Pitch Analysis in *Karnāṭaka* Music

- An Examination of Intonation and Modern Theories of 22 Śruti-s

SYNOPSIS

Of The Doctoral Dissertation

[Thesis accepted and the Degree awarded in 2005]

By

Madhu Mohan Komaragiri

Department of Indian Music

University of Madras

Chennai 600 005

© 2011 Madhu Mohan Komaragiri
CONTENTS

THE THESIS IN A NUTSHELL...............................................................................................................................3
THE MAIN CONTENTS OF THE THESIS................................................................................................................4
THE BACKGROUND ........................................................................................................................................6
CHAPTER ONE: INTRODUCTION .........................................................................................................................7
CHAPTER TWO: ŚRUTI..........................................................................................................................................8
CHAPTER THREE: FACTORS AFFECTING PITCH PERCEPTION.............................................................9
CHAPTER FOUR: EMPIRICAL PITCH ANALYSIS ................................................................................9
SAMPLE RESULTS .........................................................................................................................................12
CHAPTER FIVE: CONCLUSIONS...........................................................................................................14
EPILOGUE ..................................................................................................................................................15

© 2011 Madhu Mohan Komaragiri www.madhumohan.com
The Thesis in a Nutshell

The central focus of the thesis is pitch analysis in Karnāṭaka music. Since svara-s were measured theoretically in terms of śruti-s, a critical analysis of the concept of śruti from the ancient times was deemed necessary. The ancient Indian music was a fixed-interval, variable-tonic grāma system of seven svara-s and it gradually changed to the fixed-tonic, variable-interval mēla system comprising 12 svara-s. This change is fundamental. The thesis clearly shows that Bharata’s 2-vīṇā experiment does not apply to the changed mēla system systemically. The analysis shows that Bharata’s 2-vīṇā experiment does not consistently yield 22 śruti-s if the intervals are unequal and are changing as is indeed the case in today’s music. Therefore, the very idea of 22 śruti-s does not apply to the current rāga system in the same sense as it did in the ancient Indian music. The primary purpose of śruti-s was to distinguish between the two grāma-s as clarified by Abhinavagupta. The idea of śruti-s was valid only if they were considered as positions on a 22-śruti circular schematic, without being quantified acoustically.

In line with this analysis, interpretations by subsequent authors have been re-examined and several inconsistencies revealed. Modern theories based on a mathematical treatment of the 22 śruti-s are shown to be systemically incompatible with the ancient idea of śruti. Such adaptations to the current rāga system were shown to be untenable. Consequently, the idea of placing these śruti-s among the rāga-s is also inadmissible.

Pitch is the central focus of this study as already mentioned. The relation between pitch and śruti, and svara and between pitch and frequency has been deliberated upon to clear many prevailing misconceptions. And related issues such as the octave, intervals, scales, modal shift of tonic and consonance have been re-visited afresh. The effect of tambūra on intonation is examined to show how it might influence it.

In the realm of perception of music, pitch is the most important aspect. This is studied holistically from the points of view of Physics, Physiology and Psychology of hearing and Psychoacoustics of pitch perception. In addition, the thesis also shows the inadequacy of simple mathematical ratios to capture the dynamic complexity of rāga music.

The above analyses have been corroborated by the empirical pitch analysis of recorded music of a few selected rāga-s on the computer. The artistes were Dr. M. Balamurali Krishna, Prof. T. N. Krishnan and vidvān N. Ravikiran. The intonation in the performance of Karnāṭaka rāga music is found to be significantly variable but with definite Pitch Profiles (characteristic pitch movements of svara-s) and with an overall intervallic balance. The intonation is not acoustically based, except for the pitches of the reference notes of the tambūra. Within the formal context of doctoral research, this kind of holistic study of musical pitches in rāga music is the first of its kind.

1. Veṅkaṭamakhī in his seventeenth century Caturdaṇḍīprakāśikā treated the 12 svara-s as 16 svara-s (with four enharmonic equivalents) for taxonomical purpose.
The Main Contents of the Thesis

Chapter One: Introduction

1.1. Pitch of Musical Sounds
1.2. Just Noticeable Difference (JND)
1.3. Pitch and Śruti
1.4. Pitch and Frequency
1.5. Intonation
1.6. Impetus and Purpose
1.7. Scope of the Thesis
1.8. Organization of the Thesis

Chapter Two: Śruti

2.1. A Brief Background in Musical Treatises
2.2. Bharata’s 2-vīṇā Experiment
2.3. Bharata’s 2-vīṇā Experiment with Various Configurations
   2.3.1. The Sāranā Process with Equal Intervals
   2.3.2. The Sāranā Process with Unequal Intervals
   2.3.3. The Sāranā Process with Svara-s as Positions
   2.3.4. Physics of Vibrating Strings
   2.3.5. Bharata’s 2-vīṇā Experiment with Changing Intervals
   2.3.6. Position Analysis
   2.3.7. Practical Problems with Bharata’s 2-vīṇā Experiment
2.4. Śārṅgadēva’s Interpretation
2.5. Śruti and Svara
2.6. Śuddha and Vikṛta Svara-s
2.7. Ahōbala’s Approach
2.8. Veṅkaṭamakhī’s View
2.9. Gōvinda, Subbarāma Dīkṣitar and Others
2.10. Analysis of the Concept of Śruti
2.11. Modern Theories
2.12. Theories of Employment of Śruti-s in Rāga-s
2.13. Related Issues
   2.13.1. Octave
   2.13.2. Intervals
   2.13.3. Scales
   2.13.4. Modal Shift of Tonic
   2.13.5. Consonance and Saṃvāditva
   2.13.6. Effect of Tambūra
Chapter Three: Factors Affecting Pitch Perception

3.1. Physics of Music
3.2. Physiology of Hearing
3.3. Psychoacoustics of Perception
3.4. Holistic Appreciation [with a schematic diagram]
3.5. The Role of Mathematics

Chapter Four: Empirical Pitch Analysis

4.1. Pitch Analysis Overview
4.2. Experimental Setup and Methodology
4.3. Software and Validation
4.4. Parameters – Assumptions and Limitations
   4.4.1. Maximum Acceptable Pitch Deviation, P±δ (in Cents)
   4.4.2. Minimum Time ΔTmin for Pitch Perception
   4.4.3. Establishing Pitch
   4.4.4. Plotting Pitch Profiles
   4.4.5. Typical Frequency Range in Karnāṭaka Music
   4.4.6. PRAAT Parameters
   4.4.7. Sampling Rate
4.5. Pitch Analysis Schedule
4.6. Results and Analysis [with 80 pitch plots]
4.7. Intonational Imperatives

Chapter Five: Conclusions

5.1. Recapitulation
5.2. Conclusions
5.3. Original Contributions Made
5.4. Suggested Further Research

Appendix A: Glossary [of the physiological, psycho-acoustical and other technical terms]
Appendix B: Explanatory Notes [indicated in the text of the thesis by a superscripted number]
Appendix C: 22 Śruti-s [collated from various authors]
Appendix D: Various Śuddha and Vikṛta Svara Positions [of various lakṣṇakāra-s]
Appendix E: Artiste and Rāga Schedule
Appendix F: Empirical Pitch Analysis Results [of five selected rāga-s]

References

The CD with the privately recorded audio samples was deposited with the Madras University Music Department and the University main library.
The Background

Following up on Bharata’s Nāṭyaśāstra subsequent authors have reiterated the concept of śruti and propagated the idea of 22 śruti-s, although with differing interpretations. For the sake of authenticity, these authors attributed their ideas to Bharata. Most modern scholars in the past 150 years or so have given a mathematical treatment based on a combination of the principles of acoustics and Western tuning concepts which are alien to Indian music. The names of some of these modern scholars are given below in Chapter 2.

Madras Music Academy passed a resolution in 1927 in favour of the 22 śruti-s. It was decided by the All India Music Conference of that year, that only the system of 22 śruti-s was practical and consistent with the 12 svara sthāna-s of the vīṇā. A similar movement was initiated in the 1850s by the Gāyan Samāja of Poona for Hindustāni music. The word ‘modern’ applies to a period starting from here to the current times. Scholars disagreed with each other in so far as what exactly these 22 śruti-s were, but were almost unanimous in accepting the validity and applicability of the theory of 22 śruti-s to the current practice of music, placing these 22 śruti-s among the various rāga-s.

In a conference held in April 1929, South Indian musicologists adopted the following 22 śruti-s and of course, attributed them to Bharata:


This was based on cycle of fifths and fourths; and the pairs separated by 81/80.

Most modern scholars have since published papers in the journal of the Academy and elsewhere on the adapted 22 śruti theory; some agreeing and some suggesting changes, but mostly voting for it. According to R. Sathyanarayana, about 250 different values have been proposed so far by the modern scholars who were eager to show continuity of the core musical principals from the ancient times, conveniently overlooking the fact that the ancients never once said that śruti-s and svara-s were the same. The idea of treating śruti-s as svara-s and placing them among the rāga-s had taken root since the time of Veṅkaṭamakhī misleading the modern scholars. This idea of the applicability of the 22 śruti-s to the rāga-s is currently prevailing.
Chapter One: Introduction

In this introductory chapter, foundational concepts of pitch, just noticeable difference (JND), frequency, śruti, svara and intonation have been examined closely in relation with each other. This chapter elaborates on the essential difference between pitch and frequency. Pitch is a fundamental quality of a musical sound. It is the subjective perception of a musical tone. Frequency on the other hand is the physical attribute of any sound impulse. An analysis of musical sounds therefore calls for a study of pitch, rather than frequency, as perception in involved. But modern theories of intonation hitherto have neglected this vital distinction.

A concept like śruti has been debated upon endlessly but always within the context of 22 śruti-s, which were defined precisely in mathematical terms by the modern scholars. This thesis finds such theories as flawed. Śruti is taken to mean a musical sound that is discernable between two svara-s. It comes from the root śrū, which means to hear. But it was a conceptual unit of measurement of svara-s, without having acoustical values assigned to it. No metaphysical connotations are implied in the thesis as the focus is on objective pitch analysis. Some scholars have equated śruti with just noticeable difference (JND). The thesis shows the practical difficulty in such an equation.

Scholars like Levy in the past have used the words śruti and intonation synonymously. This thesis treats them differently. By intonation is meant the manner in which musical notes are pitched in the performance of a piece of music. In this sense, it reflects the idea of svara. But modern scholars have used śruti-s and svara-s interchangeably and consequently hypothesized the existence of the 22 śruti-s in the rāga-s of today. In this sense ‘pitch’ can encompass both śruti and svara.

Intonation in Karnāṭaka music is essentially a study of musical pitches in performance and hence the title of the thesis.

The impetus for the analysis is the following question: does the idea of 22 śruti-s as demonstrated by Bharata’s 2-vīṇā experiment, apply to the current rāga system? If not, what kind of intonation is Karnāṭaka music of today based on?

Although the scope of the thesis is limited to this investigation, several related issues have been re-examined anew. Chapter 2 elaborates further. Empirical pitch analysis, using computer software, of privately recorded music was undertaken to investigate the above question and to explore the kind of intonation employed in Karnāṭaka rāga music today.
Chapter Two: Śruti

The concept of śruti as originally demonstrated by the 2-vīṇā experiment of Bharata in his opus, the Nāṭyaśāstra has been closely examined. The 2-vīṇā experiment has been mathematically modeled. The unresolved question of whether the intervals were equal or unequal is explored. It is found that discrepancies occur in either case. The idea of śruti seems to make sense only when considered as a position, without being quantified.

It has been shown with examples that a 2-vīṇā experiment with unequal intervals that are changing will not consistently yield 22 śruti-s. Several current rāga-s with the mathematical svara values assigned by the modern scholars, can be taken as actual examples and shown clearly that the application of the 2-vīṇā experiment will yield different number of śruti-s for different svara configurations; not always 22 consistently. Of course, this logic applies only if the intervals are unequal and changing. But then the modern rāga system is based on such changing interval sizes that are unequal.

Consequently, subsequent interpretations of 22 śruti-s have been re-evaluated. For example, Śāṅgadeva presupposed the 22 śruti-s by using 22 strings but without explaining his tuning precisely. If it was equal temperament, then it has been shown that such a cyclic process will terminate with any number of śruti-s, rendering his proof redundant. The idea that his tuning was based on Just Noticeable Difference (JND) has been shown to be incorrect. Also, it is interesting to note that he used 22 strings only. In an actual experiment he would require 23 strings as Sa merges with Ni (lower Ni) in the fourth sāraṇā. It is clear that such ‘experiments’ were done conceptually and not actually. Likewise, interpretations of the other authors have also been examined. It has been shown that the interpretations of these authors hold only if svara-s were considered as positions, without being assigned precise mathematical values.

Many prominent modern musicologists such as K.B. Deval, E. Clements, F. Strangways, Abraham Pandither, B.C. Deva, Alain Daniélou, G.H. Ranade, F. Framjee, R.H.M. Bosanquet, C.S. Ayyar, H.V. Modak, S. Ramanathan, P. Sambamurthy and others, have proposed mathematical theories of 22 śruti-s based on a combination of Just Intonation and Pythagorean tuning (cycle of fifths & fourths) and even Equal Temperament. Notable exceptions were N. Jairazbhoy, M Levy, H Powers, N. Ramanathan, and Ratanjankar etc. The modern scholars sought validation by attributing their mathematical calculations to Bharata. Treating śruti-s on par with svara-s, they tried to place them among the current rāga-s. In this way, they tried to show that the idea of 22 śruti-s continues to be the basis of intonation from ancient times to the present and as such defines the rāga system. This thesis examines Bharata’s idea of the 22 śruti-s as demonstrated by the 2-vīṇā experiment and shows as untenable all such mathematically based modern theories of intonation. This is one of the primary and significant contributions of the thesis.
In line with this thinking, relevant issues such as the concept of octave, musical intervals, the idea of scales and modal shift of tonic have been freshly investigated. It has been explained that mathematical rigidities do not apply to melodic intervals (sequential notes) which the rāga music comprises. Frequency ratios assigned by scholars pertain to harmonic intervals (simultaneous notes). And, it is argued that without being endowed with a sense of Absolute Pitch (AP), modal shift of tonic would be difficult to conceive for a musician unless aided by a fretted instrument. Artistes do a modal shift of the tonic while performing based on their prior knowledge from theory. Also, with the rejection of the idea of 22 śruti-s, the concept of consonance has been re-assessed. Consonance primarily depends on the perception mechanism based on the tonotopic organization (see below) in the brain. Consonance is subjective. The idea of melodic consonance is discussed. The probable influence of tambūra on the intonation is also explored.

The main thrust of this section is to show that the original idea of 22 śruti-s pertaining to the ancient grāma system, does not apply to the current practice of rāga music.

### Chapter Three: Factors Affecting Pitch Perception

Intonation involves several aspects such as the pitch, intensity, timbre, time (tempo) etc. and the musical context as well. This thesis looks primarily at the aspect of pitch. Therefore, it has been studied more closely in terms of Physiology, Psychology of hearing and Psychoacoustics of pitch perception. The whole process of pitch perception has been put together holistically. A conceptual block diagram (given in the thesis) has been developed to illustrate the complex process of pitch perception. It has been shown how the tonotopic organization (pitch mapping) in the primary auditory cortex (brain) affects and gets affected by deliberate learning and training which actually alters the pitch maps. This is what actually guides intonation and therefore transcends physical parameters. In other words, intonation is psycho-physiological in nature and not merely physical.

Foundational concepts of mathematics have been scrutinized to show that simple mathematical models fail to explain the phenomena of music. Application of mathematics must necessarily take into account the characteristics of the complex process of pitch perception. The tonotopic organization is based on pitches and not frequencies. And it has been established that deliberate learning actually alters the tonotopic organization. Hence, the rigidities of mathematical ratios assigned to musical notes do not hold.

### Chapter Four: Empirical Pitch Analysis

Musicological discussions in the field of Karnāṭaka music on the concept of śruti and on the applicability of the 22 śruti-s to the current rāga-s are aplenty. Opinions abound. But, there is no
empirical data available to verify the opinions. In a practical art like music, empirical analyses and perception experiments are necessary to corroborate theory with the observable phenomena. This thesis takes that noteworthy step and presents empirical pitch analysis, perhaps for the first time within the formal context of a doctoral program.

A study of the intonation of musical pitches in actual performances by competent artistes could reveal intonational imperatives that will likely demystify theoretical deliberations. An empirical pitch analysis of five representative rāga-s rendered specifically for the purpose of this study by three performing artistes has been presented in the thesis. The five rāga-s are: Gaula, Sāvērī, Bhairavī, Hindōlam and Haṃsānandī. The three artistes are: vidvān M. Balamurali Krishna, vidvān T.N. Krishnan and vidvān N. Ravi Kiran. It may be noted here that these two instruments are unencumbered by frets and will likely reflect the natural intonation based on the tonotopic organization in the primary cortex.

The software tool and the computer lab setup are explained below.

**Methodology**

Empirical pitch analysis of recorded music entails a computer lab setup. Although a basic personal computer would work, for the purpose of this study, a high-end Pentium 4 with DE 5.1 creative sound card has been used. A Sony portable minidisk recorder, MZ-N1, where the recording can be done directly on to a mini CD, was used for private recordings, with a sensitive Sony electret condenser microphone, ECM-MS907.

The recorded music was then transferred to the computer using an RK-G136 type cable, with two male ends. This transfer is analogue. Proper settings were maintained as per the directions given in the manuals accompanying these equipments. Quality 5+1 i-Sound speakers with good frequency response were used for adequate hearing.

A digital śruti box with headphones facility was used to feed the śruti to the musicians so as not to record the tambūra śruti. The musicians were asked to render a brief ālāpana of a few selected rāga-s (as listed above) in a quiet and comfortable ambience. These private recordings were then ported on to the computer for the pitch analysis.

The software used for the pitch analysis is PRAAT, version 4.0.25. This was developed at the Institute of Phonetic Sciences, University of Amsterdam. The method used in this software for pitch estimation is auto-correlation. Further details are available at: [http://www.praat.org/](http://www.praat.org/). The pitch analysis in PRAAT on audio samples was in mono.
An audio CD containing the analyzed extracts from the private recordings has been submitted with the thesis and deposited with the Music Department and the main library of the University of Madras, Chennai, India.

PRAAT software is widely used in the academic circles for a variety of reasons. For the current study however, only the pitch analysis tool has been invoked and the results in terms of pitch values in cents and pitch plots have been presented in the thesis (see below for the samples).

There are several parameters that need to be handled very carefully; such as establishing the pitch of musical notes and their profiles, establishing the minimum time required to elicit pitch perception (0.1 sec), establishing the acceptable deviation ($\pm 10$ cents) in pitch measurements etc. This of course entails judgment.

A brief summary of the results is presented below:

Theories of placing the 22 śruti-s among the different rāga-s could not be supported by the empirical pitch analysis presented in the thesis. Intonation of individual svara-s, almost always deviated from the theoretical values. And svara-s that necessarily inflect to characterize a rāga, defy a mathematical treatment.

It has been found that the same svara was pitched differently at different times by the same artiste in the same rendition of a rāga. Different artistes intoned the same svara differently in the same rāga. It has also been observed that the pitches and pitch profiles do not seem to entirely depend on the immediate musical context.

It may be pointed out here that the different pitch values measured were not averaged out. They have been presented as such to demonstrate the variability in intonation.

Intonation in performance is indeed variable. There is variation even in the ādhāra-ṣadja. Consequently, variation in pañcama and tāra ṣadja was to be expected. The fluidity of the musical entity, called the svara, has been highlighted. That the svara has a profile and is not a unitary value is established by this empirical pitch analysis.

Sample results along with an explanation of the results, are given below. As an illustrative sample, only a couple of pitch values of ṛṣabha in Gaula rendered by the three artistes is provided here. In the thesis however, more elaborate results (tables & graphs) pertaining to the five rāga-s and the three artistes, as mentioned above, in a slightly different format, are presented along with the mathematical sāraṇā analyses and other relevant data in the appendices.

From the given samples below, clearly the Gaula Ri is lower than the theoretically expected value ($256/243 = 90$ cents) of ēka-śruti ṛṣabha. It may be mentioned here that all the pitch values are given in cents, for easy comparison.
Sample Results

Table 1: A Sampling of Intonation of Ri in Gaula by the Three Artistes: [All values in Cents]

<table>
<thead>
<tr>
<th>Artist</th>
<th>Mean</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Range</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>vidvān M. Balamurali Krishna [MBK]</td>
<td>20</td>
<td>154</td>
<td>-39</td>
<td>193</td>
<td>Prolonged Ri for 0.5 s</td>
</tr>
<tr>
<td></td>
<td>78</td>
<td>240</td>
<td>-58</td>
<td>298</td>
<td>Sa-Ri--- [See Pitch Profile P-01]</td>
</tr>
<tr>
<td>vidvān T.N. Krishnan [TNK]</td>
<td>23</td>
<td>107</td>
<td>-9</td>
<td>116</td>
<td>Pa-Ma-Ga-Ma-Ri--- [See Pitch Profile P-02]</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>157</td>
<td>-6</td>
<td>163</td>
<td>Prolonged Ri for 1.4 s</td>
</tr>
<tr>
<td>vidvān N. Ravi Kiran [NRK]</td>
<td>21</td>
<td>71</td>
<td>-8</td>
<td>79</td>
<td>Prolonged Ri for 0.9 s [See Pitch Profile P-03]</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>82</td>
<td>-19</td>
<td>101</td>
<td>Held for 0.78 s</td>
</tr>
<tr>
<td></td>
<td>59</td>
<td>108</td>
<td>19</td>
<td>89</td>
<td>Held for 0.18 s</td>
</tr>
</tbody>
</table>

Theoretical values: 256/243 = 90 c & 16/15 = 112 c. The minus sign indicates dipping below Sa.

Sample Pitch Profiles:

Pitch Profile P-01: MBK-Gaula-Ri

The theoretical values are 256/243 = 90 c and 16/15 = 112 c. The minus sign indicates dipping below Sa.
### Pitch Profile P-02: TNK-Gaula-Ri

![Graph](image1.png)

**Time Duration ≈ 2 sec**

**Ref: Table 1: Gaula-Ri**

### Pitch Profile P-03: NRK-Gaula-Ri

![Graph](image2.png)

**Time Duration ≈ 0.88 sec**

**Ref: Table 1: Gaula-Ri**
**Explanation of the results**

The primary information obtained from the pitch analysis is the ‘mean pitch’ value of a musical note. Keeping in mind the minimum time required for pitch perception, an appropriate segment of the pitch plot is selected which is as steady as possible and is representative of the note. But, every note will have a range (max/min). So, the tables give the mean pitch values of the notes, along with the maxima, minima and the ranges. As expected, several pitch values for each svara have been measured. Instead of averaging them out, they are presented as such to highlight the variability in intonation. The immediate musical context is also given, which could influence intonation but it is not the sole deciding factor.

Many typical Karnāṭaka rāga-s have svara-s that have highly characteristic movements. It is very difficult and even inappropriate to give one pitch value to such svara-s. Therefore, pitch plots capturing the characteristic movements, called as ‘Pitch Profiles’ have been given. These pitch plots capture the detailed svara movements and also give the theoretical reference values.

The above samples present Gaula Ri, which has a characteristic oscillation about Sa. It is clear that the value of Gaula Ri is not 256/243 (=90 cents) as predicted by the modern theories; it is typically much lower. It is in fact a slight oscillation on Sa and as such even dips below Sa. The peaks of the pitch profiles oftentimes significantly exceed the 256/243 limit and the ranges can be more than a whole tone. But aurally, the perception of Gaula Ri is unmistakable. That’s why intonation is psycho-physiological in nature that transcends physical parameters.

It may be mentioned here that many times, particularly during the faster phrases, although it is aurally discernible, pinpointing a pitch value is not always possible. This indicates that melodies transcend the idea of svara-s in the sense of having definite svara sthāna-s or precise acoustical values. The latitude in intonation defies unitary pitch values.

**Chapter Five: Conclusions**

The poser whether the theory of 22 śruti-s is still applicable to the current rāga system or not has been assertively answered in the negative. Despite a huge corpus of literature endeavoring to link the idea of 22 śruti-s elucidated by Bharata with the modern mēla system, and trying to make it a basis for the rāga classification and definition, this thesis shows clearly that the widespread belief in the sanctity of the quantification of the 22 śruti-s is inadmissible. The theory of 22 śruti-s is not valid in today’s rāga music.
Consequently, several issues germane to the *rāga* system, such as modal shift of tonic have been scrutinized freshly in relation to the sense of absolute pitch, and concepts such as consonance were re-examined.

Intonation in the performance of *Karnāṭaka* music has been shown to be variable within a rendition and across renditions by same and different artistes. It is not based on any theoretical tuning system, such as the Just Intonation, Pythagorean tuning etc. Intonation in *Karnāṭaka* music is not acoustically based, except for the pitches of the resting notes that correspond to the *tambūra*, which are also not held absolutely in performance. Musical pitches do not match with the theoretical values and no particular tuning is favored naturally.

This study is holistic in nature because it combines physics of music with physiology and psychology of hearing along with the psychoacoustical pitch perception, supported by empirical pitch analysis. This seminal work should serve as the basis for further research in this very important area of intonation in *rāga* music.

**Epilogue**

As music undergoes changes, its theoretical framework also should change accordingly to accommodate the changes. A theory should be able to adequately explain the phenomenon, and as the phenomenon changes, must necessarily adapt to those changes. In Indian musicology, as with most subjects of Indology, the tradition of unqualified reverence to the older authors and texts limits one’s objective assessment of music as practiced. The author has to reconcile the differences between the older texts and the current practice of music which already changed in significant ways. The way out of this predicament is to typically engage in ontological and esoteric discourses. In doing so, each author takes his readers further and further away from the original intent and misleads subsequent generations. For example, as Dr. Premlata Sharma rightly pointed out, the *catuḥ sāranā* process of Śāṅgadēva (13th century) is inaccurate because the *grāma* was not taken into consideration. Further, in conceptualizing a 22-stringed instrument, he had clearly gone against the grain of Bharata in that he has equated *śruti*-s with *svara*-s. This has of course misled the later authors.

The modern scholars in the past 150 years or so (with the notable exceptions as mentioned earlier) had additional limitations in that they did not deem it necessary to test their theories empirically and were drawn by the western ways of thinking. It is rather disconcerting that an entire generation of intelligentsia was sold to this untenable idea of adapting the concept of *śruti*, which operated in a totally different system of *grāma*-s, to the current *mēla* system and quantifying *śruti* the way they did.
With our better understanding of the universe we live in and our neurological functioning and with the advances in science and technology, we have no place to hide now but to confront the realities of our existence and experiences. We will some day, hopefully in the near future, have a fuller understanding of what exactly a rāga is neurologically. For that to happen, we need to continuously strive to explore and not be hesitant to modify our theories upon the latest findings to be able to explain the phenomena of rāga music which we so dearly experience and cherish.

Let music and musical sense prevail!

© 2011 Madhu Mohan Komaragiri