamental Frequency (Hertz)	Equal Tempered Scale	Frequency Difference between Gambus A and Gambus B
1st	282	C4#=277	276	C4=261	6
2nd	215	A3=220	199	G3=196	16
3rd	155	D3#=155	146	D3=146	9
4th	119	A2#=116	222	A3=220	-103
5th	80	E2=82	160	E3=164	-80
6th	78	D2#=77	122	B2=123	-44

The gambus B (C4, G3, D3, A3, E2, and B2) and the gambus A (C4#, A3, D3#, A2#, E2, and D2#) were tuned personally by the players, whereas the actual tune of the gambus was C5, G4, D4, A3, E3, and B2 (Kartomi 1984). Figure 10 shows the fundamental frequencies for both gambus A and B against the string number.

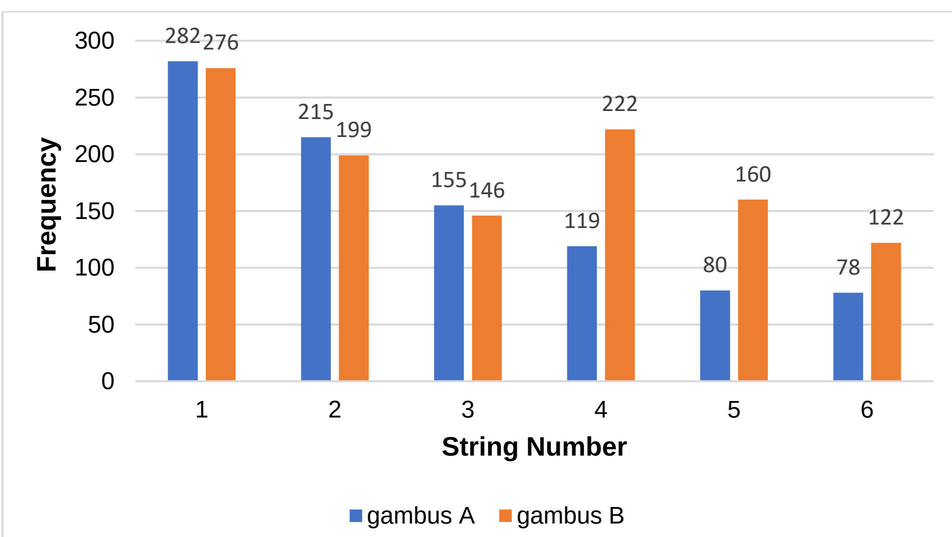


Fig. 10. Fundamental frequencies for both gambus A and gambus B against the string number

Although the gambus was tuned by the players based on their intuition (no tuner was used, and tuning was done by using their mother nature hearing), it was found that the trend of the frequency used in the tuning in gambus A was between 6 hertz (1st string) to 103 hertz (4th string) compared to gambus B. The 6th string, which is a single string in the gambus, was used as the base note.

CONCLUSIONS

1. Some strings of the gambus do not have the exact octave, with harmonic and inharmonic overtones. In the case of gambus A, the 1st string displayed 2 harmonic overtones at the 1st and 2nd octaves. The 2nd string displayed 3 harmonic overtones at the 1st, 2nd and 3rd octaves. The 3rd string exhibited 5 harmonic overtones, which were quite consistent at 1st, 2nd, 3rd, 4th, and 5th octaves. The 4th string displayed a regular pattern with the presence of 5 harmonic overtones at 1st, 2nd, 3rd, 4th, and 5th octaves. The 5th string showed a harmonic overtone at the 5th octave. The 6th string did not produce any harmonic overtones. The lowest frequency of Gambus A was shown by the 6th string, *i.e*., at 78 hertz. The most harmonic overtone frequency occurred for the 3rd string.
2. In the case of gambus B, the 1st string showed 4 harmonic overtones at 1st, 2nd, 3rd, and 4th octaves. The 2nd string showed 11 harmonic overtones at 3rd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 12th, 13th, and 14th octaves. The 3rd string showed 3 harmonic overtones at 1st, 2nd, and 3rd octaves. The 4th string showed 2 harmonic overtones at 1st and 2nd octaves. The 5th string showed 3 harmonic overtones at 1st, 2nd, and 7th octaves. The 6th string did not display any harmonic octaves.
3. The 1st and 2nd strings of the gambus A displayed many peaks in TFA, although the 1st string did not display distinct peak in PicoScope spectrum. Although the PicoScope spectrum showed a regular pattern of harmonic and inharmonic overtones with less ripples of noise frequencies for the 2nd string, the intensity was not significant in TFA from Adobe Audition compared to the 1st strings.

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