SINGER'S FORMANT IN INDIAN CLASSICAL SINGERS - CARNATIC VS. HINDUSTANI

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MAY - 2003

CERTIFICATE

This is to certify that this dissertation entitled **"SINGER'S FORM ANT IN INDIAN CLASSICAL SINGERS - CARNATIC VS. HINDUSTANI"** is a bonafide work in part fulfillment for the degree of **Master of Science** (Speech and Hearing) of the student (Register No. MSHM0104).

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CERTIFICATE

This is to certify that this dissertation entitled **"SINGER'S FORMANT IN INDIAN CLASSICAL SINGERS - CARNATIC VS. HINDUSTANI"** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier in any other University for the award of the Diploma or Degree.

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DECLARATION

This dissertation entitled **"SINGER'S FORMANT IN INDIAN CLASSICAL SINGERS - CARNATIC VS. HINDUSTANI"** is the result of my own study under the guidance of **Ms. K. Yeshoda,** Leaurer, Department of Speech Language Sciences, All India Institute of Speech and Hearing, Mysore, and not been submitted earlier in any other University for the award of any diploma or degree.

Mysore

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DEDICATED TO THE WORLD OF MUSIC

AND

MY LATE THATHA

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INTRODUCTION

"If singing is to be more than empty twittering, singers must be filled with a divine spirit, transmitting a profound joy in life and sense of assurance to all their listeners"

-Stockhausen(1989)

Voice is described as a marvelous instrument, a musical sound and the human mechanism, which produces it, is compared to a musical instrument. The universality of the human voice as an instrument is its greatest joy and its major disadvantage. Almost everybody can sing and make musically acceptable vocal sounds, however only few people become true artists. Because singing is a common musical outlet, the complexities of the vocal mechanism and the high degree of co-ordination and the amount of energy necessary for artistic performance are often overlooked, taken for granted, or not understood.

Regarded as a musical instrument, the voice consists of an actuator (the energy produced by the respiratory apparatus), a vibrator (the vocal folds), and a resonator (the vocal tract). This instrument must be capable of producing the requisite pitch, loudness, duration and timbre and respond to demands of highest level in relation to musical phrasing and articulation of text.

Singing is defined as a sensory motor phenomenon that requires particular balanced physical skills (Bunch, 1982). A sensitive performer achieves singing as an art when these skills are developed. Singing is such a human and moving activity, both for those who do it and for those who listen. Hence, singers are considered artists in the truest sense, as they combine concept, melody, text and stage movement making it all seem effortless and yet capable of winning audiences appreciation.

Sundberg (1994) stated, "the singer must gain control over all perceptually relevant voice parameters, so that they do not change by accident and signal an unintended boundary". Technical control of all vocal parameters is a pre-requisite for artistic expression.

Music is the brightest gem adorning the crown of Indian culture. India may be thought of as a "Sangita Bhumi" (musical land). A study of musical history of India is not only of cultural value, but enables one to understand something of the genius of the race which gave to the world the magnificent "raga" and "tala" systems, the idea of the "manodharma sangita" and the concepts of "rhythmical harmony" and "abhinaya".

The concept of "raga" is India's gift to the musical thought of the world and this has paved the way for the emergence of the idea of absolute music. The ragas are aesthetic facts and can be perceived by anyone with a little training in music. India has also developed an extensive "tala" system. The "tala dasa pranas" (ten elements of musical time) shows the extent to which the analysis of rhythm has been pursued.

Indian music is distinguished from other musical systems in terms of its origin and its implication. Music is considered as a gift of God and part of fourfold goals of life. This Theo centric / sociocentric view has its wide spread effect. Till today, Indian classical music in all its forms is used to worship, praise or hail the glory of the formless, so much so that even ragas and notes have their own God. The basic conceptual material is from the Vedas. No other musical system has such a definite and strong background as Indian music. (Satyanarayanan, 1983).

There are certain distinctiveness in Indian music. Musical progression is in terms of a single note. That is, at any given time only one note or its shadow is acting. Thus it is called "homophonic" or sometimes just as "melodic" music. Western music, on the other hand, is a "heterophonic" or "harmonic" system, as, progression is in terms of harmony and calls for several sounds simultaneously.

Till about the 13th century A.D. there was a single system of music prevalent throughout India, while the bifurcation into two systems, Carnatic and Hindustani music was seen in Haripala's work (cited in Sangita Sudhakara - between 1309 & 1312 A.D). Both the styles in general have the same basis, governed by the rules of 'raga' and 'tala' structure. The 'Carnatic system' is usually a South Indian art, while the 'Hindustani system' is a North Indian art, though not strictly placed. The Carnatic school claims to have maintained and developed the orthodox traditional style, while the Hindustani school is said to have experienced considerable changes and developments through the Moghul period up to the present time (Sambamurthi, 1982).

SINGER'S FORMANT (Fs)

There has long been interest in what produces the exciting 'ring' in the professional singing voice, the quality that gives an arresting 'edge' to the voice. This quality "the singer's formant" (Fs) assists register blending and legato line and is essential for singers to be heard clearly over large orchestras, electronic instruments or background noise.

Vennard (1967) stated that the Fs results when "the resonators are in tune with the vibrator", that is, when the resonators are shaped to reinforce vowel formants that are harmonics of the fundamental. According to Sundberg (1991), the Fs is a prominent spectrum envelope peak near 3kHz that appears in voiced sounds sung by classically trained singers. The acoustic effect may be reinforced by the fact that frequencies in the 3kHz range are those most easily perceived by the human ear.

In Western classical singing, it has been emphasized that the presence of Fs is essential for an eligible operatic singer. However, Fs, has been found to vary for different types of singing. The center frequency of the Fs is around 2.2kHz for basses, 2.7kHz for baritones, 2.8kHz for tenors, 3.2kHz for altos. Existence of Fs is a question in the sopranos.

In Indian context very little details are available regarding Fs in Carnatic vocalists. But there have been a few studies dealing with Fs in Hindustani vocalists, where the center frequency of Fs was found to be around the same region as in Western classical singers.

This study was planned to gain an insight into the nature of Singer's formant in Indian classical singers and also to compare the same across the two predominant styles [Carnatic Vs. Hindustani].

REVIEW OF LITERATURE

Music is, has been, and will always be a beneficial part of human cultural life. As such, music and what belongs to it need no excuse for its presence in society.

Human voice can be, and often is, a most responsive, flexible and infinitely variable sound producing instrument. Especially so, when the voice is produced by the artistic level singer or actor, as the art of voice production is a learned behaviour. The capacity to communicate through vocal sound inevitably led to the voice of singing. Voice plays the musical accompaniment to speech rendering it tuneful, pleasing, audible and coherent which are essential qualities for efficient communication through spoken word (Greene, 1964).

The vocal instrument has respiratory, phonatory, resonatory and articulatory components, and that specific functions.can be assigned to certain anatomical parts of the instrument.

- Respiratory mechanism is the power plant, consisting of the inhalatory-exhalatory system, which is housed principally in the torso but also includes the airways of the mouth, nose and throat.
- Phonatory system is the vibrating source housed in the larynx.
- Resonatory system is made up of a series of adjustable cavities in the neck and head that modify the laryngeal tone.
- The articulatory function takes place within the resonance system and involves the tongue, lips, teeth, and cheeks, which modify the product into spoken language.

The brain of course is the master of all these systems and initiates and co-ordinates, or alternatively inhibits and excites the functions that result in an acoustic signal (the voice). To produce the singing voice, these systems should work in co-ordination, but sometimes certain mechanisms need to function independently also.

Greene (1972) contends that singing requires a complete mastery of technique, control not merely of the mechanics of singing but of fine shades of tone colour, which defy analysis but convey the emotional message of the passage as compared to the act of speaking.

Singing predates all other forms of music performance. Carroll (1974) stated that the science of singing consists simply of palate up, tongue down, larynx as low as is comfortably possible, and phonating vowels as close as possible to the point where the sound originates. Then after inhaling abdominally, one allows the sound to float in a continuous stream on the breath with no interference from the consonants.

Bunch (1982) defined singing as a sensory motor phenomenon that requires particular balanced physical skills.

Sundberg (1994) stated, "The singer must gain control over all perceptually relevant voice parameters so that they do not change by accident and signal an unintended boundary". Technical control of all vocal components is a pre-requisite for artistic expression. A professional singer must be able to produce the optimal vocal product and at the same time preserve the mechanism producing it.

Singers are more systematic in their voice use than non-singers. Sundberg (1990) summarises some of the characteristics specific to singers as the breathing habits of singers are special, their phonatory habits being special in that pitch and loudness are independent, they are also special with respect to the distribution and arrangement of formant frequencies.

One such arrangement of the formant frequencies in singers voice is the "spectral prominence" in the frequency region between 2500Hz and 3400Hz approximately which aids in voice projection and enhancement of the voice quality. This region has been termed the "Singer's Formant (Fs)" and helps singers to be heard above the orchestra. The exciting ringing quality of the professional singing voice, i.e., the quality that gives an arresting "edge" to the voice is also attributed to the presence of "Singer's Formant (Fs)".

There have been lots of research on Fs from the 1930's till date. Bartholomew (1934) was the first to observe using spectrographic means, that the frequency around 3kHz is highly strengthened or amplified. He also remarked that a good operatic voice needs a concentration of energy around 3000Hz. He also reasoned that this concentration must be produced with a special resonator in the larynx or lower pharynx.

The work of Sundberg (1969,1970 and 1971) is perhaps the best known research investigating and describing the acoustic and physiologic nature of Fs. Acoustically, Fs is a clustering of 3rd and 4th formants such that the collective amplitude of these proximal resonance peaks summate to provide a wide band energy region centering around 2500-3000Hz. This bandwidth of maximal energy in the singer's vocal output coincides with a region of relatively low orchestral energy. So, the 'operatic Fs' results in a maximally projected sound enabling the singer's voice to be heard above the orchestral accompaniment.

Sundberg (1974) offered a physiological explanation for the same. He found a major hump around 3kHz in the voice spectrum of the famous tenor and this was seen particularly in the presence of a loud orchestral accompaniment.

Sundberg (1977) stated that there are four or five important formants. The first four peaks occur in the regions of 500,1500,2500 and 3500Hz respectively. These formants generally shift areas (eg: 500 to 550Hz) according to various conformations of the vocal tract. The 5^{th} formant important to singing, labeled the 'ring' of the voice by Vennard (1967), occurs between 2500-3200Hz. It was thought to result from the lengthening of the vocal tract. He opined that the commonly called "getting resonance" is really reaching "2800Hz" with reference to the center of Fs. Fant (1970) also commented that F3 and F4 are closer in singing and in trained voices.

Sundberg (1977) explains Fs as: "The insertion of an extra formant between the normal 3^{rd} and 4th formants would produce the kind of peak that is seen in the spectrum of a sung vowel. Moreover, the acoustics of the vocal tract when the larynx is lowered are compatible with the generation of such an extra formant". Fs seems to depend on the clustering of the 3^{rd}, 4^{th} and 5^{th} formant frequencies. The particular feature producing this formant frequency cluster appears to be a widened pharynx, which can be achieved by lowering the larynx. The Fs is at an optimal frequency, high enough to be in the region of declining sound energy but not so high as to be beyond the range in which the singer can't exercise good control. Because it is generated by resonance effects alone, it calls for no vocal effort, the singer achieves audibility without having to generate extra air pressure. The singer does pay a price, however, since the darkened vowel sounds deviate considerably from what one hears in ordinary speech.

It has been said that the characteristic feature of bass, tenor and alto singers voice has an unusually high spectrum envelope peak occurring somewhere between approximately 2 and 3 kHz. It appears in all voiced sounds. Schutte and Miller (1984) said that Fs is ideally present in "classical singing" regardless of register changes. The Fs contributes to making the voice timbre more distinct and shiny. This also appears in a frequency range in which the ear is particularly sensitive.

The overtones of an accompanying orchestral sound are also much softer in this frequency range than near 500Hz, where they are generally loudest. The end product is that the Fs contributes to making the voice of the singer easier to be heard even when the orchestral accompaniment is loud. It is quite fortunate that this effect can be achieved without any need for excessive recruiting of vocal effort.

Detweiler (1994) postulated that the Fs is an aggregate formant contributed by the combined resonances of two component formants and opposed Sundberg's model.

A brief overview of the points, which are in general agreement regarding Fs are,

The Fs exists and is reflected as a strong spectral reinforcement at around 3kHz (Sundberg, 1988).

The Fs is primarily identified with trained male voices (Coffin, 1975; Morris and Weiss, 1997).

The Fs is usually acquired only as a matter of training. (Morris and Weiss, 1997; Schultz-Coulon and Battmer, 1979)..

Fs is required to project on the modern stage (Titze, 1988).

The Fs is most likely also associated with the projection of requirements for stage speakers. If so, it could also be rightly called a "Speaker's Formant". (Winckel, 1971; Nawka, Anders, Cebulla and Zurakowski, 1997).

Sundberg (1995) determined the spectral location of Fs and opined that it is favoured by the hearing curve and fills a special "hole" in the typical orchestra.

The existence of Fs can be demonstrated through acoustic analysis and physiological studies (Morris and Weiss, 1997).

The precise location of Fs varies. It may be affected by individual voice types and ranges, the vowels attempted, the pitch and amplitude produced and individual physiology (Morris and Weiss, 1997)

Most agree that Fs is glottically related and it may be a resonance somehow involving the glottic or laryngeal area.

FACTORS AFFECTING Fs

Factors which have an influence on the spectral position of the Fs include : the differences in body height and the length of the vocal tract, (eg: anatomical features of the hard palate and teeth) and the professional training (Sundberg, 1974 and Dmitriev, 1979).

The level of Fs is found to be varying depending on the singer proficiency, vowel FO, vocal loudness and phonation mode (Hollien, 1983; Bloothooft and Plomp, 1986; Schultz-Coulon and Battmer, 1979; Seidner, Schutte, Wendler and Rauhut , 1985).

Burns and Austin (1986) compared the speaking and singing voice of Opera, Country and Western professional singers. A total of 21 subjects participated in the study and were asked to speak and sing |i|, |a| & |o| ten times each. Vowel spectra were derived by computer software techniques allowing quantitative assessment of formant structure (F1-F4), relative amplitude of resonance peaks (F1-F4), fundamental frequency and harmonic high frequency energy. It was found that formant structure was the most effective parameter differentiating the groups. Only the Opera singers lowered their fourth formant creating a wideband resonance area (~ 2800 Hz) corresponding to the well-known Fs. This was not seen in Country and Western singers who revealed similar voice characteristics for both the spoken and sung output. The over riding implication of the unique laryngeal based adjustments (lowered larynx) in the operatic singing voice is that the acoustic enhancement and protection mechanism is missing in informal singing styles of Country and Western performers and this could also explain the vocal abuse problems so often encountered in these two groups.

Sundberg (2001) obtained the level of Fs relative to the first formant peak, which is said to vary depending on the vowel, vocal loudness and singing proficiency factors. Based on the acoustic theory of voice production, the level difference between the first and third formant was calculated for some standard vowels. The difference between the observed and calculated levels was determined for various voices. It was found that the level varied considerably more between vowels sung by professional singers than by untrained singers. The average level of Fs in male operatic singers was obtained around 20 dB (u) and 6 dB (e). The center frequency was found to vary with the pitch range, that is, being lowest for basses and highest for tenors. LTAS revealed that the level of the peak was higher for baritones and the level was 3 dB lower for basses and tenors and about 9 dB lower for altos. They also found that in most sopranos, there was no clustering of F3 and F4 indicating that they did not possess Fs.

Weiss, Brown and Morris (2001) discussed regarding the Fs in the voice of sopranos. 10 professional sopranos were divided into 2 groups and were asked to sing sustained vowels at 3 different pitch levels - high (932 Hz), mid (622 Hz) and low (261 Hz). Spectrographic analysis showed the nature of variation of harmonic energy in relation to pitch. A resonance band somewhat resembling the tenor Fs was evident in vowels sung at low and mid pitch. Vowels sung at high pitch levels exhibited strong reinforcement of adjacent harmonics extending to 5 KHz and beyond. This type of production in essence nullifies the necessity for a typical Fs. Absence of Fs in strong soprano voices might also imply the adaptation of a sufficiently different overall VT configuration.

SOME INDIAN STUDIES

Sengupta (1990) studied some aspects of the Fs in North Indian classical singing. 4 males and 4 females served as subjects. Task was to sing |a|, |i| and |o| over their full vocal range twice a day and twice a week for 6 months in the presence of their masters, who certified that their vocal production was appropriate for singing. The analysis involved ascertaining two regions in the spectrum, that is, a region of vowel definition (in frequency upto 1.8 kHz) and region of Fs (2-4 kHz).

Fs was observed and its center frequency increased with rising pitch, which was similar to sung vowels in Western music. The bandwidth was also found to increase with increase in F0.

Banerjee, et. al. (1983) obtained spectral characteristics of sung vowels in 8 Hindustani vocalists (both male and female). The task was to sing |o|, |a| and |e| covering 2 octaves. Results revealed that for vowel |a| males lowered their Fl and raised F2. In females Fl was raised for all vowels and F2 increased considerably only for |a| and |e|. This was attributed to the lesser control of phonetic quality during vowel production in female singers. For the vowel |a| and |o|, F3 was lowered in both male and female singers but F4 was lowered only in males when compared to females. They opined that shifts in the formant frequencies could not be functionally related to the amount of increase in Fo.

Aims of the study

- This study was planned to probe into the formant characteristics in both the Carnatic and Hindustani styles of singing and check for the center frequency, bandwidth and intensity at the Fs region.
- The present study was adopted to discuss the differences, if any at all, among Indian Classical singers (Carnatic Vs Hindustani).

METHODOLOGY

The study was aimed to find the presence or absence of Fs in Indian classical singers and if present whether there existed a difference between the 2 major styles (i.e.) Carnatic and Hindustani.

Subjects

Two groups of professional Indian classical singers with a minimum of 10 years of formal training were considered for the study : Carnatic and Hindustani Vocalists. Each group consisted of 20 singers in the age range of 21-55 years with an equal distribution of male and female subjects. Carnatic male and female singers had a mean age of 32 years and 35 years and Hindustani male and female singers had a mean age of 36.6 years and 39.2 years respectively. Subjects had no complaint of any vocal or hearing problems at the time of recording.

Task

The subjects were asked to sing |a| at a comfortable pitch and loudness for a minimum of 5 secs without any instrumental accompaniment. |a| was chosen because it is probably the nearest to the original glottal tone with non-selective resonators. Also, the configuration of |a| formants is 3 to 5 times more compact than |i| and |u|. Prior to the recording, the subjects were briefed regarding the purpose of the study and future implications.

Test Environment

Recording was done in a quiet environment individually.

Procedure

Samples were recorded using a high fidelity portable digital mini disc recorder (Sony) with the AIWA unidirectional external microphone. The microphone was placed at a distance of 5"- 6" from the mouth of the singer and 2 samples of sung |a| were elicited from each singer.

Acoustical Analysis

The audio recorded samples were linefed into the SIU of the Vaghmi Software. The data were analysed using the Long Term Average Spectrum (LTAS) program of the Vaghmi Software of the Voice and Speech Systems. LTAS provides information on the spectral distribution of the acoustic signal over a period of time. In the averaging process, the short term variations due to phonetic structures are averaged out and the resulting spectrum is used to obtain information on the voice source. The results are displayed as spectrum with a frequency range of 0-8 kHz and intensity range between -18 to 83 dB.

Parameters measured

Formant structure

- The formant values Fl, F2 and Fs were obtained from each sung vowel spectrum. In the great majority of vowel spectra scrutinized, formant peaks were clearly discernible amongst the array of spectral peaks that LTAS averaging provided. When direct observation could not reliably ascertain formant peaks, the published formant data of vowels was consulted to aid our decision. The values were further confinned using the spectrogram program of the SSL software of the Voice and Speech Systems.

- Fs - is a prominent spectrum envelope peak near 3 kHz that appears in all voiced sounds. The spectral position of the Singer's formant was noted as the highest partial or the mid point of 2 highest partials in the Singer's formant region.
- Bandwidth of Fs - the difference in frequency between the 2 half power points on the slopes of a resonant curve i.e., the difference in frequency between the 3 dB points defines the formant bandwidth.
- Intensity of Fs - the highest value in dB observed at the center frequency of Fs was noted as intensity of Fs.

Statistical Analysis

The data obtained was subjected to statistical analysis using the software SPSS version 10. Independent T-test was used for comparing the above mentioned parameters in both Carnatic and Hindustani singers.

RESULTS

The sample which revealed better spectral characteristics after acoustical analysis was retained for ascertaining the formant details. From the Long Term Average Spectrum, formant frequencies Fl, F2, Fs, bandwidth and intensity of Fs were measured.

Illustrations of LTAS for the sung |a| in Carnatic and Hindustani singers are shown in figures 1 and 2 respectively.

Statistical analysis was carried out for the parameters measured. Results of the analysed data are tabulated in the following paragraphs. Out of the total 40 subjects, 3 subjects : 2 Carnatic female vocalists and 1 male Hindustani vocalist did not reveal Fs and hence were not considered for statistical analysis.

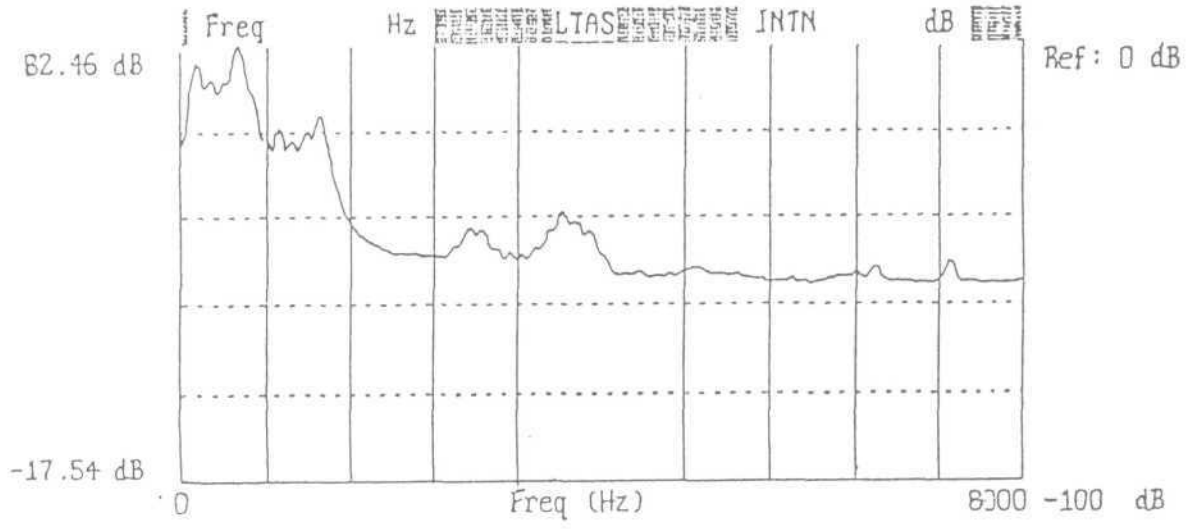

Figure 1 : Long Term Average Spectrum for the sung |a| in a Carnatic male singer

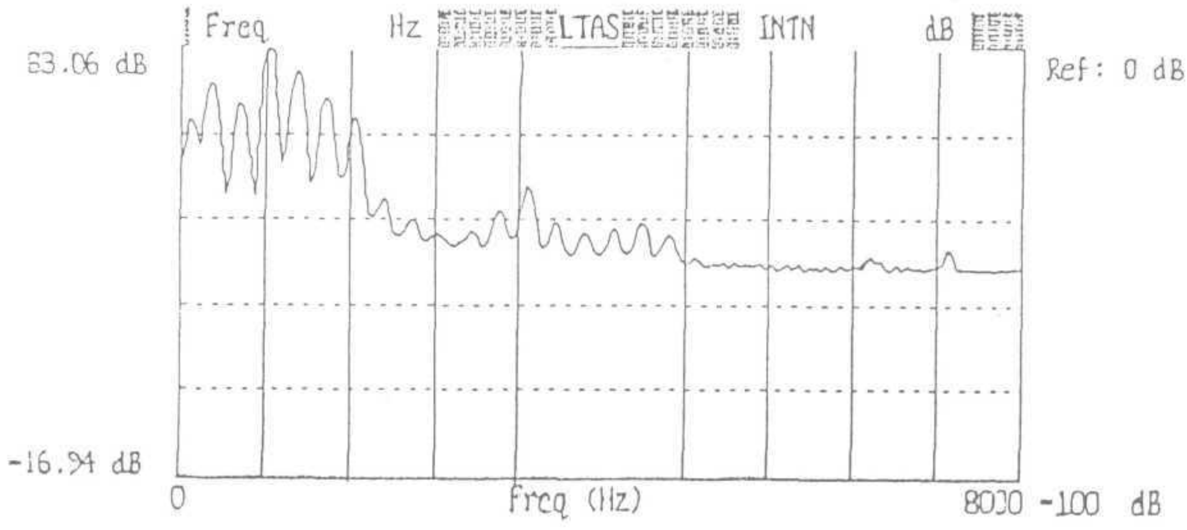

Figure 1a : Long Term Average Spectrum for the sung |a| in a Carnatic female singer

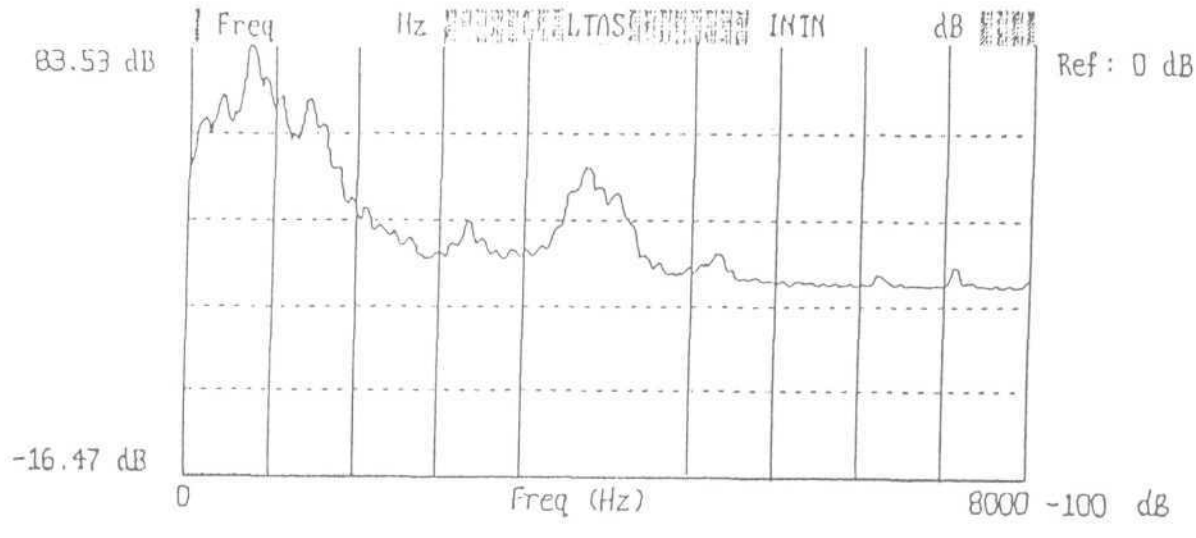

Figure 2 : Long Term Average Spectrum for the sung |a| in a Hindustani male singer

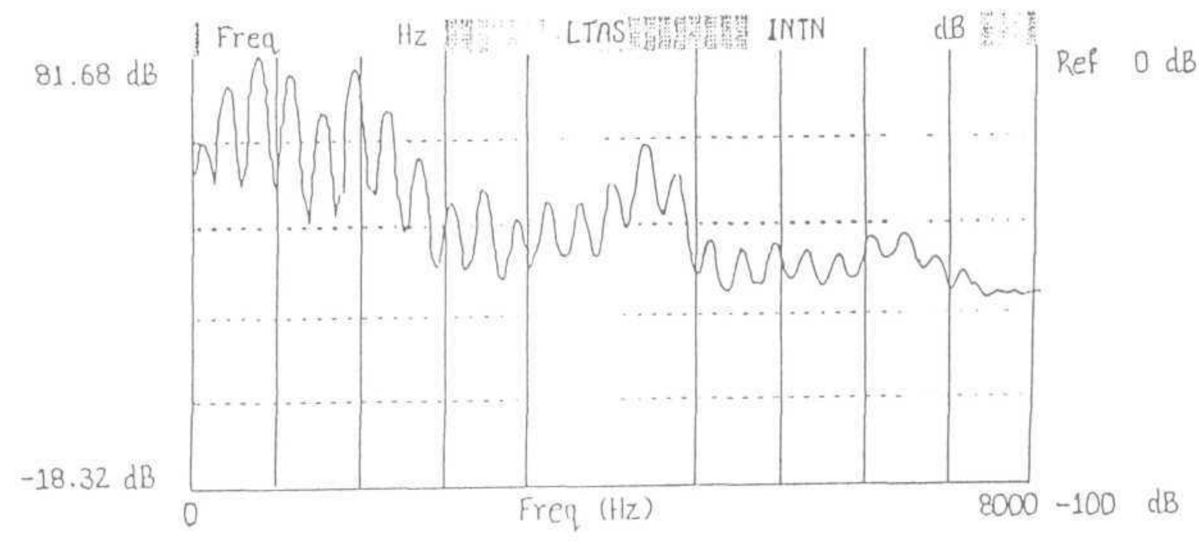

Figure 2a ; Long Term Average Spectrum for the sung |a| in a Hindustani female singer

- **Fl and F2**

The formant frequencies Fl and F2 were compared across the two groups of singers. In males, Hindustani singers showed an increasing mean value for Fl than Carnatic singers while the female singers showed no such trend. There was no significant difference observed across the two styles of singing in both male and female singers for the Fl value (Table 1**).**

Table 1 : Descriptive statistics and significance for Fl and F2 in male and female singers (Carnatic and Hindustani)

Parameter	Gender	Style of singing	Mean	SD	Sig (2T)
Fl	Male	Carnatic	757.40	56.14	.561
		Hindustani	773.00	58.38	
F2	Male	Carnatic	1355.80	144.07	.557
		Hindustani	1321.55	97.63	
Fl	Female	Carnatic	859.50	106.72	.991
		Hindustani	859.00	77.77	
F2	Female	Carnatic	1472.75	157.92	.383
		Hindustani	1408.10	147.35	

It can also be observed from Table 1 that for the parameter F2, the Carnatic singers both males and females showed an increased mean value than the Hindustani singers. But this increase in mean F2 value was not significant across sexes in both styles.

Table 2 : Descriptive statistics and significance for Fl and F2 in Carnatic and Hindustani singers

Parameter	Style of singing	Mean	SD	Sig (2T)
Fl	Carnatic	802.77	95.31	.596
	Hindustani	818.26	80.53	
F2	Carnatic	1407.77	157.59	.397
	Hindustani	1367.10	130.63	

When the formant frequencies Fl and F2 were compared across the two styles irrespective of the gender, F2 showed a higher mean value in Carnatic singers compared to Hindustani singers, while the Fl mean value was higher in Hindustani singers than Carnatic singers. But there existed no significant difference for Fl and F2 as seen in the above table.

Table 3 : Descriptive statistics and significance for Fs in male and female singers (Carnatic and Hindustani)

Parameter	Gender	Style of singing	Mean	SD	Sig (2T)
Fs	Male	Carnatic	3237.30	471.17	.097
		Hindustani	3604.11	434.87	
Fs	Female	Carnatic	3753.87	474.03	.845
		Hindustani	3800.00	499.45	

- **FS**

Table 3, indicates that the center frequency of Fs was greater in Hindustani male singers than the Carnatic male singers. A similar trend was observed even for the female singers. Statistical significance was absent for this parameter.

Table 4 : Descriptive statistics and significance for Fs in Carnatic and Hindustani singers

Parameter	Style of singing	Mean	SD	Sig (2T)
Fs	Carnatic	3407.55	501.27	.103
	Hindustani	3669.36	450.25	

From Table 4, it can be observed that when singers were considered as a group, irrespective of the gender, the center frequency of Fs was more in Hindustani singers compared to the Carnatic singers. Also this was not significant statistically.

Bandwidth and intensity of Fs

A significant increase ($p<0.05$) in mean value of bandwidth was noticed in Hindustani male singers when compared to Carnatic male singers. The same was not observed in the female singers (Table 5).

Table 5 : Descriptive statistics and significance for bandwidth and intensity in male and female singers (Carnatic and Hindustani)

Parameter	Gender	Style of singing	Mean	SD	Sig (2T)
Bandwidth	Male	Carnatic	234.30	67.92	.010
		Hindustani	332.60	80.46	
Intensity	Male	Carnatic	51.33	7.28	.423
		Hindustani	48.52	7.62	
Bandwidth	Female	Carnatic	222.62	48.34	.977
		Hindustani	222.00	42.89	
Intensity	Female	Carnatic	45.98	7.33	.246
		Hindustani	50.51	8.33	

Carnatic male singers showed a higher intensity than the Hindustani male singers. A reverse trend was seen in females where Hindustani singers showed a greater mean intensity value compared to Carnatic singers. There was no significance observed across the two styles (Table 5).

Table 6 : Descriptive statistics and significance for bandwidth and intensity of Carnatic and Hindustani singers

Parameter	Style of singing	Mean	SD	Sig (2T)
Bandwidth	Carnatic	230.83	60.69	.143
	Hindustani	266.26	80.95	
Intensity	Carnatic	49.05	7.63	.840
	Hindustani	49.56	7.85	

On the whole, as a group, Hindustani singers had a higher mean bandwidth value than the Carnatic singers, but the intensity of Fs remained the same across them. Statistical significance was not revealed for both the parameters as depicted in Table 6.

DISCUSSION

Fl and F2

Results of the present study pertaining to various parameters either support or refute the earlier studies. Sundberg (1974) and Banerjee, et. al. (1983) reported increased Fl value which is in consonance with the present study. However, Burns and Austin (1986) reported lowering of Fl for sung samples in male Operatic singers, when averaging across vowels for singing and speaking was done.

Increased F2 which was noticed in this study is in contradiction to Sundberg (1974) and Burns and Austin (1986) where they found F2 lowering in the singing act. However, this finding draws support from Banerjee, et. al. (1983) wherein they found increased F2 in both male and female Hindustani singers.

One of the possible reasons for increased F2 could be that, since the subjects participating in the study were priorly informed regarding the importance of Fs in Western Operatic singers and also the purpose of the present study, there could have been a conscious effort in using a different singing mode to enhance their vocal quality during the recording thus leading to increased F2. Also, support can be drawn from Sundberg (1995) wherein he advocates that, there could have been a constriction of the vocal tract in the glottal region leading to an increase of the formant frequencies.

Fs

The presence of Fs in Indian classical singers is consistent with the previous studies (Sundberg, 1974, Sengupta, 1990 and Schutte and Miller, 1984). In the present study, a shift in the center frequency towards the high frequency region in both the styles of singing was noticed. This shift could be attributed to the choice of singers and the filter bank used for analysis (Sundberg, 2001). Also, a clustering of the higher formants have been observed in this study in the region noted as Fs. This is in consonance with Sundberg (1977), where he found Fs to be dependent on the clustering of 3rd, 4th and 5th formant frequencies.

In the female singers, the difference in the mean value of Fs was minimal and not significant. Further a minimal difference in the mean values of intensity and bandwidth of Fs were observed. The same were not significant statistically. This could probably denote that the singers of both the styles adopt similar vocal mechanize during singing.

Male singers differed considerably when compared for bandwidth of Fs but only slightly for the parameter intensity of Fs across the two styles of singing. The significant increase in bandwidth could be because, with increase in the center frequency of Fs, there is a pharyngeal widening leading to the boosting of the adjacent frequencies thus resulting in a wider bandwidth. This could suggest that Hindustani singers place their articulators forward and also lower their larynx while singing to bring about a widened pharynx compared to the Carnatic singers. Weiss, Morris and Brown (2001), have also reported a higher bandwidth with increase in center frequency of Fs.

The absence of the Fs noticed in 3 singers in the present study can be evidenced due to various factors influencing the spectral position. Bloothooft and Plomp (1986) have opined that use of a soft voice or low intensity voice did not reveal a Fs in such singers. Other factors include : differences in body height, length of the vocal tract, individual differences in the ability of changing the shape of the vocal tract, level of professional training and singing mode (Sundberg, 1974 and Dmitriev, 1979). The individual properties of a singer's voice may be lost by averaging the results from a number of singers (Schutte and Miller, 1985). Attention needs to be paid to all these factors when considering the absence of Fs in a singer.

SUMMARY AND CONCLUSION

The present study was aimed to discern the presence or absence of Fs in Indian classical singers and if present does Fs distinguish the two styles.

The Fs is a prominent spectrum envelope peak near 3 kHz that appears in voiced sounds sung by classically trained singers (Sundberg, 1991). In Western classical singing, the presence of Fs has been emphasized for being an eligible operatic singer.

In Indian classical singing, very few studies have been done concerning the singer's formant and these are predominantly in Hindustani vocalists. A region of Fs similar to Western classical singing has been reported in Hindustani vocalists.

The present study included Carnatic and Hindustani vocalists, both males and females who were asked to sing |a| for a minimum of 5 secs at a comfortable pitch and loudness. Long Term Average Spectrum for each sample was obtained and the parameters Fl, F2, Fs, its bandwidth and intensity were noted down.

Results of the present study indicated no significant difference in the parameters measured across the 2 styles except for the parameter bandwidth of Fs which showed a significant difference in males across the 2 styles. It was wider in Hindustani males compared to Carnatic males. To conclude, Fs was present in Indian classical singers but it was not significant to distinguish the two styles. Therefore it can be speculated that Indian classical singers may be adopting an almost similar technique to bring about an appealing vocal quality. It is very premature to categorically state the differences between the two styles with regard to singer's formant as the sample size in this study was small.

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