# Analysis of Thai Tuning System by Mathematical Formula

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## Abstracts

This study focuses on the traditional Thai tuning system. Tunings of Thai classical music has been a source of disagreement. Focusing on Ranat Ek, by measuring the vibration frequency of each sound, we can analyze the sound cents of intervals, and calculate whether intervals are consonant through the existing mathematical formula. By comparing the vibration data of Ranat Ek on various school instruments, the data are analyzed, and mathematical formulas are used to calculate whether the Thai tuning system consonance or not. Research objectives were (1) to measure the tuning systems of each school to get reliable data. (2) To study the formula of western tuning system that used to measure Thai tuning system, and a tuning system is recommended as the standard of Thai tuning system. This study was qualitative research which collected data by interview 8 experts.

The result was although schools have different tuning systems, more and more schools are choosing the government's tuning system as the standard. The author boldly predicts that this is the future development trend of Thai tuning systems.

**Keywords:** Thai Tuning System; Mathematical Formula; Thai Music

## Introduction

In European music, an octave is divided into 12 notes, called the equal temperament (equal temperament is a musical temperament or tuning system approximating just intervals by dividing an octave (or another interval) into equal steps. The ratio of the frequencies of any adjacent pair of notes is the same, giving an equivalent perceived step size as the pitch is roughly the logarithm of the frequency, and there are 100 cents between nearly two notes. Thai music divides an octave into seven equal parts. Between two relative notes are 171.4 cents. So, when a person used to Western music listens to Thai music for the first time, it feels out of tune. This tuning system was first proposed by Alexander J. Ellis, who introduced the idea that Thai tuning was an equal-heptatonic scale and claimed this was an "ideal" tuning. Alexander J. Ellis was an English mathematician. He is a philologist and early phonetician who also influenced the field of musicology. Alexander J. Ellis was the first to measure Thai Musical Instruments' vibration frequency. In Buddhist calendar 2564, Ministry of Culture, Department of Fine Arts, Music Division, regulated Announcement about Tuning System based on Ellis's research. This document regulates the tuning system of Musical Instruments in Thailand and has legal effect. But the tuning system varies from school to school. The researchers will collect the vibration frequency, calculate it, and recommend a tuning system based on the actual situation in Thailand as the standard for subsequent research.

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## Research Objectives

1. To measure the tuning systems of each school to get reliable data.
2. To study the formula of western tuning system that used to measure Thai tuning system, and a tuning system is recommended as the standard of Thai tuning system.

## Literature Review

If we hold the string of a stringed instrument with the same force, the shorter the string vibrates the faster it vibrates and the higher its pitch. Make the string ½ in length and hold the force constant, and the pitch goes up an octave. When a string starts to vibrate, not only does the whole string vibrate, but the sound produced at a length of ½ is an octave higher. When lengths are ⅓, the pitch is 12th higher (octave + Perfect 5th). This means that one sound is actually a compound of octaves、twelve(octave + Perfect 5th)、seventeen (2 times octave + Perfect 3nd)、and so on. We call the vibration of the whole string fundamental tone. The various sounds produced by segmentary vibration are called overtone or partial.

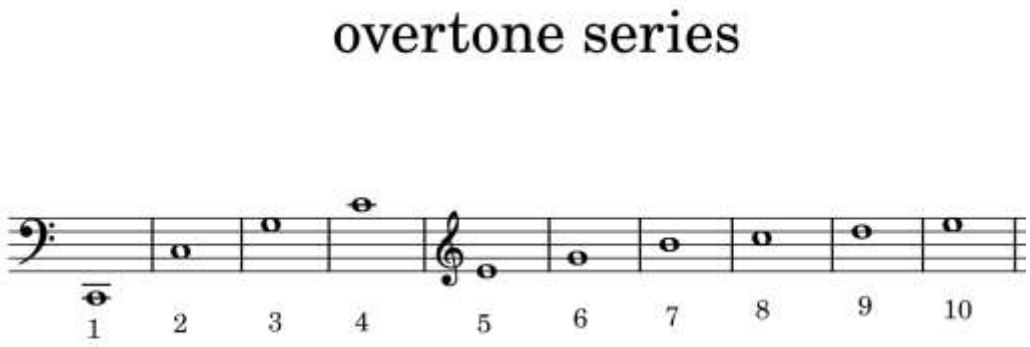



**Figure** 1 Overtone series

In the picture, the first tone is fundamental tone. The second tone is 1st Overtone, the third tone is 2nd Overtone, and so on. In other words, overtones are all pitches higher than the lowest pitch within an individual sound; the fundamental is the lowest pitch. While the fundamental is usually heard most prominently, overtones are actually present in any pitch (Fineberg, 2000 : 81).

In music, consonance and dissonance are categorizations of simultaneous or successive sounds. Within the Western tradition, some listeners associate consonance with sweetness, pleasantness, and acceptability, and dissonance with harshness, unpleasantness, or unacceptability, although there is broad acknowledgement that this depends also on familiarity and musical expertise (Lahdelma and Eerola, 2020 : 8693).

Whether the two tones are consonance depends on whether the vibration frequencies of the two tones are proportional. As we mentioned before, vibration will produce overtones, and the more overtones, the more the two tones will be in consonance. According to the principle of tuning System, Just Intonation is a major triad formed by adding the 5th Overtone on the basis of Pythagorean Tuning. Add the third notes to the tonic, dominant, and subordinate that make up the pure fifth. All the pitches are present in the tonic, so they are

most consonant. Pythagorean Tuning is the second, and Equal temperament is the worst.

To judge whether the two intervals are consonance or not, we can use the consonance coefficient K. (Chen, 2008 : 70)

**K=1/nm**

"n" represents the vibrational frequency of the upper pitch and "m" represents the vibrational frequency of the lower pitch.

We can calculate the consonance and dissonance of intervals. However, the “K” value obtained by this algorithm has a disadvantage, the distribution is not uniform. For example, the value of K at Perfect unison is 1, The octave K value is 0.5. The vibration frequency ratio of perfect fifth is ⅔, K value is 0.16666.

In order to avoid the "K" value band by this algorithm has a disadvantage, the distribution is not uniform. We get Ip(dB) by calculating K as somebody else's Logarithmic Function in mathematics. (Chen, 2008 : 71)

$$Ip = 20\log_{10}(1000/nm)(dB)$$

A new formula can be obtained by simplifying the formula.

$$Ip = 20lg(1000k)(dB)$$

The consonance of intervals is subjective to everyone. But it is also an objective thing (vibration frequency). So, there is objectivity. According to the calculated values, a classification table can be obtained by combining the musician's hearing.

| consonance | dissonance |
|---|---|
| A:48-60 (dB) Perfect consonance | D:16-24 (dB) Imperfect dissonance |
| B:36-48 (dB) Median consonance | E:8-16 (dB) Median dissonance |
| C:24-36 (dB) Imperfect consonance | F: < 8 (dB) Perfect dissonance |

**Table 1** classification table whether the interval is a consonance.

| | Vibration frequency ratio | Cents value | consonance coefficient K. | | Ip(dB) |
|---|---|---|---|---|---|
| | | | Fractional form | decimal form | |
| Perfect unison | 1/1 | 0 | 1/（1×1） | 1.00000 | 60（A） |
| Just Intonation Minor second | 16/15 | 112 | 1/（16×15） | 0.00416 | 12.40（E） |
| Just Intonation Major second | 10/9 | 182 | 1/（10×9） | 0.01111 | 20.92(D) |
| Major second | 9/8 | 204 | 1/（9×8） | 0.01388 | 22.85(D) |
| | 8/7 | 231 | 1/（8×7） | 0.01785 | 25.04(C) |
| | 7/6 | 267 | 1/（7×6） | 0.02381 | 27.54(C) |
| Just Intonation Minor third | 6/5 | 316 | 1/（6×5） | 0.03333 | 30.46(C) |
| Just Intonation Major third | 5/4 | 386 | 1/（5×4） | 0.05000 | 33.98(C) |
| Perfect fourth | 4/3 | 498 | 1/（4×3） | 0.08333 | 38.42(B) |
| Perfect fifth P5 | 3/2 | 702 | 1/（3×2） | 0.16666 | 44.44(B) |
| Just Intonation Minor sixth | 8/5 | 814 | 1/（8×5） | 0.02500 | 27.96(C) |
| Just Intonation Major sixth | 5/3 | 884 | 1/（5×4） | 0.06666 | 36.48(B) |
| | 12/7 | 933 | 1/（12×7） | 0.01190 | 21.51(D) |
| | 7/4 | 969 | 1/（7×4） | 0.03571 | 31.06(C) |
| Minor seventh | 16/9 | 996 | 1/（16×9） | 0.00694 | 16.83(D) |
| Just Intonation Minor seventh | 9/5 | 1018 | 1/（9×5） | 0.02222 | 26.94(C) |
| Just Intonation Major seventh | 15/8 | 1088 | 1/（15×8） | 0.00833 | 18.42(D) |
| Perfect octave | 2/1 | 1200 | 1/（2×1） | 0.50000 | 53,98(A) |

**Table 2** Common interval consonance coefficient K. table

When the vibration frequency of an interval cannot be expressed as a simple fraction (non-overtone vibration frequency), such as Equal temperament and the frequency ratio of each tone is irrational. The vibration and resonance phenomenon can also have an effect, but the effect is very limited. Using a relatively simple empirical formula calculation method. This method is suitable for the Equal temperament, as well as for the comparison of Thai Tuning system and Western Tuning system.

$I=Ip-\Delta I$

In Equal temperament, we can choose intervals with similar cents value (the ratio of vibration frequencies is the fraction) to calculate the $\Delta I$ value (Modified index), and then calculate δ according to the absolute value of the difference cent value.

$\Delta I=0.45(\delta-2)$

**1.2Thai tuning system**

Thailand, 7-TET has to be mentioned. This tuning system was proposed by Alexander J. Ellis in *On the Musical Scales of Various Nations*. Prince Prisdang carried three instruments in 1885: Ranat Ek, Ranat Ek Lek, Sor Sam Sai, "Tak 'hay" (Jakhe, Thai koto), and Alexander J. Ellis was allowed to test the tuning systems of these instruments when they traveled to London for an exhibition (Ellis, 1885 : 485).

They were advised by Prince Prisdang that “the intention was to make all the intervals from note to note identically the same”. Alexander J. Ellis then concluded, "Give the above division of the octave into seven equal intervals each containing 171.43 cents" (Ellis, 1885 : 1105). Although Alexander J. Ellis found that some instruments were not tuned like his published theory of the 7-TET tuning system, but he interpreted the discrepancies as "artificial" and thought that "there is no harmonic interval but the Octave" *(*Helmholtz, 1895 : 500*).* Alexander J. Ellis's mathematical interpretation of the Thai tuning system is a bit crude, dividing the European octave into seven intervals and ignoring indigenous cultural and historical factors in ethnomusicology.

The first policy that King Mongkut employed in coping with the Western threat was the introduction of Western education within the court, with the purpose of educating in the ways of the West the royal children who would become future leaders. Through this learning they would be able to negotiate with the Western powers on more equal and dignified terms and to maintain Siamese sovereignty (Rutnin, 1996 : 70). It was entrenched there by the middle of the twentieth century, by which time the Thai interval was routinely described as equidistant comprising 171.429 or 171.43 cents (Morton, 1970 : 10)

As mentioned in Professor Manop Wisuttipat's work *The Theoretical Concepts on Thai Classical Music,* in 1913, when the grand master Luang Pradit Pai Roh began implementing numerals in Thai musical instruction, he used nine numbers, more to represent the fingerings of pitches for musical instruments than to represent the actual sounds. Even in the present time we still do not have assigned names for the pitches in Thai music. We only use meaningless syllables, such as "noi-noi-noi," etc. Therefore, in the teaching of Thai music today, we favor the use of the note designations of the West, that is do re mi, etc. The assigning of the note names do re mi, etc. must be done in accordance with the basic concept in Thai music of tang - the actual pitch level of a scale (Wisuttipat, 2002 : 20).

However, among the traditional Thai instruments, almost every school has its own tuning system. Musicians adjust their intonation by ear, so usually each school has its own tuning system. This is a major obstacle to the systematization of Thai music.

## Research Methodology

The researchers measured the vibration frequency of Ranat Ek in each tone at Srinakharinwirot University: Faculty of Fine Arts. Rambhai Barni Rajabhat. Prasarnmit Demonstration School (Secondary). by using Musical Application: Sonic tools. The instrument was measured three times and averaged.

Interview

The researcher conducted a group interview with data subjects. Both formal and informal, in order to obtain information. The times by the data persons who have been interviewed are as follows.

1) Asst. Prof. Dr. Metee Punvaratorn
2) Assoc. Prof. Dr. Manop Wisuttipat
3) Asst. Prof. Dr. Chanick Wangphanich
4) Asst. Prof. Dr. Surasak Chamnongsan
5) Asst. Prof. Dr. Veera Pansuea
6) Lecturer Ratchanon Yimrayab
7) Lecturer Paritat Ruengyim
8) Supapol Saiwimarn

## Research Scope

The researcher has studied the research documents and went to the field data collection area. to obtain results according to the objectives of the research The results of the study are as follows.

To study of tuning system of Thai instruments by using the existing formula of the Western tuning system. What the researcher discovered from studying the sound system of Thai musical instruments The study results are as follows.

**1.1 The tunning system issued by the government.**

First of all, we concentrate on the scale of Thailand, Thailand's scales with the formation of a very special way, it is for every school has its unique tuning system, make it difficult to study, the Thai government promulgated tuning specification file and didn't get all the instruments of the user response, players tend to use more ears are tuning up. For the convenience of research, the researcher defined the research direction of this time, and used the tuning standards issued by the government and the Musical Instruments of the Faculty of Fine Art in Srinakharinwirot University, Rambhai Barni Rajabhat University, Prasarnmit Demonstration School (Secondary) to collect data. First let's look at the data issued by the Thai government, and we use the Concorde interval calculation formula mentioned above to calculate. In the Thai scale, โด เร มี ฟา ซอล ลา ที is usually used as the official expression. In daily communication, Pitch notes CDEFGAB, commonly used in western music, is also used to express the sound in order to facilitate communication with foreigners. In order to express the convenience and easier to understand.

| Pitch names | Relative cents | The vibration frequency (Hz) | Similar intervals vibrational ratios are fractional | | δ | △I(dB) | I(dB) | classification |
|---|---|---|---|---|---|---|---|---|
| | | | cents | Ip(dB) | | | | |
| C โด | -46 | 254.2 | 0 | 60 | 0 | 0 | 60 | A |
| D เร | 121 | 280.7 | 182 | 20.92 | 15 | 7.2 | 13.72 | E |
| E มี | 293 | 309.9 | 316 | 30.46 | 23 | 9.45 | 21.01 | D |
| F ฟา | 465 | 342.2 | 498 | 38.42 | 13 | 4.95 | 33.47 | C |
| G ซอล | 636 | 377.8 | 702 | 44.44 | 20 | 8.1 | 36.34 | B |
| A ลา | 808 | 417.2 | 884 | 36.48 | 30 | 12.6 | 23.88 | D |
| B ที | 979 | 460.6 | 1018 | 26.94 | 7 | 2.25 | 24.69 | C |
| C โด | 1150 | 508.5 | 1200 | 53.98 | 6 | 1.8 | 52.18 | A |

**Table 3** classification K of Ranat Ek from tunning system issued by the government.

Through an analysis of each interval in Thailand scales, we found a very interesting point, is that although the Thai tuning system is not calculated but ears to adjust, but on the interval, Perfect unison, Perfect octave, Perfect fourth, Perfect fifth can be consonance of definition, though not necessarily completely consonance.

This also explains the problem that in Piphat and Mahori we hear melodic progressions, but we don't hear intervals or harmonic progressions at all. In traditional Thai ensembles, the most common interval is Perfect unison or Perfect octave.

Although we can conclude that some intervals can reach consonance intervals. Still, it is important to understand that the Thai tuning system is independent of the Western tuning system, although Western musicians once tried to define the Thai tuning system in terms of the European musical tuning system.

In the earliest studies, it is not known whether it was because of convenience or because Prince Prisdang made demands on Alexander J. Ellis, the tester. The Thai tuning system is defined as a cents of 171.4 for two adjacent notes. The above data are from the Thai government. According to the comparison of the relationship between vibration frequency and tone fraction, we can almost assume that this specification of vibration frequency comes from the research results of Alexander J. Ellis.

**1.2 Measurement of Tuning System for school Musical Instruments.**

When the researcher measured Faculty of Fine Art in Srinakharinwirot University's instruments, the researcher got very confusing results. The same instrument, for example, Ranat Ek, got two kinds of data, one is close to the government Tunning system document, the other is completely different from the government document. The following table is the vibration frequency of Ranat Ek that I collected.

| Scale series number | C โด | D เร | E ม | F ฟา | G ซอล | A ลา | B ท |
|---|---|---|---|---|---|---|---|
| 1 | | 156 | 196 | 208 | 234 | 248 | 278 |
| 2 | 312 | 331 | 371 | 417 | 468 | 496 | 556 |
| 3 | 625 | 662 | 743 | 834 | 936 | 1011 | 1113 |
| 4 | 1250 | 1365 | | | | | |

**Table 4** Vibration data collected from the Faculty of Fine Art in Srinakharinwirot University

The above data is the conclusion drawn by Ranat Ek who tested the same type of tuned instruments. All the instruments were from the Faculty of Fine Art in Srinakharinwirot University. The data obtained are averaged without keeping decimals. (10F, Faculty of Fine Art in Srinakharinwirot University,02. Aug.2022)

It can be seen that there is a big discrepancy between the measured data above and the Tuning System files of the government. These differences in vibration frequencies can no longer be explained by the poor preservation of Musical Instruments and the sensory gap.

The researcher interviewed Asst. Prof. Dr. Metee Punvaratorn about this question. He said to me, "We all know that the tuning system in Thailand depends on the school you attend. Every school has its own habits in tuning system. They're more likely to use their ears for tuning."

It is for this reason that Musical Instruments in Thailand, if they come from different schools, will have different tuning, even to the point that they cannot be played together. Asst. Prof. Dr. Metee Punvaratorn also mentioned an interesting thing in the interview, "I once adjusted some instruments to the official tuning system, and it was not long before the students asked Asst. Prof. Dr. Veera Pansuea, who is the Piphat ensemble master of the school, to adjust the instruments to the familiar tuning system". From the content of these interviews, we can draw some conclusions that traditional music in Thailand is adjusted according to the ears of the performers. There are many subjective factors in the adjustment of intonation. Players are also very sensitive to intonation and will feel out of tune on adjusted instruments.

I will use the calculation method mentioned before to analyze the Ranat Ek vibration frequency data collected in the Faculty of Fine Art in Srinakharinwirot University.

| Pitch names | The vibration frequency (Hz) | Relative cents | Similar intervals vibrational ratios are fractional | | δ | △I(dB) | I(dB) | classification |
|---|---|---|---|---|---|---|---|---|
| | | | cents | Ip(dB) | | | | |
| C โด | 312 | 305 | 0 | 60 | 0 | 0 | 60 | A |
| D เร | 331 | 408 | 112 | 12.40 | 9 | 3.15 | 9.25 | E |
| E มี | 371 | 605 | 316 | 30.46 | 16 | 6.3 | 24.16 | C |
| F ฟา | 417 | 808 | 498 | 38.42 | 5 | 1.35 | 37.07 | B |
| G ซอล | 468 | 1007 | 702 | 44.44 | 0 | 0 | 44.44 | B |
| A ลา | 496 | 1108 | 814 | 27.96 | 11 | 4.05 | 23.91 | D |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| B ที | 556 | 1332 | 1018 | 18.42 | 9 | 3.15 | 15.27 | E |
| C โด | 625 | 1507 | 1200 | 53.98 | 2 | 0 | 53.98 | A |

**Table 5** classification K of Ranat Ek from Faculty of Fine Art in Srinakharinwirot University

Asst. Prof. Dr. Metee Punvaratorn asked Ratchanon Yimrayab, a Lecturer at Rambhai Barni Rajabhat University, to collect the frequency of Ranat Ek's vibration. After collecting data in the same way, the following data is obtained.

| Scale series number | C โด | D เร | E ม | F ฟา | G ซอล | A ลา | B ท |
|---|---|---|---|---|---|---|---|
| 1 | | 173 | 191 | 212 | 232 | 256 | 284 |
| 2 | 314 | 345 | 381 | 422 | 462 | 509 | 568 |
| 3 | 631 | 691 | 760 | 846 | 925 | 1020 | 1131 |
| 4 | 1260 | 1391 | | | | | |

**Table 6** Vibration data collected from Rambhai Barni Rajabhat University

Based on the Ranat Ek vibration data provided by Lecturer Ratchanon Yimrayab, the following conclusions can be calculated.

| Pitch names | The vibration frequency (Hz) | Relative cents | Similar intervals vibrational ratios are fractional | | δ | △I(dB) | I(dB) | classification |
|---|---|---|---|---|---|---|---|---|
| | | | cents | Ip(dB) | | | | |
| C โด | 314 | 320 | 0 | 60 | 0 | 0 | 60 | A |
| D เร | 345 | 481 | 182 | 20.92 | 21 | 8.55 | 12.37 | E |
| E มี | 381 | 653 | 316 | 30.46 | 17 | 6.75 | 23.71 | D |
| F ฟา | 422 | 830 | 498 | 38.42 | 12 | 4.5 | 33.92 | C |
| G ซอล | 462 | 987 | 702 | 44.44 | 35 | 14.85 | 29.59 | C |
| A ลา | 509 | 1154 | 702 | 44.44 | 32 | 13.5 | 30.94 | C |
| B ที | 568 | 1368 | 1018 | 18.42 | 30 | 12.6 | 5.82 | F |
| C โด | 631 | 1546 | 1200 | 53.98 | 26 | 10.8 | 43.18 | B |

**Table 7** classification K of Ranat Ek from Rambhai Barni Rajabhat University University

Asst. Prof. Dr. Metee Punvaratorn asked Prasarnmit Demonstration school (Secondary) Lecturer Paritat Ruengyim to help me collect the vibration frequency of Ranat Ek after collecting data in the same way, obtained the following data.

| Rnand Ek Vibration Frequency (Hz) collected from Prasarnmit Demonstration school (Secondary) | | | | | | |
|---|---|---|---|---|---|---|
| C โด | D เร | E มี | F ฟา | G ซอล | A ลา | B ที |
| 255.5 | 274.5 | 311 | 42 | 378 | 417 | 463 |

**Table 8** Vibration data collected from Prasarnmit Demonstration school (Secondary)

This data is very different from the data collected above, many of the tones are very close to each other. Recently, Prasarnmit Demonstration school started using the tuning system issued by the Thai government.

Based on the Ranat Ek vibration data provided by Lecturer Paritat Ruengyim, the following conclusions can be calculated.

| Pitch names | The vibration frequency (Hz) | Relative cents | Similar intervals vibrational ratios are fractional | | δ | △I(dB) | I(dB) | classification |
|---|---|---|---|---|---|---|---|---|
| | | | cents | Ip(dB) | | | | |
| C โด | 255.5 | -43 | 0 | 60 | 0 | 0 | 60 | A |
| D เร | 274.5 | 83 | 112 | 12.40 | 14 | 5.4 | 7 | F |
| E มี | 311 | 300 | 316 | 30.46 | 27 | 11.25 | 19.21 | D |
| F ฟา | 342 | 468 | 498 | 38.42 | 13 | 6.05 | 32.37 | C |
| G ซอล | 378 | 636 | 702 | 44.44 | 23 | 9.45 | 34.99 | C |
| A ลา | 417 | 807 | 884 | 36.48 | 34 | 14.4 | 22.08 | D |
| B ที | 463 | 990 | 1018 | 18.42 | 15 | 5.85 | 12.57 | E |

**Table 9** classification K of Ranat Ek from Prasarnmit Demonstration school (Secondary)

In an interview with Assoc. Prof. Dr. Manop Wisuttipat, who demonstrated his tuning system, which is identical to the government-issued tuning system, the researchers will not double count here.

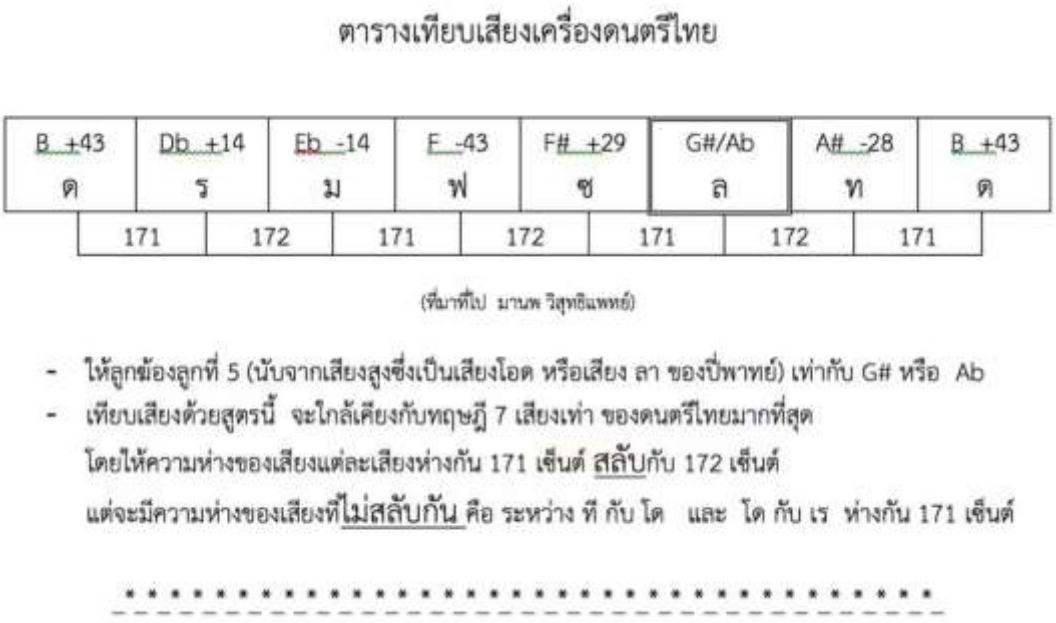



**Figure 2** Assoc.Prof.Dr. Manop Wisuttipat uses the tuning system.

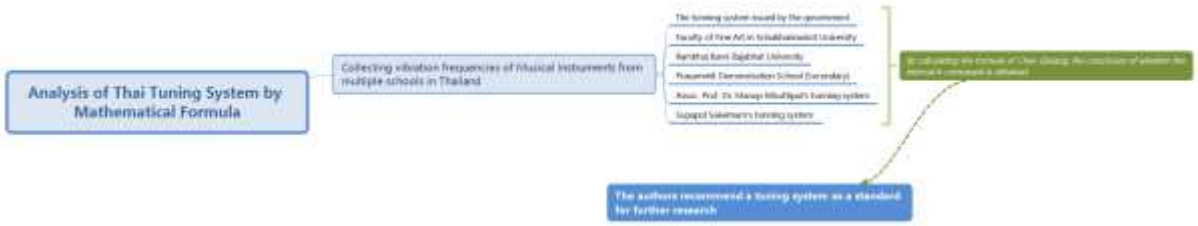
With contact from Asst. Prof. Dr. Metee Punvaratorn, the researcher got the tuning system he used from Supapol Saiwimarn. He is a Thai Instruments maker. Many universities invited him to tune the sound of the instrument. From the interview data (May 21, 2023), Mr. Supapol Saiwimarn mentioned the tuning system. Has studied from the research documents of A.Boonchuay Sowat. When considered, it is consistent with the sound system of the Fine Arts Department as shown in the announcement document. This sound calibration formula has been used in many educational institutions such as the Faculty of Education, at Chulalongkorn University. Suankularb Wittayalai School and others.

| บันไดเสียงระนาดเอก แนวเสียงกรมศิลป์ | |
|---|---|
| ลูกที่ 1 เริ่มจากซ้าย | เสียง ซอล = 171.1 Hz, F-35 Cents |
| ลูกที่ 2 | เสียง ลา = 188.9 Hz, F#+36 Cents |
| ลูกที่ 3 | เสียง ที = 208.5 Hz, G#+8 Cents |
| ลูกที่ 4 | เสียง โด = 230.3 Hz, A#-21 Cents |
| ลูกที่ 5 | เสียง เร = 254.2 Hz, C-50 Cents |
| ลูกที่ 6 | เสียง มี = 280.7 Hz, C#+22 Cents |
| ลูกที่ 7 | เสียง ฟา = 309.9 Hz, D#-7 Cents |
| ลูกที่ 8 | เสียง ซอล = 342.2 Hz, F-35 Cents |
| ลูกที่ 9 | เสียง ลา = 377.8 Hz, F#+36 Cents |
| ลูกที่ 10 | เสียง ที = 417.2 Hz, G#+8 Cents |
| ลูกที่ 11 | เสียง โด = 460.6 Hz, A#-21 Cents |
| ลูกที่ 12 | เสียง เร = 508.5 Hz, C-50 Cents |
| ลูกที่ 13 | เสียง มี = 561.5 Hz, C#+22 Cents |
| ลูกที่ 14 | เสียง ฟา = 619.9 Hz, D#-7 Cents |
| ลูกที่ 15 | เสียง ซอล = 684.4 Hz, F-35 Cents |
| ลูกที่ 16 | เสียง ลา = 755.7 Hz, F#+36 Cents |
| ลูกที่ 17 | เสียง ที = 834.4 Hz, G#+8 Cents |
| ลูกที่ 18 | เสียง โด = 921.2 Hz, A#-21 Cents |
| ลูกที่ 19 | เสียง เร = 1017.1 Hz, C-50 Cents |
| ลูกที่ 20 | เสียง มี = 1123.0 Hz, C#+22 Cents |
| ลูกที่ 21 | เสียง ฟา = 1239.9 Hz, D#-7 Cents |
| ลูกที่ 22 | เสียง ซอล = 1368.9 Hz, F-35 Cents |

จัดทำโดย จะเข้ช่างโจ ID Line 0891337203 เมื่อวันที่ 8 กรกฎาคม พ.ศ.2565

**Figure 3** Tuning system from Supapol Saiwimarn

## Research Conceptual Framework




## Research Findings

1. By collecting vibration frequency through field measurement and interviewing data, researchers obtained reliable data for calculation.

2. From the above calculation results, we can find that Ranat Ek of the Faculty of Fine Art in Srinakharinwirot University, in Major Third, Perfect Fourth, Perfect Fifth, Perfect octave those intervals are a great improvement in the interval consonance. It is also indirect evidence that Thai musicians are more inclined to use naturally vibrating frequency multiples notes as their tuning system.The tuning system of Prasarnmit Demonstration school (Secondary) is very unique, and by calculation, this tuning system is very dissonant in the intervals. But now they choose to use the government tuning system as the standard. Assoc. Prof. Dr. Manop Wisuttipat and Mr. Supapol Saiwimarn, chose to use the government-issued tuning system as the tuning standard. More and more schools are opting for government-issued tuning systems. The researchers argue that Thai tuning systems need to be standardized, the tuning system issued by the government has a very wide range of use.

## Discussion

Based on the data collected, it is concluded that the Thai tuning system proposed by Alexander J. Ellis is not entirely correct. Thai musicians tend to tune using their ears rather than following Alexander J. Ellis' tuning system. Alexander J. Ellis viewed the Thai tuning system in terms of the Western musical system. In Western music tuning system, Equal temperament is more dissonant than Just Intonation, but it is widely used. It is precisely because the tuning system of Equal temperament is easier to learn. Musicians such as Franz Joseph Haydn composed a large number of compositions, which also popularized Equal temperament. In the researchers' opinion, the reason why Thai music is not widely disseminated is that there is no uniform standard. In calculating the tuning system issued by the Thai government, it can be found that the tuning system is exactly according to the tuning system measured by Alexander J. Ellis. Although this tuning system is not perfect, it is the most reliable data available. Nowadays, more and more schools choose the tuning system issued by the government as the standard tuning system, which is a good thing. The unified tuning system is more conducive to the development of Thai music, but it also limits the diversity of Thai music. For the applicability of the study, the researcher still suggests the tuning system issued by the Thai government.

## Recommendations

**1. Theoretical Recommendation**

Study the tuning system of various schools in Thailand and try to summarize the rules and differences. The 7-TET was originally created by Alexander J. Ellis and is based on the Western tuning system, which is very different from the folk tuning system, but is still officially recognized. If we can sum up a common folk tuning system, it will be widely used.

**2. Practical Recommendations**

In future research, the researcher suggests using the tuning system issued by the government when creating ensembles or concertos with the Thai tuning system. Although this tuning system is flawed, it is being accepted by more and more schools and gained wider dissemination.

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