APPROACHES USED TO STUDY RAGA-RASA IN THE ACOUSTICAL PERSPECTIVE

In Indian music, once the performer makes a choice of raga to be rendered, it is presumed that he is bound by the traditionally prescribed set of rules that govern the exposition of the chosen raga. Within the limits of set principles, a performer has freedom to improvise and build total structure of the raga through various components known as bandish (composition), alap, bol, sargam, and tan. The performer seeks to portray the personality of the raga by employing his knowledge, skill and creativity. In an effort to bring out an appropriate aesthetic atmosphere of the given raga, various melodic and rhythmic possibilities are explored. The continuous exposition of a given theme in myriad ways brings forth a characteristic atmosphere that becomes intensely hypnotic as the performer reaches the pinnacle of his artistic endeavour. This atmosphere, although seems to be dominated by a specific mood, may possess streaks of other moods. Being of transitory nature, these do not interfere with the dominant mood but can provide special luster by way of contrast.

Various factors involved in a musical performance are represented in the chart below. The integrated effect of these factors lead to what is referred to as the aesthetic gestalt or the experience of rasa at the perceptible level.
The unique personality of the raga constitutes a major part of the total aesthetic experience, while the subjective factors such as the performer, his gharana (school), style, context, time and occasion of the performance, mental and cultural background of listeners and performers etc., constitute the rest of the aesthetic experience. Elements related to principal tenets of raga, remain unaltered, whereas, the subjective factors bring about the variance in a
*raga* performance. Further, the special elements associated with Indian classical music such as absence of written score, oral transmission of knowledge and heavy dependence on improvisation, also add to the variability of *raga*-performance. As a result, performances of the same *raga* by the same performer or different performer, at different occasions exhibit appreciable degree of divergence. In other words, the total performance is an interplay of the non-varying grammatical tenets of a *raga* and the subjective factors.

However diverse are the ideas and viewpoints of musicologists be about *raga*-rasa relation (vide chapter 2), the fact that a *raga* projects a characteristic musical idea, resulting into a unique aesthetic atmosphere capable of arousing a neuropsychological response, cannot be ruled out. Various aspects involved in a *raga* performance leading to aesthetic experience at the perceptible level, can be schematically represented as follows:

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Tradition: *raga* structure and tenets

Performer's contribution

*Raga* realised in performance

Listener's input

Perception of aesthetic experience

Listener's response: verbal/non-verbal expression, gestures
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The codified set of rules of a raga are handed down by the tradition. Following these principles, the performer with his/her skill, training and ability, enlivens the raga during a performance. The receptive listener receives at his level, the raga-image created by the performer. The aesthetic experience perceived by listeners, is really the synthesis of aesthetic ideas projected by the performer and his/her own aesthetic ideas. The listeners respond by exhibiting verbal and/or non-verbal expressions or gestures which in turn influence the performer and his creation. The Indian music tradition allows freedom for such expression to the listeners. This means that the resultant aesthetic experience or the rasa experience is a complex process involving many factors. Therefore, even though traditionally every raga is assigned with a particular rasa, the subjectivity brought-in by various factors, may not allow to establish a consistent link between a raga and a specific rasa. Nonetheless, a given raga is always projected with certain identity of its own, irrespective of the variables. This non-varying aesthetic identity of the raga is certainly due to its expositional principles which are followed by the performers. The varying factors remain subjective, so they are elusive to scrutiny. In the present study, an attempt is made to examine certain characteristics of a raga with a view to understand their relation towards creating an aesthetic experience or the rasa.

As yet, a few isolated experimental studies have been carried out to relate the psychological response of listeners to music stimuli, with a view to understand the raga-rasa
relation (vide chapter 2). Generally such studies have assumed a simplistic model that could be applicable to any work of art. Schematic representation of the model is as follows:

Artist

 Processes leading to work of art

 Work of art

 Aesthetic experience

 Effects of the experience

Schematic representation of the subject matter of aesthetics (adopted from Child - Irvine, 1969)

Such oversimplified model indicating unidirectional process, obviously does not take account of qualitative difference in performance, brought out by the audience response. Further, the recorded versions of music-stimuli used in such studies are played out of the context of real performance in an artificial environment. This method may profoundly influence the audience response and hence introduce an element of non-reliability in observations. Besides, very little is known about the neurophysiological processes involved in the comprehension of musical messages. However, music being a process that essentially presumes interaction of stimulus of sound with the response of listeners, such psychoacoustical studies can indeed prove meaningful, provided proper methodology is adopted.

The problem of music-mood can also be viewed from the other end, that is to examine and analyse the source itself and to envisage those elements in music which bear potential
to create emotional response. Music can be defined as an arrangement of, or the art of combining together, sounds that please the ear (Jacobs, 1879, p. 277). Being an organised structure of units of sound, music signals are communicated through acoustic waves and hence lend themselves to physical investigation. Like language, music provides evidence for a cognitive organisation with a logic of its own. The musical path traversed by a performer is not of a random nature, but follows a logical direction involving organised pitch combinations leading to coherent patterns. The subjective characteristics of music such as pitch, loudness, timbre etc. can be precisely quantified and evaluated using objective parameters of frequency, amplitude, harmonics and so on. During the past few decades, many powerful techniques of signal processing have been developed and are already being extensively used for the analysis and synthesis of speech. These instruments, techniques and software can be utilized for the study of musical sound, specially with a view to identify the important characteristics of this signal, which are responsible for lending emotional colour to music. In the present work, an attempt is made to conduct an acoustical study of some of the musical elements that have been traditionally accepted as factors influencing the creation of specific aesthetic atmosphere (see chart).

In India, great attention has been paid to 'pitch' in music. Bharata pioneered the concept of 'sruti' or the microtones, which was elaborately dealt by many musicologists after him. The term sruti denotes an audible sound free from resonance and is capable of being individually perceived, recognised and reproduced. Sarangdeva considered srutis to
be the factors manifesting *svāra*-s (Sangita Ratnakara, 1.3, 23). According to Sarangdeva as interpreted by Kallinatha, "Sruti signifies a pitch value which contributes to the musicality of tone and is yet by itself devoid of tonal colour" (Shringy, 1978, p.407). The different notes are assigned with different *rasa*-s by Bharata. Further, *sruti*-s have been distinguished in five classes viz. *dīpta*, *ayata*, *mridu*, *madhya*, and *karuna*. Though the basis for such classification is not clear, comments of Simhabhupala, Kallinatha and Ahobala in this regard imply that nomenclature assigned to *sruti-jati*-s by Bharata, is indicative of emotive power of the respective *sruti*-s (vide chapter 2). Even today, the musicians attach great importance to correct intonation. Their training (*taleem*) and practising (*riyaz*) is largely aimed at refining the conception of intonation. This observation suggests that study of element of 'pitch' can lead to meaningful information about the aspect of intonation. Although the word 'sruti' invariably figures while referring to intonation in the Indian classical tradition, neither musicians nor scholars have so far agreed upon a definition of *sruti*. Therefore, during the present study, the word 'sruti' is taken in a sense to describe any aspect of intonation that extends beyond the level of the gross twelve semitone categories. As indicated in chart, the different notes employed (content) and the manner (treatment) in which they are musically pronounced, together describe the intonation. Hence, in this study, parameter of 'pitch' is identified in order to throw light on these factors constituting intonation. Pitch is objectively measured by
'frequency'. However, measuring the neuropsychological sensation of 'pitch' by the physical parameter of 'frequency' (based on number of vibrations set up in the sounding body), may not be free from limitations. Some of the studies undertaken in the area of psychology of pitch-perception have concluded that, in case of more complex tones or combinations of tones, subjective pitch may not correspond to any physically measurable frequency in the originally presented sound (Plomp, 1976, pp.112-114; Ward, 1954, pp.389-380).

Further, the totality of raga structure is brought out through certain phrases that are linked to each other. In these phrases, the individual notes occur with definite pitch and duration. These phrases are of two types. First, there are some catch-phrases (pakad) which define the core of a raga and secondly, there are the complementary phrases constituting a periphery of the raga-structure. The core phrases are among the essentials of raga with almost definite structure and their presence is imperative, while the structure of the complementary phrases depend upon imagination, skill and style of the performer. Although confined by a rigid set of rules, raga assumes a dynamic personality in the actual performance through core phrases as well as the complementary phrases. These phrases embody the melodic movement of a raga. Hence, analysis of melodic movement of core phrases is carried out for exploring the aesthetic content of a raga.

Thus, for the purpose of present investigation, intonation of the notes and their melodic movements have been examined. Considering the problems of correlating the physically measured acoustical parameter of 'frequency'
representing the pitch, audibly perceived parameter of 'tonal configuration' and visually evaluated element of 'melodic shapes' (through melodic contours obtained on computer monitor) with the neuropsychologically perceived abstract feelings, the scope of this study is limited to ascertain the presence of similar intonations and melodic movements in performance of a given raga by different performers. Such similitude of intonation and melodic movement, if found, can suggest a correlation between the tonal configuration of the raga and its aesthetic effect.

Alap is one of the forms used by musicians to delineate a raga. It is rendered at the beginning of raga-exposition in a very slow (vilambit) or medium (madhya) pace, with or without the drum accompaniment. Its rendition in slow pace allows total freedom for the performer to portray the minute details of the raga in a leisurely manner. Regardless of the school and style of the performer, alap brings forth the essence of a raga. Every tenet of the raga concerning intonation, duration and combination of notes, is observed to the last detail during the performance. Identity of the given raga is easy to establish during alap presentation. The other ways of raga delineation like bol, sargam, tan etc. may be dominated by elements such as the textual/syllabic or rhythmic content, whereas, the alap section (employing vowels) due to its slow paced rendition, exhibits remarkable adherence to tonal purity. Thus, alap can be undoubtedly considered to be the vital element of raga exposition. Hence, in the present study, only alap section of a performance has been considered for analysis.
In Indian tradition, the human body is recognised as an instrument (Gatraveena or Shaririveena). The sound produced on this 'veena' is considered superior to sound produced by any other instrument like 'Daruviveena' or the veena made of wood including the flute. For the purpose of present study, vocal music has been preferred to instrumental music on the basis of two reasons. The first being, the superior position allocated to the human voice in comparison to instrumental music. The second is the optimum efficiency achieved by the computer programmes employed, for human voice. In case of Indian instrumental music, many subsidiary tones are also produced, e.g. notes given out by the auxiliary as well as the sympathetic strings of sitar. The computer system processes the subsidiary sounds and the primary melody without any discretion, which leads to confusion. Besides, the system uses a series of band-pass filters which gives meaningless display of melodic contours, if faster passages involving rapid frequency changes are used. Due to these limitations, rendition of alap by human voice has been preferred.

For the purpose of present study, recordings of raga Yaman (also known as Kalyan) rendered by the great singers late Ustad Amir Khan, Pandit Bhimsen Joshi and Dr.Prabha Atre, have been selected. They are highly reputed musicians belonging to the Kirana gharana (school) of vocal music. Recordings of the first two musicians are taken from the archives of National Centre for the Performing Arts, Bombay, (master tape nos. 1576-7 and 1235-8), while recording of Dr.Prabha Atre has been made specially at S.N.D.T. Women's University under controlled conditions. For this recording,
no drum accompaniment was allowed and the tanpura player was placed at a distance of two feet from the vocalist. The performer was requested to sing only 'alap', preferably using syllable 'āā'. In the case of first two performers' recordings, no such control was possible, since these are the recordings of live performances.

The Khayal form of raga exposition being currently popular in India, alap section associated with the rendition of this form in vocal performance of different vocalists, has been considered suitable for analysis.

The Kirana style of vocal music is recognised as 'svara-oriented' style. Because of the emphasis on intonation and filigree work, this style shows preference for slow paced alap. Study of intonation being the focus of the present endeavour, preference has been given to the performers belonging to this style of vocal music.

Raga Yaman, also known as Iman or Kalyan, having Pythagorean diatonic scale is chosen for analysis. Main reason for the choice of this raga is the simplicity of its scale i.e. heptatonic scale with all natural notes except the madhyam or F, which is sharp. Considering the fact that the methods involved in earlier attempts to study intonation in Indian classical music were not completely adequate and reliable (Bel, 1984, p. 7-12), even the very basic intonational details of the natural notes need to be comprehended. Hence, such a raga has been taken for my analysis which does not employ chromatic notes. Besides, Yaman is a prachalita raga (commonly practised) in which the tonal material bears potential for unlimited melodic
possibilities. Moreover, Yaman being one of the basic raga-s, bears an independent and clearly distinguished aesthetic identity. Popularity of this melody among performers, teachers as well as listeners, has also been a matter of consideration.

Tonal material of the raga: Sa, Re, Ga, Ma#, Pa, Dha, Ni, or C, D, E, F#, G, A, B

Ascent: Ni, Re, Ga, Ma#, Dha, Ni, Sa'

Descent: Sa', Ni, Dha, Pa, Ma#, Ga, Re, Sa

Emphatic notes: Ga and Ni or E and B

Time: Early night

Scale type: Pythagorean diatonic

Traditional profile of raga Yaman

It is considered to be a rather new melody appearing on the scene of Indian raga system. A melody under the name 'Kalyan' is first mentioned in the text of Mansollasa of Somesvara Deva who reigned about 1131-A.D. Somesvara mentions Kalyan or Kalyani as a ragini or minor melody belonging to the group of 'Natta-Narayana'. In the text of Sangita Darpana by Chatura Damodara, we find Kalyan described as a raga or major melody and given the name of 'Kalyana nata'. It is described as a sampurna or heptatonic melody, with use of three varieties of rishabh (Saraswati Mahal edition, 1952, verse 271). In somanatha's 'Raga Vibodha' (1609 A.D.), the author mentions Kalyan as one of the 23 mela raga-s or parent scales (Ramaswami Aiyar's edition, 1933, p.58). The author also describes it as a sampurna or heptatonic melody to be sung in the evening. In his 'Sadraga Cnandrodaya', Pundarik Vitthala (1562 A.D.) also
asserts the heptatonic nature of the melody. However, due to the Persian influence brought about by the great poet Amir Khusro (1375-1400), a new flavour was imparted to the old melody of Kalyan by mixing it with the imported melody of Iman. The new melody known as Iman, Kalyan or Yajan, is currently being practiced in India.

According to the contemplative verse given in 'Sangita Darpana' (1952, verse 37, p. 47), visual portrait of Kalyan is a king carrying a sword in his hand and valiant in warfare. According to Somanatha's 'Raga Viboodha' (1933, verse 200, p.77), Kalyan is presented in the portrait of a king. The textual and oral sources regarding rasa of this raga suggest that it has been predominantly associated with shringara rasa or erotic mood. However, expressions such as joyful, contended, bright, active, bhakti etc. have also been linked with this raga. The findings of psychoacoustical experiments conducted by B.C.Deva, report rasa-s such as shringara, vira and raudra to be associated with raga Yaman (1981, p.184). A Ragamala painting of raga kalyan from Mewar school of painting along with its poetic verse can be seen on the adjoining page (Ebeling, 1973, p.131).

Investigations are carried out using two independent computer systems, viz. 'Melodic Movement Analyser' (MMA) and 'LVS' system.

Melodic Movement Analyser

Analysis is carried out using a Apple IIC computer set-up configured with 64K RAM, custom built interfaces viz. 'Melodic Movement Analyser' (MMA), Fundamental Pitch Extractor (FPE) and Application Software called 'MMA
Software that has been specially developed by Dr. Bernard Bel at the 'National Centre for the Performing Arts' (NCPA) Bombay. Since no single existing machine available for acoustic analysis, can be perfectly adapted to the demands of analysing monodic and particularly Indian music, MMA, is specially designed (Bel, 1983, p. 46).

Technical particulars (Hardware)

It is hardware - programmable allowing change in the hook-up of the machine's various functional blocks and the output format of the digital information. The number of functional blocks of the machine is not limited and the blocks themselves are constructed as modules to fit into one or more 19-inch U.S. Standard racks. The measurement blocks described below are built to measure various specific aspects of Indian vocal and instrumental music.

Block diagram of 'MMA 2'

<table>
<thead>
<tr>
<th>Regulated Power Supply</th>
<th>Frequency Generator Clock</th>
<th>Tape Computer Interface</th>
<th>Parallel Port</th>
<th>Blank</th>
<th>Period-meter</th>
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Block 1) Regulated Power Supply : 230 V AC/50 Hz mains supply is rectified to provide regulated D.C. working voltages (+12, +18 & +5V) for the entire MMA blocks.

Block 2) Technical features : Format : 16 bit (binary)

Mode : linear period-meter clock frequency 3.39 MHz

Accuracy : 300 ns (0.01% - 0.08%)
Block 3) Digital parallel inputs (Parallel Port): This block samples the information from (upto) 16 digital inputs to make it available on the single channel BUS output. Soldered straps define the value of the number of inputs validated.

Technical features: TTL logic level inputs
- One to 16 inputs per block
- Output format: Serial BUS output (3 state)

Block 4) Tape - computer interface: The block is normally situated between the output of the tape recorder and the input of the microcomputer. This block demodulates the frequency modulated signal and the clock and synchronising pulses are reinstated. The output of this block (logic level and clock) are directly fed into the input of a microcomputer.

Technical feature: 5 Volt TTL logic
- Outputs: 10,000 bits/sec.

Block 5) Blank for future expansion

Block 6) It takes digitised (square wave) output of the FPE and connects into 16 bit signal. Various software parameters (compression ratio etc.) can be set from the front panels of this block.

MMA Software

The system uses a dedicated custom-designed MMA II software which is completely menu-driven. Its user-friendly interactive mode enables the researchers to 'Load' music, 'Save' the processed data, display the 'Graphic', 'Recall' data from floppy and 'Print' the graphs. It has advanced
facilities like expanding and contracting the scale, zooming-in on a pre-selected area of the display and vertically shifting the basic background grid which represents a full octave range of 12 musical notes. With the help of 'MMA', all the pitch information of a piece of music can be stored with the accuracy of digital measurements better than one cent. Use of a machine language routine, 'DATAREAD' allows receiving and storing the data flow up to 10,000 bits/second while eliminating errors due to tape speed fluctuations when the data is entered from tape (1983, p.49). Thus a large quantity of data can be stored and processed in order to have an in-depth study of intonation. Introduction of a 'compression' rate allows the experimenter to adjust the sampling time of (averaged) pitch measurements to suit to his requirements. Pitch measurements are 'octave shifted' so that everything fits within one octave and no period overflow is possible (ibid). A specially developed logarithmic conversion technique allows the pictures derived from processing music to be displayed on the monitor screen shortly after the music has been loaded into the computer via 'MMA'. The program 'melodic viewer' allows the computer to precisely plot the melodic lines on its screen and carry out measurements of each dot of the melodic line with a sampling time of 0.05 sec. or less with an accuracy better than one cent i.e. 1/1200 of one octave (Bel, 1984, p.8). Thus 'MMA' surpasses the performance of a melograph. Another program, 'Tonagram' evaluates the entire performance to determine the scale of the raga and displays the information using either linear or circular representation. When music is loaded into 'MMA', pitch lines appear immediately on the monitor screen.
with marks indicating 12 positions of equal temperament, against the background of which the pitch lines are drawn. An octave is represented in 1200 cents, thus the distance between consecutive notes is 100 cents. The dotted line represents 'Sa' (tonic). There is a 'Microscope display mode' which allows to scan a pitch line, selecting parts of it for exact analysis and measurement. Sections of pitch lines can be displayed as a sequence of numeric values and can be printed on paper. Thus MNA is indeed a microscope for music analysis. (See the adjoining page for MNA).

'LVS' System

Using the 'LVS' system, the work has been carried out at the Phonetics Laboratory, University of Leiden, The Netherlands.

It is based on the most advanced theory of pitch-perception. It uses subharmonic summation algorithm (SHS algorithm). The SHS algorithm can be considered as a direct implementation of the concept formulated by de Boer (1977) that subharmonics are actually generated in the central processor (Hermes, 1987, p.262). The SHS model assumes that each spectral component activates not only those elements of the central pitch processor that are most sensitive to the frequency of this component but also those elements that have a lower harmonic relation with this component. The contributions of the various components add up and the activation is highest for that frequency-sensitive element that is most activated by its harmonics, which is the fundamental (ibid, p.256). Thus, SHS tries to mimic the pitch processor in the auditory central nervous system. This
algortihm provides a way to calculate the fundamental frequency that best fits the harmonic structure of the spectrum (ibid, p.262) and hence can be presented as a fine model representing a biological system where nonlinearities are essentially used to increase the versatility of the system (ibid, p.263). ‘LVS’ (PDT 1200) using SHS algorithm is an adaptation made by J. Pacilly for musical analysis and has one cent precision (van der Meer, 1989).

The program 'Pitch plotter' written by Wim van der Meer in Microsoft Quick Basic 1.0, enables to examine the files created by LVS on VAX. Pitch plotter is by and large a Macintosh implementation of the 'Melodic Movement Analyser' (MMA) Software developed by Bernard Bel for the Apple II series. The size of the 'Pitch Plotter' file is limited to 10,000 points (100 points = 1 sec, i.e. 100 seconds or 20 screens). The standard screen shows 5 seconds of the file. By clicking and dragging the mouse over a pitch line, any portion of the melody can be analysed. The program offers various menus such as File, Edit, Window, Analysis, Sound and Settings with several sub-options (ibid). Further details of the 'LVS' system along with functional aspects of the 'Pitchplotter' program are given later, in this chapter.

**Methods Adopted for Acoustical Analysis of Raga-Rasa**

Procedures involved in processing and analysing the data on the 'Melodic Movement Analyser' and 'LVS' system are different.

**Method for working with 'Melodic Movement Analyser' (MMA)**

The complete experimental hardware set-up configures
Apple-IIC 64K RAM computer system with custom-built interfaces like Fundamental Pitch-Extractor (FPE), Melodic Movement Analyser II (MMA II) and a Graphic Equaliser. The block diagram of the set-up is as follows:

The set-up also indicates inclusion of a cassette-tape recorder for feeding the music data, and a cathode ray oscilloscope for simultaneous display of waveforms corresponding to the output of tape recorder (complex audio waveform) and the filtered signal (Fundamental sine wave) going into 'MMA'.

Cassette Tape Recorder: Music is transferred from the spools (Master Tapes) to cassette tapes. Using a low frequency generator and a frequency counter, the frequency of the key note given out by tanpura (the drone instrument used by vocalist which is tuned to the vocalist's key) is measured and entered so that the computer can store its average value. This key note frequency for Amir Khan (AM) is 140.3 Hz., for Bhimsen Joshi (BJ) it is 140.4 Hz. while for Prabha
Atre (PA), it is 210 Hz. These are the averages of several individual values obtained over many days. These measurements have to be repeated many times to avoid any error due to subjectivity in pitch-perception.

Graphic Equaliser: The frequency of the fundamental (key) note, thus measured, helps to adjust the filters of Graphic Equaliser (1/3 octave band). These filters are manually adjusted to band-limit the audio spectrum around the aurally-judged frequency of fundamental note. The adjustment of filters of the Graphic equaliser brings about filtering of harmonics in a coarse manner.

Fundamental Pitch Extractor: In the Fundamental Pitch Extractor (FPE), fine filter adjustment is made and thereafter the pitch extraction takes place automatically. The FPE uses a series of sixteen 4th order bandpass filters (Q=8) covering the range 60 Hz to 2000 Hz. in 1/3 octave steps. The FPE assumes that the lowest frequency periodical signal whose energy represents a given fraction of the total sound energy, is the fundamental. The outputs of the sixteen 1/3 octave bandpass filters are rectified. A counter, activated by a 1000 Hz. clock scans the output of sixteen rectifiers in order to determine which one is tracing the fundamental. A reference voltage is determined by dividing the peak amplitude of the input signal by a given number. As soon as one of the DC outputs is found to be greater than the reference voltage, the FPE assumes that the corresponding bandpass filter is capturing the fundamental. Consequently, the current value of the counter is latched in a memory and a 16-to-1 line multiplexer connects the output of the filter to
the output of FPE. This action can be visualised on the front panel – one of the 16 LEDs will be lighted indicating which filter has been selected.

The output of the FPE is then fed to the periodmeter of MMA, which gives a digital output related to the frequency of the fundamental. The extracted analogue fundamental signal is seen in the form of a pure sine wave on CRO. This waveform can be compared with the simultaneous display of waveform corresponding to the complex signal coming out of the tape recorder, to ensure filtering of harmonics.

MMA: The digitised signal is formatted (Data, sync, clock) to feed into the computer serial port. It is stored in the computer memory (RAM) in the form of 'Melodic files', so that any section of music can be recalled on the monitor. In addition, the same digital data is stored on external floppy disk for enabling repeated recall and to study in future.

With the help of an additional tape recorder, the musical data being processed was acoustically stored on the tape, so that it could be precisely related to the graphic output of the computer. The pitch-lines appearing on the monitor screen are refined to remove glitches that are caused by the pitch-extraction system. Then the entire pitch-line corresponding to the section of the performance being analysed, is printed using a dot-matrix printer.

After having the melograms (graphic representation of the melody) on paper, detailed transcription is attempted by repeatedly listening to the relevant section of the melody. This process is so laborious that to transcribe a piece of melody of 10 seconds duration, 15 to 20 minutes of concentrated effort is involved. However, the process of
transcription has its own advantages. By correlating the graphic contours with the acoustical information, minute details of the melodic progression can be studied. Attack, sustain and decay stages of individual notes in varied contexts are also examined.

Observations have been made regarding the influence of different vowels and consonants employed by the singers, upon the pitch-line. Complex characteristics of various embellishments employed by the singers, such as andolan, murki, gamak and kan etc., can be comprehended from the graphic details. Further, melodic phrases are analysed with a view to understand the manner in which the tones are linked to form a phrase. Interesting observations have been made by comparing the graphs of the same phrase intoned by different singers or by the same singer at different phases of performance. Certain characteristic features associated with the singer’s style have also been studied. In addition, the study of graphic details has allowed to comment upon the variance in the manner of intonation in the ascending and descending movement of notes.

Using the mode of ‘mini-tonagram’, pitch measurements are made only for the standing notes of the least 0.5 sec duration. The term ‘standing note’ implies a note that is audibly perceived as a ‘steady note’ or that which is judged as a ‘khada-sur’ by the north Indian musicians. The pitch measurements are obtained in ‘cents’. A range of an octave is represented by 1200 cents. Expression of intonation in cents should be taken as a statistical indication and interpretation of its significance needs proper contextual
Graph No.1: Minitonagram
Sa = 22 cents

Graph No.1A: Expanded curve for Sa

Graph No.2: Minitonagram
Sa = 11 cents

Graph No.2A: Expanded curve for Sa
considerations. The criteria of measuring a steady note has been evolved after having comprehended the difficulty associated with accurately measuring 'the ideal pitch' of a note of shorter duration, linked by ascending or descending melodic contexts. In Indian music, glides and undulations are so common that only 10-20% of even the 'alap' section of a performance consists of so called 'steady notes' or the sustained notes. Graphs 1 and 2 represent 'mini-tonagram' showing display of the tonal distribution of a selected section of a melogram. In this mode, scale of representation is enlarged considerably using the programme 'microscope'. From each enlargement, a 'tonagram' is made which is referred to as a 'mini-tonagram'. The peak in the figure indicates the average frequency of the note under consideration. For a given performer, average value of intonation for each occurrence of the given steady note is measured and then averaged out to arrive at a single average value in cents, for that note. Earlier on, the pilot study conducted for raga 'Bhismpalasi' has revealed that pitch measurements for the notes intoned with gamsak, meend etc. show wide range or deviation (Rao et al, 1989, pp. 273-278). The melodic contours of these intonations seem to be musically more significant than their pitch information. Hence, pitch measurements for such intonations have not been attempted, instead their melodic shapes are studied. (*)

Method for working with 'LVS'-system

This process involves creating melodic files of musical data with 'LVS' system on 'VAX' computer first and

(*) :- The expression 'melodic shape' implies pitch in time and does not refer to the form of objects in space
then processing them on Macintosh using 'Pitch-Plotter' programme. This system relies heavily on the powerful computers which require very little manual effort. Melodic files of maximum length 60 sec are created using the same recordings (i.e. Yaman rendered by PA, BJ and AM). Using the pitch-plotter programme, these files can be viewed. The standard screen shows 5 seconds of the file. By clicking and dragging the mouse over a pitch-line, that portion can be analysed. Among the various options that are available in the 'menu', 'analysis' offers two sub-options viz. 'tonagram' and 'selective'. The 'tonagram' gives a plain histogram of all the points plotted in the file. It first comes up with a visual image, followed by numerical statistics. 'Selective' is also a kind of 'tonagram', but it only looks at tones that satisfy a number of conditions. These conditions are set with the 'PARAMS' item including the frame size (in hundreds of a second) and the permitted standard deviation. Thus the information obtained by 'analysis' are average frequency (arithmatic average within the range of each note), standard deviation (the average standard deviation of a note) and weight (the number of times a note with the length set in 'PARAMS' occurs). The visual representation of stability of the note, i.e. weight/standard deviation is also given. Graph 3 shows graphic representation of melody on LVS and graph 4 displays selective tonagram obtained on LVS. In this system, option of using sound is available which is useful for verifying the correct movement, especially after editing a melodic line or by using interpolation.
step = 12 frame = 50 MAX  SD = 25 MAX  Angle = 20

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Graph No. 5: Graphic contours with glitches

Graph No. 6: Edited contour
Graph 5 represents graphic contour of a melody obtained on MMA and graph no. 6 shows its edited version.

For each performer, the pitch data obtained from 'MMA' and 'LVS' analysis are tabulated against the theoretically expected values. From the frequency values corresponding to the individual notes, measurements corresponding to the intervals between the consecutive notes and those having 'fifth' relation, are calculated. The adjacent intervals and 'fifths' in addition to the measurements against the reference of Sa, are calculated to avoid errors that might arise from the instability of the reference tone i.e. Sa, which can get shifted by few cents during the course of the performance and the performer may use the new reference to intone the subsequent tones. In such cases, the subsequent intonations may be judged as 'out of tune', if the 'fifth' are not measured (*). Comparison of the pitch data experimentally obtained using the two independent systems with the theoretically calculated values, has allowed to comment upon the pitch values (corresponding to different tones) conceptualised by the individual performer for the given raga. The pitch data obtained for all the three performers when compared, has allowed to assess the coherence as well as variance in pitch values assumed for different notes by these performers for the given raga.

The pitch data that has been experimentally obtained during the course of present study is also compared with the pitch data obtained by Van der Meer et al (1990) on 'MMA' for the same raga, Yaman. This additional data was

(*) :- For more details, refer to the case of shehnai performance reported by Bel, ISTAR, project # 1, p.58
available for Bhimsen Joshi, Mallikarjun Mansur and Malini Rajurkar. The methods adopted for measuring pitch during the investigation carried out by Van der Meer *et al*, are different from those adopted in the present study. The above scholars have obtained pitch data by employing 'Tonagram' and 'Selective Tonagram' on 'WMA', which gives a histogram for the complete performance without having any consideration for the different note-treatments or contexts, whereas, for the present study, 'mini-tonagram' involving manual measurements of each frame or a given small segment, have been carried out so that intonation could be related to the context. The additional data has proved useful to confirm the pitch data obtained during the present investigation.

Theoretically, the notes comprising the scale of *raga Yaman* and *Marubihag* are the same (*). Hence the pitch-measurements obtained by Van der Meer *et al* (1990) for *raga Marubihag* rendered by PA and BJ, are compared with those obtained for the same performers for *raga Yaman* during the present investigation.

Examination of the pitch lines obtained for the entire performances of PA, BJ and AM has permitted to make observations pertaining to the melodic movement of the *raga Yaman*, as it was expounded by each of these three vocalists. During this process, the melodic graphs are continuously compared with the relevant sections of melody. Factors like; stages through which the *raga* has been expounded, the melodic

(*) :- Strictly speaking, the note *Shuddha Madhyam* which is sparingly used in *Marubihag*, does not figure in *raga Yaman* at all. The variety of *Yaman* that employs this note is called *Yaman-Kalyan*. Barring this difference, the notes used in *Yaman* and *Marubihag* are the same.
centres used, the manner in which each of these centres has been developed, certain common note combinations, different melodic strategies adopted by the performers to create aesthetic atmosphere etc., are enumerated to comprehend the complete progression of the raga in case of these three performers.

Thus, in the present study, pitch-data is experimentally obtained using 'MMA' and 'LVS' system, whereas, the melodic lines obtained from 'MMA' are analysed to understand the various nuances of melodic progression with respect to raga Yaman.