STUDY OF RAGAS OF INDIAN CLASSICAL MUSIC WITH REFERENCE TO TONAL FREQUENCY AND INTERVAL (FREQUENCY RATIO) OF SWAR

(Based on North Indian Classical Music)

SUMMARY

Thesis for Ph.D degree in North Indian Classical Music

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By

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CERTIFICATE FROM GUIDING TEACHER

This is to certify that ***Mr. Trushit Piyush Vaishnav*** pursued Ph.D in Vocal music from Faculty of Performing Arts, M.S.University of Baroda under my guidance during the year 2004-2007.

He completed his thesis on *'Study of ragas of Indian Classical Music with reference to tonal frequency and interval (Frequency ratio) of swar'*. He fulfilled the requirement regarding attendance and the results incorporated in thesis are of his independent observation carried out by himself and has at no time been submitted for any other degree.

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Music is both an Art and a Science since it deals with the expression of One's feelings and emotions through sound.

In the Sanskrit tradition, unstruck sound is called Anahata Nada, and the ancients say that the audible sound, which most resembles this unstruck sound, is the syllable OM.

In Indian Philosophy of Vedanta, nada itself is Brahma. Matang muni in his book Brihaddeshi wrote

"na naden vina geetamna naden vina swarah,
na naden vina nrityam tasmannadatmakam Jagat."

There is no song or music without Nada, there are no musical notes without Nada. There is no dance without Nada, The world is filled with the essence of the Nada.

In the same connection Sarang Dev in his book 'Sangit Ratnakar' wrote

"Gitam NadatmakamVadhyam,
Nada Vyakta Prashshyate.
Tad Dwayanugatam Nratam
Nadadhi Matstayam.
Naden Vyanjatvarnah,
Padam varnapradadwachaha
Vachaso Vyavaharoyam,
Nadahin Mato Jagat."

The western Scientists say that sound is nothing but a sensation caused in the first instance by certain oscillatory motions of the particles of the body.

The music is the biggest high for me the ultimate form of emotional expression. It is a vast subject like ocean where every time you take a dip you are still in the middle of it.

I was inclined to Indian Classical Music when I listened 'Lecture cum Demonstration' programmes of eminent artistes during my schooling days I decided to master the art of classical music from a learned traditional Guru Late Pt.N.V.Patwardhan H.O.D, Vocal department,Faculty of Performing arts,M.S.Universtiy of Baroda. I was imparted extensive training to enrich my knowledge.

A value based and effective system of education is necessary to bring out one's talent for acquiring skills with greater precision.

Education in Science is a process of enlightment and progress to attain a better and higher quality of work. I therefore preferred to get academic education in Physics along with Indian Classical Music.

I got impetus on the subject topic of my research project during my practical training of Vocal Music when I did not get scientific explanation for minor differences in usage of swars in different ragas like Darbari, Multaani,Todi etc.

It is accepted that North Indian classical music is not based on standardized frequency system as used mainly in western music and is practically depend on some metaphysical concept of Raga Bhava etc.

'Little was known about the science of sound until about 1600. The first suggestion for a standard had been made about 1700 by French physicist Joseph Sauveur, who proposed C equals 256, German physicist Johann Heinrich Scheibler made the first accurate determination of pitch corresponding to frequency and proposed the standard A equals 440 in 1834.' (Microsoft ® Encarta ® Encyclopedia 2003. © 1993-2002 Microsoft Corporation.)

In Indian concept of music, "Bharatmuni discussed concept of 'shrutinirdeshan' with the help of 'Sarana Chatustai' and introduce 'antar gandhar' and 'kakali nishad' explained for experience through 'Kalsadhran'." (Bharat Ka Sangeet Itihas by Acharya Brihaspati, P.16) Later on, 'Pt.Ahobal(1665), Srinivas(1800) and Pt.Bhatkhande(1900) gave frequency of note based on Assumption.' (Sangeet Visharad by Laxminarayan Garg)

In this scientific era, music cannot be kept aside without discussing its scientific aspects so I felt the necessity to do research on the above subject.

I carried out practical work on oscilloscope and was able to get frequency of different swars through Sruti box. I thought why not frequencies of swars of ragas be established? I got software, which gave me frequencies of swars. Based on my observation I carried out analysis of different ragas in different ways and achieved desired result shown in this thesis.

I hope this subject thesis will be useful to all those in the field of music to understand the concept of Science behind Music thereby enhancing their talent for better understanding and performance.

My thesis is mainly on analysis of ragas of North Indian Classical Music. As ragas can be played also I have included some of North Indian classical music instruments to have comparative view. My main purpose is not to compare two instruments but to compare ragas played on that particular instrument with ragas played or sung by other artistes.

In era of Science with newer mathematics, and morden equipment, experimental work is an absolute necessity. Scientific analysis of Music is an area where the least experimental work has been done.

The Indian musical system is modal. In a modal system relation between successive sounds and those between any sound and fixed tonic (Reference note) are of great importance.

'The modal system permits a much more accurate, powerful, and detailed outlining of the expression.'[1]

In modal music, one can have many exotic scales because there are no harmonics. There is only relationship between one note in the scale and sa. Thus, is a seven note scale we have seven relationships.

Furthermore, for Indian classical music, standardization of tonic is not done yet in terms of the frequency and can be defined by the performer according to his/her choice.

'There is no standard pitch like the middle 'C' of western music'[2]

Actual problem arises when the artist does not get his/her tonic (Reference note) from the accompanying instrument i.e. Harmonium and he/she has to compromise by raising or lowering his/her tonic.

In my research work firstly I have tried to standardize tonic (Reference note) and also to assign frequency to 12 notes.

Secondly, Indian Scholars like Pt.Ahobal, Pt. Shrinivas and Pt. Bhatkhande tried to find out frequency of different notes. They found frequency of (SA) equal to 240 Hz. With the help of (SA) as 240 Hz they found frequencies of other Notes by mathematical ratios. They

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[1] Introduction to the study of Musical Scales by Alain Denielou, P.102
[2] Studies in Indian Music by T.V. Subba Rao, p.7

considered Sa as 240 only for easy arithmetic calculation, as frequency of other notes obtained by it are in whole number compared with the frequencies obtained by selecting Sa other than 240 Hz in which frequency of few notes are in decimal.

'Bharat did not speak of music which was ancient to him. Today more has been written on ancient music than about what we actually sing, play and hear. We are in need of newer knowledge and technique to music.'[3]

Standardization in India has not been done yet as done in western countries. Standardization was done by International Organization for standardization in 1955(and reaffirmed by them in 1975) as ISO 16. More references are given in the coming chapter.

Frequency for C (sa) varies from country to country. In England it is 273 Hz whereas in France it is 261 Hz. Physicists have adopted their standard pitch 512 Hz for C because 512Hz can be expressed as the exact power of 2, namely $2^9 = 512$ HZ.

Some scientific manufacturers once adopted a standard of 256 Hz for middle C, but musicians ignored it [4]

Based on my actual performance and experiment at Physics Laboratory, Faculty of Science, M.S.University of Baroda I found out the frequency for C as 263 Hz.

I have used Shruti Box manufactured by M/s Radal Electronics, Bangalore for standard scale, sound of Shruti Box is amplified through Microphone & Amplifier which were connected to oscilloscope giving the wave pattern. By measuring the time of waveform pattern one can easily find out frequency, which is 263 Hz. I also found frequency for other Notes, which are given in the thesis.

I have also purchased Computer software from USA based company M/s Regnow, for analysis of Ragas of India Classical Music.

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[3] Psychoacoustics of music & Sppech by B.C.Deva, P.20

[4] Culver, C.A., Musical Acoustics, New York: Mcgraw – Hill, 1956

In this software, one can easily find out the frequency of any sound by connecting microphone, Tape recorder or CD to computer. Software shows all frequencies, which are present in that sound up to four harmonics.

I measured frequency of all notes through this software and have found frequency of C of Shruti Box as 263.79 Hz, which is very near to frequency found by my experiment on oscilloscope. In the software, accuracy is more.

I took cassettes of different eminent artistes, analyzed a few ragas of Indian Classical Music through the software, and found the frequency of each swar in each raga and the associated Interval. Using that Interval, I compared ragas of nearly similar notes.

I did four different type of analysis.

1. One Raga - Different Artiste (Sung/played)
2. Different Raga - Different Artiste (Sung/played)
3. One Raga - Sung/played by one artiste at different time.
4. Different raga - one artiste Sung/played

WESTERN MUSIC & INDIAN MUSIC

Helmholtz said: "The music based on the temperate scale must be considered as an imperfect music.....If we suppose it or even find it beautiful; it means that our ear has been systematically spoiled since childhood."[5]

Observation:

Our voice can produce several frequencies with the limitation of three or four octaves only. It is known that the frequency between any key and the key immediately to its left is a constant which is being equal to the twelfth root of two or 1.059. By the time we reached the thirteenth key, we have doubled our frequency and thus spanned a whole octave. This division of the octave into twelve 'tones' which have specific ratio between adjacent keys is called an 'Equally tempered' arrangement. Besides the keyboard, most Western musical instruments are tuned to such an arrangement. The Western music defines a standard octave called the 'Middle C octave' (also called the Middle C scale).

We have no need to have just twelve keys in an octave. In fact, the traditional Indian music system over thousands of years is based on a 22 key per octave system. We do not have an 'Equally tempered scale'. One can locate one's frequencies based on some other non-geometric criteria, which might 'sound' better, and such scales are known as 'Just tempered scales'. In fact, the Indian musical system uses one such scale.

Even though Indian musical systems are very different from the traditional Western Music system, we can still get a lot of insight into Indian music using the equally tempered, twelve keys per octave methodology - essentially because it makes things simple.

Some Indian schools of thought even propose that there are infinite frequencies in an octave. The basic reason for demands for more than twelve 'srutis' per octave is that Indian music seems to 'flow' through the frequencies involving a lot of vocal acrobatics and nuances whereas a Western song seems 'jumpy' like a Piano. Because of this Indian classical music cannot be played effectively in a twelve key per octave instrument like a piano. Of course, several Western instruments have been 'adapted' with a little modification here and there, to play Indian classical music - violin, mandolin and guitar, for example. Some other instruments have been simply 'used', without modification, such as the harmonium and the keyboard.

In Indian Classical Music it is not enough to produce just twelve or twenty two tones in an octave one ought to produce even the intermediate frequencies which do not have any keys to produce them are called Microtones. The microtones add variety to the Indian classical music - an extra dimension. The very heart of Indian music is this 'continuous flow' or 'gliding through a continuum of frequencies' or gamakam or microtonal excursions. Thus, it is often said that Indian music is 'melody-based'. Since microtones are so important in Karnatic and Hindustani music and very few instruments can produce all the frequencies in an octave, the best enunciation of Indian classical music is in vocal singing. In the Western Music, 'harmony' is an important element. Orchestration and 'harmony' are absent in Indian classical music.

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[5] Introduction to the study of Musical Scales by Alain Danielou P.220s

Even if there is a 'Jugal bandhi' - a standard fare in Hindustani classical music where two instruments (or even two vocalists) are featured together, the musicians usually follow the same melodic pattern one after another with minor variation rather than play different melodies simultaneously.

'In western music all the notes have an approximately equivalent value because each note can be fifth or third and second or octave of a chord. The significance of the notes as modal degrees is consequently generally nil, and, in any case, extremely weak.'[6]

'In Indian music, melody and rhythm are more developed and offer a great variety of subtleties, not possible in Western Music. Indian notes are divided into small units called sruties (22 microtones in all), whereas western music has only 112 semitones. The microtones are more subtle then semitone.'[7]

[6] Introduction to the study of Musical Scales by Alain Denielou,P.103
[7] History of Music by Padma Iyer, P.244

Frequency given by Pt. Shrinivas, Pt. V. N. Bhatkhande & Western Notes.[8]Compared with Standard frequency and frequency obtained practically.

Swar	Pt. Shrinivas	Pt. Bhatkhande	Western Swar	Standard frquency*	Frequency (Hz) (Practical)#
SA	240	240	240	261.6	131.89
RE KOMAL	256 1	254 4	256	277.2	138.62
RE	270	270	270	293.6	148.71
GA KOMAL	301 17	288	288	311.1	158.13
GA	288	301 17	300	329.6	165.54
MA	320	320	320	349.2	176.3
MA TIVRA	344 8	338 14	337 ½	370.0	185.72
PA	360	360	360	392.0	198.51
DHA KOMAL	388 4	381 3	384	415.3	208.6
DHA	405	405	400	**440.0**	219.37
NI KOMAL	452	432	432	466.2	234.17
NI	452 4	452 4	450	493.9	248.3
SA TAR	480	480	480	523.2	263.78

* 'In 1939, an international conference met in London and agreed on A = 440 as a new standard universal use, at least in broadcasting. With this standard the frequencies of tones being determined, are given below in the Table.'[9]

Taken From Page No 57

[8] Raga Parichaya part – 3 By Prof. Harishchandra Shrivastv.

[9] Science and Music by Sir James Jeans.p.23,24

Observation

'Frequency for C (sa) varies from country to country. In England it is 273 Hz whereas in France it is 261 Hz. Physicists have adopted their standard pitch 512 Hz for C because 512Hz can be expressed as the exact power of 2, namely $2^9 = 512$ HZ.

Some scientific manufacturers once adopted a standard of 256 Hz for middle C, but musicians ignored it.'[10]

From the above reference, we can say that the frequency of Madhya 'Sa' is 256 Hz. Based on this frequency other frequency of notes are established with the help of interval.

In Indian Music and in Western Music scholar accepted frequency of Sa(C) as 240 Hz. The reason for assuming this frequency can be explained as under:

We already know three different types of tone and its interval.

Major Tone or Chtushrutik or Guru Swar	9/8
Minor Tone orTrishrutik or Laghu Swar	10/9
Semi Tone or Dwishrutik or Ardha Swar	16/15

Now if we check the frequency by lowering the frequency 256 Hz using three different intervals shown above we will get three different frequencies as: .

1 $\frac{256}{9/8} = 256 \times \frac{8}{9} = 227.5$

2 $\frac{256}{10/9} = 256 \times \frac{9}{10} = 230.4$

3 $\frac{256}{16/15} = 256 \times \frac{15}{16} = \mathbf{240}$

From the above three values only 240 is in the whole number and rest of two values are in decimal, which is unacceptable. Therefore, we have now two values for the frequency of Sa(C) 256 Hz and 240 Hz.

We know that interval 'Sa' with other notes are as under.

Sa	Re	Ga	Ma	Pa	Dha	Ni	Sa(tar)[11]
9/8	5/4	4/3	3/2	5/3		15/8	2

It seems that scholars may have selected above two values to find out which value is more appropriate.

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[10] Culver, C.A., Musical Acoustics, New York : Mcgraw – Hill, 1956

[11] Shruti ans Swar by Jashbhai Patel, P.19

Let me work out calculations.

We take **Sa = 256** and find out frequency of other notes as:

$$\text{Re} = \frac{256 \times 9}{8} = 288$$

$$\text{Ga} = \frac{256 \times 5}{4} = 320$$

$$\text{Ma} = \frac{256 \times 4}{3} = 341.33$$

$$\text{Pa} = \frac{256 \times 3}{2} = 384$$

$$\text{Dha} = \frac{256 \times 5}{3} = 426.66$$

$$\text{Ni} = \frac{256 \times 15}{8} = 480$$

$$\text{Sa tar} = \frac{256 \times 2}{1} = 512$$

Now we take **Sa = 240** to find out frequency of other notes.

$$\text{Re} = \frac{240 \times 9}{8} = 270$$

$$\text{Ga} = \frac{240 \times 5}{4} = 300$$

$$\text{Ma} = \frac{240 \times 4}{3} = 320$$

$$\text{Pa} = \frac{240 \times 3}{2} = 360$$

$$\text{Dha} = \frac{240 \times 5}{3} = 400$$

$$\text{Ni} = \frac{240 \times 15}{8} = 450$$

$$\text{Sa tar} = \frac{240 \times 2}{1} = 480$$

If we compare both the set of frequency obtained by two different frequencies of Sa, the frequency of Sa = 240 will be more appropriate as frequency of other notes obtained by it are in whole number compared with the frequency obtained by Sa = 256 in which frequency of few notes are in decimal.

So the frequency of Sa = 240 can be considered as more appropriate value for easy calculations. It also implies that every male and female has frequency of his or her Sa as 240 Hz. However, practically it is impossible as frequency of female voice is always higher than male voice.

In Indian and Western music, frequency of Sa is considered as 240 but practically it is different and is around 263 Hz, which I have tried to find out from my research.

I found out frequencies of 12 notes by practical with oscilloscope and with the help of computer software. I found out frequencies of 12 notes of shruti box and got the almost similar result in both the cases.

Scholar like Pt.Srinivas and Pt.Bharkhande also assign frequency of 12 notes but their frequencies may be arrived from the method given above and not scientific reason was given.

Indian classical music Sa (reference note) is very important and there is freedom for artiste to choose his/her 'sa' according to his/her convenience. Generally, male singers choose Black one or black two key and female singer choose black four or black five key as their 'sa'. However, there was no frequency standard assign for these keys. In Indian classical music, Harmonium is used for reference 'sa' and there is not any tuning standard for harmonium is decided yet so artiste has to compromise with their voice and have to make their scale lower or higher according to Harmonium.

In my experiment, I tried to standardize all 12 notes and assign frequency using Shruti box, which may help in future while standardization of notes of Indian classical music will be done. As we are using note only 12 notes and 22 shrutis in one saptak but also using intermediate frequencies in Ragas so we cannot standardize whole saptak but atleast we can standardize our reference notes.

I assign frequency for

Black one key =	138.62 Hz	
Black two key	=	158.13 Hz
Black four key	=	208.6 Hz
Black five key	=	234.17 Hz

Conclusion

During my research I found out following things:

1. In Indian Classical Music no standardization of notes has been done yet as done in western country, as I mentioned earlier.

   With the advancement of Science the western scholars gave importance to Frequency of notes and its Interval on the basis of Physics and Mathematics consequently Indian scholars also gave place of above matter in their books on Classical Music. *(Sangit Shashtra Tatha Raga Mala by Pandit Bhola Dutt Joshi)*

   We tune our instruments purely by perception and the tuning is within the limit of judgment of the player of the instrument. In many orchestras there is some dissonance because of the perceptional differences of individual players. Also, the same raga (say Mohana/Bhoop) is played differently by Hindustani and Karnatak musicians. Dissonance in orchestral/jagalbandi music may be avoided by carefully tuning our instruments to a reference frequency standard. This implies that we understand the 22 srutis correctly so that we can create a frequency standard of our own.

   During my analysis of 12 notes and analysis of different ragas of different artiste I found that there must be one standard Reference note with a particular frequency so that all other instruments can be tuned uniformly anywhere at anytime. By viewing different singing range of different artists I suggest the frequency of reference not C(Sa) should be between 130-133Hz.

   C=130-133Hz

   With the help of this reference frequency, I also found out frequencies of 12 notes of Indian classical music.

2. Using computer software mentioned earlier, I analyzed ragas of Indian classical music sung/played by eminent artistes

   I did four different type of analysis.

   1. One Raga – Different Artist
   2. Different Raga - Different Artist
   3. One Raga – Sung by one artist at different time.
   4. Different raga – One Artiste.

   I found from the analysis that all Indian notes, except sa can move a microtone depending on the ragas. The same note of raga differs from artiste to artiste and also for the same artiste time to time. We already know this fact but findings of this research gives scientific proof of this fact, which I have analyzed through computer software and

also derived some mathematical calculations and methods to prove my work. Harmonium is not a suitable instrument for accompaniment of Indian classical music the reason is Haromonium is tuned on the basis of equal tempered scale where whatever the key, the frequencies always match, producing harmony in a polyphonic situation. However, because of this equal temperament the individual notes lost their melody to a noticeable extent. The interval between adjacent srutis in our scale of 12 notes is not constant. It is precisely this difference that gives rise to the additional srutis in our musical scale, totalling 22 srutis. In the equi-tempered scale the difference between adjacent notes is constant, and hence there is absolutely no scope for additional frequencies or srutis to be generated.

Whenever we visit any institution we find that reference note (Sa) is different (High or low).Even students can not perform well because they have to compromise with their natural scale as all the time they get different reference note from 'swarpeti'. Electronic sruti box which is tuned on the basis of standard scale is not available every time and it is also not accompanying instrument as Harmonium. Harmonium is accepted everywhere in Air and Classical Music concerts. As I mentioned above every time the artiste has to compromise with the note during their performance so there is a need of some standard to tune the Harmonium to overcome the problem.

Findings of this research may not change the nature of any raga, but may make it easier for teacher to teach the subtleties in ragas.

I am sure the subject will be of immense value to many in the field of Music educators, learners, performers, and beginners to enhance their knowledge. Indirectly it will propagate to preserve our rich heritage of Music

A clear understanding of the 22 srutis will enable us to sing and play the ragas better and with greater feeling. It will also help immensely in teaching our music to students. For example, we can tell the student that the so-called komal gandhar of raga DARBARI is actually lower and he should use the next lower variety of gandhar (in the scale of 22 srutis), and so on.

We need not have to reconsider any srutis that we have been singing. On the other hand, this tells us what sruti we are using and we become more aware.

There are different opinions about distance between srutis while some scholar believes as equal and some as having unequal distance. We sing swars and not srutis. Sangit Martand Pt.Omkarnathji also mentions about this differences of swars in his book 'Pranav Bharati', I have made attempt to highlight this differences by scientific analysis of the cassettes of some of the artistes.

Music and grammer (Kavya) are correlated to each other. As I quoted earlier, Bharatmuni also accepted this in context of Veena and Maharishi Patanjali in context with Voice. Scholars have also given due importance during discussion on Music.

In this regard statement by learned Dr.Premlata Sharma is authentic which says "field of 'gita' and 'kavya' overlap". The following part of a well-known shloka refers to this.

'Sahitya math sangitam Saraswati Kuchadwyam' (Sangitraj by Maharana kumbha, P.78).

This may also one of the reasons of 'swarbhed' in different ragas. Their must be some other reason also like rendition of the raga along with the grammer of music depends on the mental state and the energy at that particular moment.

One gets an opportunity to listen to the same raga rendered by an expert vocalist or instrumentalist at different time. The rendering can offer the listeners different types of pleasure thus the presentation of music is largely associated with the artist's emotion and feelings. A maestro through his creative approach can make a unique presentation confining him to the grammer of music.

I would like to clear a common misconception that is associated with the relative frequency ratios of our srutis. It is very difficult to play or sing a complex ratio such as 729/512. This is actually a misconception, which is removed once you see it as a number and not a fraction. In fact, we cannot produce exactly even the simple ratio of 9/8. The point is, while we sing or play we go by perception and not by these numbers. It is however important that we stay near these ideal values. The human voice can really make extremely melodious music because it can hold on to these notes within the accuracy range of the ear.

I shall feel fruition if this research on subject thesis in the field of North Indian Classical Music finds usefulness not only to musicians and artistes but also to persons interested in carrying out research on the concept of Science behind Music.

I have tried to be precise in presenting my thesis but still however if there is an typographical error it is regretted.