Microtonality in electronic music and tailor-made timbre for 15-equal temperament: *A 15-ET Jingle* by Chan Chak Hang (b.1997)

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Introduction

A 15-ET Jingle is an electronic piece in which the tuning is based on 15 equal temperament (ET) and a specific timbre. The instrumental tone is digitally generated by PureData, synthesising individual sine waves into a musical note. All the musical notes are exported and recorded in a digital audio workstation program and recorded. The first two movements are synthesizer solo only, while movements 3 and 4 perform with gamelan ensemble.

The spectrum of the timbre is constructed with the ratios from the 15-ET. The timbre is tailor-made for 15-ET with a unique spectrum that does not follow the harmonic series pattern. Blackwood (1991) describes 15-ET as a field that has not been explored a lot, this piece and this thesis are aimed to explore 15-ET with digital technology and scientific approaches.

Aspects of Microtonality

This piece uses 15-ET, which is in the domain of mIcrotonality. In Western contemporary music, microtonality has been used by experimental and avant-garde composers to create unconventional harmonies and melodies in a 12-tone chromatic scale, to explore new sounds and musical possibilities.

There are two major definitions of microtonality[1], one is any musical interval or pitch difference distinctly smaller than a semitone; the other refers to music with intervals markedly different from the (logarithmic) 12th part of the octave and its multiples, including such scales with fewer than 12 pitches (Griffiths et al., 2001). Although the definition of a semitone in the 12th part in an octave may vary throughout history

[1] Microtonal decoration, ornamentation or fluctuation, a microtone approaches from a scaled note with glissando or portamento are not discussed in this thesis. The main focus of the thesis is the microtonal tunings compare to the 12 equal temperament.

because of different historical temperaments[2], the 12-part-in-an-octave definition has been well-established in Western classical music and as the standard of tuning, a tuning or temperament that does not follow the 12-note standard often regards as microtonality. For example, gemalen scales, 7-step pelog scale and 5-ET slendro scale. Their steps contrast with the ratios in the 12-note standard but are larger than a semitone in 12-ET. It can regard as microtonality with its exotic scale. The second definition came with the 12 equal-temperament (the ratio of a semitone as $1{:}\sqrt[12]{2}$ or 1:1.059463) standard established in the mid-20th century, the definition of microtonality is any tuning or temperament system beyond 12-ET (Keislar, 1991).

The 15-ET fits both definitions with a semitone in the ratio of $1{:}\sqrt[15]{2}$ or 1:1.047294 which is small than the semitone in 12-ET and 15 is not the 12th part of the octave and its multiples.

Inspirations from microtonal composers in western music from the 20th century

As developing my own temperament and digital instrument, the following composers have had a significant impact on my piece.

The first major tuning approach of microtonal music is based on and extends the harmonic series—composers based on the harmonic series approximations to tune in just intonation with simple ratios. Harry Partch's (1979) tuning of tonality diamond is based on the overtone (harmonic) and undertone series which create the Genesis scale. Just intonation is a key tuning feature in compositions of James Tenney, Eivind Groven, Lou Harrison, Ben Johnston and La Monte Young (Griffiths et al., 2001). After the millennium, Sarah Davachi and Catherine Lamb are major figures with just intonation.

The second major approach is dividing an octave into non-12-equal temperament. Alos Haba and Ivan Wyschnegradsky specialised in 24-TET, also known as quarter tone (Skinner, 2007). Easley Blackwood (1991) has explored all equal temperaments from 13 through 24, in addition to 6-ET and 10-ET. Wendy Carlos mixed 15-ET 12-ET in her *afterlife* from the album Tales of Heaven and Hell (Carlos, 1998). Georg Friedrich Haas in the 21st century used quarter-tone in his music. In recent decades, Daniel Wilson and Elaine Walker have used electronic instruments to compose and perform non-12 temperaments.

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[2] Temperament refers to the adjustment of tunings of the scale with some or all of the concords are made slightly impure (not in simple ratios) in order to avoid Pythagorean comma which the same pitch cannot be returned in octaves with 12 consecutive perfect fifth, or any other commas generated by simple ratios (Lindley, 2001). Different historical temperaments may include meantone temperament, well temperament, unequal temperament, equal temperament etc…

Partch’s practice of building his own instrument to achieve his own tuning is an example of how a composer can start things from scratch and build his own musical idiom from nuts and bolts. Blackwood’s Etudes for Electronic Music Media demonstrate digital synthesisers can achieve superb accuracy in tuning since equal temperaments are adjusted to a complex ratio for approximated to simple ratios. The title of my piece, the temperament and the media are heavily influenced by Blackwood.

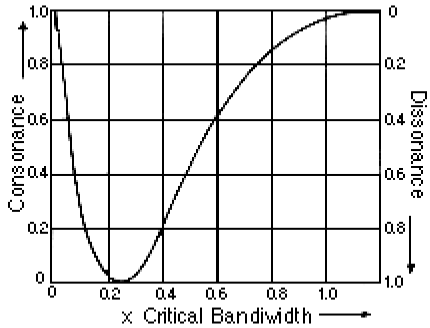
Inharmonicity and microtonality

The correlation between spectrum and tuning is the major research by Sethares(2010). He focused on Gamelan music and studied the spectra of gamelan instruments. Since the gamelan ensemble is majorly percussion, the inharmonic spectra of the percussion instruments affect the scale and tuning of the music. He concluded that the spectra of most Western instruments are harmonic which relates to the western scales based on harmonic series, so the inharmonic spectrum of gamelan instruments is related to the gamelan scales which are contrasting to the western scales. The gamelan slendro scale approximates to 5-ET and the pelog scale is a 7-note scale. In other words, gamelan scales are a kind of microtonality markedly different from the 12-ET. As I played in a gamelan ensemble, I am fascinated by the tuning and try to compose for gamelan with modern technology and this piece is a start.

The relationship between timbre and temperament

A musical note that we perceive is not just a pure sine wave. Helmholtz (1877) showed that pitch is due to the fundamental frequency and the quality of a musical sound, timbre, is due to the presence of upper partials. To consider the consonant or dissonant level of two musical notes, all pairs of partials have to be considered (Sethares, 2010).

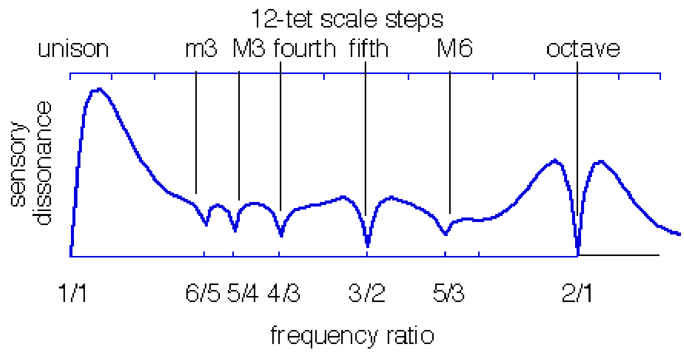
The vibration of a musical note can be reinterpreted as a summation of a series of sinusoidal oscillations according to Fourier transform (Koenig & Fandrich, 2015). For a pair of sine waves, Plomp and Levelt (1965), plotted out the critical bandwidth of maximum dissonance.



Critical bandwidth of maximum dissonance (Plomp & Levelt, 1965)

The x-axis of the graph shows the interval ratios between two sine waves; the y-axis shows the level of dissonance; the higher more consonant, the lower more dissonant. To calculate the consonant level of two notes, with partials, the sum for all pairs of fundamentals and partials level of consonance is the total level of two notes.

Temperament sets a scale of finite patterns of intervals of two notes. For instruments with harmonic series partials, 12-ET has a good approximation of most consonant intervals (Sethares, 2010).



The dissonance level of a timbre with harmonic series partials in 12-ET (Sethares, 2010)

The conflict of a harmonic series spectrum in 15-ET

The partial pattern of most strings and wind instruments is in the pattern of harmonic series. In the harmonic series, the 2nd and 3rd partials combine in the ratio of a perfect fifth, 3/2. Stacking the fifth 12 times roughly returns to the original tone in octaves. The 12-ET is the tool to solve the Pythagorean comma. The 12-ET fits the instrument with a harmonic series spectrum since the spectrum and temperament are interrelated. Comparing 12-ET and 15-ET, intervals that only line up with each other are major 3rd and octave (see table 1 in appendix 1). When an instrument with harmonic series partials is played in 15-ET, it sounds discorded as the partials do not line up with the temperament. In order to make a timbre which can be played in consonance 15-ET. The partials have to be rebuilt artificially.

In Blackwood’s thesis (1991), he marked that 15-ET is “most chromatic dissonances are either excessively discordant or sufficiently alien to be barely recognizable.

”(p.187) and in his interview by Keislar (1991), he is attracted by the jingle and discording sonority from 15-ET. Blackwood does not explain the reason that results in such sonority. According to my research on Blackwood’s instruments, polyfusion synthesiser, the sounds Blackwood designs are based on the pattern harmonic series (Chan, 2023b). The partials of the sounds that Blackwood used do not align with the steps of 15-ET causing inherent discord. The digital instruments I tailor-made for 15-ET, proved intervals in 15-ET can sound harmonious with the lineup of partials and steps in the temperament.

The process of tailor-made a timbre for 15-ET

First, calculate all the ratios of 15-ET (Appendix 1). Second, get all the intervals from the natural harmonic series and the ratios, in the first 2 columns. Compare the ratios of 12-ET and 15-ET, and pair similar ratios together. From comparing the ratios, minor third and major second in 12-ET has the closest approximation to the ratio of 1.145 in 15-ET. (table 2)

Interval	**Ratio from 12-ET**	**From harmonics order**	**Ratio from 15-ET**
Octave	2.0000	1 and 2	
Fifth	1.5874	2 and 3	1.5157
Fourth	1.3348	3 and 4	1.3195
Major third	1.2599	4 and 5	1.2599
minor third	1.2030	6 and 7	1.1487
minor seventh	1.7818	4 and 7	1.7411
Major second	1.1225	7 and 8	1.1487
minor second	1.0595	11 and 12	1.0968

(table 2)

Third, rebuild the spectrum for 15-ET based on the pattern of natural harmonic series. The intervals of the first column are one of the many ways to construct the harmonic series, but I found it can rebuild the spectrum efficiently(table 3,4). This method can use all the intervals generated from the first 11th partials, also known as the 11-limit promoted by H. Partch.

Harmonic series from 12-ET	**interval stacking with Ratios from 15-ET**	**Ratios for 15-ET spectrum**
fundamental		1.0000
octave	2	2.0000
oct+5th	2*1.516	3.0314
2 octaves	2*2	4.0000

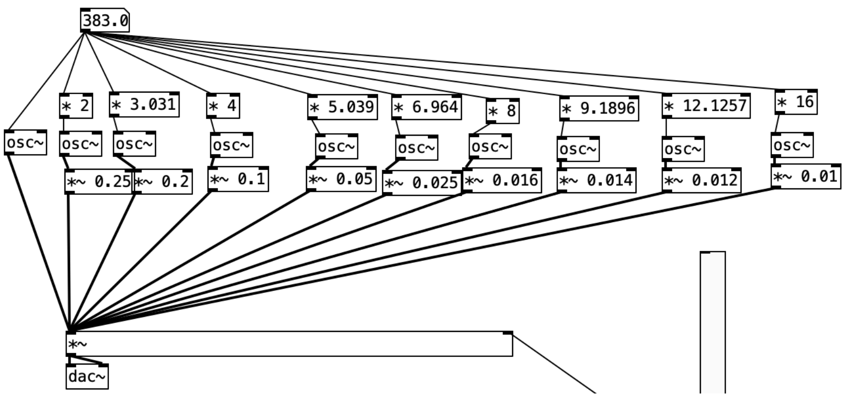
oct+5th+4th+M3	2*1.516*1.32*1.25	5.0397
oct+5th+4th+m7	2*1.516*1.32*1.26*1.741	6.9644
3 octaves	2*2*2	8.0000
oct+5th+4th+m7+M2+M2	2*1.516*1.32*1.26*1.149*1.149	9.6242
oct+5th+4th+m7+M2+M2+M2+m2	2*1.516*1.32*1.26*1.149*1.149*1.091	12.1257

(table 3)
(table 4)

Partials	1 (Fundamental)	2	3	4	5	6	7	8	9
Partial in ratios	1	2	3.031	4	5.039	6.964	8	9.1896	12.126
SPL ratio in RMS	1	0.5	0.25	0.22	0.2	0.18	0.16	0.14	0.12
SPL level in decibel	80	73.97	67.95	66.84	66.02	65.1	64.08	62.92	61.58

Making the synthesiser sound

After the ratios in the temperament and the spectrum of each note are calculated, I use Puredata to generate the sound. The patch setup is as follows, in picture 6, it is just a simple additive synthesiser. The top digit is the frequency in Hertz. An osc~ module generates a pure sine tone. There are multiple modules to generate a complex sound wave close to a musical tone. The modules above osc~ modules calculate the ratios in the spectrum from a fundamental. The modules below the osc~ control the volume of the sine tone.



pic .5

The frequencies are entered into this PureData patch according to the ratios of 15-ET(1:1.0472) starting from 220Hz for an octave. The generated sounds are recorded by Logic Pro. The sounds of each note are organised and played in a sampler in Logic Pro, pic 7, and also can be played on midi keyboard. The cutoff filter in the sampler is linked to the velocity of the midi keyboard. It can mimic real acoustic instruments when playing in louder dynamics and can excite more upper partials, providing stronger dynamic contrast.

pic 6

The composition process

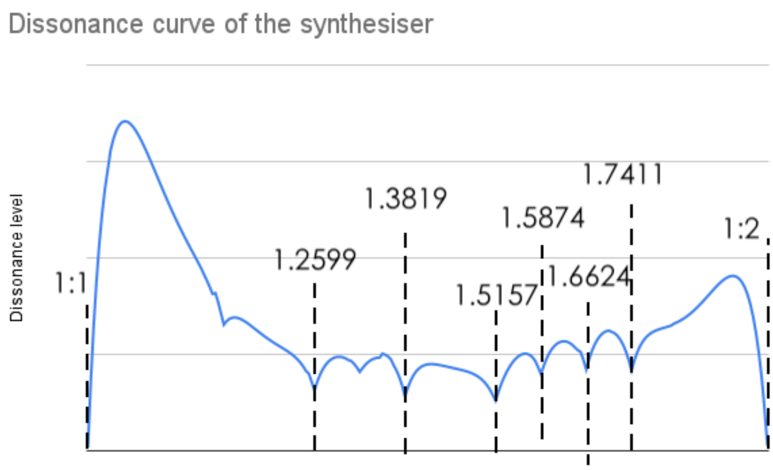
The timbre is brand-new; the 15-ET and the concept of tailor-made an instrument for a temperament are rarely explored by composers. The experimental nature of the piece makes it particularly risky when composing on a large scale. Though mathematics proved the possibility, I had concerns about practicality. The aim of the piece is to prove the practicality and explore the possibility. The scale of the piece was planned to a miniature length. My direct reference is Blackwood’s 15-note Microtonal Etude (opus 28), which only lasts for 3.5 minutes, and J. S. Bach’s Well-Tempered Clavier, 3-4 minutes for each movement -- testing in each key. They are adopting a new tuning system in their era in which small-scale testing for each element was prompted to be more applicable and easier to handle with a new system.

Homophonic texture in the first movement

The first movement of *A 15-ET Jingle* is written in homophonic texture which is directly inspired by Blackwood’s piece. The texture is constructed by a melody and chords. From the influence of western music and Blackwood’s, I borrowed the structure of major and minor chords and rebuilt them in the 15-ET system. Although Blackwood (1991) discussed different chord properties in his thesis, the timbre he used is based on harmonic series (Chan, 2023c). The perception of an interval with different spectra may vary (Setheras, 2010). The discussion of the sonority of various combinations of chords in this timbre should be separated from Blackwood’s.

To explore the homophonic texture, as notes play simultaneously, chords are constructed with the ratios in 15-ET. If the intervals are based on the ratios at local minima, the chord should sound harmonious in theory. To prove the tailor-made

timbre fits 15-ET, a dissonance curve is drawn (graph 7). All local minima of the ratios can be found in the 15-ET. The curve shows the level of dissonance, the y-axis along with different intervals along with the x-axis. When it is played in unison, the left side of the graph, the dissonance level, and the y values are close to zero; the same as in octave at the right side of the x-axis, the ratio of 1:2. The local minima align with ratios at 1 to 1.2599, 1.3819, 1.5157 etc as marked in graph 7. It implies that when an interval of two notes playing in such a ratio can offer consonant sonority.
All dashed ratios can be found in the 15-ET.

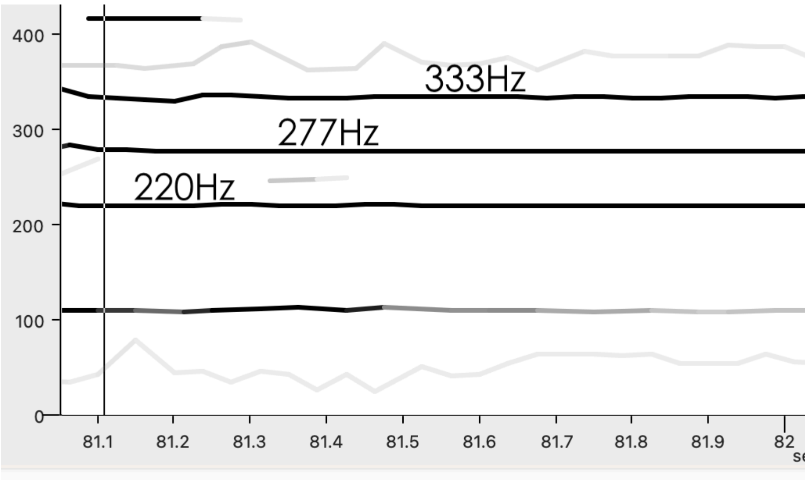


(graph 7)(Chan, 2023c)

Constructing major and minor chords is basic in tonal practice and useful for homophonic texture for accompaniment. I borrowed the structure of major and minor chords with the approximate which we used but not exactly the sonority. The ratio of 1.51 in 15-ET is as fifth is related to ratio 1.5 in the 12-ET, the ratio of major 3rd and minor 6th are the same in 12-ET and 15-ET.

> Major triad is composed of ratios of 1,1.2599 and 1.5157;
> Minor triad: 1,1.203 and 1.5157;
> Augmented triad: 1, 1.2599 and 1.5874;
> Diminished triad: 1,1.203 and 1.4473.

Yet, the major and minor chords listening experience is peculiar and hard to translate to the scope of 12-ET. With the chords system, cadential chord progression can be mimicked. At the end of the 1st movement, the chord progression suggests a cadential resolution to a major chord creating a sense of perfect cadence (pic 8). Blackwood describes the major chords in 15-ET should be avoided since the discarded nature in the ratios in 15-ET. Yet, with my timbre, the major triad has a different interpretation. The major and augmented triads provide a sense of stability which Blackwood did not discussion deliberately since the particles line with steps in 15-ET. With the tailor-made timbre, the traditional chord progression can be reused and augmented in 15-ET with more notes in an octave. At the same time, the sonority of tritone and augmented sound stable which I embraced in my piece.



pic 8

In the process of composition, the chords harmonise the melody. The melody is first created, and I harmonise the melody with multiple attempts. The process is basically trial and error. The rare exploration in 15-ET and the tailor-made approach of timbre make this piece different to compose with limited prior experience. The harmonic rules and approaches are hard to conclude with an electorate theory due to the miniature scale of this piece. Netherness, this piece is a starting point for an alternative way to develop microtonality and compositional approach in non-12-tuning.

An acoustic experiment in homophonic texture and spectra

The tailor-made timbre for 15-ET was mathematically proved to be fitted to the ratios in 15-ET in the dissonance curve. In order words, stacking chords in 15-ET with the tailor-made timbre is prompted to sound harmonious and it is in theory the best situation in terms of inharmonic spectra. However, it is important to test out does it translate to the actual experience from audience's perspective. Thus, an experiment was prompted to test it out.

Experiment setup

There are two sounds for comparison, one timbre is generated with harmonic series and one is an inharmonic spectrum but tailor-made for 15-ET. For this experiment, pairs of audio samples labelled "Sound A" harmonic timbre and "Sound B" tailor-made timbre will be played one by one closely. Each playback will only be played once. Each pair of sounds are identical except for their partial patterns, one pattern is based on harmonic and another is based on tailor-made timbre. The survey is divided into three sections, each section would focus on different aspects and all sounds will be played in soft, medium and loud dynamics.

For composing in homophonic or polyphonic texture, the tailor-made timbre is in theory the best timbre with an inharmonic spectrum compared to the harmonic spectra which Blackwood used in 15-ET. To simulate the texture, chords are spelt, and the ratios of intervals in chords are based on the ratio in 15-ET. As suggested by Blackwood (1991), the major chords in 15-ET, are a combination of 1, 1.2599 and 1.5157. This is the chord to be heard in the first section. In the second section, to resemble the minor listening experience, the combination is changed to 1, 1.2030 and 1.5157. In the last section, V to i progression in a minor key is mimicked in 15-ET as Blackwood suggested minor keys in 15-ET are preferable.

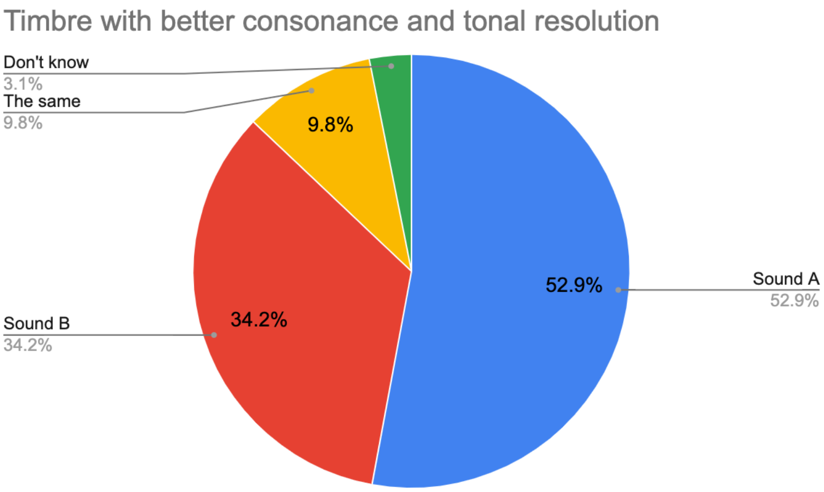
The questions in the first two sections include asking listeners if they can differentiate the partials between harmonic series and my tailor-made inharmonic spectrum, which timbre they subjectively prefer and which timbre they found to be more consonant. In the third section, the listeners were asked to choose which sound has the better tonal resolution and is subjectively preferred by the listeners.

The experiment is conducted on the 28th of February at the Lab at Royal Birmingham Conservatoire. The 26 volunteers are composition students from undergraduate to postgraduate listening via the speakers in the venue which limited the variable since they were listening to the same setup. Each sample was only played once and they are instructed to trust their initial instinct and not be influenced by any external response of others. The only-played-once approach echoes the real-life listening experience as a first impression has a great influence on the perception of treating and viewing in many contexts of everyday life (Wood, 2004).

Experiment results and discussion

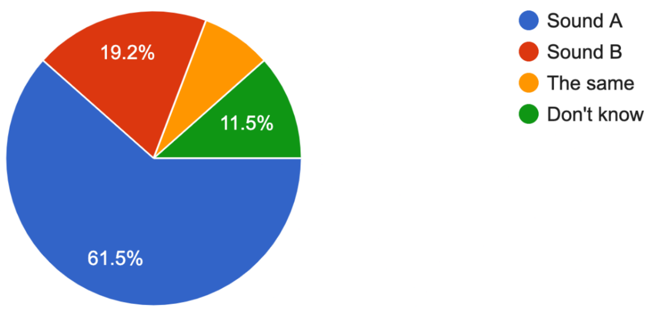
The result overthrew the theoretical aspect of the tailor-made timbre approach. The survey demonstrates the dominance of harmonic patterns in human listening perception in homophonic texture. For each section in major chord, minor chord and tonal resolution in different dynamics, most participants find Sound A, the harmonic timbre is more consonant and provide a better resolution in most of the situations in graph 4.1. For subjective preference, more than half of the responses prefer Sound A with harmonic series in graph 4.2.

As chords and harmony are basic elements of homophonic and polyphonic texture. From this experiment, playing chords and choosing which is better and preferable, Sound A is more suitable for such textures. The sound A is similar to Blackwood's synthesiser sound with harmonic series which Blackwood prompted to use the most suitable sound for his homophonic composition. However, the research here does not suggest harmonic timbre is not suitable for other musical textures, other musical transitions use instruments with harmonic spectra and performance in heterophonic texture, which is out of scope in this essay.



graph 4.1

Q4.1. Consider what have heard from section 1-3, the whole survey, which sound you prefer subjectively?
26 則回應



graph 4.2

Sound B with a tailor-made timbre for 15-ET represents an ideal scenario in the theory of using inharmonic spectra in 15-ET. It shows a contradictory result between the listening experience and mathematic calculation. From the calculation of the dissonance level, in graph 4.3 a single note or a chord, the harmonic timbre is more dissonant than the tailor-made timbre but participants regard sound A, harmonic timbre, as more harmonious. This experiment describes a human preference for patterns, harmonic series in this case.

The dissonance level of the timbre with the harmonic series itself is
0.31901
The dissonance level of the tailor-made timbre for 15-ET is
0.24705

intervals	tailor-made chord		harmonic chord	
Perfect 5th	3.11402		2.54868	
Major 3rd	3.11401	sum	4.28494	sum
Minor 3rd	3.39419	9.6222	4.74838	11.5823

Graph 4.3

Meanwhile, gamelan instruments have a high dissonance level within the spectra, playing fewer notes simultaneously in heterophonic texture can balance the overall dissonance level. This experiment concludes that the inharmonic spectra are hard to be employed in polyphonic or homophonic texture in 15-ET with regard to the psycho-acoustic.

Conclusion

The exploration of microtonality has been a popular topic since the 20th century. In addition, non-Western cultures have been inspiring contemporary composers. This piece benefits from the advances of digital music to produce sound and computer technology for the calculation; meanwhile, the psychoacoustic researches support the concept. The development of the tailor-made approach not only expands the approach of microtonality but also combines timbre and temperaments in correlation with each other. This piece expended the idea of a harmonic spectrum with good approximation with 12-ET, the synthesiser instrument with arranged inharmonic spectra should fit with the 15-ET according to the mathematic and scientific proofs in theory. At the same time, it reinterprets the harmonic language and tonal system with a distinct timbre and more combinations of harmony.

However, the scientific proof by Plomp and Levelt (1965) involved in psychoacoustic, the subjective aspect could not be neglected and may affect the ultimate outcome. Aspects discussed in this thesis, include the sensation of consonance or dissonance, and harmonic resolution involved in subjective decisions. When it is employed in an actual musical context, the theoretical aspect may dilute. The process in this state only stays at theoretical and composer's personal experience -- the tailor-made-timbre concept and chord quality respectively. When the music is played to the audience, the listening experience from the listeners is meaningful to analyse, as the music we hear nowadays is so focused on 12-ET. This concept should be developed more in the future.

Bibliography

Blackwood, E. (1991) Modes and Chord Progressions in Equal Tunings. *Perspectives of new music*. [Online] 29 (2), 166–200.

Chan. C. H. (2023a). A 15-ET Jingle 1st movement. [online video] Available through: https://youtu.be/qbiIPbz9IOg [Access 1 February 2023]

Chan. C. H. (2023b). A comparative study of E. Blackwood's Twelve Microtonal Etudes for Electronic Music Media, opus 28, 15 note (6th movement) and Gamelan Slendro scale (c. 5-ET)

Chan. C. H. (2023c). user_interface_of_plomp_levelt_curves in Dissonance calculation. [Python code] Available through: https://github.com/maxchanhi/dissconance_calculationv2/blob/master/user_interface_of_plomp_levelt_curves.ipynb [Access 1 February 2023]

Dunn, F., Rossing, T., & Fletcher, N. H. (Eds.). (2015). *Springer handbook of acoustics.* Springer New York.

Griffiths, P. et al. (2001) Microtone. New Grove Dictionary of Music and Musicians

Helmholtz, H. L. F. (1877) *On the sensations of tone as a physiological basis for the theory of music.* Cambridge: Cambridge University Press.

Hugh Davies (2001) Microtonal instruments. New Grove Dictionary of Music and Musicians

Teodorescu-Ciocanea, L. (2003) Timbre versus spectralism. *Contemporary music review*. [Online] 22 (1-2), 87–104.

Mark Lindley (2001) Temperaments. New Grove Dictionary of Music and Musicians

Manning, P. (2013) '3 Cologne and Elektronische Musik', in *Electronic and Computer Music*. [Online]. Oxford University Press.

Moog, R. A. & Gamer, C. (2022) Post-World War II electronic instruments.[Online] Encyclopaedia Britannica. Available through: https://www.britannica.com/art/electronic-instrument [Access 1 February 2023]

Keislar, D. (1991) Six American Composers on Nonstandard Tunings. *Perspectives of new music*. 29 (1), 176–211.

Partch, H. (1979) *Genesis of a music : an account of a creative work, its roots and its fulfillments.* 2nd ed., enlarged. New York: Da Capo Press.

Plomp, R. & Levelt, W. J. . (1965) Tonal consonance and critical bandwidth. *The Journal of the Acoustical Society of America.* [Online] 38 (4), 548–560.

Sethares, W. A. (2010) *Tuning, timbre, spectrum, scale*. 2nd ed. London: Springer.

Appendix

Temperament	15-ET	12-ET
Ratios	**1**	**1**
	1.0473	1.0595 minor 2nd
	1.0968	1.1225 major 2nd
	1.1487	
	1.2030	1.1892 minor 3rd
	1.2599	1.2599 major 3rd
	1.3195	1.3348 Perfect 4th
	1.3819	1.4142 Tritone
	1.4473	
	1.5157	1.4983 Perfect 5th
	1.5874	1.5874 minor 6th
	1.6625	1.6818 major 6th
	1.7411	1.7818 minor 7th
	1.8234	
	1.9097	1.8877 major 7th
	2	**2**

Microtonal music in electronic instruments

After World War II, electronic instruments have been widely applied to perform microtonal music (Moog & Gamer,2020). Synthesizer keyboard is very popular among composers to compose and play microtonal music. It can be adjusted to create any number of equal octave divisions. Moog and Gamer concluded composers, for example, Easley Blackwood, John Eaton, La Monte Young, Terry Riley etc. composed microtonal music in this medium with various brands of synthesisers. In Europe, according to Manning (2013), the studio of Nordwestdeutscher Rundfunk in Cologne, led by Karlheinz Stockhausen, he and his team produced artificial timbre and temperaments beyond equal divisions of the octave, studies 1 and 2 are recognised examples. The oscillator in the synthesiser produces individual frequency components and constructs the spectrum with the flexibility of controlling the amplitude of individual partials.

By the early 1990s, personal computers were acquiring multimedia capabilities and music-making softwares was developed for composers with graphic user interfaces to lower the entry limits (Manning, 2013). Nowadays, the personal computer offers easy access to digital music, finance and difficulty. The software I used, PureData, is free and open-source software with a graphic user interface design. It can be run on most personal computers in the market. A user does not require to know the programming language to use the software to synthesise sound.

Microtaonality may involve a huge amount of calculation without a computer, for this piece, calculating the ratio of 1:$\sqrt[15]{2}$ and the scientific approach of sensory dissonance involve psycho-acoustic also requires the calculation of mathematic functions. The second benefit of using a computer is I can calculate and generate all individual frequencies and amplitudes accurately, with a wide range of flexibility to control ratios of individual frequencies in Hertz and amplitudes in decibels. In contrast to building a physical instrument, a digital synthesised sound omits a lot of material limitations.