

Carnatic Ragam Thodi: Pitch Analysis of Notes and Gamakams

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Introduction

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 characterize a note on the basis of the entire movement rather than a single pitch. Characterization of gamakams using quantitative parameters is a difficult task especially in situations where the artist's imagination plays a 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 Carnatic 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 to 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 the 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 Hindustani Bhairavi than Carnatic Thodi. This ragam is characterized by fluidity of movements, giving much scope for individualization in alapana.

1.4 A sample analysis of alapanas in the ragam by the well-known musician, the late Mani Krishnaswamy, and by Sri Seshachari (of the 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 two artists and another artist (Prema Rangarajan) were also used. The sources of music were commercial CDs.

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; the rest 9% was taken up by the other notes. This would imply that assignment of fixed frequencies for the notes is not possible and the notes have to be characterized 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 seen in the pitch graph in Fig 1. 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.

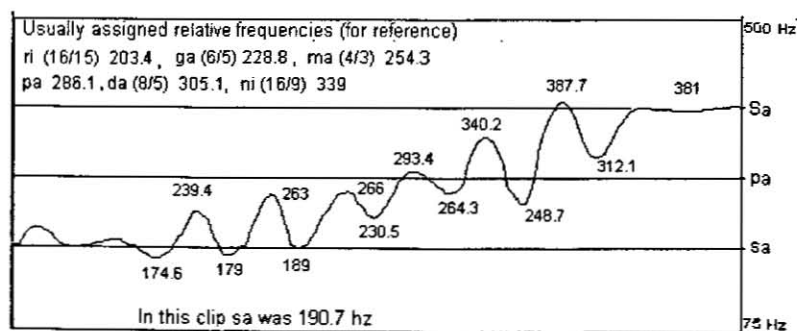


Fig. 1. The fast phrase sa ri ga ma pa da ni Saa

2.3 Of the four notes subjected to extensive gamakam in Thodi, ga and ni have many variations. On the Veena, ri and da are often played from sa and pa frets which precede them immediately but may also be 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 two 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 five 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.

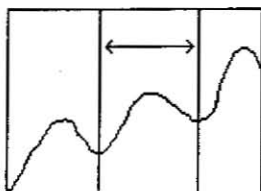


Fig. 2

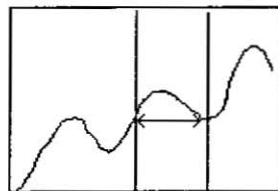


Fig. 3

It would be more appropriate in such a case to take the 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, the means taken from minimum to minimum were nearer to 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, so the values mentioned here have to be taken as indicative rather than precise.

3.3 The findings for each of the five 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 positions.

4. *Suddha Rishabham*

4.1 This note is often held for a short period while passing over to another note. A few cases of prolonged and almost plain note or the same note 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 to the context.

4.2 The relative frequencies generally assigned to Suddha Rishabham are 16/15 (112 cents) 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 to 100 cents for longer steady notes.

4.3 Fig. 4 is an example of the pitch graph of ri held in three 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

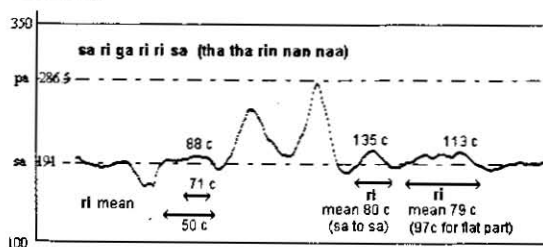


Fig. 4

CARNATIC RAGAM THODI

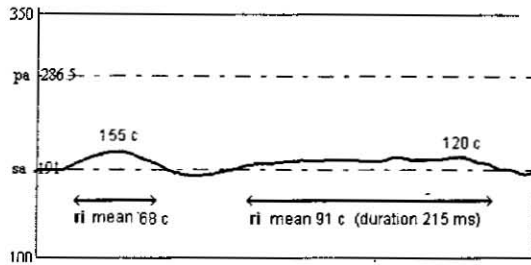


Fig. 5

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 r.f.s were found 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 the 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 is well below sa.

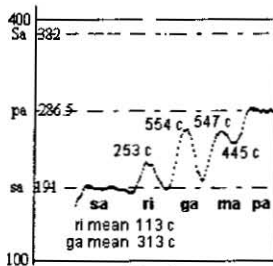


Fig. 6

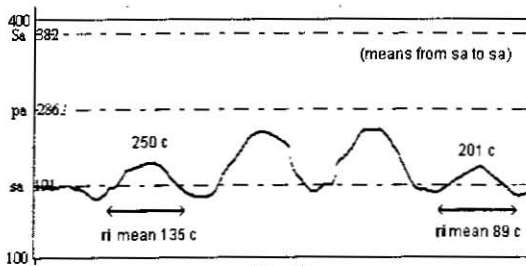


Fig. 7

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 two 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.

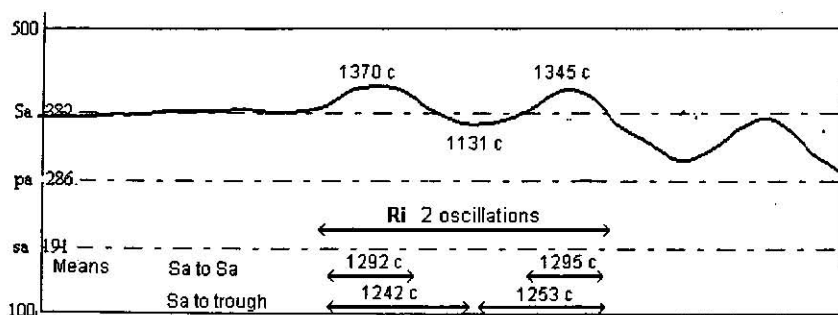


Fig. 8

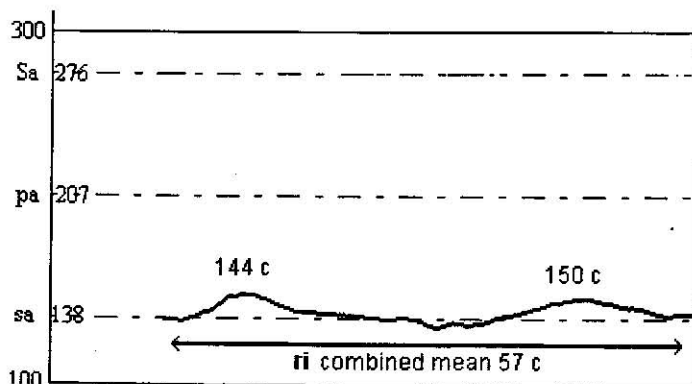


Fig. 9

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 the equally tempered scale 300 cents. In Thodi this note is rarely held without gamakam. The oscillations are generally wide and often up to four 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), imparting a softer touch and held for a comparatively 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 on 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 may be seen in Fig. 6 above. This is a very wide oscillation with a range of about 550 cents but the mean was 313 cents. 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.

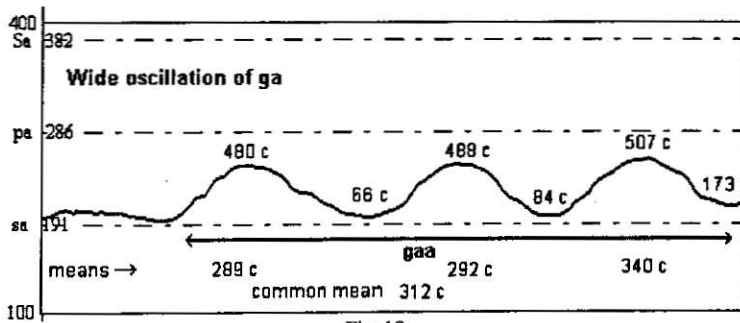


Fig. 10

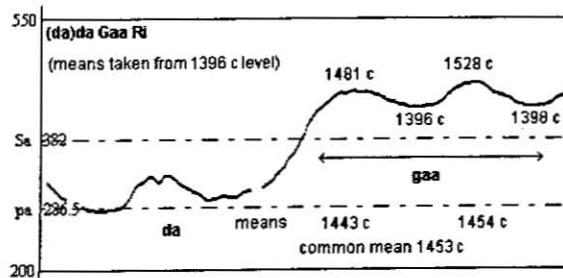


Fig. 11

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 Gandharam 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, please also see para 10.3 below.)

6. Suddha Madhyamam

6.1 The relative frequency of natural Suddha Madhyamam is $4/3$ (498 cents). In Thodi, this note is often oscillated once in a quick upward movement. 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, up to 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 three different places were found to be 488, 489, and 496 cents while those of another were found to be 498 and 517 cents ($6/5$ is 498 cents). Like other steady notes there were 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.

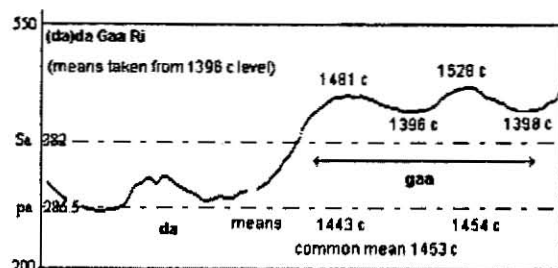


Fig. 12

In Fig.12, although the maxima of ga and ma are the 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 two figures. More steady madhyamams (including cases in the ascent) were found in the violin accompaniment. 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 the equally tempered scale. In Thodi this note is often held as an oscillation from around pa but is 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.s were seen in phrases with slow, lingering oscillations and phrases which did not reach thara 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 emphasized 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 maxima of the oscillated notes went above the theoretical value of 814 cents ($8/5$), in some cases even above Chaturruthi Dhaivatham ($5/3$ or 884 cents and $27/16$ or 906 cents)

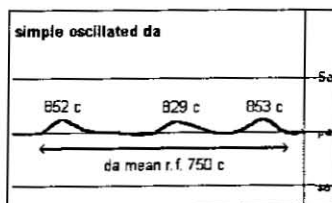


Fig. 13

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

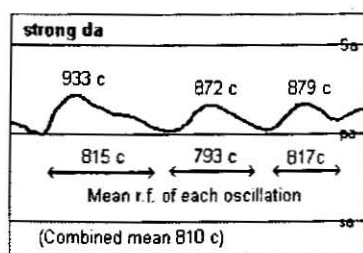


Fig. 14

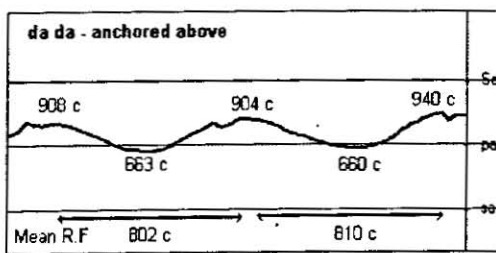


Fig. 15

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 the 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 two oscillations are nearer the value for Chathusruthi Dhaivatham and may be considered as quick touches of ni, but for notation they would be classified only as ni.

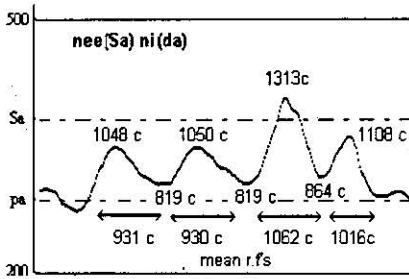


Fig. 16

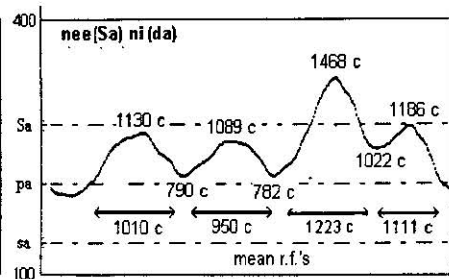


Fig. 17

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

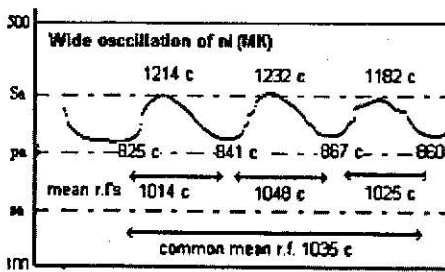


Fig 18

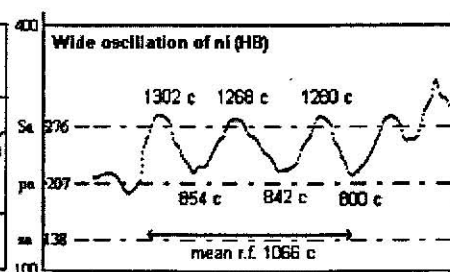


Fig. 19

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 position. 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.

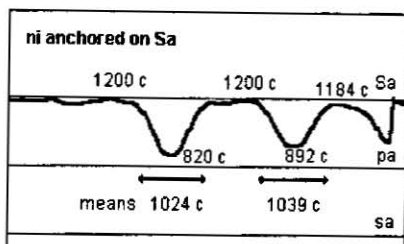


Fig. 20

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)

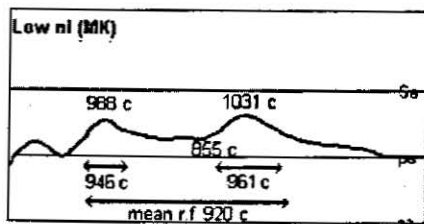


Fig. 21

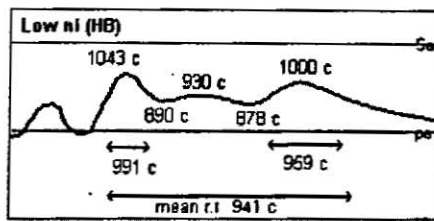


Fig. 22

9. Similarity in Pitch Curve Shapes

9.1 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 graph 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 rendered by 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.

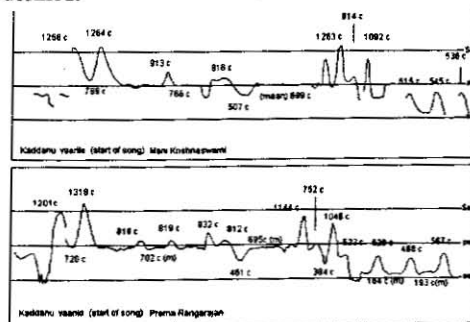


Fig. 23

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.

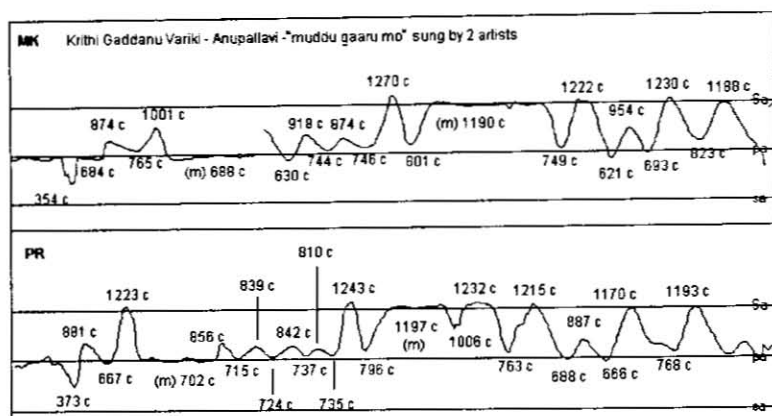


Fig. 24

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 is 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).

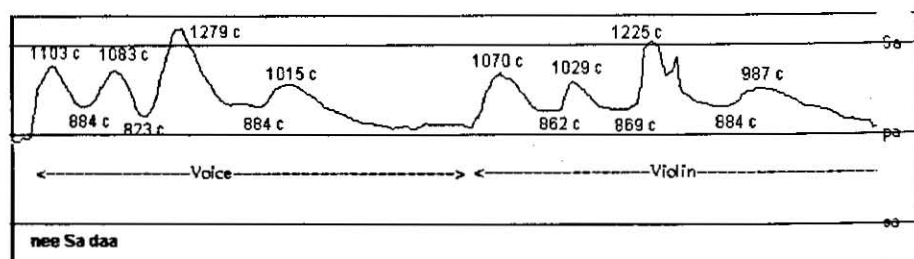


Fig. 25

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 characterized 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

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 characterize the phrases in the ragam 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 feedback mechanism of musical voice production. Another study (under way and yet to be published) appears to indicate that this feedback 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 Dheerasankarabharanam 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 a large number of 'white notes' separated by two 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 long in range. When there is a long 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 is made could a reasonably accurate method for assignment of notes to a phrase by computer analysis be attempted.

ANNEXURE
(Some Examples)

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

Rishabham

Kishanabham									
	Context	Duration: Milli-seconds	No. of Oscillations	Mean Relative Frequency		Range	Maxi- mum R.F.	Mini- mum R.F.	Figure ref- erence & comments
				Indivi- dual osc.	Com- mon				
Plain ri									
1	(sa) ri (sa)	175		97		40	117	77	Fig 4. Mean is for 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 areas below Sa between the oscillations
		50		95		214	145	-69	
14	(ma)ri ri(ree ga) -do- 2 nd osc.	160	2	65/82	60/74	138/203	150	12/-53	Fig. 9 Lower r.f values include areas below sa.
		150		60/66		117/156	129	12/-27	

ANNEXURE
(continued)

Gaandhaaram

	Context	Dura- ration Milli- second	No. of Oscilla- tion	Mean Relative Frequency		Range mum	Maxi- mum R.F.	Mini- mum R.F.	Comments and reference to fig- ures in the paper
				Indivi- dual 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- 2 nd osc.	235		292		412	488	66	
	-do- 3 rd 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- 2 nd osc.	295		254		132	328	196	
6	sa ri gaa gaa	230	5	355	348	307	506	199	
	-do- 2 nd osc..	230		330		363	539	176	
	-do- 3 rd osc.	220		330		368	509	141	
	-do- 4 th osc.	175		349		456	577	121	
	-do- 5 th osc.	160		369		496	617	121	
7	da pa ma gaa	370	2	324	333	399	536	137	
8	-do- 2 nd osc.	270		365		376	513	137	
9	pa ma gaa	275	2	352	330	314	501	187	
	-do- 2 nd osc.	260		334		332	519	187	

ANNEXURE
(continued)

Dhaivatham

	Context	Dura- tion Milli- second	No. of Oscilla- tion	Mean Relative Frequency		Range	Maxi- mum R.F.	Mini- mum R.F.	Comments
				Indivi- dual 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	Fig. 13
	-do- 2 nd oscillation	235		763		120	829	709	
	-do- 3 rd oscillation	215		743		138	853	715	
5	Violin following above	160	2	750	735	93	800	707	
	-do- 2 nd oscillation	150		744		53	754	707	
	-do- 3 rd oscillation	130		733		55	757	702	
6	(pa) da(ni Sa)	265	3	815	810	216	933	717	Fig. 14
	-do- 2 nd oscillation	200		793		155	872	717	
	-do- 3 rd oscillation	140		817		148	879	727	
7	(pa) daa(ni da)	220	2	758	769	136	836	700	
	-do- 2 nd oscillation	180		778		164	908	695	
8	da da (Gaa Ri)	320	2	802	806	245	908	663	Fig. 15
	Anchored above -do- 2 nd oscillation	300		810		280	940	660	

ANNEXURE

(continued)

Nishaadham

	Context	Duration Milli- second	No. of Oscilla- tion	Mean Relative Frequency		Range	Maxi- mum R.F.	Mini- mum R.F.	Comments
				Indivi- dual osc	Com- mon				
In upward movement									
1	(da) ni ni (Sa daa)	145	4	931	973	129	1048	819	Fig. 16.
	-do- 2 nd oscillation	210		930		131	1050	819	
	-do- 3 rd oscillation	75		1062		449	1313	864	
	-do- 4 th oscillation	140		1016		234	1108	864	
2	(pa da) ni ni (daa)	220	2	991	991	342	1164	818	
	-do- 2 nd oscillation	200		991		352	1174	818	
3	ni ni (Sa) ni (da)	140	2	1010	986	340	1130	790	Fig. 17 (first 2 oscillation..)
	-do- 2 nd oscillation	115		950		307	1089	782	
	-do- osc. after Sa	95	1	1111		64	1186	1022	Fig. 17 Last oscillation
Wide Oscillation									
4	nee nee	280	3	1014	1035	389	1214	825	Fig. 18
	-do- 2 nd oscillation	290		1048		391	1232	841	
	-do- 3 rd oscillation	275		1025		322	1182	860	
5	nee nee	180	3	1127	1066	448	1302	854	Fig. 19
	-do- 2 nd oscillation	230		1049		426	1268	842	
	-do- 3 rd oscillation	175		1051		480	1280	800	
Anchored above on Sa									
6	ni - ni	225	2	1024	1074*	380	1200	820	Fig. 20
	-do- 2 nd oscillation	265		1039		292	1184	892	
Conveying low pitch									
7	(da) nee (da)	280	2	946	920**	133	988	855	Fig. 21
	-do- 2 nd oscillation	325		961		176	1031	855	
8	(da) nee (da)	130	2	991	941**	153	1043	890	Fig. 22
	-do- 2 nd oscillation	130		959		122	1000	878	

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

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

M. SUBRAMANIAN

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