Singer’s formants in Indian singers of western classical music

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CERTIFICATE

This is to certify that this dissertation entitled "**Singer's formants in Indian singers of western classical music**" is a bonafide work submitted in part fulfilment for the Degree of Master of Science (Speech Language Pathology) of the student (Registration No.: 12SLP018). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any of the University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled "**Singer's formants in Indian singers of western classical music**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Diploma or Degree.

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This is to certify that this dissertation entitled "**Singer's formants in Indian singers of western classical music**" is the result of my own study under the guidance of Dr. K. Yeshoda, Reader and HOD, Clinical Services, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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Chapter 1

Introduction

"O, Voice of Man, organ of most lovely might." - Richard Llewellyn

The voice is indeed a marvelous phenomenon. The human voice can by all means be compared to a musical instrument of great versatility. It is an instrument used by every human. It heralds the beginning of life, to the fulfilling of basic needs such as communication, to the multifaceted ability to give life to stories as artists deliver swaying performances using their voices. An instrument so versatile that, just a simple word allows the listener to differentiate one person from another unarguably holds an imperative need to be studied.

The most readily accepted artistic exhibition of one's voice is singing. It is this ability that has allowed enormous success to few singers. What should be held accountable for their success? Is it only training that makes a difference? Or is it the instrument that produces an excellent singer's voice so different from the others?

All the elements and functions of voice organ that have been described over the years, by physicians and educators establish the fact, that, the voice organ are common to both singers and nonsingers alike. Do singers still bring other manipulative factors into action while singing? Sundberg's description in 1977 explained the singer's voice organ as an instrument consisting of power supply (the lungs), an oscillator (the vocal folds) and a resonator (the larynx, pharynx and mouth) also, that, singers adjust the resonator in special ways.

The vocal organ functionally has three units: power supply (the lungs), an oscillator (the vocal folds) and a resonator (the larynx, pharynx and mouth). With the glottis closed and an airstream issuing from the lungs, the excess pressure below the glottis forces the vocal folds apart; the air passing between the folds generates a Bernoulli force that, along with the mechanical properties of the folds, almost immediately closes the glottis, the pressure difference builds up again, forcing the vocal folds apart, again. The cycle of opening and closing, in which the vocal folds act somewhat like the vibrating lips of brass-instrument player, feeds a train of air pulses into the vocal tract.

The frequency of vibration is determined by the air pressure in the lungs and the mechanical properties of the vocal folds, these vibrations are regulated by a number of laryngeal muscles. In general, higher lung pressure results in thinner and more stretched vocal fold consequently resulting in higher frequency of the vibration in the vocal folds. The recurring pulses produce an oscillating air pressure of high speed in the vocal tract – the result is a sound. Its pitch is the evidence of the frequency of vibration of the vocal folds. Most singers need to develop full control over a pitch range of two octaves or more, whereas for ordinary speech less than one octave suffices.

The sound generated by in the manner described above is called the voice source. It forms the essential raw material for speech or for singing. It is a complex tone and it comprises of a fundamental frequency, which is determined by the vibration of the vocal folds, and a large number of higher harmonics or overtones. The amplitude of these overtones or partials decreases uniformly with frequency at the rate of about 12 decibels per octave – "the source spectrum" as described by Fant (1960). The source spectrum or plot of amplitude against frequency is not very different between singers and nonsingers, however the spectrum does tend to slope more steeply in soft speech than it does in soft singing (Sundberg, 1977).

The vocal tract is a resonator, so the sound transmission through an acoustic resonator depends highly on the frequency. Resonance frequencies are specific to each resonator and are hence less attenuates than other sounds, which results in relatively higher amplitude than the other attenuated frequencies.

The five important vocal tract resonances are formants. When many partials or overtones are fed into the vocal tract from the source, the frequencies closest to the resonance frequency are allowed and the rest of the frequencies are attenuated, resulting in relatively larger amplitude at the lip opening. The presence of these formants, disturb the uniformly sloping envelope of the voice spectrum. These formants appear as peaks on the uniformly sloping source spectrum. These changes in the voice source envelope are responsible for producing distinguishable speech sounds. The formant frequencies are determined by the vocal tract.

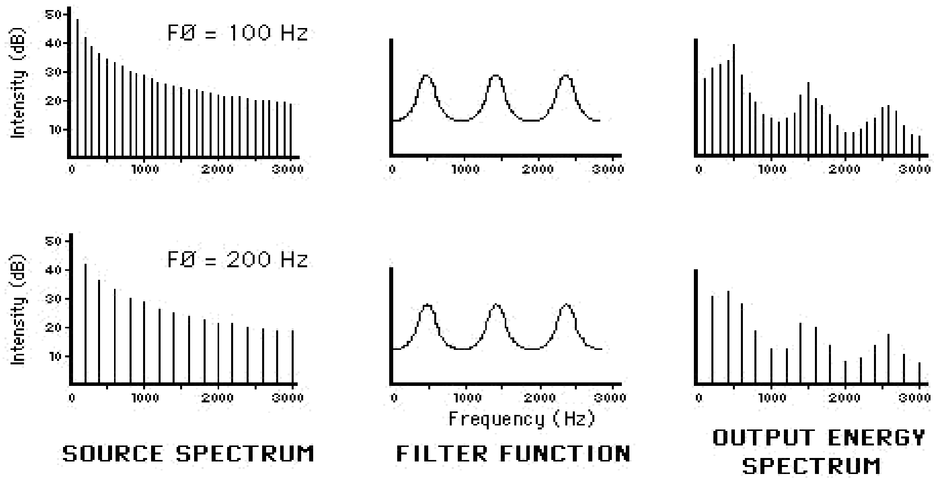

Figure 1.1 Pictographic representation of Source filter theory (Fant, 1960)

(Taken from the Haskins lab website: http://www.haskins.yale.edu *)*

The vocal tract has complicated constrictions and expansion in many ways. A constriction at one place affects the frequency of all formants in different ways. There are three major tools for changing the shape of the tract to manipulate the frequency of a particular formant so that it shifts in a particular desired direction. These tools are the jaw, the body of the tongue and the tip of the tongue also known as the articulators. The movement of the articulators is responsible for the changes in the frequencies of the lowest formants over a considerable range, which in adult males ranges over 250Hertz to 700Hertz for the first formant, and from 700 to 2,500 Hertz for the second (Sundberg, 1977). Movement of articulators is what basically happens when we speak or sing. Each articulatory configuration corresponds to a set of articulators.

Careful attention to singers' voice reveals a number of deviations in vowel quality from those of ordinary speech. These shifts in the vowel quality have been found to be associated with the peculiarities of articulation. It is common knowledge that many voice teachers tend to agree that the pharynx should be widened while singing or that it should possess the quality similar to the sensation of yawning. In other words, a low larynx position and an expanded pharynx are considered desirable while singing. This quality is reflected very early in the spectrum of a sung vowel with a characteristic spectral envelope peak between 2,500 and 3000 hertz, in sounds sung by professional male singers. Its presence regardless of the pitch, the vowel sung, and the dynamic allows us to conclude that it could be considered a criterion for quality. Hence this peak has been labeled "singer's formant" or "F_S", (Sundberg, 1977).

The significance of the singer's formant and its location is explained by Sundberg research in 1977. Among various other findings regarding the singer's formant, it was shown that a singer's voice was heard almost invariably audible because it was in a frequency region where the orchestra's sound was rather weak. It also helped the listener "imagine that he can hear other part of the singer's spectrum that may be drowned out by the orchestra. He the author explained, that singer's formant is at an optimal frequency, high enough to be in the region of declining orchestral sound energy but not so high to be beyond the range in which the singer can exercise good control. Because it is generated by resonance effects alone it calls for no extra vocal effort; the singer achieves audibility without having to generate extra air pressure.

According to psychologist, Welch (1994), singing is highly governed by the culture, and because of its variety and developmental nature any singing assessment needs to carefully account the particular culture of the singer. In the West, music has an evolving history, betraying strong cultural significance such as classical music in opera houses, jazz music in the bars, whereas India boasts of a range of musical phenomena. Carnatic in the southern region and Hindustani in the northern region, ghazals, poetic compositions, qawaalis, describe the music of our land. A combination of all these and influence from world music reflects in the Indian film music.

Interestingly, while India is the home of Carnatic and Hindustani music, it is also the home of very popular composers and singers such as A.R Rehman, Ilayaraja, Andre de Quadros, who excel in Western classical music. But this area was mainly patronized by the Indian Zoroastrian community, small esoteric groups with historical exposure to Western classical music such as the Protestant Christian community with significant patronage in western classical music in Chennai, Bangalore and Hyderabad. Choirs, dramas, plays and music governs the initial schools years of children in especially these cities. “Today, Western classical music education has improved with the help of numerous institutions in India. Institutions like K.M. Music Conservatory founded by Oscar Winning Composer, A. R. Rahman, Calcutta School of Music, Bangalore School of Music, Eastern Fare Music Foundation, Delhi School of Music, Ustad Gah Foundation, Delhi Music Academy, and many others are dedicated to contributing to the progress or growth and supporting Western classical music”.

Mr. Kushroo Suntook, founder of Symphony orchestra of India stated on 26th September 2011, on BBC news, “The audience is changing and we are finding a lot of new people coming in. It is expanding". According to a report given by Ghana Kanta Deka, the founder of Sabdarupa School of Music to The Times of India news on January 23, 2013, in Guwhati, 325 students appeared for different grade exams conducted by The Associated Board of the Royal Schools of Music, and Trinity College of music.

Need for the study

It is evident that western classical music is not only gaining ground in India but also that more persons all over the country are interested in this genre of art and training to become classically trained western musicians and vocalists. Since there is a lack of information on western classical vocalists of Indian origin it would be interesting to know the voice quality in Indian classical singers of western music, especially by investigating the characteristics of singer’s formant in their voices. Hence the present study was planned to investigate the presence of singer’s formant in Indian classical singers of western music.

Chapter 2

Review of literature

Singing is defined as a sensory motor phenomenon that requires particular balanced physical skills (Bunch, 1982). 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”. This suggests the technical requirement for a singer. The use of greater proportion of air in a singer's lungs reducing the residual volume and increasing respiratory efficiency is what differentiates a singer from a non singer (Boominathan, 2008). Pitch control is more complicated in singing than one might imagine.

Subglottal pressure is a very important factor which directly affects pitch change. Other things being equal, if the subglottal pressure is increased the pitch rises. But in a singer, the highest pitch is not sung with maximum pressure, neither is the lowest pitch sung with a very low pressure unlike an untrained singer where it is possible to roughly estimate the underlying increase in subglottal pressure from a measured sound level. A doubling of subglottal pressure generally leads to an increase in sound level of approximately 9 dB (Sundberg, 1990). Nonsingers seem to approach pressed phonation when they increase loudness. Singers, on the other hand, apparently change mode of phonation less when they change loudness.

The singer's singing voice quality is different from speech and careful observation to the vowel of the singers suggest that the voice sounds "darker" in singing, somewhat as it is when a person is yawning, sometimes teachers describe this effect as "covering". These changes in articulation are brought about by the acoustic environment in which opera and concert singer work (Sundberg, 1977). In the 1930's, Bartholomew discovered that the singer's formant is an important acoustic characteristic of male singing. He guessed that it was in some way associated with the deep pharynx.

The term “singer's formant”, (F_S) was later introduced by Sundberg (1974) who showed that the singer's formant could be interpreted in terms of articulation as a clustering of third, fourth and fifth formants, which may be an acoustic mismatch between the pharynx and the entrance of the larynx tube. It is a prominent spectrum envelope peak near 3 kHz that appears in voiced sounds sung by classically trained bass, baritone, tenor, and alto singers' voices. It makes the voice easier to hear in the presence of a loud orchestral accompaniment.

Its level has been found to vary depending on a singer’s proficiency, vowel, and fundamental frequency (F0), vocal loudness, and phonation mode and its center frequency also varies depending on various factors. Sundberg (1977) reported of its level relative to the level of the first formant and found it reasonably constant within a given operatic voice singing a given vowel at a given degree of vocal loudness at various F0.

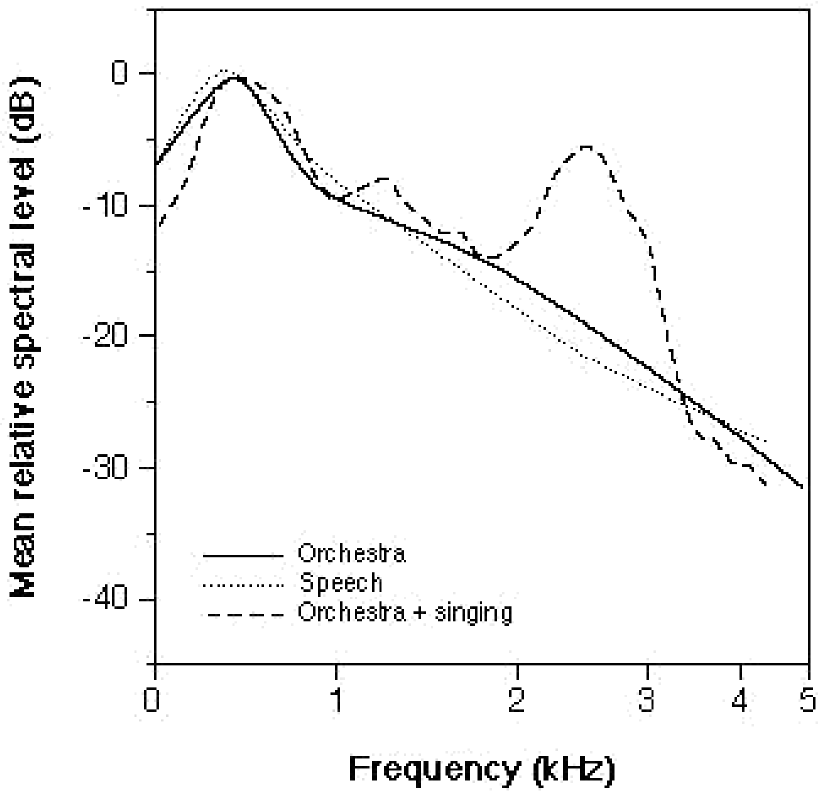

Figure 2.1. Singer's formant (Taken from Sundberg 1987)

Vennard (1967) discussed the importance of articulation in singing and stated that it is by means of consonants that expression of not merely the emotions or pattern of the movement but also the events of the past and aspirations of the future are conveyed. Sundberg (1970) reported that sung vowels as compared to spoken vowels displayed the following four characteristics as regard to the formant frequencies: a) F2 was lowered in non back vowels b) F3 was raised in back vowels and lowered in the other vowels c) F4 and F5 were lowered in all the vowels d) The frequency distance between F3 and F4 was reduced in all vowels.

Bloothooft and Plomp (1986) found two factors to be decisive in the expected levels of spectrum partials, vocal loudness, and formant frequencies after they studied the relation between the level of the singer's formant, and the overall sound level. This level increased between 16 and 19 dB for a 10 dB increase in the overall sound level, depending on phonation mode, on the singer, and the vowel being sung. Sundberg (1977) reported that the spectral location of the Singer's formant F_S is both favored by the hearing curve and fills a special "hole" in the typical orchestra.

According to Schutte and Miller (1984) the singer's ability to adjust the vocal tract to produce "l'impostazione della voice" (setting one's voice) was the result of technical voice training. According to a study by Barrichelo, Heuer, Dean, Sataloff (2001), the data obtained from singers showed more energy concentration in the singer's/speaker's formant for sung and spoken vowels.

Sundberg (1995, 2001) suggested that for a singer's formant to be marked as present the level of the third formant should be greater than or equal to 6 dB (i.e., $F3 \geq 6$ dB). He also reported that the center frequency of the peak could be determined from the mean LTAS for each of the voice classification except for sopranos. The center frequency was measured as the midpoint between the frequencies on each side of the peak. The resulting values varied systematically between classifications. The LTAS was also lowest for sopranos and showed two rather than one single peak. The tenors, baritones and basses had a clearly marked peak while it was less compared to the altos.

Recently the focus of studies shifted to the relationship between the singer's formant and other variables, such as specific vowels, changes in overall sound intensity, high fundamental pitch levels, and text intelligibility. Research by Sundberg (1997) on country singers reveals the lack of singer's formant which supports the previous studies that western classical music singer's have a characteristic high frequency prominent spectrum envelope. In agreement to the belief that western classical music training is required to achieve this unique formant feature and the lack of it in the country singers suggests this to be true.

Singer's formant is seen to have different variations among singers based on their vocal abilities. Soprano singers singing vowels at high pitch exhibited broad bandwidths as wide as 2 kilohertz (kHz) unlike those of tenors. This type of production may suggest the absence of singer's formant in sopranos and might also imply that sopranos have a significant different overall vocal tract configuration, so that maximal projection is not same as that of the tenors. (Weiss, Brown, Morris, 2001).

Scherer and Siegwart (1995) investigated the acoustic properties of a sound and emotional contents expressed in the sound of the singers as perceived by the listeners. This was carried out by the 11 listeners judging the voices of 5 internationally recognized opera singers and giving their preference. It was observed that although sopranos did not have high amplitudes in the low singer's formant range but had high values between 3500-10,000Hz. These singer's voices were preferred over those with strong energy in the typical "singer's formant" range.

Omori, Kacker, Caroll, Riley, and Blaugrund, (1996) devised a quantitative measure to quantify the ringing quality of voice in the singers which did not require pointing of a specific cluster of “singing formants”. “Singing Power Ratio,” (SPR) defined as the ratio between the greatest peak in power between 2 and 4 kHz and the greatest peak in power between 0 and 2 kHz, provides a good general indicator of the strength of higher partials (the frequency range associated with carrying power formants) vs. lower partials (the frequency range associated vowel formants). SPR was found to be higher in trained singers than untrained singers in sung tones). Higher SPR was correlated with higher perceptual ratings for "ring". The effect of vocal training had a significant relation to the maximum phonation frequency range and also in terms of fundamental frequency and vocal intensity on the singing voice (Brown, Sapienza,, Rothman, and Mendes 2003).

Kenny and Mitchell (2007) researched the correlation between acoustic measures and perceptual findings in the identification of perceptually preferred voices. They compared the sound quality using both the open throat technique and without the technique. They did find a relationship between the singing power ratio and the energy ratio, but they concluded that the LTAS measurements were not consistent with the perceptual rating of voice quality. They also concluded that this measurement cannot define voice quality. Morris and Wiess (1997) reported variations in that the precise location of singer's formant. Individual's voice type and range, the vowels sung, pitch and the amplitude of the individual affect the singer's formant.

Indian literature supporting studies using Carnatic singers and Hindustani singer also shed light on the singer's formant. Ranjini Mohan (2010) did a study on trained singers of various years of training in Carnatic music. Many of the beginner singers' production of a:dha:ra sriti did not match that of sriti box, and hence their production of the pitch was sharp. But the trained singers were successful in matching their pitch with the sriti box.

Few studies were conducted to see the usefulness of SPR and singer's formant in Indian classical music. Sujatha (1989) analyzed the singing voice of 10 trained (4-10 yrs of training) and 10 untrained singers and found that, most of the trained singers had more energy concentration between the frequencies 2500 to 2969 Hertz whereas, the energy concentration was more in 2300-2500 Hertz region in untrained singers.

Sengupta (1990) studied some aspects of singer's formant (F_S) In North Indian Classical singing. Eight singers (4 males and 4 females) participated as the subjects. The author found singer's formant and the centre frequency of F_S increased with raising pitch. The bandwidth was also found to increase with increase in fundamental frequency similar to the western - singers.

Chayadevi (2003) compared Singer's formant between Carnatic music and Hindustani music. The author analyzed the sung samples of / a/ vowel in twenty Carnatic and twenty Hindustani vocalists who had minimum 10 years of formal training. The results of study indicated no significant difference in the parameters measured across two styles of singing except for the bandwidth of F_S which showed significant difference between male singers of two styles of singing. The author observed a shift in the centre frequency of F_S in both styles of singing. Clustering of higher formants was found in the region noted as F_S.

Boominathan (2004) and Mohan (2010) did not find Singer's formant in Carnatic classical singers. They justified by explaining that the Indian music is homophonic and accompaniments usually shadow the singer and hence singer would not require projecting his or her voiceover an orchestra. This result opposed the earlier studies (Sujatha, 1989; Sengupta, 1990; Chayadevi, 2003).

Mohan (2007) evaluated the usefulness of SPR as an objective measure of singing voice quality in untrained and trained singers, in Indian context. The author considered two groups. Group I consisted of 10 female Carnatic singers who had minimum 6 years of training (mean age 9.9 years) and group II consisted of 10 female singers who did not receive Carnatic singing training. The participants were asked to sing the Indian national anthem and the sample was analyzed using Vaghmi software. LTAS was extracted on the sung sample and SPR was measured. The author did not find any significant difference between the two groups on SPR. The author concluded that SPR may not be helpful in evaluating the progress of a singer's training towards the development of perceptually rich vocal quality in Carnatic singing.

Supritha and Swathi (2011) attempted to simulate the heterophonic condition and used the orchestra to check for F_S and to analyze the correlation between SPR and F_S across different levels of trained singers. They concluded that although the SPR and F_S across different level of training were not significantly different, it was inferred that there was a strong negative correlation between the SPR and Fs.

The research presented above provides information regarding the level and the center frequency of the singer's formant in Indian music. Also the effect of loudness, vowels sung, and the classification of the voice of the singer based on the singer's formant. The relation between the SPR and the F_s was also have also been documented. But very little research is available in Indian singers of western classical music. In this context, the present study was planned with the aim of investigating presence of singer's formant in the Indian singers of western classical music.

The main objectives of this study are

1. To check for the presence of singer's formant in Indian singer's trained in western classical music.
2. To check for the influence of the level of training on singer's formant in these singers.

Chapter 3

Method

3.1 Participants

Twenty gender matched singers of the age range 20 to 40 years with a mean of 25.6 years (SD: 5.575) participated in the study. The participants reported English as their second language. They were divided into two groups. Group I consisted of 10 (5 males & 5 females) trained singers having passed any grade from 5 to 8 in western classical music. All of the singers in the group I were trained in the classical mode of singing, had undergone a minimum of 4 years of operatic

Table 3.1

Details of the participants in the two groups

Group I			Group II		
Participants	*Gender*	*Grade*	*Participants*	*Gender*	*Grade*
01	Female	7	11	Female	2
02	Female	7	12	Female	3
03	Female	5	13	Female	3
04	Female	7	14	Female	4
05	Female	7	15	Female	3
06	Male	7	16	Male	1
07	Male	6	17	Male	1
08	Male	5	18	Male	1
09	Male	5	19	Male	2
10	Male	6	20	Male	1

voice studies, and were active professional singers. Group II consisted of 10 (5 males and 5 females) trained singers having any grade from 0 to 4 in western classical music. The following table 1 provides information of the participants in group I and group II. The participants from group I were active members of the Madras Music Association (MMA) and schools which specialized in training singers in western classical music, such as, the Bangalore conservatory. Few of the participants were students, learning music in Bangalore and Hyderabad. The singers in group II had prior exposure to classical western music but did not possess training for more than 4 years. 4 singers in group II were training for grade 1, 2 singers had passed grade 1 and were training for grade 2, and 3 singers were training for grade 3 and one singer passed grade 3 and was training for grade 4.

3.2 Ethical procedures

The participants were briefed regarding the research and a written consent from the participants was obtained before carrying out the recording.

3.3 Inclusion criteria

Individuals with any vocal complaints were not included in the study and they were in good health at the time of the recording. The length of singing training varied among the singers, and voice classification was not considered. Even if the singers were performing for more than 5 years, only the grade of passing was considered while grouping, as the main aim of the study was to study the effects of training.

3.4 Stimulus and recording of tasks

A sung vowel /a/ and the first verse from the song “silent night” were recorded. The reason for selecting the vowel /a/ for the study is based on the evidence provided in the study by Sundberg (2001), which suggests that the resonance characteristics of the vowel provide for better visualization of the singer's formant. The song silent night was selected as it is a popular composition. Singers who were not familiar with the lyrics were given the lyrics of the song and were instructed to rehearse till they were confident before recording. Each singer was familiarized with the lyrics of the song before recording and was allowed to sing once before recording, so that any discrepancies due to inappropriate pitch or errors in the lyrics would not alter the values. Recording was carried out in relatively quiet environment. After instructing the participant, the recording started. The input levels in the recorder were checked and set depending on the level loudness of the participant before the recording procedure began.

Instructions: The following instructions were given for the 2 tasks.

"Task 1: Hold the microphone 5 cm away from your mouth; do not move the microphone while singing. When you are ready, sing the vowel /a/ in your most comfortable pitch and loudness. Task 2: sing silent night in your comfortable pitch and loudness".

3.5 Instrumentation

Olympus LS -100, multi track linear PCM recorder was used for recording. The software PRAAT (Version 5.3.56) was used to obtain Long term average spectrum

(LTAS) of the recordings. A Toshiba laptop with Windows 7 software served as the workstation to carry out the analysis.

3.6 Analysis

The recordings obtained were transferred on to the hard drive of the Toshiba laptop and saved as .wav format using Adobe Audition (Version 6.0) software. PRAAT (Version 5.3.56) was used to display and visualize the samples. LTAS was extracted and the frequency peaks were examined for their amplitudes.

A steady state of 3 seconds was visualized in the sung vowel /a/ recording and LTAS was obtained. The amplitude of singer's formant was picked manually. In the recordings of the song a vowel from the song "silent night- all is calm, all is bright" was used for analysis. The steady portion of the vowel /a/ from the word "calm" was used to check for the presence of singer's formant as it was sung uniformly by all the singers without variation. The amplitude and frequency of this vowel in song was analyzed in all the singers

1) Singer’s Formant (F_S): was noted as the amplitude in dB of the prominent peak between 2500 Hz to 3500 Hz. Both the values of the peak in Hertz (F_S) and the amplitude in dB were noted. Figures 3 and 4 depict the spectrum of the sung vowels in two participants with the cursor at the region of location of F_S.

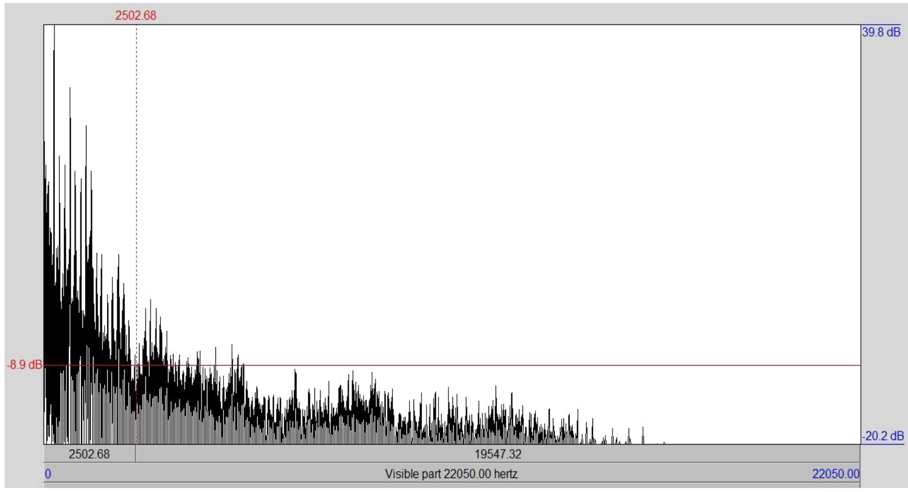

Figure 3.1. Spectrum of the sung vowel of a singer training for grade 1

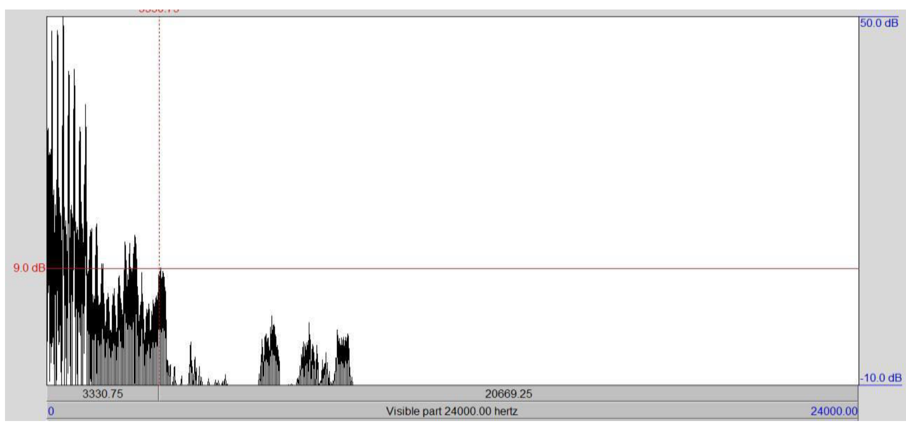

Figure 3.2. Spectrum of the sung vowel of a singer training for grade 5

2) Singing Power Ratio (SPR): Manual calculation was done to calculate SPR using the method given in the study by Omori et al. (1996).

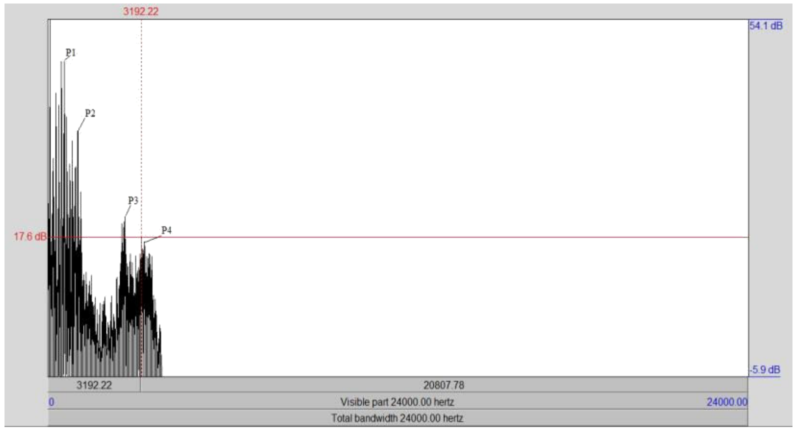

Figure 3.3. Calculation of SPR following the method described by Omori et al. (1996)

Between 0 and 2 kHz, two harmonics peaks were identified in the spectrum envelope at 563.42 Hz termed as (P1) and (P2) at 1041.24 Hz. Between 2 and 4 kHz, two harmonics peaks were identified in the spectrum envelope at 2640.91 Hz as (P3) and (P4) at 3201.83 Hz. These harmonics peaks (P1, P2, P3, and P4) correspond to the first, second, third, and fourth formant, respectively. The greatest harmonics peak between 2 and 4 kHz was termed singing power peak (SPP). Power ratio of SPP and the greatest peak between 0 and 2 kHz, termed singing power ratio (SPR), was calculated and expressed in dB, the ratio between the greatest peak in power between 2 and 4 kHz and the greatest peak in power between 0 and 2 kHz.

3.7 Statistical analysis

The statistical analysis was carried out using the SPSS software. The data was fed into the SPSS 17.0 version. The amplitude of the singer's formant in the sung vowel and the SPR was correlated using Spearman's rank correlation. The amplitude of the singer's formant for both the sung vowel and the singing of a line from the song were compared between groups using descriptive statistics such as mean and standard deviation. Independent t-test was carried out to compare the mean of group I and group II. Spearman rank correlation was applied to assess the relation between singer's formant within group across genders.

Chapter 4

Results

The aims of the present study were: to check for the presence of singer's formant in Indian singer's trained in western classical music and to check for the influence of the level of training on singer's formant in these singers.

The results of the study can be studied under three sub-headings,

1. Presence or absence of singer's formant
2. Effect of training on the singer's formant
3. Within and across group differences

4.1. Presence or absence of singer's formant in the two groups of participants

Table 4.1

Tabulated data of Mean and standard deviation of Fs and its amplitude for sung vowel and vowel in song in the two groups

Groups	Frequency of F_S - Sung vowel Mean (SD)	Amplitude of F_S - Sung vowel Mean (SD)	Frequency of F_S – Vowel in song Mean (SD)	Amplitude of F_S - Vowel in song Mean (SD)
Group I	3333.54 (293.54)	14.10 (5.95)	3324.85 (275.60)	11.70 (8.50)
Group II	3419.76 (341.127)	13.08 (9.61)	3365.36 (356.31)	11.35 (7.76)

The participants in Group I showed the presence of F_S in both tasks, i.e., in sung vowel and vowel in song. The mean frequency and amplitude of group I for the sung vowel and vowel in song tabulated in Table 2. The observed values in the frequency did not vary much with a mean of 3333.54 Hz for sung vowel and a standard deviation (SD) of 293.54 Hz, statistically this deviation is considered high. The mean amplitude was 14.10 dB with an SD of 5.95dB.

In Group II, it was observed that four participants (16, 17, 18 and 20), did not exhibit F_S. It was noted that these singers were training for Grade I of classical western music, their period of training for Grade I of western classical music were between 8 months to 1 year.

Four out of 10 participants in group II did not exhibit a singer's formants as high level spectrum in the 2500 Hz to 3500 Hz region was not observed. The mean frequency of this group was observed to be 3419.76 Hz for sung vowel and 3365.36 Hz for vowel in song with an SD of 341.127 Hz and 356.31 Hz respectively. The mean amplitude of Fs for group II was noted as 13.08 dB for sung vowel and 11.35 dB for vowel in song with an SD of 9.61 dB and 7.76 dB respectively.

4.2. Effect of training on the singer's formant

The performance of sung vowel showed that participants in group I performed better, having a mean of 14.100, while the participants from group II had a mean of

13.080. However, no significant difference was observed as p>0.05, for the sung vowel and for vowel in song at't' = 0.663 and 't' = 0.474 respectively.

The mean frequency of all the groups, however, did not differ much in terms of frequency, i.e., most of the participants exhibited a peak at the level of 2500Hz to 3500Hz but for a few males it was not considered as the presence of a singer's formant due to lack of 6dB. For the rest of the participants no significant difference was observed at p >0.05, having 't' value of 0.606 and 0.284 for the sung vowel and vowel in song respectively.

Table 4.2

Correlation between grade of the singer, singing power ratio, amplitude of F_S *in sung vowel and vowels in song*

	Grade of singer ρ - (2 – tailed)	Singing power Ratio ρ - (2 – tailed)	Amplitude of F_S - Sung vowel ρ - (2 –tailed)	Amplitude of F_S – vowel in song ρ - (2 –tailed)
Grade of singer	1.000	0.629* (0˙016)	0.207 (0.477)	-0.049 (0.868)
Singing power Ratio	0.629* (0.016)	1.000	0.213 (0.464)	-0.424 (0.131)
sAmplitude of F_S – Sung vowel	0.200 (.477)	0.213 (0.464)	1.000	-0.415 (0.140)
Amplitude of F_S – vowel in song	-0.049 (0.868)	-0.424 (0.131)	-0.415 (0.140)	1.000

* symbolizes correlation significant at 0.05 level of significance. (2 tailed).

Spearman's correlation was done to obtain the relation between grade of the singer and SPR. It was found that there was significant moderate positive correlation (ρ = .016, $p < 0.05$) between the grade of the singer and SPR. This positive correlation is shown in figure 6, containing the scatter plot, it can be observed that trend shows a moderate correlation in the positive direction. There was no significant statistical correlation between grade of the singer and amplitude of F_S in sung vowel and between grade of the singer and amplitude of F_S in vowel in song. Also no correlation was observed in the F_S between tasks, that is, the amplitude of the F_S in the sung vowel and F_S for vowel in song did not correlate.

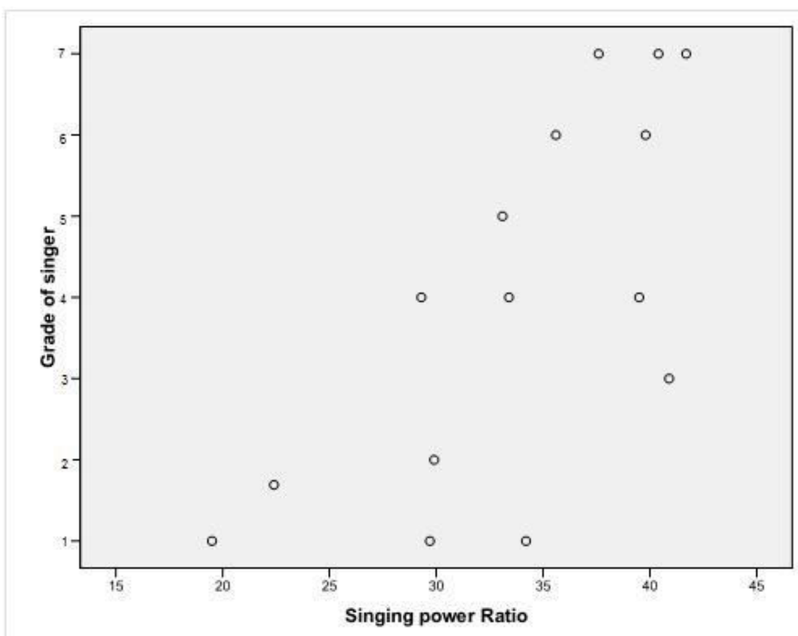

Figure 4.1 Scatter plot of the correlation between SPR and Grade of singer

4.3. Within and across group differences

Table 4.3

Mean, standard deviation of the Fs amplitude across gender and group

		Group I Mean (SD)	Group II Mean (SD)
Amplitude of F_S (Sung vowel)	M	15.56 (11.63)	11.32 (5.791)
	F	10.60 (7.55)	11.38 (10.103)
Amplitude of F_S (vowel in song)	M	13.84 (4.21)	6.10 (6.986)
	F	14.36 (7.86)	17.30 (5.949)

Table 4 provides the mean and standard deviation across male and female participants of group I and group II. The mean amplitude of F_S for sung vowel of male participants in group I was 15.56 and female participants had a mean of 10.60 while that of those of group II had 11.32, and 11.38 for males and females respectively. It is observed that for this task i.e., sung vowel, males had higher mean than the female participants in group I while the participant in group II did not vary widely. Also the female participants of group II had a higher mean than those of group I.

Mean of amplitude of F_S was calculated across gender and across groups for vowel in song. It was noted that the male participant of group I had a higher mean (13.84) than the mean of their male counterparts in group II (6.10). Results of the female participants do not follow the trend, as the participants of group I had a lower mean (14.36) than the mean of the participants in group II (17.30).

The results show presence of singer's formants for participants with training above grade I level. A significant positive correlation was observed between the SPR and the grade of the singer. The amplitude of singer's formant was higher for males in the group I for both tasks than males in group II, in females as reverse trend was observed, i.e., the females in group I had lower mean amplitudes for both sung vowel as well for the vowel in song.

Chapter 5

Discussion

The primary aims of the study were to check for the presence of singer's formant in Indian singer's trained in western classical music and for the influence of the level of training on singer's formant in these singers.

5.1 Presence or absence of singer's formant in the two groups of participants

Participants of group I exhibited the Presence of F_S, while four participants in group II did not exhibit a F_S while performing both tasks i.e., sung vowel and vowel in song. It was also observed that these singers were training for grade one had an experience in singing ranging from 8 months to 1 year. This reduced period of training compared to the rest of the participants may be attributed to the lack of F_S in these singers.

5.2. Effect of training on the singer's formant

The level of F_S was found to vary depending on a singer's proficiency, vowel, and fundamental frequency (F_0), vocal loudness, and phonation mode; its center frequency also varies depending on various factors. Sundberg (1977) reported of its level relative to the level of the first formant and found it reasonably constant within a given operatic voice singing a given vowel at a given degree of vocal loudness at various F_0.

It is established that, the proficiency of the singers is a major contributor the presence of the singer's formant. If the singer is quite proficient or has enough years of experience, the prominence of the singer's formant will be directly affected. Although no statistically significant difference was found between the two groups, positive correlation between the experience of the singer and singing power ratio implies the gradual mastery of respiratory dynamics while singing achieved through training.

The results presented in table 2 represent the means of the group I and II and their standard deviation along with their statistical significance. The mean frequency of group I and group II suggest high variation from the mean, due to the grouping, i.e., voice classification was not considered in the grouping criteria, hence a large deviation from the mean was observed. Lack of significant statistical difference in the amplitudes of the F_S was unexpected as the previous research shows a significant effect of the experience of a singer on the location and amplitude of the singer's formant.

However, the level of training considering, the grade passed, did not entirely portray the singer's proficiency. The grouping of the participants based on the grade of music exam passed did not effectively define the groups on their quality of singing. The reason for this may be explained this way. Though the participants passed a grade, the number of years of training and the number of years of performing would definitely play a role in the appearance of a singer's formant. A person with 12 years of performing without passing a grade and a person who passed 8^{th} grade with just 4 years of professional training may have the same results, or the person with more years of experience may, by all means, would have better singer's formant in terms of level, bandwidth and frequency.

The correlation between grade of the singer, singing power ratio, amplitude of F_S (song) and amplitude of F_S (sung vowel) are tabulated in table 3. As mentioned earlier, the grade of the singer and the SPR correlated significantly at $\rho=0.629$ $p < 0.05$. This correlation suggests a straightforward relation between level of training and SPR. Also the positive correlation between amplitude of F_S of sung vowel and SPR could be accounted for the physiology of the unobstructed manner of production of the vowel /a/.

Sundberg (2001) reported that females with very high fundamental frequencies (F_O) exhibited great variability both between and within vowels, and the mean over all data points were a negative value, which he accounted partly due to the high F_0 and the associated great frequency distance between adjacent partials, which decide the level of F_S. Even in this study it was observed that the females with high F_O had widely varying data, which might contribute to the negative correlation between the F_S (vowel in song) and the SPR.

5.3 Within and across group differences

The males of group I had higher mean compared to the females of the same group as seen in table 6. This could be explained by accounting the loudness of the male voices, as Sundberg in 2001 reported that overall vocal loudness was a factor on which the level of the F_S depended. It is readily accepted that males in general have a lower pitch and higher amplitude. All 5 females in group I were had higher F_O compared to the males of group I, hence it can be concluded that lower pitch and higher amplitude of the males has contributed to the higher mean of F_S in sung vowel. There was no significant difference observed in group 2 in this task. This could be attributed to the level of training in the male singer's, - 4 participants of grade 1 and 1 of grade 2. If the male participants were able to exhibit higher amplitudes their mean would have been higher than that of the females of the same group, but a high amplitude peak was not observed, it could be attributed to their lack of training.

Across the groups, the males of group I had higher amplitude of F_S for sung vowel than males of group II while performing the task of vowel in song, there is a wide difference between the males of group I and group II. Conversely the females showed a reverse trend although not statistically significant. This is in consonance with the research of Weiss et al (1996) who reported that singers with high fundamental frequencies have a different method of projection which need not use a high amplitude spectrum in the F_S region. This is acquired through training. Hence, singers who have not received enough training may not exhibit such mastery of high pitched singing similar to an experienced singer. However, the groups were not based on the experience of the singers but the grade of passing; this explains the lack of statistically significant variation between groups and across genders.

Chapter 6

Summary and Conclusion

This study was conducted to check for the presence of singer's formant F_S in singers with two levels of training, and to compare the effect of the training across the groups. 20 singers all trained and at different grades in western classical music participated in the study. They were categorized into 2 group; Group I and Group II. Group I consisted of participants with training above grade 5 and group II consisted of participants with training below grade 5. The participants were required to perform a sung vowel and a vowel /a/ the song "silent night" (All is calm) in their most comfortable pitch and loudness. Audio samples were analyzed using the software PRAAT version 5.3.56 to identify the amplitude of F_S in sung vowel and in the vowel in song and SPR was calculated. Statistical analysis was done using SPSS 17.0.

Effect of training was checked using the grade of singing the singer passed to the amplitude of the F_S in sung vowel and while singing "silent night". Positive correlation was seen between grade of the singer and SPR, where no significant correlation was observed between SPR and F_S of sung vowel and F_S of vowel /a/ in singing "silent night". Singer's formant was observed in participants of both the groups; a high level amplitude spectrum was observed around the region 2500 kHz to 3500 kHz. Four singers from the group II did not have this spectrum. In group I the F_S was observed in all the participants, suggesting training does affect the appearance of the singer's formant. The females did not have a high amplitude at the region where singer's formant is expected to be, suggesting that singer with high frequency fundamentals use a different method of projection when compared othrers. This was noticed in group I as their experience and training would have allowed them to sing such high pitches without more projection in the lower frequencies, i.e., at around 2500Hz to 3500Hz level. Also, dividing the groups bases on the grade of singing passed, would not efficiently describe the quality of the singing as the grade of singing and experience do not necessarily correlate.

In conclusion it can be stated that singer's formant was present in Indian singers of western classical music. The results of the present study proved that appearance of singer's formant depended on the training of the singer. The findings of the present study confirmed on larger subject group and with different levels of training starting form beginners to established singers. The findings of the present study also shed light on western classical music being different from other classical music of Indian origin i.e. Hindustani or Carnatic styles. Wherein results of majority of the studies in the recent past did not report of presence of singer's formant in Carnatic and Hindustani vocal music. The current study is unique, in the sense that no research has been done in classical singers of Indian origin.

References

Barrichelo, V. M. O. Heuer, R. J. Dean, C. M. Sataloff, R.T. (2001). Comparison of singer's formant, speaker's ring, and LTA spectrum among classical singers and untrained normal speakers, *Journal of voice* 15, 3, 344 – 350

Bartholomew, W. T. (1934). A physical definition of "good voice quality" in the male voice. *Journal of the Acoustic Society of America*, 6, 25, 25 - 33

Bloothooft. G, & Plomp. R. (1986). The sound level of the singer's formant in professional singing. *Journal of Acoustic Society of America*, 79 (2028–2033)

Boominathan, P. (2004). Do Carnatic singer's have Singer's Format? Proceeding of Frontiers of Research in Speech and Music.

Boominathan, P. (2008). In Assessment of professional voice. Proceedings of Seminar on Voice: Assessment and Management, All India Institute of Speech & Hearing, Mysore.

Brown Jr, W.S., Sapienza, C., Rothman, H. B., Mendes. A. P. (2003) Effects of vocal training on the acoustic parameters of singing voice. *Journal of voice* 17,(4), 529-543.

Bunch, M. D. (1982). *The Dynamics of the Singing Voice*. 5th ed. New York, Vienna: Springer, 2009.

Chayadevi, N. (2003). Singer's formant in Indian classical Singer's Carnatic vs. Hindustani. Student research at AIISH; Articles based on dissertation, Vol II

Fant, G. (1960). Acoustic theory of speech, In Acoustic theory of speech production, s'Gravenhage: Mouton1, 15 – 60.

Kenny, D.T., Mitchell, H. F. (2007). Vocal quality in female classical singers; The role of acoustics, perception and pedagogy. Proceedings of the third conference on interdisciplinary Musicology (CIM07)

Mohan, Ranjini. (2010). The effect of training I the voice of Carnatic classical singers. Students research at AIISH; Articles based on Dissertation, Vol II.

Mohan, R.G., (2007). The singing power ratio: An objective measure of singing voice quality in untrained singers, usefulness in Indian context. Proceedings of frontiers of research in speech and Music.

Morris, J. Wiess, R. (1997). The singer's formant revisited: Pedagogical implication based on on a new study. *Journal of singing*, 53(3), 21-25

Omori, K., Kacker,A., Caroll,L. M., Riley, W. D. & Blaugrund, S. M. (1996) Singing power ratio: quantitative evaluation of singing voice quality. *Journal of voice*.10, (3), 22-235.

Sengupta. R (1990)Study on some aspects of the "singers formant" in North Indian classical singing voice. *Journal of voice.* 4, (2), 129-134.

Scherer, K. R. Siegwart, H., (1995). "Acoustics concomitatnts of emotional expression in operatic singing: The case of Lucia in Argi gli incenti". *Journal Of research in Music education.* 31, (3), 227-233.

Schutte, H. K.., Miller, R. (1984). Resonance balance in register categories of the singing voice: a spectral analysis study. *Folia Phoniatrica*, 36, pp. 289–295

Sujatha (1989). Analysis of singing voice, Students research at AIISH: Articles based on Dissertation Vol II

Sundberg, J. (1970) “Formant Structure and Articulation of Spoken and Sung Vowels.” *Folia phoniatrica* 22, 28-48.

Sundberg, J. (1974) “An Articulatory Interpretation of the ‘Singing Formant’.” *Speech Transmission Laboratory Quarterly Progress and Status Report* 1, 45-53.

Sundberg, J. (1977). The Acoustic of the singing voice. *Scientific American*, 236(3), 82-4, 86, 88-91.

Sundberg, J. (1987).The Science of the Singing Voice. Dekalb, Illinois; Northern Illinois University Press, 1-194

Sundberg, J. (1994)

Sundberg, J. (1995) “Acoustic and Psychoacoustic Aspects of Vocal Vibrato.” *Vibrato* (1995): 35–62.

Sundberg, J. Stone, R. E., & Cleveland. T., (2001). Long-Term-Average Spectrum Characteristics of Country Singers During Speaking and Singing. The singing foundation, 15(1), 54–60

Sundberg, J. (2001). "Level and center frequency of the singer's formant". Journal of voice 15(2) 176-186

Supritha, A. & Swathi, S. (2011). Effect of different levels of training on singing power ration and singer's formant in classical Carnatic singers. In Journal of ITC Sangeet research academy, 25, 46-57

Vennard, W. (1967). *Singing, The Mechanism and the Technic.* 5th ed. New York: C. Fischer, 1968.

Weiss, R. Brown, W. S., & Morris, J (2001) Singer's Formant in Sopranos: Fact or Fiction?" *Journal of Voice* 15, (4) 457-468.

Welch, G. F. (1994) The assessment of singing. *Psychology of music*. 22(1), 3-19

Online References:

Pictographic representation of Source filter theory (Fant, 1960) (Taken from the Haskins lab retrieved from http://www.haskins.yale.edu/featured/heads/mmsp/acoustic.html Article titled "The Acoustic Theory of Speech Production: the source-filter model"