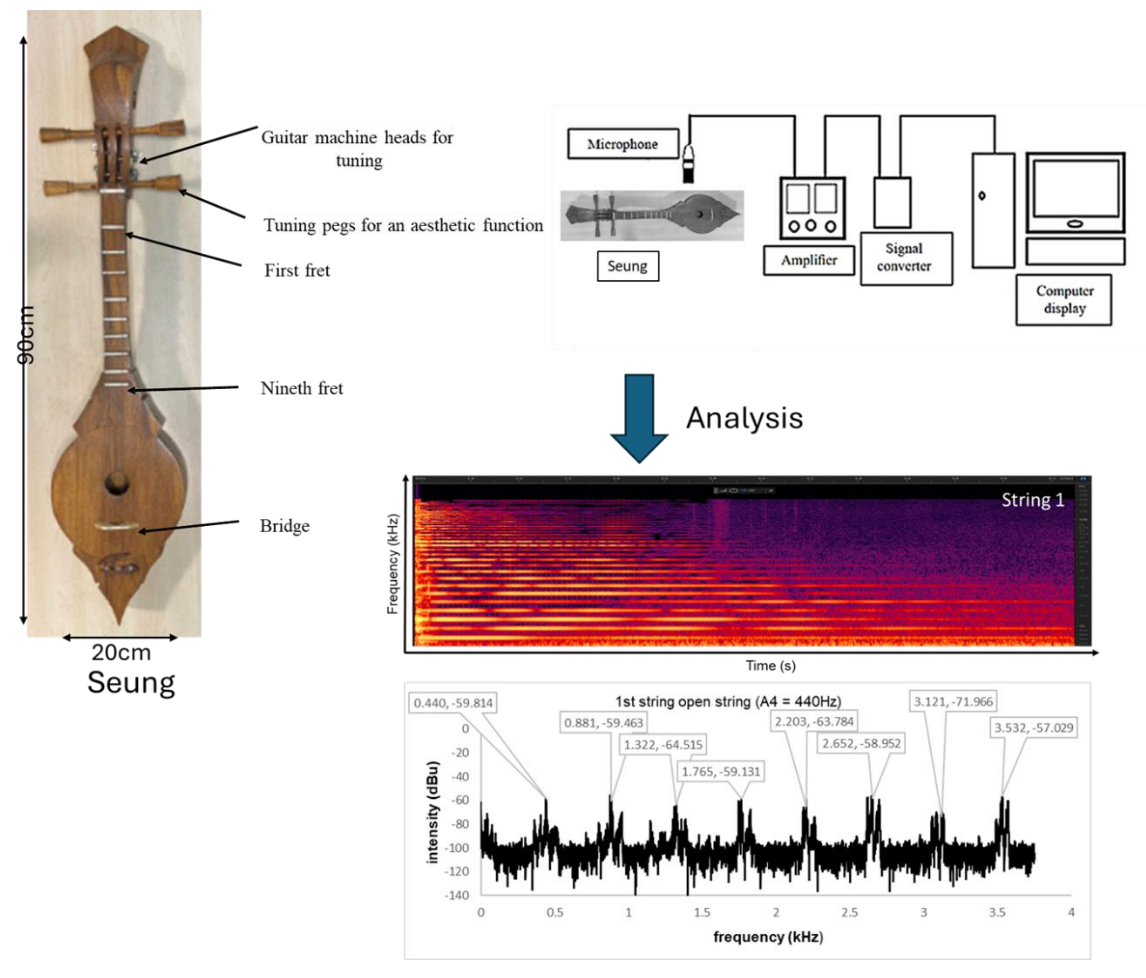
# The Seung (Sueng or Sung), a Plucked Fretted Lute from the Northern Region of Thailand

Ezra M. A. Duin,[a] Sinin Hamdan,[b,*] Khairul Anwar Mohamad Said,[b] Mawar Suhaila Ab Razak,[a] and Aaliyawani Ezzerin Sinin [c]

** Corresponding author: hsinin@unimas.my*

*DOI: 10.15376/biores.20.2.3234-3251*

## GRAPHICAL ABSTRACT



# The Seung (Sueng or Sung), a Plucked Fretted Lute from the Northern Region of Thailand

Ezra M. A. Duin,[a] Sinin Hamdan,[b,*] Khairul Anwar Mohamad Said,[b] Mawar Suhaila Ab Razak,[a] and Aaliyawani Ezzerin Sinin [c]

The seung instrument is played in one key (minor key) because the fret spacing creates a diatonic scale. Due to the fact that the frets are not uniformly spaced on the fretboard, the fret spacing produces a diatonic scale (do-re-mi-fa, *etc*.) instead of a chromatic scale of a guitar, where all the flats and sharps are available. The partial frequency (Hz) *versus* harmonic number for string 1 and 2 are very linear. The gradients of the linear equations fit very well with the fundamental frequency of the open string 1 and 2 and fret 1 to fret 9. The sounds were digitally captured using a PicoScope oscilloscope and were subsequently examined utilizing PicoScope software, emphasizing Fast Fourier Transform (FFT). The Time Frequency Analysis (TFA) was obtained *via* Adobe Audition. The notes for open string 1 and 2 are A4 followed by B4, C5, D5, E5, F5, G5, A5, B5, C6, and D4 followed by E4, F4, G4, A4, B4, C5, D5, E5, F5 from the 9 frets respectively. The 10 notes up to the 9$^{th}$ frets for string 1 and 2 are A4 to C5 and D4 to F5 respectively.

*DOI: 10.15376/biores.20.2.3234-3251*

*Keywords: Seung instrument; Fast Fourier transform (FFT); Time frequency analysis (TFA); Adobe Audition; Diatonic scale*

*Contact information: a: Faculty of Applied and Creative Art, Universiti Malaysia Sarawak, 94300, Kota Samarahan, Sarawak, Malaysia; b: Faculty of Engineering, Universiti Malaysia Sarawak, 94300, Kota Samarahan, Sarawak, 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 seung is a traditional plucked string instrument from northern Thailand's Lanna region. It is sometimes spelled 'sueng' or 'sung'. This instrument is an important part of the region's musical and cultural legacy, reflecting its social and historical settings. The seung is an essential component of the traditional music of the Lanna region because of its well-known distinctive musical qualities. Its adaptability and cultural relevance are emphasized by its tonal range, playing styles, and function in both solo and ensemble situations. The higher-sounding strings pair is tuned a musical fifth above the lower-sounding strings pair, and each pair is tuned in unison, meaning that both strings play the same note. The fretboard's placement, leading to a diatonic scale, determines the instrument's primary tonality. The tuning of seung consists of perfect fifth interval tuning. For example, if the note C is tuned for the top two strings, then the note G is tuned for the bottom two strings. Only the lowest two strings are being strummed. The top strings will be left as a drone sound or sustain note. The fretboard has a diatonic scale. The tuning is well established in the diatonic scale where the fret spacing creates a diatonic scale and the instrument is played in one key (minor key). In this work the discussion of harmonic structures will be compared with other plucked string instruments (*e.g.*, gambus or oud).

The seung offers a multitude of expressive options because it is played using a combination of strumming and plucking methods. Strumming is a rhythmic and percussion-based technique that sustains the rhythm of the group by producing a constant pulse. Conversely, plucking is utilized to precisely enunciate particular melodies or embellishments. Additionally, in order to enhance melodies, musicians frequently use ornamentation methods such as tremolos, pull-offs, hammer-on, and slides, which reflects the complex and subtle nature of Thai music (see Fig. 1).


**Fig. 1.** This excerpt score shows a beautiful melody (key B major) played by Lanna's Musicians, which incorporates tremolos techniques and pull-offs (articulation stated as staccato). (source: Thai Lanna musician playing the Seung. (May 1st, 2013). YouTube: https://www. youtube.com/watch?v=tkytm KNL7YQ).

The seung is a perpetual and adaptable representation of Lanna's musical history because of its capacity to combine traditional and contemporary components. Both musicians and audiences inside and outside of Thailand are still motivated by its musical depth. However, in some cases, Thai's seung could have microtonal issues due to the placement of the fretboard. For example, in Fig. 2, some issues with the note on the scale degree of fifth (note F) have been encountered. Most of the melodies being played are in pentatonic major scales, despite the seung's fretboard, to produce a melody up to a diatonic scale, and expect to hear similarities to Thai folk tunes.


**Fig. 2.** Excerpt score showing another beautiful melody (key Bb Major) consisting mostly of a plucking melody. (Source: Thai Seung (July 15th. 2007).
YouTube: https://www.youtube.com/watch?v=6dgT5prjDfM).

The seung is made from hardwood and falls under the category of chordophones (Terry and Sean 2018). Unlike the guitar or ukulele, the strings are not evenly spaced so its string is not evenly separated on the fretboard. They are in pairs, with the two strings of each pair tuned to the same note. The instrument is designed for playing melodies, rather than chords. The second strings are tuned to a musical fifth lower than the first string. It can be tuned to E-flat (lower-second string) and B-flat (upper-first string.) making it compatible with band instruments such as trumpets and saxes, which are commonly flat key scales. Alternatively, it can be tuned down a half-step with the lower pair tuned to D and the higher pair to A. The fret spacing gives a diatonic scale (do-re-mi-fa...*i.e.*, C, D, E, F, G, A, B) rather than a chromatic scale like a guitar, for which all the sharps and flats available (C, C#, D, D#, E, F, F#, G, G#, A, A#, B). Thus, it is tuned for playing in a particular key.

Using a PicoScope, measurements were made to get the sound spectrum. The sound data were collected in multiple rounds to guarantee reliability and endurance. This choice ensures that the comparison will be relevant and logical. In order to smooth out anomalies and create a more reliable comparison that provided a comprehensive and accurate portrayal of the acoustic properties of the seung, the recordings from these multiple rounds were then averaged. The presented method guarantees a strong and dependable comparison by employing many rounds of data gathering and averaging the outcomes. The validity of the conclusions to the current work is reinforced by this thorough technique, which also offers a precise and transparent comparison across these multiple iterations. Earlier acoustic studies of similar instruments have been carried out, including the Nirai guitar (Duin *et al.* 2025), Gambus Hadhramaut (Hamdan *et al.* 2023), Sape (Hamdan *et al.* 2023), Tapi (Sinin *et al.* 2023), and Hasapi (Sinin *et al.* 2025). This work aimed to determine the diatonic scale (do-re-mi-fa, *etc*.) produced by the fret spacing and the key that can be played, together with the harmonics produced by both open string 1 and 2 and the 9 frets.

## EXPERIMENTAL

Figure 3 shows the seung with nine frets. It is made from hardwood. The strings are most often made of steel wire, either four or six and arranged in courses of two. 'Suengs' are commonly made from jackfruit wood. Rosewood and teak woods are also used for the construction of the seung. The jackfruit (*Artocarpus heterophyllus*) is a tree species belonging to the Moraceae family. It is ideally adapted to tropical lowlands and is extensively farmed in the Philippines, India, Bangladesh, Sri Lanka, Indonesia, Malaysia, and Australia. Botanist Ralph Randles Stewart proposed that it was named in honor of William Jack (1795 to 1822), a Scottish botanist associated with the East India Company in Bengal, Sumatra, and Malaya. 'Nangka' is an alternative term derived from Tagalog, corresponding to 'nangkà' in Cebuano and Malay, all belonging to the same Austronesian language family. 'Nangka' possesses a rather brief trunk and a compact canopy. It readily attains heights of 9 m to 21 m and trunk diameters of 30 cm to 80 cm. The leathery leaf blade is 20 cm to 40 cm in length and 7.5 cm to 18 cm in width.

The seung is carved into a round sound board. Nowadays, the tuning pegs are for aesthetic function. Modern seungs use guitar machine heads for tuning. The bridge is made from either bone or hardwood. The frets on the seung are spaced so that the instrument plays in the diatonic scale. In one octave the instrument plays seven tones, not the twelve tones of western music. This temperament is found in traditional Thai music. The technique for playing resembles the oud, for which the two strings in the course are tuned to unison and played together as one (Hamdan *et al*. 2023). Players do not usually strum it like a guitar. Instead, a pick is used in a rapid up/down motion. The frets are spaced in the intervals of a minor scale instead of in half steps like a guitar.

The experiment was conducted in an anechoic room in the music department of Universiti Malaysia Sarawak (UNIMAS). In an anechoic environment, the radiated sound was measured using an omnidirectional microphone positioned 20 cm above the subject. The seung's location was carefully considered in order to maximize sound gathering and minimize interference. The seung was played in the traditional seated position to allow for a fair comparison. This posture is most representative of typical playing conditions and encourages natural sound output and resonance. A microphone was placed in front of the seung at a consistent distance and angle throughout the recording process in order to capture the sound's genuine acoustic characteristics. This setup ensures that the recordings faithfully convey the sound's tonal characteristics without introducing bias or distortion from various microphone placements.

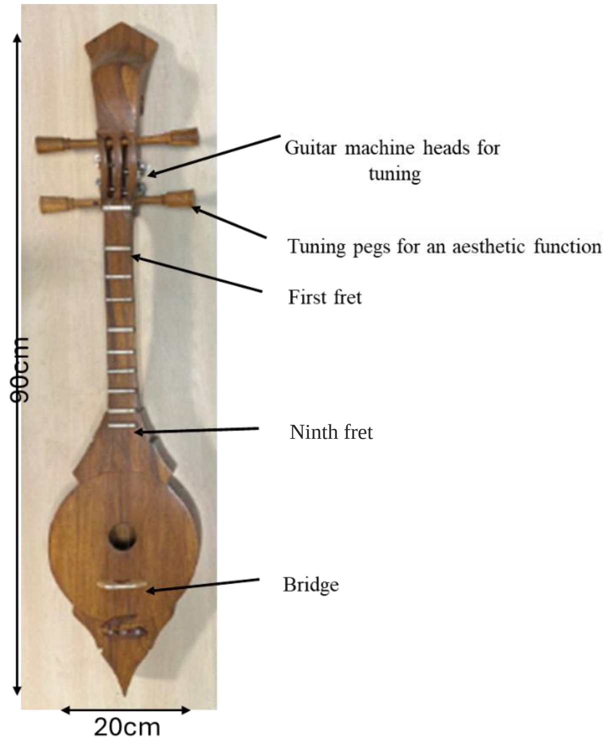



**Fig. 3.** The seung

The amplifier helped the signal converter recognize the capture sound due to its sufficient loudness (Behringer Powerplay Pro XL, Behringer, Zhongshan, Guangdong, China). Using a PicoScope, measurements were taken to obtain the sound spectrum. After the sound data were recorded and captured, Adobe Audition was used to analyze the FFT and identify the dominant frequency for each tone at a specific moment. The Fourier transform is a mathematical method used to determine fundamentals, harmonics, and sub-harmonics. The acoustic data was collected over multiple cycles to ensure reliability and consistency. To minimize any irregularities or variations, it was played and recorded under identical conditions. To ensure that the recordings accurately captured the acoustic characteristics of each instrument without introducing bias, it was played in its usual sitting position with microphones placed in front of the seung at the same height and angle. In order to smooth out anomalies and create a more reliable comparison that provided a comprehensive and accurate portrayal of the acoustic properties, the recordings from these multiple rounds were then averaged. The authors ensured that the comparison was robust and trustworthy by conducting multiple rounds of data gathering and averaging the outcomes. This thorough approach offers a precise and transparent comparison while bolstering the legitimacy of the current findings.

Figure 4 illustrates the schematic design of microphone data collections. The seung sound was digitally recorded using a PicoScope oscilloscope and microphone data collecting systems. The Fast Fourier transform (FFT) was carried out using an oscilloscope from Pico Technology's 3000 series, Eaton Socon, UK. The FFT algorithm was used to mathematically convert the resulting digital time record into an FFT spectrum. The Fourier theorem is implemented by a simple series of operations known as the FFT. The frequency components of the input signal are displayed in the generated FFT spectrum. The results were then analyzed using PicoScope software (version 6), with a focus on spectrum analysis, voltage-based triggers, and FFT. The use of Pico Scope software was extensively practiced using the exact plucking motions prior to the recordings in order to minimize discrepancies. This methodological rigor enhances the repeatability and dependability of the experimental results by reducing the influence of human variability.

The microphone was situated 20 cm from the string. This 20 cm microphone position is most representative of typical playing conditions and encourages natural sound production and resonance. The microphone was placed in front at a consistent distance and angle throughout the recording procedure to capture the genuine acoustic characteristics. This configuration ensures that the recordings faithfully convey the tonal characteristics without introducing distortion. To reduce any irregularities or deviations, the instrument was played and recorded in the exact similar conditions. To ensure that the recordings faithfully caught the instrument's acoustic characteristics without introducing any bias, the microphones were placed above them at the same height and angle.

The audio recordings were acquired at a sample frequency of 48 kHz. The Time Frequency Analysis (TFA) was performed in Adobe Audition, concentrating on the specific intensity in hertz to distinguish the power of partial frequencies, utilizing measurements in seconds. The Time Frequency Analysis (TFA) was carried out in Adobe Audition, concentrating on the precise intensity in hertz to distinguish the power of partial frequencies. The frequency components that make up a complex sound, like a vibrating musical instrument, are called partial frequencies, or partials. Partials are the many distinct frequencies or pitches that make up a complicated sound. The harmonic series or overtone series is the name given to the group of partials. Usually the strongest frequency to the ear, the fundamental frequency is the first partial. The pitch of the sound is defined by it. The partials above the fundamental are called overtones. The tone, color, and timbre of the sound are determined by the relative strength of the overtones. This method is frequently used in sound analysis and re-synthesis to study tone systems (Hamdan *et al.* 2020).

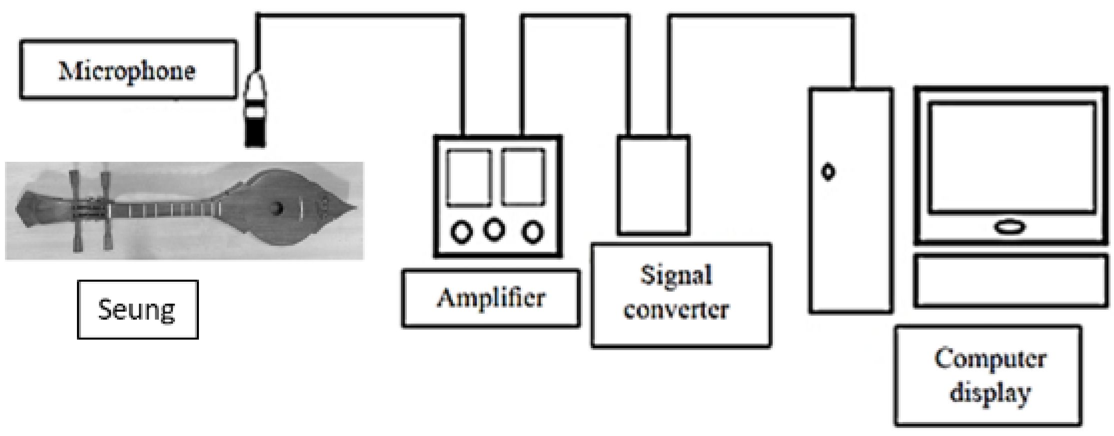



**Fig. 4.** Schematic diagram of microphone data acquisitions

The vibrations generate sound waves that produce the notes perceived in music. The audio signals were recorded in monaural format with a resolution of 24 bits and a sampling rate of 48 kHz. The audio profile was preserved in ".wav" format for further processing. A calibration was conducted before the session to guarantee proper settings.

The calibration test tone was restricted to a 1.0 kHz sine wave, adhering to the European Broadcasting Union (EBU) methodology. The EBU stipulates that the device must provide a digital recording level of 0 VU at either +4 dBu or -18 dBFS in analog or digital format. No other devices nearby might have affected the signal amplitude during the calibration process. The recording equipment comprised the Steinberg UR22mkII audio interface, Audio-Technica AT4050 microphone, Behringer Powerplay Pro XL amplifier, and XLR cable. The microphone was set to record with a low-cut filter.

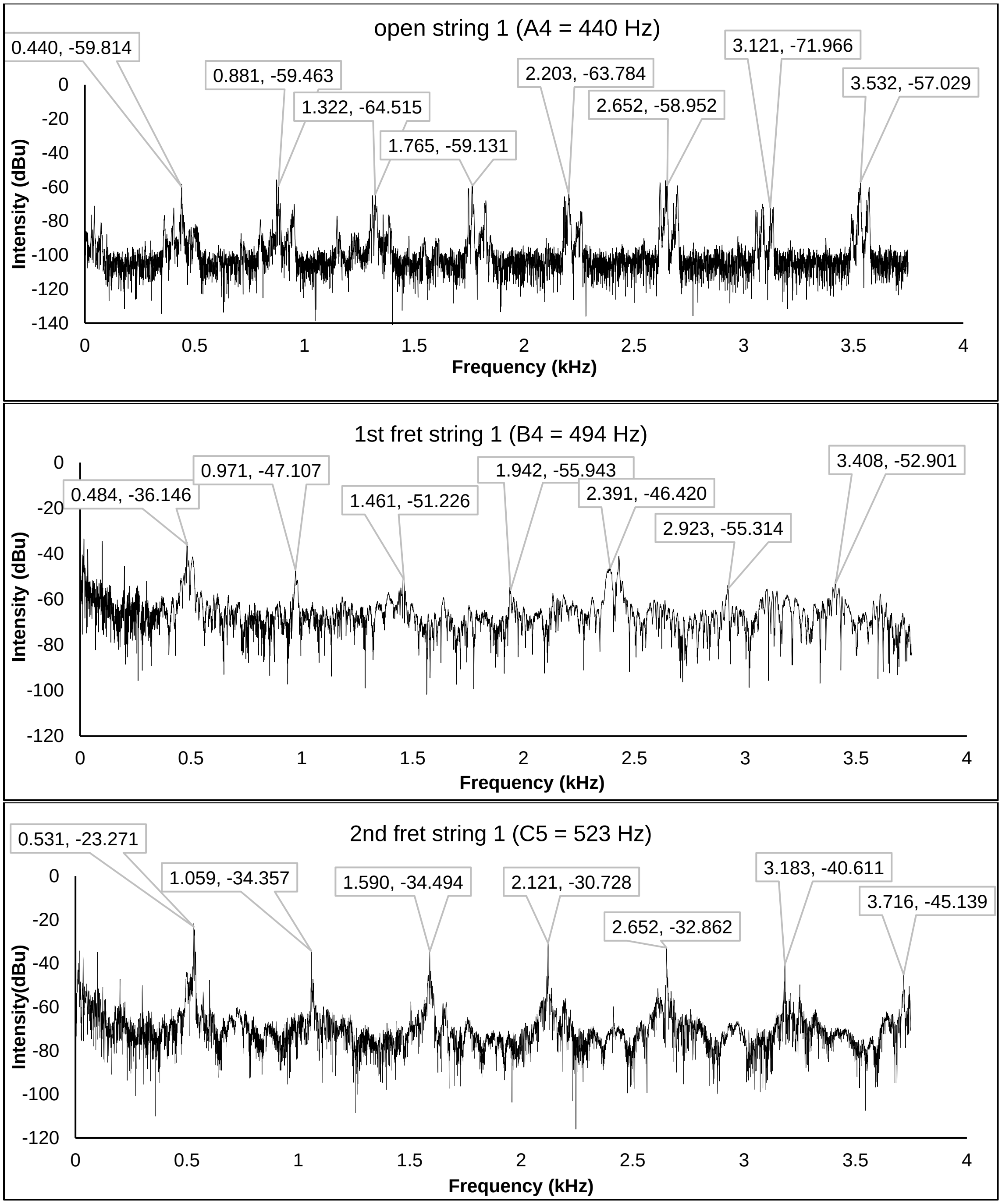
This choice ensures that the comparison is relevant and logical. The sound data were collected in multiple rounds to guarantee reliability and endurance. In order to smooth out anomalies and create a more reliable comparison that provided a comprehensive and accurate portrayal of the acoustic properties, the recordings from these multiple rounds were then averaged. The presented method guarantees a strong and dependable comparison by employing many rounds of data gathering and averaging the outcomes. This method strengthens the validity of our findings by incorporating multiple rounds of data collection and averaging the results, ensuring a robust and reliable comparison.

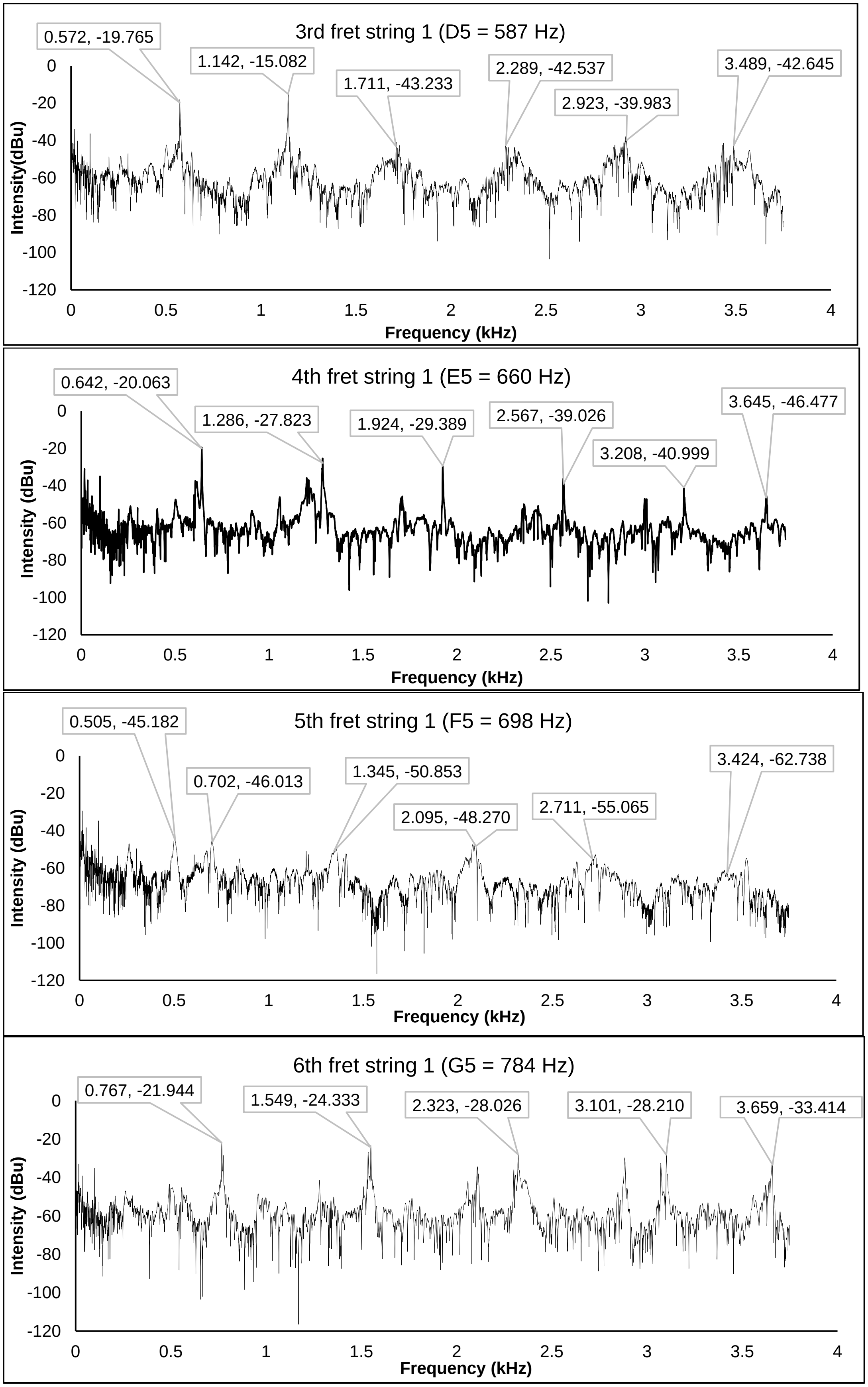
Using a PicoScope oscilloscope and microphone data acquisition, the seung sounds were digitally recorded. The Steinberg UR22mkII audio interface, Audio-Technica AT4050 microphone, XLR cable (balance), microphone position on axis (20 cm), and low cut (flat) 0 dB were the recording equipment. The time signals from PicoScope oscilloscopes (Pico Technology, 3000 series, Eaton Socon, UK) and data recorders for real-time signal capture were viewed and analyzed using the PicoScope computer software. FFT, a spectrum analyzer, voltage-based triggers, and the capacity to save and load waveforms on a disc are all made possible by PicoScope software. Similar experimental setups using FFT and TFA methodologies were used earlier in Nirai guitar (Duin *et al*. 2025), Hasapi (Sinin *et al*. 2025), Pratuonkg (Hamdan *et al*. 2024), and Tongkungon (Hamdan *et al*. 2024) musical instrument.

## RESULTS AND DISCUSSION

Figure 5 showed the fundamental and the higher partials frequency for the open string 1 and the 9 frets. The open string 1 note is A4 followed by B4, C5, D5, E5, F5, G5, A5, B5, and C6 from the 9 frets respectively. The 10 notes up to the 9$^{th}$ frets are A4 to C6. Figure 5 clearly displays the fundamental frequency for the open string 1, which is approximately the frequency of the note A4, B4, C5, D5, E5, F5, G5, A5, B5, and C6, together with the harmonics produced by both open string 1 and the 9 frets. The notes from the open string up to the 9$^{th}$ frets are D4 to F5. Seven-tone equal temperament (7-tet) is the traditional Thai tuning scheme. This indicates that seven equal portions, each measuring 171.429 cents, make up an octave. Traditional Thai music is categorized using chromatic scale, which is superior to other western music scales. Traditional Thai music follows a seven notes system based on a single pitch reference. The chromatic scale comprises of twelve semitone levels, encompassing the complete range of diatonic scales. The higher-pitched string pair is tuned a musical fifth above the lower- pitched string pair (heavier-gauge), and each pair is tuned in unison (both strings of a pair play the same note) to produce a cohesive melodic sound. The instrument can only be played in one key (and its corresponding minor key), since the fret spacing creates a diatonic scale. Due to the fact that the strings are not uniformly spaced on the fretboard, it is not possible to finger each one independently. Not chords, but melodies are what the instrument is meant to perform.

Compared to the lighter strings, the two heavier strings are tuned one musical fifth lower. E-flat (lower) and B-flat (higher) were the tuning settings. Instead of a chromatic scale like a guitar, where all the flats and sharps are available, the fret spacing produces a diatonic scale (do-re-mi-fa, etc.). As a result, it is adjusted to play in a specific key. It will play in C minor or E-flat major with the Eb-Bb tuning.




3rd fret string 1 (D5 = 587 Hz)
0.572, -19.765
1.142, -15.082
1.711, -43.233
2.289, -42.537
2.923, -39.983
3.489, -42.645
Intensity(dBu)
Frequency (kHz)
4th fret string 1 (E5 = 660 Hz)
0.642, -20.063
1.286, -27.823
1.924, -29.389
2.567, -39.026
3.208, -40.999
3.645, -46.477
Intensity (dBu)
Frequency (kHz)
5th fret string 1 (F5 = 698 Hz)
0.505, -45.182
0.702, -46.013
1.345, -50.853
2.095, -48.270
2.711, -55.065
3.424, -62.738
Intensity (dBu)
Frequency (kHz)
6th fret string 1 (G5 = 784 Hz)
0.767, -21.944
1.549, -24.333
2.323, -28.026
3.101, -28.210
3.659, -33.414
Intensity (dBu)
Frequency (kHz)

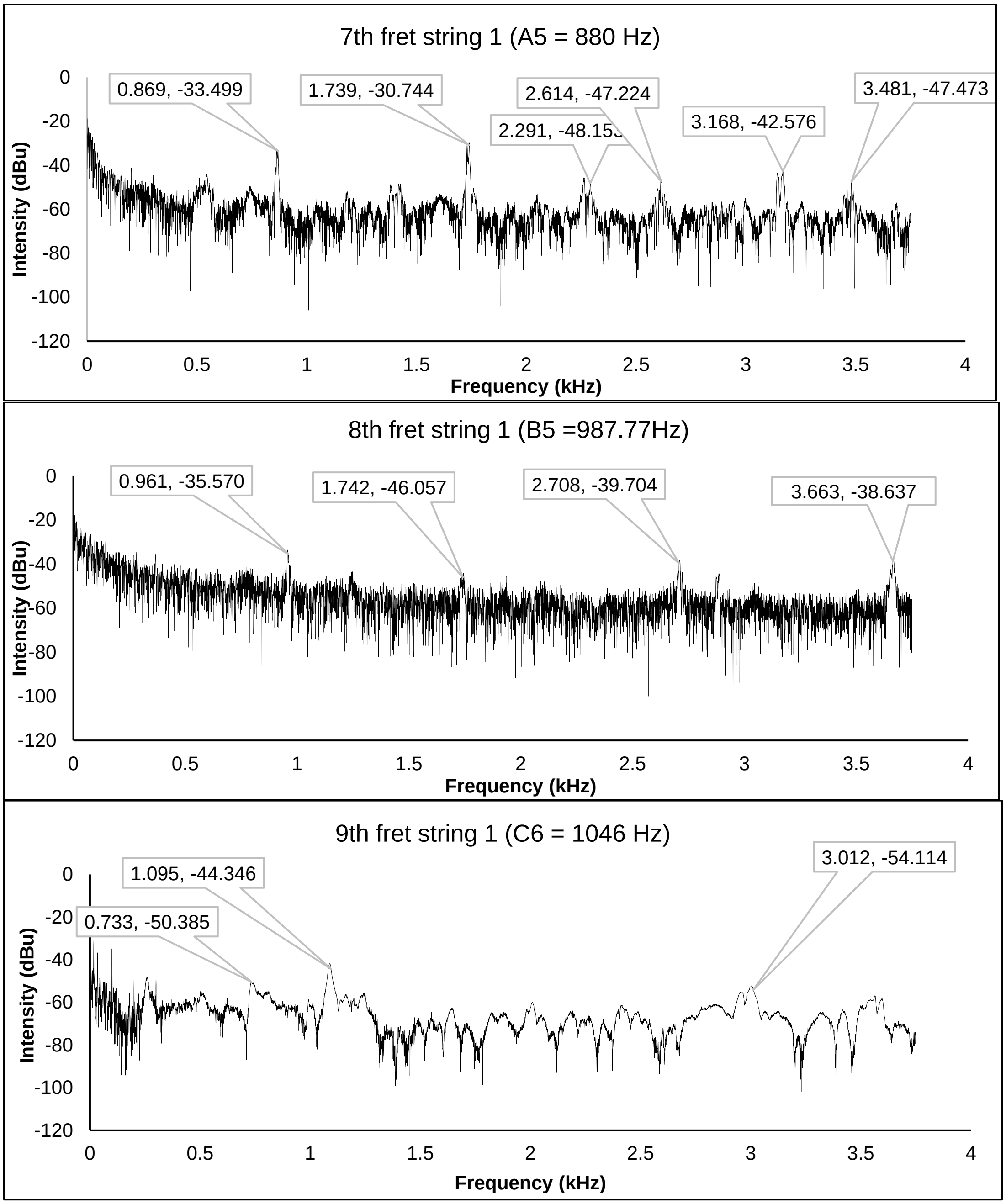



**Fig. 5.** The fundamental and the higher partials frequencies for the open string and the 9 frets from string 1

Table 1 shows the fundamental frequency with the higher partials (Hz) and the harmonic number for open string and the 9 frets from string 1 (A4, B4, C5, D5, E5, F5, G5, A5, B5, C6). Figure 6 shows the partial frequency (Hz) *versus* harmonic number for string 1 (Harmonic number 1 is the fundamental frequency). Open string (A4) displays up to 8$^{th}$ harmonic, 1$^{st}$ fret (B4), and 2$^{nd}$ fret (C5) display up to 7$^{th}$ harmonic, 3$^{rd}$ fret (D5) display up to 6$^{th}$ harmonic, and 4$^{th}$ fret (E5), 5$^{th}$ fret (F5), and 6$^{th}$ fret (G5) display up to 5$^{th}$ harmonic, 7$^{th}$ fret (A5), and 8$^{th}$ fret (B5) displays up to 4$^{th}$ harmonic and 9$^{th}$ fret (C6) display up to 3$^{rd}$ harmonic. The harmonics number decreased with the pitch.

**Table 1.** The Open String and the 9 Frets Fundamental Frequency with the Higher Partials for String 1 (A4, B4, C5, D5, E5, F5, G5, A5, B5, and C6).

| Open string ±2Hz | Harmonic | 1st Fret ±2Hz | Harmonic | 2nd Fret ±2Hz | Harmonic | 3rd Fret ±2Hz | Harmonic | 4th Fret ±2Hz | Harmonic |
|---|---|---|---|---|---|---|---|---|---|
| 440 (A4) | 1 | 484 (B4) | 1 | 531 (C5) | 1 | 572 (D5) | 1 | 642 (E5) | 1 |
| 881 | 2.00 | 971 | 2.00 | 1059 | 1.99 | 1142 | 1.99 | 1286 | 2.00 |
| 1322 | 3.00 | 1461 | 3.01 | 1590 | 2.99 | 1711 | 2.99 | 1924 | 2.99 |
| 1765 | 4.01 | 1942 | 4.01 | 2121 | 3.99 | 2289 | 4.00 | 2567 | 3.99 |
| 2203 | 5.00 | 2391 | 4.94 | 2652 | 4.99 | 2923 | 5.11 | 3208 | 4.99 |
| 2652 | 6.02 | 2923 | 6.03 | 3183 | 5.99 | 3489 | 6.09 | 3645 | 5.67 |
| 3121 | 7.09 | 3408 | 7.04 | 3716 | 6.99 | | | | |
| 3532 | 8.02 | | | | | | | | |

| 5th Fret ±2Hz | Harmonic | 6th Fret ±2Hz | Harmonic | 7th Fret ±2Hz | Harmonic | 8th Fret ±2Hz | Harmonic | 9th Fret ±2Hz | Harmonic |
|---|---|---|---|---|---|---|---|---|---|
| 702 (F5) | 1 | 767 (G5) | 1 | 869 (A5) | 1 | 961 (B5) | 1 | 1094 (C6) | 1 |
| 1345 | 1.91 | 1549 | 2.01 | 1739 | 2.00 | 1742 | 1.81 | 3012 | 2.75 |
| 2095 | 2.98 | 2323 | 3.02 | 2641 | 3.03 | 2708 | 2.81 | | |
| 2711 | 3.86 | 3659 | 4.77 | 3168 | 3.64 | 3663 | 3.81 | | |
| 3424 | 4.87 | | | 3481 | 4.00 | | | | |

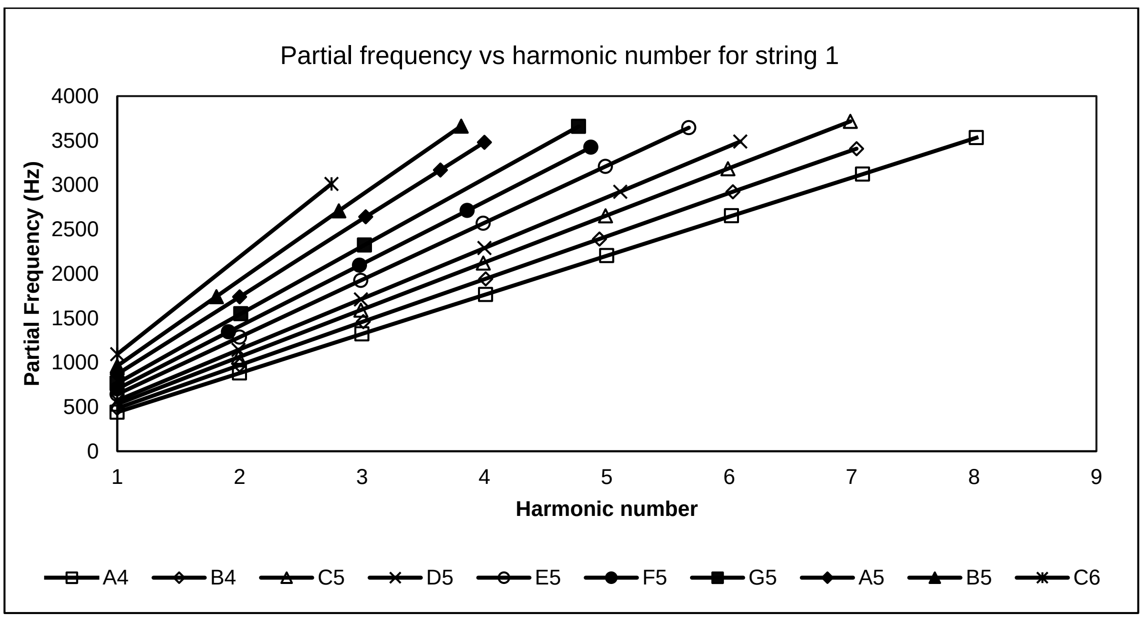



**Fig. 6.** Partial frequency (Hz) *versus* harmonic number for string 1 (Harmonic number 1 is the fundamental frequency)

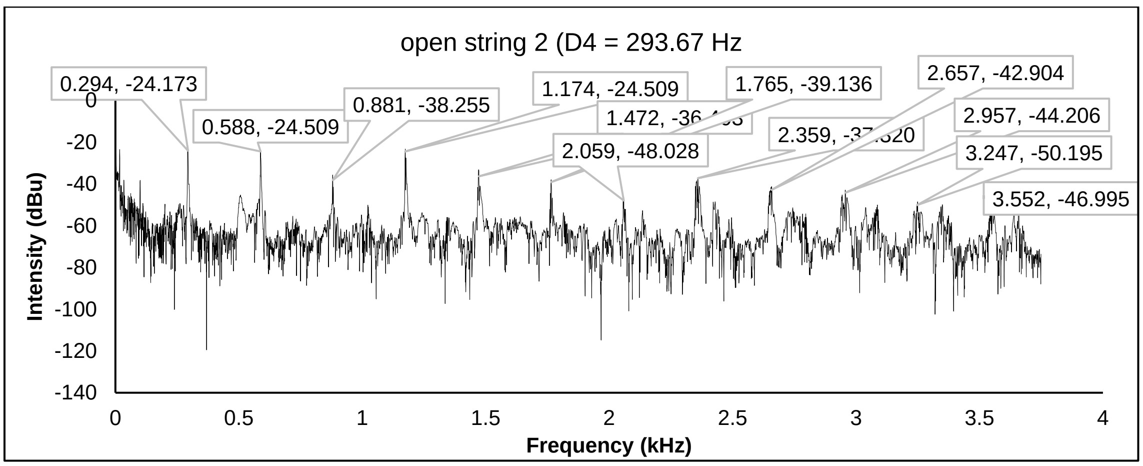
From Figure 6 the linear equation for the open string 1, fret 1 to fret 9 is as follows:

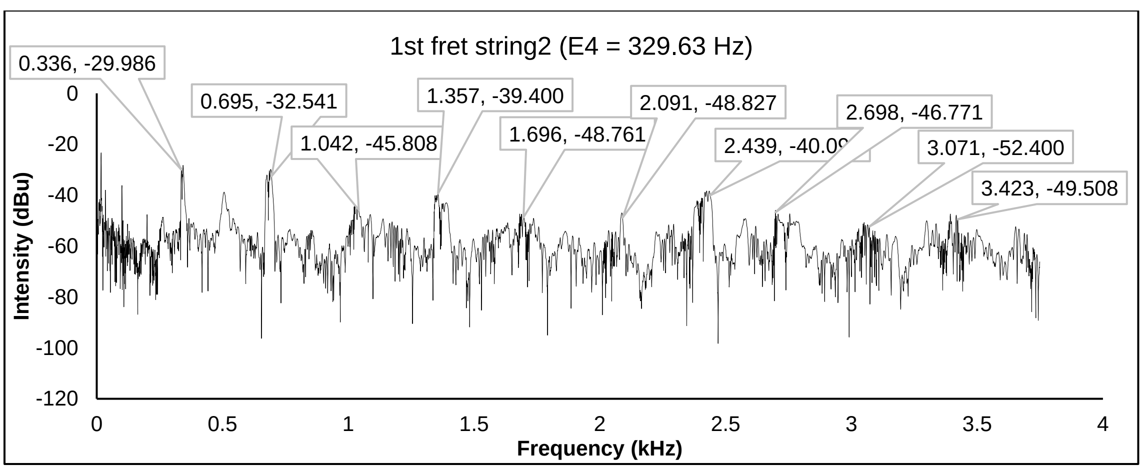
$$Y_{open\ string1} = 440.36x + 0.189$$
$$Y_{fret1} = 484.03x + 1.7962$$
$$Y_{fret2} = 531.46x + 0.4218$$
$$Y_{fret3} = 572.47x + 0.1823$$

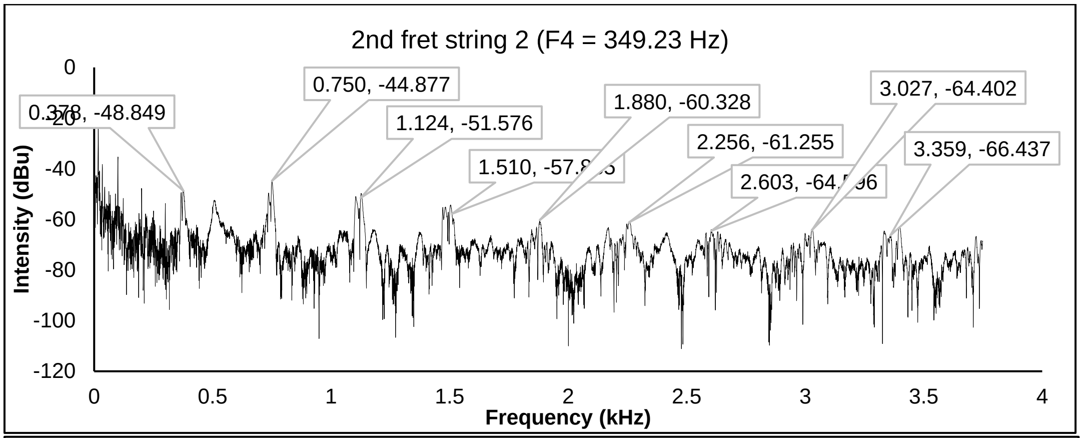
$Y_{fret4} = 642.99x + 0.1031$
$Y_{fret5} = 702.78x + 0.4598$
$Y_{fret6} = 766.73x + 4.3236$
$Y_{fret7} = 871.04x - 1.811$
$Y_{fret8} = 961.97x + 0.6544$
$Y_{fret9} = 1096x – 2$

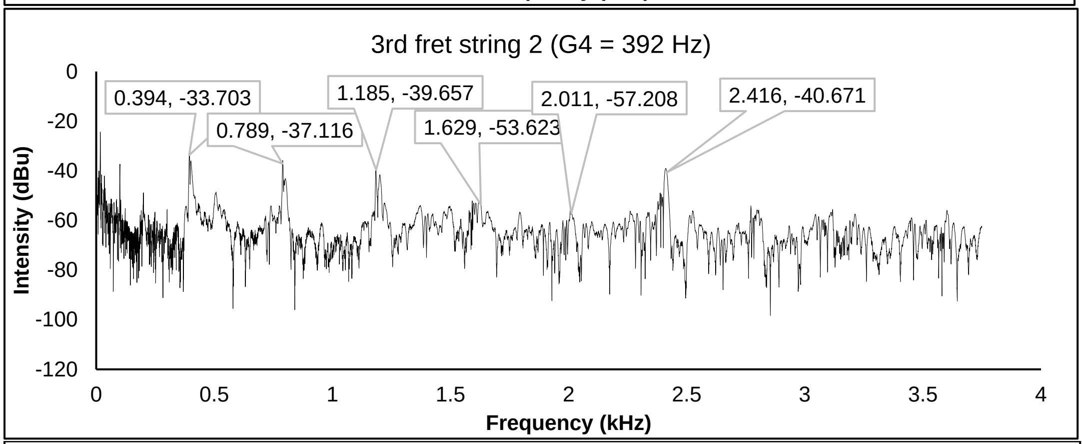
The gradients of the linear equations fit very well with the fundamental frequency of the open string 1 and fret 1 to fret 9.

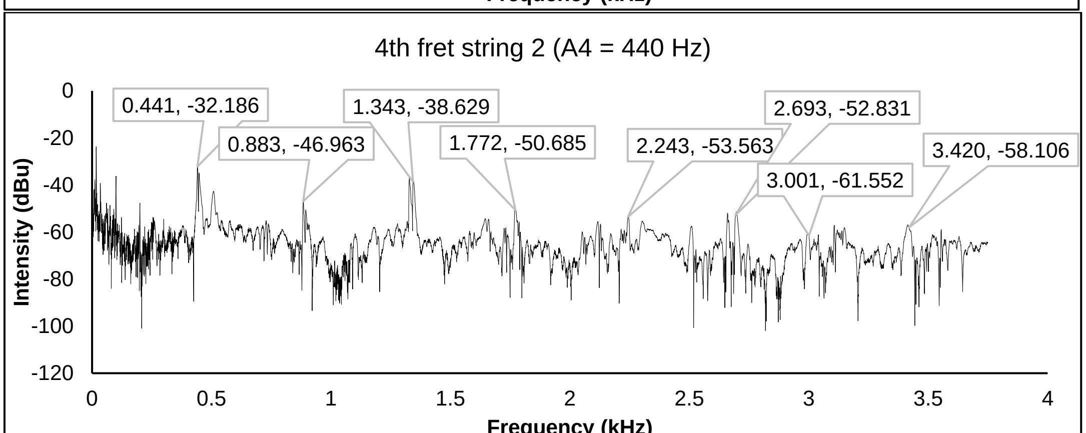
Figure 7 shows the fundamental and the higher partials frequency (Hz) for the open string and the 9 frets from string 2. The open string note is D4 followed by E4, F4, G4, A4, B4, C5, D5, E5, and F5 from the 9 frets, respectively. The 10 notes up to the 9$^{th}$ frets are D4 to F5. Figure 7 clearly displays the fundamental frequency for the open string 2 which is approximately the frequency of the note D4, E4, F4, G4, A4, B4, C5, D5, E5, and F5, together with the harmonics produced by both open string 2 and the 9 frets.

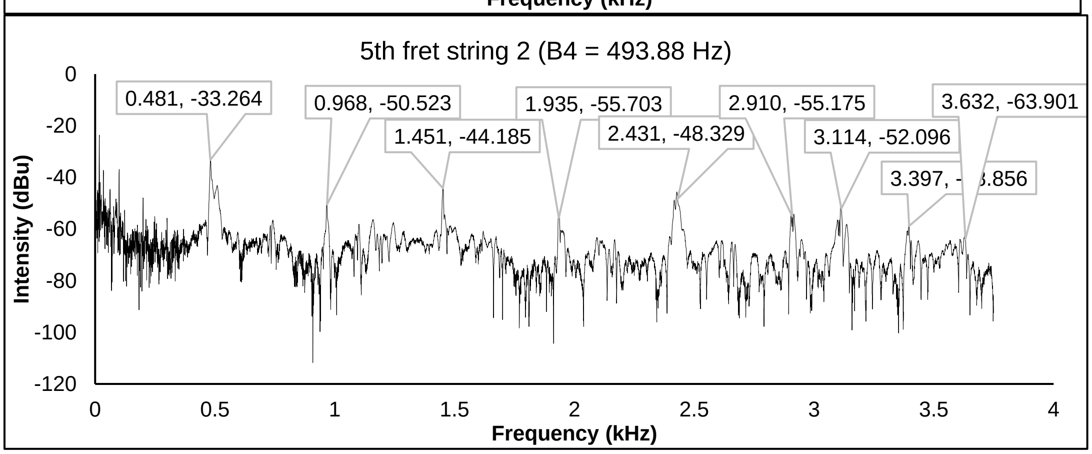



2nd fret string 2 (F4 = 349.23 Hz)
0.750, -44.877
1.124, -51.576
1.880, -60.328
2.256, -61.255
3.027, -64.402
3.359, -66.437
Intensity (dBu)
Frequency (kHz)


3rd fret string 2 (G4 = 392 Hz)
0.394, -33.703
0.789, -37.116
1.185, -39.657
1.629, -53.623
2.011, -57.208
2.416, -40.671
Intensity (dBu)
Frequency (kHz)


4th fret string 2 (A4 = 440 Hz)
0.441, -32.186
0.883, -46.963
1.343, -38.629
1.772, -50.685
2.243, -53.563
2.693, -52.831
3.001, -61.552
3.420, -58.106
Intensity (dBu)
Frequency (kHz)


5th fret string 2 (B4 = 493.88 Hz)
0.481, -33.264
0.968, -50.523
1.451, -44.185
1.935, -55.703
2.431, -48.329
2.910, -55.175
3.114, -52.096
3.632, -63.901
Intensity (dBu)
Frequency (kHz)

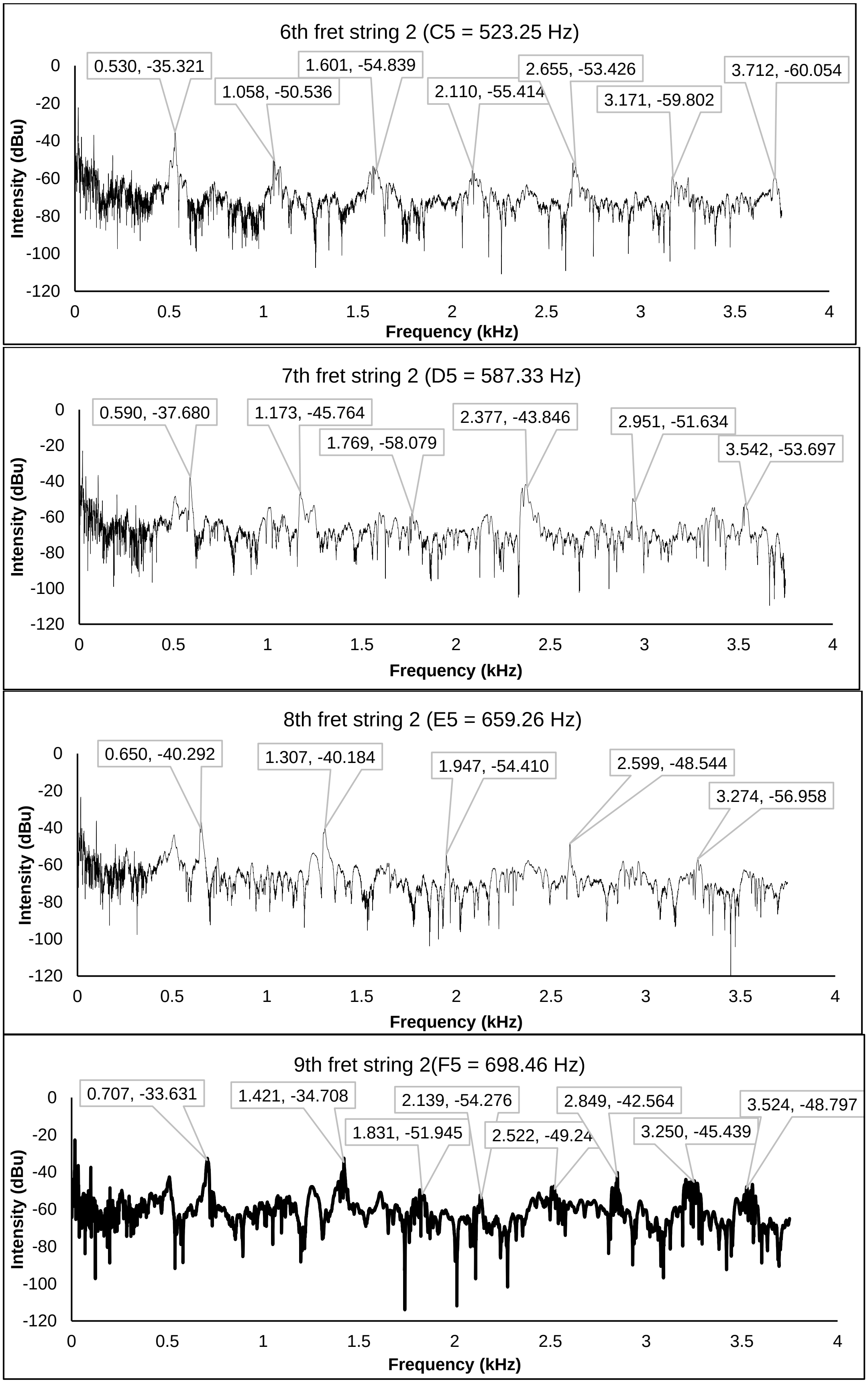



**Fig. 7.** Fundamental and higher partials frequencies for open string and the 9 frets from string 2

Table 2 shows the fundamental frequency with the higher partials and the harmonic number for open string and the 9 frets from string 2 (D4, E4, F4, G4, A4, B4, C5, D5, E5, and F5). Figure 8 shows the partial frequency (Hz) *versus* harmonic number for string 2 (Harmonic number 1 is the fundamental frequency). Open string (D4) displays up to 12th harmonic, 1st fret (E4) and 2nd fret (F4) display up to 10th and 9th harmonics respectively, 3rd fret (G4) and 4th fret (A4) display up to 6th and 8th harmonic respectively, 5th fret (B4) and 6th fret (C5) display up to 7th harmonic, 7th fret (D5), and 8th fret (E5) displays up to 6th and 5th harmonic respectively, and 9th fret (F5) display up to 5th harmonic. The actual tune of the gambus (1st to 6th string) was C4, G3, D3, A3, E2, B2 (Hamdan *et al.* 2023). Some strings of the gambus do not have the exact octave, with harmonic and inharmonic overtones. The 1st string displayed 2 harmonics. The 2nd string displayed 3 harmonics. The 3rd string exhibited 5 harmonics. The 4th string displayed a regular pattern with the presence of 5 harmonics. The 5th string showed a harmonic overtone at the 5th octave. The 6th string did not produce any harmonic overtones. The lowest frequency was shown by the 6th string, i.e., at 78 hertz. The most harmonic overtone frequency occurred for the 3rd string.

**Table 2.** The Open String and the 9 Frets Fundamental Frequency with the Higher Partials for String 2 (D4, E4, F4, G4, A4, B4, C5, D5, E5, F5).

| Open String ±2Hz | Harmonic | 1st Fret ±2Hz | Harmonic | 2nd Fret ±2Hz | Harmonic | 3rd Fret ±2Hz | Harmonic | 4th Fret ±2Hz | Harmonic |
|---|---|---|---|---|---|---|---|---|---|
| 294 (D4) | 1 | 336 (E4) | 1 | 378 (F4) | 1 | 394 (G4) | 1 | 441 (A4) | 1 |
| 588 | 2 | 695 | 2.06 | 750 | 1.98 | 789 | 2.00 | 883 | 2.00 |
| 881 | 2.99 | 1042 | 3.10 | 1124 | 2.97 | 1185 | 3.00 | 1343 | 3.04 |
| 1174 | 3.99 | 1357 | 4.03 | 1510 | 3.99 | 1629 | 4.13 | 1772 | 4.01 |
| 1472 | 5.00 | 1696 | 5.04 | 1880 | 4.97 | 2011 | 5.10 | 2243 | 5.08 |
| 1765 | 6.00 | 2091 | 6.22 | 2256 | 5.96 | 2416 | 6.13 | 2693 | 6.10 |
| 2059 | 7.00 | 2439 | 7.25 | 2603 | 6.88 | | | 3001 | 6.80 |
| 2359 | 8.02 | 2698 | 8.02 | 3027 | 8.00 | | | 3420 | 7.75 |
| 2657 | 9.03 | 3071 | 9.13 | 3359 | 8.88 | | | 3598 | 8.15 |
| 2957 | 10.05 | 3423 | 10.18 | | | | | | |
| 3247 | 11.04 | | | | | | | | |
| 3552 | 12.08 | | | | | | | | |

| 5th Fret ±2Hz | Harmonic | 6th Fret ±2Hz | Harmonic | 7th Fret ±2Hz | Harmonic | 8th Fret ±2Hz | Harmonic | 9th Fret ±2Hz | Harmonic |
|---|---|---|---|---|---|---|---|---|---|
| 481 (B4) | 1 | 530 (C5) | 1 | 590 (D5) | 1 | 650 (E5) | 1 | 707 (F5) | 1 |
| 968 | 2.01 | 1058 | 1.99 | 1173 | 1.98 | 1307 | 2.01 | 1421 | 2.00 |
| 1541 | 3.20 | 1601 | 3.02 | 1769 | 2.99 | 1947 | 2.99 | 1831 | 2.58 |
| 1935 | 4.02 | 2110 | 3.98 | 2377 | 4.02 | 2599 | 3.99 | 2139 | 3.02 |
| 2431 | 5.05 | 2655 | 5.00 | 2951 | 5.00 | 3274 | 5.03 | 2522 | 3.56 |
| 2910 | 6.04 | 3171 | 5.98 | 3542 | 6.00 | | | 2849 | 4.02 |
| 3114 | 6.47 | 3712 | 7.00 | | | | | 3250 | 4.59 |
| 3397 | 7.06 | | | | | | | 3524 | 4.98 |
| 3632 | 7.55 | | | | | | | | |

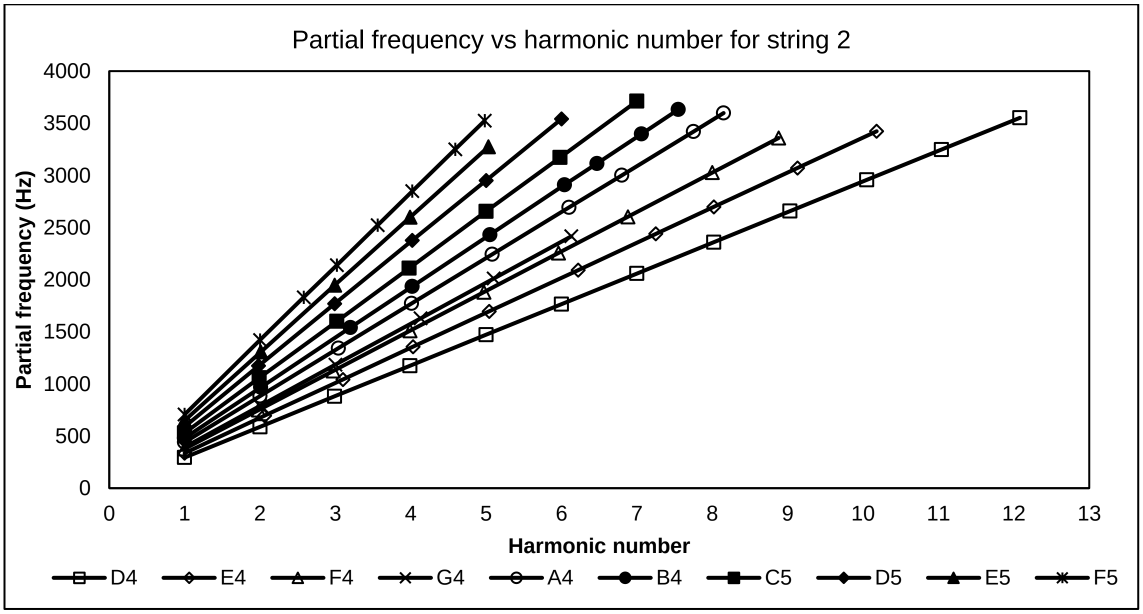



**Fig. 8.** Partial frequency (Hz) *versus* harmonic number for string 2 (Harmonic number 1 is the fundamental frequency).

From Fig. 8, the linear equation for the open string 2, fret 1 to fret 9 is given as follows:

$Y_{open\ string2} = 294.08x + 0.6759$
$Y_{fret1} = 336.23x + 0.8965$
$Y_{fret2} = 378.29x + 0.4375$
$Y_{fret3} = 394.12x + 0.9307$
$Y_{fret4} = 441.33x + 0.7134$
$Y_{fret5} = 481.18x + 0.7943$
$Y_{fret6} = 530.26x + 0.8144$
$Y_{fret7} = 589.97x + 3.0949$
$Y_{fret8} = 651.39x - 1.37$
$Y_{fret9} = 707.45x + 3.2604$

The gradients of the linear equations fit very well with the fundamental frequency of the open string 2 and fret 1 to fret 9.

The note for open string 2 and open string 1 are D4 and A4 respectively *i.e.*, a perfect fifth apart. Although all strings and notes displayed harmonic frequency, some non-harmonics occur at higher frequencies (9$^{th}$ fret (F5) from string 2). The harmonic for open string 2 is up to 12$^{th}$ harmonics, whereas the harmonic for open string 1 is up to 8$^{th}$ harmonics only.

Figure 9 shows the TFA for string 2 and string 1 from Adobe Audition. Previous studies had been done using FFT and TFA methodologies in Nirai guitar (Duin *et al.* 2025), Hasapi (Sinin *et al.* 2025), Pratuonkg (Hamdan *et al.* 2024a) and Tongkungon (Hamdan *et al.* 2024b) musical instruments.

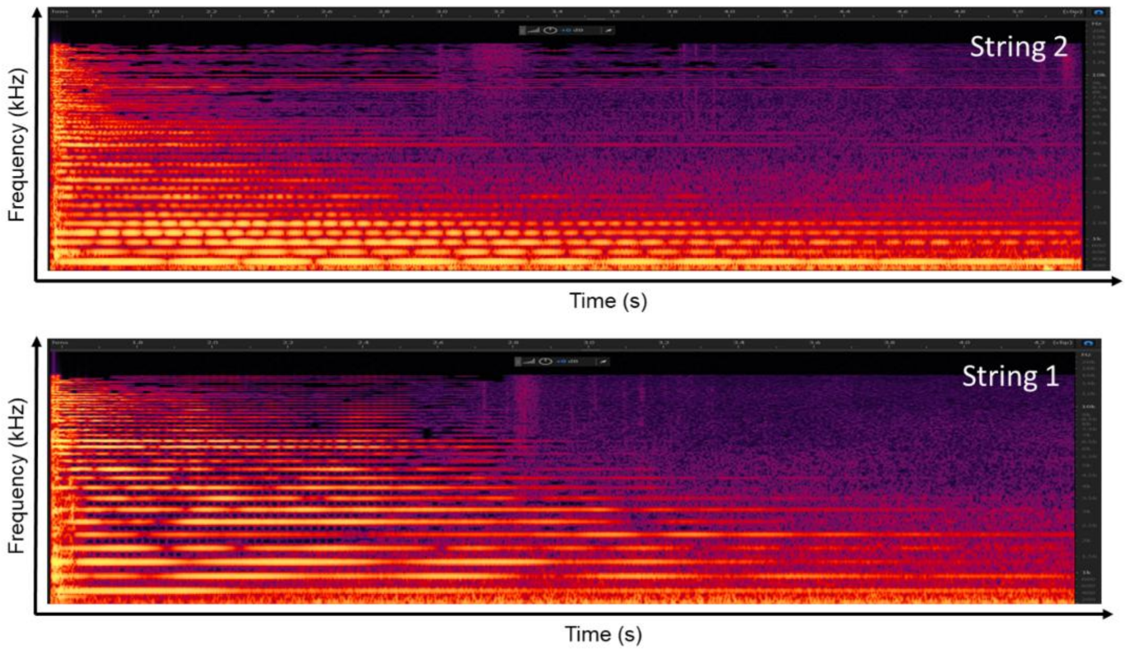



**Fig. 9.** The TFA for string 2 and string 1 from Adobe Audition

## CONCLUSIONS

1. This study confirmed that the notes for open string 1 and fret 1 to fret 9 are not uniformly spaced on the fretboard, such that the fret spacing produces a diatonic scale (do-re-mi-fa, *etc.*) instead of a chromatic scale as is used on a guitar, for which all the flats and sharps are available. The diatonic scale is created by the spacing from A4 followed by B4, C5, D5, E5, F5, G5, A5, B5, and C6.
2. In addition, it was confirmed that the notes for open string 2 and fret 1 to fret 9 are not uniformly spaced on the fretboard, such that the fret spacing produces a diatonic scale (do-re-mi-fa, *etc.*) instead of a chromatic scale such as it used with a guitar, where all the flats and sharps are available. The diatonic scale is created by the spacing from D4 followed by E4, F4, G4, A4, B4, C5, D5, E5, and F5.
3. The partial frequencies (Hz) *versus* harmonic number for string 1 are very linear. The linear equation for the open string 1, fret 1 to fret 9 is as follows:

$$Y_{\text{open string1}} = 440.36x + 0.189$$
$$Y_{\text{fret1}} = 484.03x + 1.7962$$
$$Y_{\text{fret2}} = 531.46x + 0.4218$$
$$Y_{\text{fret3}} = 572.47x + 0.1823$$
$$Y_{\text{fret4}} = 642.99x + 0.1031$$
$$Y_{\text{fret5}} = 702.78x + 0.4598$$
$$Y_{\text{fret6}} = 766.73x + 4.3236$$
$$Y_{\text{fret7}} = 871.04x - 1.811$$
$$Y_{\text{fret8}} = 961.97x + 0.6544$$
$$Y_{\text{fret9}} = 1096x - 2$$

The gradients of the linear equations fit very well with the fundamental frequency of the open string 1 and fret 1 to fret 9.

4. The partial frequencies (Hz) *versus* harmonic number for string 2 are very linear. The linear equation for the open string 1, fret 1 to fret 9 is as follows:

$Y_{open\ string2} = 294.08x + 0.6759$
$Y_{fret1} = 336.23x + 0.8965$
$Y_{fret2} = 378.29x + 0.4375$
$Y_{fret3} = 394.12x + 0.9307$
$Y_{fret4} = 441.33x + 0.7134$
$Y_{fret5} = 481.18x + 0.7943$
$Y_{fret6} = 530.26x + 0.8144$
$Y_{fret7} = 589.97x + 3.0949$
$Y_{fret8} = 651.39x - 1.37$
$Y_{fret9} = 707.45x + 3.2604$

The gradients of the linear equations fit very well with the fundamental frequency of the open string 2 and fret 1 to fret 9.

## FUTURE RESEARCH DIRECTIONS

In the future the authors will incorporate the changes of the signal with time using the Melda Analyzer. Using this method, it will be possible to trace the changes of the fundamental and overtone frequency with time.

## ACKNOWLEDGMENTS

We would like to acknowledge Universiti Malaysia Sarawak (UNIMAS) and Universiti Putra Malaysia Bintulu Campus for the technical and financial support.

## REFERENCES CITED

Hamdan, S., Mohamad Said, K. A., Faudzi Musib, A., Rahman, M. R., Sawawi, M., and Sinin, A. E. (2024a). "Pratuokng: The Borneo bamboo zither of Bidayuh Sarawak," *BioResources* 19(1), 1305-1315. DOI: 10.15376/biores.19.1.1305-1315.

Hamdan, S., Mohamad Said, K. A., Kipli, K., Duin, E. A. M., and Sinin, A. E. (2024b). "The Tongkungon: A Traditional Kadazan Dusun plucked musical instrument from Sabah, Malaysia," *BioResources* 20(1), 357-367. DOI: 10.15376/biores.20.1.357-367.

Hamdan, S., Mohamad Said, K. A., Rahman M. R., Sawawi, M., and Sinin, A. E. (2023). "Gambus hadhramaut: The Malaysian Malay lute tuning retrieval," *BioResources* 18(2), 3387-3399. DOI: 10.15376/biores.18.2.3387-3399

Hamdan, S., Musoddiq, I. A., Musib, A. F., and Sawawi, M. (2020). "Time frequency analysis of peking gamelan," *Pertamina Journal of Science and* Technology 28(2), 441-457

Hamdan, S., Said, K. A. M., Rahman, M. R., Sawawi, M., and Sinin, A. E. (2023). "Borneo lute sape: The frequency spectrum and time frequency analysis (TFA)," *BioResources* 18(4), 6761-6771. DOI: 10.15376/biores.18.4.6761-6771.

M. Duin, E.A., Hamdan, S., Mohamad Said, K. A., Sinin, A. E., Musib, A. F. and Sosiati, H. (2025). "The Nirai Guitar (Ichigo ichie) of Okinawa Japan," *BioResources* 20(2), 2643-2655. DOI: 0.15376/biores.20.2.2643-2655.

Sinin, A. E., Hamdan, S., Mohamad Said, K. A., Abdul Aziz, D.S. and Musib A. F. (2023). "Acoustics of the forgotten tapi two-strings lute of Lun Bawang," *BioResources* 18(4), 7905-7914. DOI: 10.15376/biores.18.4.7905-7914.

Sinin, A. E., Hamdan, S., Mohamad Said, K. A., M. Duin, E. A., and Musib, A. F. (2025). "The Hasapi of the Batak Toba from Sumatra Indonesia," *BioResources* 20(1), 1110-1126. DOI: 10.15376/biores.20.1.1110-1126.

Terry, M., and Sean, W. (2018). *The Garland Handbook of Southeast Asian Music*, Routledge, New York, NY.

The Metropolitan Museum of Art. (n.d.). Seung (https://www.metmuseum.org/art/collection/search/500927), accessed on 1st December 2024.

Article submitted: December 22, 2024; Peer review completed: February 16, 2025; Revised version received: March 2, 2025; Accepted: March 3, 2025; Published: March 11, 2025.
DOI: 10.15376/biores.20.2.3234-3251