FLAME UNIVERSITY

THE DOCTRINE OF *SHRUTI* IN INDIAN MUSIC

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The Doctrine of *Shruti* in Indian Music

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Dedicated to **Bharatmuni**

-The proponent of *Shruti-Nidarshanam* or *Sarana-Chatushtaya* experiment which is the first ever systematic exposition of 22 *shrutis* (microtones) in Indian Music.

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I would like to thank Dr. Kiran Thakur for constantly discussing the progress of the research. It kept me on track and helped me complete it.

Finally, my family needs to be mentioned although they are beyond formality. Any research that I have done so far has not escaped the critical eye of my wife Archana. She not only edited the final draft, but also discussed some of the critical research issues and provided some valuable suggestions. I also appreciate my son Vihang's curiosity about highly technical research topic such as *Shruti* (microtones) in Indian Music.

Dr. Vinod Vidwans

Contents

From the Vice Chancellor's Desk

I am glad that FLAME University embarked on the second phase of its research publications program with the release of a series of monographs. It is noteworthy that this monograph and few other books are being released for publication within six months after FLAME University came into being.

The mission of FLAME University includes offering a platform for research in all fields of learning. We encourage faculty and students to undertake original, theoretical, and applied research that is relevant to society. Our teachers participate in national and international conferences to present their research papers. Our endeavor is to take their research into the public domain so that researchers, scholars and laypersons can benefit from the findings of their studies. This publication is the logical extension of this mission.

The present monograph titled `The Doctrine of *Shruti* in Indian Music', authored by Dr. Vinod Vidwans demonstrates that FLAME University researchers are keen to take up research on Indian themes and concerns. This monograph tries to throw light on the doctrine of microtones in Indian classical music and their relevance today.

My compliments to Dr. Vinod Vidwans for writing this monograph.

Dr. Devi Singh

January 26, 2016

About the Monograph

Monograph is an extended essay dedicated to a single topic. It gives comprehensive information about the topic in terms of the significance of the topic in the context of particular field, historical or evolutionary development of the topic, technical and updated information and finally the future prospects. This monograph is dedicated to the single topic of *`shruti'* (microtone) in Indian music. Although it does not discuss the concept of *shruti* from evolutionary point of view and historical perspective in strict sense, it does not shy away from it either. Focus is more on conceptual understanding of all the relevant issues related to *shruti* and their significance and relevance in today's context while historicity is secondary. The doctrine of *shruti* in Indian music has been discussed and debated for at least two thousand years. The debate has become livelier during last two centuries after Western musicologists such as William Jones started taking keen interest in it. For almost last two decades the topic is being studied using scientific and technological tools. It is interesting to see that the topic of *shruti* in Indian music is highly revered and respected but still remained an enigma for practicing musicians, scholars and musicologists.

This monograph is written for Indian musicologists, researchers, scholars of Indian music, and Information Technology (IT) professionals who have strong inclination towards Indian music. The implied readership is highly diverse and well-informed about Indian music. It is certain that this monograph is not for a beginner in Indian music. The theoretical concepts discussed in this monograph are highly complex and require deeper level understanding of Indian music. The discussion involves conceptual analysis and at times rigorous technical analysis. The author of this monograph does not distinguish between Hindustani music or Carnatic music. At certain fundamental level all Indian music is one: *Samavedic, Dhrupad, Hindustani, Carnatic, Rabindra Sangita*, Spiritual music, popular and folk music. The doctrine of *shruti* is valid for all categories and varieties of Indian music.

For centuries *shrutis* are considered as an enigma in Indian music. Researchers attempted to demystify the enigma by interpreting three seminal texts on Indian music, namely: *Naradiya Shiksha*, Bharata's *Natyashastra* and *Sangita Ratnakara* of Sharangadeva. However, none of these attempts led to conclusive and convincing understanding of *shruti*. With thorough scrutiny of the original text from the above-mentioned

three treatises, this monograph comes up with a conclusive proof for equal temperament twenty two *shruti* paradigm of Bharata. Apart from that it provides a comprehensive frame-work of hundred and ten *shrutis* called *`shruti-Punja'* model or *`Shruti-Megha'* model that may be useful for computational Indian music. This model integrates concepts of *shruti* from *Naradiya Shiksha* into the Bharata's paradigm of equal temperament twenty two *shrutis*. This may open up the possibility to explore new musical spaces, new consonances, new dissonances, new melodies and harmonies to take Indian music forward.

As discussed throughout this monograph there are certain concerns among musicologists about the nature and significance of *shruti* in Indian music. Some of the scholars are concerned about the textual interpretation of *Natyashastra* or *Naradiya Shiksha*. This monograph thoroughly scrutinizes the original text from *Naradiya Shiksha*, *Natyashastra* and *Sangita Ratnakar* and through conceptual analysis tries to fine-tune our understanding about *shruti*. The crux of this analysis is that during ancient times the concept of *shruti* has evolved in two or three stages. Although the Vedas are called *shruti*, the meaning of the term *`shruti'*, was more spiritual than musical during Vedic period. During Vedic period, the term *`swara'* was more prevalent than the term *`shruti'* to denote tonalities of Vedic *`mantras'*. *Naradiya Shiksha* uses the term *shruti* to denote sonar qualities of Vedic *swaras* (especially *swaras* used in *Samaveda)* achieved through tonal variation and modulation and further *Naradiya Shiksha* identifies five categories of *shruti*. This monograph attempted to clarify various notions related to *shruti* with the help of important available resources and Bhatta Shobhakara's commentary on *Naradiya Shiksha*. At the end of this analysis this monograph provides a brief summary of results that may be a useful tool for *Samagana* practitioners.

Bharata's *Natyashastra* provides a robust paradigm of equal temperament twenty two *shrutis* accommodating the Vedic *swaras*. Bharata's paradigm is completely different from *Naradiya Shiksha*. For *Naradiya Shiksha shrutis* are sonar qualities of a *swara* while for Bharata *shrutis* are twenty two distinct places equally distributed (having equal temperament) across the octave. Sharangadeva in his *Sangita Ratnakar* tries to integrate concept of *shruti* from *Naradiya Shiksha* into Bharata's paradigm. He is quite successful in doing so to certain extent but there are few outstanding issues which are discussed in this monograph.

This monograph stringently scrutinizes all conceptual and definitional issues including the sequence of textual references through rigorous analysis of all the original Sanskrit text of the above-mentioned three treatises. Thus the definitional issues, conceptual issues, issues related to the sequence of description and interpretation in ancient text, have been taken care by this monograph & arrived at certain clarity about these issues.

The monograph addresses the ontological issues that in what way *shrutis* exist- as microtones, sound qualities, mental concepts or something else? As it is discussed, according to *Naradiya Shiksha shrutis* are microtonal sonar qualities of a *swara*. On the other hand according to Bharata's paradigm *shrutis* are microtones as equal temperament tonal positions in an octave. Thus *shrutis* have physical existence and in modern times can be understood in terms of their frequency values. These are not merely mental concepts. It addresses other epistemological issues about how one recognizes *shruti*? *Naradiya Shiksha* does not give any clear clue about how to recognize *shrutis*. It provides a textual description that is not really sufficient but probably the living tradition of *Samaveda* must have been so strong that such a description was sufficient to recognize *shrutis* those days. Bharata's *`Shruti Nidarshanam'* experiment as thoroughly discussed is a conclusive proof of the equal temperament twenty two *shrutis*. This also tells a musician to how to establish *shrutis* on *Veena* and perceive them in a step-by-step manner. Bharata gives highly sophisticated *Shruti-Nidarshanam* or *Sarana-Chatushtaya* experiment to experience and demonstrate twenty two *shrutis* which is discussed at appropriate place in present monograph. This experiment is so accurate and sophisticated, as discussed, that one gets awe-struck by the intellectual and mathematical genius of the creator of such an experiment. Sharangadeva also had devised a variation of the same experiment which also conclusively demonstrates the existence of equal temperament twenty two *shrutis*. The present monograph also developed a different variation of the *Shruti Nidarshanam* experiment as discussed in the monograph.

During last two centuries many models of *shruti* were proposed by scholars who believed that *shrutis* are not equi-distanced. Computational simulation of the *`Shruti-Nidarshanam'* experiment, using some of the above-mentioned models, shows that all these models are wrong. On the other hand computational simulation succeeds only with Bharata's paradigm of equal temperament *shrutis*. With comparative analysis of Bharata's equal temperament scale, contemporary twelve tone equal

temperament scale and just intonation scale it was shown that Bharata's equal temperament scale will also be acceptable to musicians and audience. Perception and acceptance of musically pleasing notes is a psycho-acoustic phenomenon and therefore purely logico-mathematical theories will not do any justice to musical experience. Just intonation scale is considered as a logico-mathematical ideal scale. From psycho-acoustic point of view audience look for some kind of repeatability and consistency among the musical notes that produce musical experience. Any equal temperament scale will provide such a consistency. Therefore, musicians and audience have no problem in accepting twelve tone equal temperament scale. Similarly Bharata's twenty two *shruti* equal temperament scale also should not have any problem for acceptance because the consonance tolerance ratio of Bharata's scale and twelve tone scale is same.

This monograph puts forth two types of arguments: a stronger or primary argument and few secondary arguments. The stronger argument is based on the critical analysis of Bharata's original Sanskrit text from *Natyashastra* and then the analysis of the *`Shruti Nidarshanam'* experiment as a confirmatory proof of equal temperament twenty two *shrutis*. While doing so, *Shruti Nidarshanam* experiment is discussed in its letters and spirit, `as it is', without any twist of words or interpretation. This monograph completely relies on the original text of Bharata and that is the strength of the stronger argument. *Shruti Nidarshanam* experiment is a proof where it shows that any proposal of non-equal temperament *shrutis* fails to fulfill the requirement of the `magic' number twenty two. It means that there exists only one solution that fulfils the requirement: equal temperament *shrutis*. The number twenty two is very important because Bharata has mentioned it in the text at many occasions very clearly and there is no confusion about the number. This stronger argument is the crux of this monograph while other arguments are supplementary in nature. Apart from the stronger argument, this monograph provides a step-by-step method of establishing *swaras* in an octave (*swara-sthapana* or *swara mandala sadhanam*) based on the original text of Bharata. This was not attempted in any other earlier studies. This is another original contribution of this monograph.

There are pragmatic issues related to *shrutis* those focus on application of *shrutis* in a musical performance. As it is well-known, just intonation scale cannot be used for harmonic music using chords. Equal temperament scale provides flexibility for octave-shift and so most suitable for chord-

based music. Thus Bharata's equal temperament twenty two *shrutis* paradigm will help extending the boundaries of Indian music. It will also help exploring new *Raga* possibilities and microtonal *swara*-phrases, new musical spaces as well as the possibility of inventing new chords. Thus Bharata's paradigm is highly pragmatic that does justice to ancient Vedic music as well as it can be relevant to modern music.

Some of the researchers try understanding *shruti* from Western point of view and apply Western theories to the concept of *shruti.* This issue is addressed by this monograph. It clearly argues that the Western models including Pythagorean model as well as just intonation scale have many practical difficulties in practicing Indian and Western music. During last two centuries researchers un-necessarily tried to force-fit Western models on Bharata's paradigm and eventually could not succeed. In last century, due to developments in the field of science and technology, many scholars try to frame their arguments by using scientific terminology. Similarly in recent times due to advent of Information Technology (IT), the whole language of *shruti* discourse has changed. This new rhetoric helps in strengthening Bharata's paradigm. Computer simulation of *`Shruti Nidarshanam'* experiment and further analysis help in re-establishing Bharata's paradigm. This analysis also shows that equal temperament scale is acceptable to audience and therefore Bharata's equal temperament scale is the most pragmatic solution for the problem of *shruti*. This led to the development of a *`Shruti-Punja'* or *`Shruti-Megha'* frame-work of equal temperament hundred and ten microtones in an octave that integrates all the earlier ancient models of *shruti*. This frame-work is an extension of Bharata's paradigm of equal temperament twenty two *shrutis*. This monograph attempted to argue that Bharata's paradigm is very robust and highly relevant for Indian music in modern times. With the help of advanced computational technology it can help exploring newer possibilities to enrich Indian music.

Dr. Vinod Vidwans

Date: January 26, 2016

The Doctrine of *Shruti* in Indian Music

Dr. Vinod Vidwans

1. INTRODUCTION

The concept of *`shruti'* or microtone in Indian music has been a topic of scholarly debate for centuries. The concept of *shruti* appears in *Naradiya Shiksha* in a codified way. An elaborate and systematic description of *shruti* is found in Bharata's celebrated work on theatrical arts called *`Natyashastra'*. It is considered to be the most revered treatise on Indian theatrical arts that includes, apart from theatre, the art of music and dance. Twenty eighth chapter of *Natyashastra* is specifically dedicated to the discussion on various concepts in Indian music and discussion on *shruti* in particular.

The concept of *shruti* or microtone in Indian music also has been a topic of lively debate in recent times as well. The debate has taken many twists and turns in the last and current century. A huge number of researchers are engaged in this debate, it will suffice to mention some of the most respected researchers and musicologist such as: Bhatkhande, Telang, Popley, Ranade, Bake, Ratanjankar, Kaufmann, and Jairazbhoy who rejected the relevance of the concept of *shruti* to contemporary music. Others include Deval, Clements, Fox Strangways, Danielou, Bose, Lobo, Omkarnath Thakur, Arnold and Bell who believed in direct linkages of the concept of *shruti* with the tradition and contemporary musical practices [Rao, S., p. 681]. Apart from these there are many other scholars such as Acharya Brihaspati who have significantly contributed to the research on *shrutis*. They reflected on the concept of *shruti* in their own ways and postulated various theories. In recent times there have been many studies published on *shruti*. Many authors have also published comprehensive reviews of the available literature on *shruti*-research. In these studies scholars have very aggressively argued their own points of views about the nature and significance of *shruti* in Indian music. The present monograph is an attempt to take a stock of all the earlier studies and reviews. It is not possible to respond to all the points of views expressed by the above-mentioned researchers and other individuals in this work.

However, one can see certain patterns of arguments in their research. There are few select lines of arguments and this monograph tries to address the concerns raised by these arguments. These are considered as prime concerns since they challenge basic concepts related to *shrutis* described in *Naradiya Shiksha* and Bharata's *Natyashastra*. Some concerns are raised about the textual interpretation of *Naradiya Shiksha* or *Natyashastra.* Some other issues are purely conceptual in nature. In last century, due to the developments in the field of physics and acoustics, many scholars have tried to frame their arguments by using scientific terminology while in recent times due to revitalized interest into *shruti*-research augmented by information technology; the whole language of *shruti*-discourse has changed. Some of the researchers try understanding *shruti* from Western point of view and apply Western theories to the concept of *shruti*. Thus broadly speaking, issues and concerns related to *shruti* can be classified into following categories. There are definitional and conceptual issues. For example *shrutis* can be defined in terms of their positions, frequency or quality of sound. Once a particular definition is accepted it leads to a particular type of theorization. The other issues are related to the sequence of description of *shrutis* and their interpretation in ancient text. The ontological issues such as, in what way *shrutis* exist - as microtones, qualities, mental concepts or something else are also very important. For instance, do *shrutis* exist only as concepts that are in the minds of performers and listeners or they are frequencies or a pitch positions? The epistemological concerns are about how one recognizes *shruti* correctly. That is how to validate *shruti*. Finally, the pragmatic issues related to *shruti* focus on application of *shruti* in a musical performance. That means how to play a *shruti* on the instrument or how to render it through voice? This monograph attempts to take a stock of these concerns and tries to bring in clarity about the significance of *shruti* in Indian music and its relevance. While doing so if necessary these concerns are addressed at macro-level as well as at micro-level depending on the kind of scrutiny they demand. At times these issues and concerns are addressed directly or otherwise they are addressed indirectly.

1.1 A Brief Overview of the Rhetoric on *Shruti*

The word *shruti* is derived from Sanskrit root *`shru'*, which means `to hear' [Apte, V. S., 1970]. The term *shruti* is originally used to refer Vedas. Vedas are called *`shruti'* since they are considered as the revelations by seers

[Apte, V. S., 1970]. In Indian musical rhetoric, however, the word *shruti* has completely different connotation and is primarily used as `microtone' in general. Some scholars however, have interpreted the term *shruti* in different ways. During ancient times in the context of Vedic recitations the word *swara* was most commonly used to refer musical notes. The word *shruti* was less prevalent though it is used in *Naradiya Shiksha* in a theoretical discussion. In the tradition of Rigvedic recitation, *Udatta, Anudatta* and the *Swarita* are referred as *swaras* and not as *shrutis*. From musical point view here the word *swara* refers to the accent and/ or pitch of the sound of Vedic *mantras*. Samaveda rendering of *mantras* was done following well-defined rules of *swara* and *shruti* usage. Thus the terms *swara* and *shruti* were understood during Vedic age in a special way and their purely musical usage is as ancient as *Naradiya Shiksha* but not beyond that. It seems that *shruti* and *swara* have special role in Vedic recitation but still the term *swara* was more prevalent in usage than the term *shruti*.

Shruti is essentially, a specific frequency or a pitch position in an octave. This is the core property of a *shruti*. Apart from that a *shruti* has many additional or peripheral properties such as volume, timbre, various effects such as vibrato, relational properties such as `low' or` high' pitch, consonance, ornamentation as well as an ability to evoke aesthetic emotions and so on and so forth. Somehow many scholars have understood and interpreted *shruti* on the basis of these peripheral properties. This has led to confusion among many scholars regarding the meaning of the term *shruti*. During ancient period from Bharata to Abhinavagupta and Sharangadeva, all of them have used the term *shruti* as a pitch position as well as its peripheral meanings. Many a times they used highly metaphorical language to describe *shruti* [Rao, S., pp. 674-675]. However, it is certain that whenever, the term *shruti* is used in a technical sense or in a theoretical sense, it means a `pitch' position in an octave and when the term *shruti* is used for explanation or discussion, they have used a metaphorical language. For instance Sharangadeva in *Sangita Ratnakar* clearly mentions that a *shruti* is an aurally recognizable difference in pitch [Sharangadeva, pp. 56-57]. He also gives separate names to all the twenty two *shrutis*. This is technical information about musical notes and therefore Sharangadeva describes *shruti* in terms of twenty two pitch positions on twenty two strings of a *Veena*. So it may be argued that till the times of Sharangadeva, there was no confusion about the concept of *shruti*. *Shruti* was understood as a pitch position in an octave in theoretical parlance.

From historical perspective, by the time of Ramamatya in 1550 AD and Ahobala in seventeenth century, music scholars started making attempts to establish positions of *swaras* and *shrutis* in an explicitly quantifiable manner. All earlier description tells us that earlier musician used to establish *swaras* and *shrutis* based on the musical sensitivity of the ear or based on the auditory/ aural competence of a musician to distinguish the difference between two musically significant sounds. Bharata says that seven *swaras* to be established on the *Veena* like instrument by *`swara-mandala sadhanam'* [Bharata, p. 15]. That appears to be the well-known method and common process of establishing *swaras* those days, although he does not give the explicit details of the process. The process was simple (as discussed somewhere else in this monograph) and very commonly used and therefore, he might not have felt the need of giving the description of this process. In the *Sangita Ratnakar* of Sharangadeva a process of establishing *shrutis* is very clearly articulated but it is certain that it was different from the Bharata's process of *`swara-mandala sadhanam'*. Sharangadeva clearly describes to adjust twenty two strings which are aurally equi-distanced on an instrument that has twenty two strings and each string stands for each *shruti*. This has to be done using musical sensitivity of the ear that means the distance between two *shrutis* to be judged by ears. Till this time there was no problem about establishing *shrutis* or *swaras*. However, it seems when Ahobala tried to place *swaras* as per the length of the string (though Abhinava also mentions establishing *swaras* by *`angula pramana'* i.e. measurement by using finger width [Bharata, p. 17] - but Ahobala's system might be different); where the musicians started finding some gap between the aurally defined places of *shrutis* and *swaras* and the places defined by the lengths of the string. Probably, this was the first time due to quantifiable process of establishing *swaras*, the ancient and traditional places of *swaras* and *shrutis* got displaced. [Rao, S., pp. 675-677]. Ancient musical sensitivity was perfectly tuned with aurally established *shrutis* by Bharata and substantiated by Abhinava Gupta in his commentary [Bharata, pp. 15-17]. Sharangadeva also seconded this practice of establishing *shrutis*. [Sharangadeva, p. 57]. With the new development there appeared to be a change in the musical perception and sensitivity and musicians started questioning the earlier paradigm of aurally established *shrutis*. Even today for example, contemporary musicians are comfortable with twelve note equal temperament scale, though the puritans argue for `just intonation' scale in the Western Music. Musical sensitivity is a conditioned phenomenon to a great extent although; basic laws of physics have to be

followed. So after sixteenth and seventeenth century onwards, there appears to be a conflict between ancient description of twenty two *shrutis* and medieval musical practices.

1.2 The Modern Debate

Bharata's *Natyashastra* gives an elaborate treatment to the concept of *shruti* though it does not give explicit definition of the term *shruti*. Modern debate revolves around Bharata's description of *shruti*. Bharata uses the term *shruti* as a `unit' of measurement or the *`shrutyantara'* to define the relationship between two musical notes in terms of consonances (*Samvadas*) and dissonance (*Vivada*) [Bharata, p. 15]. This usage provides some scholars to interpret *shrutis* as units of measurement such as *`Dvi-shruti'*, *`Tri-shruti'*, *`Chatuh-shruti'* etc. According to these scholars *shruti* is not a pitch position but a `unit' of measurement to aurally measure the distance between two *swaras*. Bharata uses the term *`Pramana shruti'* as well [Bharata, p. 20]. Some scholars got carried away by this usage and delimited their understanding of *shrutis* to it. According to them *`Pramana'* means standard and *`Dvi-shruti'*, *`Tri-shruti'*, *`Chatuh-shruti'* are the three standard units of categorizing *swaras*. As it is well-known that consonances and dissonances are understood in terms of the pitch of notes, it is evident that *Pramana shruti* is the standard unit of differentiating and correlating consonant and dissonant musical notes in terms of their pitch. However, these scholars do not agree with this interpretation and the debate continues. The pitch distinction and correlation is done using ear alone where it is expected that a musician has a good capability of differentiating musical pitch. Bharata provides highly sophisticated description of *shruti* in his discussion on *Gramas* (musical scales), *Swara-Mandala-Sadhanam* (establishment of seven swaras in an octave) and his well-illustrated experiment called *`Shruti-Nidarshanam'* to ascertain, verify, generate, demonstrate and validate twenty two *shrutis* in an octave. Each one of these topics has been the issue of debate in modern times.

The modern scholars have developed many theoretical models (which do not agree among themselves) of *shruti*. Based on their own models they try to interpret *shruti*-distances and various other concepts related to *shrutis*. There are three unit distances as mentioned above in the *Natyashastra*: two-*shruti* distance (*Re-Ga* and *Dha-Ni*), three-*shruti* distance (*Sa-Re* and *Pa-Dha*), and four-*shruti* distance (*Ga-Ma, Ma-Pa* and

Ni-Sa). This clearly indicates that the unit of measuring the musical distance is *shruti*. Due to this, most of the modern scholars assume that un-equal twenty two *shrutis* among seven *swaras* are distributed in an uneven manner. As a result, many scholars have interpreted this description in such a way that it appeared as a mathematical problem of distributing unequal *shruti* distances among seven *swaras.* So it became a mathematical problem in the context of this description and its interpretation. However, this problem is a recent one since scholars have tried to understand *shrutis* in terms of their frequencies. During ancient period this problem never appeared because from the description of Bharata as well as Sharangadeva, *shrutis* were understood with aural sensitivity of ears.

The problem became more and more critical when Bharata's octave is compared with the Pythagorean cyclical model of musical scale and the `just intonation' scale that is developed in the West. There exists a big mismatch. Interestingly, Pythagorean formula of generating microtones by applying the `rule of fifth' six times in ascending and descending directions leads to twelve tones having unequal distances among themselves (by this method one can generate infinite number of microtones within a scale). Pythagorean scale is not an equal temperament scale. Apart from the Pythagorean scale there is a `just intonation' scale that is developed by applying a mathematical formula based on simple ratios. This formula claims that musical notes that adhere to simple ratios such as 2/1, 3/2, 4/3, 5/4 and so on are musically pleasant. An octave based on these ratios is called a `just intonation' scale. In this scale, any two notes have a ratio that is based on harmonic series. `Just- intonation' is the tuning system supposed to be codified by Ptolemy; it was the aesthetic ideal of the Renaissance music as well. It is considered as the most mathematical and aurally perfect scale. Bharata's description of twenty two *shrutis* scale does not match either with Pythagorean microtones or so-called logical and aurally perfect `just intonation' scale. Adjusting twenty two *shrutis* of Bharata's scale, among notes of Pythagorean scale or `just intonation' scale of seven *swaras* is absolutely impossible. In this sense it is not at all a mathematical problem. It is an impossibility. However, surprisingly, the intelligentsia in the last century has spent their time and energy in attempting this. In this process majority of scholars, have unanimously assumed that twenty two *shrutis* of Bharata's scale being aurally pleasant and perfect, should adhere to Pythagorean scale or `just intonation' scale. This conclusion goes against ancient practices and also against the textual description of Bharata and

Sharangadeva. The paradigm of `just intonation' scale is so fascinating and powerful that the author of the present monograph had also got carried away by it for more than last twenty years. However, close scrutiny of various interpretations of Bharata's paradigm of twenty two *shrutis* using computational simulations and analysis helped the author realize that these interpretations are not correct. Another realization was that the Pythagorean scale and the `just intonation' scale are rational and mathematical scales; but not necessarily empirical scales. There exists a conflict between logic and reality. Having overcome the fascination for the Pythagorean scale and `just intonation' scales, the author has examined Bharata's paradigm of twenty two *shrutis* as dispassionately as possible. Therefore, this monograph has tried to scrutinize the original text from *Naradiya Shiksha, Natyashastra* of Bharata, and *Sangita Ratnakar* of Sharangadeva in a rigorous way to understand the concept of *shruti*.

2. ANCIENT LITERATURE ON *SHRUTI*

Naradiya Shiksha, Natyashastra of Bharata, and *Sangita Ratnakar* of Sharangadeva are considered as the ancient most literary sources to understand music of Vedic age as well as traditional Indian music. The original text of *Natyashastra* and *Sangita Ratnakar* is available in almost its original form without much loss of the text. But in the case of *Naradiya Shiksha* it seems certain portions have been added after the age of Panini and some after Bharata's *Natyashastra*. Dr. Usha Bhise writes, "A collation of Mss. [Manuscripts] from different parts of India indicates that they do not differ vitally from each other. Their evidence goes to prove that the text of *Naradiya Shiksha* has come down to us intact. However, the internal evidence points in another direction. There are losses as well as change of order. Spurious portions added a few centuries later are not lacking". [Bhise, P. 2]. The available text of *Naradiya Shiksha*, in its present form, is thus does not appear to be a consistent document. Therefore, many scholars completely disregard *Naradiya Shiksha* as reliable source of reference. However, there is no option since all the versions of manuscripts appear originating from the same document. Nevertheless, *Naradiya Shiksha* is revered among Indian scholars and considered as the most ancient resource on Indian music. Abhinavagupta and many other commentators of *Natyashastra* have frequently quoted from *Naradiya Shiksha*.

Naradiya Shiksha has been referred in this monograph extensively. According to the author of this monograph, *Naradiya Shiksha* is a valuable resource for following reasons. After close scrutiny of the text of the *Naradiya Shiksha* one arrives at the conclusion that many parts of the *Naradiya Shiksha* are ancient. There might be some interpolations of text but Abhinavagupta and later commentators have not doubted the authenticity of *Naradiya Shiksha*. One can say that though interpolated, the text still can be considered as ancient and even these interpolations are also ancient. Secondly, it is also possible that one need not look at it

from historical point of view. It is quite likely that many of the concepts and practices of music must be as ancient as Vedas. Their theoretical codification must have happened in later stage. Thirdly, the so-called interpolation of text can be considered as integration and upgradation of text since *Naradiya Shiksha* was an instructional manual for practical manifestation of Samaveda. For example, the authors of the Kaundinyayan commentary of *Naradiya Shiksha* that is referred in this monograph clearly mentions that certain *shlokas* have been realigned while writing the commentary for the ease of understanding [Kaundinyayan, S., pp. 24-26]. Since it was about the practical science of music such realignment, integration (even interpolation) and assimilation is imminent. Authenticity of *Naradiya Shiksha* may not stand for the strict scholarly scrutiny still it can be said that by and large it is an ancient document and it is possible to segregate concepts which are specific to *Naradiya Shiksha* and which are not. For instance, there is no mention of twenty two *shrutis* in *Naradiya Shiksha*. One can say that the concept of twenty two *shrutis* is a later development during Bharata's age. But other concepts such as *Grama, Murchchhana, swara-mandala* etc. were there. Probably, Bharata has borrowed them from *Naradiya Shiksha*. Similarly *swara* positions of seven *swaras* and their order were certainly well-known during the time of *Naradiya Shiksha* since they have Vedic origins and context (this point is explained at appropriate place in this monograph). Bharata must have inherited them. (However all this discussion is beyond the scope of this monograph). Therefore, *Naradiya Shiksha* is a valuable resource for study of Indian music in general and study of *shrutis* in particular.

Thus any discussion of *shrutis* remains incomplete without referring *Naradiya Shiksha*. One of the important available commentaries on *Naradiya Shiksha* is supposed to be by Bhatta Shobhakara but even that is also not available in authentic form. There are many alterations and inconsistencies. The complex issue is that the text of *Naradiya Shiksha*, Bhatta Shobhakara's commentary and the *Samaveda* surviving practice do not match with each other satisfactorily. In such a situation a research cannot rely on either of commentaries, text and the practice. Still, based on the available literature, issues related to *shruti* and their types are discussed in this monograph to bring out some order in understanding. For the following discussion thus apart from Bhatta Shobhakara's commentary, three other sources on *Naradiya Shiksha* are also referred. There is an English translation of *Naradiya Shiksha* by Dr. Usha Bhise. It is supposed to be highly meticulous and fine-tuned translation done in consultation with well-known musicologist Dr. Ashok D. Ranade. This

translation is highly precise and follows grammarian tradition (but has become highly literal). It is a valuable resource. Another important resource is the Hindi translation of *Naradiya Shiksha* by Kaundinyayan tradition of Samaveda from Nepal. This is very helpful because it relates ancient musical concepts to living tradition of Samaveda. The third very important resource is *Naradiya Shiksha* published by Sanskrit *Mahapathashala* Mysore. It gives Bhatta Shobhakara's commentary as well as the elaborate analysis of *Naradiya Shiksha.* Bhatta Shobhakara's commentary is further elaborated by Narayana Swami Dikshit who was the head of the Samaveda School (*Pradhana Upadhyaya*) in Mysore. He refers to the manuscript of *Naradiya Shiksha* and familiarizes readers with many conventions of diacritical marks in the manuscript/ calligraphy as well as decoding many subtle musical conventions. For instance, at times in Samaveda rendering a particular *swara* is not actually rendered but there is just a suggestion of that *swara*. These insights are very valuable for any researcher. Encoding, decoding and diacritical representation of such subtleties is explained in his commentary. This is the most valuable commentary available on *Naradiya Shiksha* in this regard. Thus every attempt is made to be as authentic as possible.

As far as the *shruti*-research is concerned, it is certain that during the age of *Naradiya Shiksha, shrutis* were understood as qualities of *swaras* classified into five *`jatis'* or types. Bharata's *Natyashastra* provides a new paradigm of twenty two *shrutis*. *Sangita Ratnakar* of Sharangadeva gives us the list of *shruti* names and classifies twenty two *shrutis* into five *jatis* mentioned in *Naradiya Shiksha*. Bharata does not talk about five *shruti jatis* as well as he does not give the name-list of *shrutis*. So there exists some strong logic to believe that *Naradiya Shiksha*, Bharata's *Natyashastra* and *Sangita Ratnakar* tried to codify and theorize the then prevalent musical knowledge in their own ways. There are many similarities as well as striking differences in theorization of music in these treatises. Following discussion greatly relies on the above-mentioned available resources in their present form. Therefore, this monograph does not go into the historical debate. This monograph tries to probe various concepts related to *shruti* from purely theoretical point of view and not from historical perspective. It tries to compare and analyze concepts of *shruti* discussed in *Naradiya Shiksha*, *Natyashastra* of Bharata and *Sangita Ratnakar* of Sharangadeva purely as theoretical constructs and develop insights. *Natyashastra* of Bharata and *Sangita Ratnakar* of Sharangadeva are available in their original authentic form so there is not much dispute about the authenticity of the contents of them. It appears that

Natyashastra provided profound theoretical foundations for the concept of *shruti* and *Sangita Ratnakar* preserved it. The *Natyashastra* text referred in this monograph is published by the Oriental Institute of Baroda in 1964. It is along with the commentary in Sanskrit by Abhinavagupta. The whole text is edited by M. Ramakrishna Kavi and J. S. Pade. Another source for *Natyashastra* used is a Hindi translation and commentary of 28th chapter of *Natyashastra* by *Acharya* Brihaspati. Both the sources are highly respected by scholars. Sharangadeva's *Sangita Ratnakar* is another important source. For this monograph Marathi translation and commentary of *Sangita Ratnakar* by G. H. Taralekar published by *Maharashtra Rajya Sahitya Sanskriti Mandala*, Mumbai in 1975 is referred. Every attempt is made to refer original Sanskrit text in authentic form as a primary source for this monograph.

The flow of discussion in this monograph is as follows. Initially an analysis of the concept of *shruti* according to *Naradiya Shiksha* is presented. It will cover *Vedic swara/ shruti* concepts, musical *swara/ shruti* and its thorough discussion. Next part of the monograph is dedicated to explore the conceptual theorization of *shruti* according to *Natyashastra* covering the topics such as *`Swara-Sthapana'* or establishing *swaras/ shrutis*, *Pramana Shruti*, and *Shruti-Nidarshanam*. This section attempts to provide justification in favor of equal temperament twenty two *shruti* paradigm. It will also cover views of Sharangadeva from his treatise titled *Sangita Ratnakar* and will discuss how the concepts of *shruti* from *Naradiya Shiksha* are integrated with the concepts of *shruti* from *Natyashastra*. The last part of the monograph will attempt to look at issues related to *shruti* in the context of contemporary understanding of wide-ranging domains including scientific, technological, psycho-acoustic and computational perspectives. At the end a comprehensive frame-work to understand phenomenon of *shruti* is developed and presented.

3. VEDIC CONCEPT OF *SHRUTI/ SWARA*

The word *shruti* is derived from Sanskrit root `*shru*', which means `to hear' as already mentioned. The term is also used to refer Vedic *mantras* (sacred verses). Vedas are called *`shruti'* since there is a faith among the believers that Vedic *mantras* are not composed by humans, but are the revelations by seers. These revelations are in the form of divine inner voice, sounds/ visions or inspirations. In Indian musical rhetoric, however, the word *shruti* has more specific technical meaning. *Shrutis* are considered as `microtones' or subtle sonar qualities of *swaras* in Indian music. Rigveda, Yajurveda, Samaveda and Atharvaveda are the four Vedas. *Mantras* of each Veda are chanted, recited or sung in different styles. *Mantras* of Rigveda are supposed to be chanted or recited. *Mantras* of Yajurveda and Atharvaveda are recited while *mantras* from Samaveda are considered as musical compositions or songs. *Samaveda* is one of the four Vedas which is dedicated to music thus, mostly chanting and recitation of Vedic *mantras* is done in at least three accents/ tonalities. These three tonalities are considered as three Vedic *swaras*, namely: *Udatta swara, Anudatta swara* and *Swarita swara*. All these three types of *swaras* are used in Rigveda and Samaveda but in their own ways. The Samavedic rendering is supposed to be musical rendering. From musical point of view here the word *shruti* refers to, apart from musical pitch, timbre, tonal quality, subtle sonar qualities and defines the qualities of Samavedic *swaras*. It is believed that the ritualistic musical renderings of Samavedic *swaras* following laws of *shruti* intonations have spiritual significance. Main motivation behind practicing Vedic chanting and recitation has been to attain spiritual goals in life. So there seems a very strong connection between the larger Vedic-divine and spiritual, context of the meaning of the word *shruti* and its musically significant application or usage in Vedas in general and Samaveda in particular. It seems that *shrutis* and *swaras* have special role in meditation and they were considered as important tools for achieving spiritual goals. *Naradiya Shiksha* provides a vital link

between Vedic concept of *shruti* and the musical concept of *shruti* since it gives account of *shrutis* from both the perspectives: spiritual and musical.

Within Rig-Veda, Yajurveda, Samaveda and Atharvaveda there were many practices and norms. Readings from *Naradiya Shiksha* gives us some glimpses of them. The second *shloka* from *Naradiya Shiksha* gives description of various prevalent practices of Vedic recitation prevalent those days as follows.

आर्चिकं गाथिकं चैव सामिकं च स्वरान्तरम् | कृतान्ते स्वरशास्त्राणाम् प्रयोक्तव्यं विशेषतः ||
[*Naradiya Shiksha:* 1-1-2]

The different notes or *swaras* employed in the recitation of Rigvedic verses, *Gathas* or the narratives which are sung during *`Yajnya'*, and the *Samaganas* should be rendered after thorough understanding of the science of intonations [Bhise, p.75].

Bhatta Shobhakara in his commentary says that the objective of this *shloka* is to understand the ways and means of rendering *swaras* for Vedic recitation as well as *`Jagadadi'* that is for the `worldly' applications of *swaras* or the non-spiritual, non-Vedic music [Narada, p.2]. He further says that Rigvedic recitation, *Gatha* recitation and *Samagana* rendering should be performed after thorough understanding of the science of *swaras*. One should also know the *`swarantaram'* or the relationships between one *swara* and the other *swaras* that are being used and then only *swaras* should be rendered appropriately [Narada, p.2]. In the case of *Gatha* recitation, while rendering the `Text' from the *Brahmana* treatises, it should be rendered according to the instructions provided. Probably he indicates that the text with diacritical marks should be followed rigorously- *`gatha swarakshara prayojyani'* [Narada, p. 2]. The next *shloka* of *Naradiya Shiksha* gives more details or description of Vedic practices and manifestation of *swaras*.

एकान्तरस्वरो ह्यृक्षु गाथासु द्व्यन्तरः स्वरः | सामसु त्र्यन्तरं विद्यादेतावत् स्वरतोऽन्तरम् ||
[*Naradiya Shiksha:* 1-1-3]

In the recitation of Rigvedic verses, the interval between two notes is one (unit). It is two in the case of the *Gathas* and three in the case of the Samaveda. This much is the interval between one note and the other. [Bhise, pp. 1-2]

This *shloka* throws light on the ancient concepts of employing *swaras* for Rigveda, *Gathas* and *Samagana*. The above-mentioned translation actually does not convey much about the ancient practice of rendering *swaras* in Vedic recitation. While Narayana Swami Dikshit on elaborating on Bhatta Shobhakara's interpretation of this *shloka*, mentions that as per the tradition established by Sharangadeva and Kallinatha this *shloka* should be understood in a slightly different way. Accordingly, Rigvedic verses used to be *`eka-swara'* i.e. recited using only one *swara- `richam eka swarashrayatvat'*. The *Gathas* that are the parts of *Brahmana* texts were recited using two *swaras- `gathiko dviswarah'* and the *Samagana use* three *swaras* for recitation- *`triswarah tanah samikah'*. Further he says that three *swaras* range of *Samagana* can be extended up to seven *swaras* including three octaves- *`samnantu triswaratvam sapta swaratvepi mandradi sthana trayam vivakshaya'* [Narada, p.2]. As per Bhatta Shobhakara, this *shloka* describes the Vedic practice of the degree of pitch accent of the *Udatta*, *Anudatta* and *Swarita* notes. Thus in the Rigvedic recitation the pitch accent should be within the range of one *shruti*. Even for the *Swarita* note the pitch range should be of half a *shruti* [Narada, p.3]. Here certainly Bhatta Shobhakara is referring to *shruti* as a unit of pitch difference between any two pitch positions (following Bharata's paradigm) and not *shruti* as a subtle sonar intonation as postulated by *Naradiya Shiksha* in a strict sense. Bharata's paradigm of twenty two *shrutis* was so powerful and robust that most of the later commentators such as Bhatta Shobhakara used Bharata's vocabulary at many places while discussing concepts from *Naradiya Shiksha*. For instance, as mentioned above Bhatta Shobhakara in his commentary explains *swara* rendering for *Richas, Gathas,* and *Sama* in terms of *`one shruti'*, *`two shrutis' and `three shrutis'*. At one occasion he also talks about *`half-shruti'* distance. It means that the later commentators tried to understand and interpret earlier literature such as *Naradiya Shiksha* from Bharata's point of view.

Rigvedic *richas* (two line stanzas) are supposed to be recited as prayers. These are not songs. Therefore they are recited as chants with minimum tonal variation. More importance is given to stress accent rather than pitch accent though if one looks at the tradition the stress accent of Rigveda has slight pitch variation which is natural. Vedic accent is nothing but the phonetic importance given to a particular syllable in a Vedic word since these *mantras* are composed in *chhandas* (Vedic meters). When this importance is highlighted through greater force, typically by a combination of loudness of a syllable or extending it to a full articulation

of the vowel, without much change in the pitch of the sound, then it is called a stress accent. It is of three types: *Udatta*- acute accent (raised), *Anudatta*- grave accent (lowered) and the third is known as *Swarita*- the circumflexed or rounded accent. Therefore, there is not much pitch variation in Rigvedic recitation. Such a recitation is called *Archika*- originated from word *richa* in Sanskrit. Stress on a particular syllable is intentional (spiritual) or purely linguistic (phonetic) due to the forth-coming conjunct, pro-longed vowel, or even complex consonants etc. Bhatta Shobhakara tries to indicate that the stress accent should be within the range of one *shruti*. If it surpasses the range of one *shruti* then it is converted into a pitch accent that is designated for *Gatha* recital. Naturally, if the tonal range crosses the limit of one *shruti* then the stress accent gets converted into a pitch accent. Mostly the difference of tonal range between *Udatta* and the *Anudatta* swara then would be of two *shrutis* while the *Swarita* would be still of half a *shruti* range. Thus when the accent is produced through tonal variation, it is called pitch accent and also it attains some musical quality. Rigvedic *richas* were rendered within the range of one *shruti* while *Gathas* were rendered in the range of two *shrutis*.

Pitch accent is a term that is used for a variety of tonal accent-practices that either use variations in pitch to give importance to a syllable within a word or have a contrast between different tones in the stressed syllables alone. The accent is also influenced by the Vedic meter or *chhandas* that are used for composition of *mantras*. The *chhandas* influence Vedic *mantras* in two ways. C*hhanda* triggers force on specific syllables resulting into accent due to metric rhythm. Secondly, *chhanda* also generates metrical rhythmic pattern due to pauses (*yati*), complex conjuncts and phonetic variations. Generally the accent and tonal variation of *mantras* co-exist leading to metrical rhythmic patterns that are reflected in *tala* patterns of Indian music. Again it is intentional (spiritual) or purely linguistic and musical (this itself is a promising area of further research). Pitch-accented recitation practices may have a more complex accent practices than stress-accented recitation due to more codified metrical system as elaborately explained in the *Chhandasutras* of Pingalacharya. In some cases they have more than a binary tonal distinction and can have more tones employed. The Vedic recitations have a pitch-produced stress accent, and the Vedic Sanskrit has preserved this pitch accent by working it into the *Udatta*- `acute' (raised) tone and *Swarita*- `circumflex' (going upwards and then falling) tone, and the *Anudatta* as a `grave' tone (i.e. lower) as already mentioned. However, there were multi-pitch based

systems such as of *Samagana* that eventually led into full-fledged seven *swara* musical systems. Tradition believes that all music originates from *Samagana*. Thus Bhatta Shobhakara says the *Samagana* recitation would have the range of three *shrutis* that is extending beyond two *shruti*-ranges of *Gathas*.

Surviving traditions of Rigveda have preserved both the accents- stress accent and pitch accent. We find Rigvedic `chanting' with stress accent while the Rigvedic `recitation' follows the pitch accent up to three pitch variations i.e. *Udatta*, *Anudatta* and *Swarita* rendering. Even the *Swarita* has one variation called *Prachaya* and *Anudatta* has a variation called *Nighata* so it means that multi-pitch rendering has become a natural requirement of Vedic recitation. If carefully studied it is evident that traces of Rigvedic stress accents are preserved in ancient musical systems of India. Similarly traces of *chhandas* or Vedic metrical system are preserved in Indian *tala* system (this is beyond the scope of present monograph). Especially Bharata's music system is significant in this respect because it articulates pitch positions of musical notes by following Vedic practices as discussed in following paragraphs. If one compares Bharata's seven *swaras* with contemporary musical notes then it is evident that the *Shadja, Madhyama* and *Panchama* of Bharata's system and contemporary *Shadja, Madhyama* and *Panchama* notes are almost the same. There is not much difference. Major difference lies with Bharata's *Gandhara* and contemporary *Gandhara swara*. Contemporary *Gandhara* matches with Bharata's *Antara Gandhara*. It means Bharata was aware about this *swara* position. Even its counterpart *Kakali Nishada* was also recognized by Bharata in his system. He continued with his system as the standard system of seven *swaras* that included- *Shadja*, Bharata's *Rishabha* (*tri-shrutic*), Bharata's *Gandhara* (*dvi-shrutic*), *Madhyama, Panchama*, Bharata's *Dhaivata* (*tri-shrutic*), and Bharata's *Nishada* (*dvi-shrutic*).

Interestingly the origin of Bharata's *Rishabha* (*tri-shrutic*), and Bharata's *Gandhara* (*dvi-shrutic*), as well as the origin of their counter parts Bharata's *Dhaivata* (*tri-shrutic*) and Bharata's *Nishada* (*dvi-shrutic*) lie in the practice of Vedic recitation using stress accent and pitch accent. When a Rigvedic stress accents transform into a pitch accents they get certain tonality. The acute accent becomes more raised and the grave accent gets more lowered simply because of tonality and force. After the analysis of audio recordings of *Samagana* renderings, Dr. Sulabha Thakar has arrived

at the conclusion that Bharata's *Gandhara, Nishada, Rishabha* and *Dhaivata* have a strong connection with Vedic recitation [Thakar, S., pp. 5-13]. However, in her analysis, Dr. Sulabha Thakar argues that Bharata's *shrutis* were not equal temperament *shrutis*. Therefore her analysis of *shrutis* is not accepted in the present monograph but her insights about the genesis of Bharata's *Gandhara, Nishada, Rishabha* and *Dhaivata swaras* from Vedic practices are considered valuable and further developed in this monograph as follows. When a Rigvedic recitation is performed, it starts with a loud and raised voice. If we assume this as the *Shadja swara* of the contemporary octave then this is called the *Udatta* swara of Rigvedic recitation. When it is lowered down for *Anudatta* swara it is lowered down towards *Komal Nishada* and because of the forceful stress it is lowered a bit further so it becomes *Ati-Komal Nishada*. This is actually the Bharata's *Nishada* (*dvi-shrutic*) four *shrutis* lower to *Shadja*. Similarly, when rounded accent of *swarita* is rendered, the voice is raised with some force towards *Rishabha* (*Rishabha* of contemporary octave) but does not reach up to the *Rishabha* proper (contemporary *Rishabha*) since *Swarita* is a circumflex note and it has to just go close to that point and come back to the normal position (that is *Udatta*). That particular higher point is slightly lower than the *Rishabha* (contemporary *Rishabha*). This is actually the Bharata's *Rishabha* three *shrutis* higher than *Shadja* and one *shruti* lower than contemporary *Rishabha*. The contemporary *Rishabha* is called *Chatuh-shruti Rishabha* (*Rishabha* with four *shrutis*) in Bharata's traditional system. This description is seen when the recitation is performed in a *Shadja Grama*. If the recitation of Rigveda is performed in a *Madhyama Grama* then respective *Udatta* etc. *swaras* would be as follows. *Udatta* swara will be the *Madhyama swara*. *Anudatta* will become the Bharata's *Gandhara,* i.e. being four *shrutis* lower than *Madhyama*. Similarly, the *Swarita* would be slightly lower than the *Panchama*. This *Panchama* is nothing but the *`Chyuta Panchama'* or *Panchama* lowered by one *shruti* as mentioned by Bharata. This also discloses the secret why *Madhyama Grama* has a *Panchama* that is one *shruti* lower than the *Panchama* of a *Shadja Grama*. It is also said by Abhinavagupta that thus lowered *Panchama* (*Chyuta Panchama*) is the defining *swara* of a *Madhyama Grama* and therefore it is not omitted from *Madhyama Grama* ever [Bharata, p. 21]. If the same recitation is performed in *Shadja Grama* starting with *Panchama* then the *Panchama* will become *Udatta swara*. *Madhyama* will become the *Anudatta,* i.e. being four *shrutis* lower and the *tri-shrutic Dhaivata* of Bharata's system will become the *Swarita*. This property of *Udatta* etc. *swaras* for *Rigvedic* recitation is amazing and

makes a very strong case for inclusion of *Dvi-shrutic Gandhara, Tri-shrutic Rishabha, Tri-shrutic Dhaivata, and Dvi-shrutic Nishada* among the twenty two *shrutis*. Thus, Bharata's system has a strong legacy of Vedic recitation.

Vedic practices were very richly integrated in Bharata's system. Looking at its connection with categories of *Rigvedic* and *Samavedic swaras* such as *Udatta, Anudatta* and *Swarita*, it is fairly clear that Vedic *swaras* are understood in terms of *shrutis* as postulated in Bharata's system. Traditionally, these three *swaras* are understood in terms of the number of *shrutis* assigned to each one of them. For instance, out of the three Vedic *swaras*, in the tradition of *Rigvedic* recitation as mentioned by Abhinavagupta, *Udatta* swara is considered to have four *shrutis* (*Udatta* means big or large so maximum number of *shrutis* are assigned to it), *Anudatta swara* is considered to have two *shrutis* (since *Anudatta* means opposite of *Udatta* so it has only two *shrutis* assigned) and the *Swarita swara* is considered to have three *shrutis* (as it is the middle state between *Udatta* and *Anudatta*) [Abhinavagupta in Bharata, p. 14]. This scheme is consistent with Bharata's paradigm of *shrutis.* Bharata assigns four *shrutis* to *Shadja, Madhyama* and *Panchama swaras*. According to Rigvedic practice these are also considered as *Udatta swaras*. *Gandhara* and *Nishada* have been allotted two *shrutis* each in Bharata's scheme which are considered as *Anudatta swaras* in Rigvedic practices. Rishabha and Dhaivata have been assigned three *shrutis* each in Bharata's paradigm which are the *Swarita swaras* of Rigvedic recitation. Thus Vedic *swaras* were attempted to be understood in terms of *shrutis*. However this convention is valid only in the case of Rigveda. In the case of Samaveda this convention does not apply.

Due to strong Rigvedic recitation practices Bharata's octave with *Tri-shrutic Rishabha, Dvi-shrutic Gandhara and Tri-shrutic Dhaivata and Dvi-shrutic Nishada* and with *Chatuh-shrutic Shadja, Madhyama*, and *Panchama* became relevant and got established. *Naradiya Shiksha* has mentioned these *swara* positions and Bharata preserved them in his system. The three *swara* system of Rigveda and Samavedic recitation using seven *swaras* were co-existing paradigms and they are comprehensively accommodated within Bharata's octave. There is a marked difference between the *swara* positions of Rigvedic *swaras* and Samavedic *swaras*. Rigveda uses only three pitch positions and some minor variations of them. On the other hand Samaveda uses mainly three to five swaras but can go up to seven *swaras* in rendering. Samaveda

recitation is more musical than the Rigvedic recitation. The Samavedic *swara* positions are described in the following *shloka* of *Naradiya Shiksha*.

उदात्ते निषादगान्धारावनुदात्ते ऋषभधैवतौ | स्वरितप्रभवा ह्येते षड्जमध्यमपञ्चमाः॥ [*Naradiya Shiksha:* 1-8-8]

Nishada and *Gandhara* originate from the *Udatta swara*, while *Rishabha* and *Dhaivata* originate from *Anudatta swara*. *Shadja, Madhyama* and *Panchama* have their origins in the *Swarita* [Bhise, U., p. 108].

The above *shloka* explains how to convert Rigvedic *swaras* into Samavedic *swaras*. As discussed earlier, the Rigvedic recitation is rendered in three *swaras*. When same hymns are converted into Samaveda recitation, certain changes occur. As a result, as mentioned in this *shloka, Udatta swara* of Rigvedic recitation is replaced by either *Nishada* or *Gandhara* (of Bharata's octave) in an appropriate way. In the earlier discussion we mentioned that *Udatta* of Rigveda could be set to *Shadja, Madhyama* or *Panchama*. However, in Samavedic paradigm they were replaced by *Nishada* or *Gandhara*. In the same manner *Anudatta* is replaced by either *Rishabha* or *Dhaivata* (of Bharata's octave) appropriately. The *Swarita* becomes *Shadja, Madhyama* or *Panchama* (of Bharata's octave) depending on the context. This *shloka* also highlights the importance of Bharata's paradigm since it provides foundational frame-work for conversion of Rigvedic *swaras* into Samavedic *swaras*.

Samagana is performed in *Madhyama Grama.* Therefore, with the above mentioned scheme of *swaras*, if *Madhyama* is considered as the *Swarita* then *Gandhara* becomes *Udatta* and *Rishabha* becomes *Anudatta*. If the *Samagana* is performed in *Shadja Grama* then *Swarita* would be *Shadja*. *Udatta* will be Bharata's *Nishada* and *Anudatta* will be Bharata's *Dhaivata*. However interestingly, *Samagana* uses more than three *swaras* and therefore other *swaras* are used appropriately to enrich the performance. *Samagana* also adheres to Bharata's octave and therefore the *swara* places are different as compared to Rigvedic recitations and the whole musical impact of Samaveda is different. Due to redefining of the *Udatta* etc. *swaras* the *swara* relations have changed in *Samagana*. In Rigvedic recitation *Anudatta* was four *shruti* lower than *Udatta*. In *Samagana Anudatta* i.e. Bharata's *Rishabha* is two *shrutis* lower than the *Udatta* i.e. Bharata's *Gandhara*. Similarly, in Rigvedic recitation *Swarita* was three *shrutis* raised than the *Udatta* while in *Samagana Swarita* i.e. *Madhyama* is

four *shrutis* raised than the *Udatta*. So *Anudatta* and *Swarita swaras* have moved out of the stress/ pitch accent paradigm. This actually brings Samaveda music much closer to contemporary practices. For instance, if *Udatta* is set to *Shadja* then *Anudatta* will be the *Kakali Nishada* of Bharata's octave which is actually the *Nishada* of present day octave. Similarly, then *Swarita* will have to be set to four *shrutis* higher i.e. *Chatuh shruti Rishabha* of Bharata's octave which is actually the *Shuddha Rishabha* of present day octave. So it is possible to re-interpret and revive *Samagana* rendering in today's context and make it sound familiar.

Thus the Rigvedic recitation and Samavedic music have their own identities and one can see its connection with contemporary music. All types of music, so-called *`Laukika'* (worldly) music and classical music grow and evolve simultaneously. Therefore the growth of ancient classical Indian music must have been occurring along with Vedic as well as non-Vedic music and that is documented in *Naradiya Shiksha* as well as in *Natyashastra*. However, it is important to note that the term *`swara'* was used prominently instead of the term *`shruti'* in the above discussion. Following sections deal with the concept of *shruti* in *Samagana* music as well as in non-Vedic music as discussed in *Naradiya Shiksha*.

4. *SHRUTI* IN *NARADIYA SHIKSHA*

Chapters in *Naradiya Shiksha* are called *`Prapathakah'*, and sections are called `*Kandika*'. The *Kandika* is made up of number of *shlokas*. Vedic music and *`Laukika'* or worldly music is discussed in the fifth section of the first chapter of *Naradiya Shiksha*. First two *shlokas* introduce the seven *swaras* that are used in *Samagana.* Then a set of *swara-names* is also mentioned that is used in worldly music. It is also possible that flute may have been a popular musical instrument that is used as an accompaniment for Samavedic performances, as Samavedic *swaras* are explained in terms of their positions on a flute using popular *swara*-names. With the new settings, as mentioned earlier and replacement of *swaras*, *Samagana* became distinct from Rigvedic recitation. It is worth noticing that the vocabulary of Rigveda uses *swara* names as *Udatta*, *Anudatta* and *Swarita* however, Samaveda no more uses this vocabulary. It uses *swara* names as *Madhyama, Gandhara, Rishabha, Shadja* etc. on one hand and *Prathama*, *Dwitiya, Tritiya, Chaturtha* etc. on the other as mentioned in the following *shlokas*.

यः सामगानां प्रथमः स वेणोर्मध्यमः स्वरः | यो द्वितीयःस गान्धारस्तृतीयस्त्वृषभः स्मृतः ||
[*Naradiya Shiksha:*1-5-1]

The first note of *Sama*- singers is known as the *Madhyama swara* of a flute. The second one is the *Gandhara* of a flute. The third one is known as the *Rishabha* of a flute [Bhise, U., p. 37].

चतुर्थः षड्ज इत्याहुःपञ्चमो धैवतो भवेत् | षष्ठो निषादो विज्ञेयः सप्तमः पञ्चमः स्मृतः || 2 ||
[*Naradiya Shiksha:*1-5-2]

The fourth note is regarded as *Shadja* of the flute while the fifth one is known as *Dhaivata*. The sixth should be known as *Nishada* and the last one, the seventh one is considered as *Panchama* [Bhise, U., p. 37].

Above-mentioned two *shlokas* give us ancient/ archaic order of *swaras* which appears to be the most ancient way of arranging *swaras* in descending order on a flute. However, when *Veena* (a string instrument) is used, the currently practiced ascending arrangement of *swaras* is applicable. It seems that those days `*Sama'* singers were accompanied by flute. Also the reference to flute might have been provided to give proper understanding of *swaras* used in *Samagana*.

स्वरात् स्वरं संक्रमस्तु स्वरसन्धिरनुल्बणम् | अविच्छिन्नं समं कुर्यात् सूक्ष्मछायातपोपमम् ||
[*Naradiya Shiksha:*1-6-18]

While going from one musical note to another the transition between the two notes should be indistinct, unbroken and normal. It should be made uniform, continuous as the joining of light-shadow and the sunlight [Bhise, U., p. 97].

Melody has been a special quality of Indian music from ancient times. Melody needs smooth transition from one note to another. It should be gradual, even and steady as a day is transformed into night through evening and a night is transformed into a day through morning. Both evening and morning are called the `*sandhikala*' (twilight or transitory phases). Transition between two notes should be so smooth and gradual. This is very important because as it will be discussed later, that *shrutis* are rendered at the beginning or at the end of such a melodic transition if appropriate in *Samagana.* Rendering *shrutis* is a special act. *Shrutis* are to be rendered at the end of significant melodic transitions from one *swara* to the other following certain rules described at appropriate place in this monograph. Routine musical phrases are rendered without *shrutis*. To achieve this one needs to understand the possible mistakes in melodic rendering of *swaras*.

अनागतमतिक्रान्तं विच्छिन्नं विषमाहतम् | तन्वन्तमस्थितान्तं च वर्जयेत् कर्षणंबुधः ||
[*Naradiya Shiksha:*1-6-19]

A knowledgeable person should avoid the mere extensions of a *swara* while joining two notes. It amounts to saying that the distinction between one note and the other should be very smooth. The transition should not be noticeable. While doing this, one needs to extend the note but this act of extending should not be faulty. There are six types of faults possible which are mentioned here. These are as follows [Bhise, U., p. 97].

Anagata: This defect arises when the next note is touched prematurely before completing the previous note.

Atikranta: It is called skipping over the in between note/s.

Vichchhinna: The continuity is broken.

Vishamahata: This involves giving irregular stress during the transition.

Tanvat: Extending for more or undesirable duration.

Asthitanta: Ending a note to indefinite point.

This description is very important to understand the phenomenon of *shruti*. While employing *shrutis* the performer has to be careful about these faults and avoid them.

स्वराः स्थानाच्च्युतो यस्तु स्वं स्थानमतिवर्तते | विस्वरं सामगा ब्रूयुर्विरक्तमिति वीणिनः ॥ [*Naradiya Shiksha:*1-6-20]

The notes that deviate from their places are called *Viswara* by the singers of *Saman* and *Virakta* by the players of a *Veena* [Bhise, U., pp. 97-98].

This *shloka* suggests that a specific *swara* has to be used with due accuracy indicating that the places or locations of *swaras* are fixed. We know that *Bharata* gives clear description of *swaras* and *shrutis* in *Natyashastra* and as it is being argued in this paper, Bharata's *shrutis* were equal temperament and *swaras* had fixed positions. Although *Naradiya Shiksha* is considered as older than *Natyashastra* we find many concepts and terms common to both the treatises. Some scholars argue that many of such common terms was a later addition to *Naradiya Shiksha*, still one cannot assume that all the common terms are the later additions. There must be substantial musical vocabulary that is shared by both the treatises. The terms such as *Grama*, *Raga, Murchchhana, Swara,* and *Shruti* etc. are splendidly used in *Naradiya Shiksha* so much so, that it appears that it was a part of the musical vocabulary of the ancient times. These terms are so innately connected with each other that one cannot exist without the others. So in all probability *Naradiya Shiksha* and *Natyashastra* of Bharata share the same common musical vocabulary. So it is most likely that *swara* and *shruti* positions were fixed (fixed in relation to each other in an octave) those days. This *shloka* [*Naradiya Shiksha:*1-6-20], goes by this premise without giving elaborate details

while *Natyashastra* gives elaborate details of the *swara* and *shruti* positions. This will help in bringing out clarity in understanding the following *shlokas* from *Naradiya Shiksha.*

4.1 Definition of *Shruti*

After introducing *swaras,* the next important reference occurs in the sixth section of the first chapter of *Naradiya Shiksha* and that is about *shrutis*. The following *shloka* is the frequently referred *shloka* from *Naradiya Shiksha.* This most celebrated *shloka* is often quoted to suggest that *Naradiya Shiksha* does not give the precise definition of *shruti*. But in fact this *shloka* illustrates the subtle nature of *shrutis*. It also metaphorically suggests that it is not easy to master *shrutis*. It says *shrutis* are like footprints of fish and birds that do not leave any traces in water and sky respectively. This description is not a definition of *shrutis* but is a metaphorical description of *shrutis*. Many scholars have attempted various interpretations in this regard to the extent some of the scholars argued that *Naradiya Shiksha* does not give any clear meaning of *shrutis*. The *shloka* is as follows.

यथाप्सु चरताम् मार्गो मीनानाम् नोपलभ्यते | आकाशे वा विहंगानां तद्वत् स्वरगता श्रुतिः ||
[*Naradiya Shiksha:*1-6-16]

The footprints of fish in the water and the traces of bird's path in the sky are not easy to track. In a similar way *shrutis* in a musical note are not easily perceivable [Bhise, U., p. 97].

Bhatta Shobhakara in his description says that navigation of fish and birds in the water or in the air is natural (and intuitive). Similarly while rendering musical notes during *Samagana* composition; *shrutis* are employed effortlessly (and intuitively) by the singers [Narada, p. 35]. *Shrutis* are not shown discretely because impact of *Samagana* is more important than highlighting the *shrutis*. Thus it may be said that use of *shruti* in music is so natural and involuntary that one does not need any efforts to employ them. On the other hand, if one tries to deliberately and consciously use them then such a rendering will be very difficult and sound artificial.

Interestingly, the next *shloka* is very rarely referred by the scholars as compared to this *shloka*. The next *shloka* again metaphorically suggests

that one can master the *shrutis* with right efforts in right direction. It says that *shrutis* are not hypothetical or as slippery as the footsteps of fish or birds but can be understood and mastered with right efforts in right direction.

यथा दधनि सर्पिः स्यात् काष्ठस्थो वायथानलः | प्रयत्नेनोपल्भ्येत तद्वत् स्वरगता श्रुतिः ||
[*Naradiya Shiksha:*1-6-17]

However, as one can extract ghee from the curds or create fire out of wood with special efforts, in a similar fashion if one makes some efforts, one can easily perceive *shrutis* in musical notes [Bhise, U., p. 97]..

As mentioned in the previous *shloka*, rendering of *shrutis* happens intuitively but if one makes extra efforts to understand how they are rendered and analyze them then it is possible to extract *shrutis* from *swaras*. Even for the performers as well as the listeners it is possible. The next few *shlokas* are highly important to understand the subtleties of rendering *shrutis*.

स्वरविशेषश्रुतिःप्रयोगार्थमवश्यमवधारणीयेत्युच्यते---
[Bhatta Shobhakara in Narada, p.39].

Bhatta Shobhakara describes *shruti* as *`swara vishesha'.* It means that *shrutis* are special aspects or qualities of a *swara* that are necessary to enhance the quality of a performance or presentation of a *Samagana* composition. *Shruti* is a subtle sonar quality of a *swara*. *Shruti* is so special that it is used judiciously and parsimoniously at appropriate places. *Shrutis* are tonal flavors or intonations used at the end of legato or *`meend'* like effects in special *swara*-phrases to enhance consonant relationships of *swaras.* This point will be explained in later sections.

The *Kaundinyayan* School of Samaveda, on the other hand, defines *shruti* as special element of a *swara* or special qualities of musical sound. The traditional *shloka* or *karika* of this school is as follows.

प्रथमश्रवणाच् शब्दः श्रूयते ह्रस्वमात्रकः | सा श्रुतिः संपरिज्ञेया स्वरावयवलक्षणा ||

श्रुतः स्वरुप मात्रेण हीनोऽनुरणनेन तु | नादः श्रुतिः स्यादस्यास्तु भेदा द्वाविंशतिः स्मृताः ||

As per *Kaundinyayan* tradition, *shruti* is an important element or aspect of a *swara*. It's a sound that we hear immediately after its production and sustains for a very short period. *Shruti* is a pure sound, an essential part of

the *swara* and does not have a quality of resonance. There are twenty two types of *shrutis* [Kaundinyayan, S. p. 19].

The above *shloka* is not from *Naradiya Shiksha*. It belongs to the *Kaundinyayan* tradition. It tries to distinguish *shruti* from *swara. Swara* is considered as a sound that sustains on its own and has a quality of resonance. It rules the hearts and minds of the audience and provides ecstatic enjoyment and fulfillment [Kaundinyayan, S. p. 19]. However, here it is said that *shruti* does not have the quality of resonance which is a differentiating criterion. So *shruti* and *swara* can be distinguished on the basis of the property of resonance. *Swara* has a resonating property while *shruti* does not have it. This description makes *shruti* very similar to a *`kana swara'* or a grace note. The notion of *shruti* as commonly understood as microtone is an ancient concept but apart from that *shruti* also has certain aesthetic and evocative qualities but does not have the property of resonance according to above description.

The following verses from *Naradiya Shiksha* give thorough and complex description about the concept of *shruti* prevalent in those days especially in the context of *Samaveda* tradition. *Naradiya Shiksha* is primarily considered as an instructional manual to understand *Samavedic* practices. One finds striking difference between the description of *shrutis* in *Naradiya Shiksha* and the description of *shrutis* from *Natyashastra* and *Sangita Ratnakar*. Although, the phenomenon of *shrutis* or microtones was well-acknowledged and recognized by all these three treatises, their description and theorization was done in different ways. There are many points of differences in the description of *shrutis* as well as similarities. *Naradiya Shiksha* does not mention twenty two *shrutis*. It classifies *shrutis* into five types as *Aayata, Madhya, Mrudu*, *Dipta* and *Karuna*. It is certain that *shrutis* are understood there as subtle shades or microtonal variations of a *swara*. These micro variations are classified into five types. On the other hand Bharata's *Natyashastra* clearly mentions the number of *shrutis* as twenty two pitch positions in an octave and at least fourteen of them can attain the status of a *swara* in different contexts. *Antar Gandhara* and *Kakali Nishada* are the most prominent examples of such instances.

4.2 Characterizing *Shruti*

The description of *shrutis* in *Naradiya Shiksha* begins with providing a name-list of the types of *shrutis* saying that a *Samaveda* teacher should

have thorough knowledge of these varieties of *shrutis.* As mentioned earlier, according to *Naradiya Shiksha, shrutis* are important and special aspects of a *swara*. *Naradiya Shiksha* mentions five types of *shrutis* as follows.

दीप्तायताकरुणानाम् मृदुमध्यमयोस्तथा । श्रुतीनां योऽविशेषज्ञो न स आचार्य उच्यते ॥ [*Naradiya Shiksha:*1-7-9]

One who does not know the distinction between the *shrutis* such as *Dipta*, *Aayata*, *Karuna*, *Mrudu* and *Madhyama* is not considered as a teacher of *Samaveda* music. Thus this stanza enlists five types of *shrutis* [Bhise, U., p. 99].

Shiksha treatises are the instructional manuals and compilations of then prevalent knowledge in a specific area. The style and treatment of these treatises is highly compact and codified. The next few *shlokas* from *Naradiya Shiksha* are a good example of such compactness. The above *shloka* mentions a list of five *shrutis* but does not mention that these are five different types of *shrutis*. However, the way further description goes on it becomes clear from the usage that these are not mere names of *shrutis* but these represent five types of *shrutis*. The next few *shlokas* give further description and associates *shruti*-types with appropriate *swaras*.

दीप्ता मन्द्रे द्वितीये च प्र चतुर्थे तथैव च । अतिस्वारे तृतीये च क्रूष्टे तु करुणा श्रुतिः ॥ [*Naradiya Shiksha:*1-7-10].

Dipta shruti resides in *Mandra swara* (*Nishada*) and *Dwitiya swara* (*Gandhara*), *Prathama swara* (*Madhyama*) and *Chaturtha swara* (*Shadja*), *Atiswarya swara* (*Dhaivata*)and *Tritiya swara* (*Rishabha*), while *Karuna shruti* resides in *Krushta swara* (*Panchama*) [Bhise, U., p. 100].

Except *Krushta* i.e. *Panchama swara* all the other six *swaras* have a *Dipta shruti*. It also suggests that this *shloka* is explaining the *`swara sthapana'* or describing how to identify *swara* positions. Interestingly, pairing of *Mandra* and *Dwitiya*, *Prathama* and *Chaturtha*, as well as *Atiswarya* and *Tritiya* indicates that these relationships of *swaras* are natural tools to establish and cross-check *swara* positions. All these pairs are governed by *Shadja-Madhyama Bhava* or *Shadja-Panchama Bhava*. *Swara* resonates at a consonant pitch position in relation to the position of *Shadja swara*. Once the *Shadja* is established other *swaras* can be established on a *Veena* like instrument. On a flute one can experience the exact resonating *swara*

position in similar way by adjusting finger positions. *Dipta shruti* is the blossoming and resonating pitch position of a *swara* (though it may slightly shift from its natural pitch position). Therefore, description of *shruti* begins with description of *Dipta shruti*. By following natural principles of consonance one can experience the *Dipta shruti* of a particular *swara*.

As a part of ongoing saga of codification in *Naradiya Shiksha*, this *shloka* is very interesting because it uses a letter `*pra*' (`प्र') in a cryptic way. Although it is not mentioned in the *shloka,* Bhatta Shobhakara mentions that the *Mrudu shruti* resides in the *Prathama swara*. However, there is no mention of it in the *shloka*. On the other hand the *Kaundinyayan* tradition believes that instead of *Mrudu shruti*, the *shruti* that resides in the *Prathama swara* is a *Dipta shruti* since the alphabet *`Pra'* in the *shloka* stands for *Prathama swara*. The letter *`Pra'* in the *shloka* appears to be cryptic and special according to them [Kaundinyayan, S., p. 92]. Narayanaswami Dikshit who wrote explanatory commentary on Bhatta Shobhakara defends Bhatta Shobhakara's statement. Accordingly, he says the letter *`Pra'* stands for *Prathama swara* that means *Dipta shruti* also resides in *Prathama swara*. However, taking into account the statement *`prathamena mrudu smrutah'* that comes in the thirteenth *shloka* of the seventh *kandika* of *Naradiya Shiksha* (1-7-13), which means the *shruti* of *Prathama swara* is *Mrudu*. Therefore Bhatta Shobhakara's view appears correct. This view is certainly debatable but it may be asserted that both types of *shrutis* can reside in *Prathama swara*. As we will discuss in further sections, a *swara* can have multiple *shrutis* in different contexts. As it is already mentioned, *shruti* is a special sound quality of a *swara*. A *swara* can have multiple sound qualities. The eleventh *shloka* of the seventh *kandika* of *Naradiya Shiksha* (1-7-11) for instance, mentions that there are additional *shrutis* for *Dwitiya swara*.

These *shlokas* are very important because they give an illustrative example of a *Dwitiya swara* to explain various types of *shrutis*. *Dwitiya swara* is a representative of all *swaras*. Whatever is explained about *Dwitiya swara* is applicable to rest of the seven *swaras* though this is not clearly mentioned anywhere. These are the ways of codification in ancient treatises. However, Bhatta Shobhakara in his commentary does not consider this aspect. Even many scholars do not look at these *shlokas* from this perspective. For instance, Dr. Usha Bhise in her introduction to the critical commentary of *Naradiya Shiksha* has mentioned that there is a loss of verses regarding the description about other *swaras*. Dr. Bhise says, "...

After this additional *shrutis* of *Dwitiya* are mentioned in details. The remaining six notes are not referred to. This indicates a further loss of several verses". [Bhise, U., p. 4]. Thus this point of view is debatable again. Actually it appears from the flow of *shlokas* that the description about *Dwitiya swara* is an illustration. What applies to *Dwitiya swara* is applicable to rest of the *swaras*. If there are specific differences then such differences are specifically mentioned. For instance in the previous *shloka* it is mentioned that there resides a *Karuna shruti* in *Krushta swara*. It means that there is something special about *Karuna shruti*. *Krushta* literally means `cry'. The *Krushta swara* is produced on the flute as *Panchama/ (Teevra Madhyama)* but since the air flow is forceful it produces sharp sound. It means if the *shruti* has sharpness/shrillness in it then it is called a *Karuna shruti*. But this does not mean that *Krushta swara* does not have a *Dipta shruti* or *other shrutis*.

श्रुतयोऽन्या द्वितीयस्य मृदुमध्यायताः स्मृताः | तासामपि तु वक्ष्यामि लक्षणानि पृथक् पृथक् ॥ [*Naradiya Shiksha:*1-7-11]

There are three additional *shrutis* that reside in *Dwitiya swara*. Their names are *Mrudu*, *Madhya* and *Aayata*. The detailed description is given separately [Bhise, U., p. 100].

Thus a *swara* can have multiple *shrutis*. *Dwitiya swara* has *Dipta shruti* as mentioned in previous *shloka*. Apart from that there are three more *shrutis* to it. This description is not restricted to *Dwitiya swara* alone. It means that all the *swaras* can have additional *shrutis*. The description then proceeds further by defining *Aayata*, *Madhya* and *Mrudu shrutis*. Thus so far one can say that *Prathama, Dwitiya, Tritiya, Chaturtha, Mandra, Atiswarya swaras* have four *shrutis* each- *Dipta, Aayata, Madhya, and Mrudu*. The *Krushta* swara has *Karuna shruti* and *Aayata, Madhya, and Mrudu shrutis*. So as a conclusion it may be said that apart from *Dipta* quality, all the seven *swaras* can have three additional qualities- *Aayata, Madhya* and *Mrudu* as their additional qualities. Except *Krushta*, all the remaining six *swaras* can have *Dipta shruti* as their quality. The *Krushta swara* has *Karuna shruti* may be along with *Dipta.*

आयतात्वं भवेन्नीचे मृदुत्वं तु विपर्यये | स्वे स्वरे मध्यमात्वं तु तत्समीक्ष्य प्रयोजयेत् ॥ [*Naradiya Shiksha:*1-7-12]

When one moves from *Dwitiya swara* to its lower *swaras* the *shruti* of *Dwitiya swara* becomes *Aayata*. On the other hand when one moves from

Dwitiya swara to higher notes, the *shruti* of *Dwitiya swara* becomes *Mrudu*. However, when a *Dwitiya swara* is followed by *Dwitiya swara* that means it is repeated, the *shruti* of *Dwitiya swara* is called *Madhya*. *Shrutis* should be employed in a *swara* keeping in mind this phenomenon [Bhise, U., p. 100].

It is assumed that when a *swara* is at its natural position, then it is considered as belonging to *Madhya shruti jati* or *Madhya* type of *shruti*. Sound of such a *shruti* is normal, neutral and of medium volume. When we shift from one *swara* to another, to maintain the continuity, a subtle shift towards higher side or lower side takes place. When this shift is towards the lower side it is said that the swara has shifted from *Madhya* position to *Mrudu* position. *Mrudu* tone of a *shruti* is very soft, subtle, delicate and emotive which is achievable through modulation. If there is a shift towards higher side then it is said that *swara* has shifted from *Madhya* type to *Aayata* type. *Aayata* tone of a *shruti* is slightly sharper, pointed, louder and forceful due to modulation. These three types of *shruti* give importance to change of a pitch. So micro-level shift or change in a frequency due to modulation that evokes emotive feeling is a defining criterion for deciding the type of a *shruti* according to *Naradiya Shiksha*.

It is mentioned in *Naradiya Shiksha* that while rendering *swaras* one should move from one *swara* to another *swara* without breaking the continuity. In Western music it is called legato effect. In Indian music it happens during taking a *meend* or a *soonth*. Similarly *raga*-specific musical phrases are formed with the *swaras* having pleasing relationships among them such as *Shadaj-Pancham Bhava* or *Shadja-Madhyama Bhava* etc. Bhatta Shobhakara in his commentary calls this as *`Swarantara'*, consonant relationship or musically significant distance between two *swaras*. In such cases every *swara* is related to its previous *swara* by a particular ratio. In musical terms it may be said that the next *swara* is derived from its previous *swaras* by following musical reasoning or aural logic. In such transition from one *swara* to the other *swara, a* very subtle shift takes place. The following discussion takes into account all such factors. It is interesting to note that Bhatta Shobhakara most of the times, mentions about *Swarantara* instead of *shrutyantara*. On the other hand for describing the consonant relations among *swaras* Bharata uses the terminology of *`shrutyantara'*.

One important aspect of melodious transition is that a shift from one *swara* to the next is smooth and continuous but this shift is not like a

straight line. The shift is like a curve. As per the above discussion when one moves from a *swara* to higher *swara* the *shruti* type of the previous *swara* is defined as *Mrudu shruti*. This *Mrudu shruti* is not higher pitched than the *swara*; however, it is slightly lower than the pitch of the *swara*. For example, when a musician moves from *Shadja swara* to say *Gandhara swara,* the movement from one *swara* to another is not straight. Actually, a singer first takes few lower microtones of the *Shadja swara* and then embarks upon the higher side towards *Gandhara*. The lower microtones of a *swara* which are rendered by the singer are considered as the *Mrudu shruti* according to *Naradiya Shiksha*. The opposite happens when a singer goes from a particular *swara* to its lower *swara*. Therefore, pitch of a *Mrudu shruti* is lower than the pitch of the *swara* while the pitch of the *Aayata shruti* is higher than the pitch of the *swara*. So the natural pitch of the *swara* is called *Madhya shruti* while a pitch position few microtones on the lower side is called a *Mrudu shruti* and few microtones on higher side is called the *Aayata shruti*. Abhinavagupta while defining the *`Pramana Shruti'* in *Natyashastra*, describes the *Mardavatva* (quality of softness of a musical note) and *Aayatatva* (quality of sharpness of a musical note) in the same manner i.e. in terms of lower and higher pitch respectively [Abhinavagupta in Bharata, pp. 21-22]. Even today the lower tones of a *swara* are called soft notes or *Komal swaras* and the higher tones are called sharp notes or *Teevra swaras*. This is specifically explained here because literal translation of the above *shloka* would be exactly opposite and misleading. A non-musician can make such a mistake in translating this *shloka*. The *shloka* says *`Aayatatvam bhaved neeche'* means *Aayata* is towards lower side of the *swara* but it is not correct since actual process of musical rendering while connecting two *swaras* is very subtle as explained earlier. *Shlokas* from *Naradiya Shiksha* carry cryptic and musically dense content. Even Bhatta Shobhakara's commentary is also equally dense and musically loaded. To interpret these texts correctly one should take into account the actual musical rendering practices of the *swaras* and not just the literal meaning.

In the case of *Aayata, Madhya and Mrudu shrutis*, the criteria for deciding their status was their relative pitch position (of course the intonations and emotions do have their role there). Secondly, when two notes are connected or rendered one after another, *Aayata, Madhya and Mrudu shrutis* are assigned to the first note appropriately. However, in the rest of the *shlokas* it is highlighted that for describing the quality of *Dipta shruti* the criteria that are used are different. Description of *Dipta shruti* is always in terms of musical relation with other *swaras* or the *`Swarantara'*.

When the tone of a *swara* is voluminous, pleasing, resonating and consonant then such a *shruti* is called *Dipta shruti*. It is supposed to be based on some of the consonances (such as *Shadja-Panchama Bhava, Shadja-Madhyama bhava, Shadja-Gandhara Bhava* etc.). The word *Dipta* literally means `bright', `shining', or blossoming. When *swaras* have a relationship based on consonances then such *swaras* have the quality called *Dipta*. Secondly, Dipta *shruti* is assigned to the second *swara* when two *swaras* are connected. *Dipta* is not assigned to the first *swara*. This is a major distinguishing factor in characterizing *Dipta shruti* and *Aayata, Madhya and Mrudu shrutis*. The *Karuna shruti* is a special case. This comparison gives more clarity about *Dipta shruti*. *Dipta shruti* is certainly not characterized by only pitch position. It is characterized by its aesthetic and evocative quality due to *swarantara* (consonance). In this sense if *swara* is rendered at its normal pitch position with normal sonar qualities then it is called *Madhya shruti* as mentioned earlier. However, if it is rendered at same pitch position but augmented with resonating and evocative impact it is called *Dipta shruti*. In the process, the pitch position of the *swara* may shift a little bit or it may not shift depending on the previous *swara* and consonance that is rendered. In that case a *Dipta shruti* can have a quality of modulated softness making it towards *Mrudushruti* or can have sharpness making it tilting towards *Aayata* position. It may be termed as *`Mrudu-bhuta Dipta or Aayata-bhuta Dipta'* respectively. Bhatta Shobhakara uses the phrase *`Mrudu-bhuta Dipta'* in his commentary [Narada, p. 40].

The *Karuna shruti* may also carry similar qualities except that it is sharper, emotional, and passionate and generates pathos through modulations. So when a tone of the *shruti* is modulated to generate pathos then it is *Karuna* shruti. The three types of *shruti*, namely, *Mrudu, Madhya* and *Aayata* are understood by their pitch positions mainly (*Mrudu* has qualities of modulated softness), while *Dipta* is characterized by its qualities of consonance and modulation. The *Karuna shruti* is special in the sense that it is understood by its quality of sharpness, modulation and ability to generate pathos. Specifically it is mentioned in the earlier *shloka* that *Panchama* has a *Karuna shruti* [Narada, p. 40]. It may be inferred from this statement that the *Shadja-Panchama Bhava* leads to *Karuna shruti*. The other consonances may lead to *Dipta shruti*.

द्वितीये विरताया तु क्रुष्टश्च परतो भवेत् । दीप्तां तां तु विजानीयात् प्रथमेन मृदुःस्मृता ॥ [*Naradiya Shiksha:*1-7-13]

When one begins with *Krushta swara* and finally reaches *Dwitiya swara* and rests there then in such a case the *shruti* of *Dwitiya swara* would be *Dipta*. If one begins with *Prathama swara* and then finally rests in *Dwitiya* then the *shruti* of *Dwitiya* would be *Mrudu* [Bhise, U., p. 100].

The *swarantara* between *Krushta* (*Panchama*) and *Dwitiya swara* (Bharata's *Gandhara*) may be called *Panchama-Gandhara swarantara* while *swarantara* between *Prathama swara* (*Madhyama*) and *Dwitiya* (Bharata's *Gandhara*) may be called *Panchama-Madhyama swarantara*. So one can infer that if the *swara* distance between two connected *swaras* is equal or less than *Panchama-Madhyama swarantara* then the *shruti* of the next *swara* would be *Mrudu shruti*. On the other hand if there is a *swara*-distance such as *Panchama-Gandhara swarantara* between two *swaras* then the *shruti* of the next *swara* would be *Dipta shruti*. *Panchama-Gandhara swarantara* is larger swara-distance than the *Panchama-Madhyama swarantara*. So any *swarantara* that is larger than the *Panchama-Madhyama swarantara* will lead to *Dipta shruti*. In his commentary Bhatta Shobhakara specifically uses the term *`Swarantara'* while elaborating on this *shloka*. *Swarantara* here certainly means consonance.

However, Bhatta Shobhakara's interpretation of this *shloka* (*Naradiya Shiksha:* 1-7-13) is slightly different. According to him *Dwitiya swara* has a *Dipta shruti* but the *Prathama swara* will have *Mrudu shruti*. Probably, because the *swara* distance between *Krushta* and *Prathama* is of *Panchama-Madhyama swarantara*. The distance between Bharata's *Panchama-Madhyama* and Bharata's *Madhyama-Gandhara* is equal. However, this may not be the only reason. It appears, even though there is no substantial reference, that the *swara Madhyama* will always have *Mrudu shruti*. In the earlier *shloka* (*Naradiya Shiksha*: 1-7-10) [Narada, p. 40] in his commentary Bhatta Shobhakara says that *Prathama swara* has *Mrudu shruti* though it is not mentioned in the *shloka*. So it seems that as per practices during those times, the *Prathama swara* would always have *Mrudu shruti*. As per this inference the *Shadja-Madhyama Bhava* will always lead to *Mrudu shruti*. However, this inference does not have any strong support. There is another way to look at it. The statement, *`prathamena' ' mrudu smrutah'* (*Naradiya Shiksha*: 1-7-13) [Narada, p. 41] is understood as the *shruti* of *Prathama swara* is *Mrudu shruti* according to

Bhatta Shobhakara. Still the rule of *Panchama-Madhyama swarantara* remains intact because the distance between *Krushta* and *Prathama swara* is also of *Panchama-Madhyama swarantara*. Actually, this statement if interpreted in the context, it means that if one begins with *Prathama swara* and then finally rests in *Dwitiya swara* then the *shruti* of *Dwitiya* would be *Mrudu* as interpreted earlier.

अत्रैव विरता या तु चतुर्थेन प्रवर्तते | तथा मन्द्रे भवेद्दीप्ता साम्नश्चैव समापने ॥ [*Naradiya Shiksha:*1-7-14]

As mentioned in the previous *shloka* if one begins with *Chaturtha* or *Mandra* and finally rests in the *Dwitiya swara* then the *shruti* of *Dwitiya* would be *Dipta*. Similarly if the *swara* occurs at the termination of the *Saman* rendering or as the last *swara* of *Saman* then its *shruti* would be *Dipta*.

Again the *swarantara* (distance between two swaras) between the *Chaturtha swara* (*Shadja*) and *Dwitiya* (Bharata's *Gandhara*) is more than *Panchama-Madhyama swarantara* so the *shruti* of *Dwitiya* qualifies to be *Dipta shruti*. Similarly, the *swarantara* between *Mandra swara* (Bharata's *Nishada*) and the *Dwitiya* (Bharata's *Gandhara*) is more than *Panchama-Madhyama swarantara*.

Alternately, Bhatta Shobhakara has a different interpretation of this *shloka* which is not strictly grammatically correct but it could be right in the context of actual practice. He says, *"chaturthe sware avasthita shrutih sa Dipta mrudubhavatiswarantaranugamane sati (anyatha) Dipta bhavati"* [Narada, p. 41]. It means *shruti* that rests at *Chaturtha swara* should be *Dipta shruti* due to the *swara*-distance between *Krushta swara* and the *Chaturtha swara* however; this *Dipta* is with *Mrudu* tonality because it rests on the *Chaturtha swara* which is actually the *Shadja swara*. So can one draw a conclusion that *Shadja* will always have *Mrudu shruti*? In actual practice even today when a *Shadja swara* is rendered few frequencies lower than its actual frequency then it gives the maximum rich effect. He further says that if the *shruti* rests on *Mandra swara* (Bharata's *Nishada*) then there should be *Dipta shruti* due to the *swarantara* between *Krushta* and *Mandra swara*. Rightly the *swarantara* between *Krushta* and the *Mandra swara* is of more than *Panchama-Madhyama swarantara*. Finally he says if *shruti* rests at the end of the *Sama* composition then that *swara* will have *Dipta shruti* (irrespective of *swarantara*). The last resting *swara* is supposed to be the *`nyasa' swara*

(resting *swara*). So the *shruti* of a *nyasa swara* is always *Dipta shruti*. Thus Bhatta Shobhakara has described all the critical *swara* positions and their respective *shrutis*.

Bhatta Shobhakara's interpretation does not match with Dr. Bhise's interpretation at many places. Dr. Bhise has always tried to follow the Paninian grammarian tradition. She has attempted more a grammatical translation of *Naradiya Shiksha*. [Bhise, U., p. 101]. On the other hand Bhatta Shobhakara's interpretation does not stick strictly to grammatical tradition. It takes into account prevalent *Samagana* practicing tradition as well as `not so strictly grammatical' language usage. *`Prayoga sharanah Vaiyyakaranah'*, that means grammarian bows down to the `language usage' (practice/ experimentation). So it is suggested that though Bhatta Shobhakara's interpretation is not in strict conformity with grammarian tradition, it is still recommended that one needs to accept it, as it might have been in tune with the prevalent practices of *Samagana* in those days. So also his views not really affect the earlier mentioned two rules: rule of *Panchama-Madhyama swarantara* and the rule of *Panchama-Gandhara swarantara*. At other instances Bhatta Shobhakara has just mentioned few exceptions to these rules.

Second point is even more important. As stated earlier *Naradiya Shiksha* has a certain type of codification and therefore the mention of *Dwitiya swara* in the relevant *shlokas* is understood as an illustration. Whatever is applicable to *Dwitiya swara* is applicable to all other *swaras*. Bhatta Shobhakara, however, does not look at it in this way. He considers each *swara- Dwitiya, Prathama, Chaturtha* and *Mandra* as separate instances or cases in relation to *Krushta swara*. These are representative rules of *swarantaras* for assigning *shrutis* to *swara* rendering. The rendering of remaining *swaras* such as *Tritiya,* and *Atiswarya* (and even *Krushta*) can be done by following the thus explained rules of *swarantara*. Probably the *Krushta swara* can have special treatment since it is earlier mentioned that the *shruti* of *Krushta swara* is *Karuna*. It may be the case that *Shadja-Panchama swarantara* leads to *Karuna shruti* but this is not mentioned explicitly in the text. Very important principle of rendering *shrutis* is emerging out of this discussion and that is, *shrutis* should be rendered only in the case of above-mentioned *swarantaras*. *Shrutis* should be rendered in special occasions of consonant relationships. It is evident that these consonant relationships lead to legato effect or melodic *`meend'* effect in Indian music. In such a case always at least two *swaras* are involved. For the starting *swara* one of the *Mrudu, Madhya or Aayata*

shruti is appropriately assigned while for the last/ resting *swara Dipta shruti* is assigned (contextually it can be *Mrudu-Dipta* or *Dipta-Aayata*) following laws of *swarantara* and various other rules that are described in next few *shlokas*.

नाविरते श्रुतिं कुर्यात् स्वरयोर्वापि चान्तरे | न च ह्रस्वे च दीर्घे च न चापि घुटसंज्ञिके || [*Naradiya Shiksha:*1-7-15]

The *shruti* should not be pronounced before the end of the musical note, not even in between the notes. *Shruti* should not be pronounced before short or long syllable or the special syllables called *`ghuta'* syllables [Bhise, U., p. 101].

It means *shruti* should be employed when a musical note reaches its final destination and rests at specific desired *swara*. This needs some more explanation. When two *swaras* are melodically connected then *shruti* should be pronounced when one rests on the second/ resting *swara*. There might be many *swaras* during this transition but *shruti* should not be pronounced for these in-between *swaras*. Such a transition may involve many *swaras* or consonants, vowels or special syllables called *`ghuta'*. All these are part of the transition so *shruti* should not be assigned to them. To sum up *shruti* should be pronounced only at the end i.e. the resting *swara* of the melodic transition and not in-between. However, Bhatta Shobhakara in his commentary mentions that the *`pluta' swaras* (prolonged *swaras*) can have appropriate *shrutis* employed (he is mentioning an exception to the rule).

द्विविधा गतिः पदान्ताः स्थितिसंधिः सहोष्मभिः | पञ्चस्वेतेषु स्थानेषु विज्ञेयं घुटसंज्ञिकम् || 16 || [*Naradiya Shiksha:*1-7-16]

The *`ghuta'* syllables occur at five places in a recitation. There are two types of *`gatis'*: the first *gati* occurs when *`i'* sound is converted into *`ai'* sound in a *sandhi* and the other *gati* is when *`u'* sound is converted in *`au'* sound in a *sandhi*. Both the pronunciations are called *`ghuta'*. The other three varieties of *`ghuta'* are as follows. When three fricatives- syllables- *`sha', `shha'*, and *`sa'* are inflected in a word or a *`pada'* or in a half verse then these three syllables are considered as *`ghuta'*[Bhise, U., p. 101].

स्वरान्तरा विरतानि ह्रस्वदीर्घघुटानि च | स्वरस्थानेष्वशेषाणि श्रुतिवत् स्वरतो भवेत् || [*Naradiya Shiksha:*1-7-17]

As mentioned in previous *shlokas shrutis* should be employed if and only if the musical note reaches its final resting destination. *Shrutis* should not be employed in between or when in the process of transition. This situation arises in melodic phrases where *Samagana* singer brings the legato effect while moving from one *swara* to the next *swara* where the next *swara* is the desired concluding point of the phrase.

Dr. Bhise has translated this *shloka* as follows: "The interval between notes [intervening *`shrutis'*], long syllables and the *ghuta* - all these without exception should be expressed by *shruti*-like notes [in transition] when they are in the place of a musical note"[Bhise, U., pp. 101-102].

On the other hand *Kaundinyayan* tradition interprets it in a slightly different way. They say all short vowels, long vowels and *`ghuta'* syllables can be there in the second *swara* but if that *swara* is not a resting or desired concluding point of a legato phrase then *Dipta* etc. *shrutis* should not be employed. Normal *swara* itself represents the *shruti* [Kaundinyayan, S., p. 97]. One can manage just with a regular *swara* rendering. So there is a difference of opinion. Dr. Bhise says that *shruti*-like expression is required at such places while the *Kaundinyayan* tradition says that normal *swara* rendering is sufficient.

However, Bhatta Shobhakara has more profound interpretation. He says all the *swaras*, consonants, short vowels, long vowels and *`ghuta' swaras* should not be expressed by *shruti* if they are not at the desired resting points. In all such places *shruti*-like expression of a *swara* itself is sufficient. The phrase, *`shruti*-like expression of a *swara*', is very interesting. Bhatta Shobhakara is suggesting here that *swara* can be expressed as a *swara*, or as a *shruti* belonging to any of the five types and apart from that a *swara* can be expressed in a third way that is un-defined or something like a *shruti* but not a *shruti* proper. So in a way he is indicating that when a *swara* is rendered as a *swara* then it should be rendered as a *Madhya shruti* in a specific way at specific position. The five types of *shrutis* should be expressed in a well-defined way with a precision as mentioned earlier. While there can be a different way of rendering *swara* other than these five types which might be different but suits the occasion and may have implicit consonance or some kind of modulation. In all possibilities Bhatta Shobhakara's view appears to be more precise and also throws light on the subtleties of *shruti* rendering in *Samagana* practices. This again reiterates that there are strict restrictions on *shruti* rendering. *Swaras* should be rendered at their normal positions

for common rendering. *Shrutis* are employed only in the case of consonant *swarantaras* and rendered in legato or melodic fashion (starting *swara* and/ or at the resting *swara*) and that too following above-mentioned constraints. Thus *shruti* rendering was a special phenomenon. This is a major difference between the concept of *shruti* in *Naradiya Shiksha* and the concept of *shruti* in *Natyashastra*. According to *Natyashastra* of Bharata, *shrutis* are the distinct pitch positions in an octave (this is discussed in the next part) and can attain the status of a *swara*. While as per *Naradiya Shiksha*, *shrutis* are the special sonar qualities of a *swara* itself.

दीप्तामुदात्ते जानीयाद्दीप्तां च स्वरिते विदुः | अनुदात्ते मृदुर्ज्ञेया गान्धर्वे श्रुतिसंपदः ॥ [*Naradiya Shiksha:*1-7-18]

It should be known that there is a *Dipta shruti* in the *Udatta swara* and also in *Swarita swara*. There exists *Mrudu shruti* in the *Anudatta swara*. If this is followed properly then the performance of *shruti* rendering excels in *Samagana* or *Gandharva gana* [Bhise, U., p 102].

As *Anudatta* note is lowest note as compared to *Udatta* or *Swarita*, the singer always has to move in upward direction from *Anudatta swara,* therefore *Anudatta swara* will always have *Mrudu shruti*. For the *Udatta* and *Swarita* a *Dipta shruti* is recommended because it fulfils the requirement of *swarantara* but apart from that they may have *Aayata* or *Mrudu shrutis* depending on the positional context, however, *Naradiya Shiksha* recommends *Dipta shruti* for *Udatta* and *Swarita swaras*. First of all it is important to note that the concept of *shruti* as discussed in *Naradiya Shiksha* is very special. From the above description and discussion, some profound rules can be inferred. These rules indicate that type of a *shruti* is decided on the basis of relationships between *swaras* with each other.

They are as follows.

1. If you go from *swara* X towards its lower *swara* then the *shruti* of *swara* X would be *Aayata shruti*.
2. If you go from *swara* X towards its higher *swara* then the *shruti* of *swara* X would be *Mrudu shruti*.
3. If *swara* X is repeated again and again then the *shruti* of *swara* X would remain its natural *shruti* which is called *Madhya shruti* or *Madhyama shruti*.

4. If *swara* Y is related to its previous *swara* X by the consonance larger than *Krushta-Prathama swarantara* i.e. *Panchama-Madhyama Bhava* then *swara* Y will have *Dipta* type of *shruti*.
5. If *swara* Y is related to its previous *swara* X by the consonance equal or shorter than *Krushta-Prathama swarantara* i.e. *Panchama-Madhyama Bhava* then *swara* Y will have *Mrudu* type of *shruti*.
6. *Shruti* of *Panchama* is said to be of *Karuna* type. It means that if *swara* Y is related to its previous swara X by the consonance of *Shadja-Panchama Bhav*a then *swara* Y will have *Karuna* type of *shruti*. It means that *Shadja-Panchama Bhava* leads to *Karuna shruti* (this is not clearly stated in *Naradiya Shiksha*).
7. Similarly as per Bhatta Shobhakara, *Shadja-Madhyama Bhava* may lead to *Mrudu shruti*. Actually if *swara* Y is related to its previous *swara* X by the virtue of consonance of *Krushtha-Chaturtha Bhava* then *swara* Y will have *Dipta* type of *shruti*. However, if the *swara* Y happens to be a *Madhyama swara* then that *Dipta shruti* will shift a bit and will be called *`Mrudu-Bhoota' Dipta shruti*. Interestingly, according to *Kaundinyayan* tradition *shruti* type of *Madhyama swara* in this case also is *Dipta*. In the original text of *Naradiya Shiksha*, the *shruti* of *Prathama swara* is not explicitly mentioned.
8. *Shruti* of a *Nyasa swara* (last resting *swara* of a stanza or composition) is *Dipta shruti*.
9. While transitioning from *swara* X to *swara* Y, *shruti* will not be employed during the `transition', but only at the beginning or at the end of such a transition that is on the resting *swara*.
10. As per Bhatta Shobhakara all the *swaras*, consonants, short vowels, long vowels and *`ghuta' swaras* should not be expressed by *shruti* if they are not at the desired resting points. In all such places *shruti*-like expression of a *swara* itself is sufficient.
11. If *swara* Y is a resting *swara* and rests on *`pluta'* (prolonged) syllable then *swara* Y will have the appropriate *shruti* according to Bhatta Shobhakara.
12. If *swara* X is *Udatta* or *Swarita* then its *shruti* would be *Dipta* while if it is *Anudatta* then its *shruti* would be *Mrudu*.
13. *Shadja swara* or the *Chaturtha swara* will have *Mrudu shruti* irrespective of the relations with other *swaras* according to Bhatta Shobhakara.

14. *Madhyama swara* or the *Prathama swara* will have *Mrudu shruti* irrespective of the relations with other *swaras* according to Bhatta Shobhakara.
15. *Shruti* is a special sonar quality of a *swara*. It is to be rendered sparingly and parsimoniously to enhance melodic consonant relationships between *swaras*. *Shrutis* are not to be rendered for routine sequential *swara* phrases.

Naradiya Shiksha does not give an explicit definition of *shruti* in the original text as seen earlier though Bhatta Shobhakara and later commentators provide the definition of *shruti*. Bhatta Shobhakara says that *shrutis* are known by their sonar qualities (*Dhwani-vishesha*) or the special quality of sound as mentioned earlier. Looking at its connection with categories of *Rigvedic* and *Samavedic swaras* such as *Udatta, Anudatta* and *Swarita*, it is fairly clear that Vedic *swaras* are understood in terms of certain sonar qualities called *shrutis*. All the sound `qualities' present in Vedic *swaras* are understood as *shrutis*. Thus although there is no definition of *shruti* given in *Naradiya Shiksha*, one can infer that *shrutis* are nothing but sonar qualities of Vedic *swaras*/ musical pitches. It is certain that the concept of *shruti* in *Naradiya Shiksha* was different from that of *Natyashastra*. Since the description from *Naradiya Shiksha* is supposed to be earlier than the *Natyashastra*, it has its due importance.

5. *SHRUTI* IN *NATYASHASTRA* OF BHARATA

Bharata's *Natyashastra* does not give a clear definition of the term *shruti*. Though Bharata is very particular about defining important concepts such as *Vadi, Samvadi, Vivadi* and other concepts in *Natyashastra,* somehow he has not given a clear definition of the term *shruti*. There is a contextual description of *shrutis* and even Bharata has described a highly sophisticated method of demonstrating *shrutis* in the experiment called *`Shruti Nidarshanam'*. Elaborate discussion of *shruti* and *swara* comes in the twenty eighth chapter of Bharata's *Natyashastra*. This chapter is known as *`Swaradhyaya',* a chapter dedicated to description of musical notes. Bharata's *Natyashastra* is a *`samgraha'* or a collection of theatrical and musical knowledge handed over to him from generations to generations. However, there are certain concepts which appear in the *Natyashastra* for the first time. The terminology of *Shruti, Grama, Raga, Jati, Moorchhana* etc. is certainly inherited from earlier tradition and one can find its links with *Naradiya Shiksha*. However, it is very clear that the meaning of the term *shruti* in *Natyashastra* is completely different from any other earlier treatises. Bharata provides a robust system of concepts, a completely new paradigm of *shruti* in *Natyashastra*. The *`Shruti Nidarshanam'* experiment is a major mile-stone in ancient Indian musicology. The reasons for it being so will be discussed later in this monograph. The original text of Bharata's *Natyashastra* along with Sanskrit commentary by Abhinavagupta edited by Ramakrishna Kavi is referred here as the basic text. For clarity on certain issues Acharya Brihaspati's Sanskrit and Hindi commentary of *Natyashastra* is also referred where ever required. The English translation and interpretation of *shlokas* is by the author of this monograph himself.

The first mention of the term *shruti* occurs in the fourteenth *shloka* of twenty eighth chapter of *Natyashastra* along with *yati* and *swaras* as mentioned in the following *shloka*.

स्वरा ग्रामौ मूर्च्छनाश्च तानाः स्थानानि वृत्तयः | शुष्कं साधारणे वर्णा ह्यलंकाराश्च धातवः ||
[*Natyashastra:*28-13]

श्रुतयो यतयश्चैव नित्यं स्वरगतात्मकाः | दारव्यां समवायस्तु वीणायां सामुदाहृतः||
[*Natyashastra:*28-14]

Veena (a string instrument made up of wood) provides facility for generating music. One can produce *Swaras* or musical notes, two *Gramas* (two musically significant groups of notes), *Murchchhanas, tanas, Sthanas* or three octaves, *Vrittis* or styles of musical rendering, *Shushka*, *Swara-Sadharana*, *Jati-Sadharana*, *Varnas*, *Alamkaras*, *Dhatu, Yatis*, and *Shrutis*. All this is possible with a Veena made of wood [Bharata, p. 8].

This *shloka* gives an introductory description or briefly mentions the term *shruti* along with the other musical concepts, styles of playing music, description of musical instrument etc. More detailed treatment of the concept of *shruti* occurs in later *shlokas*. *Natyashastra* text has its own flow and rhythm. The *Natyashastra* text is not written sequentially in this sense. Broadly speaking, *Natyashastra* text follows a pattern of deductive description where first the major concepts are mentioned in few stanzas and then systematically elaborated and discussed as per the context in later *shlokas*. There exists a hidden structure in such an approach. The description of the concepts like, *swaras*, *shrutis* etc., in the *Natyashastra,* is spread across multiple stanzas. The researcher needs to take stock of all the instances of the description and then make sense out of it. The first occurrence of the term *`shruti',* is in the fourteenth *shloka,* as mentioned here in the context of a generic mention of musical concepts. It is mentioned here at the end of *shloka* number fourteen that the *shrutis* and *yatis* (pauses), apart from other aspects of music, always reside within the bounds of *swaras* (*swaragatatmakah*) [Bharata, p. 8].

Next reference of *shrutis* occurs as part of the description of *Samvadi* (consonant) and *Vivadi* (dissonant) *swaras* in the twenty second and twenty third stanzas. These *swara* places are defined in terms of *shrutis*. As a part of the same explanation it is mentioned that twenty two *shrutis* reside within the bounds of *gramas* known as *Shadja grama* and *Madhyama Grama*. Thus, *shrutis* are mentioned in the context of *Gramas*. This raises questions for some scholars who argue that *shrutis* are mentioned in the context of *`Gramas'* and not in the context of *swaras* [Rao, S., p. 674]. According to them significance of *shrutis* is limited to the domain of *Gramas* alone. However, this is an undue concern because first

of all, it is not fully correct to say that *shrutis* are mentioned in the context of *Gramas* alone. Actually *shrutis* are first mentioned in the *shloka* number fourteen and then the term *`shrutyantara'* (distance between two *swaras*) is used splendidly while defining *`Samvada-bhavas'* (rules of consonance between *swaras*). This will be discussed later. So, the concern that *shrutis* are mentioned only in the context of *Gramas* and not in the context of *swaras* is highly superfluous. It is also said in *Natyashastra,* at the end of this description that the twenty two *shrutis* are generated by using the (`*mandala*' or a cycle of *swaras* or the) technique known as `*Swaramandala sadhanam*` *(swaramandalasadhita*) [Bharata, p. 15]. Then much elaborated description of *shrutis* occurs in *shlokas* twenty fourth to twenty sixth where Bharata describes number of *shrutis* assigned to each *swara*. It is followed by the much celebrated description of *shrutis* known as the experiment called *`Shruti-Nidarshanam'*. The objective of this experiment is to show *shrutis* in a special way (*Nidarshanam*).

In the *Natyashastra*, *shrutis* are discussed along with *`swaras'* i.e. musical notes and therefore it is clear from the discussion that the status of *shrutis* is also equivalent to musical notes. Bharata first describes the characteristics of *swaras* and then moves over to the description of *shrutis*. *Shrutis* are the additional musical notes or places in a *`saptaka'* or an octave apart from the main seven notes. This has led to the debate that, 'is *shruti* different from *swara* or it is the same?' But this debate is unwarranted. It is possible to pick up and select some of these *shrutis* and use them as *swaras* in a musical rendering. Due to this reason, apart from seven main notes, in *Natyashastra*, there is a description of seven more notes which are nothing but *shrutis*. *Kakali Nishada* and *Kaishiki Nishada* or *Antar Gandhara* and *Sadharana Gandhara* are nothing but *shrutis. Antar Gandhara, Chyuta Panchama, Chyuta Madhyama, Chyuta Shadja* are nothing else but different *shrutis.* They can attain the status of *swaras*. Thus it is certain that the status of *swaras* and *shrutis* is considered different but in essence there is no difference as such. *Shrutis* are the well-recognized additional places in an octave other than the *swaras* but these places can also attain the status of *swaras*. In other words there is a larger set of twenty two *shrutis* according to Bharata and depending on the requirement seven or more *shrutis* are selected out of them and a status of *swara* is assigned to them.

5.1 *Swara Sthapana* (Establishing Musical notes)

The issue of establishing *swaras* first and establishing *shrutis* in a *saptaka* is widely debated among scholars. From the description of the *Natyashastra* some of the scholars have argued that *swaras* are established first because description of *swaras* comes before the description of *shrutis*. But if we closely read the text then it is evident that it is not the case. It is true that the description about *swaras* comes before *shrutis* but one should also note that the process of establishing *swaras* in a *saptaka* is explained in terms of *shrutis*. This clearly shows that Bharata presupposes the knowledge of *shrutis* as well as the knowledge of *`shrutyantara'* or the distance between *swaras* in terms of number of *shrutis*. It is worth mentioning here that *Naradiya Shiksha* uses *`swarantara'* (distance between two *swaras* in terms of *swara-bhava*) as the unit of measurement while *Natyashastra* uses *`shrutyantara'* (distance between two *swaras* in terms of number of *shrutis*) as a unit of measurement. In the *Sangita Ratnakar* of Sharangadeva, which will be discussed later, it is very clear that *shrutis* precede *swaras*. He establishes twenty two strings on the *Veena* and then establishes *swaras* on them. It is also true that the ancient musical practices were still alive till the time of Sharangadeva. There existed a continuity of musical tradition from Bharata to Sharangadeva. The process of *swara-sthapana* described in *Natyashastra* clearly indicates that the knowledge of *shruti* is necessary for the establishment of *swaras* in a *saptaka*. Only major difference between Sharangadeva's description and Bharata's description is that Sharangadeva has aurally established equi-distanced twenty two different strings (each dedicated to each *shruti*) for establishing *swaras* in a *saptaka*. Bharata does not mention where to establish *swaras*. Probably he assumes that *Veena* already has aurally equi-distanced frets and on any of the frets the first *swara*, the *Vadi*, has to be established. Of course, this assumption is also not required. Even today many musical instruments do not have frets viz. violin, *Sarod* and *Rudra Veena*. Still musicians know exact places and locations of *swaras* on the strings by aural judgement. Therefore, it is quite possible that Bharata's *Veena* may not have twenty two frets for twenty two *shrutis*. Therefore, *`swara-sthapana'* in Bharata's description could be with frets or without frets.

If we read Bharata's description of *swara-sthapana* carefully then it is clear that he describes relationship between *Vadi* and *Samvadi* in terms of number of *shrutis*. He says distance between *Vadi* and *Samvadi* is either thirteen *shrutis* or nine *shrutis*. Similarly *Vivadi* swara is also described in

terms of two-*shruti* distance. It means knowledge of *shrutis* as well as the knowledge of *shruti-distances* is necessary to establish *swaras* in a *saptaka*. It is possible that the *shruti* distances can be differentiated by ear alone. There is no need of frets on the Bharata's *Veena*. For a musically trend ear it is very easy to recognize the *Shadaj-Pancham Bhava* which is supposed to be the thirteen-*shruti distance*. Similarly, the nine-*shruti* distance i.e., *Shadja-Madhyama Bhava* is very prominent, though not very easy to recognize. In the same manner two-*shruti* distances is also distinct and unique that Bharata terms as *Vivadi* (dissonance) distance. In contemporary piano or a harmonium the semitone distance is the distance between *Ga* (E) and *Ma* (F) notes which is very easily distinguishable due to its dissonant qualities. It is approximately close to two-*shruti* distance. So it is quite likely that musically trained ears can easily recognize and remember these distances. This possibility is more realistic and practical.

It is important to note that Bharata himself has nowhere given the description of *swara-sthapana* explicitly. But if we follow the textual description closely, we realize that the description of *swara-sthapana* is implicitly present in the text. He mentions that

वादिसंवादिविवादिषु स्थापितेषु शेषास्त्वनुवादिनः| [Bharata, p. 15].

After `establishing' the *Vadi, Samvadi* and *Vivadi swaras* as explained all the remaining *swaras* are called *Anuvadi swara* [Bharata, p. 15]. The word *`sthapiteshu'* clearly assumes that all the description in the relevant *shlokas* is aimed at establishing *Vadi, Samvadi* etc. *swaras* as described. The *shloka* numbers twenty one, twenty two and twenty three, from the twenty-eighth chapter of Bharata's *Natyashastra* give the description of seven *swaras* and their names and then say that there are four musically significant qualities called *Vaditva*, *Samvaditva*, *Vivaditva* and *Anuvaditva*. This is clearly mentioned in the next two *shlokas*.

षड्जश्च ऋषभश्चैव गान्धरो मध्यमस्तथा | पञ्चमो धैवतश्चैव सप्तमोऽथ निषादवान् ॥ [*Natyashastra:*28-21]

There are seven swaras as: *Shadja, Rishabha, Gandhara, Madhyama, Panchama*, *Dhaivata,* and *Nishada* [Bharata, p. 10]. As per the tradition of *sutra* codification Bharata gives a name-list of *swaras* in order. Then he goes further to describe their potential and musical application.

चतुर्विधत्वमेतेषां विज्ञेयं गानयोक्तृभिः | वादी चैवाथ संवादि विवादी चानुवाद्यपि ॥ [*Natyashastra:*28-22]

These *swaras* are used by musicians in four different ways as: *Vadi* (tonic or fundamental note), *Samvadi* (consonant), *Vivadi* (dissonant), and *Anuvadi* (Assonant) [Bharata, p. 14]. In connection with the previous *shloka* it means that each of the above-mentioned seven *swaras* can have important functions/ roles in musical rendering. These functions are useful in composing music. In this sense *Vaditva, Samvaditva, Vivaditva* and *Anuvaditva* are four important functions of *swaras* in Indian music. Next statement gives a cryptic definition of a *Vadi swara*.

तत्र यो यदंशः स तदावादी| [Bharata, p. 15].

Swara that defines the octave and musical significance of other *swaras* is called a *Vadi swara* [Bharata, p. 15]. It's a tonic or fundamental *swara*. It is the basis of octave and other *swaras* can be located in reference to the *Vadi swara*. Once the *Vadi swara* is established the other *swaras* can be established accordingly.

Along with this description there is textual description defining the above-mentioned four qualities of *swaras* in terms of *Shadaj-Pancham Bhava*, *Shadja-Madhyama Bhava* and *Vivadi Bhava*. These *Bhavas* are understood in terms of *shruti-distances*. Very interestingly immediately after this description it is mentioned that `Thus after establishing *Vadi, Samvadi* and *Vivadi swaras*, all the remaining *swaras* are considered as *Anuvadi swaras*'. But first one needs to fix the position of a *Vadi swara* and then the position/s of *Samvadi swara*/s.

ययोश्च नवकत्रयोदशकमन्तरं तावन्योन्यं संवादिनौ| [Bharata, p. 15].

If the *shruti*-distance between two *swaras* is of nine *shrutis* or thirteen *shrutis* then these two *swaras* are *Samvadi swaras* of each other [Bharata, p. 15]. In reference to the *Vadi swara* then by using the rules mentioned in these *shlokas* two *Samvadi swaras* can be generated. *Swara-Sthapana* is a generative process in *Natyashastra*. Other *swaras* are also generated from the *Vadi swara* using these rules. Bharata also gives a description of valid pairs of *Samvadi swaras* (consonants). As per the prevalent tradition during Bharata's times, he has given a name-list of such pairs. Today one can say that there are more such pairs possible but in Bharata's paradigm these extra pairs were not considered. Bharata gives a list of valid pairs of

swaras that qualify the above-mentioned rule of thirteen *shrutis* and nine *shrutis*. The description is as follows.

तद्यथा --- षड्जपञ्चमौ, ऋषभधैवतौ, गांधारनिषादवन्तौ षड्जमध्यमाविति षड्जग्रामे| मध्यमग्रामेऽप्येवमेव| षड्जपञ्चमवर्ज्यं पञ्चमर्षभयोश्च अत्र संवादः| [Bharata, p. 15].

For example- *Shadja-Panchama, Rishabha-Dhaivata, Gandhara-Nishada, Shadja-Madhyama* in *Shadja Grama* is the valid pairs of *swaras* that adhere to the rule of consonance (*samvadabhava*). Similarly in *Madhyama Grama* except *Shadja-Panchama* pair all the rest of the above-mentioned pairs is valid *Samvadi swaras* of each other [Bharata, p. 15].

अत्र श्लोकः ---

संवादो मध्यमग्रामे पञ्चमस्यर्षभस्य च | षड्जग्रामे तु षड्जस्य संवादः पञ्चमस्य च ||

[*Natyashastra:*28-23].

Here is a *shloka*- In *Madhyama Grama* there exists a consonance between *Panchama swara* and *Rishabha swara*. In *Shadja Grama Shadja-Panchama* are the consonant *swaras* of each other. This becomes the differentiating criterion for *Madhyama Grama* and *Shadja Gram* respectively. After describing consonant pairs of *swaras* Bharata defines dissonant *swaras* as follows. This descriptive list of pair of *swaras* is also a generative list of *swaras*.

विवादिनस्तु ते येषां द्विश्रुतिकमन्तरं... [Bharata, p. 15].

All *swaras* which are located at two-*shruti* distance from each other are called *Vivadi swaras* of each other [Bharata, p. 15]. This describes the rule of dissonance and again Bharata gives representative pairs of *swaras* that are dissonant to each other as follows.

तद्यथा--- ऋषभगाम्धारौ, धैवतनिषादौ| [Bharata, p. 15].

For example-*Rishabha-Gandhara* and *Dhaivata-Nishad*a are the representative pairs of *Vivadi swaras* [Bharata, p. 15]. These are the two representative examples but the rule of two-*shruti* distance applies to all the *swaras* and their respective *Vivadi swaras*. Bharata is indicating that if the distance between two *swaras* is of two *shrutis* then all such *swaras* are *Vivadis* of each other. Later commentators like Abhinavagupta have followed it as a rule and applied it to all the *swaras* to decide their *Vivadi swaras* [Bharata, p. 18].

वादिसंवादिविवादिषु स्थापितेषु शेषास्त्वनुवादिनः| [Bharata, p. 15].

After establishing the *Vadi, Samvadi* and *Vivadi swaras* all the remaining *swaras* are called *Anuvadi swara* [Bharata, p. 15]. Bharata has not given the name-list of *Anuvadi swaras* however; the name-list of *Anuvadi swaras* provided by Mr. Ramakrishna Kavi is as follows [Bharata, p. 15].

अनुवादिसंज्ञकाः यथा--- *Anuvadi swaras* are understood as follows:

षड्जस्यर्षभगांधारधैवतनिषादाः (*Rishabha, Gandhara, Dhaivata* and *Nishada* are the *Anuvadi swaras* of *Shadja swara*.), ऋषभस्यमध्यमपञ्चमनिषादाः (*Madhyama, Panchama* and *Nishada* are the *Anuvadi swaras* of *Rishabha*.), गांधारस्यापि मध्यमपञ्चमधैवताः (*Madhyama, Panchama, Dhaivata* are the *Anuvadi swaras* of *Gandhara*.), मध्यमस्य धैवतपञ्चमनिषादाः(*Dhaivata, Panchama, Nishada* are the *Anuvadi swaras* of *Madhyama*.), पञ्चमस्य धैवतस्य षड्जमध्यमपञ्चमाः षड्जग्रामे| *Anuvadi swaras* of *Panchama* are *Shadja* and *Madhyama* while *Anuvadi swaras* of *Dhaivata* are *Shadja, Madhyama* and *Panchama*. All these are the valid *Anuvadi swaras* in *Shadja Grama*.

मध्यमग्रामेपि (In *Madhyama Grama Anuvadi swaras* would be as follows.) मध्यमस्य धैवतनिषादर्षभषड्जगांधाराः (*Anuvadi swaras* of *Madhyama* are *Dhaivata, Nishada, Rishabha, Shadja*, and *Gandhara*.), पञ्चमस्य धैवतनिषादर्षभगान्धाराः (*Anuvadi swaras* of *Panchama* are *Nishada, Rishabha*, and *Gandhara*.), धैवतस्य षड्जर्षभगान्धाराः (*Dhaivata* has *Anuvadis* as *Shadja, Rishabha*, and *Gandhara*.), निषादस्य षड्जर्षभौ,षड्जस्यर्षभगान्धारौ|| (*Nishada* has *Shadja* and *Rishabha* as *Anuvadi* while *Shadja* has *Rishabha* and *Gandhara* as *Anuvadis*.).

Here the word *`sthapiteshu'* is very important in the above statement. It suggests that the description of *swaras* and their qualities is aimed at establishing *swaras* on the *Veena* (musical instrument). Issue of establishing *swaras* in an octave has been very critical and debated by modern scholars. Since there is no explicit process of establishing *swaras* mentioned in the *Natyashastra*, scholars have been hesitant to fix the *swara* and *shruti* positions in an octave. Especially, the position of Bharata's *Rishabha* is very critical to establish the position of *`Chyuta Panchama'* that defines the *`Pramana Shruti'* and *Madhyama Grama*. However, in the absence of clear description of establishing *swaras* in the

Natyashastra, scholars have postulated many diverse theories. However, the word *`sthapiteshu'* in the Bharata's text provides the clue. Accordingly the same description can be used as a guideline for establishing seven *swaras*. The detailed process of establishing seven *swaras* based on this description is outlined in the later part of this section. Meanwhile, Bharata summarizes the above discussion as follows.

तत्र वदनाद्वादि, संवदनात्संवादि, विवदनाद्विवादि, अनुवदनादनुवादीति| [Bharata, p. 15].

Thus *swara* that expresses by itself is known as *Vadi*. *Swaras* that are consonant to each other are called *Samvadis*. *Swaras* that are dissonant are called *Vivadis* and *swaras* that are *assonant* are called *Anuvadis* [Bharata, p. 15].

Vadi swara is the most powerful resonating *swara* and is having the most evocative power and plays a seminal role in music-making. The *Samvadi swaras* have secondary importance in music-making as compared to *Vadi swara*. *Samvadi swaras* can be used in important musical phrases depending on their relationship with the *Vadi swara*. *Vivadi swaras* also have important role as they can evoke softer emotions being very close to *Vadi*. *Anuvadis* are supposed to be used splendidly in the musical rendering depending on their association with the *Vadi swara*. They are supportive *swaras* and help enriching the impact of musical composition. Thus these four categories of *swaras* are very important in music. The *Vivadi swaras* are used tactfully. Their presence or absence helps enhancing aesthetic flavor of the rendering.

एतेषां च स्वराणां न्यूनत्वमधिकत्वं वा तन्त्र्युपवादनदण्डेन्द्रियवैगुण्यादुपलभ्यते स्वरविधान मेतच्चतुर्विधत्वमिति| [Bharata, p. 15]

Defects may occur in these relationships between *swaras* if there are defects in the frets, wooden body of the *Veena* or the faulty playing. Defect may also occur if the performer has some deformity [Bharata, p. 15].

This whole description is termed as *`swaravidhana'* (a comprehensive `statement' about *swaras*) in *Natyashastra*. So it appears that this specific description implicitly gives clues for establishing *swaras* in a *saptaka* (octave) since the term *`sthapiteshu'* (for establishing) is used there [Bharata, p. 15]. If we follow the above description in a step-by-step manner it should be possible to establish *swaras* in a *saptaka*. There are two possibilities. The first possibility is to establish *swaras* on a *Veena*

having twenty two frets for twenty two *shrutis*. The second possibility is establishing *swaras* on a *Veena* having no frets. The first case is relatively easy but the second case requires musically sensitive ear to establish *swaras*. If we deal with the second case then it will be easier to understand the first case.

Accordingly, if we take a *Veena* having four strings, and adjust and tune the second string in such a way that it will produce the best possible sound which is not unwarrantedly low or high in pitch. For this experiment all the seven *swaras* can be established on the second string as described below. Then tune all the other remaining strings like a *Tanapura*, appropriately assuming that the second string stands for the middle *Shadja* of an octave. It's a common experience that a *Veena* or a *Tanapura* can be tuned to its natural frequency of that particular instrument. Each instrument has its own natural frequency depending on its material and its quality, length and dimensions of the instrument, quality and length of the strings used etc. By the above method one can tune the instrument to its own natural frequency. Once that is done, this natural frequency can be considered as a *Vadi swara*. This is also called *Amsha swara* because it is a tonic and acts as a basis for establishing other *swaras* as well as other octaves. Optionally one can choose any position on the string and consider that as a *Vadi* or *Amsha swara* as per Bharata's description. In this case *Vadi* and *Amsha* are the same (although the term *`Amsha'* is used in a wider sense by Bharata in the later part of *Natyashastra*).

The next statement gives the rule that *swaras* having nine-*shruti* distance and thirteen-*shruti* distance are *Samvadis* of each other. So once the *Vadi* is fixed on the *Veena*, one can always set two *swaras* on the *Veena* having nine-*shruti* distance and thirteen-*shruti* distance. These are the two *Samvadis* of the *Vadi swara*. The issue will arise that how to decide the nine-*shruti* distance and thirteen-*shruti* distance. It is done by using the aural sensitivity of ears. These two distances are so natural that if a person starts exploring on the instrument very quickly these distances will be noticed. For a trained musician it is an easy task. In the above description Bharata must have professional musician in mind and not a novice. So from a *Vadi swara* we get two *Samvadi swaras*. If the same rule is applied to these two *Samvadi swaras* then two more *Samvadis* of these *Samvadis* will be generated. This also suggests the cyclical relationship between *Vadi* and *Samvadi*. This triggers a generative process since one can establish two *Samvadis* of these two *Samvadis*. This in turn becomes a

cyclical method of establishing an entire octave. Abhinavagupta in his commentary on the above-mentioned description [Bharata, p. 15] says that internal distances or relationships among the positions of *swaras* form a *`Chakra'* a wheel or a cycle that makes an octave- a *swara mandala*. Earlier sages like Aangirasa and Kashyapa had demonstrated such a *`Parimandala'* or cyclical structure of *swaras* [Abhinavagupta in Bharata, p. 19].

तत एव स्थानान्तरे स्वरमंडलत्वमिति चक्रमुच्यते| तच्च परिमंडलं आंगिरसकाश्यपादिभिः मुनिभिः दर्शितम् | [Abhinavagupta in Bharata, p. 19].

Such a *Parimandala* (cyclical structure) is achieved only through appropriate relationships between *swaras* such as *Shadja-Madhyama Bhava* and *Shadja-Panchama Bhava* as discussed in next few paragraphs. This method may be termed as a *`Chakriya* Method' of establishing a *saptaka*. Although not mentioned in *Natyashastra*, by applying *Chakriya* method by using both the *samvada bhavas*: *Shadaj-Pancham Bhava* and *Shadja-Madhyama Bhava*, all the twenty two *shrutis* can be generated. Along with this, Abhinavagupta also says that there had been a common practice of establishing *Shadja* etc. *swaras* on *Veena* by using finger-widths as a unit of measurement and stretching the strings accordingly [Abhinavagupta in Bharata, p. 17].

वीणायांच षड्जादिस्थाने अङ्गुल्यन्तर पीडनपूर्वकम् अभिहन्यमाने तत्संपाद्यमिति व्यवहारः| [Abhinavagupta in Bharata, p. 17].

In the tradition this is called a method of *`angula pramana'* (measurement by width of fingers). Therefore, they might have a set measurement for establishing seven *swaras* in a *saptaka*.

There exists one more possibility. Once the *Panchama* and *Madhyama* are established then it was known that the aural distance between *Panchama* and *Madhyama* is of four *shrutis* as mentioned by Bharata. On this basis one can establish *Bharata's Gandhara* because the aural distance between *Madhyama* and *Bharata's Gandhara* is also of four *shrutis*. Once Bharata's Gandhara is established as discussed earlier the two-*shruti* distance is distinct and easy to recognize which is a *`Vivadi'* distance. So using this distance one can derive *Bharata's Rishabha* from *Bharata's Gandhara* because as mentioned by Bharata the distance between *Bharata's Rishabha* and *Bharata's Gandhara* is of two *shrutis*. Then by applying *Shadja-Panchama Bhava* one can derive *Bharata's Nishada* from *Bharata's*

Gandhara and *Bharata's Dhaivata* from *Bharata's Rishabha*. Thus all the basic seven *swaras* of a *saptaka* can be established by using the above method. With a little variation in the above description it is possible to generate all the Bharata's seven *swaras* in a step-by-step manner as follows.

1. First establish a *Vadi swara* on a chosen position on a string of the *Veena*.
2. By using *Shadja-Panchama Bhava* i.e. thirteen-*shruti* distance establishes a *Panchama swara* on the string.
3. By using *Shadja-Madhyama Bhava* i.e. nine-*shruti* distance establishes a *Madhyama swara* on the string.
4. By applying *Shadja-Panchama Bhava* to this newly generated *Madhyama* you also get the higher *Shadja*. The higher *Shadja* can be generated by various methods. It can be generated from the original *Shadja* by applying *Shadja-Shadja Bhava* also.
5. By applying *Shadja-Madhyama Bhava* or nine-*shruti* distance to the newly generated *Madhyama* one gets Bharata's *Nishada*.
6. From Bharata's *Nishada* it is possible to infer back to the Bharata's *Gandhara* by applying *Shadja-Panchama Bhava* or the thirteen-*shruti* distance.
7. Now with the help of *Vivadi Bhava* i.e. two-*shruti* distance to Bharata's *Gandhara* in a backward direction one can get the Bharata's *Rishabha*. Similarly, Bharata's *Dhaivata* can be generated by applying *Vivadi Bhava* to Bharata's *Nishada* in the same manner.

Thus in seven steps one can generate seven basic *swaras* by applying two *Samvada Bhavas* (rules of consonance) and the *Vivadi Bhava* (rules of dissonance). Bharata also says that by applying *Vivadi Bhava* to all seven *swaras* we get pairs of *Vivadi swaras*. It can be done in a following manner.

1. Apply *Vivadi Bhava* to Bharata's *Gandhara* to get *Antara Gandhara*.
2. Apply *Vivadi Bhava* to Bharata's *Nishada* to get *Kakali Nishada*.
3. Apply *Vivadi Bhava* to Bharata's *Madhyama* to get *Teevra Madhyama* or *Prati Madhyama* although Bharata has not mentioned about its use in the *jatis* or *ragas*. But this *shruti* is certainly generated and was a part of Bharata's scheme of an octave.

4. Apply *Vivadi Bhava* to Bharata's *Panchama* to get *Komal Dhaivata* which is also not mentioned by Bharata anywhere in the text.
5. Apply *Vivadi Bhava* to *Shadja* to get *Komal Rishabha* or *Dvi-shruti Rishabha* which is also not mentioned in the text.

Thus by applying *Vivadi Bhava* to Bharata's seven *swaras* we get five more *swaras* of which *Antara Gandhara* and *Kakali Nishada* are mentioned by Bharata and discussed their use in *`Jati'* music. By this approach we get total twelve *swaras*. Bharata considers all the remaining *swaras* as *Anuvadis*. Here again it is indicated that there exists a given set of twenty two *shrutis* using *Chakriya* method and by using *Shadja-Panchama Bhava* and *Shadja-Madhyama Bhava* we select seven *shrutis* and call them *swaras*. Then by applying *Vivadi Bhava* to these seven *swaras* we select five more *swaras* making the total number twelve. All the other *shrutis* are called *Anuvadi swaras*. It means that out of the given set of twenty two *shrutis*, remaining ten *shrutis* are considered as *Anuvadi swaras*. However, even in the absence of *Chakriya* method, it is possible to establish *Anuvadi swaras* using *Shadja-Panchama Bhava* and *Shadja-Madhyama Bhava* that Bharata has not indicated.

This description clearly indicates that it is possible to establish Bharata's *saptaka* of basic seven *swaras* by following the textual description in a step-by-step manner. As mentioned by Bharata in the text, with the help of *Shadja-Panchama Bhava* (thirteen-*shruti* distance), *Shadja-Madhyama Bhava* (nine-*shruti* distance) and *Vivadi Bhava* (two-*shruti* distance) it is possible to establish a *Saptaka* of seven *swaras*. In the process five more *Vivadi swaras* are also selected. Remaining ten *swaras* are considered as *Anuvadi swaras*. Bharata calls this process as *`Swara-Mandala-Sadhanam'*. This also explains why *Vadi, Samvadi, Vivadi* and *Anuvadi swaras* are mentioned in that particular order in the *shloka*. They are stated in the same sequence because they are supposed to be used in that order to generate a *`swara mandala'* or a *saptaka*. It is worth mentioning that the whole process of establishing *Saptaka* is carried out using aural sensitivity of the musicians. Now it becomes quite crucial that such a process may not precisely match with mathematical formulations. If the same process is executed by mathematical formulation then the *swara* positions which are generated would be different. Contemporary musicologists understand *`Samvada Bhavas'* in terms of mathematical ratios: *Shadja-Panchama Bhava* as a ratio of 3/2, *Shadja-Madhyama Bhava*'s ratio of 4/3 and *Vivadi Bhava* as the ratio of 16/15 (semi tone) that give precise frequency values of the *swaras*. On the other hand if *swaras* are generated with aural

sensitivity, they will not match these values exactly. It may be considered as mathematical approximation but from musical point of view since these *swaras* sound acceptable and musically pleasant to musicians it is certainly an aural perfection. During Bharata's times the mathematical ratios were not used for ascertaining the *swara* positions in a *saptaka*. On the other hand, as Sharangadeva also mentions in his *Sangita Ratnakar* that *swara* positions were established by aural sensitivity. The *Natyashastra* text is highly compact, compressed with cryptic meaning and very rich in content. Every word is used very carefully and carries definitive meaning. While understanding such *sutras* and each and every word of the text one needs to take utmost care while understanding and interpreting them.

5.2 *Grama Sthapana* (Establishing Scales)

The most important reference to *shrutis* comes in the context of establishing *Gramas* because there it is mentioned that twenty two *shrutis* reside in the bounds of two *Gramas*.

अथद्वौ ग्रामौ षड्जग्रामो मध्यमग्रामश्चेति| अत्राश्रिता द्वाविंशतिश्रुतयः स्वरमण्डलसाधिताः| तद्यथा--- [Bharata, p. 15]

Thus there are two *Gramas*: *Shadja Grama* and *Madhyama Grama*. Here reside twenty two *shrutis* that are generated by using the technique of *`swara mandala sadhanam'* (generating/ establishing a *saptaka*) [Bharata, p. 15].

As already discussed seven *swaras* can be established by following the cyclical method so also twenty two *shrutis* can also be generated by extending the same method. *`Swara mandala Sadhanam'* is the same cyclical method of establishing *shrutis*. The Sanskrit word *`mandala'* means a circle or a cycle, *`swara'* means a musical note and *`sadhanam'* means to achieve or establish in this context. The next *shloka* gives the distribution of twenty two *shrutis* among seven *swaras* as follows.

तिस्रो द्वे च चतस्रश्च चतस्रस्तिस्र एव च| द्वे चैवाद्य चतस्रश्च षड्जग्रामे भवेद्विधिः ॥ [*Natyashastra:*28-24]

The *shruti* distances between respective *swaras* in the *Shadja Grama* starting with *Shadja* are as follows: 3-2-4-4-3-2 and previous 4 *shrutis* (of

Shadja) [Bharata, p. 19]. As it is observed by many scholars, twenty two *shrutis* are not distributed evenly among seven *swaras*. First of all mathematically it is not possible to divide twenty two *shrutis* among seven *swaras*. But apart from that the process of evolution of seven *swaras* and twenty two *shrutis* were mainly responsible for this kind of division. Bharata's seven *swaras* are originated from Vedic accents as discussed earlier and later on the number *swaras* has increased. The concept of *shrutis* in *Naradiya Shiksha* was quite different. *Shrutis* were considered as special sonar qualities of *swaras*. *Shrutis* as pitch positions is a gift of Bharata's *Natyashastra*. Bharata inherited *swara* positions from Vedas and *Naradiya Shiksha*. The *Chakriya* method of establishing *swaras* was in use and Bharata clearly extended it for establishing twenty two *shrutis*. Probably this was the magic formula to accommodate seven and more *swara* positions of Vedas and few more positions such as *Antara Gandhara* and *Kakali Nishada*. There are indications that more *swara* positions were known to *Naradiya Shiksha* than the Vedic *swara* positions. Even the *Chatuh Shruti Rishabha* and *Chatuh Shruti Dhaivata* were known to them.

It seems that *Chatushruti Rishabha* and *Chatushruti Dhaivata* which are considered quite prominent *swaras* in contemporary musical scales were not part of Bharata's scheme of thinking. They were just treated as *Anuvadi swaras*. But in *Naradiya Shiksha* the *Chatushruti Dhaivata* is called *`Swaara' swara*. Bharata's *Dhaivata swara* was termed as *`Atiswaara'* i.e. beyond *`Swaara' swara* (beyond Bharata's *Dhaivata* on *flute* and below Bharata's *Dhaivata* on *Veena*). As per *Naradiya Shiksha Gandhara* and *Nishada* are considered as *Udatta swaras* while *Rishabha and Dhaivata* are called *Anudatta swaras*. *Naradiya Shiksha* says that the *shruti* that is in between the *Udatta* and *Anudatta* is called *`Sadharana' shruti* and the same *shruti* is also called *`Swaara' swara*. The *shloka* is as follows.

उच्चनीचस्य यन्मध्ये साधारणमिति श्रुतिः| तं स्वारं स्वारसंज्ञायां प्रतिजानन्ति शैक्षिकाः|| [*Naradiya Shiksha* 1-8-7]

The *shruti* between high and low *swaras* is known as *`Sadharana'.* It is known to be *`Swaara'* in the terminology of *swaras* (Vedic *swara*) by those who are familiar with recitation [Bhise, U., p. 105]. Bhatta Shobhakara in his commentary, mentions that such a *`Swaara' swara* is considered as *`Viswara'* or wrong *swara*. One is supposed to be careful in not using it.

In this sense if Bharata's *Gandhara* is called *Udatta* and Bharata's *Rishabha* is called *Anudatta* then the in between *shruti* that resides exactly in the

middle is *Chatuh-shruti Rishabha*. The *shruti* distance between Bharata's *Gandhara* and Bharata's *Rishabha* is of two *shrutis*. *The Chatuh shruti Rishabha* falls exactly in the middle being *Chatuh shruti Rishabha*. Same is true with *Chatushruti Dhaivata*. So it appears that *Chatushruti Rishabha* (contemporary pure *Rishabha*) and *Chatuh shruti Dhaivata* (contemporary pure *Dhaivata*) were well- recognized (of course as wrong *swaras*) by *Naradiya Shiksha* and though accommodated in the Bharata's scheme of twenty two *shrutis* they have not been granted the status that they enjoy today.

Bharata's scheme of *swaras* and associated *shrutis* is explained in following *shlokas.*

चतुःश्रुतिर्भवेत् षड्ज ऋषभस्त्रिश्रुतिः स्मृतः| द्विश्रुतिश्चैव गान्धारो मध्यमश्च चतुःश्रुतिः॥ [*Natyashastra:*28-25]

Shadja is of four *shrutis* (*Shadja* is established on the fourth *shruti*), after that *Rishabha* is of three *shrutis* (*Rishabha* is to be established on seventh *shruti*), *Gandhara* is of two *shrutis* (*Gandhara* on ninth *shruti*) and the *Madhyama* is of four *shrutis* (and finally *Madhyama* on *thirteenth* shruti).

पञ्चमस्तद्वदेव स्यात् त्रिश्रुतिर्धैवतो मतः| द्विश्रुतिश्च निषादः स्यात् षड्जग्रामे विधिर्भवेत् ॥ [*Natyashastra:*28-26]

Similarly *Panchama* is also of four *shrutis* (that is on the seventh *shruti*) and *Dhaivata* is of three *shrutis* (on twentieth *shruti*). *Nishada* has two *shrutis* (*Nishada* is on the last *shruti*). This is the procedure of distributing seven *swaras* in a *Shadja Grama*. This arrangement of *shrutis* and *swaras* is specifically useful for performing the *`Shruti-Nidarshanam'* experiment which will be discussed later on. In the above description *Shadja* is of four *shrutis* so it is established on the fourth *shruti* of a *Veena* but it is not always necessary. *Shadja* can be established on any *shruti* and the distances of other *swaras* can be followed. The above description is given as a reference point for the fourth coming *`Shruti-Nidarshanam'* experiment. Therefore it has its purpose and beauty which will be explained later on. These *swara* positions are the valid positions for *Shadja Grama*. The *Madhyama Grama* is generated out of *Shadja Grama* by making just one change. *Grama* is a group of *swaras* and in today's terminology it may be defined as a *scale*. The above-mentioned *swara* positions define the *Shadja Grama* scale. By changing the positions of *Panchama swara* the same scale is converted into *Madhyama Grama* scale.

मध्यमग्रामे तु पञ्चमः श्रुत्यपकृष्टः कार्यः| [Bharata, p. 20]

In *Madhyama Grama* Panchama needs to be lowered by one *shruti* [Bharata p. 20] that means *Panchama* will have three *shrutis* and *Dhaivata* will have four. Rest of the *swaras* will have *shrutis* as intact. With this statement it is clear that the earlier discussion was about the *Shadja Grama*. To transform it into a *Madhyama Grama* the position of the *Panchama swara* needs to change. As per the earlier description of *swarasthapana*, *Panchama swara* was established on the fourth *shruti* (seventeenth *shruti*) after *Madhyama*. For *Madhyama Grama* the position of *Panchama* has to be shifted one *shruti* lower. So it should be established on the third *shruti* (sixteenth *shruti*) after *Madhyama*. Positions of the rest of the *swaras* remain the same. To achieve this one should know how to shift *Panchama swara* one *shruti* lower. So far Bharata has described thirteen-*shruti* distance, nine-*shruti* distance, two-*shruti* distance but he has not mentioned the one-*shruti* distance. He calls one-*shruti* distance as a *`Pramana Shruti'*. That is explained as follows.

5.3 *Pramana Shruti* (Establishing Standard *Shruti*)

The concept of *`Pramana Shruti'* has attracted a big debate among scholars. The word *`Pramana'* literally means a `standard', or a standard `unit' of measurement. In reference with Bharata's text, *Pramana shruti* means a standard unit of aural difference between any two *shrutis*. The following quotation from *Natyashastra lays* down the procedure to demonstrate *`Pramana Shruti'* or the standard unit *shruti* in a certain and definite way is as follows.

एवं स्वश्रुत्युत्कर्षादपकर्षाद्वा यदन्तरं मार्दवादायतत्वाद्वा तत्प्रमाणं श्रुतिः निदर्शनंत्वासामभिव्याख्यास्यामः| [Bharata, p. 20]

The *Pramana shruti* is understood as described above. On a naturally tuned *Veena*, a position of a particular *shruti* is called its own position or *`swa-sthana'*. Tightening of a string of a *Veena* is called *Utkarsha* and loosening of a string is called *Apakarsha*. By tightening the string we get the higher position of the *shruti* which is termed as *Aayata* position. When a string is loosened the *shruti* position is shifted towards a lower frequency. This is called the *Mrudu* position of a *shruti*. This shifting on

higher and lower sides should be very minimal but musically distinguishable from the original position of a *shruti*. So we get two positions one on higher side and the other on the lower side. They are termed as *Aayata* and *Mardava* or *Mrudu* positions respectively. The distance between the *Aayata* and the *Mrudu shruti* is considered as a *`Pramana' shruti* or a `Unit' *shruti* distance [Bharata, pp. 20-21].

Abhinavagupta clearly mentions, while elaborating the process of understanding *`Pramana' shruti* that the *shruti* divisions are Niyata' (uniform), based on the rule of *Pramana shruti.* He further says that those who believe in *`Aniyata'* (unequal) *shruti* divisions have a false perspective. [Abhinavagupta in Bharata, p. 22]. Even *Naradiya Shiksha,* as discussed earlier, uses the concepts of *`Aayata'* and *`Mrudu'* as two *jatis* or types of *shrutis*. These two pitch positions are very important for *Naradiya Shiksha* as types of *shrutis* but according to Abhinavagupta these are used as the extreme boundary positions of a *shruti* itself. This shows how ancient concepts of *Aayatatva* and *Mardavatva* from *Naradiya Shiksha* were followed in *Natyashastra* of Bharata and understood by later musicologists and how seamlessly they were integrated in the theory. This clarifies that if the original position of a *swara* is considered as the *Madhya shruti* according to *Naradiya Shiksha* then *Mrudu shruti* is half a *Pramana Shruti* lower than the *swara* and the *Aayata shruti* is half a *Pramana Shruti* higher than the *swara*.

Pramana shruti is a standard unit-*shruti* distance. Bharata describes all the *Samvada Bhavas* and *Vivada Bhavas* in terms of unit-*shruti* distance. For him *Shadja-Panchama Bhava* is of thirteen-*shruti* distance while *Shadja-Madhyama Bhava* is of nine-*shruti* distance. The *Vivada Bhava* is of two-*shruti* distance according to Bharata. Here distance means aural distance between two *shrutis*. Logically it follows from this description that thirteen-*shruti* distance should be made up of thirteen *Pramana shrutis*, nine-*shruti* distance is made up of nine *Pramana shrutis* and two-*shruti* distance is made up of two *Pramana shrutis*. The logical conclusion is that Bharata's *shrutis* were equi-distanced or equal temperament. It means that Bharata's scale was an equal temperament scale of twenty two *shrutis* or *shruti* positions. Even as discussed elsewhere; Sharangadeva's description of *shrutis* in *Sangita Ratnakar* is consistent with this description. Therefore, it is certain that till the time of Sharangadeva twenty two *shrutis* were considered equal temperament and thus the phrase *`Pramana shruti'* is valid and also makes sense while understanding *shrutis*.

However, in the course of *shruti* analysis and *shruti* discussion in last two centuries there has been a tendency among the scholars to assume *shrutis* of unequal distance. The debate arises out of postulating three different standards for *shrutis*. Some scholars have argued that thirteen-*shruti* distance, nine-*shruti* distance and two-*shruti* distance are the three different standards of *shrutis*. In this sense there are three *`Pramana Shrutis'* according to them. This leads to unequal division of *shrutis*. But still there is no agreement on the exact ratios of these three standard distances. This led to multiple theories of *shrutis*. Thus there have been multiple interpretations of the phrase *`Pramana Shruti'* but eventually they have realized that the argument for multiple standards for *shrutis* is not tenable. After analyzing all the arguments, it appears that all scholars tend to consider *Pramana Shruti* as a `smallest' *shruti*. They do not consider *Pramana shruti* as `unit' *shruti*. Somehow, there is a grand agreement among the scholars, by applying various mathematical formulations and with certain assumptions that the value of *Pramana Shruti* is denoted by the smallest ratio of 81/80. The ratio of 81/80 gives the value of 1.0125 as the value of so-called smallest *Pramana Shruti.* Bharata's equal temperament twenty two *shrutis* will give the value of *Pramana shruti* as 1.032. Thus from Bharata's description the value of *Pramana Shruti* is 1.032 while the modern scholars do not agree with this value. So the scholars tend to assume that *shrutis* are unequal. Many scholars have recommended many formulations for unequal *shrutis*. As a result, the scholastic community conducting research on twenty two *shrutis* has become stagnated with multiple theories of *shrutis*. On the one hand their results are not consistent with Bharata's views and on the other hand Bharata's theory of equal temperament *shrutis* is not acceptable to them because it does not match with the `just intonation scale' and Pythagorean scale. As a result there is no consensus among scholars about *shruti* positions as well as the concept of *shruti* itself. There is a feeling among the new generation musicians that the whole *shruti*-research is a futile effort since all these theories are inconclusive.

Another interesting fact is that Bharata mentions of twenty two *shrutis*, but in the entire text it is no-where mentioned that all twenty two *shrutis* are used in *Jatis* and *Ragas*. On the other hand there is a mention of only fourteen *shrutis* which are used as *swaras* in *Jatis*. So it seems that out of twenty two *shrutis* only fourteen *shrutis* could attain the status of *swaras* in actual practice. This leads to a question that if only fourteen *shrutis* are used in actual music then what is the need of remaining eight *shrutis*. So the discussion of twenty two *shrutis* is futile. However, if one reads

Bharata's description carefully it is not correct to say that *shruti*-research is a futile effort. All the twenty two *shrutis* are potential *swaras* and their usage depends on the performers in various musical applications. For example today *Chatu-shruti Rishabha* and *Prati-Madhyama* are considered as legitimate *swaras* but they had no role in Bharata's system of music. Bharata has not mentioned their applications but recognized their pitch positions as *shrutis*. They remained as potential *swaras* till modern times. Also, one must understand that Bharata's paradigm of twenty two *shrutis* is a broader theoretical frame-work that provides possibilities of musical explorations and most importantly it accommodates Vedic *swaras* seamlessly. Bharata has developed an amazing device called *`Shruti-Nidarshanam'* to demonstrate *shrutis* in a definite and certain way. It is discussed as follows.

5.4 *Shruti-Nidarshanam* (Demonstrating Microtones)

The *Shruti-Nidarshanam* experiment is a unique gift of Bharata to the world of music to demonstrate existence of twenty two *shrutis*. This experiment is described in twenty eighth chapter of Bharata's *Natyashastra*. It is not mentioned in any of the earlier treatises on Indian music therefore it is certain that this experiment was invented during Bharata's times. The original creator of this experiment is not known but since it is mentioned in Bharata's *Natyashastra* it is assumed that Bharata himself must have designed it. This experiment is a conclusive proof of equal temperament twenty two *shrutis*. As per this experiment *Shrutis* can be demonstrated in a definitive way through an experiment on two *Veenas*. The procedure for this experiment is called *`Sarana Chatushtaya'* method. This experiment is described as follows in a step-by-step manner.

The first *Sarana*:

यथा--- द्वे वीणे तुल्यप्रमाणतन्त्र्युपवादनदण्डमूर्छनेकृत्वा षड्जग्रामाश्रिते कार्ये| [Bharata, p. 20]

Take two *Veenas* of same size with equal number of strings (and frets), with same dimensions in terms of length and other parameters. Tune both the *Veenas* in a *Shadja Grama*. Establish seven *swaras* properly on both the *Veenas*. One of them is called *`Dhruva Veena'* or *`Achala' Veena* while the other is called *`Chala' Veena*. Both the *Veenas* need to be tuned by using the method of *`swara sthapana'* discussed earlier. By this all the seven

swaras will be at their original natural positions. The experiment allows mapping *swaras* of *`Chala Veena'* onto the *swaras* of *`Achala Veena'*. At every step mapping happens in such a manner that groups of two *shrutis*, three *shrutis* and four *shrutis* are demonstrated in a decisive manner along with their individual positions.

Process of establishing *swaras* on both the *Veenas* is already explained during the discussion on *`swara-sthapana'*. As per the description *Shadja* is set on the fourth *shruti* and then rest of the *swaras* are placed as per relative distances as mentioned in the description of *`swara-sthapana'*. The process of establishment of *swara* must have been a simple process. It is possible that the *Veenas* that were commonly used by musicians those days would have frets for these twenty two *shrutis*. Out of these musicians can choose the required seven *swaras*. Even today twelve positions of *swaras* are predetermined on the *Veena*. But it is certain that the instrument-makers as well as musicians should have the theoretical knowledge of setting up the frets on the *Veena*. If there are predetermined seven or twenty two frets on both the Veenas then this experiment is easier to perform. If there are no predetermined frets then a skilled musicians only can perform this experiment. Since it's a theoretical experiment and therefore it is expected that the person should have adequate musical knowledge. Only condition is that both the *Veenas* should be identical in all the respects. If there are no pre-existing frets on both the *Veenas* then after *`swara-sthapana'* one can put marks on both the *Veenas* to identify *swara* positions.

तयोरन्यतरस्यां पञ्चमस्यापकर्षे श्रुतिं मध्यमग्रामिकीं कृत्वा तामेव च पञ्चमस्य श्रुत्युत्कर्षवशात् षड्जग्रामिकीं कुर्यात्। [Bharata, p. 20]

Now lower down the *Panchama swara* of *Chala Veena* by one *shruti* (*Pramana shruti*) as discussed earlier during the description of a *`Pramana Shruti'*. So the *Chala Veena* becomes a *Madhyama Grama Veena*. This is achieved by lowering down the *Panchama* of *Chala Veena* such that it will tune with the Bharata's *Rishabha* on the *Achala Veena* with a *Samvada Bhava* of nine-*shruti* distance i.e. *Shadja-Madhyama Bhava*. This is done because there exists a *Shadja-Madhyama Bhava* between Bharata's *Rishabha* and *Panchama* of *Madhyama Grama*. By this a *`Pramana shruti'* is demonstrated. Then tune all the rest of the *swaras* of a *Chala Veena* in such a way that keeps the *Panchama's* new position intact, the *Chala Veena* becomes the *Shadja Grama Veena* again [Bharata, p. 20].

एकश्रुतिरपकृष्टा भवति| [Bharata, p. 20]

Now the *Chala Veena* is one *shruti* lower than the *Dhruva Veena*. All the *swaras* of *Chala Veena* are one *shruti* lower than all the *swaras* of *Dhruva Veena* [Bharata, p. 20].

Swara positions of the *Chala Veena* keep shifting at every step in the whole experiment towards lower side while *Achala Veena swara* positions are kept in the original positions. The beauty of the experiment is that at every step one can compare the relative positions of each *swara* of the *Chala Veena* with their counter parts on the *Achala Veen*. For instance, at this first stage, every *swara* of the *Chala Veena* is one *shruti* (*Pramana Shruti*) lower than all the *swaras* of the *Achala Veena*. One can cross check and understand what the aural distance of the Pramana Shruti is. In other words one knows the *Pramana Shruti* distance in a definite way.

Along with this process one very important phenomenon is happening and that is as every *swara* of *Chala Veena* is lowered by one *shruti*, each *swara* is mapped on the one-*shruti* lower position on the *Achala Veena*. As a result apart from original *swara/ shruti* positions, seven new positions are generated or mapped on the *Achala Veena*. These new positions are nothing but seven more *shruti* positions. These can be marked and recorded on the *Achala Veena*. So at the end of first step itself seven original *swara/ shruti* positions plus seven new *shruti* positions are generated. As a whole fourteen *shrutis* are demonstrated at the end of the first step. The newly generated *shrutis* thus would be as follows: *Dvi-shruti Rishabha, Chatuh-shruti Rishabha, Chyuta-Madhyama, Chyuta-Panchama, Dvi-shruti Dhaivata, Chatuh-shruti Dhaivata, and Chyuta-Shadja*. These are the seven new *shrutis* generated at the end of the first step or first *Sarana*. Interestingly newly generated *shrutis* do not overlap on any of the existing seven *swaras/ shrutis*. These are absolutely new *shrutis*.

The Second *Sarana*:

पुनरपि तद्वदेवापकर्षेत्, यथागान्धारनिषादवन्तावितरस्यामृषभधैवतौ प्रवेक्ष्यतः द्विश्रुत्यधिकत्वात् ... [Bharata, p. 20]

Again in the same manner lower down the *Chala Veena* by one *shruti* so that *Gandhara* and *Nishada* of *Chala Veena* will be tuned into *Rishabha* and *Dhaivata* of the *Dhruva Veena* respectively because now the *Chala Veena* is two *shrutis* lower than the *Dhruva Veena* [Bharata, p. 20].

This is the conclusive process of lowering the *Chala Veena* by two *shrutis*. During the earlier step the *Chala Veena* was lowered down by one *shruti*. The process was tricky because one needs excellent aural skill to recognize *`Pramana Shruti'* distance. However this second step is easy because one needs to lower down the *Nishada swara* of *Chala Veena* till it is tuned in with the *Dhaivata* of the *Achala Veena*. Automatically the *Gandhara* of *Chala Veena* will merge into *Rishabha* of *Achala Veena*. If this does not happen then it means that the original establishment of seven *swaras* is not correct or the earlier aural positioning of *`Pramana Shruti*' is not correct. Here the performer can cross-check both the possibilities and make corrections if required. If corrections are not required then it shows that the *swaras* are tuned and established properly. As a result all the *swaras* of *Chala Veena* are now two *shruti* lowered than all the *swaras* of *Achala Veena*. One can enhance the aural skill of recognizing two-*shruti* distance by comparing all seven *swaras* of *Chala Veena* with their counter parts on the *Achala Veena*. At the end of this second step of the experiment the knowledge of `two-*shruti*' distance is enriched.

As a result of the mapping process five more *shrutis* are generated at the end of the second *Sarana*/ step. These are as follows: *Eka-shruti Rishabha, Antara-Gandhara, Prati-Madhyama* or *Teevra-Madhyama, Eka-shruti Dhaivata and Kakali Nishada*. So in all seven plus five i.e. twelve *shrutis* are demonstrated at the end of second stage of the experiment. Although all the seven *swaras* of *Chala Veena* are lowered by one *shruti*, only five new *shrutis* are generated because two *swaras* of *Chala Veena*, *Nishada* and *Gandhara* have been mapped on the pre-existing *Dhaivata* and *Rishabha* of the *Achala Veena*. The new *shrutis* are generated on the *Achala Veena* and since *Dhaivata* and *Rishabha* were already there they are not counted as new *shrutis*. So at the end of this step five new *shrutis* are generated.

The Third *Sarana*:

पुनरपि तद्वदेवापकृष्टायां धैवतार्षभावितरस्यां पञ्चमषड्जौ प्रवेक्ष्यतः त्रिश्रुत्यधिकत्वात्। [Bharata, p. 20]

Again in the same manner lower down the *Chala Veena* by one *shruti* so that *Dhaivata* and *Rishabha* of *Chala Veena* will be tuned (enter) into *Panchama* and *Shadja* of the *Dhruva Veena* respectively because now the *Chala Veena* is three *shrutis* lower than its original position [Bharata, p. 20].

As a result of the mapping process three more *shrutis* are generated at the end of the third step. These are as follows: *Sadharana-Gandhara, Chyuta-Prati-Madhyama, and Kaishiki Nishada*. Although, all seven *swaras* of *Chala Veena* are lowered by one *shruti*, only three new *shrutis* are generated as mentioned above because *Dhaivata* and *Rishabha* are mapped on pre-existing *Panchama* and *Shadja swaras* of the *Achala Veena*. Also two more *swaras* of *Chala Veena*: *Gandhara* and *Nishada* are mapped on *Dvi-shruti Rishabha* and *Dvi-shruti Dhaivata* of *Achala Veena* that were newly generated during the first step of the experiment. Therefore they are not treated as new *shrutis*. As a result only three *shrutis* are newly generated at this step.

So in all seven plus five plus three i.e. fifteen *shrutis* are demonstrated at the end of the third stage of the experiment. If the original seven *swara* positions are added to this then the number becomes twenty two. So actually at the end of the third step twenty two *shrutis* are demonstrated in this experiment. Then what is the need of the fourth step in the experiment? The fourth step is a concluding step to show that beyond these twenty two *shrutis* no new extra *shruti* is generated.

The Fourth *Sarana*:

तद्वत्पुनरपकृष्टायां पञ्चममध्यमषड्जा इतरस्यां मध्यमगान्धारनिषादवन्तः प्रवेक्ष्यन्ति चतुःश्रुत्यभ्यधिकत्वात्। [Bharata, p. 20]

Again in the same manner lower down the *Chala Veena* by one *shruti* so that *Panchama, Madhyama* and *Shadja* of *Chala Veena* will be tuned (enter) into *Madhyama, Gandhara* and *Nishada* of the *Dhruva Veena* respectively because now the *Chala Veena* is four *shrutis* lower than the *Achala Veena* [Bharata, p. 20].

Interestingly no new *shruti* is generated at this step. All the lowered *swaras* of the *Chala Veena* map exactly on pre-existing or pre-generated *swara/ shruti* positions of the *Achala Veena*. For instance, four remaining *swaras* of *Chala Veena*: *Rishabha, Gandhara*, *Dhaivata* and *Nishada* are mapped on *Chyuta Shadja*, *Eka-shruti Rishabha*, *Chyuta Panchama* and *Eka-shruti Dhaivata* of *Achala Veena* respectively. So there is no generation of new *shruti* positions and therefore this is the concluding step of the experiment.

The beauty of the experiment is that at every step *Chala Veena* is lowered by one-*shruti* distance. Thus in first steps *one-shruti* distance, second step *two-shruti* distance, third step *three-shruti* distance and in the fourth step the *four-shruti* distance is demonstrated. Original seven *swaras* are the seven *shruti* positions established by *`swara-mandala-sadhanam'* process. At the end of first step maximum number of *shrutis* i.e. seven new *shrutis* are generated. At the end of second step slightly less i.e. five new *shrutis* are generated and in the third step only three new *shrutis* are generated. Thus in all twenty two *shrutis* are demonstrated out of which seven *shrutis* were already there and fifteen *shrutis* are newly generated during the experiment. The last step does not generate a *shruti*. So it makes a statement that no more new *shrutis* are possible. If the process continues then the same *shrutis* will keep on mapping one above other but no new *shruti* will be generated. At the same time an interesting phenomenon is happening. As it is mentioned, during the process of *swara-sthapana*, *Shadja* of both the *Veenas* was established on the fourth *shruti*. So the octaves of both the *Veenas* were four *shrutis* higher than the normal *swara* positions. But now at the end of the experiment the *Chala Veena* is four *shrutis* lower than the earlier position. So now *Shadja* of *Chala Veena* has shifted to four *shrutis* lower position i.e. the natural position of *Shadja swara.* Similarly, all the remaining *swaras* also attain their natural positions and thus now it is in its own natural octave. If you tune back the A*chala Veena* to natural *swara* positions of *Chala Veena* then the *Achala Veena* will also attain the natural *swara* positions. Since the *shruti* positions are marked on the *Achala Veena* all the *shrutis* are now at their natural positions and both the *Veenas* are now in their natural octave. Thus the beauty of the whole description unfolds if we connect the *`swara-sthapana'* process to the *`Shruti-Nidarshanam'* experiment.

एवमेतेन श्रुतिनिदर्शनेन द्वौ ग्रमिक्यौ द्वाविंशतिश्रुतयः प्रत्यवगन्तव्या। [Bharata, p. 20]

As a result of this *`Shruti Nidarshanam'* experiment twenty two *shrutis* of two *Gramas* can be experienced or demonstrated [Bharata, p. 20].

A very important insight from the experiment is that the *`Shruti-Nidarshanam'* experiment is successful if and only if the twenty two *shrutis* are having equal temperament. This is the unique condition of *`Shruti-Nidarshanam'* experiment. If they are not having equal temperament then the mapping will go haywire. Logically and mathematically this is the only possibility. If the *shrutis* are not equi-distanced then they will not map evenly or they will map on extra

positions and generate more number of *shrutis* or less number of *shrutis* depending on the ratios. *Swara* positions of *Chala Veena* will not map on the seven *swaras* of *Achala Veena* evenly if *shrutis* are not equi-distanced. That is why Bharata puts a strict condition that *Chala Veena* and *Achala Veena*, both should be exactly similar in all respects. Then only one can conduct this experiment. He does not clearly mentions that the *shrutis* should be equi-distanced because the experiment begins with seven *swaras* and not with *shrutis*. In Bharata's system *shrutis* are equal temperament *shrutis* while *swaras* do not have equal temperament. If the *swaras* are fixed on appropriate places then at the end of the experiment it will result into twenty two equal temperament *shrutis*. The *`Shruti-Nidarshanam'* experiment is such a profound paradigm that one gets awe-struck by the elegance and precision of the experiment. Only a musical genius having mathematical and logical bent of mind can design such an experiment.

5.5 *Shruti-Nidarshanam* on *Veena:* Demonstrating *Shrutis* on *Veena*

Bharata's *Shruti-Nidarshanam* experiment is a definitive way to demonstrate equal temperament twenty two *shrutis*. Sharangadeva also has another version of *Shruti- Nidarshanam* experiment which will be discussed later in this monograph. Both the experiments are discussed thoroughly in this monograph. There is one more possibility to demonstrate *shrutis* on a *Veena*. In both the *Shruti Nidarshanam* experiments we need two equally tuned *Veenas* while it is possible to demonstrate *shrutis* on single *Veena/ Sitar*. For this experiment we need to modify *Veena/ Sitar* with having twenty two frets in an octave. We may call this Veena/ Sitar with twenty two frets in every octave as *`Shruti Veena'*. *Veena* has four strings (if a *Sitar* is used then we can use additional strings to establish *Madhyama Grama/ Gandhara Grama* etc.). Tune the first string of a *Veena* in the lower *Shadja swara* (*Kharja*) while the fourth string needs to be tuned in lower *Panchama*. The middle two strings are tuned in the middle *Shadja swara*. Twenty two *shrutis* can be demonstrated on these two middle strings. First tune the *Shruti Veena* appropriately as mentioned above- first string in lower *Shadja*, fourth in lower *Panchama swara* and the middle two strings in middle *Shadja swara*. Then raise both the middle strings to *Chatu-shruti Rishabha swara*. Now consider the second string as *Achala* string and the third string as

Chala string (using the terminology of Bharata). We need to follow the description of Bharata's *Shruti Nidarshanam* experiment in a step-by-step manner on these two strings (detailed description of each step of the experiment is not mentioned here to avoid repetition since Bharata's experiment is already discussed thoroughly). The second string in this experiment acts as an *Achala Veena* and the third string acts as a *Chala Veena* of Bharata's experiment. At the end of the experiment the third string will be lowered by four *shrutis* i.e. it will be tuned to middle *Shadja swara*. Then tune in the second string into this *Shadja*. The frets will help in ascertaining the *shruti* positions on *Chala* and *Achala* strings as it happens with *Chala* and *Achala Veenas* of Bharata. This is a simpler and contemporary version of Bharata's *Shruti Nidarshanam* experiment. For such an experiment we need to make a special *Veena* having equal temperament twenty two frets in every octave. We can have fixed frets like a *Veena* or movable frets like a *Sitar*. Movable frets can really help in exploring various possibilities of un-equal *shruti* positions. Eventually the experiment will prove that Bharata's *Shruti Nidarshanam* experiment is valid only for equal temperament *shrutis* and thus substantiates the case for equal temperament twenty two *shrutis*.

It is interesting to see that Bharata himself has not devised the seven *swaras*. Bharata's seven *swaras* have origins in the Vedic accents. Initial *Udatta, Anudatta* and *Swarita* accents were accommodated by Bharata into seven *swaras* as discussed earlier. *Naradiya Shiksha* mentions seven *swaras* of Samaveda but also mentions few more *swaras*. *Naradiya Shiksha* does not mention the twenty two *shrutis*. Bharata inherited the Vedic *swara* positions and assimilated the prevalent *swara* positions during his times and came up with a paradigm of twenty two *shrutis*. How these complex processes of assimilation from Vedic *swaras, swaras* of Samaveda and *Naradiya Shiksha* eventually culminated into Bharata's equi-distanced twenty two *shrutis* is a miracle. The major challenge happens to be this mathematically precise experiment of *`Shruti Nidarshanam'* that leads to laying down foundations for the domain of Indian music. Bharata's paradigm of equal temperament twenty two *shruti* is not a hypothetical mathematical construct. On the other hand it was a profound practical paradigm till the times of Abhinavagupta and Sharangadeva i.e. till the thirteenth century A.D. at least.

6. *SHRUTI* ACCORDING TO *SANGITA RATNAKARA*

Sangita Ratnakar of Sharangadeva is considered as one of the most reliable treatise on ancient music. After *Naradiya Shiksha* and Bharata's *Natyashastra*, this is the treatise that is highly respected by all the musicologists of India irrespective of their own styles and affiliations to *Gharanas*/ school of thoughts. It is a compilation of musical knowledge of India during twelfth century. It is quite comprehensive treatise that provides thorough insights about music. The treatise *Sangita Ratnakar* is organized as follows. It has seven *Adhyayas* or chapters. Within each chapter there are *Prakaranas* or sub-chapters which are composed of *shlokas*. Most of the discussion on *shruti* is in the first chapter. Although the term *shruti* appears in the first *shloka* of the first *Prakarana* (sub-chapter) of the first *Adhyaya* (chapter) more detailed discussion about *shruti* comes in the third *Prakarana* (sub-chapter) of the first *Adhyaya* (chapter). Description of *swaras* and *shrutis* for worldly music begins from the seventh and the eighth *shlokas*. It states that sound is articulated in three ways. It starts at the core of heart and is called *`Mandra'* i.e. lower octave sound, the second level of articulation is called *`Madhya'* i.e. middle octave sound and the third is called *`Taara'* i.e. higher octave sound and each one is twice higher than the previous one. It means that musicians of those days were aware about the relative ratios of octaves. It further says that there are twenty two finely differentiable varieties of sounds called *shrutis* in an octave.

व्यवहारे त्वसौ त्रेधा हृदि मन्द्रोऽभिधीयते । कण्ठे मध्यो मूर्ध्नि तारो द्विगुणश्चोत्तरोत्तरः ॥ [*Sangita Ratnakara:*1-3-7]

In music, production sound that is used is of three types. The sound that is produced by deep breathing around the region of heart is called `*Mandra*' while sound that is produced through vocal cords is called `*Madhya*'. The third type of sound is produced in the region of nasal cavities is called

`*Tara*'. Each of this sound is double in pitch than the previous one [Sharangadeva, p. 55].

तस्य द्वाविंशतिर्भेदाः श्रवणात् श्रुतयो मताः | द्युर्ध्वनाडीसंलग्ना नाड्यो द्वाविंशतिर्मताः || [*Sangita Ratnakara:*1-3-8]

Each of such sound is divided into twenty two distinguishable microtones. These are called `*Shrutis*'. These are associated with twenty two energy channels located in the region of heart [Sharangadeva, p. 56].

In Indian tradition music is considered as a device for Yogic meditation. This *shloka* has a contextual reference to Yogic concept of *`Nadi'*. *Nadi* is an energy channel. In Yoga (especially *Hatha Yoga*) it is assumed that there exist thousands of energy channels in the body. During the Yogic meditation a Yogi activates these channels. This *shloka* describes that there exist twenty two energy channels in the region of heart that are associated with a major energy channel called *`Urdhva Nadi'*.

6.1 *Shruti* and *Swara-Sthapana* (Establishing microtones and musical notes on *Veena*)

Shloka number ten onwards of the third sub-chapter of the first chapter is a description of demonstration of establishing *swaras* and *shrutis* and then demonstrating the existence of twenty two *shrutis* in a definite way. As the description goes Sharangadeva says, first take two exactly similar *Veenas*, and tune them with precision. Each of these *Veenas* should have twenty two strings. Tune the first string in such a way that it should produce lowest possible but clearly audible and distinguishable sound. Thus the first *shruti* is established. Then tune the second string of each *Veena* in such a way that the sound of the second string is slightly higher but clearly distinguishable from the sound of the previous string. This string stands for the second *shruti*. One needs to take care that no significant distinguishable sound be heard between these two *shrutis*. Thus again Sharangadeva recommends to tune strings of *Veena* using the sensitivity of ears. It seems that during ancient times, musicians were so accustomed with tuning instruments by sensitivity of ears that it appears to be very common practice. Even today also while tuning musical instruments musicians rely more on sensitivity of ears though now-a-days they take help of Harmonium or other electronic devices. Sharangadeva further says

tune all the remaining strings of both the *Veenas* in the same way and establish twenty two *shrutis*.

द्वे वीणे सदृशौ कार्ये यथा नादः समो भवेत् | तयोर्द्वाविंशतिस्तन्त्र्यः प्रत्येकं तासु चादिमा ||
[*Sangita Ratnakara:*1-3-11]

कार्या मन्द्रतमध्वाना द्वितीयोच्चध्वनिर्मनाक् | स्यान्निरन्तरता श्रुत्योर्मध्ये ध्वन्यन्तराश्रुतेः ||
[*Sangita Ratnakara:*1-3-12]

First, take two exactly similar *Veenas*, traditional Indian string instruments, and tune them with precision. Each of these *Veenas* should have twenty two strings. Tune the first string in such a way that it should produce lowest possible but clearly audible and distinguishable sound. Thus the first *shruti* is established. Then tune the second string of each *Veena* in such a way that the sound of the second string is slightly higher but clearly distinguishable from the sound of the previous string. This string stands for the second *shruti*. One needs to take care that no significant distinguishable sound be heard between these two *shrutis* [Sharangadeva, p. 57]. In the above description, the second line of the *shloka* is very important. The word *`nirantarata'* in this context means consistency. It says there should be consistency among *shrutis*. This consistency is of the audible difference between *shrutis*. Such a consistency is possible only if the *shrutis* are equi-distanced/ equal temperament. In any other case such a consistency is not possible. Therefore it is certain that during Sharangadeva's times *shrutis* were considered to have equal temperament.

अधराधरतीव्रास्तास्तज्जो नादः श्रुतिर्मतः | वीणाद्वये स्वराः स्थाप्यास्तत्र षड्जश्चतुःश्रुतिः||
[*Sangita Ratnakara:*1-3-13]

Tune all the remaining strings of both the *Veenas* in the same way and establish twenty two *shrutis*. Sound of the strings becomes sharper and sharper as you go on tuning the strings in a sequential manner. Such sequentially arranged sounds are called *shrutis* [Sharangadeva, p. 57].

The word *`adharadhara'* is very important here. It means change of sound is gradual. It means as you go on tuning strings one after other, the sound of strings becomes gradually sharper and sharper. It clearly suggests that since the aural difference between the first string and the second string is of one *shruti*, by following same method of tuning, remaining strings should be tuned gradually by maintaining the one *shruti* difference among

rest of the strings. This description by *Sharangadeva* clearly states that the twenty two *shrutis* have to be tuned with equal temperament. Earlier it is mentioned that pitch of the second octave (*Shadja*) should be double as compared to the pitch of the first octave (*Shadja*). So once all the shrutis are tuned, it is possible to cross-check whether the tuning is appropriate or not. Thus from Bharata's times to Sharangadeva's times *shrutis* were tuned equi-distanced. Even as earlier said, Abhinavagupta also mentions that *shruti* distances are *`Niyata'* or equal.

Once these *shrutis* are established, *Shadja* and other *swaras* can be established. *Shadja* is supposed to be on the fourth string and then establish other *swaras* as mentioned in following *shlokas*.

स्थाप्यस्तन्त्र्यां तुरीयायामृषभस्त्रिश्रुतिस्ततः | पञ्चमीतस्तृतीयायां गांधारो द्विश्रुतिस्ततः॥ [*Sangita Ratnakara:*1-3-14]

अष्टमीतो द्वितीयायां मध्यमोऽथ चतुःश्रुतिः | दशमीतश्चतुर्थ्यां स्यात्पञ्चमोऽथ चतुः श्रुतिः॥ [*Sangita Ratnakara:*1-3-15]

चतुर्दशीतस्तुर्यायां धैवतस्त्रिश्रुतिस्ततः | अष्टादश्यास्तृतीयायां निषादो द्विश्रुतिस्ततः॥ [*Sangita Ratnakara:*1-3-16]

Then establish *Rishabha* on seventh string, *Gandhara* on ninth string, *Madhyama* on thirteenth string, *Panchama* on seventeenth string, *Dhaivata* on twentieth string, and finally, *Nishada* on the last string i.e. twenty second strings. For the next stage of the process of demonstrating *shrutis*, treat one of these *Veenas* as a `*Achala*' or fixed/ stable *Veena* and the other one as a `*Chala*' i.e. changeable *Veena* [Sharangadeva, p. 58].

6.2 *Shruti-Nidarshanam* According to *Sangita Ratnakara*

Sharangadeva also explains the process of demonstrating *shrutis* in a certain and definite way. The process is same though the details are slightly different than the *Shruti-Nidarshanam* process of Bharata. The process of demonstrating *shrutis* is very subtle and therefore should be performed with due care. Only a knowledgeable person who has very keen sense of tuning is capable of performing this experiment. The description goes on as follows.

एकविंश्या द्वितीयायां वीणैकाऽत्र ध्रुवा भवेत् | चलवीणा द्वितीया तु तस्यां तन्त्रीस्तु सारयेत् ॥ [*Sangita Ratnakara:*1-3-17]

स्वोपान्त्यतन्त्रीमानेयास्तस्यां सप्त स्वरा बुधैः | ध्रुववीणास्वरेभ्योऽस्यां चलायां ते स्वरस्तदा ॥ [*Sangita Ratnakara:*1-3-18]

एकश्रुत्यपकृष्टाः स्युरेवमन्याऽपि सारणा | श्रुतिद्वयलयादस्यां चलवीणागतौ गनी ॥ [*Sangita Ratnakara:*1-3-19]

ध्रुववीणोपगतयो रिधयोर्विंशतः क्रमात् | तृतीयस्यां सारणायां विंशतः सपयो रिधौ ॥ [*Sangita Ratnakara:*1-3-20]

निगमेषु चतुर्थ्यां तु विंशन्ति समपाः क्रमात् | श्रुतिद्वाविंशतावेवं सारणानां चतुष्टयात् ॥ [*Sangita Ratnakara:*1-3-21]

Once the *swaras* are established on both the *Veenas* then reduce all the seven *swaras* by one *shruti* on the *Chala Veena*. This is called first *sarana*. Again follow the same method of reducing all seven *swaras* by one *shruti*. After the second *sarana*, *Gandhara* and *Nishada* of the *chala Veena* will tune in with the *Rishabha* and *Dhaivata* of the *achala Veena* respectively because Gandhara and Nishada are reduced by two shrutis each on *Achala Veena*. Now as a part of the *sarana* process, reduce all the seven *swaras* again by one *shruti* so that *Rishabha* and *Dhaivata* of *Chala Veena* will tune in with the *Shadja* and *Panchama* of the *Achala Veena* respectively. This is called third *sarana*. In the fourth *sarana*, by reducing all the seven *swaras* once again by one *shruti*, *Shadja*, *Madhyama* and *Panchama* of *Chala Veena* will merge into *Nishada*, *Gandhara* and *Madhyama* of the *Achala Veena* respectively. Thus, the twenty two *shrutis* are demonstrated [Sharangadeva, pp. 60-61]. In this experiment, at every stage or in every *sarana*, *Chala Veena swaras* are reduced by one *shruti* each and simultaneously, *shrutis* are mapped on the *Achala Veena* for demonstration of all the twenty two *shrutis*. The number of *shrutis* thus generated and demonstrated is exactly twenty two, not less nor more.

There are some interesting observations. At the time of *swara-sthapana*, twenty two strings are tuned and seven out of them are selected as *swaras*. Sharangadeva in the process of *Shruti-Nidarshanam* asks to reduce seven *swaras* of a *Chala Veena* by one *shruti*. But he does not mention what happens to the remaining strings on which *swaras* are not established. It opens up many possibilities. So this experiment of *Shruti-Nidarshanam* is different as compared to Bharata's experiment. With a

close scrutiny of this experiment it is clear that again it's a mapping process. In Bharata's experiment new *shrutis* are generated and mapped on the *Achala Veena*. In Sharangadeva's experiment *shrutis* are not newly generated because *shrutis* are already established on twenty two strings. Seven *swaras* of *Chala Veena* are mapped on the pre-existing *shrutis* or strings of *Achala Veena*. Again it is logical to say that unless the *shrutis* on the twenty two strings of *Achala Veena* are equi-distanced, the experiment will not succeed. By reducing seven *swaras* by one-*shruti* distance every time, they will map on pre-existing strings respectively since the *shrutis* have to be equi-distanced. If the *shrutis* are un-equally established then seven *swaras* will require new places (but actually there are no extra strings available to map) on the *Achala Veena* and will generate extra *shrutis* that goes against the magic number twenty two. Therefore, as per Sharangadeva's experiment of *`Shruti-Nidarshanam' shrutis* have to be equi-distanced. Thus it is concluded that from Bharata's times to Sharangadeva's times *shrutis* were equi-distanced or equal temperament.

श्रुतिभ्यः स्युः स्वराः षड्जर्षभगांधारमध्यमाः | पञ्चमो धैवतश्चाथ निषाद इति सप्त ते ॥ [*Sangita Ratnakara:*1-3-23]

Swaras originate from these *shrutis.* There are such seven *swaras*, namely, *Shadja, Rishabha, Gandhara, Madhyama, Panchama, Dhaivata and Nishada*. [Sharangadeva, p. 65]. This *shloka* is important because in clear terms it says that *swaras* originate from *shrutis*. So as discussed earlier that whether *shrutis* originate from *swaras* or *swaras* originate from *shrutis* was a major issue of debate among modern scholars. This shloka addresses that issue in clear terms.

6.3 Integrating *Shrutis* of *Naradiya Shiksha* into Bharata's Paradigm

Once *shrutis* and *swaras* are established Sharangadeva proceeds further and describes the types of *shrutis*. He borrows the scheme of typification of *shrutis* from *Naradiya Shiksha* and applies it to twenty two *shrutis* thus established. *Naradiya Shiksha* defines types of *shrutis* on the basis of subtle sonar qualities of a *swara* and a *swara* can have five such shades or such qualities. However, Sharangadeva defines *shruti* as pitch positions by following Bharata's paradigm and thus defines types of *shrutis* also as pitch positions but it is quite likely that these pitch positions have specific

sonar qualities. The concept of *shrutis* from Bharata's times has changed. *Shrutis* were considered as pitch positions in Bharata's *Natyashastra*. Sharangadeva follows the same definition of *shrutis* as distinct pitch positions in an octave and specific pitch positions are selected as *swaras*. But it does not mean that the concept of *shruti* in *Naradiya Shiksha* was wrong. *Shrutis* are pitch positions but they do have certain sonar qualities achieved due to modulations. So Sharangadeva tries to integrate both the perspectives in his scheme. Sharangadeva assigns a particular type or sonar quality (*shruti* type as per *Naradiya Shiksha*) to an individual *shruti* or pitch position. Therefore according to him these are not subtle shades of *swara* pitch but are independent *shruti* positions which possess a particular sonar quality. So in his scheme of *swaras/ shrutis* there is a hierarchy. *Swaras* are prominent and certain number of *shrutis* belong to them since these come within their range. Each of these *shrutis* has certain dominant sonar quality assigned. This dominant quality is identified as one of the types mentioned in *Naradiya Shiksha*. One can assume that Sharangadeva must have arrived at this decision on his own or on the basis of a consensus among the practitioners. There is a striking difference between understanding of the concept of *shruti* in *Naradiya Shiksha* and *Sangita Ratnakar*. It may have strong reference to Bharata's legacy and prevalent practice of *shruti* rendering those days. The textual description reflects this. The most significant contribution of Sharangadeva in this regard is that he has provided a name-list of all twenty two *shrutis*. Bharata developed a paradigm of twenty two *shrutis* but he has not given names to *shrutis*. By the time of Sharangadeva, probably musicians have developed more insights about emotional and aesthetic properties of twenty two *shrutis*. Probably Sharangadeva's name-list of *shrutis* has attempted to capture these aesthetic properties of *shrutis*.

निर्धार्यतेऽतः श्रुतयःपूर्वा अप्यत्र हेतवः | दीप्ताऽऽयता च करुणा मृदुर्मध्येति जातयः ॥ [*Sangita Ratnakara:*1-3-27]

Swaras are defined by the specific *shruti* and its certain previous *shrutis* and therefore it is assumed that *swaras* are defined by all of them. There are five *Jatis* or types of *shrutis*. These are known as *Dipta, Aayata, Karuna, Mrudu and Madhya.* Thus according to Sharangadeva *swara* is not just a pitch position but the entire range of previous *shrutis* on which the *swara* has jurisdiction [Sharangadeva, p. 70].

श्रुतीनां पञ्च तासां च स्वरेष्वेवं व्यवस्थितिः | दीप्ताऽऽयता मृदुर्मध्या षड्जे स्याद्दृषभे पुनः ॥ [*Sangita Ratnakara:*1-3-28]

The five *shruti* types are appropriately assigned to *shrutis* that come within respective *swaras*. The four *shrutis* of *Shadja* are known as *Dipta, Aayata, Mrudu and Madhya* respectively. *Shrutis* of *Rishabha* are mentioned next. [Sharangadeva, p. 70].

संस्थिता करुणा मध्या मृदुर्गांधारके पुनः | दीप्ताऽऽयते मध्यमे ते मृदुर्मध्ये च संस्थिते ॥ [*Sangita Ratnakara:*1-3-29]

Rishabha has *Karuna, Madhya and Mrudu shrutis* while *Gandhara* has *Dipta* and *Aayata shrutis*. Again *Madhyama* has *Dipta* and *Aayata Shruti* as well as *Mrudu* and *Madhya shrutis* also reside there. [Sharangadeva, p. 70].

मृदुर्मध्याऽऽयताऽऽख्या च करुणा पञ्चमे स्थिता | करुणा च आयता मध्या धैवते सप्तमे पुनः॥ [*Sangita Ratnakara:*1-3-30]

Mrudu, Madhya, Aayata and *Karuna* respectively are known as the *shrutis* of *Panchama*. Similarly *Karuna, Aayata* and *Madhya* are the *shrutis* of *Dhaivata*. The seventh *swara – Nishada' shrutis* are mentioned next. [Sharangadeva, p. 70].

दीप्ता मध्येति तासां च जातीनां ब्रूमहे भिदाः | तीव्रा रौद्री वज्रिकोग्रेत्युक्ता दीप्ता चतुर्विधा ॥ [*Sangita Ratnakara:*1-3-31]

Nishada has, thus, *Dipta* and *Madhya shrutis*. The *Shrutis* are distributed according to *shruti jatis* as mentioned next. *Teevra, Rudra, Vajrika and Ugra* fall under *Dipta jati* [Sharangadeva, p. 70].

कुमुद्वत्यायता याऽस्याः क्रोधा चाथ प्रसारिणी | संदीपनी रोहिणी च भेदाः पञ्चेति कीर्तिताः ॥ [*Sangita Ratnakara:*1-3-32]

Kumudvati, Krodha, Prasarini, Sandipani and *Rohini* are part of the *Aayata jati*. [Sharangadeva, p. 70].

दयावती तथाऽऽलापिन्यथ प्रोक्ता मदन्तिका | त्रयस्ते करुणाभेदा मृदोर्भेदचतुष्टयम् ॥ [*Sangita Ratnakara:*1-3-33]

Dayavati, Aalapini and *Madantika* are the three *shrutis* which are considered as part of *Karuna jati*. *Mrudu jati* has four *shrutis* as mentioned next. [Sharangadeva, p. 71].

मन्दा च रतिका प्रीतिःक्षितिर्मध्या तु षड्विधा | छन्दोवती रञ्जनी च मार्जनी रक्तिका तथा ॥ [*Sangita Ratnakara:*1-3-34]

Thus *Manda, Raktika, Preeti* and *Kshiti* fall under *Mrudu jati*. The *Madhya jati* has six *shrutis* under it. *Chhandovati, Ranjani, Marjani* and *Raktika* fall under *Madhya* as well as two more as mentioned next. [Sharangadeva, p. 71].

रम्या च क्षोभिणीत्यासामथ ब्रूमः स्वरस्थितिम् | तीव्राकुमुद्वतीमन्दाच्छन्दोवत्यस्तु षड्जगाः ॥ [*Sangita Ratnakara:*1-3-35]

Ramya and *Kshobhini* fall under *Madhya jati*. Now begins the description of positions of *shrutis* in relation to each *swaras*. *Teevra, Kumudvati, Manda* and *Chhandovati* fall under *Shadja swara*. [Sharangadeva, p. 71].

दयावती रञ्जनी च रक्तिका चर्षभे स्थिताः | रौद्री क्रोधा च गांधारे वज्रिकाऽथ प्रसारिणी ॥ [*Sangita Ratnakara:*1-3-36]

Dayavati, Ranjani and *Raktika* stay with *Rishabha swara*. *Raudri* and *Krodha shrutis* belong to *Gandhara swara*. *Vajrika* and *Prasarini* belong to *Madhyama* and there are two more. [Sharangadeva, p. 71].

प्रीतिश्च मार्जनीत्येताः श्रुतयो मध्यमाश्रिताः | क्षिती रक्ता च संदीपन्यालापिन्यपि पञ्चमे ॥ [*Sangita Ratnakara:*1-3-37]

Preeti and *Marjani* are the two remaining *shrutis* of *Madhyama*. *Kshiti, Rakta, Sandipani* and *Aalapini* reside with *Panchama swara*. [Sharangadeva, p. 71].

मदन्ती रोहिणी रम्येत्येतास्तिस्रस्तु धैवते | उग्रा च क्षोभिणीति द्वे निषादे वसतः श्रुती ॥ [*Sangita Ratnakara:*1-3-38]

Madanti, Rohini and *Ramya* are the three *shrutis* of *Dhaivata*. *Ugra* and *Kshobhini* reside with *Nishada swara.* [Sharangadeva, p. 71].

Thus the allocation of *shrutis* with *swaras* is complete. Sharangadeva meticulously adheres to the *swara* and *shruti* division described by Bharata. He is perfectly within Bharata's paradigm. In the above

description he attempts to smoothly integrate concept of *shruti* from *Naradiya Shiksha* in the Bharata's paradigm. Following is the table that gives an overview of the above-mentioned description of *shrutis* by Sharangadeva. The table gives the description of *shrutis*- their names, *jatis*, old *swara* names and also the modern *swara* names. According to Bharata's paradigm of *shrutis*, the *Shadja swara* is located on the fourth *shruti*. Therefore, all the following tables begin with the fourth *shruti*.

S.N.	***Shruti* Names**	***Shruti-Jati***	**Old *Swara* Names**	**Present *Swara* Names**
4.	*Chhandovati*	*Madhya*	*Shadja*	*Shadja*
5.	*Dayavati*	*Karuna*		
6.	*Ranjani*	*Madhya*		*Komal Rishabha*
7.	*Raktika*	*Mrudu*	*Bharata's Rishabha*	
8.	*Roudri*	*Dipta*	*Chatuh shruti Rishabha*	*Shuddha Rishabha*
9.	*Krodha*	*Aayata*	*Bharata's Gandhara*	
10.	*Vajrika*	*Dipta*	*Sadharana Gandhara*	*Komal Gandhara*
11.	*Prasarini*	*Aayata*	*Antar Gandhara*	*Gandhara*
12.	*Priti*	*Mrudu*		
13.	*Marjani*	*Madhya*	*Madhyama*	*Madhyama*
14.	*Kshiti*	*Mrudu*		
15.	*Rakta*	*Madhya*	*Prati Madhyama*	*Teevra Madhyama*
16.	*Sandipani*	*Aayata*	*Chyuta Panchama*	
17.	*Aalapini*	*Karuna*	*Panchama*	*Panchama*
18.	*Madanti*	*Karuna*		
19.	*Rohini*	*Aayata*		*Komal Dhaivata*
20.	*Ramya*	*Madhya*	*Bharata's Dhaivata*	
21.	*Ugra*	*Dipta*		*Dhaivata*
22.	*Kshobhini*	*Madhya*	*Bharata' Nishada*	

1.	*Teevra*	*Dipta*	*Kaishiki Nishada*	*Komal Nishada*
2.	*Kumudvati*	*Aayata*	*Kakali Nishada*	*Nishada*
3.	*Manda*	*Mrudu*	*Chyuta Shadja*	
4.	*Chhandovati*	*Madhya*	*Tara Shadja*	*Tara Shadja*

Table No. 1

Shruti jatis are mentioned in *Naradiya Shiksha* but they are not mentioned in Bharata's *Natyashastra*. Also there is no mention of twenty two *shrutis* in *Naradiya Shiksha*. Even the names of *shrutis* are not mentioned by Bharata. The names of *shrutis* first appear in *Sangita Ratnakar* of Sharangadeva but its true source is not known. A closer analysis of the allocation of *shrutis* to *swaras* as well as *jatis* will lead to the feeling that Sharangadeva has attempted to integrate Bharata's theory of *shrutis* as well as earlier views on *shrutis* described in *Naradiya Shiksha*. Probably this integration might have reference to actually prevalent musical practices of that era.

It is possible to decipher the logic behind this integration with the help of above table. Except *Rishabha, Gandhara and Panchama, Madhya shruti jati* is assigned to all the remaining swaras as their normal *shruti* position by Sharangadeva. *Mrudu shruti* is always lower than the *Madhya jati* except Bharata's *Rishabha*. Similarly position of *Aayata* is higher than the *Madhya* or *Dipta* (*Dipta* replaces *Madhya* in some cases) *shruti jati* which is again properly assigned except *Panchama*. *Panchama* has a *Karuna shruti* which is a special case. *Naradiya Shiksha* does not mention the exact position of *Dipta* and *Karuna shruti* and therefore, Sharangadeva keeps them floating or by replacing *Madhya* or *Mrudu shruti jati*. In the case of *Panchama swara, Karuna* has replaced *Madhya jati* completely. In most of the cases *Dipta* and *Karuna* are kept lower than the *Aayata shruti jati*. All this is understandable and seems logical.

The integration is quite successful but there are few weak points where it does not match with the textual references from *Naradiya Shiksha* on one hand and raises questions about practical application of rendering *shrutis* according to this scheme. The first major discord occurs as it is mentioned in *Naradiya Shiksha* that *Dwitiya swara* i.e. Gandhara has *Dipta shruti* and three other *shrutis* as *Mrudu, Madhya* and *Aayata*. But in Bharata's scheme of *shrutis*, Bharata's *Gandhara* has been assigned only two *shrutis*. So how four *shruti jatis* be assigned to Gandhara? So Sharangadeva assigned two *shruti jatis* to the two *shrutis* of Gandhara- *Dipta* and *Aayata* respectively.

Then he again assigned same *shruti jatis- Dipta* and *Aayata shruti jatis* to *Sadharana Gandhara* and *Antara Gandhara* respectively. But in the process *Mrudu* and *Madhya shruti jatis* have not been assigned to any of the *Gandhara*. Therefore there is a mis-match between textual description of *Naradiya Shiksha* and Sharangadeva's scheme of assigning *shruti jatis* to *Gandhara swara*. Another important issue is that, can these *shruti jatis* be assigned to individual *shruti*-places described in *Natyashastra*? From the description of *Naradiya Shiksha shruti jatis* are the finer qualities or microtonal variations of a *swara*. It cannot be extended up to two-*shruti* distance or three/four-*shruti* distances. This will pose a problem in actual rendering of *swaras*. It is said in *Naradiya Shiksha* that *Dwitiya swara* i.e. *Gandhara* has *Dipta shruti*. In this scheme to have *Dipta shruti* for *Gandhara* one has to shift to either *Chatuh-shruti Rishabha* or *Sadharana Gandhara* which themselves are quite prominent notes. It means that if one is rendering a *Dipta shruti jati* for *Gandhara* then actually one is not rendering Bharata's *Gandhara* but either *Chatuh-shruti Rishabha*(*Naradiya Shiksha* treats it as a *`Swaara'* or a wrong note) or *Sadharana Gandhara*. Same happens with Bharata's *Nishada swara*. This can create practical problem of rendering *shruti jatis* for *swaras* if Sharangadeva's scheme is followed. However, in spite of certain weaknesses in Sharangadeva's scheme one can say that this scheme provides some vital insights about *shruti jatis*. Following inferences can be drawn from the above-mentioned scheme.

- Firstly, *Mrudu jati* is lower than the *Madhya jati*.
- Secondly, *Aayata jati* is higher than the *Madhya jati*. This is evident from the above description.
- *Dipta* and *Karuna jatis* are floating pitch positions and can replace *Madhya jati*.
- *Karuna* can also be higher than *Madhya* and lower than the *Aayata jati*.
- *Dipta* can be lower or higher than *Madhya jati*.
- As mentioned by Bhatta Shobhakara, in the case of *Chaturtha swara* or *Shadja, Dipta shruti jati* can be softer or *Mrudu* (*Mrudu bhootah*). Thus *Dipta* can replace *Mrudu jati* or can be closer to it (*Mrudu-Madhya*).
- With these inferences it becomes easier to clarify the concept of *shruti jatis* mentioned in *Naradiya Shiksha*.

Thus Sharangadeva's scheme of integration of the concepts of *shruti* from *Naradiya Shiksha* is partially successful and provides some vital insights about the understanding about *shrutis* during his times. His major contribution lies in providing a name-list of twenty two *shrutis*. His *Shruti-Nidarshanam* experiment is different from Bharata's experiment but arrives at the same conclusion. In this sense one must appreciate his innovation of Bharata's experiment. Most importantly he comes up with clarity about establishing *shrutis* on two *Veenas* having twenty two strings each and then establishing *swaras* on them. His procedure of establishing *shrutis* and *swaras* clearly indicates that twenty two *shrutis* were with equal temperament.

7. COMPUTING AND RECONSTRUCTING *SHRUTIS*

Throughout the discussion so far it is established that from the ancient times to Sharangadeva's times i.e. till 13th century, *shrutis* were considered as equal temperament. During medieval period questions were raised about the exact nature of *shrutis* by musicologists. In the modern times musicologists have almost refuted the paradigm of equal temperament twenty two *shrutis* and started coming up with diverse theories and models. The present monograph, taking into account the perspectives of *Naradiya Shiksha*, *Natyashastra* and *Sangita Ratnakar*, now attempts to critically analyze the phenomenon of *shrutis* or microtones in Indian music from modern perspectives. Eventually this monograph proposes a broader frame-work for understanding the phenomenon of *shrutis* in Indian music.

7.1 Music as a Psycho-acoustic phenomenon

Music making and music perception are phenomena that are neither purely scientific nor mathematical nor purely psychological. *Shruti-perception* is a psycho-acoustic phenomenon. The scholars, in recent times, focused only on the physics of music and applied mathematical formulations to understand *shrutis*. Even the `just intonation' scale is also a purely mathematical construct, however, elegant and logical it is, in musical practice, the most popular scale in contemporary music happens to be the equal temperament scale for various pragmatic reasons. It shows that, in the musical research in general and *shruti*-research in particular, there is an undue emphasis on mathematical formulations and mathematical precision.

It is a common experience when a musician plays a musical note; it is never a pure frequency. Musical note is a collection of multiple frequencies with varying amplitude/ volume. Every time a musician plays

the same note, there will be a minute variation in its physical parameters. In spite of variations in the physical parameters every time, musicians as well as the audience consider it as the same musical note or a *swara*. Therefore, at some level of musical perception, an abstraction and approximation takes place and musical perception is complete. Music perception is not mathematically precise and perfect as it is assumed. It is claimed that musicians are trained enough to sense the difference between frequencies up to multiple decimal points and it may be true. Even with digital technology it is possible to produce music with the precision up to multiple decimal points and technically it is possible to distinguish also. But when two musical notes are played in a harmony or consecutively in a melodious tune, this level of precision is unwarranted. Because music making is not about precision, it is about creating musical experience where perceptive processes are important. Thus the contemporary equal temperament scale of twelve notes is good enough to create the desired musical experience to which musicians as well as the audience adapt. The equal temperament scale provides the necessary frame-work or a template to generate desired musical experience. Even in this case also, a musician should not be precise or perfectly tuned with equal temperament. It may be argued that such an absence of precision generates a microtonal dissonance that adds to the aural aesthetics of music but this issue is beyond the scope of this monograph.

Musical experience is a holistic phenomenon, when for instance, *Tanapura* (a drone instrument) strings are plucked, multiple frequencies and upper partials or overtones are generated following the laws of physics. The strongest frequencies up to tenth to fifteenth harmonics dominate our musical experience. The rest do exist but have lesser impact. However, apart from these physically produced overtones and harmonics, human ears perceive many more tones which are actually not there. Perception of *`swayambhu Gandhara'* and many other such so called *`swayambhu' swaras* belong to this category. This is due to the phenomenon called `missing fundamentals'. Human ears due to their structure and perception mechanism are capable of inferring and generating the lower partials of the heard frequencies. This is due to the auditory or aural inference mechanism. It's a pure psycho-acoustic phenomenon. Thus, musical perception is a highly complex phenomenon composed of physical sounds those are there, psycho-acoustically inferred sounds which are not there but inferred by ears, and previous musical experiences, musical knowledge as well as the cultural context of the listener.

Experiential complexities of musical perception defy physics and mathematics in many ways. The phenomenon of musical consonance is well-known. Accordingly, the musical note of *`Sa'* or *`Shadja'* is considered consonant with the higher *`Sa'*. Also a musical note called *`Pa'* is also considered consonant with the *`Sa'*. In Indian music it is known as *`Shadja-Shadja Bhava'* and the *`Shadja-Panchama Bhava'* respectively. The *Shadja-Shadja* consonance means if two musical notes have frequencies having ratio of 2/1 then they are considered consonant with each other. Similarly, if two musical notes have frequency ratio of 3/2 then there exists *`Shadaj-Pancham Bhava'* between them and they are also considered consonant with each other. Musicians found that if two musical notes have simple frequency ratios such as 2/1, 3/2, 4/3, 5/4, 6/5 and so on then such notes are consonant with each other though, the degree of consonance will reduce sequentially. The well-known scale called the `just intonation' scale of music is based on this logic. Musicologists in the West and India started extending this logic for further mathematical formulations in music. That led to the tendency of seeking mathematical precision in music. Over the period, musicians have started to realize that all the musical consonances are not mathematically so precise. They do not follow these mathematical ratios so meticulously. For example, if the frequency of *`Sa'* is 240 hertz, then the frequency of the higher *`Sa'* should be 480 hertz as per the mathematical ratio. However, with the use of computational technology now it can be experimentally proved that the actual consonant frequency of the higher *`Sa'* happens to be 481.208 hertz. Same is the case with *`Shadja-Panchama Bhava'*. If *`Sa*' has a frequency of 240 hertz then *`Pa*' should have the frequency of 360 hertz but in reality the consonant *`Pa*' has a frequency of 361.6157 hertz [Thakar, S., p. 27]. This experiment was conducted by a vocalist, Dr. Sulabha Thakar who belongs to *Kirana Gharana* that is known for rendering musical notes with high precision. She has also used computers to generate precise values of *swaras* in her experiment. This suggests that when it comes to the musical consonance, the mathematical ratios are not applicable with such a precision. There exists a minute displacement or shift in consonant frequency. It is also noticed that while relating one note to its higher consonant note this displacement is towards higher side i.e. the consonant note is displaced further. So 240 hertz, frequency note seeks consonance with 481.208 hertz (displacement of 1.208 hertz towards higher side). It is to be noted here, that as per Bharata's equal temperament scale *Panchama's shruti* is slightly towards higher side than the logico-mathematical exact value of *Panchama*. This point will be

discussed in more details at appropriate place. So with the help of high-precision computational technology, it can be argued that the logico-mathematical ratios of consonance are not applicable with assumed precision. The musical consonance is governed by psycho-acoustic principles and aural inference and does not follow mathematical precision.

When a musical note seeks consonance towards lower side the resultant note happens to be more soft, delicate, broader, deep, emotional and pleasant. This quality of sound is called *`Mardavatva'*. When it seeks consonance toward higher side the resultant note is more voluminous, pointed, sharp, and bold. This is known as *`Aayatatva'*. Thus the musical consonance cannot be understood in terms of frequency ratios alone. Experimentally it can be seen that mathematical frequency values of musical notes are displaced and impacted by other sonar properties such as volume, timbre, attack, decay, resonance etc. So the resultant frequency is altered minutely due to above-mentioned factors. This brings in the point that the mathematical formulations are not completely wrong. Logical and mathematical formulations provide the essential basic structure to the aural/ musical calculus. The undue mathematical precision is unrealistic and unwarranted. Taking logico-musical formulations as the base helps in providing theoretical foundations. The resultant values of musical frequencies then need to recalculate by considering the above-mentioned factors. The modified values of musical notes then will fulfill the psycho-acoustic expectations of consonance and attain the status of musical consonance.

With the above considerations, it is a good idea to compare and evaluate select contemporary models of *shrutis* as well as Bharata's twenty two *shruti* equal temperament scales. In this context two celebrated texts, as already thoroughly discussed, Bharata's *Natyashastra* and *Sangita Ratnakar* of Sharangadeva are referred. Both these treatises clearly describe that the traditional ancient musical scale was an equal temperament scale consisting of twenty two *shrutis*. Especially the *`Shruti-Nidarshanam'* experiment is a conclusive proof of Bharata's equal temperament scale as discussed in details earlier. However, some of the recent studies argue that Bharata's scale is not relevant today as discussed in the following paragraphs [Komaragiri, pp. 140]. They tried to show that the distribution of Bharata's twenty two *shrutis* among seven *swaras* of contemporary scales (contemporary *swara* positions are different) is not practical and leads to varied results in terms of number of *shrutis*. If the

typical just intonation scale is used and the *`Shruti-Nidarshanam'* experiment is performed then the number of *shrutis* generated would be twenty four and if the swara positions are altered then the number could vary drastically. As Mr. Madhu Mohan Komaragiri puts it-

"…This shows that the 2-vīṇā experiment with changing intervals does not always yield 22 śruti-s. For unequal intervals, as the interval size varies, the 2-vīṇā experiment yields different number of śruti-s for different intervallic configurations (swara arrangements)…" [Komaragiri, pp. 140].

According to this research the *`Shruti-Nidarshanam'* experiment is not relevant for contemporary music as changing intervals does not always yield twenty two *shrutis*. This is true mainly because today's *swara* positions are different from those of Bharata and there is no clarity about various theories of *shruti*. It also shows that in recent times some researchers such as Mr. Komaragiri [Komaragiri, pp. 140, 2010], are becoming aware that distribution of unequal *shrutis* among seven *swaras* of contemporary musical scale is not viable but somehow they missed the unique possibility of equal temperament distribution of *shrutis* among seven *swaras*. As a result they started arguing that Bharata's paradigm of twenty two *shruti* is not applicable to contemporary music. There exists a debate about the contemporary scales as discussed somewhere else in this monograph, still apart from that many researchers have come up with varied proposals/ models to show that their theories represent Bharata's paradigm correctly. So it was thought that the comparative analysis of some of these theories in the context of *`Shruti-Nidarshanam'* experiment will be good idea. For comparative analysis models developed by Mr. Acharekar, Acharya Brihaspati, and Dr. Vidyadhar Oak are referred. Similarly Pythagorean scale of twenty two microtones is also referred as a hypothetical model since there is no un-disputed reference available. All these models are compared with Bharata's equal temperament scale. Advanced technology is very useful for simulating these theoretical models on computers. Therefore *shrutis* are generated on computers using the above-mentioned models. It is also possible to simulate *`Shruti-Nidarshanam'* experiment on the computers. Since Bharata uses this experiment to demonstrate *shrutis* on two *Veenas* in a certain and definite way therefore the *Shruti-Nidarshanam* experiment is simulated on computers and then tested all the above-mentioned models and compared the results.

7.2 Simulating *Shrutis*

Both the experiments, by Bharata and Sharangadeva, of demonstrating twenty two *shrutis* are highly elegant and precise as discussed earlier. This leads to the stronger argument in favor of the equal temperament twenty two *shrutis*. With the use of computational technology now it is possible to simulate *`Shruti-Nidarshanam'* experiment on the computer and it can be demonstrated that there exists only one case of *shruti* distribution among seven *swaras* and that is equi-distanced distribution. Any other ratios or combination of distribution will lead to extra *shrutis* or less *shrutis*. The four-step *`Shruti-Nidarshanam'* experiment follows a mapping process and at every step, all seven *swaras* of *Chala Veena* are displaced by one *shruti*. Unless, *shrutis* are equi-distanced, they will not map exactly on the seven *shrutis* of *Achala Veena*. If they are non-equal distanced then they will map un-evenly on the *Achala Veena* and generate extra places or extra *shrutis*. Thus the *`shruti-Nidarshanam'* experiment happens to be highly accurate and very intelligently designed experiment. As per the computational simulation of this experiment following are the results that show clearly that ancient *shrutis* were equi-distanced and therefore, Bharata's scale was that of equal temperament twenty two *shruti* scale. Author of the present monograph is working on computational Indian music for quite some time and has developed these simulations for testing various models of *shrutis*.

Simulation 1

Saranas are as follows as per the description from Bharata's *Natyashastra* and *Sangita Ratnakar* of Sharangadeva (equal temperament *Shrutis*)

Sarana	***Sa***	***Re***	***Ga***	***Ma***	***Pa***	***Dha***	***Ni***
Dhruva Veena	240	263.79	280.94	318.68	361.48	397.32	423.16
Chala Veena	240	263.79	280.94	318.68	361.48	397.32	423.16
1st	232.55	255.60	272.23	308.79	350.27	384.99	410.03
2nd	225.34	247.68	263.79	299.22	339.41	373.05	397.32
3rd	218.35	240	255.60	289.94	328.88	361.48	384.99
4th	211.58	232.55	247.68	280.94	318.68	350.27	373.05

Table No. 2

Number of *shrutis* generated is: 22
Number of *shrutis* generated does not match with Bharata's 22 *shrutis*

Simulation 2

Saranas are as follows as per the Pythagorean model (hypothetical)

Sarana	***Sa***	***Re***	***Ga***	***Ma***	***Pa***	***Dha***	***Ni***
Dhruva Veena	240	266.36	284.44	320	360	399.54	426.66
Chala Veena	240	266.36	284.44	320	360	399.54	426.66
1st	227.81	252.83	270	303.75	341.71	379.25	405
2nd	225	240	256.28	288.32	324.36	360	384.43
3rd	216.00	230.40	246.03	276.79	311.39	345.60	369.05
4th	213.33	227.55	243.00	273.37	307.54	351.33	364.50

Table No. 3

Number of *shrutis* generated is: 31
Number of *shrutis* generated does not match with Bharata's 22 *shrutis*

Simulation 3

Saranas are as follows as per the model developed by Mr. Acharekar

Sarana	***Sa***	***Re***	***Ga***	***Ma***	***Pa***	***Dha***	***Ni***
Dhruva Veena	270	300	320	360	405	450	480
Chala Veena	270	300	320	360	405	450	480
1st	266.66	296.29	316.04	355.55	400	444.44	474.07
2nd	253.16	281.29	300.04	337.55	379.74	421.94	450.07
3rd	243.00	270.00	288.00	324.00	364.91	405.01	432.01
4th	240.00	266.67	284.45	320.00	360.01	400.01	426.67

Table No. 4

Number of shrutis generated is: 26
Number of *shrutis* generated does not match with Bharata's 22 *shrutis*

Simulation 4

Saranas are as follows as per the theory developed by *Acharya* Brihaspati

Sarana	***Re***	***Ga***	***Ma***	***Pa***	***Dha***	***Ni***	***Sa***
Dhruva Veena	266.66	284.44	320	360	400	426.66	480
Chala Veena	266.66	284.44	320	360	400	426.66	480
1st	263.37	280.93	316.04	355.55	395.06	421.39	474.07
2nd	250.00	266.66	300.00	337.50	375.00	400.00	450.00
3rd	240	256	288	324.00	360	384.00	432.00
4th	237.03	252.83	284.44	320.00	355.55	379.25	426.66

Table No. 5

Number of shrutis generated is: 26
Number of *shrutis* generated does not match with Bharata's 22 *shrutis*

Simulation 5

Saranas for *shruti* theory developed by Dr. Vidyadhar Oak

Sarana	***Re***	***Ga***	***Ma***	***Pa***	***Dha***	***Ni***	***Sa***
Dhruva Veena	269.99	299.99	319.99	359.99	404.99	449.99	480/240
Chala Veena	269.99	299.99	319.99	359.99	404.99	449.99	480/240
1st	266.66	296.29	316.04	355.55	399.99	444.44	237.03
2nd	256	284.44	303.40	341.33	384.00	426.66	227.55
3rd	252.83	280.93	299.66	337.11	379.25	421.39	224.74
4th	240.00	266.66	284.44	320.00	360.00	400.00	213.33

Table No. 6

Number of shrutis generated is: 28
Number of *shrutis* generated does not match with Bharata's 22 *shrutis*

It is very clear from the above tables that number of *shrutis* mapped by Pythagorean model is 31, Mr. Acharekar's model and Acharya Brihaspati's models map 26 *shrutis* each while Dr. Vidyadhar Oak's model generates and maps 28 *shrutis* when *`Shruti-Nidarshanam'* experiment is simulated on the computer using these models. Only Bharata's model maps and

generates exact 22 *shrutis* in the simulation. Above-mentioned tables are representative tables that show that if the *`Shruti-Nidarshanam'* experiment generates extra *shrutis,* if *shrutis* are considered unequal. There exists only one possibility of equal temperament *shrutis* where the *`Shruti-Nidarshanam'* experiment generates twenty two *shrutis* exactly. It's a confirmatory proof of the equal temperament *shrutis* of Bharata. The *Shruti-Nidarshanam* experiment generates twenty two *shrutis* if and only if the *shrutis* are aurally equi-distanced. For any other ratios or any other non-equal distances number of *shrutis* will be either more than twenty two or less than twenty two *shrutis*. Therefore, there exists consistency, soundness in the results of *Shruti-Nidarshanam* experiment, cyclical generation of *shrutis* and equal temperament twenty two *shrutis*.

Contemporary Indian musicologists hesitate to accept the paradigm of equal temperament *shrutis* because it does not match with the so-called just intonation scale as well as mathematically calculated consonances as earlier discussed. However, if we compare the contemporary twelve note equal temperament scale with the just intonations scale, then we realize they also do not match. There exists a significant mis-match which musicians `feel' or experience but it is considered as within the acceptable limits. If the same logic is followed then the following comparison can prove that the mis-match between Bharata's twenty two *shruti* equal temperament scale and just intonation scale is also within the acceptable limits.

7.3 Comparative Facts: Bharata's *Shrutis* and Contemporary Practices

All the following values of various *swaras* and ratios are calculated considering the base frequency of *Shadja swara* as 240 Hertz.

- The correct value of Bharata's *Pramana Shruti* is

  1.032008279734209631593240741954 3, derived from the equal temperament 22 *shruti* scale. This value represents the correct interpretation of *Natyashastra* and *Sangita Ratnakar* and is valid in all respects.

- *Pramana Shruti* ratio: 22nd root of 2 =

1.032008279734209631593240741954 3 - (1.032), this is the correct value of the *Pramana Shruti* of Bharata.

- Logico-mathematical consonances and actual consonances generated by 22 *shruti* equal temperament scale by Bharata do not match. Logico-mathematical *Shadja-Panchama Bhava* is supposed to have the ratio of 3/2 i.e. 1.5, however, in Bharata's theory the ratio (value) of *Shadja-Panchama Bhava* happens to be 1.506195553333333... (1.5062).
- Logico-mathematical *Shadja-Madhyama Bhava* ratio is supposed to be 4/3 i.e. 1.333 however, in Bharata's scales value of *Shadja-Madhyama Bhava* happens to be 1.3278488279166... (1.3279). so that means there is a very minute difference between logical consonance and Bharata's consonance.
- *Shadaj-Pancham-Bhava*: 1.506195553333333... (1.5062).
- *Shadja-Madhyama-Bhava*: 1.3278488279166... (1.3279).
- Bharata's consonance tolerance ratio for *Shadaj-Pancham Bhava* is: 1.506195553333333/ 1.5 = 1.0041304.
- For contemporary twelve note equal temperament scale consonance tolerance ratio for *Shadaj-Pancham Bhava* is: 1.5/1.498307076876 = 1.00112989.
- Bharata's consonance tolerance ratio for *Shadja-Madhyama Bhava* is: 1.3333333/ 1.3278488279166 = 1.0041304.
- For contemporary twelve note equal temperament scale consonance tolerance ratio for *Shadja-Madhyama Bhava* is: 1.33483985417/1.3333333= 1.00112989
- This shows that there is not much difference between the consonance tolerance ratio between the Bharata's twenty-two *shruti* equal temperament scale and the contemporary twelve note equal temperament scale as compared to the logico-mathematical consonance ratios. The tolerance difference is just 0.003 between these two scales which actually does not matter much for musical experience. The way twelve note equal temperament scale is acceptable to common audience, the same way Bharata's scale was also acceptable to audience during ancient times. Even today experts do not agree with Equal Temperament scale.
- Bharata's *shrutis* are deviated from the logico-mathematical *shrutis*. Therefore, the difference ratio between mathematical value and Bharata's value can be considered as `Bharata's

Consonance Tolerance Ratio' (BCTR). Bharata's Consonance Tolerance Ratio (BCTR): 1.0041304.

- The maximum difference is between *Chatushruti Rishabha* i.e. mathematical value is 270 and Bharata's value is 272.2350053. Therefore, Bharata's Maximum Consonance Tolerance Ratio (BMCTR):

  272.2350053/270=1.00827779740. Approximately BCTR is 1.00828.

- Similarly, the maximum difference with just intonation scale is between *Gandhara-Ga* i.e. mathematical value is 300 hertz and Equal temperament scale value is 302.3810519748. Therefore, Equal temperament Scale's Maximum Consonance Tolerance Ratio (ETMCTR):

  302.3810519748/300=1.007936839916. Approximately BCTR is 1.008.

For Bharata's scale the maximum tolerance ratio is for *Chatushruti Rishabha* which is approx. 1.00828 while for Equal temperament twelve tone scale that is in use presently has a maximum tolerance ratio for the *Gandhara swara* as compared with mathematical value which comes about 1.008 as mentioned above. Thus the contemporary audience is comfortable with 1.008 tolerance value of the contemporary equal temperament scale and therefore there should not be any problem for accepting Bharata's *Chatushruti Rishabha* since it has also the same value. Even contemporary musicians are aware that *Gandhara swara* of twelve note equi-tempered scale does not match with the *Gandhara* of just intonation scale and they make adjustment through various musical means such as modulation if required. Many vocalists prefer customized harmoniums for accompaniment. *Gandhara* is an important *swara*. In the case of Bharata's twenty two *shruti* equal temperament scale *Antara Gandhara* matches with the *Gandhara* of just intonation scale. However, *Chatuh-shruti Rishabha* does not match with *Rishabha* of just intonation scale (That's why probably *Chatuh-shruti Rishabha* was not a very important *swara* in Bharata's system. Relatively *Rishabha* is less important *swara* as compared to *Gandhara*). So Bharata's scale does justice to *Gandhara* scarifying on *Rishabha*. This is the case of acceptance

of maximum difference in the consonance ratios. Other *swaras* and *shrutis* of Bharata's scale do not match exactly with just intonation *swaras* but there are minor differences and therefore not necessary to discuss in details here since the detailed discussion on these cases will also yield the similar conclusions.

Bharata's twenty two *shruti* equal temperament scale has many virtues. The worth discussing among them is that the Bharata's scale happens to be the best way to eliminate Pythagorean comma. Pythagorean comma is a major issue of debate in the Western music. Comma means an error. When one tries to generate *swaras* by applying *Shadja-Madhyama Bhava* and *Shadja-Panchama Bhava* in a cyclical manner to *Shadja swara* it generates infinite series of frequency values. The cyclical process never completes. In other words the Pythagorean comma results from the `circle of fifths'. For instance when the *Shadja swara* frequency value is multiplied by the ratio 3/2 (rule of fifth) repeatedly, the resulting *swaras* would be as follows. *Sa - Pa - Re - Dha - Ga - Ni - Teevra Ma* and will never result in an in-tune octave (2/1). Similarly if *swara Sa* is multiplied by 4/3 (inverse rule of fifth) then *Sa-Pa - Re - Dha - Ga – Ni - Teevra Ma* (all lower *swaras*) and they will never reach the lower octave in-tune (1/ 0.5). This is the simple example of the Pythagorean tuning problem. Ideally, in both the above-mentioned cyclical calculations the resultant cyclical swara and the in-tune octave should meet but it never happens. There is a `difference' between the resultant *swara* at the end of the cycle, and the desired `in-tune' octave value of *swara Sa.* This is called Pythagorean comma. This is considered as an error in tuning. The rule of fifth is considered as universal rule of consonance and represented by the ratio of 3/2. This precise mathematical ratio is the root cause of Pythagorean comma. In Bharata's scheme rule of fifth or the *Shadja-Panchama Bhava* is not defined by mathematical ratio. It is defined by sensitivity of ears and therefore it is purely aural ratio. In Bharata's scale, aurally defined rule of fifth (*Shadja-Panchama Bhava*) has different mathematical value as discussed as follows.

Bharata's scale results into following ratios of *Shadaj-Pancham Bhava* and *Shadja-Madhyama Bhava* as:

Shadaj-Pancham-Bhava: 1.506195553333333... (1.5062) as against the universally accepted value of rule of fifth that is 1.5 or the ratio of 3/2. The difference is just 0.0062 but it has an impact in eliminating Pythagorean comma.

Shadja-Madhyama Bhava: 1.3278488279166... (1.3279) as against the universally accepted value of inverse rule of fifth that is 1.3333... Or the ratio of 4/3.The difference is just 0.0054 but it has an impact in eliminating Pythagorean comma.

If *shrutis* are generated by cyclical method, by using Bharata's values of *Shadja-Panchama Bhava* and *Shadja-Madhyama Bhava* with above values then Pythagorean comma is eliminated completely after twenty one cycles. Also after ten cycles *shrutis* start repeating with minor decimal point variation. Actually, after ten cycles itself the Pythagorean comma is partially eliminated. Bharata's equal temperament scale of twenty two *shrutis* is thus the most efficient and elegant solution to eliminate Pythagorean comma. Pythagorean approach leads to an error of tuning at the end of an octave while Bharata approach accepts an error of 0.0062 at every cycle of the rule of fifth. The value of the displacement of a *shruti* position is so minimal that by and large it does not have any major impact. This may be termed as Bharata's comma. Here the objective is not to plead for Bharata's equal temperament scale but to show that even Bharata's scale is not a `perfect' scale. However since it resolves the issue of Pythagorean comma to a great extent it may be considered as the best possible solution for the issues related to *shrutis*.

8. A COMPREHENSIVE FRAME-WORK

8.1 *`Shruti Punja'* or *`Shruti Megha'* Model (A cluster or cloud of microtones)

As it is already discussed the concept of *shruti* in Indian music has evolved in various phases from *Naradiya Shiksha* to Bharata. The present monograph conclusively asserts that the Bharata's paradigm of equal temperament twenty two *shrutis* was a robust frame-work followed till the time of Sharangadeva. From the mediaeval period to modern times due to loss of knowledge and probably due to loss of scholastic lineage there was no clarity about Bharata's paradigm though there was great regard for Bharata's paradigm. Till today musicologists and scholars are debating about the exact interpretation of Bharata's paradigm. Secondly, due to the influence of just intonation scale and logico-mathematical models of musical scales scholars are perplexed about the exact nature of *shrutis* (irrespective of Bharata's paradigm). They are in search of a frame-work that will justify latest understanding of *shrutis* or microtones. There is lot of data available in this regard. The data comes from various sources. Researchers probing from scientific perspective are trying to collect data of actual musical performance using available means, devices and technology. Others are using technology to correlate technology generated data with actual musical practices. The third approach is to look at *shrutis* as harmonics and overtones and arrive at some results. Some other scholars are trying to rely on purely logical models of *shrutis*. Efforts are being made from all directions but satisfactory solution is not in sight. All the above-mentioned attempts are trying to prove either Bharata's paradigm with their interpretation or Pythagorean or just intonation models. Very few researchers are probing the third path- a completely new frame-work. Researchers who are probing for new frame-work genuinely want to capture the phenomenon of microtones but an agreeable model is not emerging. The author of the present monograph is of the view that such a frame-work is not possible because the kind of

mathematical precision that is expected in such a frame-work is practically not warranted. Secondly considering psycho-acoustic aspects of musical experience as discussed earlier, such a logico-scientific frame-work will not be practically implementable. The contemporary twelve-tone equal temperament scale is acceptable to the musical audience though not mathematically precise. It also does not capture many musically pleasing places within an octave. Still the twelve tone equal temperament scale is acceptable and appreciable to musicians as well as audience because there are certain reasons. Equal temperament scale provides opportunity for chord-based harmonic music. Also it provides more operational flexibility for instrumentalists. Looking at all these advantages it seems the solution for the problem of microtones would be a paradigm of equal temperament *shrutis*. So there is a need of an equal temperament scale that can capture wide range of aesthetically pleasing microtonal places in an octave and opens of possibilities for wide-ranging musical exploration. Therefore, paradigm of equal temperament *shrutis* or microtones is the most pragmatic and workable solution to the problem of *shrutis* or microtones. Bharata's paradigm is a strong contender for the solution. However, in last two centuries there has been a big debate about exact interpretation of Bharata's paradigm. The present monograph argues with strong evidence from the textual analysis of Bharata's *Natyashastra* and the description of *Shruti-Nidarshanam* experiment and proves that Bharata's twenty two *shrutis* were with equal temperament. As it stands Bharata's paradigm is sufficient enough to capture most of the musically pleasing microtones in an octave. Bharata's frame-work of *shrutis* provides a uniform base for all such microtones (though not with mathematical precision). It covers Vedic practices as well as modern practices. To further fine- tune Bharata's paradigm, it is possible to divide each *shruti* into five sub-divisions to do justice to five types of *shrutis* mentioned in *Naradiya Shiksha*. Even this fine-tuning should be with equal temperament. Therefore, a frame-work of hundred and ten *shrutis*/ microtones is developed that can address most of the traditional issues as well as contemporary issues related to *shrutis*/ microtones. For all practical purposes and musical performances Bharata's scale is sufficient enough to do justice to all required *shrutis*/ microtones. However, frame-work of hundred and ten *shrutis* can bring in further fine-tuning. With the help of computational technology, to certain extent, it is possible to develop a technology that uses hundred and ten *shrutis* and with appropriate algorithm can compute the desired microtones suitable for a particular musical rendering. This frame-work can be a handy tool for

such a computation. This can be a promising area of further research and development in computational music.

A table of twenty two *shrutis* with total hundred and ten places is developed here. Each *shruti* has five subtle equi-distanced tonal variations. As mentioned elsewhere, mathematical precision is ideally desirable but cannot be implemented practically in a musical composition. Therefore, the Bharata's equi-distanced twenty two *shrutis* is the most workable solution to the problem of *shrutis*. Moreover, it has certain musical advantages such as flexible octave, possibility of playing chords, exploring new musical spaces and most importantly resolves the issue of Pythagorean comma. Taking one step further here a frame-work is developed as follows. Bharata's equal temperament twenty two *shrutis* are taken as the base. Each of the *shruti* is divided into five places so there are hundred and ten positions in an octave. All the positions are equi-distanced. So as a result an octave is divided into hundred and ten musically equal divisions and mapped within twenty two *shruti* positions. Following the scheme of *Naradiya Shiksha-Mrudu, Madhya* and *Aayata jati* positions are assigned appropriately as shown in the table, while *Dipta, Karuna* and `*shruti*-like *swara*' positions are assumed as floating positions. *Mrudu-Madhya*, *Madhya* and *Madhya-Aayata* positions shown can be replaced by these *Dipta, Karuna* and `*shruti*-like *swara*' positions depending on the context and the application of appropriate consonance in a rendering. When the consonances are employed the resultant value may not exactly match the frequency that is mentioned in the table. But it will be within the range of one of these frequencies whichever is closer. It is suggested that it is not practically possible to assume precise pitch position as a *shruti*. Instead a *shruti* may be defined as a cluster or cloud of all musically significant pitch positions around each of Bharata's twenty two *shrutis*. Therefore each *shruti* is considered as a cluster. The *shruti* itself is the center of the cluster and called *Madhya shruti*. Thus each of Bharata's *shruti* or a cluster of such pitch positions may be called *`shruti punja'* or *`shruti megha'*.

The scheme of reconstruction of such clusters would be as follows. Every *shruti* will have *Madhya* as its own *shruti jati* by default. It will have two lower microtones as *Mrudu-Madhya* and *Mrudu*. Similarly it will have two higher microtones as *Madhya-Aayata* and *Aayata*. For operational simplicity these microtones would be equi-distanced. *Mrudu jati* is the lowest extreme of a *shruti* cluster and *Aayata* is the highest extreme of a *shruti* cluster. *Mrudu-Madhya* and *Madhya-Aayata* are closer to the center.

Mrudu-Madhya, Madhya and *Madhya-Aayata* would be considered as floating points since they can be replaced by *Dipta, Karuna* (or *Shruti*-like *swaras* as mentioned by Bhatta Shobhakara). The following table gives an idea about such a scheme of reconstructing clusters for *shrutis*. The table provides frequency values of all the hundred and ten microtones, *shruti* names, *shruti jatis* and *swara* names. The table is self-explanatory.

SN.	Frequency in Hertz.	*Shruti* Names	*Shruti-Jati*	*Swara* Names
4.	240	*Chhandovati*	*Madhya*	*Shadja*
	241.517		*Madhya-Aayata*	
	243.043		*Aayata*	
	244.579		*Mrudu*	
	246.125		*Mrudu-Madhya*	
5.	247.681	*Dayavati*	*Madhya*	*Eka-shruti Rishabha*
	249.247		*Madhya-Aayata*	
	250.822		*Aayata*	
	252.408		*Mrudu*	
	254.003		*Mrudu-Madhya*	
6.	255.609	*Ranjani*	*Madhya*	*Dvi-shruti Komal Rishabha*
	257.224		*Madhya-Aayata*	
	258.850		*Aayata*	
	260.487		*Mrudu*	
	262.133		*Mrudu-Madhya*	
7.	263.791	*Raktika*	*Madhya*	*Tri-shruti Bharata's Rishabha*
	265.457		*Madhya-Aayata*	
	267.135		*Aayata*	
	268.824		*Mrudu*	
	270.523		*Mrudu-Madhya*	*Shuddha Rishabha*

8.	272.235	*Roudri*	*Madhya*	*Chatuh shruti Rishabha*
	273.954		*Madhya-Aayata*	
	275.686		*Aayata*	
	277.428		*Mrudu*	
	279.182		*Mrudu-Madhya*	
9.	280.948	*Krodha*	*Madhya*	*Bharata's Gandhara*
	282.723		*Madhya-Aayata*	
	284.510		*Aayata*	
	286.308		*Mrudu*	
	288.118		*Mrudu-Madhya*	*Komal Gandhara*
10.	289.941	*Vajrika*	*Madhya*	*Sadharana Gandhara*
	291.772		*Madhya-Aayata*	
	293.616		*Aayata*	
	295.472		*Mrudu*	
	297.340		*Mrudu-Madhya*	
11.	299.221	*Prasarini*	*Madhya*	*Antar Gandhara/ Shuddha Gandhara*
	301.110		*Madhya-Aayata*	
	303.014		*Aayata*	
	304.929		*Mrudu*	
	306.857		*Mrudu-Madhya*	
12.	308.799	*Priti*	*Madhya*	
	310.748		*Madhya-Aayata*	
	312.712		*Aayata*	
	314.689		*Mrudu*	
	316.678		*Mrudu-Madhya*	
13.	318.683	*Marjani*	*Madhya*	*Bharata's Madhyama*
	320.694		*Madhya-Aayata*	*Shuddha Madhyama*

	322.721		*Aayata*	
	324.761		*Mrudu*	
	326.816		*Mrudu-Madhya*	
14.	328.884	*Kshiti*	*Madhya*	
	330.959		*Madhya-Aayata*	
	333.051		*Aayata*	
	335.156		*Mrudu*	
	337.275		*Mrudu-Madhya*	
15.	339.411	*Rakta*	*Madhya*	*Prati- Madhyama*
	341.552		*Madhya-Aayata*	*Teevra Madhyama*
	343.711		*Aayata*	
	345.883		*Mrudu*	
	348.070		*Mrudu-Madhya*	
16.	350.275	*Sandipani*	*Madhya*	*Chyuta Panchama*
	352.484		*Madhya-Aayata*	
	354.712		*Aayata*	
	356.954		*Mrudu*	
	359.210		*Mrudu-Madhya*	*Shuddha Panchama*
17.	361.486	*Aalapini*	*Madhya*	*Bharata's Panchama*
	363.766		*Madhya-Aayata*	
	366.065		*Aayata*	
	368.379		*Mrudu*	
	370.708		*Mrudu-Madhya*	
18.	373.057	*Madanti*	*Madhya*	
	375.409		*Madhya-Aayata*	
	377.782		*Aayata*	
	380.170		*Mrudu*	
	382.573		*Mrudu-Madhya*	

19.	384.998	*Rohini*	*Madhya*	*Dvi-shruti Komal Dhaivata*
	387.425		*Madhya-Aayata*	
	389.874		*Aayata*	
	392.338		*Mrudu*	
	394.818		*Mrudu-Madhya*	
20.	397.321	*Ramya*	*Madhya*	*Tri-shruti Bharata's Dhaivata*
	399.825		*Madhya-Aayata*	*(Shuddha Dhaivata)*
	402.352		*Aayata*	
	404.896		*Mrudu*	*Shuddha Dhaivata*
	407.455		*Mrudu-Madhya*	
21.	410.039	*Ugra*	*Madhya*	*Chatuh-shruti Dhaivata*
	412.622		*Madhya-Aayata*	
	415.231		*Aayata*	
	417.855		*Mrudu*	
	420.497		*Mrudu-Madhya*	
22.	423.163	*Kshobhini*	*Madhya*	*Bharata' Nishada*
	425.829		*Madhya-Aayata*	*(Komal Nishada)*
	428.521		*Aayata*	
	431.230		*Mrudu*	*Komal Nishada*
	433.955		*Mrudu-Madhya*	
1.	436.708	*Teevra*	*Madhya*	*Kaishiki Nishada*
	439.459		*Madhya-Aayata*	
	442.237		*Aayata*	
	445.032		*Mrudu*	
	447.845		*Mrudu-Madhya*	
2.	450.686	*Kumudvati*	*Madhya*	*Kakali Nishada/ Shuddha Nishada*
	453.525		*Madhya-Aayata*	

	456.391		*Aayata*	
	459.276		*Mrudu*	
	462.179		*Mrudu-Madhya*	
3.	465.112	*Manda*	*Madhya*	*Chyuta-Shadja*
	468.041		*Madhya-Aayata*	
	470.999		*Aayata*	
	473.976		*Mrudu*	
	476.972		*Mrudu-Madhya*	
4.	480	*Chhandovati*	*Madhya*	*Tara Shadja*

Table No. 7

The exact position of *Dipta* and *Karuna shruti* can be calculated using the logic of `*swarantara*' or consonance as mentioned by Bhatta Shobhakara. By applying these consonances *Dipta shruti* can be inferred. Similarly, he also talks about *Shadja-Madhyama* consonance and *Shadja-Panchama* consonance for deciding about *Mrudu* and *Karuna shruti* respectively. By this logic *Madhyama swara* always will have *Mrudu shruti jati* and *Panchama* will always have *Karuna shruti jati*. There exists a difference between Bharata's *Shadja-Madhyama Bhava* and the *Shadja-Madhyama* consonance that we accept today since Bharata's *shrutis* were equi-distanced. Similarly, there exists difference between Bharata's *Shadja-Panchama Bhava* and the *Shadja-Panchama* consonance that we accept today. So by applying today's consonances we get today's positions of *Madhyama* and *Panchama*. When we apply Bharata's *Shadja-Madhyama Bhava* we get the position that is lower than the *Madhya* position and therefore it is *Mrudu-Madhya jati*. Similarly, when we apply Bharata's *Shadja-Panchama Bhava* we get the position that is higher than the *Madhya* position and therefore it is a *Madhya-Aayata* position which is named as *Karuna jati*. Since in both the cases the actual consonance leads to pleasing *swara* position it should be called *Dipta jati*. So *Dipta shruti jati* for *Madhyama swara* is higher than Bharata's *Madhyama swara* and *Dipta jati* for *Panchama* is lower than Bharata's *Panchama*. Both of them are the actual pleasing consonant positions of *swaras*. This certainly throws light on the scheme of *shruti* elaborately discussed in *Naradiya Shiksha* and further elaborated by Bhatta Shobhakara. For a *shruti*-like swara position Bhatta Shobhakara does not give any clear instructions. However, by applying rules of *swarantaras* described by Bhatta Shobhakara

appropriate pitch positions can be decided (can be computed for a computational system) depending on context of rendering.

The following table shows the possibility of employing *Dipta/ Karuna shruti jatis* if *Shadja* is fixed. In that case using consonances, location of *Dipta* and *Karuna* can be decided in the region of *Mrudu-Madhya, Madhya or Madhya-Aayata* places. This is just one hypothetical case of implementing *shruti jatis*. However in actual rendering depending on the context appropriate consonances can be used and *Dipta, Karuna* or *shruti*-like *swaras* can be rendered. Actually there is not much dispute about the positions *of Mrudu, Madhya* and *Aayata shruti jatis*. Their positions are definitively fixed as shown in the previous table. The real issue arises about the positions of *Dipta* and *Karuna shruti jatis*. Therefore it is recommended that the logico-mathematical values of the consonances or *Bhavas* should be considered for deciding the position of a *Dipta shruti jati*. The position of a *Karuna shruti jati* is decided by Bharata's *Shadja-Panchama Bhava* and so it will be slightly higher than the logico-mathematical *Shadja-Panchama Bhava*.

The following table is just suggestive and not a prescriptive table. The table shows frequencies of hundred and ten microtones, *shruti* names, *and shruti jatis, special cases of Dipta and /* or *Karuna* etc. and finally *swara* names.

SN.	Frequency	*Shruti* Names	*Shruti-Jati*	*Dipta/ Karuna* etc.	*Swara* Names
	473.976 (236.988)		*Mrudu*	237 *Mrudu*	
	476.972 (238.486)		*Mrudu-Madhya*		
4.	240	*Chhandovati*	*Madhya*	240 *Dipta*	*Shadja*
	241.517		*Madhya-Aayata*		
	243.043		*Aayata*	243.75*Aayata*	
	244.579		*Mrudu*		
	246.125		*Mrudu-Madhya*		
5.	247.681	*Dayavati*	*Madhya*	247.5 *Dipta*	
	249.247		*Madhya-Aayata*		

	250.822		*Aayata*		
	252.408		*Mrudu*		
	254.003		*Mrudu-Madhya*	253.12 *Dipta*	
6.	255.609	*Ranjani*	*Madhya*	256 *Dipta*	*Komal Rishabha*
	257.224		*Madhya-Aayata*		
	258.850		*Aayata*		
	260.487		*Mrudu*		
	262.133		*Mrudu-Madhya*	261.8 *Dipta*	
7.	263.791	*Raktika*	*Madhya*	*Madhya*	*Bharata's Rishabha*
	265.457		*Madhya-Aayata*		
	267.135		*Aayata*	266.6 *Aayata*	
	268.824		*Mrudu*		
	270.523		*Mrudu-Madhya*	270 *Dipta*	*Shuddha Rishabha*
8.	272.235	*Roudri*	*Madhya*	*Madhya*	*Chatuh shruti Rishabha*
	273.954		*Madhya-Aayata*	274.28 *Karuna*	
	275.686		*Aayata*		
	277.428		*Mrudu*		
	279.182		*Mrudu-Madhya*		
9.	280.948	*Krodha*	*Madhya*	280 *Dipta*	*Bharata's Gandhara*
	282.723		*Madhya-Aayata*		
	284.510		*Aayata*	284*Aayata*	
	286.308		*Mrudu*		
	288.118		*Mrudu-Madhya*	288 *Dipta*	*Komal Gandhara*
10.	289.941	*Vajrika*	*Madhya*	*Karuna*	*Sadharana Gandhara*

	291.772		*Madhya-Aayata*		
	293.616		*Aayata*	292.7 *Aayata*	
	295.472		*Mrudu*	296.4*Mrudu*	
	297.340		*Mrudu-Madhya*		
11.	299.221	*Prasarini*	*Madhya*	300 *Dipta*	*Antar Gandhara/ Shuddha Gandhara*
	301.110		*Madhya-Aayata*		
	303.014		*Aayata*	303.75 *Aayata*	
	304.929		*Mrudu*		
	306.857		*Mrudu-Madhya*		
12.	308.799	*Priti*	*Madhya*	*Madhya*	
	310.748		*Madhya-Aayata*		
	312.712		*Aayata*		
	314.689		*Mrudu*		
	316.678		*Mrudu-Madhya*	316 *Mrudu*	*Mrudu-Bhuta Madhyama*
13.	318.683	*Marjani*	*Madhya*	*Madhya*	*Bharata's Madhyama*
	320.694		*Madhya-Aayata*	320 *Dipta*	*Shuddha Madhyama*
	322.721		*Aayata*		
	324.761		*Mrudu*	324 *Mrudu*	
	326.814		*Mrudu-Madhya*		
14.	328.884	*Kshiti*	*Madhya*	*Madhya*	
	330.959		*Madhya-Aayata*	330 *Dipta*	
	333.051		*Aayata*		
	335.156		*Mrudu*		
	337.275		*Mrudu-*	337.5 *Dipta*	

			Madhya		
15.	339.411	*Rakta*	*Madhya*	*Madhya*	*Prati Madhyama*
	341.552		*Madhya-Aayata*	341.3*Karuna*	*Teevra Madhyama*
	343.711		*Aayata*		
	345.883		*Mrudu*		
	348.070		*Mrudu-Madhya*		
16.	350.275	*Sandipani*	*Madhya*	349.09 *Madhya*	*Chyuta Panchama*
	352.484		*Madhya-Aayata*		
	354.712		*Aayata*	355.5 *Aayata*	
	356.954		*Mrudu*		
	359.210		*Mrudu-Madhya*	360 *Dipta*	*Shuddha Panchama*
17.	361.486	*Aalapini*	*Madhya*	361.6 *Karuna*	*Bharata's Panchama*
	363.766		*Madhya-Aayata*		
	366.065		*Aayata*	365.6 *Aayata*	
	368.379		*Mrudu*		
	370.708		*Mrudu-Madhya*	371.25 *Dipta*	
18.	373.057	*Madanti*	*Madhya*	*Madhya*	
	375.409		*Madhya-Aayata*		
	377.782		*Aayata*		
	380.170		*Mrudu*	379.6*Mrudu*	
	382.573		*Mrudu-Madhya*		
19.	384.998	*Rohini*	*Madhya*	384 *Dipta*	*Komal Dhaivata*
	387.425		*Madhya-Aayata*		
	389.874		*Aayata*		
	392.338		*Mrudu*	392.7 *Mrudu*	
	394.818		*Mrudu-*		

			Madhya		
20.	397.321	*Ramya*	*Madhya*	*Madhya*	*Bharata's Dhaivata*
	399.825		*Madhya-Aayata*	400 *Dipta*	*(Shuddha Dhaivata)*
	402.352		*Aayata*		
	404.896		*Mrudu*	405 *Dipta*	*Shuddha Dhaivata*
	407.455		*Mrudu-Madhya*		
21.	410.039	*Ugra*	*Madhya*	*Madhya*	*Chatuh shruti Dhaivata*
	412.622		*Madhya-Aayata*	411.4*Dipta*	
	415.231		*Aayata*		
	417.855		*Mrudu*		
	420.497		*Mrudu-Madhya*	420 *Dipta*	
22.	423.163	*Kshobhini*	*Madhya*	*Karuna*	*Bharata' Nishada*
	425.829		*Madhya-Aayata*	426 *Dipta*	*(Komal Nishada)*
	428.521		*Aayata*		
	431.230		*Mrudu*	432*Mrudu*	*Komal Nishada*
	433.955		*Mrudu-Madhya*		
1.	436.708	*Teevra*	*Madhya*	*Madhya*	*Kaishiki Nishada*
	439.459		*Madhya-Aayata*		
	442.237		*Aayata*		
	445.032		*Mrudu*	444.4 *Mrudu*	
	447.845		*Mrudu-Madhya*		
2.	450.686	*Kumudvati*	*Madhya*	450 *Dipta*	*Kakali Nishada/ Shuddha*

					Nishada
	453.525		*Madhya-Aayata*		
	456.391		*Aayata*	455.6 *Aayata*	
	459.276		*Mrudu*		
	462.179		*Mrudu-Madhya*		
3.	465.112	*Manda*	*Madhya (Mrudu)*	464 *Dipta*	
	468.041		*Madhya-Aayata*		
	470.999		*Aayata*		
	473.976		*Mrudu*	*Mrudu*	
	476.972		*Mrudu-Madhya*		
4.	480	*Chhandovati*	*Madhya*	480 *Dipta*	*Tara Shadja*

Table No. 8

The following table tries to summaries all the hundred and ten microtones in terms of *swaras* of *Naradiya Shiksha.* So the table shows Samavedic *swara*-names, their frequency values in Hertz, Bharata's *shrutis, shruti jatis* and finally Bharata's *swara* names.

Samaveda Swara-Name	Frequency	Bharata's *Shruti*	*Shruti-Jati*	Bharata's *Swara* Names
	473.976 (236.988)		*Mrudu*	
	476.972 (238.486)		*Mrudu-Madhya*	
Chaturtha	240	*Chhandovati*	*Madhya (Dipta)*	*Shadja*
	241.517		*Madhya-Aayata*	
	243.043		*Aayata*	
	260.487		*Mrudu*	
	262.133		*Mrudu-Madhya*	
Tritiya	263.791	*Raktika*	*Madhya*	*Bharata's Rishabha*
	265.457		*Madhya-Aayata*	

	267.135		*Aayata*	
	277.428		*Mrudu*	
	279.182		*Mrudu-Madhya*	
Dwitiya	280.948	*Krodha*	*Madhya*	*Bharata's Gandhara*
	282.723		*Madhya-Aayata*	
	284.510		*Aayata*	
	314.689		*Mrudu*	
	316.678		*Mrudu-Madhya*	
Prathama	318.683	*Marjani*	*Madhya (Mrudu/ Dipta)*	*Bharata's Madhyama*
	320.694		*Madhya-Aayata (Dipta)*	
	322.721		*Aayata*	
	356.954		*Mrudu*	
	359.210		*Mrudu-Madhya (Dipta)*	
Krushta	361.486	*Aalapini*	*Madhya (Karuna)*	*Bharata's Panchama*
	363.766		*Madhya-Aayata*	
	366.065		*Aayata*	
	392.338		*Mrudu*	
	394.818		*Mrudu-Madhya*	
Atiswarya	397.321	*Ramya*	*Madhya(Mrudu)*	*Bharata's Dhaivata*
	399.825		*Madhya-Aayata (Dipta)*	
	402.352		*Aayata*	
	417.855		*Mrudu*	
	420.497		*Mrudu-Madhya (Dipta)*	
Mandra	423.163	*Kshobhini*	*Madhya (Karuna)*	*Bharata' Nishada*
	425.829		*Madhya-Aayata*	
	428.521		*Aayata*	
	473.976		*Mrudu*	
	476.972		*Mrudu-Madhya*	
Chaturtha	480	*Chhandovati*	*Madhya*	*Tara Shadja*

Table No. 9

8.2 Analysis and Discussion

The recent experimental studies conducted provide evidence for flexible intonation as a statistical phenomenon in which the note densities occur not as exact points but rather as clusters within a certain tonal regions. [Rao, S., pp. 692-693]. In a performance musicians visualize a particular musical phrase with specific intonation on a particular *swara* depending on the melodic context of a *Raga* but a performer may not reach the specific point always. A performer reaches a tonal range in and around that specific point. This is described as a statistical phenomenon. In actual performance, the pitch values of *swaras* do not vary randomly. A performer has clear idea about the desired *swara* in mind however; the *swara* that is actually rendered may not fall on that particular point due to some musical and non-musical reasons. In principle it is possible to calculate and compute the exact position of a *swara* using computers but due to psycho-acoustic considerations of a musical experience such a precision is undesirable. The integrated frame-work anchored in the Bharata's paradigm of equal temperament twenty two *shrutis* augmented with manifestation of five sonar qualities of a *swara* mentioned in *Naradiya Shiksha* can provide a theoretical as well as practical solution to the problem of *shrutis*/ microtones. As already discussed this frame-work may be termed as a *`Shruti-Megha'* frame-work or a *`Shruti-Punja'* frame-work that captures the statistical phenomenon of flexible intonations.

It is quite evident that *Naradiya Shiksha* does not prescribe equal temperament *shrutis*. On the other hand Bharata provides a robust frame-work of equal temperament *shrutis* preserving the Vedic pitch positions of *Gandhara, Rishabha, Nishada* and *Dhaivata*. After Vedic era few more pitch positions became prominent such as *Antara-Gandhara* and *Kakali-Nishada* that *Naradiya Shiksha* also mentioned. Bharata tried to accommodate all of them. Bharata's system could not do true justice to actual pitch positions of *Chatuh-shruti Rishabha* and *Chatuh-shruti Dhaivata* however they are a part of Bharata's system. Even the so-called *Prati-Madhyama* or *Teevra-Madhyama* is not mentioned by Bharata but that is also accommodated in Bharata's system. Bharata's system appears to be pragmatic solution to all the issues related to *shrutis* and *swaras*, though bit negotiated with mathematical precision of pitch positions. It is a dichotomy of ideal against pragmatic. Still the author of present monograph feels that Bharata's paradigm is the best ever solution provided to address the issues related to *shrutis*. The *`Shruti-Punja'* frame-work of equal temperament, hundred and ten *shruti* position in an octave could be a

further enhancement of Bharata's paradigm. As the current research argues, *shrutis* are statistical pitch states; this frame-work can provide relatively more definitive structure which is closer to these statistical states. *Naradiya Shiksha* already provides a vocabulary for the same.

In prevailing diverse perspectives on *shrutis* with contradictory theories it is necessary to develop some rational theoretical structure that addresses various issues. Bharata's equal temperament *shrutis* is a well-established paradigm but modern scholars are not happy with it since it does not address the issue of precise *shruti* values of frequencies. *Naradiya Shiksha* gives a vital tool to classify *shrutis* into five categories but it became obsolete in Bharata's days itself. Modern scholars no longer are familiar with it. Contemporary research is progressing on two lines apart from the logical models. The empirical research focuses on analyzing live performances or recordings of musical maestros and it is yielding some satisfactory results. A. K. Datta and others have done some important work in this regards. Their research proves the existence of twenty two *shrutis* or microtones in the actual performance of musical rendering of Ragas beyond doubt. They could successfully extract *shrutis* from the musical data. The extracted ratios are generally in good agreement with the ratios given by Deval and the Western sources according to them [Datta A. K., p. 7].This approach is significant because they have followed scientific methodology very rigorously. The second approach is to use computational technology to analyze musical data to arrive at some satisfactory conclusions. Such attempts are very few. There is a need of more a comprehensive approach that covers traditional theories as well as modern research.

This paper attempts to rely on four types of data. The first data comes from the *shruti* values generated by all possible consonances. These include *Shadja-Panchama Bhava, Shadja-Madhyama Bhava*, and all the variations of *Gandhara Bhava, Rishabha Bhava* etc. These *Bhavas* are significant because it is widely accepted that these *Bhavas* have ability to generate pleasing musical notes. The other important data comes from the natural spectrum of harmonics/ overtones those are generated when various musical notes are played. Computational analysis shows that these values/ overtones around 80 to 100 cycles saturate at certain frequency values. Such values are identified. This data is again very valuable because it helps in identifying clusters of frequencies that are significant from harmonic point of view. The third type of data is an empirical data by Dr. Sulabha Thakar who is a traditionally trained

musician. In an independent experiment, she attempted to identify significant frequencies in various *Hindustani Ragas*. Being a professionally trained vocalist of *Kirana Gharana*, which is known for its precision of *swara* rendering, her observations are considered reliable. She took help of a computer to generate specific *shruti* frequencies in a particular *Raga* and verified it. She could identify around twenty seven such *shruti* values in an octave which are employed by practicing musicians in their performance. The fourth type of data comes from an objective analysis of *shrutis* from the *'aalaaps'* (or the elaborate renderings of a *Raga*-specific phrases in the beginning) from hundred and fifty *Bandishs* or songs performed by fifty three eminent musicians and scholars covering twenty one different *Ragas*. The total time of singing analyzed is nearly eight and half hours. The audio samples are taken from recorded performances [Datta A. K., p. 1].This data is very important. However, one interesting observation about these data is that all the identified *shrutis* appear to be influenced by the contemporary equal temperament twelve tone scale. A glance at the data suggests that there are pairs of *shrutis* which are located around the major *swaras* of twelve tone scale that is in use in contemporary music. For instance, R1- 251.21 and R2- 256.98 are around *Komal Rishabha*-254.27; R3- 266.68 and R4-272.32 are around *Rishabha*-269.39; G1- 281.54 and G2- 289.33 are around *Komal Gandhara*-285.40; G3- 298.41 and G4-305.07 are around *Gandhara*- 302.38; M1- 316 and M2- 323.66 are located around *Madhyama*- 320.36; M3- 335.67 and M4-342.72 are around *Teevra Madhyama*- 339.41; P1- 354.15 and P2- 362.40 are located around *Panchama*: 359.59and so on and so forth. It also suggests that contemporary equal temperament musical scale has strong enough impact on learning process of musicians, their performance as well as appreciation. Thus Datta et al have identified twenty two microtones around the twelve notes of (equal temperament?) scale therefore total number of tones used in actual performance becomes thirty four. In a sense one can say that present day musicians use thirty four *shrutis* in their music. However, Datta et al have given the ratios for twenty two *shrutis.* They have not given the *ratios* for the *swaras* used in the performance so it cannot be confirmed that they have used the equal temperament scale or not. Another interesting and valuable inference that can be drawn from this data is that none of the *shrutis* from this data match with the just intonation values. So this data can prove that just intonation scale is not an empirical scale- it is just a logico-mathematical scale.

The following table captures hundred and ten equal temperament frequency values in an octave and distributes them in equal temperament twenty two *shrutis* mentioned by Bharata. Thus each *shruti* has four variations- two on lower side and two on upper side. The middle value is the *shruti* value itself which is called *Madhya shruti*. The lowest value is called *Mrudu shruti*. In-between value is called *Mrudu-Madhya shruti*. On the other side, the most upper value is termed as *Aayata shruti*. The in-between is called *Madhya-Aayata shruti*. The frequency values generated by various consonances, frequency values generated by harmonics and overtones and the *shruti* frequency values identified by Dr. Sulabha Thakar and Datta et al are then arranged in the table as per their proximity to these hundred and ten values. This helps in comparing various values and aligning them with *Mrudu, Mrudu-Madhya, Madhya, Madhya-Aayata,* and *Aayata* categories. As earlier mentioned, *Dipta* and *Karuna shruti jatis* are the floating *jatis*. This arrangement helps in defining criteria for *Dipta* and *Karuna shruti jatis*. Comparative table of twenty two *shrutis*- equal temperament frequencies, select consonant frequencies, *Tanapura* overtones, empirical data by Dr. Sulabha Thakar and *shrutis* by Datta et al is as follows. Prof. A. K. Datta et al have given ratios of *shrutis* in their monograph. Based on these ratios the values are calculated and mentioned in the last column of the table. They have not provided the ratios of *swaras* used and therefore values for *swaras* are not added here.

SN.	**Frequency *Shruti* 22**	***Shruti Names***	***Shruti-Jati***	**Freq. by *Bhava***	**Freq. *Tanapura* Overtones**	**Freq. Thakar Sulabha**	**Freq. Datta et al**
	473.976 (236.984)		*Mrudu*				
	476.972 (238.486)		*Mrudu-Madhya*				
4.	240	*Chhandovati*	*Madhya*	240	240	240	240
	241.517		*Madhya-Aayata*				
	243.043		*Aayata*	243.75	243.75	243	
	244.579		*Mrudu*				
	246.125		*Mrudu-Madhya*			246	
5.	247.681	*Dayavati*	*Madhya*	247.5	247.5		
	249.247		*Madhya-Aayata*			249.11	
	250.822		*Aayata*		251.25		251.21
	252.408		*Mrudu*				

	254.003		*Mrudu-Madhya*	253.125	253.125		
6.	255.609	*Ranjani*	*Madhya*	256	255		
	257.224		*Madhya-Aayata*				256.98
	258.850		*Aayata*		258.75		
	260.487		*Mrudu*				
	262.133		*Mrudu-Madhya*	261.8	262.5	261.8	
7.	263.791	*Raktika*	*Madhya*				
	265.457		*Madhya-Aayata*		265.7		
	267.135		*Aayata*	266.66	266.66		266.68
	268.824		*Mrudu*				
	270.523		*Mrudu-Madhya*	270	270		
8.	272.235	*Roudri*	*Madhya*				272.32
	273.954		*Madhya-Aayata*	274.28	273.7		
	275.686		*Aayata*		275.6	275.14	
	277.428		*Mrudu*		277.5		
	279.182		*Mrudu-Madhya*			278.58	
9.	280.948	*Krodha*	*Madhya*	280	281.2		281.54
	282.723		*Madhya-Aayata*			282.06	
	284.510		*Aayata*	284.2	285		
	286.308		*Mrudu*				
	288.118		*Mrudu-Madhya*	288	288.7		
10.	289.941	*Vajrika*	*Madhya*			289.15	289.33
	291.772		*Madhya-Aayata*				
	293.616		*Aayata*		292.5	292.77	
	295.472		*Mrudu*		295.3		
	297.340		*Mrudu-Madhya*	296.2	296.25	296.43	
11.	299.221	*Prasarini*	*Madhya*	300	300	300.13	298.41
	301.110		*Madhya-Aayata*				
	303.014		*Aayata*		303.75	303.75	
	304.929		*Mrudu*				305.07
	306.857		*Mrudu-Madhya*				
12.	308.799	*Priti*	*Madhya*	309.3	307.5		
	310.748		*Madhya-Aayata*				
	312.712		*Aayata*				
	314.689		*Mrudu*		315		

	316.678		*Mrudu-Madhya*	316.04			316
13.	318.683	*Marjani*	*Madhya*			319.37	
	320.694		*Madhya-Aayata*	320			
	322.721		*Aayata*		322.5		
	324.761		*Mrudu*	324			323.66
	326.814		*Mrudu-Madhya*				
14.	328.884	*Kshiti*	*Madhya*				
	330.959		*Madhya-Aayata*	330	330	331.49	
	333.051		*Aayata*				
	335.156		*Mrudu*				335.67
	337.275		*Mrudu-Madhya*	337.5	337.5		
15.	339.411	*Rakta*	*Madhya*			339.83	
	341.552		*Madhya-Aayata*	341.3	341.7		342.72
	343.711		*Aayata*			344.08	
	345.883		*Mrudu*		345		
	348.070		*Mrudu-Madhya*				
16.	350.275	*Sandipani*	*Madhya*	349.09			
	352.484		*Madhya-Aayata*		352.5		
	354.712		*Aayata*	355.5	354.43		354.15
	356.954		*Mrudu*				
	359.210		*Mrudu-Madhya*	360	360		
17.	361.486	*Aalapini*	*Madhya*			361.615	362.4
	363.766		*Madhya-Aayata*				
	366.065		*Aayata*	365.6			
	368.379		*Mrudu*		367.5		
	370.708		*Mrudu-Madhya*	371.25		370.74	
18.	373.057	*Madanti*	*Madhya*				
	375.409		*Madhya-Aayata*		375	375.34	
	377.782		*Aayata*				377.53
	380.170		*Mrudu*	379.68	379.6	380.03	
	382.573		*Mrudu-Madhya*		382.5		
19.	384.998	*Rohini*	*Madhya*	384			
	387.425		*Madhya-Aayata*				387.02
	389.874		*Aayata*		390	389.59	
	392.338		*Mrudu*	392.72	393.7		

	394.818		*Mrudu-Madhya*				
20.	397.321	*Ramya*	*Madhya*		397.5		
	399.825		*Madhya-Aayata*	400		399.39	400.27
	402.352		*Aayata*				
	404.896		*Mrudu*	405	405		
	407.455		*Mrudu-Madhya*				
21.	410.039	*Ugra*	*Madhya*	411.4			410.21
	412.622		*Madhya-Aayata*		412.5/ 413.4		
	415.231		*Aayata*				
	417.855		*Mrudu*				
	420.497		*Mrudu-Madhya*	420	420	419.75	
22.	423.163	*Kshobhini*	*Madhya*		421.8		422.05
	425.829		*Madhya-Aayata*	426.3		424.99	
	428.521		*Aayata*		427.5		
	431.230		*Mrudu*	432		430.30	
	433.955		*Mrudu-Madhya*				432.83
1.	436.708	*Teevra*	*Madhya*		435		
	439.459		*Madhya-Aayata*				
	442.237		*Aayata*		442.5		
	445.032		*Mrudu*	444.4			
	447.845		*Mrudu-Madhya*			446.64	448.56
2.	450.686	*Kumudvati*	*Madhya*	450	450		
	453.525		*Madhya-Aayata*				
	456.391		*Aayata*	455.6	455.6/ 457.5		
	459.276		*Mrudu*				459.27
	462.179		*Mrudu-Madhya*				
3.	465.112	*Manda*	*Madhya*	464.06	465		
	468.041		*Madhya-Aayata*				
	470.999		*Aayata*				
	473.976		*Mrudu*		472.5		
	476.972		*Mrudu-Madhya*				
4.	480	*Chhandovati*	*Madhya*		480	481.208	480

Table No. 10

A glance at the table will unfold some interesting observations.

1. Out of hundred and ten *shruti* values only seventy-nine *shruti* values correspond with the consonant values, harmonic values and empirical values. It means that the rest of the thirty one values are not really required. It also means that seventy nine values are potential microtones (*shrutis*) and in some or other context they can be used. This is a big number to implement in musical rendering.
2. Microtonal values generated using consonances or *Bhavas* are important but these are the ideal values. By using primary *Bhavas* such as *Shadja-Panchama Bhava* etc. secondary *Bhavas* such as *Shadja-Gandhara Bhava* etc. and other allied *Bhavas* such as *Shadja-Rishabha Bhava* etc. Thirty nine microtonal values are computationally generated in this monograph. Out of them, there are twenty nine values that closely match with the proposed hundred and ten values. But these *Bhavas* are applied to contemporary- just intonation seven *swaras*. If these *Bhavas* are applied to Bharata's seven *swaras* then the resultant values will be different. Therefore even this analysis is also indicative and not final.
3. Apart from that, fifty two *Tanapura* harmonics with eighty cycles are computationally generated. Out of those thirty five values closely match with the proposed hundred and ten values.
4. Dr. Sulabha Thakar could identify twenty seven *shrutis* in her monograph that are used in contemporary *Ragas*. Out of these seventeen *shruti* values closely match with the proposed hundred and ten values.
5. From the set of twenty two values of Datta et al, all the values closely match with the proposed value set of hundred and ten values. But interestingly out of twenty two values of Datta et al eight values match exactly with Bharata's values while seven values are very close to Bharata's *shrutis*. It is worth noticing that Bharata's *Chatuh-shruti Rishabha,* Bharata's *Gandhara*, *Sadharana Gandhara* and *Antara Gandhara, Panchama, Chatuh-shruti Dhaivata* and Bharata's *Nishada* match exactly with the respective *shrutis*. It may be considered as the conclusive proof of the existence of these *swaras* from Bharata's equal temperament scale in the contemporary musical performance. Eight values from Datta et al list of *shrutis* do not match with Bharata's equal temperament *shrutis* though.

6. Over all there are thirty six values that closely match with at least two components from consonant values: harmonic values or empirical values. It means thirty six values are strong contenders for the status of *shrutis*.
7. Bharata's three *shrutis* do not match with any of these value-sets: consonant values, harmonic values or two sets of empirical values. But they miss the mapping by the difference of just two hertz which is very negligible. So it can be argued that Bharata's equal temperament twenty two *shrutis* have strong proximity with the above-mentioned four data-sets. The remaining values can be accommodated within the *Shruti Punjas*.

This analysis is indicative and may not be treated as conclusive. It suggests possibilities for future research. As the more empirical data is collected and analyzed, the picture will be clear. It is certain that musical experience is a highly complex phenomenon. The equal temperament twenty two *shrutis* theory of Bharata is the best possible and pragmatic solution to the problem of *shrutis*. If it is augmented with the *Shruti Punja* or *Shruti Megha* model then it can be the most comprehensive solution to the problems of *shrutis*.

9. CONCLUSIONS

This monograph concludes with five important insights about the concept of *shruti* in Indian music. Firstly, it provides clarity about the five types of *shrutis* mentioned in *Naradiya Shiksha* and their applications. Secondly, the monograph conclusively proves that Bharata's octave has strong foundations in Vedic *swaras* that eventually resulted in twenty two *shrutis*. Thirdly, the monograph conclusively establishes Bharata's paradigm of equal temperament twenty two *shrutis* with thorough analysis of Bharata's original text from *Natyashastra*. Bharata's *`Shruti Nidarshanam'* experiment as thoroughly discussed is a conclusive proof of the equal temperament twenty two *shrutis*. This also tells a musician, how to establish *shrutis* on *Veena* and perceive them in a step-by-step manner. Fourthly, an attempt has been made to integrate Narada's paradigm of *shrutis* with Bharata's paradigm of *shrutis*. Each of Bharata's *shruti* is considered as a cluster called *Shruti-Punja* or *Shruti Megha*. Every such cluster is divided into five types mentioned in *Naradiya Shiksha* to fine-tune Bharata's paradigm. Finally, this monograph attempts to accommodate the latest findings of the empirical and computational research in the above-mentioned *Shruti Punja* model.

Other important conclusions of this monograph are as follows.

Bharata's paradigm is completely different from *Naradiya Shiksha*. For *Naradiya Shiksha, shrutis* are sonar qualities of a Vedic *swara* while for Bharata *shrutis* are twenty two microtones or distinct places equally distributed (having equal temperament) across the octave. Thus *shrutis* have physical existence and in modern times can be understood in terms of their frequency values. *Shrutis* are not merely mental concepts. Bharata gives highly sophisticated *Shruti-Nidarshanam* or *Sarana-Chatushtaya* experiment to experience and demonstrate twenty two *shruti* that conclusively demonstrates the existence of equal temperament twenty

two *shrutis*. The present monograph also developed a different variation of the *Shruti Nidarshanam* experiment as discussed. Computational simulation of the *`Shruti-Nidarshanam'* experiment has helped to clarify many concepts more conclusively. It suggests that computational approach towards musical research is worth exploring and fulfilling at the end.

This monograph puts forth two types of arguments: a stronger or primary argument and few secondary arguments. The stronger argument is based on the critical analysis of Bharata's original Sanskrit text from *Natyashastra* and then the analysis of the *`Shruti Nidarshanam'* experiment as a confirmatory proof of equal temperament twenty two *shrutis*. This stronger argument is the crux of this monograph while other arguments are supplementary in nature.

Apart from the stronger argument, this monograph provides a step-by-step method of establishing *swaras* in an octave (*swara-sthapana* or *swara mandala sadhanam*) based on the original text of Bharata. This was not attempted in any other earlier studies. This is another original contribution of this monograph.

Computer simulation of *`Shruti Nidarshanam'* experiment and further analysis help in re-establishing Bharata's paradigm. This led to the development of a *`Shruti-Punja'* or *`Shruti-Megha'* frame-work of equal temperament hundred and ten microtones in an octave.

This monograph attempted to argue that Bharata's paradigm is very robust and highly relevant for Indian music in modern times. With the help of advanced computational technology it can help exploring newer possibilities to enrich Indian music.

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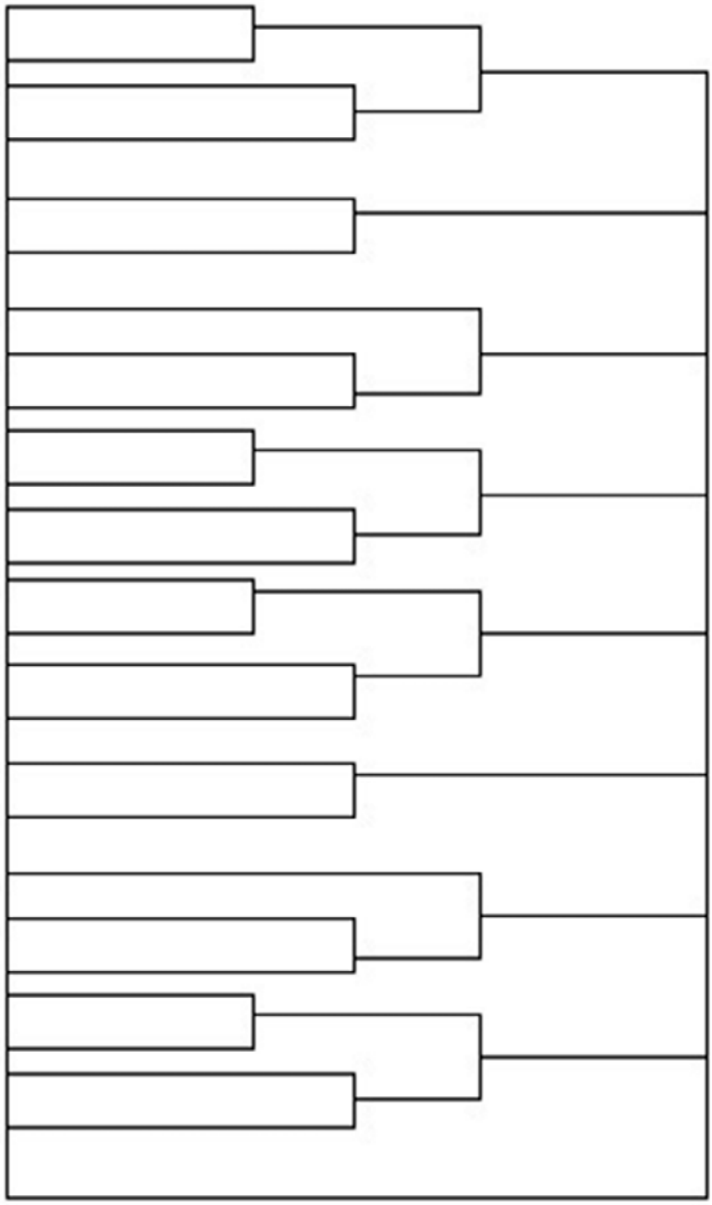
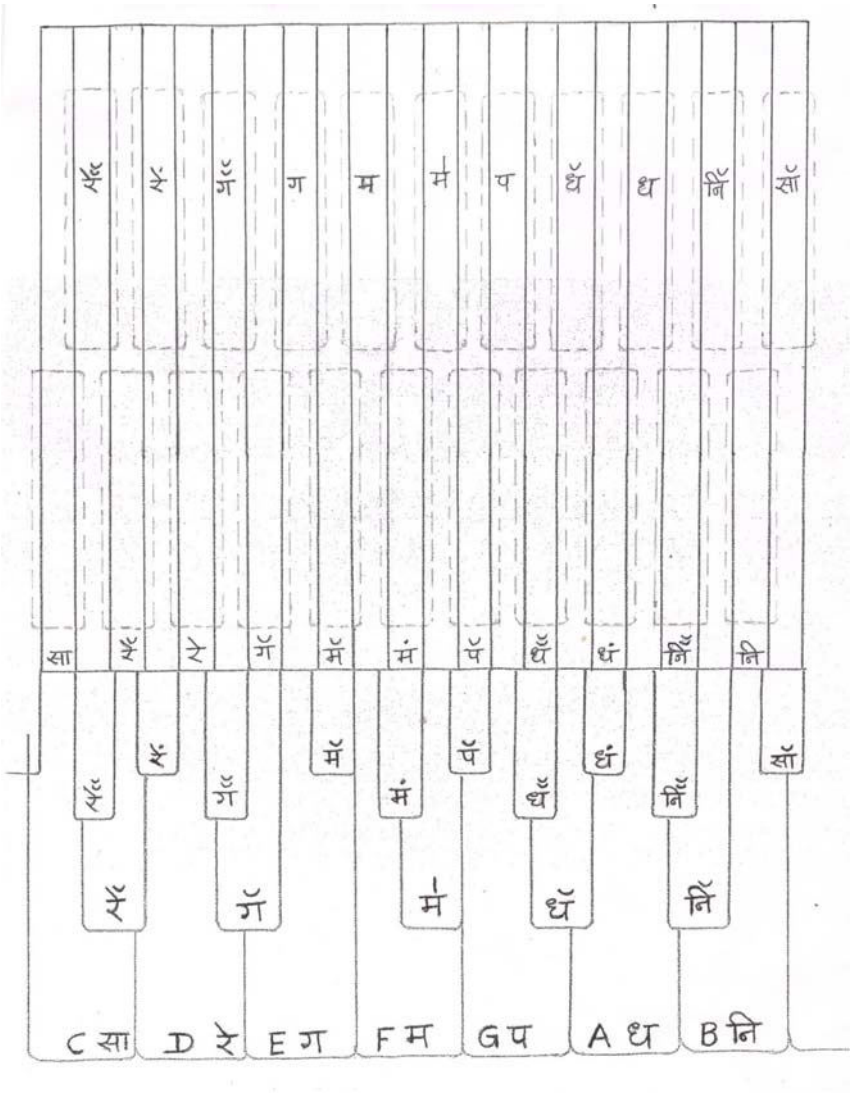
Appendix

Shruti Harmonium Key-Board

Harmonium came to India around 1850 and became popular as an accompaniment instrument for popular and classical music. Indian musicians felt that this Western instrument is not quite suitable for classical music since subtle microtones or *shrutis* are not captured by harmonium. There had been many attempts in the past by musicologists such as K. B. Deval and G. B. Acharekar to develop a harmonium on which *shrutis* can be played [Rao, S., pp. 683-684]. They developed their own theories of *shrutis*. But none of these theories of *shrutis* are based on Bharata's description of *shrutis* in true sense. Therefore, there were many outstanding issues regarding the exact nature of *shrutis* and these theories could not solve these issues satisfactorily and thus these attempts were short-lived and did not get wider acceptance. However, there is no documented information available about the structure and construction of these harmoniums. It is said that on Acharekar's harmonium one could play Western tempered scale as well as twenty-two-*shruti* Indian scale [Rao, S., p. 684]. In recent times also there have been many attempts of constructing a *shruti* harmonium but due to lack of authentic theoretical foundations these attempts also had limitation. In most of these so-called *shruti* harmonium designs they tried to preserve the twelve tone key-board of Western tempered scale and by changing internal arrangements of the instrument they provided facility for playing *shrutis* (in a limited way). Major problem with these designs is that they tried to fit twenty two *shrutis* in twelve keys. So you cannot play *Ragas* having two or more varieties of *shrutis* of the same *swara*. Therefore a key-board design with twenty two keys in an octave is recommended here. Each key stands for one separate *shruti* in this key-board. So each octave has twenty two keys dedicated for twenty two *shrutis*. Following is a schematic sketch of a key-board for an equal temperament twenty two *shruti* harmonium. This sketch is suggestive and with few simple extensions can be used to construct a *shruti* harmonium key-board.



Schematic structure of an equal temperament twenty two *shruti* keyboard designed by Dr. Vinod Vidwans



Internal structure of reeds for the above-mentioned equal temperament twenty two *Shruti* Harmonium Keyboard designed by Dr. Vinod Vidwans.

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