THE DAY THE MUSIC DIED

Did you know that the frequencies of notes used in music were different 150 years ago? Western music is based on a series of notes having fixed pitches or frequencies. But have you ever wondered why the notes have the frequencies they have, and whether there could be reasons to use others?

In this article we will compare the tonal system of Western music with that of other traditions, and especially that of the original Indian music. We will show how the modern tonal system is artificial and distorted, because of not being really harmonious, and how it also has distorted the original Indian tonal system.

THE ESSENCE OF MUSIC

The essence of music can be said to be relationships of sounds.

Definition of music according to Oxford dictionary

Vocal or instrumental sounds (or both) combined in such a way as to produce beauty of form, harmony, and expression of emotion.

When two notes have different frequencies, their relationship is called an interval. The interval between a note and another having twice the frequency is called an octave. A tonal system is a sequence of notes with different frequencies within the span of an octave. Normally 5 or 7 notes within an octave are used to make up what is called a scale, and by which one makes music.

In the Western tonal system the octave is divided into twelve so called half notes, from which one selects the notes of the scales. The intervals between these twelve notes are equalized. It means that one can take the frequency of any note and multiply it with one specific decimal number and get the frequency of the next half note. By a fixed starting note, one defines the frequencies of all the other notes. The fixed frequency in Western music is 440 Hz, which represents the note A at the middle of a piano keyboard.

Calculating the frequency ratio between the half tones of the twelve-tone equal temperament scale

R = The frequency ratio

Start frequency x R x R x R (twelve limes) = Start frequency x 2

Start frequency x R^{12} = Start frequency 2 (440 Hz x R^{12} = 440 Hz x 2 = 880 Hz)

1 x R^{12} = 2 (440 Hz x R^{12} = 880 Hz)

R = 12 √2 ≈ 1.0594630943593

R is an irrational number (cannot be converted to a whole number ratio)

This tonal system is called equal temperament, and was made a standard in Western music around 1850. Before that musicians used other tonal systems, where the intervals between the notes were not equalized. All the great composers of the classical period composed their music in other tonal systems. Mozart even said that he would kill anyone who would play his music in equal temperament. Also many other musicians and musicologists at the time protested against the standardization of the equal temperament. So for trained ears, the difference in tonal systems really meant something.

The tonal system of equal temperament is artificial, because none of the intervals are in accordance with the natural harmonies of nature. This is in contrast to the tonal system of the original Indian music, and also many types of folk music around the world, which are based on the natural harmonics we will explain below.

THE NATURE OF SOUND

When we strike a string on a guitar, it makes a sound. The sound comes about by the vibrating string making the adjacent molecules of air vibrate. The vibration spreads in all directions, like ripples in a pond. When it reaches our ear membranes, it makes them vibrate, and this is then transformed into nerve impulses that we perceive as a continuous sound of a definite pitch.

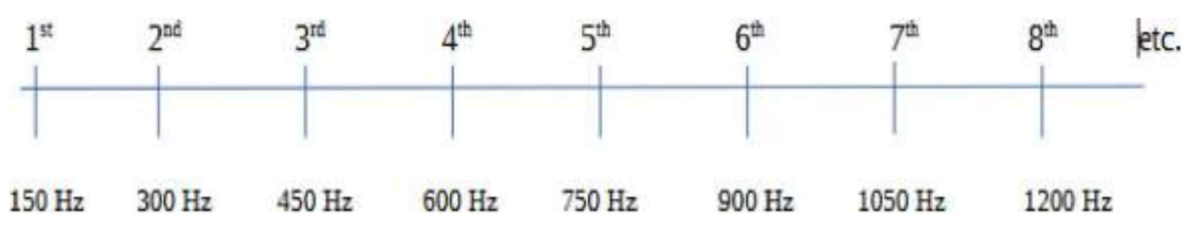
The air vibrate in the same speed as the string, and the pitch of the sound is determined by the speed of the vibration, which is called the frequency. The frequency is measured in Hz, which is the number of vibrations per second. The frequency of the vibrating string is determined by its length, thickness and tightness.

Disregarding possible amplification devices, the amplitude of the vibration determines the volume. While the frequency, and thus the pitch of the sound, remains the same as long as the string is vibrating, the amplitude gradually diminishes, making the sound slowly fade away.

THE INTERVALS OF THE HARMONIC SERIES

However, when we listen to the sound of a guitar string, we do not hear only one sound, but many sounds of different pitch. We actually hear a compound of sounds. We hear one sound that has the lowest pitch, called the fundamental sound, and which defines the frequency of the compound, but in addition we hear so called overtones.

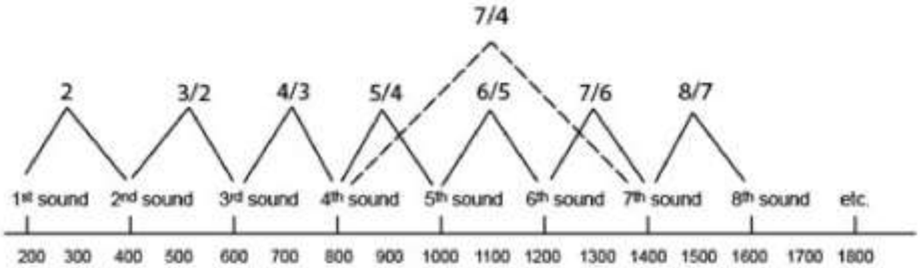
Disregarding possible limitations of the physical medium of the string, the overtones are exact multiplications of the frequency of the fundamental sound. If for instance the fundamental sound is 150 Hz, the first overtone, which is the second sound, will be 300 Hz, twice the fundamental frequency. The second overtone, or the third sound, will be 450 Hz, three times the fundamental frequency. The third overtone, or the fourth sound, will be 600 Hz, four times the fundamental frequency. The fourth overtone, or the fifth sound, will be 750Hz, five times the fundamental frequency, and so on.



This sequence of sounds is called the harmonic series and are a collection of natural intervals. They are the sound intervals of nature. In the prominent cultures of the world's history, musical scales were transmitted from generation to generation by oral traditions based on such intervals.

MATHEMATICS OF HARMONIC INTERVALS

The intervals of the harmonic series can be expressed as ratios of the sound numbers, one number divided by a lower number. Here are some examples with the fundamental frequency set to 200 Hz:



Interval from 1 to 2 Interval ratio = 2/1 = 2 1 x Interval ratio = 2	from 200 Hz to 400 Hz Interval ratio = 400 Hz / 200 Hz = 2 200 x Interval ratio = 400
Interval from 2 to 3 Interval ratio = 3/2 2 x Interval ratio = 3	from 400 Hz to 600 Hz Interval ratio = 600 Hz / 400 Hz = 3/2 400 x Interval ratio = 600
Interval from 3 to 4 Interval ratio = 4/3 3 x Interval ratio = 4	from 600 Hz to 800 Hz Interval ratio = 800 Hz / 600 Hz = 4/3 600 x Interval ratio = 800
Interval from 4 to 7 Interval ratio = 7/4 4 x Interval ratio = 7 etc.	from 800 Hz to 1400 Hz Interval ratio = 1400 Hz / 800 Hz = 7/4 800 x Interval ratio = 1400

2/1 – 3/2 – 4/3 – 5/4 – 6/5 – 7/6 – 8/7 etc.
5/3 – 6/4 – 9/7 etc.
etc.

The intervals between the overtones and the fundamental tone, and between the overtones themselves, are all considered pure intervals. In Western musicology these intervals are also called just intonation, but which is a term mostly related to a few scales with intervals of the smallest ratio numbers. In folk music and Indian music the selection of ratios are much more comprehensive, making up hundreds of scales with a mixture of both small and higher number ratios. In Indian music, the combination of the ratios of a scale is such as to create a specific mood.

In our chart, the first interval is from sound 1 to sound 2, which in this case is from 200 Hz to 400 Hz. This is called an octave and has the ratio of 2/1. It is thus the largest interval within the octave.

The second interval is from sound 2 to 3, which in this case is from 400 Hz to 600 Hz. The ratio for this interval is 3/2, which is 1.5 as decimal number, and which is called a pure fifth.

The third interval is from sound 3 to 4, which in this case is from 600 Hz to 800 Hz. The ratio for this interval is 4/3, which is called a pure fourth.

But we also have intervals comprising more than one small interval, like for instance from sound 4 to 7, which in this case is from 800 Hz to 1400 Hz and has the ratio of 7/4.

COMPARISON BETWEEN EQUAL TEMPERAMENT AND HARMONIC SCALES

One of the notes of a music scale is called the keynote, the basic note of the scale. Comparing it to a family, the keynote is like the mother, while the rest of the notes are like the children. Sometimes the children play between themselves, but always with the mother in the background and always returning to the mother.

The keynote is the starting note from which a music scale is defined. The different notes of a scale are often named by their position from the keynote. Hence, the second note of a scale is called the second, the fourth note the fourth, the fifth note the fifth, and so on.

If one wants to tune a fixed pitched instrument in accordance with a harmonic scale, one has to do it on the basis of one specific keynote, which means that one cannot play the scale based on any other keynote without retuning the instrument.

While the intervals between the notes of equal temperament are equal, they all differ in harmonic scales. This means that if you have tuned the keyboard to one specific harmonic scale, and then try to play the same scale from another keynote, the sequence of the intervals, which are all different, will be altered, and it will thus not be the same scale. In the classical era of Western music, the composers re-tuned the keyboard instruments themselves before performing their compositions.

The reason why Europe adopted the equal tempered system is because it makes it easy to modulate scales on fixed pitched instruments. If one for instance plays a scale where the keynote is A, the scale can easily be transferred to any other key, so that any other note can become the keynote.

Both in Western and Indian music theory, one divides the octave into twelve parts. But while the ratios in Western music is fixed for each division, the division in Indian music is just guides, as the ratios for each division often varies depending on the scale.

Because of the influence of Western instruments, like the harmonium and other keyboard instruments, The original Indian music scales are about to be lost. The music tradition in India that best has preserved the original Indian scales is an age old oral tradition called Dhrupad.

Some of the foremost experts of Dhrupad have in the latter years, by the help of computer technology, defined the ratios of 40 of the most popular Indian scales − also called ragas. By using one of these scales, Darbari, as example, we will show why the original Indian scales can not be rendered properly by a fixed pitched instrument tuned in equal temperament. We choose the note A, 440 Hz, as the keynote. All the decimal numbers are rounded.

	Equal temperament			**Dhrupad**		
Notes	**Ratios from keynote in decimals**	**Notes from A**	**Frequency**	**Whole number ratios from keynote**	**Ratios in decimals**	**Frequency**
Keynote	1.0	A	440.0000	1/1	1	440.0000
2nd minor	1.0594					
2nd	1.1223	B	493.8245	9/8	1.1250	495.0000
3rd minor	1.1889	C	523.1577	20/17	1.1765	517.6600
3rd	1.2596					
4th	1.3344	D	587.1547	4/3	1.3333	586.6520
4th raised	1.4137					
5th	1.4976	E	653.9803	3/2	1.5000	660.0000
6th minor	1.5866	F	698.1238	85/54	1.5741	692.6040
6th	1.6808					
7th minor	1.7807	G	783.5241	72/41	1.7560	772.6400
7th	1.8865					
Octave	2.0	A	880.0000	2/1	2.0	880.0000

In equal temperament, the ratios of the twelve notes is always the same. The 2nd is for instance always 1.1223 = 1.0594 * 1.0594, while the 3rd is always 1.2596 = 1.0594 * 1.0594 * 1.0594 * 1.0594, etc.

To find the ratio between two adjacent notes we divide the ratio from the higher note to the keynote by the ratio from the lower note to the keynote.

The ratios in classical Indian music varies from scale to scale, constituting many more different intervals than in Western music, and makes up hundreds of discrete scales.

THE INFLUENCE OF SOUND INTERVALS ON THE MIND

The difference between harmonic scales and the equal temperament scale might be considered subtle, but subtle differences can have strong impact on the mind. An essential consideration regarding intervals of sound is how they affect the mind. In classical texts of Indian music, as also in the Greek philosophy of Pythagoras and Plato, a key factor for music to have a positive effect is that it is pleasing to the mind. Studies show that when people hear pure harmonic intervals, they find them to be more pleasing and more beautiful than the equivalent in equal temperament. Often people are amazed that intervals of equal temperament actually can be considered harmonious when hearing them after having heard the equivalent intervals in pure harmonics.

Aesthetic reasons were also the main argument against the equal temperament when it was introduced in Europe. Musicians of the time meant that equal temperament degraded the purity of each chord and the aesthetic appeal of music. Neither did any of the renowned Western classical composers write for equal temperament, as they were earlier in time, which includes among others Bach and Mozart.

However, considering that the difference in frequency between the notes in equal temperament and the equivalent notes in harmonic scales are not very large, as seen in terms of percentage, one might ask why there should be such a difference in pleasantness of hearing the intervals. Could it be just a question of imagination, or some kind of a placebo effect?

The answer is that the intervals of harmonic scales are more consonant, or harmonious, than the equivalent intervals in equal temperament, which is also confirmed by modern science.

CONSONANCE AND DISSONANCE

The pleasantness of an interval is related to the terms consonance and dissonance.

Consonance is a word derived from Latin: com, "with" + sonare, "to sound." If we look it up in the Wikipedia, it will be defined as follows:

Consonance

A harmony, chord or interval that are considered stable, as opposed to dissonance, which is considered unstable.

Dissonance is also a word derived from Latin: dis, "apart" + sonare, "to sound." It is defined by the modern musicologist Roger Kamien as follows:

Dissonance

An unstable tone combination is a dissonance; its tension demands an onward motion to a stable chord. Thus dissonant chords are 'active'; traditionally they have been considered harsh and have expressed pain, grief, and conflict.

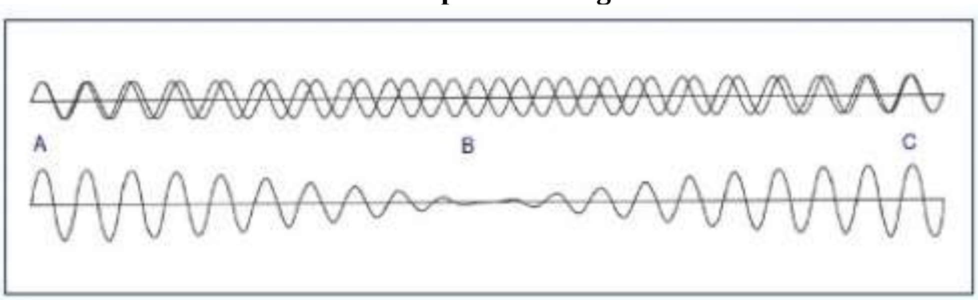
THE PHENOMENA OF BEATING

When the difference in frequency between two sounds is more than zero Hz and less than about 20, we will perceive them as one sound. The frequency of the combined sound we hear will be the average of the two sounds. The volume of the combined sound, however, will constantly vary, and this is what is called beating. It is a phenomena that is considered to be the principal cause of dissonance. The reason why beating occurs is because of the constantly changing relationship between the vibrations of the two sounds.

A sound is created by the vibration of air, and the amplitude of the vibration determines its volume. When the frequency of two sounds are so close together that they are perceived as one sound, the amplitude of the combined sound is the summation of the amplitudes of the two sounds. As one of the two sounds vibrates slightly faster than the other, the relationship between their vibrations will continuously vary. At one point they will be synchronous, which means that they will swing back and forth simultaneously so the sum of their amplitudes will be the maximum. Then they will gradually be less synchronous, which also means that the sum of the amplitudes will gradually be less, until they reach a point when they vibrate opposite each other. If they then have the same amplitude, the sum of their amplitudes will be zero, making no sound. If the amplitude of one of the two sounds is larger than the other, the amplitude of the combined sound will not be zero, but less than the sound with the largest amplitude. Then gradually the vibrations of the two sounds will move back to being synchronous, which also means that the amplitude of the combined sound gradually will increase until they again reach their maximum, and so on.

The sound we hear is the result of the two sounds working against our ear membranes. When their vibrations are synchronous, they will push and pull the ear membranes simultaneously, and thus with a combined force that is stronger than with one of them alone. When their vibrations are opposite each other, one sound will push the membranes, while the other will pull it, and thus they will more or less block each other, making us perceive a reduced sound, or no sound at all. It can be likened to listening to a radio while turning the volume rapidly up and down. The frequency of the beating is the difference in frequency between the two sounds. We can illustrate this phenomena by the following figure, which shows the sound vibrations as waves:

Example of beating



The two upper waves are the sounds, while the lower wave is the combined sound we hear. The two sounds have the same amplitude. The changing amplitude of the lower wave shows the change in volume of the combined sound. At point A the two sounds are somewhat synchronous, and the combined amplitude is at its highest. Then they become less synchronous and the combined amplitude becomes less. At point B they vibrate opposite each other and the combined amplitude becomes zero, making no sound. Then they gradually move back to synchrony, while the combined amplitude gradually increases and reaches its maximum when the two waves again become synchronous, and so on.

When the difference in frequency increases between two sounds, while still being less than about 20 Hz, the frequency of the beating increases. When the difference between the sounds becomes larger than about 20 Hz, the beating is replaced by an experience of roughness. When the difference reaches a point somewhere between a whole note and a third flat, the beating stops and we hear two separate sounds.

EXAMPLES OF BEATING

As an example, we can make a comparison between an equal tempered fifth and a pure harmonic fifth, with the latter having a ratio of 3/2. We will see what happens when these are played together with the keynote or with each other. We choose the key of A, which in the tempered system has a frequency of 440 Hz. First we will look at the equal tempered fifth together with the keynote.

	Sound	Key note	5th tempered
Overtones	10th sound	4400 Hz	6590 Hz
	9th sound	3960 Hz	5931 Hz
	8th sound	3520 Hz	5272 Hz
	7th sound	3080 Hz	4613 Hz
	6th sound	2640 Hz	3954 Hz
	5th sound	2200 Hz	3295 Hz
	4th sound	1760 Hz	2636 Hz
	3rd sound	1320 Hz	1977 Hz
	2nd sound	880 Hz	1318 Hz
	1st sound	440 Hz	659 Hz

The equal tempered fifth is actually 659.2564 Hz.

We see that we get beating on many levels. There is beating between the 3rd sound of the keynote and the 2nd sound of the 5th, between the 6th and the 4th and between the 9th and the 6th.

We then look at the harmonic fifth played together with the keynote:

	Sounds	Key note		5th harmonic 3/2
	10th sound	4400 Hz		5940 Hz
	9th sound	3960 Hz		5400 Hz
	8th sound	3520 Hz		5280 Hz
	7th sound	3080 Hz		4620 Hz
Overtones	6th sound	2640 Hz		3960 Hz
	5th sound	2200 Hz		3300 Hz
	4th sound	1760 Hz		2640 Hz
	3rd sound	1320 Hz		1800 Hz
	2nd sound	880 Hz		1320 Hz
	1st sound	440 Hz		660 Hz

We see there is no beating. The third sound of the keynote corresponds to the second sound of the 5th, the 6th with the 4th and the 9th with the 6th.

But how would it work if we tried to combine equal temperament with a pure harmonic scale? If for instance we tried to sing in pure harmonics accompanied by a harmonium tuned in equal temperament. Again we use a tempered and harmonic fifth as example.

	Sound	5th harmonic 3/2		5th tempered
	10th sound	6600 Hz	↔	6590 Hz
	9th sound	5940 Hz	↔	5931 Hz
	8th sound	5280 Hz	↔	5272 Hz
	7th sound	4620 Hz	↔	4613 Hz
Overtones	6th sound	3960 Hz	↔	3954 Hz
	5th sound	3300 Hz	↔	3295 Hz
	4th sound	2640 Hz	↔	2636 Hz
	3rd sound	1800 Hz	↔	1977 Hz
	2nd sound	1320 Hz	↔	1318 Hz
	1st sound	660 Hz	↔	659 Hz

We see there occurs beating on all levels, which probably will create a high level of dissonance and force the singer to sing in equal temperament.

CONCLUSION

Western musicology has marred the harmony and beauty of the sound intervals of music by distorting their natural relationships, and also made a prison for its music by locking it out from a vast universe of potential musical expressions.

By using fixed-pitched Western instruments in Indian music, the original strength and purity of this music is distorted and polluted. It brings the music away from the harmony of the laws of nature, while music should do the opposite, bring us more in tune with the laws of nature.

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