

# Pitch Analysis in *Karṇāṭaka* 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]

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## The Thesis in a Nutshell

The central focus of the thesis is pitch analysis in *Karṇāṭaka* 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<sup>1</sup>. 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 *Karṇāṭaka 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.

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

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### 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:

1, {256/243 & 16/15}, {10/9 & 9/8}, {32/27 & 6/5}, {5/4 & 81/64}, {4/3 & 27/20}, {45/32 & 64/45}, {3/2}, {128/81 & 8/5}, {5/3 & 27/16}, {16/9 & 9/5}, {15/8 & 243/128} and 2.

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 is 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 *Karṇāṭaka* 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 *Karṇāṭaka* 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 *Karṇāṭaka rāga* music today.

## Chapter Two: *Śrutī*

The concept of *śrutī* 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 *śrutī* 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 *śrutī-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 *śrutī-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 *śrutī-s* have been re-evaluated. For example, Śārṅgadeva presupposed the 22 *śrutī-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 *śrutī-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 *śrutī-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 *śrutī-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 *śrutī-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 *śrutī-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 *śrutī-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 *śrutī-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 *Karṇāṭaka* music on the concept of *śrutī* and on the applicability of the 22 *śrutī-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*, *Hindōlaṃ* 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/>. 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-ṣaḍja*. Consequently, variation in *pañcama* and *tāra ṣaḍja* 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

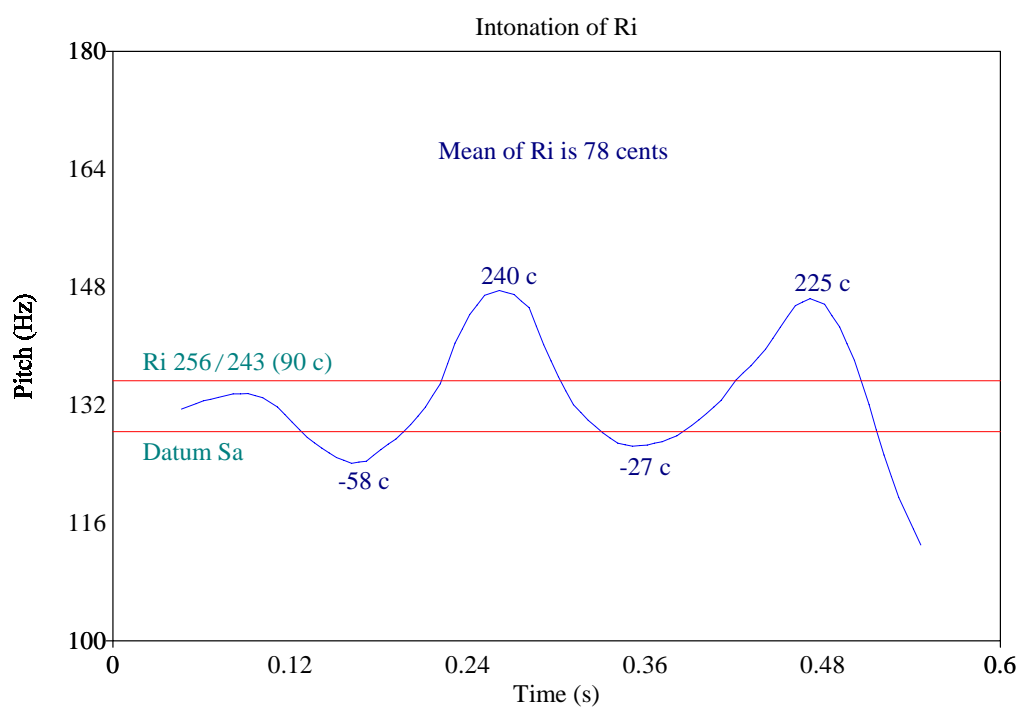
**Table 1:** A Sampling of Intonation of *Ri* in *Gaula* by the Three Artists: [All values in Cents]

Mean	Maximum	Minimum	Range	Context
<i>vidvān</i> M. Balamurali Krishna [MBK]				
Measured Value of <i>Sa</i> = 130 Hz				
20	154	-39	193	Prolonged <i>Ri</i> for 0.5 s
78	240	-58	298	<i>Sa-Ri--</i> [See Pitch Profile P-01]
<i>vidvān</i> T.N. Krishnan [TNK]				
Measured Value of <i>Sa</i> = 350 Hz				
23	107	-9	116	<i>Pa-Ma-Ga-Ma-Ri--</i> [See Pitch Profile P-02]
36	157	-6	163	Prolonged <i>Ri</i> for 1.4 s
<i>vidvān</i> N. Ravi Kiran [NRK]				
Measured Value of <i>Sa</i> = 199 Hz				
21	71	-8	79	Prolonged <i>Ri</i> for 0.9 s [See Pitch Profile P-03]
33	82	-19	101	Held for 0.78 s
59	108	19	89	Held for 0.18 s

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

### Sample Pitch Profiles:

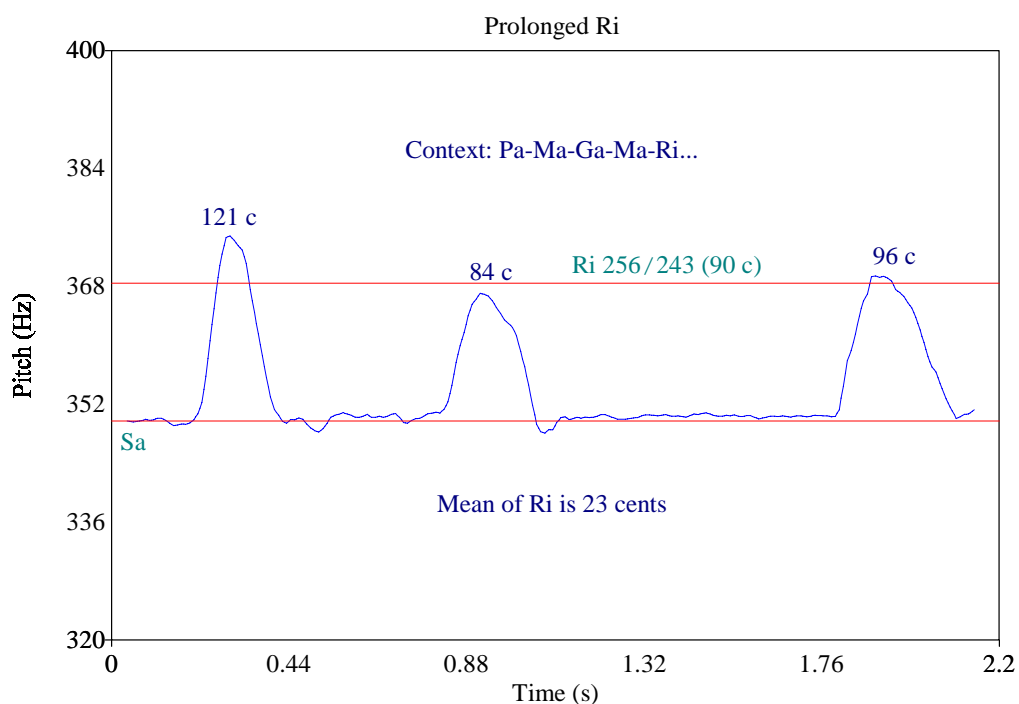
#### Pitch Profile P-01: MBK-*Gaula-Ri*



Time Duration  $\approx$  0.48 sec

Ref: Table 1: *Gaula-Ri*

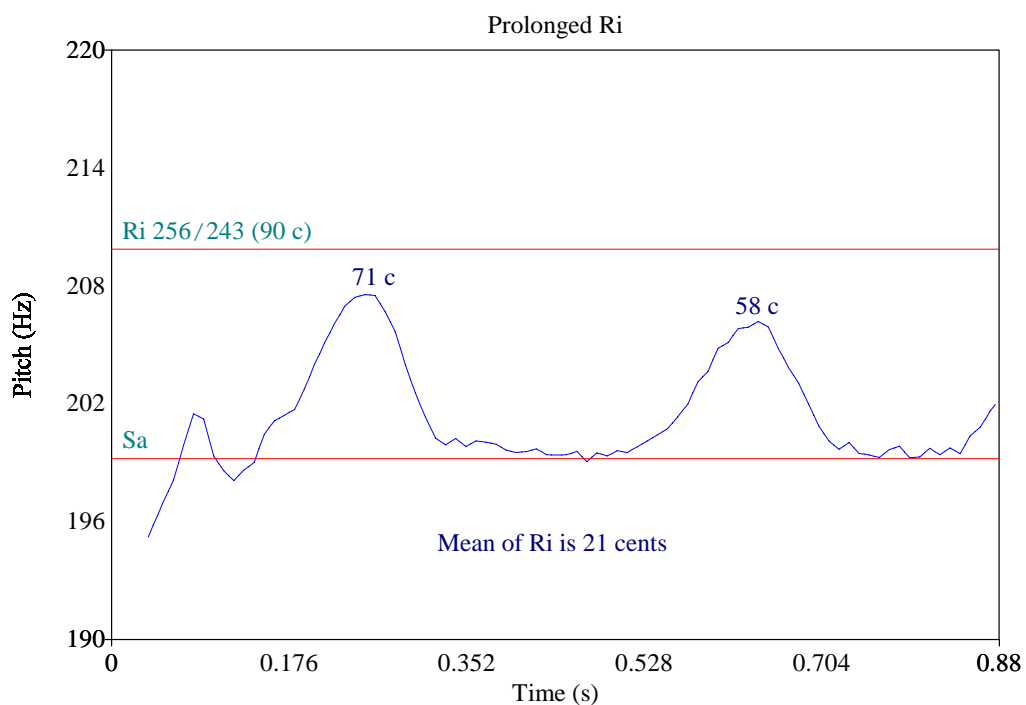
### Pitch Profile P-02: TNK-*Gaula-Ri*



Time Duration  $\approx$  2 sec

Ref: Table 1: *Gaula-Ri*

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



Time Duration  $\approx$  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 *Karṇāṭaka 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 *Karṇāṭaka* 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 *Karṇāṭaka* 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 sārāṇā* process of Śārngadēva (13<sup>th</sup> 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!

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