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Time Frequency Analysis of Peking Gamelan

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ABSTRACT

The tone of peking 1, 2, 3, 5, 6, 1’ was investigated using time-frequency analysis (TFA). The frequencies were measured using PicoScope oscilloscope, Melda analyzer in Cubase version 9 and Adobe version 3. Three different approaches for time-frequency analysis were used: Fourier spectra (using PicoScope), spectromorphology (using Melda analyzer) and spectrograms (using Adobe). Fourier spectra only identify intensity-frequency within entire signals, while spectromorphology identify the changes of intensity-frequency spectrum at fixed time and Adobe spectrograms identify the frequency with time. PicoScope reading produces the spectra of the fundamental and overtone frequencies in the entire sound. These overtones are non-harmonic since they are non-integral multiples of the fundamental. The fundamental frequencies of peking 1, 2, 3, 5, 6 were 1066Hz (C6), 1178Hz (D6), 1342Hz (E6), 1599Hz (G6) and 1793Hz (A6) respectively while peking 1’was 2123Hz (C7) i.e. one octave higher than peking 1. Melda analyzer reading proved that all peking sustained the initial fundamental frequency and overtone at t=0 until 2s. TFA from Adobe reading provides a description of the sound in the time-frequency plane. From TFA, peking 1, 2 and 6 exhibited a much gentler attack and more rapid decay than peking 3, 5 and 1’.

Keywords: FFT, fundamental, gamelan, overtones frequencies, peking

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INTRODUCTION

Mantle Hood was one of the earliest pioneers of gamelan in the West that initiated gamelan performance study and understood the widest applications of gamelan (Sorrell, 1990). The measurements of scales and tunings were carried out in metallophones and xylophones found in Southeast Asia and on African xylophone with fixed tunings

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and related to equal temperaments (Schneider, 2001). When digital signal processing was introduced in the 1980s sound analysis and re-synthesis became available for investigating tone systems and tunings of non-Western music cultures (Schneider & Beurmann, 1990, Schneider & Beurmann, 1993). Ellis and Hipkins (1884), Stumpf (1901) and Kunst (1934) studied the metallophones of the Indonesian gamelan because the tunings in gamelan were different from the Western systems and was difficult to explain in terms of their origins with regard to relevant perceptual and cognitive issues. The data from some of the measurements helps in understanding the structure of *slendro* and *pelog* (Lentz, 1965; Hood, 1966; Morton 1976). New interpretations and hypotheses regarding the gamelan tone systems and their possible relationships to those of other regions were presented (Rahn, 1979; van Zanten, 1986; Widdess, 1993; Voisin, 1994). This topic has gained attraction for several generations of earlier researchers.

Gamelan music is in *pelog* or *slendro,* and cannot be reproduced by the piano tunings. This avoids confusion of Western music with specifically Javanese gamelan instrument. Composers such as Henry Cowell, John Cage and Lou Harrison were pioneers that were interested in Eastern cultures (Sorrell, 1990). Javanese, Balinese and Sundanese gamelans exist largely in America. In California, Dennis Murphy, William Colvig, Daniel Schmidt and Paul Dresher built their own gamelan from aluminium, scrapped cars and other materials (Sorrell, 1990). The American pieces for gamelan were composed along with the production of these instruments, where the Westerners rather than Indonesians who objected to such works. Historically the Javanese incorporated instruments from the Dutch military bands into their ensembles during the colonial period.

The most comprehensive set of data on gamelan tunings was published by Indonesian scientists (Surjodiningrat et al., 1972). Nevertheless, these measurements and numerical data lack of explanation of tuning as an art because it is regarded as a process guided by musical sensibilities and experience (Vetter, 1989). To understand tuning, the concepts and terminology of a tuner and his actions while tuning need to be considered and understood. The behavior and verbal comments of tuners must be taken into account where these data need to be checked with regard to reliability and cultural validity. Even a complete tuning event recorded with all of the verbal commentaries of a tuner might not necessarily reveal his cognitive framework regarding concepts such as step, scale, or octave equivalence in every detail (Schneider, 2001). The uniqueness of our research is visualizing the sound sonically through PicoScope oscilloscopes and Melda analyzer in Cubase version 9. The sound spectra of all peking are obtained from PicoScope measurements. After the data sound was captured and recorded the FFT was also analyze using Melda analyzer in Cubase version 9 to obtain dominant frequency for each tone at specific time.

The tuning of the seventeen keys (wooden bars) of Buganda *arnadinda* xylophone by Evaristo Muyinda when visiting the Ethnological Museum of Berlin in 1983 was recorded in complete detail in order to find out whether or not Muyinda tune the instrument according to the equipentatonic scale (Kubik, 1991). This experiment yielded some interesting results which indicated that the tuning was additive in nature (i.e. carried out by adding up an interval about the size of a major second) rather than being based on the division of an octave into equal parts. However, it is not totally clear whether his intention with respect to the tuning was finally achieved. The tuning was measured objectively by calculating the frequencies of the spectral components which represent the base mode of vibration of each bar which is *not* equipentatonic. It shows considerable deviations (standard deviation=30.6, range=97.5 cents) from the unit step of 240 cents that has been proposed with respect to both certain African scales and the Javanese and Balinese slendro (Schneider & Beurmann, 1990). The spectral components for the description of the tuning are decisive with respect to pitch. Precise measurement in this case permits examination of the work of the tuner and compared the interpretations that a number of ethnomusicologists have given as to intended tuning and scale structure with factual data.

Idiophones are instruments which, as the term implies, sound by themselves. Sound generation in instruments typically consist of three dimensional solid bodies such as bars, slabs, lamellae, plates, or shells is effected by an impulse which accelerates a given bar and plate. This causes a pattern of vibrations which consist of the eigen modes (natural frequencies) of the given body. In certain idiophones, bars or shells are set in motion by means of one or several mallets (e.g., gamelan instruments such as the Balinese gangsa (Kartomi, 1985). With the case of gongs such as the *bonang* or *trompong* the compound shape of each of the bossed result in complex patterns regarding both temporal and spectral behavior. Without going into details of vibrational theory (Cremer & Heckl, 1967; Fletcher & Rossing, 1998; Schneider, 1999), it can be said that bending stiffness and other factors (material and dimensions) of the vibrating solid cause in-harmonicity within the pattern of vibration as well as in the pattern of spectral components that can be extracted from the sound radiated. Since solids typically vibrate in two or even three dimensions, and produce a great many eigen modes, patterns of vibration can be quite irregular or even chaotic (in terms of nonlinear dynamics) in certain idiophones, notably in flat gongs such as the Asian *tam-tam* (Schneider, 1999). Further, because there are different types of vibration as well as frequency dispersion, in metallophones such as the Javanese saron (also called peking), modes need not be immediately and fully developed at the onset. Rather, actual distribution of spectral energy and temporal development of patterns of vibration depends considerably on the place at which the mallet hits the bar or plate as well as on the magnitude of the force transmitted through the impulse. As can be imagined, the number of eigen modes elicited in general increases in proportion with the force that is applied (Perrin et al., 2013). Thus, in styles of soft playing, the pattern of vibration is simpler and the spectral energy contained in a sound is lower than is the case in styles such as the gong kebayar in Balinese music

(McPhee, 1966) known for loudness as well as a metallic sound. There are, however, some instruments which respond in a very sensitive way to even small impulses because damping and other loss factors are small. This is particularly in the gender family which comprise of very thin bronze plates as keys suspended over tube resonators. In these instruments, a rich spectrum (including components at rather high frequencies (Schneider, 1999)), for each single plate is produced with the use of relatively small force.

In gamelan performances the mallet makes the contact and on some instruments the hands are used for damping. The tuning of gamelan is easy to grasp and distinguish one gamelan from the other. There are two types of tone set in gamelan instrument. There are pelog and slendro tuning. Slendro is a pentatonic scale with five notes and no semitones (exactly like the scale on the black notes of the piano). The five notes of slendro are more or less equally spaced but the black notes have clear difference between the whole tone and minor third. Pelog is easily distinguished from slendro because it has seven notes (not all seven are used) and the size of interval varies far more than slendro and includes semitones.

The terms simple and complex tone invariably stand for sinusoidal and non-sinusoidal sound respectively. Any periodic sound wave should be heard as a sum of sinusoidal components or partial with their corresponding frequencies. A complex tone is the sum of sinusoidal components or partial which are harmonics (Plomp, 1976). In general, a typical musical tone consists of a large number of harmonics with frequency ratios 1: 2: 3: 4: 5 etcetera. The sound of music instrument results in the sensation of single note with a single definite pitch which is equal to the pitch of the fundamental and a specific timbre depending upon the relative amplitude of the harmonics. Gamelan has their own characteristic in term of their tone and pitch. The intensity and frequency of the instruments are different between gamelan. The instruments also have different shapes and material. The peking has the shape of a bar with rounded shapes on the top side (Sethares, 2005). The frequency of gamelan Swastigitha and Kyai Kaduk Manis has been measured by Surjodiningrat et al. (1972) using oscilloscope (Sudarjana et al., 1993) while the gong frequency was measured by Kuswanto using sonogram (Pramudya et al., 2018).

In Pramudya et al. (2018) paper the bonang barung and peking frequencies were measured using Audacity. It is low cost software to record and analyse the sound. It can process the sounds to generate the FFT of them. The sounds were measured in the non-acoustical room (Hall of Universitas Ahmad Dahlan- a regular meeting room) where the gamelan is located. The frequency of Bonang Barung and Peking was measured at night to reduce the noise. Audacity software is used along with a computer, microphone, and speakers, to generate and observe the frequency spectra of various audio waveforms, from simple waveforms such as sine waves to more complex waveforms. Audacity as an education tool in high school level physics classrooms, including several in which students play simple musical instruments and study the resulting spectra in the time and frequency domain. The gamelan frequency especially the Laras Pelog of Bonang Barung is measured using Audacity and the frequency measurement between the Bonang Barung and Peking using Audacity is compared. Our experiments were conducted in the University Malaysia Sarawak (UNIMAS) Faculty of Applied and Creative Art (FACA) Music department studio with full acoustic room facility. The signal produced from both PicoScope and Melda analyzer both displayed sharp and distinct fundamental and overtone frequencies peak compared to the low signal level from the background noise. The PicoScope detects the whole voltage versus time signal and generate the whole intensity (dB) versus frequency signal. Using PicoScope the signals displayed voltage versus fundamental and overtone peaks at a particular time or intensity (dB) versus fundamental and overtone peaks at a particular frequency. When using Melda analyzer the spectrogram displays the intensity (dB) versus frequency at a specific time. Using Melda analyzer the changes of the intensity versus frequency can be detected every 0.5 second interval and thus displaying the changes of the intensity of the fundamental and overtones frequencies over time.

The intuitive tuning by the gamelan tuner in each village is normally based on what one feels to be true even without conscious reasoning. Using their instinct knowledge or understanding the tuning are based on their feelings rather than facts or proofs. Having said that, each has its references and therefore this study could be one out of many tuning schemes waiting to be extracted and scheme out. In this paper, we investigate the comparison of frequency measurements of peking using PicoScope oscilloscope, Melda analyzer in Cubase version 9 and Adobe version 3. The physical parameters of the tone that were analyzed are the sound pressure level and frequency. The non-harmonicity of the overtones was measured by the PicoScope while the time evolution of the dominant pitches was detected by the Melda analyzer. Fourier analysis yields the frequency content and associated TFA to understand the sound. The purpose of this work is to study the TFA in a peking sound. FFT performs a TFA of an input signal by hitting the peking. The time-frequency content of the signal is visualized by creating a spectrogram which is done by PicoScope, Melda analyzer and Adobe. The output is a time-frequency with intensity varying according to the frequency content of the signal. Understanding the spectra gives the pitch based on the equal tempered scale. Spectrograms display frequencies on a uniform scale, whereas musical scales such as the well-tempered scale are based on a logarithmic scale for frequencies (Johnston, 2009). Since the human ear is not capable of distinguishing the individual harmonics of a complex tone, the identification of the partials may be nearly impossible in listening to tones in a musical context (Plomp, 1976). Thus, experimental evidence using Adobe analyzing the frequency leads to TFA. We interviewed the behavior and verbal comments of tuners, but these data need to be checked with regards to reliability and cultural validity. Even a complete tuning event, recorded with all of the verbal commentaries of a tuner might not necessarily reveal his cognitive framework regarding concepts such as step, scale, or octave equivalence in every detail. Each assessed peking includes considerably distinct harmonic structures that have not been discussed in the research of Mantle Hood (Sorrell, 1990). Therefore, the objective of this work is studying peking harmonics which is a necessity since the peking is a major instrument of melody in any gamelan ensemble. Preliminary results of peking tuning from University Putra Malaysia (UPM), University Kebangsaan Malaysia (UKM), Universiti Teknologi Mara (UiTM) and Universiti Malaysia Sarawak (Unimas) indicate that there is a distinction in tuning for each peking evaluated despite the fact that the scale is usually Pelog or Salendro. This uniqueness can only be sonically visualized through PicoScope oscilloscopes and Melda analyzer in Cubase version 9. The sound spectra of all peking are obtained from PicoScope measurements. After the data sound was captured and recorded the FFT was also analyzed using Melda analyzer in Cubase version 9 to obtain dominant frequency for each tone at specific time.

MATERIAL AND METHODS

The cast bronze peking 1, 2, 3, 5, 6 and 1' was chosen from a range of Malay gamelan ensemble. Figure 1 showed a set of 6 peking. The acoustic spectra of the measured sets of just-tuned cast bronze peking which were made in Indonesia was captured using PicoScope oscilloscopes and Melda analyzer in Cubase version 9 to investigate the fundamental and overtone frequencies. Excitation was done by beating the peking with a mallet by an expert peking player. The microphone was held above the top surface along the axis of symmetry of the peking at a distance of about 20 cm. The frequency of peking was measured using PicoScope oscilloscope. The Picoscope software display the real signal which is voltage versus time and dBu versus frequency as shown in Figure 2. The frequency reading was verified by recording a sound of 1KHz from a signal generator. The microphone is a flat response microphone capable of capturing only 20Hz-20kHz. The setup to capture the sound is based on Owsinski (2009).

The arrangement of microphone and apparatus for the measurement are shown in Figure 3. The microphone was placed right above the bar. The PicoScope computer software (Pico Technology, 3000 series, Eaton Socon, UK) was used to view and analyze 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 analyzer, voltage-based triggers, and the ability to save/load waveforms to a disk. Figure 2 shows the schematic diagram of the experimental setup. The peking was placed to where the sound could be captured with minimum interference. In our work the recording was done in the University Malaysia Sarawak (UNIMAS) Faculty of Applied and Creative Art (FACA) Music department studio with full acoustic room facility. The signal produced from both PicoScope and Melda analyzer both displayed sharp and distinct fundamental and overtone frequencies peak compared to the low signal level from the background noise.

The amplifier (Behringer Powerplay Pro XL, Behringer, China) ensured the sound capture was loud enough to be detected by the signal converter. The peking spectra were also digitally recorded using the Melda analyzer in Cubase version 9. In conducting this study, the audio signal derived from the striking of the peking played by an expert peking player was recorded. The audio signal was recorded in mono, at 24-bit resolution, 48 kHz sampling rate. The audio signal was recorded with the aid of a digital audio interface in a .wav format. To ensure the recorded audio signal of the peking was at the optimum level, audio signal calibration of the recording system was carried out. A test tone of 1 kHz sine wave was used in calibrating the recording system. Here the 'unity' calibration level was at +4dBu or -10dBV and was read by the recording device at '0 VU'. In this regard the EBU recommended the digital equivalent of 0VU is that the test tone generated to the recording device of the experimentation is recorded at -18 dBFS (Digital) or +4dBu (Analog) which is equivalent to 0VU. In this thorough procedure of calibration, no devices are unknowingly boosting or attenuating its amplitude in the signal chain at the time of the recording is carried out. The recording apparatus was the Steinberg UR22 mkII audio interface, Audio-Technica AT4050 microphone, XLR cable (balance), with microphone position on axis (<20 cm), microphone setting with low cut (flat) 0dB.

Figure 1. A typical Malay Gamelan Peking

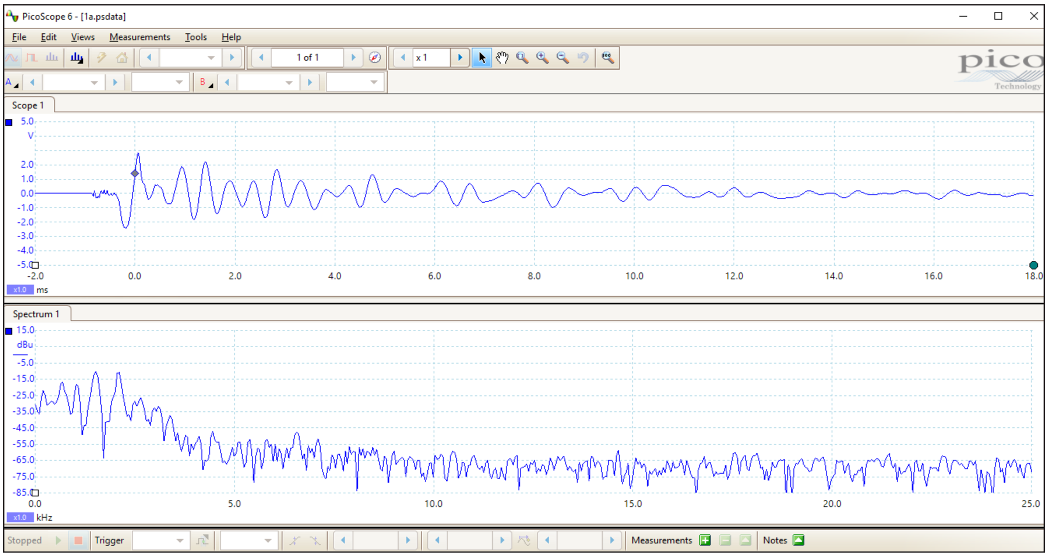

Figure 2. A typical signal which is voltage versus time and dBu versus frequency using the Picoscope software

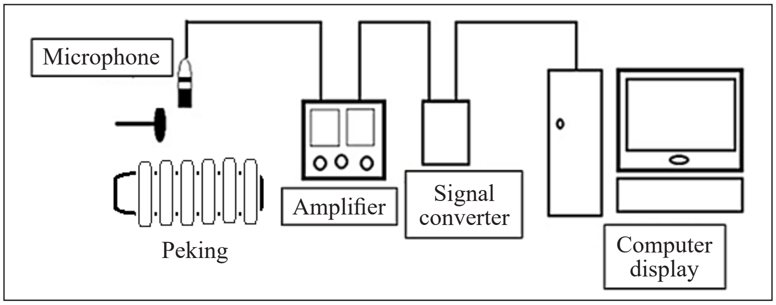

Figure 3. Schematic diagram of the experimental setups

RESULTS AND DISCUSSION

The sound spectrum of all peking from PicoScope measurements is shown in Figure 4 until Figure 9. Table 1 shows the calculated ratio for first, second, third, fourth and fifth overtone with respect to the fundamental frequency for each peking.

Table 1 shows that the overtones are non-harmonic of the fundamental except the first, second, third, fourth and fifth overtone for peking 6, 1, (2 & 1'), 3 and 2 respectively (highlight in bold). These non-harmonics yield difficulties in discriminating sound wave by human ear since individual harmonics are not easily distinguish because human ear is not capable of distinguishing the individual harmonics of a complex tone and the identification of the partials may be nearly impossible in listening to tones in a musical context (Plomp, 1976). Therefore, identification of the partial may be nearly impossible when listening to peking. From Figure 4 to Figure 9, the frequencies that are present in the signal are easily identified, but no information about time localization is available. After the data sound was captured and recorded the FFT was also analyzed using Melda analyzer in Cubase version 9 to obtain dominant frequency for each tone at specific time. The spectrogram from the Melda was used to identify time localized frequency content. Figure 10 to Figure 14 show typical pulse signal from peking 1 spectrogram at t=0, 0.5, 1, 1.5 and t=2s.

From the FFT analysis the dominant frequency of peking instruments using Melda analyzer is obtained in Table 2.

Table 1
The calculated ratio for first, second, third, fourth and fifth overtone with respect to the fundamental frequency for each peking

	f_o (kHz)	$1^{st}/f_o$	$2^{nd}/f_o$	$3^{rd}/f_o$	$4^{th}/f_o$	$5^{th}/f_o$
Peking 1	1.05	2.76	**3.11**	4.80	4.81	**6.7**
Peking 2	1.18	2.18	2.67	**5.05**	6.22	**7.03**
Peking 3	1.32	2.55	2.74	4.66	**5.03**	**-**
Peking 5	1.57	2.20	2.34	4.45	4.75	**5.38**
Peking 6	1.77	**1.93**	2.62	4.32	4.88	**-**
Peking 1'	2.10	1.76	2.55	**4.02**	-	**-**

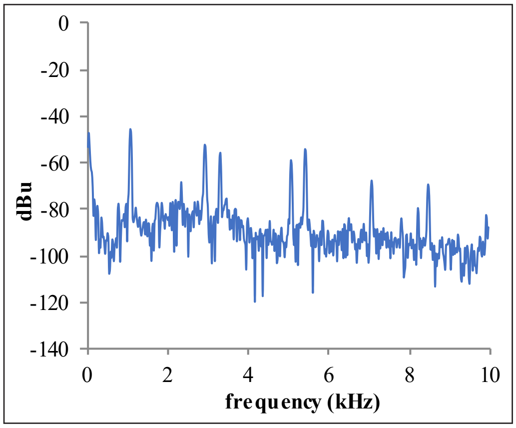

Figure 4. The sound spectrum of Peking 1 from PicoScope measurement

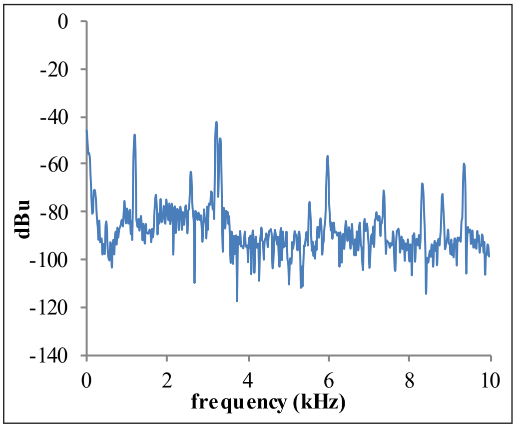

Figure 5. The sound spectrum of Peking 2 from PicoScope measurement

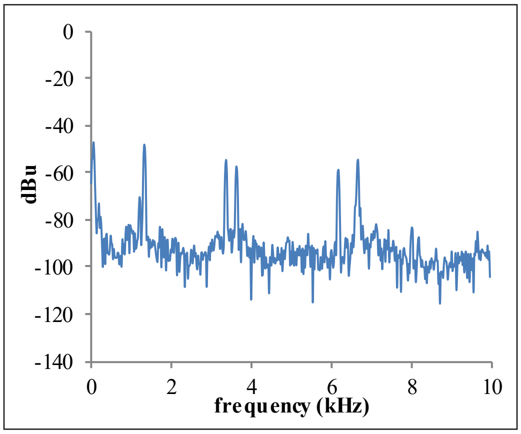

Figure 6. The sound spectrum of Peking 3 from PicoScope measurement

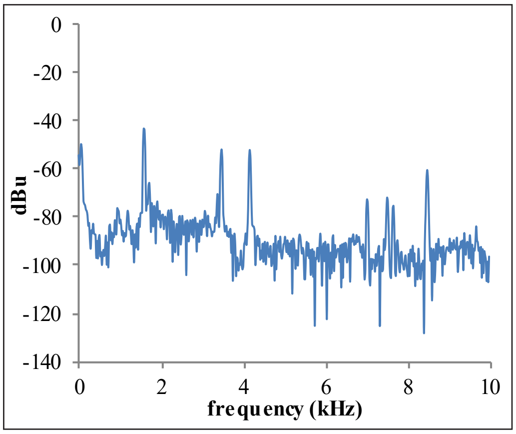

Figure 7. The sound spectrum of Peking 5 from PicoScope measurement

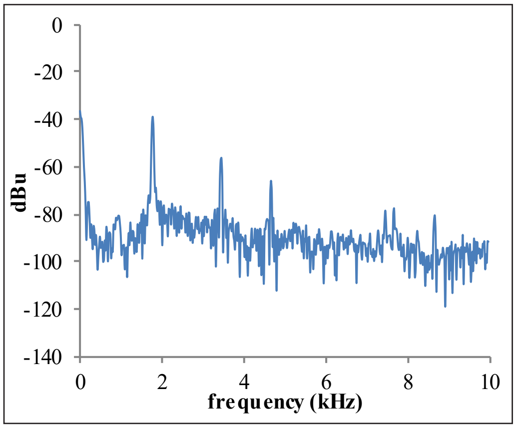

Figure 8. The sound spectrum of Peking 6 from PicoScope measurement

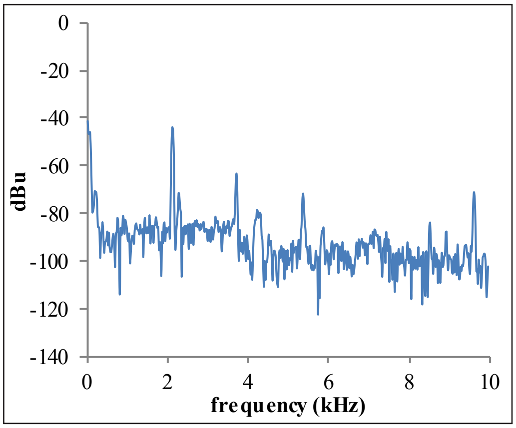

Figure 9. The sound spectrum of Peking 1’ from PicoScope measurement

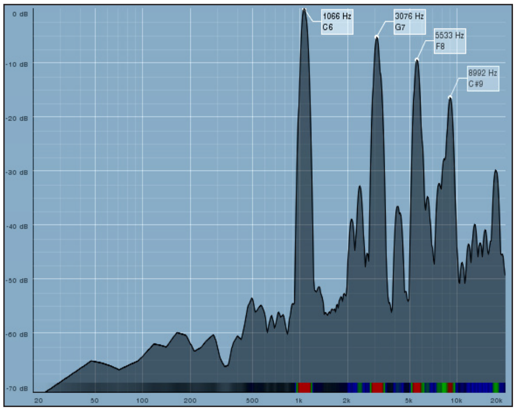

Figure 10. Typical FFT analysis of peking 1 at t=0 sec from Melda analyzer in Cubase version 9 measurement

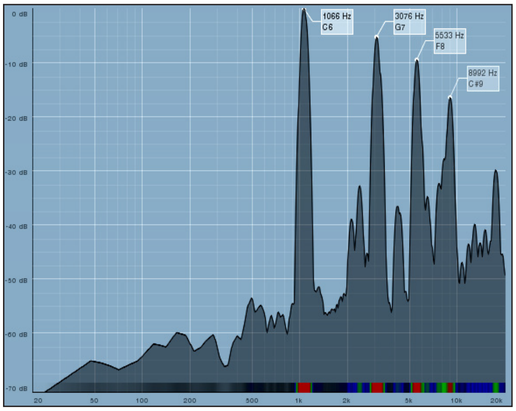

Figure 11. Typical FFT analysis of peking 1 at t=0.5sec from Melda analyzer in Cubase version 9 measurement

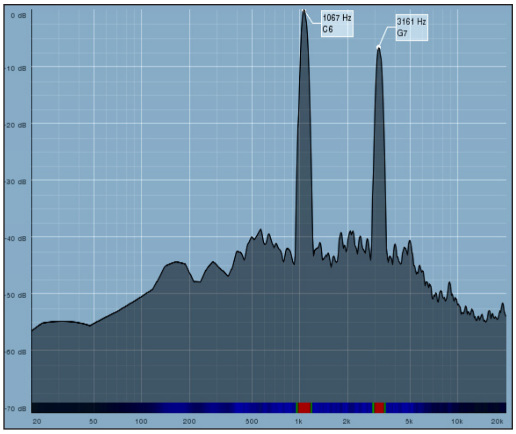

Figure 12. Typical FFT analysis of peking 1 at t=1sec from M elda analyzer in Cubase version 9 measurement

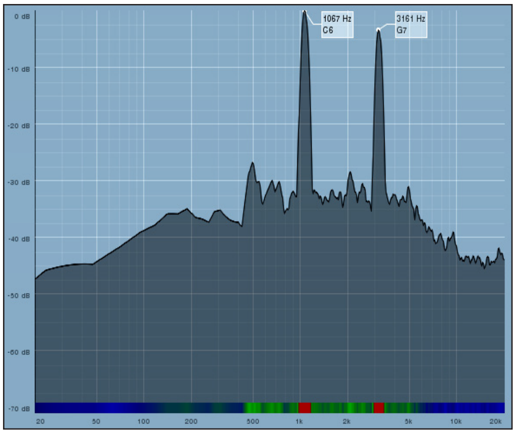

Figure 13. Typical FFT analysis of peking 1 at t=1.5sec from Melda analyzer in Cubase version 9 measurement

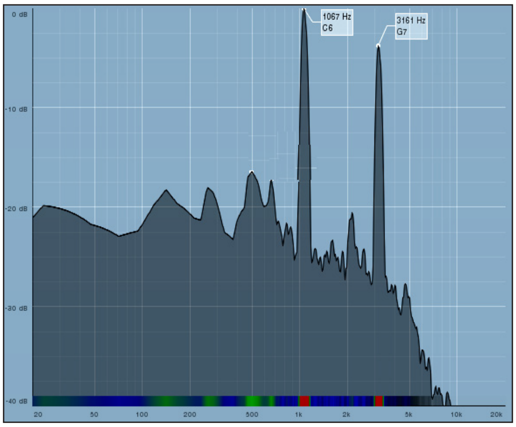

Figure 14. Typical FFT analysis of peking 1 at t=2 sec from Melda analyzer in Cubase version 9 measurement

Table 2
The dominant frequency (Hz) of peking 1, 2, 3, 5, 6 and 1' with their pitch using Melda analyzer

	frequency at t=0s (Hz)	frequency at t=0.5s (Hz)	frequency at t=1s (Hz)	frequency at t=1.5s (Hz)	frequency at t=2s (Hz)
Peking 1	1066(C6) 3076(G7) 5533(F8) 8992(C#9)	1067(C6) 3161(G7) 5494(F8)	1067(C6) 3161(G7)	1067(C6) 3161(G7)	1067(C6) 3161(G7)
Peking 2	1178(D6) 3247(G#7) 6040(F#8) 13000(G#9)	1180(D6) 3139(G7)	1180(D6) 3139(G7)	1180(D6) 3139(G7)	1180(D6) 3139(G7)
Peking 3	1342(E6) 3404(G#7) 6774(G#8)	1342(E6) 3379(G#7)	1342(E6)	1342(E6)	1342(E6)
Peking 5	1599(G6) 3521(A7) 7101(A8)	1599(G6) 3467(A7)	1599(G6) 3467(A7)	1599(G6)	1599(G6)
Peking 6	1793(A6) 3423(A7) 5356(E8)	1793(A6) 3423(A7) 5356(E8)	1793(A6) 3423(A7)	1793(A6) 3423(A7)	1793(A6) 3423(A)
Peking 1'	2123(C7) 3545(A7)	2123(C7) 3511(A7)	2123(C7) 3511(A7)	2123(C7) 3545(A7)	2123(C7) 3545(A7)

The measurements of frequency from peking using Melda analyzer are compared to the other measurements using different gamelan ensembles and methods (Table 3). Table 3 shows the frequency of pelog and slendro peking from other work using different ensembles and methods as references (Pramudya et al., 2018). Table 3 also shows the comparison to other frequency measurement on different gamelan ensembles i.e. from gamelan ITB (Institute Technology Bandung, Indonesia) using different methods (Pramudya et al., 2018).

From the results, the frequency measurements have small different compared to the references. These differences are due to different gamelan ensembles and methods. The frequency measurement of slendro peking 1, 2, 3, 5, 6 and 1' are having similar values as shown by the differences in Table 3. The peking in our works 1, 2, 3, 5, 6, 1' has the frequency 1066, 1178, 1342, 1599, 1793 and 2123 as compared to 1046 (C6), 1174 (D6), 1318 (E6), 1568 (G6), 1760 (A6), and 2093 (C7) respectively from the piano scale Table 3. This fact is interesting since the frequency different between our peking and the piano scale is quite small. Figure 15 to Figure 20 show the TFA from peking 1, 2, 3, 5, 6 and 1' over time with the black and grey part that explains its intensity at the frequency range on the vertical axis. The vertical scale on this figure is a frequency scale (in Hz), and the horizontal scale is a time scale (in second). This figure provides a description of the sound in the time frequency plane.

Table 3
The frequencies of pelog and slendro peking and their comparison to the other measurements (Pramudya et al., 2018)

Pelog tone	Hertz (Pramudya et al., 2018)	Gamelan ITB (Pramudya et al., 2018)	Slendro tone	Hertz (**) (Pramudya et al., 2018)	Gamelan ITB (Pramudya et al., 2018)	Our work (*)	**-*	Piano scale (***)	*-***
Peking 1	1176	1208	Peking 6’	928	928	-	-		
Peking 2	1272	1300	Peking 1	1075	1073	1066	9	1046	20
Peking 3	1409	1391	Peking 2	1234	1246	1178	56	1174	4
Peking 4	1643	1639	Peking 3	1423	1418	1342	81	1318	24
Peking 5	1765	1757	Peking 5	1636	1639	1599	37	1568	31
Peking 6	1862	1854	Peking 6	1870	1854	1793	77	1760	33
Peking 7	2101	2050	Peking 1’	2118	2167	2123	-5	2093	30

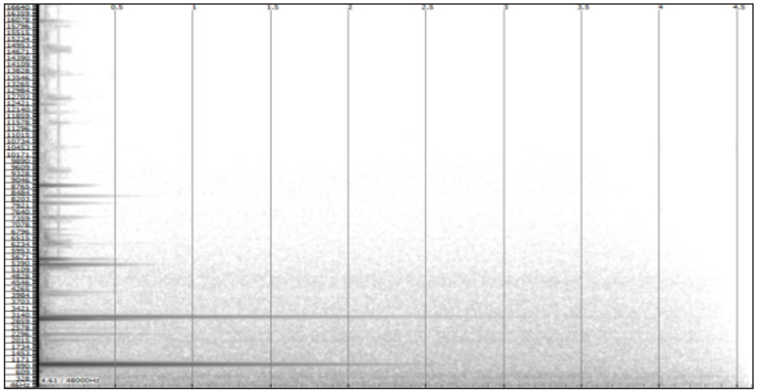

Figure 15. Time-frequency analysis from peking 1

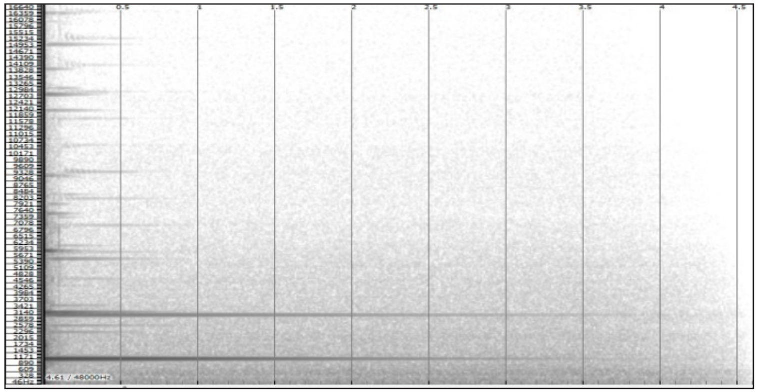

Figure 16. Time-frequency analysis from peking 2

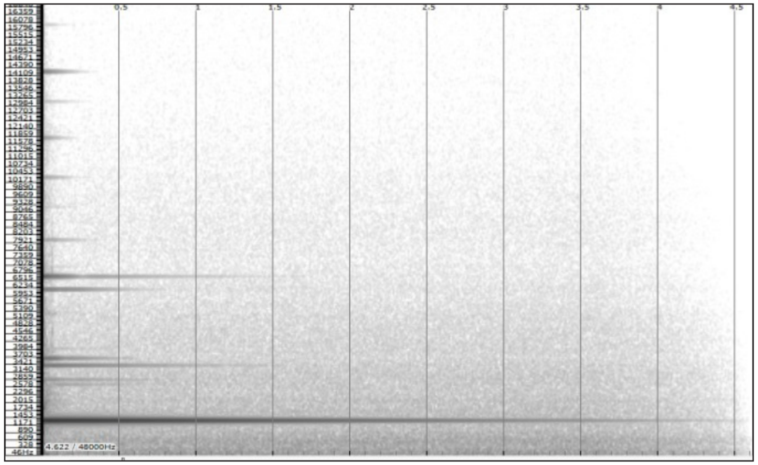

Figure 17. Time-frequency analysis from peking 3

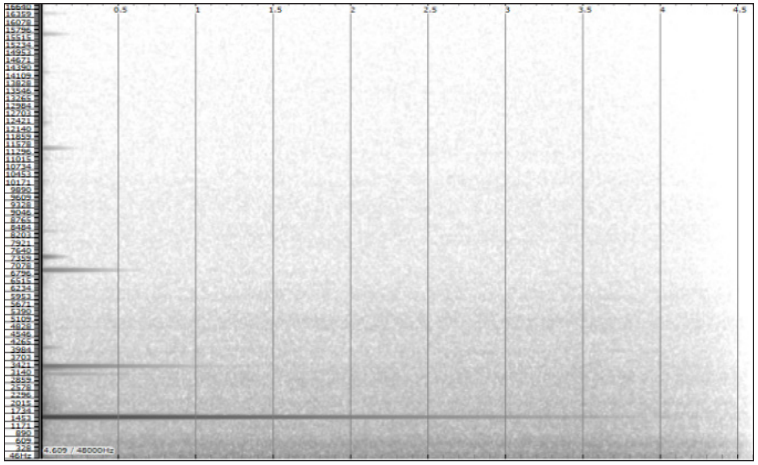

Figure 18. Time-frequency analysis from peking 5

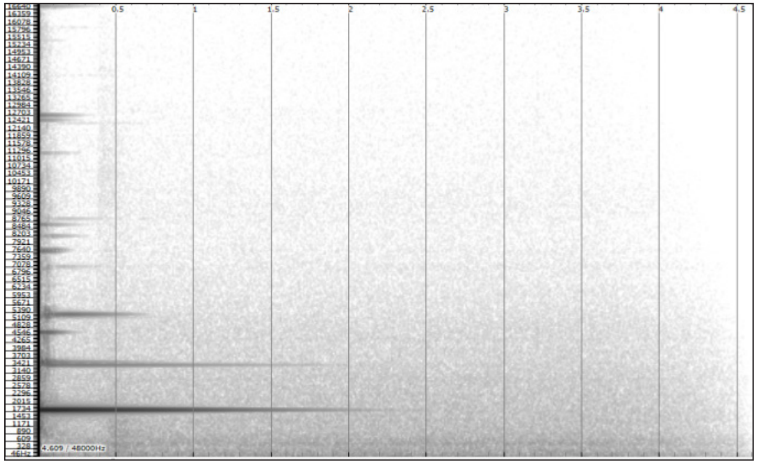

Figure 19. Time-frequency analysis from peking 6

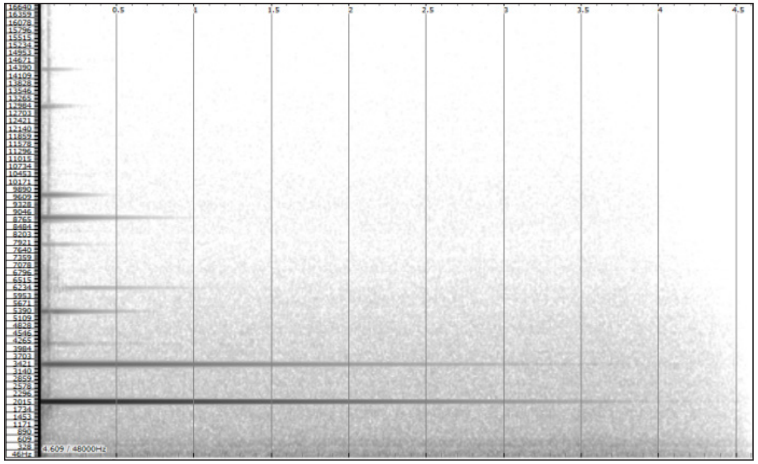

Figure 20. Time-frequency analysis from peking 1’

From the TFA, peking 1, 2, 6 and 1' obviously show 2 distinct peaks at the fundamental and overtone frequencies while peking 3 and 5 show a small intensity of overtones. The larger values of these spectra are displayed darker. The gray regions represent values that are near zero in magnitude. The spectra for the individual frequency are clearly separated in the y-axis and clearly divided into line segments, lying above each frequency and corresponding to the fundamentals and overtones in each note. There are clear differences between the attack and decay of the spectral line segments for the frequency obtained from peking. These differences are visible where a very prominent attack due to the striking by the mallet which is showed in the black regions in its spectrogram near the beginning of the fundamental and first overtone line segments for each frequency. These regions can be termed non-harmonic spectra, since they are non-integral multiples of the fundamental. These regions arise from transient, non-linear effects during the attack of each note. There is also a longer decay for peking 3, 5 and 1' due to the slow damping down of the peking vibrations which is evident in the overlapping of the black and gray part for each note line segment. Peking 1, 2 and 6 exhibits a much gentler attack and rapid decay than Peking 3, 5 and 1'. It is well known that, in addition to the harmonic structure of fundamentals and overtones, the precise features of attack and decay in notes are important factors in human perception of musical quality. This comparison of 5 peking illustrates how all of these features of musical notes can be quantitatively captured in the TFA provided by spectrograms.

Figure 21 illustrates a uniform scale of frequencies in the Adobe spectrogram of peking 1'. In this spectrogram there is a number of spectral line segments crowded together at the lower end of the frequency scale. Figure 21 identifies the pitch of the sound by the high pixel intensity. The fundamental and overtones frequencies correspond to the pitch of the sound. These line segments correspond to the fundamental and higher frequency peaks in the Fourier spectrum for the sound in Figure 22. Figure 22 spectrum shows a fundamental at 2.1 kHz which is close to the standard frequency of 2093Hz (for C7) and overtones at 3.7 kHz (which is close to the standard frequency of 3729 Hz for A#7), 5.36 kHz and 9.6 kHz. It is these frequencies that are crowded together in the spectral lines at the lower end of the spectrogram in Figure 21. These overtones frequencies ratio are approximately 1.8, 2.6, and 4.6 since $3.7/2.1=1.76\approx1.8$, $5.36/2.1=2.55\approx2.6$ and $9.6/2.1=4.57\approx4.6$ respectively. These overtones ratio are non-harmonic since they are non-integral multiples of the fundamental. It may be that they are overtones resulting from body cavity resonances in the peking. The sound can also be associated to the intensity frequency profile at particular time given by the spectrogram as shown in figure 14. It is straight forward to interpret the rest of the spectrogram with respect to time. The numbers on the vertical axis is directly interpreted as physical frequency values. These attributes are determined by Adobe for computing the frequency in Hertz and the pitch corresponding to the equal tempered scale.

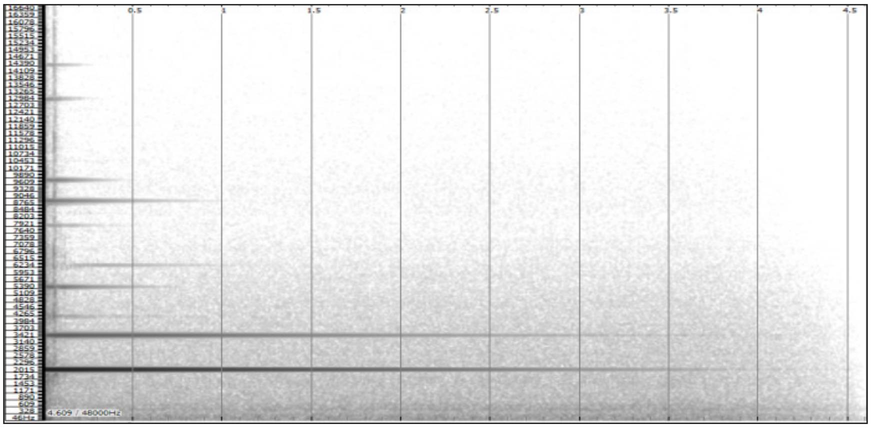

Figure 21. Time-frequency analysis (TFA) from Adobe for peking 1’

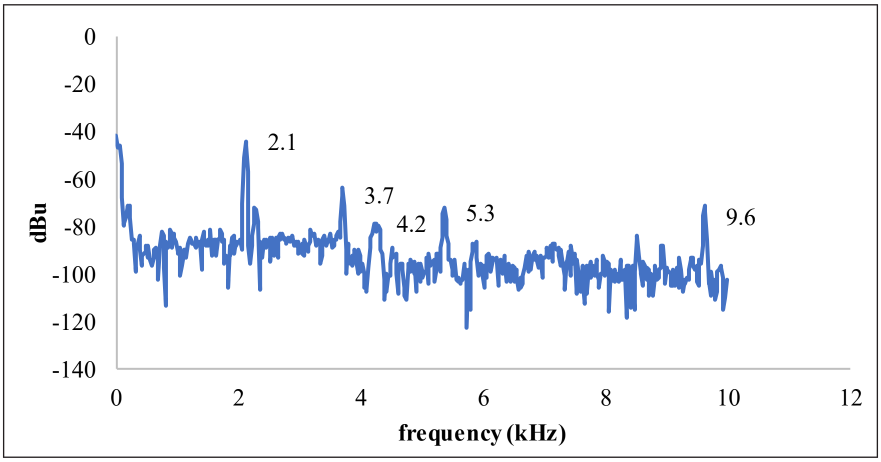

Figure 22. Frequency spectrum from PicoScope reading for peking 1’

CONCLUSION

The intuitive tuning by the gamelan tuner is normally based on their instinct knowledge or understanding the tuning is based on their feelings rather than facts or proofs. Each tuner has its references. Therefore, this study attempted to extract the intuitive tuning by the gamelan tuner and examined it using three different time-frequency analysis approaches: Fourier spectra (using PicoScope), spectromorphology (Using Melda analyzer) and spectrograms (using Adobe). PicoScope reading provides the fundamental and several overtones frequencies in the entire signals, while spectromorphology identify the changes of frequency spectrum at fixed time and Adobe spectrograms identify the frequency with time. The spectromorphology are associated with the intensity frequency profile captured at one particular time from the intensity frequency content of the signal. Adobe provides TFA with the black and grey part that explains its intensity at the frequency range stated on the vertical axis. The peaks from PicoScope are non-harmonic since they are non-integral multiples of the fundamental. Melda reading proved that all peking sustained the initial fundamental frequency and overtone at t=0 until 2s. TFA provides a description of the sound in the time frequency plane. From TFA, peking 1, 2 and 6 exhibit a much gentler attack and more rapid decay than peking 3, 5 and 1’.These non-harmonics yield difficulties in discriminating sound wave by human ear since individual harmonics are not easily distinguished because human ear is not capable of distinguishing the individual harmonics of a complex tone and the identification of the partials may be nearly impossible in listening to tones in a musical context. The identification of the partial may be nearly impossible when listening to peking but the frequencies that are present in the signal are easily identified, with information about time localization giving dominant frequency for each tone at specific time.

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