# Carnatic Ragam Thodi – Pitch Analysis of Notes and Gamakams

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## 1.Inttrocuction

1.1 Carnatic music is highly phrase oriented, with movements from note to note or oscillations (gamakams) of a note playing a greater part than the use of steady notes of a particular scale. For computer applications such as generating score or notation from live music or generating synthetic music from notation, ragam identification etc., it is necessary to have a knowledge of the pitch values of the notes and the manner in which the pitch of the melody varies in a phrase or within an oscillated note in a particular ragam. Gaurav Pandey et.al. had tried raga identification of Hindustani ragas using computer analysis of recorded melody [Ref 1]. In this study they have presumed a certain minimum duration of constant pitch for a note, but as may be seen from the pitch graphs in this paper, in Carnatic music the notes may be entirely held as oscillations without any perceptible steady pitch for even a short period. It therefore becomes necessary to charcterise a note on the basis of the entire movement rather than a single pitch. Characterisation of gamakams using quantitative parameters is a difficult task especially in situations where the artist's imagination plays very significant role and wide variations are possible within broad limits.

1.2 An analysis of the gamakams of the Carnatic Ragam Mayamalavagowla using Computer tools was published earlier [Ref 2]. It was found that the ranges and actual end points of oscillations varied considerably, but the mean relative frequencies (r.f.) varied less and came closer to, but mostly below the theoretical r.f. value of the steady note. This article gives the results of Computer analysis of the notes of Carntic ragam Thodi in which the use of steady notes is even less than other ragams. Similar studies with other ragams would be required to evolve general parameters for the 12 notes in different contexts and even for different ragams.

1.3. Thodi is one of the most popular ragams in Carnatic Music. The ragam is classified as the Raganga ragam of the Hanumathodi scale (Melam 8 - equivalent of Bhairavi That of Hindustani music). The notes used are (Carnatic) Suddha Rishabham, Sadharana Gandharam, Suddha Madhyamam, Panchamam, Suddha Dhaivatham and Kaisiki Nishadham (except Madhyamam all are Komal notes in Hindustani system). However, it is one of the ragams where the *bhavam* (mood) cannot be established by the mere notes but by the manner in which they are sung, especially the gamakams associated with the notes. In fact singing the notes in their own positions without gamakam would convey a mood nearer to Sindhubhairavi or the Hndustani Bhairavi than Carnatic Thodi This ragam is characterised by the fluidity of movements giving much scope for individualisation in alapana

1.4. A sample analysis of alapanas in the ragam by the well known musician (late) Srimathi Mani Krishnaswamy and by Sri Seshachari (of Hyderabad brothers) was undertaken using the same Computer tools (with some additions) as in the earlier study on Mayamalavagowla [Ref 2]. A few instances of the music in the krithi 'Kaddanu Vaariki' sung by these 2 artists and another artist (Prema Rangarajan) were also used. The sources of music were commercial CD's

## 2.Gamakams and Fluidity of notes

2.1 An analysis of the alapana of the artist named first above showed that 72% of the duration of the music is in the form of movements i.e. gamakams and movement between notes. The parts which could be considered as steady notes accounted for only 28% of the time. These were also mostly in Shadjam (15%) and Panchamam (9%). Madhyamam, Rishabham and Dhaivatham accounted for a total of 4% only. In the alapana of the accompanying violinist, movements accounted for 56% and in the balance of 44% Shadjam accounted for 31% and Panchamam 4% of the duration and the rest of 9% for the other notes This would imply that assignment of fixed frequencies for the notes is not possible and the notes have to be characterised by other parameters like boundaries of movements, mean frequency, range and the general shape of the movement.. (Also see Ref 4 which uses ‘Melodic Atoms’ to classify notes in Carnatic Music)

2.2 In Thodi the same note can be rendered very differently according to the context. In particular the notes Gandharam and Nishadam have a variety of intonations. The analysis also revealed that in certain phrases where the music is continuously flowing over different pitches with a series of ups and downs, it is even difficult to assign a particular note to parts of the phrase based on frequencies as may be seem in the pitch graph in Fig1.. A carnatic music student would however, easily assign the notation ‘sa ri ga ma pa da ni Saa’ for this clip. The continuous flow of melody over the entire range of notes makes it difficult to pinpoint the start and end of a note for the measurement of mean frequency and range of a gamakam.

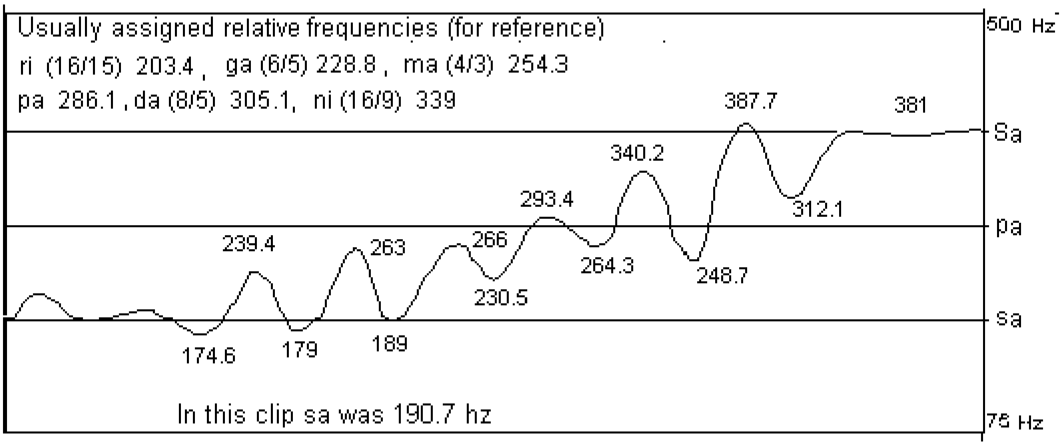



Fig. 1 - The fast phrase sa ri ga ma pa da ni Saa

2.3 Of the 4 notes subjected to extensive gamakam in Thodi, ga and ni have many variations. On theVeena ri and da are often played from sa and pa frets which precede them immediately but may also played on their own frets, The notes ga and ni are generally played from the immediately preceding (by a semitone) frets Chathusruthi Rishabham and Chathusruthi Dhaivatham. As these 2 notes are not present in the scale ga and ni are to be played carefully without conveying the impression of the lower notes.

**3. Analysis Methods**.

3.1 The objective of the study was to analyse the manner in which the 5 notes ri,ga,ma,da and ni are sung i.e. relative frequencies used, ranges of oscillations, anchoring points and shapes. For a discussion of problems of Frequency Estimation see Appendix 3 of Ref 2. The program referred to in Ref 2 written by me was used for Fast Fourier Transform based frequency estimation and generating graphs. In addition the excellent freeware program ‘Praat’ written by Paul Boersma and David Weenink [Ref. 3] was used. In this program Pitch is estimated by Autocorrelation method, which unlike the Fourier Transform method, basically aims at establishing the periodicity of the signal rather than the frequency components. In uncomplicated simple sounds these two are identical, but in the presence of other sounds (like the thamboora, the accompanying violin etc.) the results could be different. In some cases while Praat is unable to indicate a pitch, the Fourier Transform is able to show frequencies from which the pitch could be arrived at.

3.2. Frequency Averaging: In Ref 2 it was suggested that the impression of pitch conveyed by an oscillated note may be related to the mean frequency over the period of the gamakam.. Measuring the mean is quite easy in the case of gamakam of a note which is anchored on another steady note (as ri is anchored on sa in Mayamalavagowla), the starting and ending points of the oscillation being the anchor. This approach was often not possible in this study (as the pitch graph of Fig 1 would show). In the case of an upward movement the averaging could be on the segment starting with the point where the upward movement begins and up to the downward end point as in Fig 2 below This could however, give distorted results since even steady notes are often reached from below and part of the initial upward movement is only to reach the required note and not part of the gamakam.

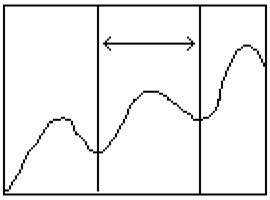


Fig 2

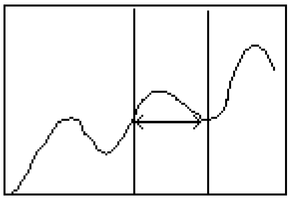


Fig 3

It would be more appropriate in such a case to take average over a range with the same starting and ending frequencies as in Fig 3. However, in cases where the lowering of pitch from the previous note before going to the next note was deliberate, the mean has to be taken as indicated in Fig 2. For the Clip in Fig 1, means taken from minimum to minimum were nearer theoretical values for ri, ma, da and ni while means taken as in Fig 3 was nearer in the case of ga. Even small changes in the positions of the end points could give very different mean pitch values and the values mentioned here have to be taken as indicative rather than precise.

3.3 The findings for each of the 5 notes ri,ga,ma,da and ni are briefly described below with selected illustrations of the pitch graphs. A tabular summary of the findings is given in the annexure. Much more data was collected than detailed here and in the tables in the annexure. Selected examples have been given in the text of the article, figures and the tables. In all cases cyclic cent values are given for the relative frequencies as they give a better appreciation of the pitch position.

## 4.Suddha Rishabham

4.1 This note is often held for a short period in passing to another note. A few cases of prolonged and almost plain note or sliding up from sa were noticed. When held in passing the note is mostly sung as a single oscillation from sa or from a lower position The note is also often paired (Janta) with a consonant like 'ta' or 'na' in between, in the alapana. The shape and frequencies vary according the context.

4.2 The relative frequencies generally assigned to Suddha Rishabham are 16/15 (112 cemts) or a comma less (90 cents). In the equally tempered scale it would be 100 cents. In this study for the notes which are reasonably steady, the mean relative frequencies (r.f.) with reference to sa varied from about 70 cents to 99 cents. R.f of 91 cents for a duration of 215 ms (Fig 5) and another lasting 300 ms with r.f. of 93 cents were found. R.f of 1261 cents (upper octave equivalent to 61 cents) for 275 ms was observed in a phrase in the krithi where the artist wanted to express softness. These indicate that even in notes not having extensive gamakam there is considerable variation in pitch but generally the pitch was in the region 75 to100 cents for longer steady notes.

4.3 Fig 4 is an example of the pitch graph of ri held in 3 different manners (with ga in between). The first and the last ri's sound plain. Fig 5 shows one quick oscillation and one almost plain ri held for 220 ms

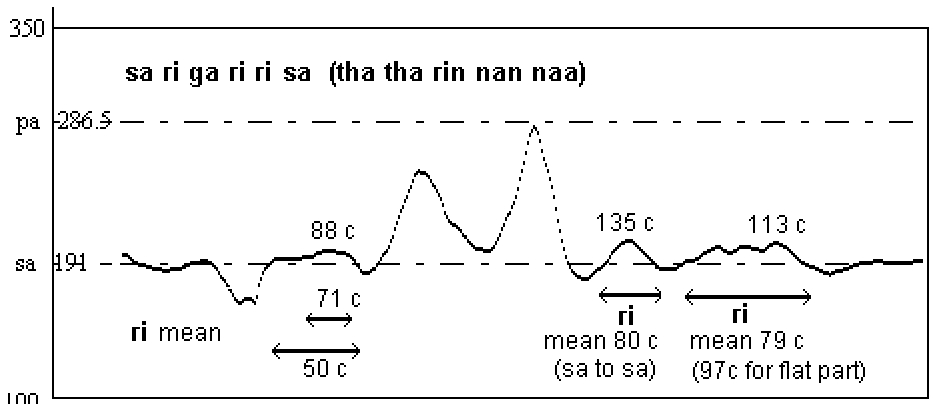



Fig. 4

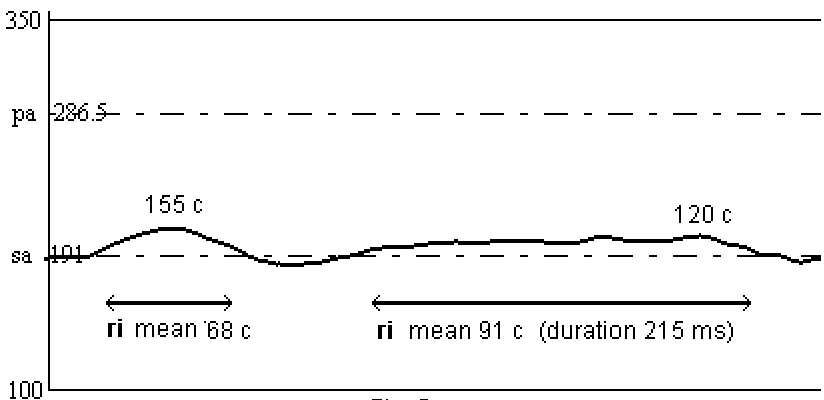



Fig. 5

4.4 Oscillated notes: True slow oscillations of ri (as in Saveri or Poorvikalyani) are not common in Thodi. Most of the ri notes touched in passing consisted of single quick upward oscillations and the mean r.f's (calculated from sa to sa or sa to trough if trough was higher) varied from 60 cents to 135 cents. Mean r.f's in upward phrases tended to be higher than elsewhere. The r.f's of over 90 cents were found only in upward phrases and lower ones found both in upward, downward and turning phrases. An example of high mean r.f (113 c) is given in Fig 6. An example of low mean r.f is the first ri in Fig 5 above .This would be even lower if the mean was taken from minimum to minimum. Another example showing the difference in means between upward and downward movements is in Fig 7 where the mean in the upward movement is 135 cents and the mean in the downward movement is 89 cents but this is not a universal phenomenon. The mean in the upward movement would be found to be lower if measured from trough to trough

4.5 However, irrespective of the mean r.f., practically all the maxima in the oscillations were far above 100 cents - mostly above 150 cents and in many cases even above 204 cents (i.e., above Chathusruthi Rishabham point). This type of shooting far beyond the r.f. of even the next semitone is noted in the cases of other notes in this study (see ga in Fig 6.). This phenomenon was already noted in the analysis of Mayamalavagowla [Ref 2]. In many cases the note also started from a point below sa (even in a downward movement) as in Fig. 4 and Fig 7. In these cases the means would be even lower if taken from trough to trough which well below sa.

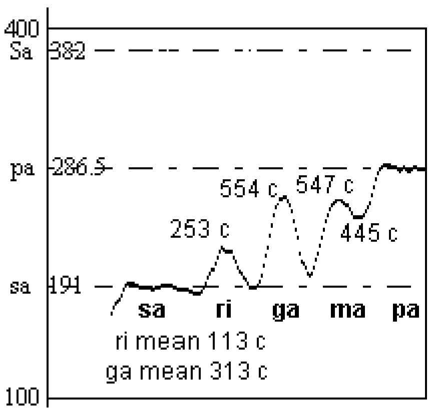


Fig 6

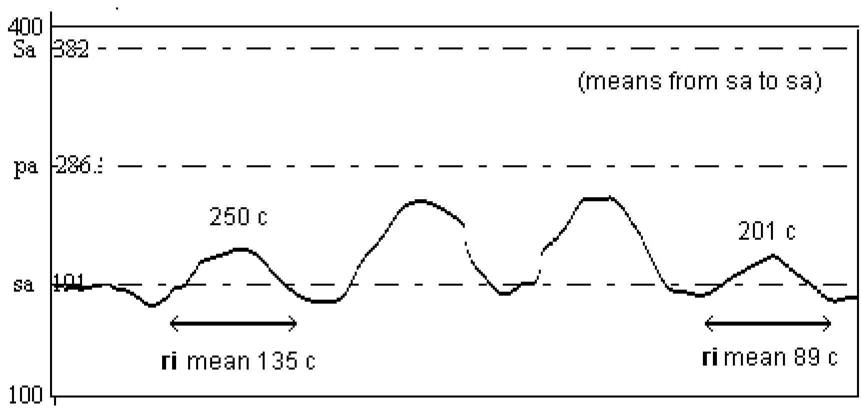


Fig 7

4.6 Though true multiple oscillations of ri are not common, a few were found. The voice tended to go below sa between oscillations (Figs 8 and 9). Because of this the mean r.f.'s. if measured up to the trough were quite low (around 50 cents) while when measured from sa to sa they were higher. This is indicated in Fig. 8 (Deduct 1200 to get middle octave values). For the 2 oscillations in Fig. 9 if areas below sa are excluded the means would be 70 cents and 80 cents. The maxima however, went above 100 cents - up to around 150 cents

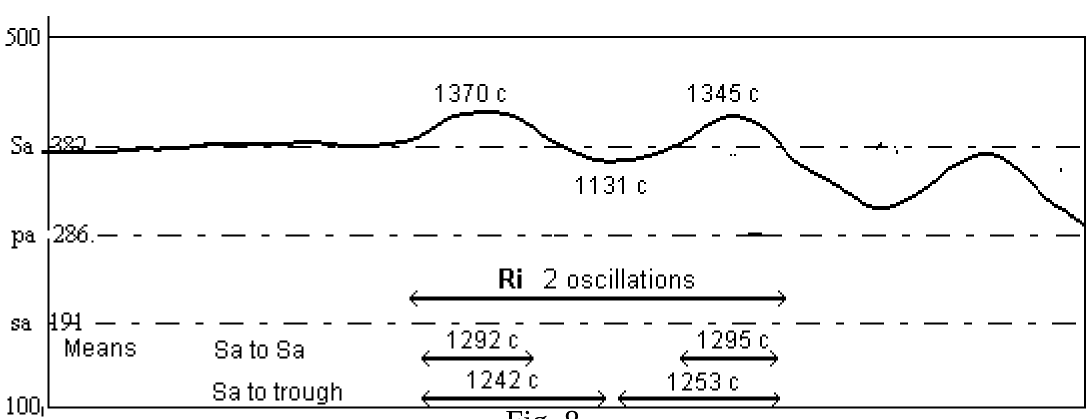


Fig. 8

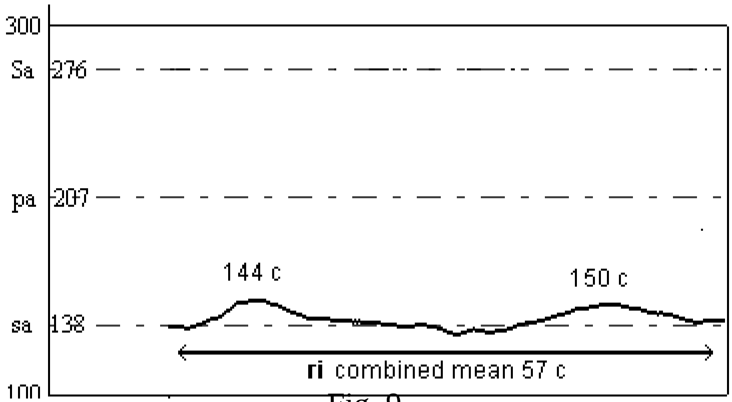



Fig. 9

**5. Saadharana Gaandhaaram**

5.1  The relative frequencies generally assigned to this note are 6/5 (316 cents) or a comma less (292 cents) and in equally tempered scale 300 cents. In Thodi this note is rarely held without gamakam. The oscillations are generally wide and often up to 4 oscillations are seen except in fast upward movements where a single oscillation is used. Occasionally in the phrase sa ri ga - ri ga ma - ga ma pa an impression of short steady note is conveyed but even this is found with a reverse gamakam For the ga notes with gamakam found in this study, the mean relative frequencies varied from 243 cents to 368 cents. (The alapana of Sri Seshachari figured more in the higher means.). The lowest mean r.f  of 243 cents was found in the phrase 'da da Gaa Ri' with Gaa in the upper octave (Fig 11), trying to impart a softer touch and held comparatively for a longer duration of 400 ms. The lower r.f’s were found mostly in phrases ending in gaa without stressing ma or in descending phrases. Higher r.f’s were found in quick upward movements or movements in which at the end of the phrase ma was held or quickly touched before going to another note,. This is only a general observation and there were many exceptions. Actually the wide variation in mean relative frequencies could not be fully correlated with any factor like duration, upward or downward movement, indicating that the artist chose to convey the sense of a higher or lower pitch according to his 'manodharma'.. The only consistent finding was that the mean r.f. tended to be higher than 300 in fast upward movements.

5.2 An example of single oscillation of ga  in upward movement is in Fig 6 above. This is a very wide oscillation with a range of about 550 cents but the mean was 313 c An example of ga oscillated thrice is in Fig. 10 and another with low mean r.f. at the higher octave is in Fig 11. Reduced to the middle octave this is 253 cents.

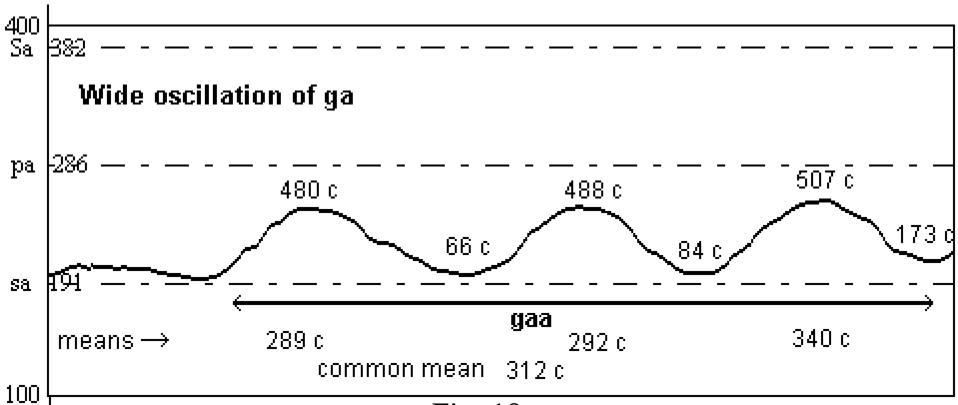



Fig. 10

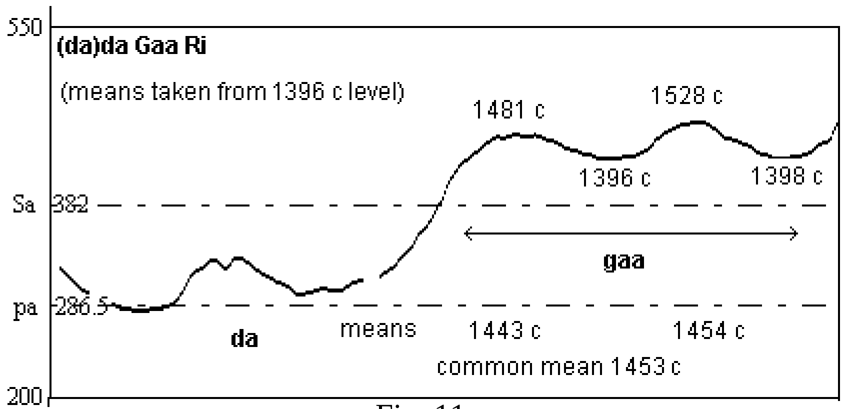


Fig. 11

5.3 Fig 11 is an example where the note rises from far below and so the mean is taken from the level of the next trough. (1200 cents is to be subtracted from the values to get the corresponding middle octave r.f.)

5.4 On the Veena this note is generally played by deflecting the string from the Chathusruthi Rishabham fret and so the minimum point could be expected to be around 200 cents. In the samples of vocal music analysed for this study the minimum point varied from 41 cents to 200 cents i.e. in most cases the note started below the Chathusruthi Rishabham. The maximum limit of the oscillation varied from 384 cents to 616 cents i.e. well above the normal Sadharana Gaandharam position of around 300 cents and above even the Suddha Madhyamam position of around 500 cents. The range of oscillation also varied from 85 cents to 580 cents. The wide variation in parameters indicates the variety of expressions that can be conveyed by the gamakam on this note. (However, also see para. 10.3 below)

**6. Suddha Madhyamam**:

6.1 The relative frequency of natural Suddha Madyamam is 4/3 (498 cents). In Thodi this note is often oscillated once in quick upward movements. Elsewhere (mostly in the descent) it is held for short durations (300 ms) without gamakam. Prolonged steady Madhyamam in Thodi is found in some compositions and in alapanas.

6.2 In upward movements with single oscillation the mean r.f's tended to be around 500 cents and the ranges were around 230 cents. The maxima as in the cases of other notes went well above 500 cents, upto 620 cents in one case and 580 cents in another case. The minimum point of the oscillation (reached before proceeding to panchamam) were around 380 cents (near Anthara Gaandharam).

6.3. In the case of steady notes, for one artist the relative frequencies in 3 different places were found to be 488,489 and 496 cents while those of another were found at 498 and 517 cents (6/5 is 498 cents). Like other steady notes there was fluctuations within the note ranging from 25 to 72 cents. In many cases the range was more than the fluctuations in Shadjam or Panchamam (of around 30 cents)

6.4 Graphical illustrations of the oscillated Madhyamam in the ascent may be seen in Fig. 6 above and Fig 12 below. In Fig.12 although the maxima of ga and ma are same, the mean for ga is 346 cents (6/5 equals 316 cents) while that of ma is 505 cents taken in the manner illustrated in Fig 3. Occasionally the top of the oscillation is somewhat flatter than in these 2 figures. More steady

Madhyamams (including cases in the ascent) were found in the violin accompaniment.

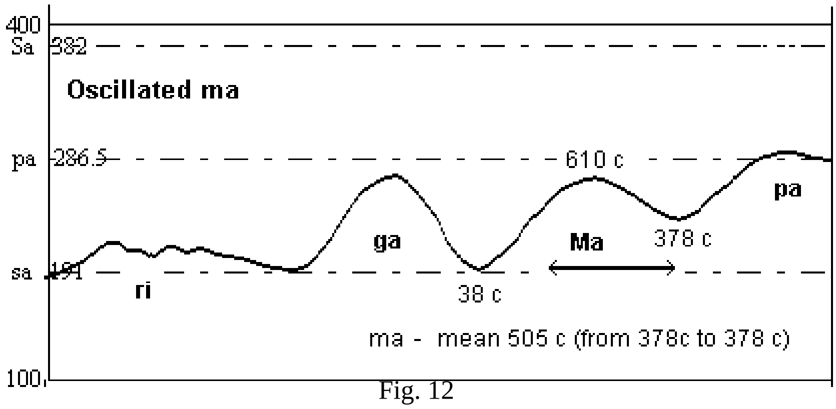



Fig. 12

In the descent, however, the madhyamam even when touched for short periods is held straight or occasionally with movements over narrow ranges.

**7. Suddha Dhaivatham**

7.1 The relative frequency usually assigned to this note is 8/5 (814 cents) or a comma less (792 cents) and 800 cents in equally tempered scale. In Thodi this note is often held as an oscillation from around pa but also held as a steady note. In this study in oscillated notes the mean r.f. varied from 743 cents to 822 cents. Lower mean r.f. were seen in phrases with slow lingering oscillations and phrases which did not reach thaara Shadjam (Fig. 13). True slow oscillations of da were found (which was less common in ri). Higher mean r.f's were noted in phrases like '(pa) da daa (ni Sa)' which emphasised on da (Fig. 14) or in phrases in which the oscillations were anchored on the upper boundary (Fig 15 The kinks at the top of each oscillation represent the consonants and anchoring there). As in the case of Rishabham the maximua of the oscillated notes went above the theoretical value of 814 cents (8/5), in some cases even above Chatusruthi Dhaivatham (5/3 or 884 cents and 27/16 or 906 cents)

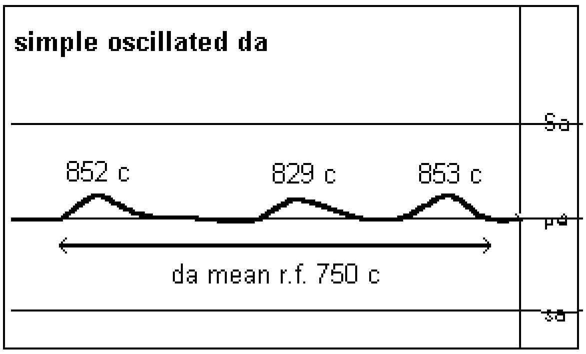



Fig. 13

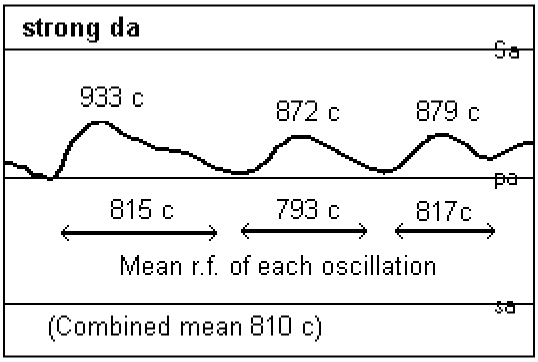



Fig 14

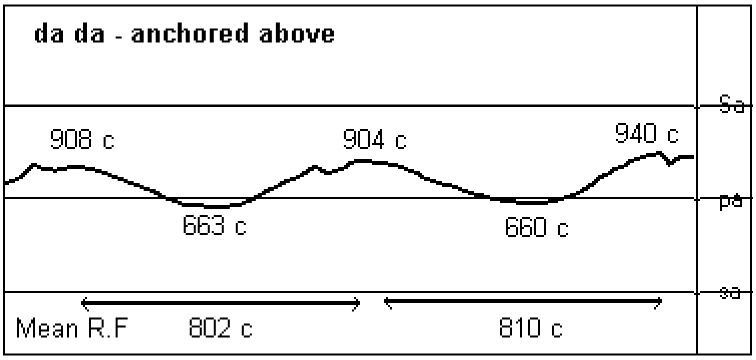



Fig 15

7.2 In steady notes the mean r.f's varied from 777 cents to 795 cents

**8. Kaisiki Nishadam**

8.1 The relative frequencies assigned to this note are 16/9 (996 cents) or a comma higher (1018) cents and sometimes 7/4 (969 cents) and 1000 cents in equally tempered scale. This note is invariably held with gamakam in Thodi and even apparently steady notes (often held as janta 'ni ni') were found to be oscillated. The mean relative frequencies found in the study varied from 930 cents to 1066 cents. The range of oscillations varied from 113 cents to 486 cents. Different means were found in the same note when oscillated 3 or 4 times. The r.f. of the 3rd or 4th oscillation is found to be higher, as a result of the peak being higher.(Figs 16 and 17 which are from different artists). The two pitch graphs look very similar in shape though differing in actual r.f's. In Fig 17 the mean r.f for the third oscillation is found to be 1223 cents (higher than thara Shadjam) suggesting that this could be a quick touch of Sa rather than a gamakam of ni.. In Fig.16 the mean r.f.'s of the first 2 oscillations are nearer the value for Chathsruthi Dhaivatham and may be considered as quick touches of ni but for notation it would be classified only as ni.

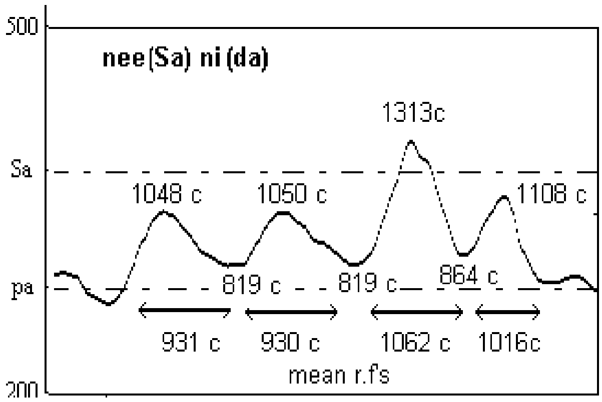



Fig. 16

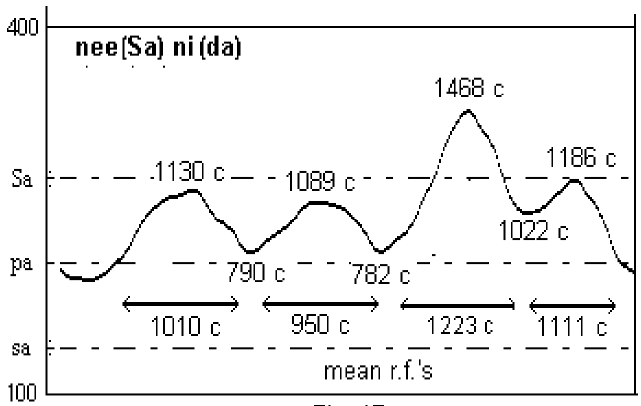



Fig. 17

The ranges of oscillations in the above vary from 229 cents in Fig 16 to 340 cents in Fig.17. Deliberate wider oscillations with the ranges around 400 cents are also seen corresponding to similar oscillations in ga (Figs 18 and 19 again from different artists)

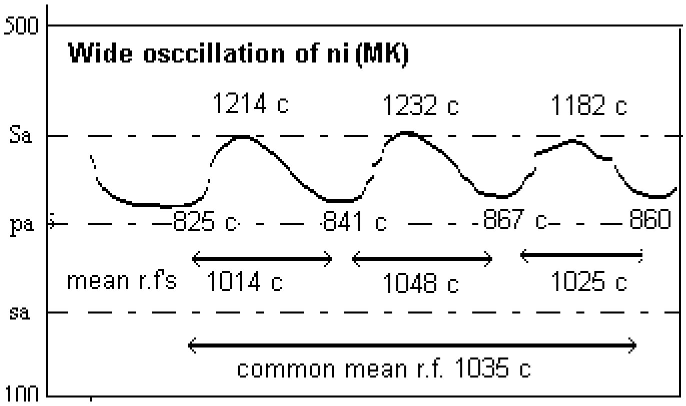



Fig 18

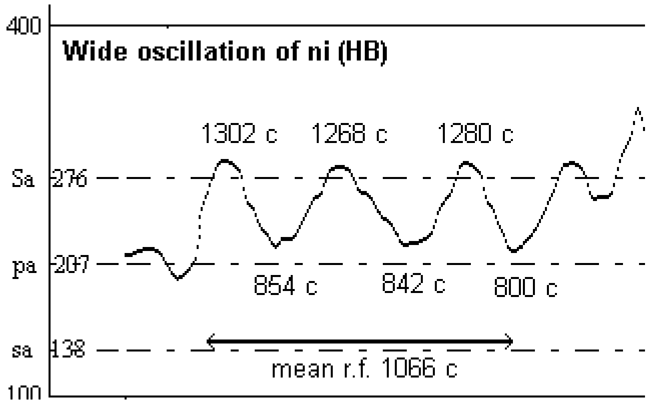



Fig. 19

8.2 On the Veena these wide oscillations would be played on the Chathusruthi Dhaivatham fret by deflecting the string up to about the Sa positon. In the vocal recordings illustrated above the lower point is well below Chathusruthi Dhaivatham (900 cents) and the higher reaches are in some cases well above thara Shadjam

8.3 An oscillation of nishadam anchored on sa can be seen in Fig 20

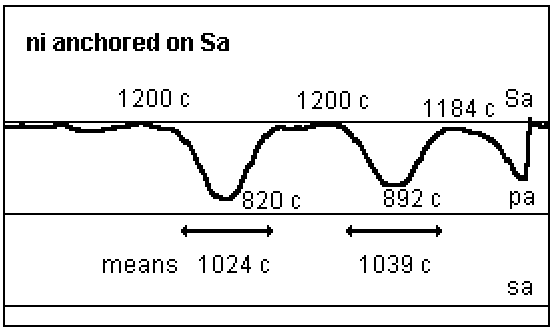
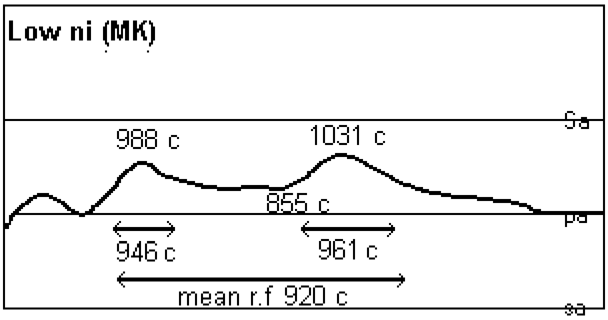



Fig 20

8.4 A low pitched Nishadham held as a reverse oscillation with a slight increase in the middle is found in the alapana of both the artists with similar shapes (Figs 21 and 22)

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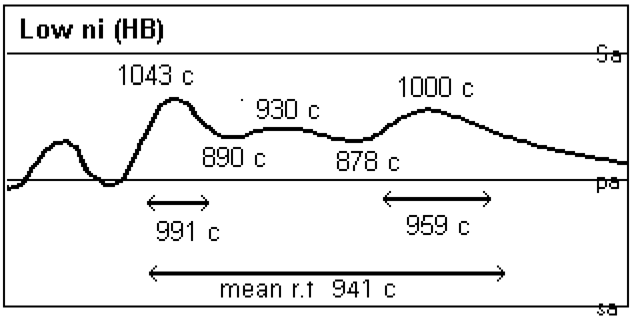


Fig 22

**9. Similarity in pitch curve shapes**

The above analysis would show that the actual relative frequency values of notes vary considerably for the same note, both in the mean values and the limits of the oscillations. This raises the question of how a particular note with gamakam is recognized. The pairs of figures above (Figs 16 - 17 and Figs 21 - 22) show that despite difference in actual relative frequencies there is similarity in shape. Many more such similar shapes were observed when comparing the pitch graphs renderings of different artists for the same phrase and when comparing the shapes of the pitch graphs of a phrase sung by a vocalist and that of the accompanying violinist (who in the carnatic style of alapana often repeats the vocalist's short phrase after the vocalist). Some examples are given below. The similarity is more pronounced while singing a krithi where the basic tune is well defined.

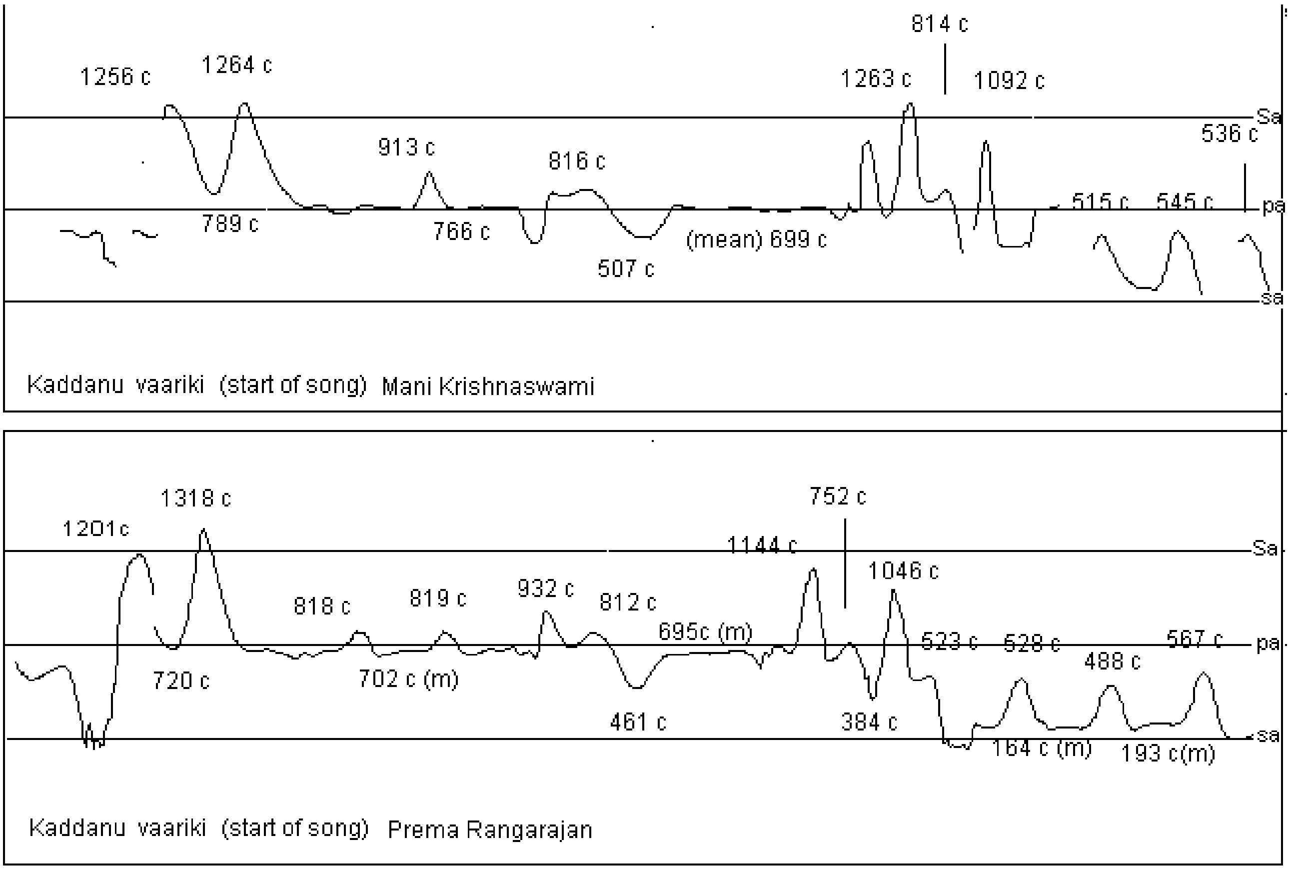


Fig. 23

Fig 23 is the start of the krithi 'Kaddanu Variki' and Fig 24 is a phrase in anupallavi of the same krithi. The pitch graphs of rendering by two different artists show close resemblance in shape while the actual relative frequencies are different.

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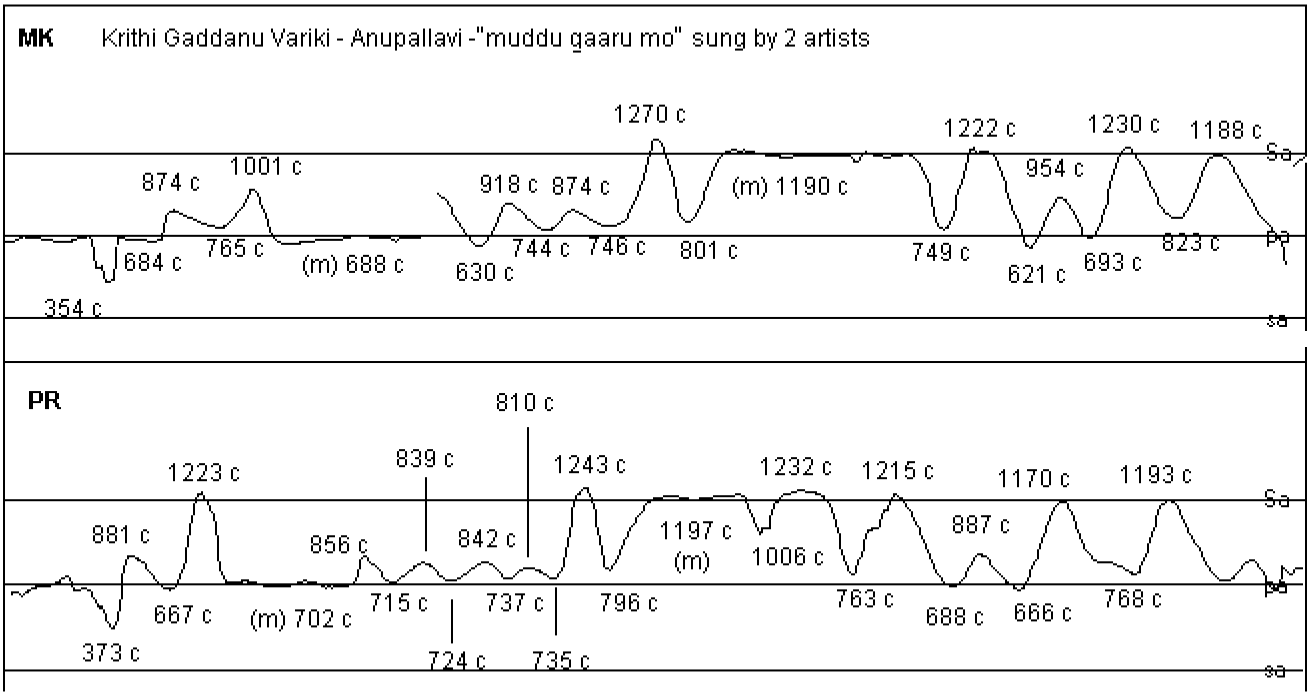


Fig. 24

Fig 24 is the pitch graph of a phrase in the alapana sung by the vocalist followed by the repetition of the same by the violinist. The shapes are similar but the range of the gamakam are less in the case of the violinist (which was also noticed in other places in this study and in the analysis of Mayamalavagowla earlier in Ref 2)

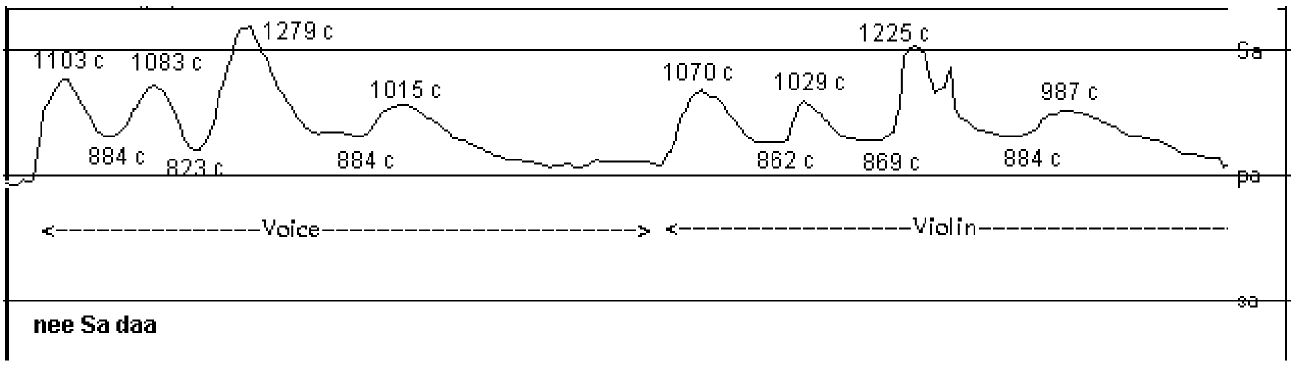


Fig. 25

## 10. Conclusions:

10.1 The study has covered the intonation of notes used in the carnatic ragam Thodi. The notes ri, ga ,da and ni are generally held with gamakam and therefore cannot be characterised by a single relative frequency value. The mean relative frequency can be an indicator of the pitch sensation conveyed. However, calculating the mean relative frequencies was also a problem as it was difficult to assign correctly the start and end points of a note in a continuous gamakam filled flowing phrase.

10.2 It was found that the range of oscillations and the relative frequencies of the limits of the oscillations of pitch varied considerably among artists and in different contexts for the same artist. The mean relative frequency values also varied but to a lower extent, more often being below the theoretical values ascribed to the steady note. The upper limits of the gamakams in most cases went far above the theoretical r.f of the notes and in some case even above the r.f. of the next semitone. Certain characteristic shapes were noticed for similar phrases sung by the two artists studied and these were more pronounced in the singing of the krithi. These pitch curves of similar shapes conveyed similar musical expression in spite of the actual relative frequencies being different. Thus a combination of the mean relative frequencies (within a certain range) and characteristic shapes of the pitch contours appear to characterise the phrases in the raagam leading to quick recognition or identification.

10.3 One possible reason for wider ranges in the voice compared to the violin and the reason for the voice reaching far above the note’s theoretical frequency (or going well below the anchor note) could be the time delay involved in the feed back mechanism of musical voice production. Another study (under way and yet to be published) appears to indicate that this feed back mechanism could also explain the variations in steady notes if we apply the concept of Just Noticeable Difference in pitch (JND)

10.4 The study covered in this article and the earlier one on Mayamalavagowla, were of Carnatic ragams where extensive gamakams were applied to the 'black notes' (i.e.notes other than those in the Dheerasnkarabharanam scale or Bilawal that) such as Suddha Rishabham, Kaisikin Nishadham etc. or in the case of Mayamalavagowla, 'white notes’ (ga and ni) juxtaposed to another note separated by a semitone. Studies are also required for ragams having large number of 'white notes' separated by 2 semitones from the adjacent note, such as Kalyani, Mohanam etc. where the notes are held both as steady notes and with gamakam which may be short or large in range. When there is a large or short range gamakam (say) in the Dhaivatham of Mohanam the mean relative frequency within the oscillation is bound to be higher than the expected value for Dhaivatham, since in such cases the main note itself is the lower limit (unlike in the case of 'black notes' where generally the next lower 'white note' is the lower limit). Only after a study of such ragams are made could a reasonably accurate method for assignment of notes to a phrase by computer analysis could be attempted.

## Annexure (Some Examples)

(R.F. Relative Frequency.  Osc. Oscillation)

**Rishabham**

| | Context | Dura-tion -Milli- | Num of Oscil- | Mean Relative Frequency. | | Rang | Maxi- R.F | Mini- R.F. | Figure reference and Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Indivi-du osc. | Com-mon | | | | |
| **Plain ri** | | | | | | | | | |
| 1 | (sa) ri (sa) | 175 | | 97 | | 40 | 117 | 77 | Fig 4. Mean is fo the flat part |
| 2 | (sa) ri (sa) | 240 | | 99 | | 41 | 120 | 79 | |
| 3 | Violin fol-lowing 2 | 280 | | 74 | | 12 | 92 | 80 | |
| 4 | (ga ri) ree (gaa) | 230 | | 74 | | 42 | 124 | 82 | |
| 5 | Ree (Gaa) | 450 | | 93 | | 28 | 113 | 85 | |
| 6 | sa ree sa | 275 | | 96 | | 31 | 116 | 85 | |
| 7 | Sa Ree Sa | 275 | | 61 | | 32 | 78 | 46 | From Krithi |
| **Oscillated ri** | | | | | | | | | |
| 8 | (sa) ri (ga ri) | 160 | 1 | 50 | | 135 | 88 | -47 | Fig 4 first osc. |
| 9 | (sa ri ga) ri | 100 | 1 | 80 | | 130 | 130 | 0 | Fig 4 third osc. |
| 10 | (ga) ri (ree) | 125 | 1 | 89 | | 172 | 173 | 0 | Fig 5 |
| 11 | (sa) ri (ga ma) | 175 | 1 | 113 | | 286 | 286 | 0 | Fig 6 |
| 12 | (sa)ri (ga ma gaa) | 125 | 1 | 135 | | 235 | 235 | 0 | Fig 7. first osc. |
| 13 | (Saa Ri) daa | 90 | 2 | 92 | 60 | 239 | 170 | -69 | Fig 8. Common mean includes ar below Sa betwee the oscillations |
| | | 50 | | 95 | | 214 | 145 | -69 | |
| 14 | (ma)ri ri(ree ga) | 160 | 2 | 65/82 | 60/74 | 138/2 | 150 | 12/-5 | Fig 9 Lower r.f values include ar below sa. |
| | -do- 2nd osc. | 150 | | 60/66 | | 117/1 | 129 | 12/-2 | |

## Annexure (Continued)

### Gaandhaaram

| | Context | Dura-tion Milli-s | Nu of Osc | Mean Relative Frequency. | | Range | Maxi R.F | Mini R.F. | Comments and Reference to Figures in the article |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Indivi-osc. | Com-mon | | | | |
| **In fast upward movement** | | | | | | | | | |
| 1 | (sa ri) ga(ma) | 145 | 1 | 307 | | 581 | 616 | 65 | |
| 2 | (sa ri) ga(ma) | 90 | 1 | 348 | | 468 | 500 | 32 | |
| 3 | (sa ri) ga(ma) | 310 | 1 | 341 | | 520 | 561 | 41 | Mean is 293 c if taken from trough (-35) to trough (41) |
| **Longer ga** | | | | | | | | | |
| 4 | (sa ri)gaa gaa | 275 | 3 | 289 | 312 | 414 | 480 | 66 | Fig 10 |
| | -do- 2nd osc. | 235 | | 292 | | 412 | 488 | 66 | |
| | -do- 3rd osc. | 225 | | 340 | | 423 | 507 | 84 | |
| 5 | (da da)Gaa (Ri) | 450 | 2 | 243 | 249 | 85 | 281 | 196 | Fig 11. Values reduced to middle octave |
| | -do- 2nd osc. | 295 | | 254 | | 132 | 328 | 196 | |
| 6 | sa ri gaa gaa | 230 | 5 | 355 | 348 | 307 | 506 | 199 | |
| | -do- 2nd osc.. | 230 | | 330 | | 363 | 539 | 176 | |
| | -do- 3rd osc. | 220 | | 330 | | 368 | 509 | 141 | |
| | -do- 4th osc. | 175 | | 349 | | 456 | 577 | 121 | |
| | -do- 5th osc. | 160 | | 369 | | 496 | 617 | 121 | |
| 7 | da pa ma gaa | 370 | 2 | 324 | 333 | 399 | 536 | 137 | |
| 8 | -do- 2nd osc. | 270 | | 365 | | 376 | 513 | 137 | |
| 9 | pa ma gaa | 275 | 2 | 352 | 330 | 314 | 501 | 187 | |
| | -do- 2nd osc. | 260 | | 334 | | 332 | 519 | 187 | |

## Annexure (Continued)

**Dhaivatham**

| | Context | Dura-tion Milli-s | Nu of Osc. | Mean Relative Frequency. | | Range | Maxi R.F | Mini R.F. | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Indivi osc. | Com-mon | | | | |
| **Plain da** | | | | | | | | | |
| 1 | (pa) daa (paa) | 215 | | 776 | | 22 | 783 | 761 | |
| 2 | (pa) daa (paa) | 145 | | 795 | | 14 | 812 | 798 | |
| 3 | (ma pa)daa(pa | 295 | | 796 | | 40 | 811 | 769 | Rising slowly |
| **Oscillated da** | | | | | | | | | |
| 4 | (pa)daa.. | 200 | 3 | 767 | 750 | 143 | 852 | 709 | Fig13 |
| | -do- 2nd oscillation | 235 | | 763 | | 120 | 829 | 709 | |
| | -do- 3rd oscillation | 215 | | 743 | | 138 | 853 | 715 | |
| 5 | Violin following above | 160 | 2 | 750 | 735 | 93 | 800 | 707 | |
| | -do- 2nd oscillation. | 150 | | 744 | | 53 | 754 | 707 | |
| | -do- 3rd oscillation | 130 | | 733 | | 55 | 757 | 702 | |
| 6 | (pa)da(ni Sa) | 265 | 3 | 815 | 810 | 216 | 933 | 717 | Fig 14 |
| | -do- 2nd oscillation. | 200 | | 793 | | 155 | 872 | 717 | |
| | -do- 3rd oscillation | 140 | | 817 | | 148 | 879 | 727 | |
| 7 | (pa)daa(ni da) | 220 | 2 | 758 | 769 | 136 | 836 | 700 | |
| | -do- 2nd oscillation. | 180 | | 778 | | 164 | 908 | 695 | |
| 8 | da da (Gaa Ri) Anchored above | 320 | 2 | 802 | 806 | 245 | 908 | 663 | Fig 15 |
| | -do- 2nd oscillation. | 300 | | 810 | | 280 | 940 | 660 | |

## Annexure (Continued)

**Nishaadham**

| | Context | Dura-tion Milli-s | Num of Osc. | Mean Relative Frequency. | | Range | Maxi-R.F | Mini-R.F. | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Indi-v | Com-mon | | | | |
| **In upward movement** | | | | | | | | | |
| 1 | (da) ni ni (Sa daa) | 145 | 4 | 931 | 973 | 129 | 1048 | 819 | Fig 16. |
| | -do- 2nd oscillation | 210 | | 930 | | 131 | 1050 | 819 | |
| | -do- 3rd oscillation | 75 | | 1062 | | 449 | 1313 | 864 | |
| | -do- 4th oscillation | 140 | | 1016 | | 234 | 1108 | 864 | |
| 2 | (pa da) ni ni (daa) | 220 | 2 | 991 | 991 | 342 | 1164 | 818 | |
| | -do- 2nd oscillation | 200 | | 991 | | 352 | 1174 | 818 | |
| 3 | ni ni (Sa) ni (da) | 140 | 2 | 1010 | 986 | 340 | 1130 | 790 | Fig 17 (fir 2 osc..) |
| | -do- 2nd oscillation | 115 | | 950 | | 307 | 1089 | 782 | |
| | -do- osc. after Sa | 95 | 1 | 1111 | | 64 | 1186 | 1022 | Fig 17 Las oscillation |
| **Wide Oscillation** | | | | | | | | | |
| 4 | nee nee | 280 | 3 | 1014 | 1035 | 389 | 1214 | 825 | Fig 18 |
| | -do- 2nd oscillation | 290 | | 1048 | | 391 | 1232 | 841 | |
| | -do- 3rd oscillation | 275 | | 1025 | | 322 | 1182 | 860 | |
| 5 | nee nee | 180 | 3 | 1127 | 1066 | 448 | 1302 | 854 | Fig 19 |
| | -do- 2nd oscillation | 230 | | 1049 | | 426 | 1268 | 842 | |
| | -do- 3rd oscillation | 175 | | 1051 | | 480 | 1280 | 800 | |
| **Anchored above on Sa** | | | | | | | | | |
| 6 | ni – ni | 225 | 2 | 1024 | 1074* | 380 | 1200 | 820 | Fig 20 |
| | -do- 2nd oscillation | 265 | | 1039 | | 292 | 1184 | 892 | |
| **Conveying low pitch** | | | | | | | | | |
| 7 | (da) nee (da) | 280 | 2 | 946 | 920** | 133 | 988 | 855 | Fig 21 |
| | -do- 2nd oscillation | 325 | | 961 | | 176 | 1031 | 855 | |
| 8 | (da) nee (da) | 130 | 2 | 991 | 941** | 153 | 1043 | 890 | Fig 22 |
| | -do- 2nd oscillation | 130 | | 959 | | 122 | 1000 | 878 | |

* Voice remained at the higher limit for considerable duration between the 2 oscillations and hence the common mean is higher than the 2 means
** Voice remained at the lower limit for considerable duration between the 2 oscillations and hence common mean is less than the 2 means

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