The Temporal and Spectral characteristics of Gamelan Sunda Music

I.G.N. Merthayasa and B. Pratomo

Institute of Technology Bandung, Dept. of Engineering Physics - ITB, Jln. Ganesha no. 10,
40132 Bandung, Indonesia
ignmerth@tf.itb.ac.id

In order to design a dedicated Concert hall for Gamelan Sunda, first of all, it is important to determine the temporal and spectral parameters of Gamelan Sunda Music (Degung Music). Gamelan Sunda's music compositions are strongly affected by the sound envelope and timbre. The fundamental frequencies of instrument keys also affect the musical scale, notes placing and the communication between the musical ensembles. The acoustical parameters of the anechoic studio recorded sound waves has been analyzed to determine the acoustical parameters. The sound envelopement factors have been compared with the note configuration in the musical composition, in order to analyze the influence of the sound envelopement to the music composition. In addition, the effective duration of the autocorrelation has also been analyzed to determine the preffered reverberation time in the proposed Concert hall for Gamelan Sunda.

Keywords : *Gamelan Sunda, concert hall, the effective duration of the autocorrelation, reverberation time.*

1 Introduction

1.1 Gamelan

Gamelan is kind of traditional musical ensemble art form originated from Indonesia. As an ensemble, gamelan features numbers of musical instruments. The instruments have some unique characteristics that distinguished themselves from contemporary musical instruments, such as using different musical scales. Gamelan's musical composition use traditional pentatonic (five notes) scales, *salendro* and *pelog*. The word "gamelan" derives for "*gamel*", which means "to strike" [6].

The main material of gamelan is a metal alloys, consist of 77% copper and 23% tin [10]. The fabrication of gamelan ensemble is a complex process, and requires experienced gamelan makers or "*mpu*".

The gamelan's ensemble consists by:

- *Bonang* : two lines of seven small sized "*penclon*"-shaped keys, mounted on a horizontal frame
- *Saron* : xylophone-liked musical instrument, made of metal and consist of fourteen notes, mounted on a horizontal frame.
- *Jengglong* : six medium sized "*penclon*"-shaped keys, mounted on a vertical frame.
- *Goong* : two big sized "*penclon*"-shaped keys, hanged on a vertical frame.
- *Kendang* : Consist of three pieces of traditional drums, covered by calf skin membrane.

Besides using its own traditional musical scales, gamelan has a lot of uniqueness. Not like the European classical music, the musical instruments in the gamelan ensemble can't perform the musical composition as a stand-alone instrument. One of the distinguished uniqueness is the notes configuration. In contemporary musical instrument, the first note is the base not, but in the gamelan, the first note is the third note [6]. The base note is located at the fifth note. The instrument notes arrangements illustrated in Fig. 1 and Fig. 2.

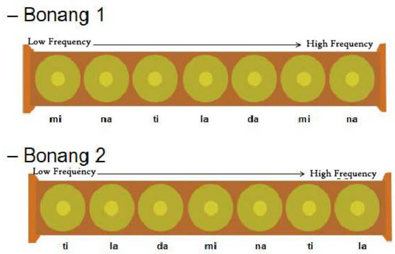

Fig. 1 *Bonang* Note Arrangements

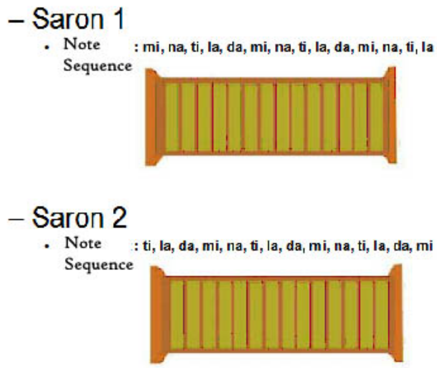

Fig. 2 *Saron* Note Arrangements

Despite its origins, gamelan does not develop well in Indonesia. There is no suitable concert hall for gamelan and no well improved recordings either, although there are many gamelan group spread over the country. These facts have proved that the development of Indonesian traditional music should be enhanced using the latest well developed technology, especially in the field of acoustics.

The development of concert halls, which is specifically and dedicated for gamelan music, will help to promote gamelan music to the public. Certainly before building a concert hall, the acoustical characteristic of the instruments and music must be known. Unfortunately, only few persons, such as gamelan artists, cultural observers and gamelan makers whose understand the subjective characteristics of gamelan. Based in the facts, researches on objective acoustical characteristics need to be established.

1.2 Acoustical Characteristics Of Musical Instrument

Every musical instrument produces a unique sound wave with distinguished characteristics. Human's hearing perception could detect the differences between two or more musical sound waves. The unique characteristics of sound wave can be determined by frequency, sound pressure level, time duration of sound wave's propagation, and time envelope [2].

Those acoustic parameters received by the human's hearing system, and caused an influence to the hearing perception. This influence is the main cause, why human can differentiate the sounds that came from several different musical instruments [3]. Human perception on several sound sources can be analyzed based on physical acoustic parameters, such as:

1 Pitch, is a human perception towards fundamental frequency

2 Loudness is a human perception towards sound pressure level.

3 Timbre, or sound colour, is the main factor that can distinguished various types of sound waves, consist of :

3.1 Harmonic Content : Representing the component of frequencies hat exist in a sound wave.

3.2 Sound Envelope : Representing the amplitude alteration of a sound wave, compared with the sound duration, illustrated in Fig. 3.

3.3 Vibrato : A musical effect, produced on musical instruments by a regular pulsating pitch shifting.

3.4 Tremolo : A regular and repetitive variation in amplitude for the duration of a single note.

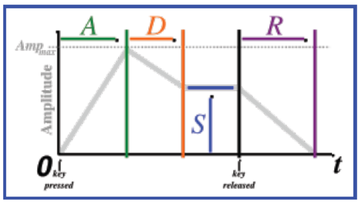

Fig. 3 Sound Envelope

1.3 Autocorrelation Function

Autocorrelation is a mathematic formula being used to analyze a time based-function or series, such as sound wave signal. Autocorrelation formula works by correlating a signal with the signal itself. The applications of the autocorrelation function are to detect repetitions pattern in a signal, such as determining the existence of a periodic form under a noisy signal. The other application is to identifying a fundamental frequency under a harmonic frequencies-dominant signal. In signal processing, autocorrelation function is being used to detect tempo, although the time attribute if the tempo cannot be detected.

Autocorrelation function is described in Eq (1).

$$\Phi_p(\tau)=\lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{+T}p(t)p(t+\tau)dt \qquad (1)$$

p(t) = sound wave equation (N/m^2)
τ = delay time (s)
2T = integration interval (s)

τ_e is a unique parameter that related to the autocorrelation process. The parameter τ_e is obtained at the ten percentile(or – 10 dB) delay of the envelope of the ACF of a source signal, the – 60 dB delay time of the ACF-envelope corresponding roughly to the "reverberation time" containing the source signal itself. The reverberation time determine the suitable places for presenting the sound wave. The value of τ_e also shows the richness of frequency components. The higher τ_e value indicates that the reverberation components in the audio signal are high [1]. The high reverberation components indicate the audio signals have few frequency components. In this case, the audio signals are gamelan *degung sunda* compositions.

τ_e function is described in Eq.(2)

$$\tau_e = 10\log_{10}|\phi_p(\tau)|[dB] \qquad (2)$$

ϕ_p = autocorrelation function
τ = delay time (s)

2 Experiment

2.1 Measurement

The gamelan's sound waves is recorded in a semi anechoic chamber with 5,43 x 4,47 x 2,5 meters (l x w x h) dimensions, after considering the resonance mode at the recording chamber. The resonance mode can produce interference patterns inside the chamber, which could disturb the recording process. The anechoic chamber has a resonance mode at frequency 250 Hz [6]. As illustrated in Fig. 4, the resonance mode causes an interference pattern.

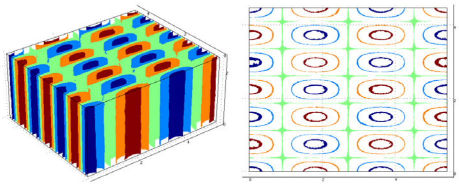

Fig. 4 Anechoic Chamber's Room Mode

But since the recorded waves are not stationary waves, the room resonance mode can be ignored. Three microphone has used in the recording process, StudioProject B3 (condenser) and two dynamic BSWA MPB201 microphones.

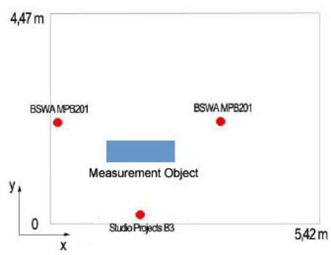

Fig. 5 Recording Position Layout

The measured gamelan ensemble is owned by The Sundanese Art Students Organisation in Bandung Institute of Technology. The scale is *pelog*, which is according to the expert at the Organisation, has a compatibility with pentatonic minor scale.

2.2 Autocorrelation Measurement

Five songs are being used in the auto correlation measurement. *Sabilulungan, Dina Jandela, Dikantun Tugas, Bandung* and *Ayun Ambing* are analyzed by Yoshimasa YMEC Sound analyzing system to determine the value of τ_e which contained in the compositions. Obtained τ_e values could be helpful to determine reverberation time of the exhibition hall/concert room that suits gamelan music exhibition.

3 Measurement Result

3.1 Frequency Components

From the measurement result, the obtained frequency range for *bonang* extends from a certain amount between 250 Hz to 1,6kHz. For *saron*, the frequency range extended from 250 Hz to 2 kHz. The notes configuration between the two instruments is different. The second *bonang*'s notes are extension to the first one, whereas for *saron*, the second saron take the base tone from the third note of the first saron. *Goong* has fundamental frequency range extend from 125 Hz to 250 Hz. Whereas *jengglong* also has frequency range extends from 125 Hz to 250 Hz, but with more many notes than *goong.*

3.2 Sound Pressure Level

The Sound Pressure Levels of the instruments have even distribution. *Kendang* is the instrument of gamelan that has the lowest sound pressure level, which has an average value for about 79.92 dB. Whereas, *Saron* is the instrument which has the highest Sound Pressure Level, with the average value of Sound Pressure Level for about 87.78 dB.

3.3 Time Envelope

3.3.1 Attack Time

Like any other percussive musical instruments, gamelan instruments have a fast attack time. *Goong* is the instrument of gamelan that has the slowest attack time, which has an average value for about 0,14 s. Whereas, *Bonang* is the instrument with the fastest attack time, which has an average value for about 1,6 ms.

3.3.2 Decay Time

In the gamelan sound waves sound envelopes, decay time duration is the longest event. *Goong* is the instrument of gamelan that has the slowest decay time, which has an average value for about 4.33 s. Whereas, *Kendang* is the instrument with the fastest decay time, which has an average value for about 82,5 ms.

3.3.3 Sustain Time

Gamelan instruments have a long sustain time. *Goong* is the instrument of gamelan that has the slowest sustain time, which has an average value for about 3,08 s. Whereas, *Kendang* is the instrument with the fastest sustain time, which has an average value for about 48,3 ms.

3.3.4 Release Time

Goong is the instrument of gamelan that has the slowest sustain time, which has an average value for about 1,433 s. Whereas, *Kendang* is the instrument with the fastest sustain time, which has an average value for about 34,1 ms.

4 Discussion and Conclusion

4.1 Fundamental Frequency

A comparison between the gamelan's traditional scale and the contemporary musical scale has to be done in order to prove the compatibility.

Bonang 1	f		f reference	difference	note
1	250		225	25	mi
2	250		260	10	na
3	315		300	15	ti
4	400		337.5	62.5	la
5	400	Next octave	400	0	da
6	500		450	50	mi
7	500		520	20	na
Bonang 2	f		f reference	difference	note
1	630		600	30	ti
2	800		675	125	la
3	800	Next octave	800	0	da
4	1000		900	100	mi
5	1000		1040	40	na
6	1250		1200	50	ti
7	1600		1350	250	la

Table 1 Comparison between *Bonang*'s Fundamental Frequencies and Pentatonic Minor Scale

From the comparison table, it can be seen that the difference between *bonang*'s fundamental frequencies and pentatonic minor scale frequencies has a repeating pattern. Every octave shifting, the difference value become twice larger than the differences compared to the previous octave. The difference's pattern shows that the *pelog* scale has no compatibility with the pentatonic minor scale.

Saron 1	f		f reference	difference	note
1	250		225	25	mi
2	250		260	10	na
3	315		300	15	ti
4	400		337,5	62,5	la
5	400	Next octave	400	0	da
6	500		450	50	mi
7	500		520	20	na
8	630		600	30	ti
9	800		675	125	la
10	800	Next octave	800	0	da
11	1000		900	100	mi
12	1000		1040	40	na
13	1250		1200	50	ti
14	1600		1350	250	la

Saron 2	f		f reference	difference	note
1	315		300	15	ti
2	400		337,5	62,5	la
3	400	Next octave	400	0	da
4	500		450	50	mi
5	500		520	20	na
6	630		600	30	ti
7	800		675	125	la
8	800	Next octave	800	0	da
9	1000		900	100	mi
10	1000		1040	40	na
11	1250		1200	50	ti
12	1600		1350	250	la
13	1600	Next octave	1600	0	da
14	2000		1800	200	mi

Table 2 Comparison between *Saron*'s Fundamental Frequencies and Pentatonic Minor Scale

From the comparison table for *saron*, the same differences value pattern with *bonang* also occurred.

4.2 Sound Envelope

The sound envelope characteristics that derive from the instruments through recording process could diffuse if the instruments playing together in a composition. The diffusion could be happen because of the interfering sound waves produced by the gamelan instruments. Because of that phenomenon, comparison between measured sound envelope and the sound envelope originated from the song compositions has to be done. *Saron* and *bonang* are the dominant and melodic musical instruments in the gamelan ensemble.

Bonang is the lead melodic instruments in the gamelan music's arrangement. In the gamelan music arrangement, the distance between two notes or the tempo never changes from the beginning of the song until the song stops

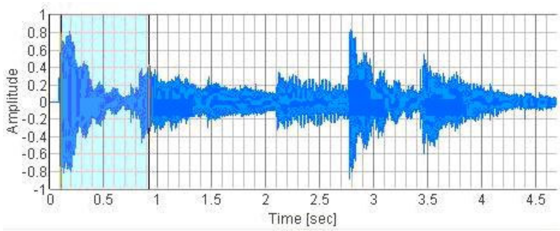

Fig. 6 Bonang performance in "*Sabilulungan*"

Fig 6 shows the distance between notes in a bonang performance in the song titled "*Sabilulungan*". The distance is 0,81s, and as described before, the average of bonang decay times is 0,89s. It shows that bonang performance would not be disturbed by interference phenomena, because when the player strike the next note, the sound wave produced from the previous note has reached the sustain time.

Saron, in the gamelan music's arrangement, has a role as the melody accompanist. Just as *bonang*, the note distance in an arrangement would not change, from the beginning of the song until the song stops.

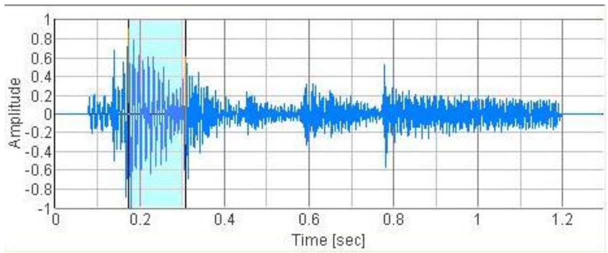

Fig. 7 Saron performance in "*Sabilulungan*"

Fig 7 shows that the distance between notes in a saron performance in "*sabilulungan*" is 0,14 s. As described before, the average decay time for *saron* is 1,30 s. That means if *saron* players hit the notes normally, there would be an interference phenomena. But the gamelan music's arrangements do not allowed any interference between notes from the same instrument, because it would ruin the sound composition. In that case, there is a specific technique in saron playing, it is called "*menengkep*". *Menengkep* is a technique where the players touch the saron's keys in order to shorten the decay time. This technique is very important in cancelling the interference phenomena.

4.3 Autocorrelation

From the τ_e value graphs, the value is dominant at 100 ms. It is proven by the average values of the songs that used in the autocorrelation process: "*Sabilulungan*" with the average τ_e value is 108,1 ms, "*Dina Jandela*" with the average τ_e value is 127,5 ms, "*Dikantun Tugas*" with the average τ_e value is 146,6 ms, "*Bandung*" with the average τ_e value is 109,8 ms, and "*Ayun Ambing*" with the average τ_e value of τ_e is 99,8 ms. The τ_e values of the "*Sabilulungan*" and "*Dina Jandela*" are shown in Fig. 8 and Fig. 9. From Fig. 10, gamelan music can be classified between orchestra music and organ pipe music, with 2, 4 s as the suitable reverberation time.

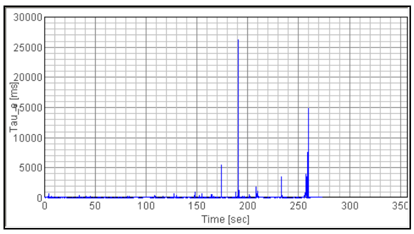

Fig. 8 τ_e value of "*Sabilulungan*"

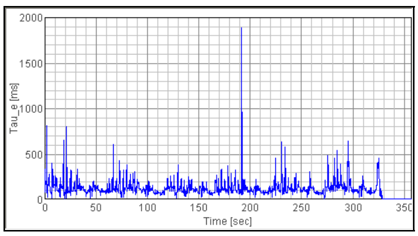

Fig. 9 τ_e value of "*Dina Jandela*"

For flat frequency characteristics reverberation, the preferred subsequent reverberation time is expressed approximately by Eq.(3) :

$$[T_{sub}]_p \approx 23\tau_e \quad (3)$$

T_{sub} = Reverberation Time

τ_e = Ten percentile value of the ACF envelope delay

The τ_e values also show the richness of the audio signal's frequency components. Higher τ_e value means that there's only a few frequency components inside the audio signals. In the gamelan compositions, the high τ_e values indicate that the ensembles stop playing to make room for one instrument to play solo performances.

From Eq.(3), the suitable values for gamelan's reverberation time could be known. Fig. 10 represents the relationship between various sound sources and the suitable reverberation time for the audio signals.

The gamelan's music, with τ_e values varied from 99,8 ms until 146,6 ms has a suitable reverberation time values varied from 2,3 s to 3,4 s.

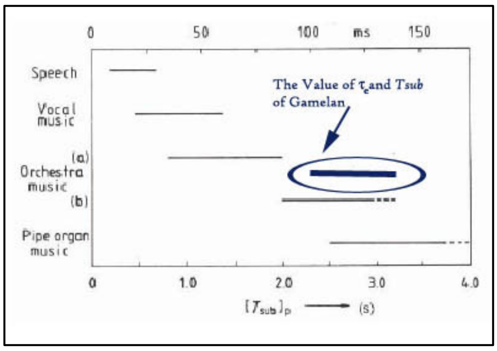

Fig. 10 Relationship between τ_e from various sound sources and the suitable reverberation time

4.4 Conclusion

From the comparison between *pelog* musical scale and the pentatonic minor scale, it can be seen that there is no compatibility between the scales. The difference pattern shows that the *pelog* scale has no relationship with the pentatonic minor scale. The gamelan's scale, in this case *pelog* scale, is a pure Indonesian traditional musical scale.

Gamelan's music arrangement and the gamelan's playing technique has been arranged in such a way that prevent any wave interferences between the musical instruments. The *Bonang*'s playing technique and the notes arrangement regulate the spaces between notes, to prevent interferences. In *Saron* playing technique, there is one specific technique called "*menengkep*". This specific technique prevents the interferences from happening, by altering the duration of the decay time to shorten.

The τ_e values from the gamelan's music composition had showed that the suitable reverberation time value for the gamelan music exhibition is around 2.3 s until 3.4s. The suitable reverberation time also correspond with the sound envelopes of gamelan's musical instruments, especially the decay and sustain time. The sustaining gamelan's audio waves need a chamber that could support the nature of gamelan's sound.

For the future research, there is a lot of problems need to be solved. The characteristics of other gamelan ensembles need to be measured. Especially from the gamelan ensembles that come from another regions with different traditional musical scales. The spatial characteristics of the gamelan's musical instrument also need to be known, to complete the archive of the acoustic characteristics.

The research that focused on gamelan concert hall designs, the improvements of gamelan's music recordings and gamelan recording studio designs will help the socialization process of the richness and humane gamelan's music and culture.

References

[1] Yoichi Ando, "Architectural Acoustics", *Springer-Verlag*, New York, (1998)

[2] William A. Sethares, "Tuning, Timbre, Spectrum, Scale", *Springer-Verlag*, (2005)

[3] Carl R. Nave, Hyperphysics, "Sound Quality or Timbre", *http://hyperphysics.phyastr.gsu.edu/hbase/hframe.html*, (2006)

[4] Andhika Pradana, Bayu Pratomo, Yuriano Adikusumo, "Analisis Karakteristik Akustik Instrumen Musik Saron – Gamelan Jawa dan Sunda", *Tugas Khusus: Program Studi Teknik Fisika Fakultas Teknologi Industri Institut Teknologi Bandung*, (2006) – (In Indonesian Language)

[5] Randi Bayu Prathama, "Disain Konfigurasi Loudspeaker Untuk Memperluas Cakupan Area Pendengaran Dengan Metoda Perbandingan Penyebaran Polar", *Tugas Akhir: Program Studi Teknik Fisika Fakultas Teknologi Industri Institut Teknologi Bandung*, (2006) – (In Indonesian Language)

[6] Maman Suarman S.Kar, "Penuntun Praktek Gamelan Dasar", *Akademi Seni Tari Indonesia Bandung*, (1986) – (In Indonesian Language)

[7] Rahayu Supanggah, "Bothekan Karawitan I", *Masyarakat Seni dan Pertunjukkan Indonesia*, (2002) – (In Indonesian Language)

[8] Pandi Upandi BA, "Gamelan Tradisi", *Akademi Seni Tari Indonesia Bandung*, (1982) – (In Indonesian Language)

[9] Pandi Upandi BA, "Gending Tradisi, Gamelan Pelog Dan Salendro", *Akademi Seni Tari Indonesia Bandung*, (1986) – (In Indonesian Language)

[10] Ir Priadi Dwi Hardjito, "Mengenal Gamelan Dan Pembuatannya", *Penerbit ITB*, (1981) – (In Indonesian Language)

[11] Hadi Santoso, "Tuntunan Memukul Gamelan", *Dahara Prize*, (1986) – (In Indonesian Language)