PATRICIA CALLAWAY
The Use of Spectrographic Analysis of Female Voices in the College Voice Studio
(Under Direction of MARY LEGLAR)

The purpose of this study was to examine the potential usefulness of spectrographic analysis technology for the training of female singers in a college voice studio. Specifically, the following questions guided the study: (1) What information can be satisfactorily delivered through the study of spectrographic wave files? (2) Will subjective data, including the teacher's evaluation and subjects' self-evaluation of their performance in the vocal studio, be consistent with the objective data from the spectrographic wave files? (3) Will the subjects find the use of the spectrograph helpful? (4) Will the use of spectrographic technology prove to be compatible with traditional teaching techniques?

Subjects were 10 students, ranging from ages 18-23, assigned to the investigator's voice studio at a small private women's college. Data collection took place during 10 sequential weekly lessons. After the warm-up segment of the lesson, students repeated three sequences of the same vocalise in ascending keys. A wave file recording was made of the third (highest) repetition. After recording the wave file, each subject completed a Likert-type questionnaire regarding her perception of the usefulness of the spectrograph. The teacher completed a comparable questionnaire

The findings were reported via graph analysis and case studies of each student. Analyses of the findings indicated that: (1) A rich variety of information may be gleaned from wave files. This information includes, but is not limited to, the strength of upper and lower level frequencies and the presence of vibrato, glottal attacks, uneven breath, and diction problems. (2) The spectrographic data were consistent with the instructor's overall assessment of each subject, but little consistency was observed between that data and the instructor's or the subjects' assessment of their weekly or long-term progress; (3) The subjects found the spectrograph helpful, and appreciated its ability to provide a visual picture of vocal strenghths and weaknesses; (4) The use of the spectrograph is compatible with traditional voice teaching techniques

INDEX WORDS: Singing, Voice teaching, Vocal pedagogy, Spectrographic analysis

THE USE OF
COMPUTER GENERATED SPECTROGRAPHIC ANALYSIS OF
FEMALE VOICES IN THE COLLEGE VOICE STUDIO

by

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DEDICATION

This work is dedicated with grateful thanks to Inge Manski-Lundeen of the Metropolitan Opera and West Georgia College, who taught me not only how to sing, but also how to listen to voices.

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CHAPTER 1

INTRODUCTION

Although voice teachers have displayed interest in the physiological and acoustical characteristics of the singing voice throughout the history of vocal pedagogy (Miller, 1998, p. 297), until recently few have undertaken serious study of these characteristics. Rzhevkin, writing in 1954, attributes the “insufficient study of a singer’s voice” to

> the fact that only random individual work is being done in the field, i.e., no systematic investigations are being conducted. The utilization of the methods of modern acoustics is completely inadequate in vocal pedagogy as well as in the study of the physiological and psychological aspects of the singing voice. . . . Up to this time there is actually no theory of the singing voice. (p. 330)

In order to produce empirical data, these “random individual” studies, conducted chiefly by “voice scientists” rather than teachers, were necessarily narrow in focus, and some years passed before enough information was accumulated to serve as a foundation for teaching.

Some of these studies provided scientific verification of traditional precepts and practices. For example, in 1967 William M. Tripplet concluded that most vowels sung on a high C (c^3) are indeed heard as [a], and offered a suggestion for improving diction:

> This investigation confirms the observation of Howie and Delattre that most vowels produced on high C are heard as (a). However, it has brought to light the distinct possibility that, in the initial stage of a tone it is possible for a singer to emphasize a partial which corresponds to a formant of a vowel; . . . If a singer could learn to relegate voice quality to second place, and allow vowel color to predominate just for the split second it takes, at the beginning of a tone, to establish the vowel, more intelligible sounds could be sung on high pitches. (pp. 407-408)

Voice teachers who were aware of these studies often found this kind of information interesting but not germane to their daily practice. Even though some of the studies were widely disseminated, in such publications as the *Bulletin* of the National Association of Teachers of Singing (now the *Journal of Singing*), most were not easily applicable to everyday practice. Still, publication of the studies served to make voice teachers aware that scientific knowledge had an important role to play in the improvement of practice.

Although pedagogical practices dating from the seventeenth-century choir schools still have a prominent place in the modern vocal studio, advances in technology are making a more scientific approach to instruction feasible. Total reliance on the teacher's ear and descriptive powers is no longer necessary because of the ready availability of audio and video technologies that can provide empirical feedback on vocal production.

One such technology is the spectrograph, a device that provides an almost instantaneous visual analysis of sound in terms of frequency and amplitude. Traditionally, singers strive for a "full" or "complete" sound, characterized by the balance of strong lower frequency overtones with higher frequency overtones; it is the presence of these higher overtones that distinguishes the professional from the amateur singer. Using the spectrograph, vocal students are able to see, through the increase of colorful lines on the computer screen, when the higher frequencies of the singers' formant are becoming part of their own "fuller" sound. The spectrograph also offers useful feedback about other facets of vocal training. Vowel formation, onset, and vibrato, for example, can also be instantly viewed.

In spite of its capabilities, to date the spectrograph has not been used extensively in private studios. Initially, the equipment was expensive and required much operational expertise. Although a few voice teachers at major conservatories and universities were able to experiment with spectrographs in voice labs, few were able to use it on a day-to-day basis in their private studios. Recently, however, spectrographic software has become widely available, offering more studio teachers an opportunity to employ it in their instruction.

Need for the Study

To date, little research has been done on the use of the spectrograph in traditional voice studios. Research-based models of effective use of this technology are needed. Gareth Nair (1999) contributes to the establishment of such a model, but Nair's emphasis on a particular instructional style probably diminishes its usefulness for most teachers.

Research is also needed on the effect technology-based instruction has on students. Research reports often provide more information about the nature of the technology and experimental controls than about the singers who participated. For example, Tripplet described the subjects and the methodology of his study as follows:

> Two voice students at the University of Southern California volunteered to have their voices recorded. A tape recording was made in a sound-treated radio studio; the microphone and recording equipment used were capable of handling frequencies up to 18,000 cps. The singers were given a card which had on it the five primary vowels in the following sequence: (i̲) — (ee) as in *beet*; (e̲) — (ay) as in *date*; (a̲) — (ah) as in *father*; (o̲) — (oh) as in *tote*; and (u̲) — (oo) as in *boot*. So that the singers might feel more at ease, the recording session was conducted rather informally. Each singer was asked to speak the series of vowels as printed on the card, and to sing the same series on each of the following pitches: C_4 (middle C), E_4, G_4, C_5, E_5, G_5, and C_6. (1967, p. 407-408)

A number of questions are not answered by this description. What kinds of voices did the two students have? How old were they? How much training did they have? Had they warmed up their voices before making this test? What singing techniques did they use?

Moreover, as Nair (1999, p. 6) points out, studies of discrete elements of voice science are difficult for voice teachers to use when they are not connected to the environment of the studio and real teaching. Regardless of how much information voice scientists discover and disseminate, the research still does not address the totality of what singers experience.

Studies on the use of science and technology in the context of traditional vocal instruction are sorely needed. In 1967 Ralph Appelman called for voice teachers to become better educated in the physiological and physical realities of voice function:

> Vocal pedagogy cannot survive as an independent educational entity if the physiological and physical facts which comprise its core remain subjects of sciolism (superficial knowledge). Researchers must constantly interpret these scientific facts so that they may become realistic pedagogical tools which may be employed by future teachers of voice. (p. 5)

Although the education of voice teachers has improved in the last 30 years, it is certainly not ideal. Nair urges the profession to make "a greater effort both in everyday practice and in the training of future singers and voice teachers, to understand and incorporate scientific knowledge of the voice. The voice scientists cannot carry the burden alone" (1999, p. 9).

Pointing out that voice teachers tend to teach as they have been taught, Richard Miller calls attention to the need to update traditional studio teaching methods and techniques:

> We should not fool ourselves, however, into believing that what generally takes place in vocal studios in America or elsewhere is based on acquaintance with the current literature of vocal science. Many teachers of singing give a nod of approval to the helpful scientists, and exhibit tolerance and indulgence toward colleagues who have an interest in the subject, but deep in their hearts they know that "singing and teaching are matters of instinct and artistry." There is no possibility of improving on what Madame X handed down to Maestro Y, who in turn gave it unadulterated to "my teacher." Comparative vocal pedagogy reveals stratified systems of both fact and nonsense existing side by side. (1998, p. 218)

Teaching today's students without using today's technology may limit their willingness and perhaps even their ability to use the technology available to them in the future. Studies which introduce current technology into traditional voice teaching studios are necessary to demonstrate not only that the technology is useful, but that it is compatible with and complementary to more familiar teaching techniques.

Purpose of the Study

The purpose of this study is to examine the potential usefulness of spectrographic analysis technology for the training of female singers in a college voice studio. Specifically, the usefulness of spectrography in developing a resonant tone quality and in adjusting that tone quality for various styles of vocal music is examined. The research questions are:

(1) What information can be satisfactorily delivered through the study of spectrographic wave files?

(2) Will subjective data, including the teacher's evaluation and subjects' self-evaluation of their performance in the vocal studio, be consistent with the objective data from the spectrographic wave files?

(3) Did the subjects find the use of the spectrograph helpful?

(4) Will the use of spectrographic technology prove to be compatible with traditional teaching techniques?

Limitations

This study was limited to a 10-week teaching session. The subjects were 10 voice students assigned to the investigator's voice studio at a small private women's college. The students, whose ages ranged from 18 to 23, were at various levels of vocal training, including beginners. Except for the presence of the spectrograph, which was in operation throughout each lesson, instruction was conducted as usual. However, only data collected during the vocalises were used for the study.

Although observations may be made about other uses of spectrography in teaching voice, no attempt has been made to report all of these. Analysis of spectrographic displays was conducted only in the context of their usefulness in a traditional voice studio; no attempt at a full scientific analysis, such as might be made in an acoustics laboratory, has been attempted. Conclusions drawn from the study are limited to the generalizations allowed by the design, procedures, and method of analysis employed.

Definitions

Amplitude – the intensity or strength of a sound wave, frequency, partial, overtone, or formant. Amplitude is shown on a spectrograph either as colors, the brighter colors being more intense or stronger, or as a separate graph called a power spectrum. A spectrograph usually graphs sound on an x-y axis where the vertical y-axis is the frequency, given in Hertz, and horizontal x-axis is the time elapsed in seconds. In this type of graph, amplitude is shown by color, brighter colors indicating greater amplitude.

For a detailed amplitude display at a given instant a power spectrum graph is useful. A power spectrum can be thought of as a third dimension, a z-axis. A power spectrum graph shows only one instant of time, as if the x-y-z axis had been rotated ninety degrees to put the frequency in the horizontal plane (x-axis) and the amplitude in the vertical plane (y-axis). No passage of time occurs in this graph; it is a snapshot of the amplitudes of various frequencies at one instant.

Chiaroscuro effect – the balance between the upper and lower formants of the singing voice.

Chiaroscuro level – author's term for a numerical value representing the ratio between the lower (warm/dark) and upper (brilliant/carrying) frequencies of a vocal tone at a single instant.

$F_{1\text{-}2}$ Power spectrum ratio – author's term for the ratio of the number of strong frequencies (≥ –40 dB) in the $F_{1\text{-}2}$ (0-2000 Hz) area to the total number of frequencies in that area.

Formant – an area of acoustical strength. Just as pitches have overtones, the sounds created by voices and instruments produce formants, areas of the sound spectrum in which sympathetic resonance augments any partials in the tone that are in tune with it. Not only the voice itself, but vowels too, are thought to have formants of their own. An individual voice's own formants are part of the physical sound of the voice and are probably not readily adjusted. It is by adjusting the vowel, and thereby the vocal formants, that resonant tone quality is maximized. The most resonant tone quality is achieved when the sympathetic resonance of the vocal formants reinforces overtones, particularly the higher frequency overtones, of a pitch.

On the spectrographic display of a voice, there are three main areas in which up to five formants may be seen. The frequencies in Hertz measurements are given approximately because they differ from voice to voice. The first formant is an important area of acoustic intensity found between 500 and 800 Hz, near the lowest portion of the spectrum. The fundamental pitch may be represented in this area along with the acoustical energy that produces the warmer dark sounds in a voice.

The second formant is the region in which vowel definition may be seen. Often the variability in this area disturbs first time viewers of spectrographic displays, until they realize that the visual image changes as the vowels change.

> The relative frequencies of the first two formants, which account for most of the resonating power of the vocal tract, determine the vowel that listeners hear. Singers should understand the factors that influence formant frequencies as they cope with the twin tasks of producing clear vowels and modifying these to enhance resonance. (Miller and Schutte, 1999, p. 191)

The third area, called the singer's formant, is in the 2500-3300 Hz range for male voices and up to 10,000 Hz in female voices. It is this acoustical energy that allows trained singers to project their voices without amplification over orchestras and in large concert halls. The natural resonance frequency of the ear is approximately 3100 Hz, which seems to mean that the ear hears best in this frequency range (Titze, 1993). Within the singer's formant a spectrographic display may show one large or up to three smaller areas of strength.

Frequency – the number of vibrations per second that occur at a given pitch, both in the fundamental pitch and in all the partials (or overtones) that occur with that pitch or the instrument that produced the pitch. The overtone series is the mathematical representation of this phenomenon.

Gram spectrographic software – a software program which produces spectrographic analysis on any PC that is equipped with a sound card, a microphone, and a minimum requirement of a Windows 95/98 or Win NT 4.0 operating system with a 6x (or higher speed) CD ROM drive, 16-bit sound card, and at least 16 MB of RAM.

Helmholtz resonator – a glass bulb with a narrow neck. When excited by a brief acoustic pulse, air in the neck is forced downward. Energy is transferred to the bulb, compressing the air in the bulb, which then re-expands, sending the air back through the neck. The rate of flow of the air is determined by the volume of the bulb and the width of the neck, and thus the bulb resonates at certain frequencies. By changing the size and shape of the bulb and its neck, early acoustic researchers could model the vocal tract. (Arcell, 2000)

Hertz (Hz) – a unit of frequency equal to one cycle of the vibration of a sound wave per second (named for the German physicist Heinrich Rudolph Hertz [1857-1894]).

Overtone – a component frequency that is part of a complex tone, such as a tone produced by the voice, which is higher than the fundamental frequency. A particularly good chart of the overtone series is found on page 11 in William Vennard's *Singing: The Mechanism and the Technic* and is reproduced here as Appendix E.

Partial – the overtones that are produced along with any fundamental pitch. The term "partial" refers to the way that a vibrating string vibrates not only along its full length, but by fractions of its length, thus producing overtones.

Passaggio – one of two areas in the voice, either the area between pure chest register and mixed voice or the area between mixed voice and pure head register, that are of concern to singers when they have difficulty in making smooth transitions between registers. The second passaggio, which in female voices usually lies between b^1 and e^2, is the main area of concern in teaching college-age students. The difficulty arises because of muscular changes in laryngeal function. One of the main topics for the first years of voice study is the matter of blending registers so that the transitions through the passaggi are smooth and no "breaks" are audible.

Power spectrum graph – a spectrographic display in which the relative strengths, or amplitudes, of various frequencies are graphed (*see* Amplitude). It can be a real-time display running as the singer is singing or a "snapshot" graph of any given moment on a wave file or other recorded sample that has undergone spectrographic analysis.

Power spectrum ratio – author's term for the ratio between the number of frequency peaks at or above the 2000 Hz level with the total number of peaks in the entire power spectrum graph.

Singer's formant – *See* Formant.

Sonograph – the brand name of a commercial spectrograph. The terms "sonograph" and "spectrograph" are often used interchangeably.

Spectrogram – the display produced by a spectrograph. A sound is graphed on an x-y axis, where the vertical x-axis is the frequency in Hz, and the horizontal y-axis is the time elapsed in seconds. Amplitude is shown by color. A power spectrum can be thought of as a third dimension, a z-axis. A power spectrum graph shows only one instant of time, as if the x-y-z axis had been rotated 90 degrees to put the frequency (x-axis) in the horizontal plane and the amplitude in the vertical plane.

Spectrograph – a device or software program which analyzes sound and produces a display called a spectrogram, which is a graphic representation of the acoustic output of a sound.

Spectrum – the band of audible frequencies which are analyzed by a spectrograph, approximately from 15 to 20,000 Hz.

Wave file – a recording made by a computer of sound input by microphone that can be saved on a disk and used for later spectrographic analysis.

Zygomatic arch – the zygomatic bones are the framework for the upper part of the face and are particularly noticeable as the cheekbones. The zygomatic muscles are the muscles in the area of the cheekbones which move the mouth into a smiling position.

Summary of Procedures

Subjects for the study were 10 female students—3 freshmen, 1 sophomore, 2 juniors, and 4 seniors—assigned to one studio at a small private women's college. Various majors were represented, including vocal performance, musical theater, music education, mass communications, and arts management. The subjects had extensive performance experiences during the semester in which the study was conducted: all except the musical theater majors participated in student recitals and college chamber choir concerts; the two musical theater majors had leading roles in a musical theater production. All except the freshmen were familiar with the spectrograph, having participated in the pilot study conducted during the spring semester of 2000.

Each subject received one 50-minute voice lesson per week for a period of 10 weeks. Data were collected during the warm-up portion of the lesson, for which the same vocalises were used each week. After the warm-ups were completed, a wave file for that week was created and saved on a disc. Immediately afterward, the student and teacher watched a replay of the wave file, and each completed a short Likert-style questionnaire eliciting their reactions to using the spectrograph and a comparison of the current week's performance with previous performances. The wave files and the questionnaires provided the quantitative data for the study; qualitative data were drawn from descriptive reports of the process written each week by the teacher and at the end of the study by each student. Quantitative data were analyzed statistically and presented in the form of graphs for each student and for the students as a group. Qualitative data was analyzed in student profiles describing the student's natural vocal ability, training, and progress as assessed by the teacher and by the student.

Organization of the Study

This document contains five chapters accompanied by appendices and two bibliographies. Chapter One includes (1) introductory remarks, (2) need for the study, (3) purpose of the study, (4) limitations of the study, (5) definitions of specialized terms used in the document, (6) a summary of the methodology used in the study, and (7) a description of the organization of the study. Chapter Two provides a review of the literature related to this study. Chapter Three describes the procedures and methodology used in the study. Chapter Four contains the findings of the study along with an analysis and discussion. Chapter Five includes the conclusions and suggestions for further research. Appendices include a description of the vocal levels attained by each student, a copy of the form used for student evaluation of the spectrograph test unit, verification from voice teachers not participating in the study that the questions on the student form would be clear to most voice students, a copy of the form used for similar teacher evaluation, the vocalises used before and during the spectrograph test unit, spectrograms from the wave files made at each test unit along with analyses, a copy of the explanation given students on how they were to write their report at the end of the study, the Vennard chart of the overtone series, a chart of passaggio occurrences in various voice types, a chart of pitch names used in this study, and an IPA chart.

CHAPTER 2

SURVEY OF THE LITERATURE

Introduction

The literature related to the training of the singing voice can be divided into two major areas, voice science and vocal pedagogy. Research in voice science is concerned with physiological and acoustical problems; studies in vocal pedagogy deal with problems related to the development of the singing voice. While the two areas are obvious complementary, this relationship has not always been acknowledged. In fact, voice science and vocal pedagogy were viewed as quite distinct until the nineteenth century. Throughout the twentieth century the trend has been to treat these two areas as interrelated, and the present study is firmly grounded in that viewpoint. Of necessity, however, the following literature review to some extent reflects that historical dichotomy.

Even within the more inclusive twentieth-century approach to vocal development, distinctions have been made, particularly between what is sometimes called “scientific voice teaching” and a more traditional “gestalt” approach. Duggan describes scientific voice teaching as being “concerned with the various physical phenomena of voice production and how the understanding of these phenomena can lead to definite standards of vocal training” (1992, p. 16). The traditional approach, in contrast, can be defined as

> any method of teaching based on the assumption that singing is the result of an complex series of physical actions that may not always be individually controllable or scientifically explainable. . . . The pedagogical theories of writers which show aspects of the gestalt approach are intended to be based on scientific

> knowledge; however, detailed scientific descriptions of vocal functions are generally avoided. (Duggan, 1992, p. 16)

Although voice teachers who adopt a “scientific” approach are perhaps more likely to incorporate technological advances in their teaching, both gestalt- and scientifically oriented teachers have made contributions to the literature on the use of spectrographic analysis in the voice studio. Regardless of orientation, most voice teachers and researchers now recognize the necessity of understanding the physiology of the voice and the way that physiology interacts with the acoustics of the voice. Nonetheless, the distinction between the two approaches is real and is reflected in the literature review.

The review is organized chronologically, in order to demonstrate clearly the historical movement toward the integration of voice science and vocal pedagogy. The discussion is divided into five periods: (1) pre-nineteenth century, (2) 1800-1920, (3) 1920-1980, (4) 1980-1995, and (5) 1995 to the present. These divisions are consistent with identifiable developments in science and technology related to vocal pedagogy and with observed changes in the attitudes of voice teachers toward those developments.

Pre-Nineteenth Century Studies of the Voice

Voice studies before the nineteenth century fall into three categories: medical studies, studies of the voice as a musical instrument, and vocal pedagogy treatises. Medical studies of the structure and function of the larynx were carried on from the time of Galen of Pergamum, who lived from 129 to 199 A.D. (Kennedy-Dygas, 1999, pt. 1, p. 20), but need not be reviewed here. Studies of various historical points of view about how to use the voice as a musical instrument, fascinating though they are, also have no place here.

Literature on vocal pedagogy before the nineteenth century was primarily concerned with skills that should be taught to singers, not with theories on how the voice functioned. For voice teachers, the most familiar pre-nineteenth-century works on voice are Pier Francesco Tosi's *Observations on the Florid Song* (1743) and Giovanni Battista Mancini's *Practical Reflections on the Art of Singing* (1774). Both are treatises on how to train singers in the manner that was traditional in the eighteenth century. Both Tosi and Mancini discuss ear training, ornamentation, and musical style as much as or more than techniques of training the voice, but the parts of their books that are relevant to this study are their reflections on vowels as tools to achieve resonant tone quality.

Richard Miller summarized their points of view as follows:

> [The] Castrato Tosi . . . offered more specific information as to the effects of the articulators on the resonator tract. In keeping with the age-old Italian preference for front vowels over the back vowels in upper range, he maintained that the vowels [i] and [e] were less fatiguing than the vowel [a]. . . .
>
> Much of [Mancini's] pedagogic comment is directed to the resonator system, with particular attention to the maintenance of natural postures of the buccal cavity, and to the smiling posture as an adjustor of the vocal tract. . .He thought the Italian vowels [a, e, o, u] could be sung on each note in the position of a smile with the [o] and the [u] being slightly rounded. . . . Mancini felt the [i] vowel was difficult and should be sung in the position of a "composed smile." (1998, p. 303-304)

The facial posture of a slight smile, or raised zygomatic arch, has long been used as part of the process of finding the best vowel sound to achieve a resonant tone. When a singer sings the correct vowel—in other words, when the frequencies of the formants of a vowel approach the frequencies of the overtones of a pitch produced by the voice—both frequencies are strengthened. The acoustic cause of this phenomenon is that when the higher partials of the sound reinforce one another at around the 3000 Hz level, the frequencies are strengthened and the sound is perceived by the listener as fuller, rounder, more complete, or simply better. This concept is behind both the old bel canto ideal of a full sound produced with the minimum of air and current vowel modification strategies.

Thus, although the voice literature of the 17th and 18th centuries should be characterized as prescientific, the theories and practices developed by pre-nineteenth-century voice teachers with the aid only of their excellent ears have been confirmed by twentieth-century acoustical research. In the twenty-first-century studio, spectrographic analysis functions simply as a visual extension of the teacher's ear.

Nineteenth Century Studies of the Voice

In the nineteenth century scientific interest in the function of the voice and in the acoustical functions of vocal sounds and vowels produced a newer physiological and acoustical point of view in the literature of vocal pedagogy. Descriptions of how the voice worked appeared regularly in the voice literature, as did new theories of voice production. According to Margaret Kennedy-Dygas (2000),

> One may observe that science's understanding of the anatomy and function of the voice largely developed separately from the art of singing and voice teaching until the nineteenth century, a time when the development of science and technology exploded into many previously unrelated areas of human endeavor. . . .
>
> When knowledge of how the voice functioned was added to knowledge of its structure in the nineteenth century, scientists and medical practitioners rejoiced in beginning to understand a previously inscrutable art in a more quantifiable way. Suddenly articles and books by scientists and doctors were published that explained the process of singing and learning how to sing. On the other side of the equation, some singers and voice teachers began to acquire the new scientific knowledge and to develop theories about singing based on this new information. . . . Now, arguing from a scientific basis, voice teachers developed new theories about singing, altered old methods, or simply justified old methods. Some of this change was thoughtful and effective; some of it was ill conceived and has died out, thankfully. (pt. 2, p. 23)

Gordon Holmes, writing in 1885, expressed a similar opinion about the activity in the field of laryngology over the period from 1775 until the middle of the nineteenth century:

> In fact, there remained but little in the way of absolute discovery to reward fresh researches in connection with the larynx. But while the growing importance of laryngology attracted a yearly increasing number of observers, the efforts put forth did not always tend manifestly to advance the topics treated of; views of a retrograde character, especially in physiology, were sometimes brought forward with the greatest sincerity, and new-born truths were often obscured by the specious reasoning of prejudiced or short-sighted opponents. The enumeration alone of all the authors in the domain of laryngology would occupy several pages, and, amidst the wide entanglement of proposition, objection, and mere verbosity, it is often extremely difficult to discern, pursue, and at length to extricate the slender thread of progress. (quoted in Kennedy-Dygas, 1999, pt. 1, pp. 21)

These two descriptions portray a period of discovery rife with entrepreneurs in both pedagogy and medicine who rushed into print with partially considered opinions. A further example of this type of "scientific" voice study was described by Richard Miller:

> Not even a brief overview of historic vocal pedagogy can dispense with at least passing reference to Emma Seiler (c. 1875). Her own experiences as a singer, which she describes as having been in both Italian and German traditions, appear to have been frustrating. She finally associated herself with the eminent physicist/acoustician Hermann Helmholtz, who expressed indebtedness to her in his formulation of acoustic theories of voice production. Some of Seiler's assumptions regarding the function of the laryngeal mechanism are insupportable. In explaining her vocal registration hypotheses, she heavily relied on proprioceptive sensations of mouth, throat, stomach, and sternum. Her treatise [*The Voice in Singing*, Philadelphia: Lippincott, 1875] is largely important as a prototype of forthcoming Germanic pseudoscientific pedagogic literature that attempts in imaginative ways to apply physiology and acoustics to the singing voice. (1998, p. 308)

The work of Heinrich Helmholtz (1821-1894) made fundamental contributions in many areas of science including physiology, optics, electrodynamics, mathematics, and meteorology. He was firmly opposed to Immanuel Kant's philosophy of nature, which had been accepted by many biologists of the previous generation. Kant suggested that the concepts of time, space, and causation did not result from the experience of human senses but were themselves attributes of the mind, which made it possible for human beings to perceive the world. Helmholtz believed that knowledge entered the human brain only through the senses, and his varied research was carried out to prove his theory.

In studying the way the brain makes use of information supplied by the senses, Helmholtz made major contributions in many areas of science. His contributions to acoustic research included the invention of the Helmholtz resonator, a small glass sphere with a short, narrow neck that has a single isolated resonant frequency and no other resonances below about ten times that frequency. It was useful for the study of musical tones before electronic sound analyzers were invented because it made it possible to identify the spectral components of a complex sound wave like those created by musical instruments or the human voice. This information was useful in understanding how groups of harmonics when reinforced by vocal tract frequencies (formants) create different vowel sounds. Research of this type was carried on well into the twentieth century but was rarely a part of voice teaching in the nineteenth century.

The two great families of nineteenth-century voice teachers were the Garcias and the Lampertis. The Garcia family included Manuel Garcia and his children Manuel Garcia the Younger, Pauline Viardot-Garcia, and Maria Malibran. The Lamperti group consisted of two Lampertis, father and son, and the son's student William Brown.

In some respects the Garcia family can be thought of as the first scientific voice teachers. Manuel Garcia the Younger (1805-1906), the teacher of Jenny Lind, was particularly interested in the new scientific study of the voice and in fact was long thought to be the inventor of the laryngoscope. Traditionally trained by his father, Manuel Garcia the Elder (1775-1832), and his father's teacher, Giovanni Ansani (1744-1826), Garcia evidently employed traditional techniques; his interest in voice science was partly due to curiosity and partly to a desire to confirm his own ideas of how to teach voice (Kennedy-Dygas, 2000, pt. 3, pp. 26-29). Garcia's writings do not expose any startlingly new ideas, but he did include in his *Garcia's Complete Singing School* (1847) the kind of description of voice function that soon became a regular part of almost every voice teacher's method book.

Francesco Lamperti (1813-1892) described the well-known *appoggio* technique of breath management in his undated *Treatise on the Art of Singing* (Miller, 1998, p. 306). His son Giovanni Battista (Giambattista) Lamperti (1839-1910) taught many of the most famous singers of the late nineteenth century but left no treatise of his own. His ideas were recorded by William Earl Brown between 1891 and 1893, when Brown was the younger Lamperti's student and assistant in Dresden. Brown's book, *Maxims of G. B. Lamperti*, was published in the United States in 1931.

The nineteenth century was also the period during which the Germanic-Nordic singing styles developed in response to the growing literature in German and Scandinavian languages. The seminal German voice teacher was Julius Stockhausen (1826-1906), whose 1884 *Gesangsmethode* had tremendous influence on singers in Germany, Scandinavia, and the United States. Stockhausen, born in Paris, was enrolled at the Paris Conservatoire and studied voice privately with Manuel Garcia. Throughout his life he claimed Garcia's method as his own, but in actuality he made several changes to the traditional Italian style of singing in order to accommodate the German repertoire. He advocated a consistently low larynx and avoidance of the smiling facial expression, that the lips be drawn backward on back and mixed vowels and that they be not merely rounded, but pursed forward for [e] and [a]. "Yet, more in keeping with the Italian pedagogic heritage, Stockhausen recommended the use of closed vowels in ascending pitch patterns, and of open vowels in descending pitch patterns" (Miller, 1998, p. 307).

Clearly Stockhausen's techniques recognized the use of vowels as a critical method of achieving tone color. A similar emphasis on vowels was displayed by both the Garcia and the Lamperti families, both of whom taught what may be described as bel canto singing techniques. The term bel canto, first used in the late nineteenth century by German writers and scholars, is open to more than one interpretation, and it is beyond the scope of this paper to try to distinguish among them. One of the few things that adherents of differing definitions of bel canto tend to agree upon is the use of pure Italian vowels to achieve resonant tone quality, although sometimes they disagree on exactly which are the sought-after vowels. It is this aspect of nineteenth-century bel canto that pertains to the present study.

1920-1980

Beginning in the 1920s, serious scientific study of the voice generated a strong interest in new methods of voice teaching. Although national styles of singing had appeared (Miller, 1977), the differences among those styles tended to be focused on breath management, authentic pronunciation of the native language, and preferences for brighter or darker tone color. The concept of producing and adjusting tone color by choice of vowel was still accepted, even when differing styles of singing preferred different vowels as a tonal ideal.

The lack of unanimity in the voice world was increased by the numerous studies of discrete elements of voice function, which also began to appear in the 1920s. A representative selection of these studies is contained in John Large's *Contributions of Voice Research to Singing* (1980). Everything from breathing movements (Stetson, 1931) to vibrato (Kwalwasser, 1926) to acoustical analysis (Wolf, Stanley, & Sette, 1935) was studied, and voice teachers frequently chose to read and adhere to one idea without regard for competing points of view.

Many voice teachers chose to disregard entirely the new scientific information because it was "unartistic" and continued to teach imaginatively and inaccurately by trying to describe their own physical sensations during the singing process. In his series "Sharpening Up Some Old Pedagogical Saws" in the *Journal of Singing* Richard Miller (1994) held many of these old techniques up to ridicule by comparing long-accepted dictums of vocal pedagogy with simple physiological and acoustical truth. In 1998 he reported that

> comparative vocal pedagogy reveals an immense stratified structure of both fact and nonsense. There exist systems of vocal technique built on assumptions without foundation in fact. Several brief illustrations will suffice: a world-renowned premier tenor recently explained during a master class that the vowel [i] was the only vowel narrow enough to enter the frontal sinuses, while a rival tenor who occupies the very pinnacle of the heap informed his master class participants (while demonstrating slight laryngeal descent on inspiration) that for the "open throat," the epiglottis must be held low at all times". A third noted artist advised "squeezing the uvula with the tonsils." Results from students trying to apply such advice were just short of disastrous. (Miller, 1998, p. 298)

Miller was not the first to advocate putting voice teaching on a sound scientific footing. In the first half of the twentieth century scientific literature about voice function burgeoned. Friedrich Brodnitz, a laryngologist, wrote an excellent manual for singers and speakers entitled *Keep Your Voice Healthy* (1953), in which he explained what was currently known about voice function and hygiene. As physicians like Brodnitz were crossing over into the singing world, some voice teachers were beginning to assist in scientific research. Oren Brown (2000), for example, traveled from the voice teacher’s studio into the voice researcher’s laboratory and back again, eventually bringing what he had learned to the actual teaching process in his own studio. Other voice teachers, such as William Vennard, Ralph Appelman, and Richard Miller, made similar journeys.

A crucial development in the middle decades of the twentieth century was the invention of new technologies that offered more convenient and flexible methods of detecting and graphically representing sound. For example, various types of oscilloscopes became available for use by music researchers. In the 1930s Carl Seashore purchased a Henrici Analyzer for the psychology lab at the University of Iowa. According to Himie Voxman, who used it to make oscillograms of clarinet tones at different pitch and dynamic levels, it was not easy to use: “Two hands were employed to move a pointer across each oscillogram. Numbers recorded on dials plus some mathematical manipulation gave the percentage strength of each partial” (Nelson, 2000). The first commercially available sound spectrograph, or sonograph, was offered in 1951. The spectrograph is a much simpler machine to operate than the Henrici Analyzer, and with its computer interfaces it does most of the work of calculation and analysis.

Among the more important early studies using spectrographs was the 1958 article "Vowel Color and Voice Quality" by Pierre Delattre, which assigned frequencies to some of the more common complexes of vocal sound. In 1962 John Howie and Pierre Delattre used a spectrograph to confirm the long-held belief that it is difficult to distinguish among vowels sung at high pitches; a further study on this topic was published in 1967 by William Tripplet. In 1970 two studies of precisely where in the acoustic spectrum various vocal events took place were made in "Chest, Head, and Falsetto" by William Vennard, Minoru Hirano, and John Ohala, and "Formant Structure and Articulation of Spoken and Sung Vowels," by Johann Sundberg. Sundberg continued this work in his 1977 "Studies of the Soprano Voice," and the 1978 "Studies of the Marchesi Model for Female Registration," by John Large and Thomas Murry, explored similar problems. All of these studies were reprinted in *Contributions of Voice Research to Singing*, edited by John Large, in 1980.

The most influential book for voice teachers of the period from 1920 to 1980 included a summary of voice research to date that had used spectrographic analysis. William Vennard's 1949 *Singing: The Mechanism and the Technic*, which was revised and enlarged in 1967, set the new standard for works on vocal pedagogy. It is an extremely well written description of voice function and the acoustics of the voice. The factual information that it contains is so clearly explained that it remains in use in vocal pedagogy classes even though Vennard's ideas about teaching singing are not all accepted today. Vennard's book includes both stop motion photographic views of the vocal folds in action and spectrographic comparisons of vowels sung with different techniques. For many voice teachers this book was the first understandable application of these technologies to voice teaching.

Ralph Appelman's *The Science of Vocal Pedagogy: Theory and Application* (1967) was written with four objectives in mind: (1) to intentionally and directly train the singer's aural awareness of his utterance of the word in song; (2) to describe the scientific theories of vocal pedagogy in a simplified and direct manner; (3) to suggest a phonetic system of teaching voice based upon the International Phonetic Alphabet (IPA); (4) to offer an acoustic model of phonemic utterance that may be accepted as a standard of imitation (p. vii). Appelman's work was significant in that he tried to use acoustic models of correct speech, not just "pure" vowels to create appropriate tone quality. Among voice teachers today, his concept of a word- and diction-oriented pedagogy has still has a large number of adherents, who tend to find spectrographic analysis not only useful but vital. In contrast, Berton Coffin's *The Sounds of Singing: Vocal Techniques with Vowel Pitch Charts* (1976), which is related to Helmholtz's vowel research, is not in wide use today.

Between 1920 and 1980, both national style preferences and scientific discoveries began to influence traditional teaching techniques. As the twentieth century proceeded voice science gained acceptance among most voice teachers at least as background material necessary for good teaching.

1980-1995

Between 1980 and 1995 the main events in voice teaching were the near universal acceptance of physiology and acoustics as important elements of good voice teaching and the slow acceptance of a more universal standard of what constitutes good singing, possibly brought about by advances in worldwide communications. As scientific knowledge entered the voice studio, scientific equipment such as the spectrograph accompanied it. Voice teachers with access to this type of equipment soon realized that spectrographic analysis confirmed many of the traditional teaching techniques of the 18th and 19th centuries. The results of this research influenced some of the textbooks that are standard in vocal pedagogy classes today such as James C. McKinney's 1982 (revised 1994) *The Diagnosis and Correction of Vocal Faults: A Manual for Teachers of Singing and for Choir Directors,* Richard Miller's 1984 *The Structure of Singing*, and Ingo Titze's 1994 *Principles of Voice Production*

Two recent DMA documents (Bernard, 1995; Duggan, 1992) are compilations of the literature of voice science related to singing and vocal pedagogy. Duggan divided the major scholars writing in the period 1967-1991 into two categories: those favoring the scientific approach, in which he included William Vennard, Ralph Appelman, and Meribeth Bunch; and those taking more of what he called a "gestalt" approach, for example, Lloyd Sunderman, Berton Coffin, Van Christy, and Richard Miller. Of these four the best known is Richard Miller.

The founder and director of the Otto B. Schoepfle Vocal Arts Laboratory at Oberlin College, Miller has long advocated spectrographic analysis as a teaching tool (Miller and Franco, 1991), although not in the studio because, "It is difficult for a singer, especially in the early stages of technical development, to be simultaneously both a producer of the sound and a critical listener of the sound." (Miller, 1995). Although his pedagogical orientation is traditional, Miller emphasizes the importance of being fully informed of the scientific background of voice teaching and of making full use of the available technology. His quest to bring a measure of objectivity to the figurative and often fanciful language of vocal pedagogy led him to combine the languages of vocalism, acoustics, and physiology to write a comprehensive textbook, *The Structure of Singing* (Miller, 1986).

Two of the most prominent names in voice science research are Johann Sunderberg and Ingo Titze. Sunderberg's 1977 article in *Scientific American*, "The Acoustics of the Singing Voice," was a popular presentation of the information that was becoming available about the interaction of voice and vowel formants studies through spectrographic analysis. His 1984 book *The Science of the Singing Voice* became a standard text. Ingo Titze's 1994 *Principles of Voice Production* is the current standard in technical books about the physics of the voice and spectrographic analysis of vocal sound.

The widely circulated *Journal of Singing*, the official publication of the National Association of Teachers of Singing, has played an important part in the changing attitude of voice teachers toward voice science. The *Journal of Voice*, which began publication in 1986, focuses directly on voice medicine and research.

1995 to the Present

The categorization of works on the voice as ”scientific“ or “gestalt” is less useful for some of the more recent works, because the separation between the two categories has begun to narrow. More and more books on vocal pedagogy combine serious science with teaching issues, as is the case with recent books by Robert Sataloff, Jean Callaghan, and Gareth Nair.

Sataloff’s *Vocal Health and Pedagogy* (1998) is a large compendium of articles by prominent researchers including both scientists and voice teachers. Although this book does not discuss spectrography, a review of current literature would be hard to complete without mentioning such a prolific author/editor.

Jean Callaghan (2000) offered a number of criticisms of previous studies that used spectrography: that they tend to be very specific, focusing on one small aspect of singing and using only a few subjects; that they tend to use only isolated syllables or sustained vowels or to sing in only a limited pitch range; that sample populations in early studies were not identified as to voice type, training, or experience. She points out that more recent studies still tend to compare amateur singers with postgraduate students and retired professionals, most of them men; that they tend not to say how much warm-up or preparation was done by the subjects or to evaluate how much invasive techniques might affect the performance; and they often do not detail which of competing vocal techniques are being used by the subject. Her list of objections to spectrographic studies of the past has been taken into account in the planning of this study.

Nair (1999) makes a well-reasoned case for the inclusion of spectrography in the vocal studio and explains in detail how to use spectrographic software. Nair calls for the use of technology in studios and for the sharing of information gained by such usage.

The literature of vocal pedagogy has changed over the years from the short statements on pertinent issues found in Tosi, Mancini, and Lamperti to the excellent textbooks by Titze, Sundeberg, and Miller, which include detailed descriptions of voice function and of the relationship of function to singing technique. As voice science and vocal pedagogy continue to converge, technical guidebooks like Nair’s (1999) will be increasingly valuable, as will evaluations, like Callagan’s (2000), of the contributions of science to pedagogy.

CHAPTER 3

METHODOLOGY

The purpose of this study is to examine the potential usefulness of spectrographic analysis technology for the training of female singers in a college voice studio. Specifically, the usefulness of spectrography in developing a resonant tone quality and in adjusting that tone quality for various styles of vocal music is examined. The research questions are:

(1) What information can be satisfactorily delivered through the study of spectrographic wave files?

(2) Will the subjective data, including the teacher's evaluation and subjects' self-evaluation of their performance in the vocal studio, be consistent with the data provided by the spectrographic wave files?

(3) Did the subjects find the use of the spectrograph helpful?

(4) Will the use of spectrographic technology prove to be compatible with traditional teaching techniques?

Both quantitative and qualitative data were used in answering the research questions. The quantitative data were drawn from (a) spectrograms produced from the wave files and (b) Likert-type questionnaires. The wave file data can be considered both quantitative and objective; the questionnaire data are quantitative expressions of subjective judgments. The qualitative data consisted of (a) the instructor/investigator's written assessment of each subject's background and vocal strengths and weaknesses; (b) subjects' written evaluations of the usefulness of the spectrograph; (c) the instructor's recorded lesson plans and comments on student performance during the lesson; (d) the instructor's comments based on examination of the spectrographic wave files. The data were gathered and analyzed as follows.

Subjects

Subjects for the study were 10 female voice students assigned to the investigator's voice studio at a small private women's college. The subjects ranged in age from 18 to 23 and included 3 freshmen, 1 sophomore, 2 juniors, and 4 seniors. All were natives of Georgia, Alabama, or South Carolina—a factor in their pronunciation of vowels. Three of the students had backgrounds in African-American gospel music, which influenced their vocal production. All except the freshmen were familiar with the experimental equipment, having participated during the preceding semester in a pilot study conducted by the investigator.

As members of the same studio, the students had similar postsecondary vocal training, which is summarized herein as pertinent background information for the study. The instructor's basic approach was traditional, with the addition of instruction in basic physiology and acoustics to increase the students' ability to make judgments about their own vocal production. On entering the studio, each student's voice was evaluated and then the student received a thorough grounding in the physiological basis of healthy vocal technique. Initial studies included basic concepts of breath management (using the *appoggio* technique and the Farinelli exercise) and resonance. Traditional frontal vowels were suggested as the means for easing navigation of the second passagio and upper register. Bright vowels were to be balanced with pharyngeal space.

A brief profile of each subject, including pertinent information about vocal characteristics, musical background, personal data, and a repertoire list, is provided in Appendix A.

Equipment

The equipment used in this study was selected to represent average equipment that could be available in a college voice teaching studio. The computer used is an Intel processor based system (Panasonic CF-45, Pentium 166 MHz, 96Mb RAM, Windows 98SE). The PC used an integral sound card with no special modifications or drivers. The unidirectional, dynamic microphone used is an Audio Technica (AT816) and was placed on an adjustable microphone stand that allowed the microphone to be raised to a height level with each singer's mouth. Singers were instructed to stand so that their mouths were approximately three inches from the microphone. Although headset-type microphones are available, the chose not to use one was made because the researcher considered them to be distracting to students working to release jaw tension. The Gram spectrographic software is available as freeware for Windows based PCs and the latest revision can be downloaded from the Internet at http://www.mnsinc.com/rshorne/gram.html. Commercial spectrographic software is available for Apple Macintosh computers. Otherwise the voice studio contained a piano, mirror, and recording equipment.

Data Collection

Data collection took place during 10 sequential weekly lessons, and care was taken to disrupt the lessons as little as possible. Each 50-minute lesson was structured as follows: warm-ups, 10 minutes; data collection for the study, 5 minutes; technical instruction, 15 minutes; work on literature, 20 minutes.

The warm-ups used regularly in the studio (nos. 2, 5, and 6 or 7 on the exercise sheet reproduced in Appendix B) consisted of three exercises on *si* [si], *oh* [o], and *ah* [a], syllables often used for vocalises because of their smooth progress from a closed to an open vowel. The exercises began in speech range, in A major on the pitch a, and continued moving up by half-steps for approximately an octave, until the singer had entered her passaggio area and passed into head voice, and then moved down to the starting point by half-steps. Thus the highest note sung in the exercise depended on the individual voice and varied from week to week. For the first two exercises (Appendix B, nos. 2 and 5), the top note was approximately g^2; the third (Appendix B, no. 6 or 7) ended between f^2 and c^2. Each exercise was completed three times in each key (once on each syllable).

The spectrograph was in operation throughout the warm-ups and was consulted throughout, but no recordings were made until the warm-up series was completed. At that time the subject repeated three sequences of the second exercise (Appendix B, no. 5) in ascending keys. This exercise was selected because it moves through both the first and second passaggi; the choice of keys was based on the location of the subject's second passaggio and in most cases did not vary from week to week. Variations in key occurred when the singer was ill or when another circumstance made a slightly different key more appropriate. A wave file recording was made of the third (highest) repetition. Most voices were recorded in E-flat, with two in D major and one F major.

After recording the wave file, each subject completed a short Likert-type questionnaire concerning her assessment of the usefulness of the spectrograph and her progress. At the same time the teacher completed a comparable questionnaire for each student, as well as a written evaluation of the student's progress. The questionnaires are reproduced in Appendix C; compilations of the questionnaire data for each student are included in the student's profile in Appendix A. At the end of the 10 weeks, subjects were asked to write a descriptive report on their experience with the spectrograph, a copy of which is included with the student profiles in Appendix A.

Also reproduced in Appendix A are 10 spectrograms made from the wave files for each subject, recorded as described above. The spectrograms are 6-second graphic representations of the frequencies produced by the student's voice singing the same exercise once a week for 10 weeks. (Several students missed lessons because of illness; consequently the 10 wave files do not in all cases represent 10 consecutive weeks.) The location of an event on the spectrogram is marked by the approximate number of seconds which elapsed from the beginning of the spectrogram.

Data Analysis

Wave file analysis was carried out by means of a chart (reproduced beneath each wave file in Appendix A) which compared the vowels in the three syllables ([si], [o], and [a]) used in the recorded exercise. Each vowel was analyzed in terms of the presence and strengths of frequency indications in four parts of the spectrogram. In the first part, called the first formant, the lower frequencies that produce the dark or warm sounds in the voice are present. The second part, or second formant, includes the frequencies that cause vowels to be distinguishable. For the purposes of this analysis the third area of the spectrogram, called the singer's formant, is divided into two parts, the 2000-4000 Hz range, in which frequency indications are most commonly found, and the 4000-10,000+ Hz range, in which indications occur less commonly. Also included is an analysis of the balance between upper and lower formants.

An estimation of the power spectrum, which appears as a yellow bar graph at the top of the spectrogram, is also included in the analytical chart (Appendix A). The power spectrum on the spectrograph gives an overall impression of the changing amplitude of the voice but does not provide measurements. In order to quantify it, reference was made to the approximate percentage of the area filled by the power spectrum bar graph. The amplitude of the voice relates to the interaction of several factors, especially the air pressure being applied to the vocal cords and the strength of the frequencies that are being produced. The strength of frequencies is shown on the spectrogram by a color scale from dark (weakest) to bright (strongest). More precise information about the strength of frequencies is available from the power spectrum graphs (Appendix A).

A power spectrum graph was taken within each vowel at an instant in which the most and/or highest frequencies were being produced, in other words at the “best” part of the phrase. The power spectrum graphs show the strengths of individual frequencies in decibels (dB). This information supports the perception of the amplitude of the voice given by the power spectrum bar graph, but care must be taken to remember that the power spectrum graphs represent only brief instants within the six-second spectrogram. Analysis of the power spectrum graphs was made by comparing the strengths of the first and second formants ($F_{1\text{-}2}$) with the presence of higher frequencies in the singer’s formant area ($F_{3\text{-}5}$). Since higher frequency vocal sounds, especially in the 2000-4000 Hz areas, seem to be more perceptible than lower frequency sounds of the same decibel (dB) strength, it seems that a vocal sound with strong low-frequency partials is aurally perceived as balanced by the presence of much weaker high frequency sounds.

Comparison of the three power spectrum graphs that accompany each spectrograph was accomplished by means of a numerical value representing the balance of lower level frequencies that produce the dark, warm qualities in the voice at the instant in which the graph was made with the upper level frequencies that produce the brilliant, carrying properties of the voice at that instant. For the purposes of this investigation, that numerical value was called the chiaroscuro level for the vowel. An average of the three chiaroscuro levels from the three power spectrum graphs was called the chiaroscuro level for the spectrograph.

The computation of the chiaroscuro level of a power spectrum graph was accomplished by comparing two ratios. The first ratio refers to the $F_{1\text{-}2}$ area (0-2000 Hz) and compares the number of strong frequencies, those > -40 dB (referred to as “b”), with the total number of frequencies in that area (referred to as “a”). The ratio of b:a is called the $F_{1\text{-}2}$ power spectrum ratio. The second ratio refers to the $F_{3\text{-}5}$ area (2000+ Hz), also known as the singer's formant. This ratio compares the number of peaks (frequencies) that are > 2000 Hz (referred to as "c") with the total number of peaks (frequencies) in the entire power spectrum graph (referred to as "d"). The ratio of c:d is called the power spectrum ratio.

The F_{1-2} power spectrum ratio indicates strength in the low-frequency area of the voice at the instant the power spectrum graph was made. The power spectrum ratio indicates the strength in the high-frequency area of the voice at the same instant. The average of these two ratios produces a number that indicates the balance of high and low frequencies in one instant of a vocalise. For the purposes of the study this number was called the chiaroscuro level of the vowel represented by a power spectrum graph.

In order to reduce the information in a spectrogram to a single number for the purpose of graphic comparison, the chiaroscuro levels for all three power spectrum graphs were averaged. The resulting number was called, for purposes of this study, the wave file chiaroscuro level. Since it was not the purpose of this investigation to make acoustic comparisons of vocal sound, but only to determine the usefulness of the spectrograph as a teaching tool, it is important not to imply an unwarranted level of accuracy in reading the Gram spectrogram. The attempt to quantify results from the Gram spectrograph was made only for the basis of comparison in this study.

To determine whether the information contained in the spectrograms supported the student's and the teacher's assessments of the student's improvement during the test period, a quantified result from the spectrograms was compared with compiled responses to the Likert-type questionnaires filled out each week by the student and teacher. The results of that comparison were further compared with the written statements prepared by the student and the teacher.

Data on students' assessment of the helpfulness of the spectrograph were drawn from their weekly written reactions to making the wave files and their final written assessment of the usefulness of the spectrograph in their voice study. The data from all the students' questionnaires were quantified as a group, and the overall written responses were quantified for a generally positive, neutral, or negative response.

Representations of the qualitative data include (1) an individual profile of each student written by the teacher at the end of the study describing the student's background in music and performance, her natural voice, the skill level that she has achieved in using it, and an analysis of the usefulness to her of the spectrograph; and (2) a written assessment by each student of the usefulness of the spectrograph. These data may be found in Appendix A.

Representations of the quantitative data may also be found in Appendix A. These include graphs for each student which report the findings as follows:

(1) Chiaroscuro level line graphs, which show the weekly chiaroscuro levels of each vowel and the average of all three vowels, were created from spectrograph information using power spectrum graphs at points of comparison. These graphs show the relative strength of formants 1 and 2 compared with formants 3-5, the degree of strengthening in formants 3-5 over the 10-week period, and the improvement in evenness of strength in formants 3-5 moving from low to high pitch over the 10-week period by means of the chiaroscuro levels computed for each spectrograph.

(2) Line graphs comparing information from the weekly Likert-type questionnaires for students and teacher with the line graph of the weekly chiaroscuro levels were created by averaging the numerical answers given by students on a weekly questionnaire to create a number representing the student's or teacher's answers for that week and comparing it with the chiaroscuro level for that week. By using a double scale on the graph, the shapes of the three line graphs could be compared. The five-point Likert scale is given on the left-hand vertical axis of the graph, and the percentage scale used for the chiaroscuro levels is given on the right-hand vertical axis.

Whether the student's or teacher's positive or negative reactions were supported by the chiaroscuro levels is indicated by whether the general contours of the lines are similar.

(3) Bar graphs of the correlation between information supplied by the spectrograph and assessments by students and teacher were made possible by creating an "improvement average" from the weekly averages of Student Questions 6, 7, and 8 and Teacher Questions 10-11. These particular questions relate to the student's or teacher's assessment of the student's improvement from the preceding week or overall in the 10-week period. Bar A is the 10-week average of the chiaroscuro level. Bar B on the graph for each student represents the student's weekly assessment of her improvement. Bar C indicates the teacher's corresponding assessment of the student's improvement and Bar D indicates a quantification of the written assessments on the scale given below. The scale for Bar D is as follows:

1 Enthusiastic written assessment by the student of the usefulness of the spectrograph
2 Positive written assessment by the student of the usefulness of the spectrograph
3 Neutral written assessment by the student of the usefulness of the spectrograph
4 Hesitant written assessment by the student of the usefulness of the spectrograph, possibly showing lack of understanding
5 Negative written assessment by the student of the usefulness of the spectrograph

On the recommendation of the Department of Statistics at the University of Georgia, statistical analysis was deemed inappropriate due to the nature of the data.. Therefore results are reported in a descriptive mode only.

CHAPTER 4
FINDINGS AND DISCUSSION

Four research questions, as listed in Chapter 1, guided the research. Analysis of the qualitative and quantitative data collected during the study led the researcher to answer these questions as follows:

Research Question #1:
What information can be satisfactorily derived from the study of spectrographic wave files?

Examination of the spectrograms made in this study confirms the results of the literature review (e.g., Nair, 1999) in clearly indicating that a rich variety of information may be gleaned from wave files. This information includes, but is not limited to, the strength of upper and lower level frequencies and the presence of vibrato, glottal attacks, uneven breath, and diction problems.

The present study focused on the balance between upper and lower frequencies in the voice, which the spectrograph reports quite accurately. It was found that, by making weekly spectrographic wave files of a portion of each student's lesson, a quantitative measure of the balance between upper and lower frequencies in that student's voice could be obtained. These measures, called the chiaroscuro levels, could be mathematically manipulated to obtain a mean chiaroscuro level, which could serve to describe the ratio between upper and lower frequencies in the student's voice. In addition, individual weekly chiaroscuro levels could be compared to provide an objective measure of the student's progress throughout the 10-week research period. It should be noted, however, that extraneous factors such as distance from the microphone and transitory respiratory illnesses can and do affect the spectrographic results. For this reasons, week-by-week comparisons must be approached with caution.

Research Question #2:

Will subjective data, including the teacher's evaluation and students' self-evaluation of student performance in the vocal studio, be consistent with the objective data from the wave files?

This question was divided into three subquestions, which are addressed separately below.

Subquestion 2a. Will the objective data derived from the spectrographic wave files be consistent with the instructor's subjective assessment of the student's overall skill level?

The average chiaroscuro level (as defined in Chapter 1) for the 10-week period was used as a quantitative representation of each student's overall skill level. On the basis of their average 10-week chiaroscuro levels, subjects were divided into three groups: advanced, intermediate, and less skilled (Table 1).

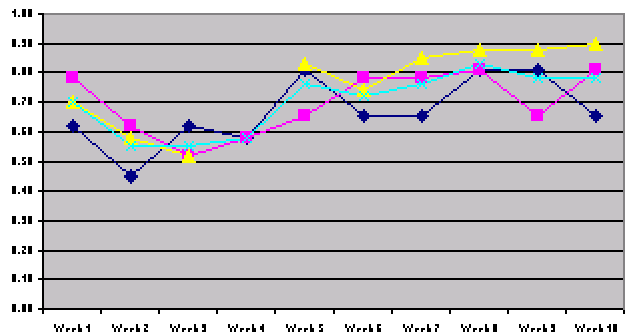
Table 1
Classification of Subjects by 10-Week Average Chiaroscuro Level

Advanced		Intermediate		Less Skilled	
Chiaroscuro	Subject	Chiaroscuro	Subject	Chiaroscuro	Subject
.70	Subject #7	.48	Subject #1	.43	Subject #8
.54	Subject #9	.46	Subject #5	.42	Subject #10

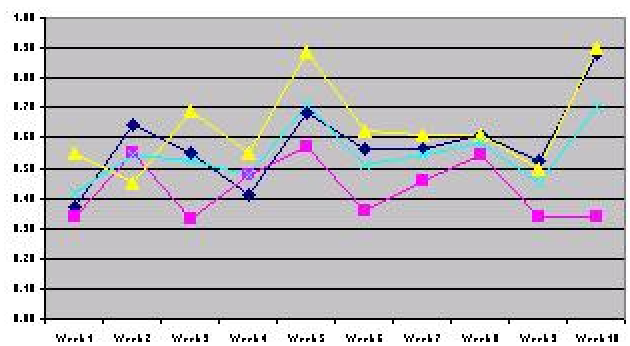
.53	Subject #6	.46	Subject #4	.33	Subject #2
		.46	Subject #3		

This grouping was further supported by graphic evidence from the Chiaroscuro Graph made for each student. Although these graphs are included in Appendix A, they are reproduced here in miniature for the basis of comparison. It is readily noted that the subjects in the advanced group show more consistency in the shapes of their individual vowel lines, the intermediate group show less, and the less skilled group show the least consistency.

Subject # 7



Subject # 9



Subject # 6

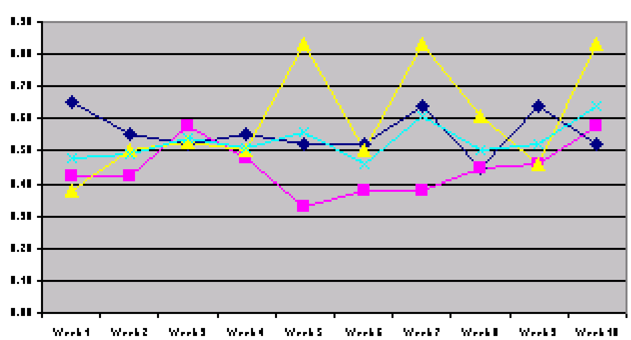


Figure 1 Advanced Subjects

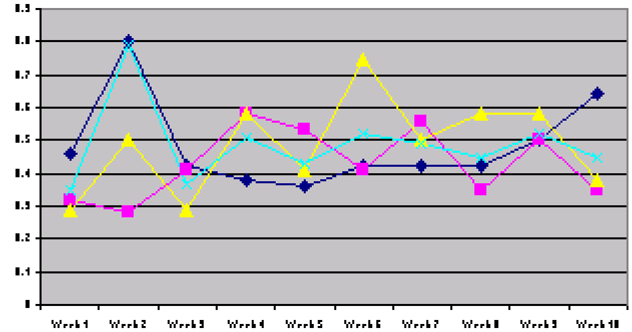
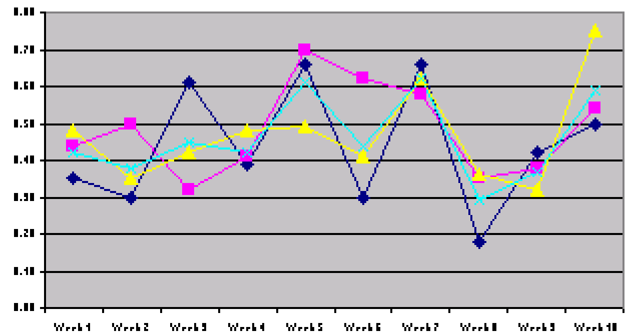
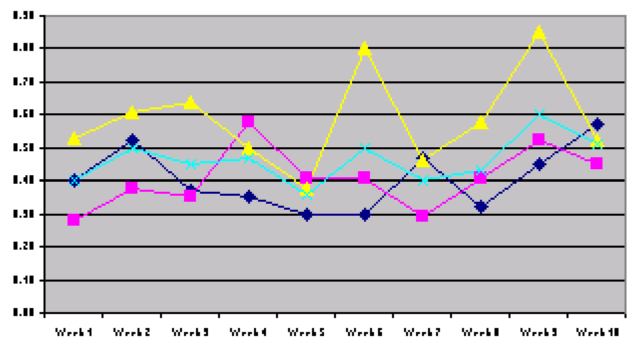
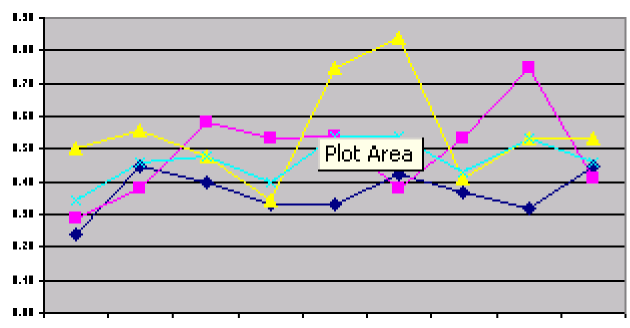
Subject # 1	
Subject # 5	
Subject # 4	
Subject # 3	

Figure 2 Intermediate Subjects

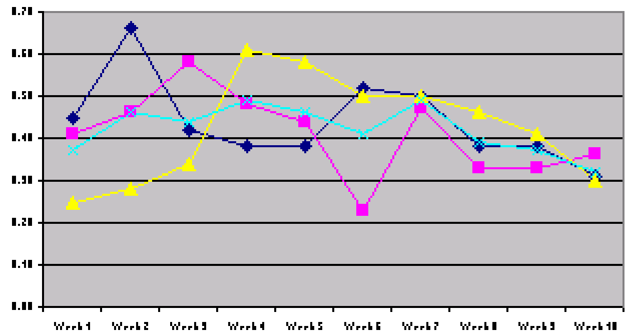
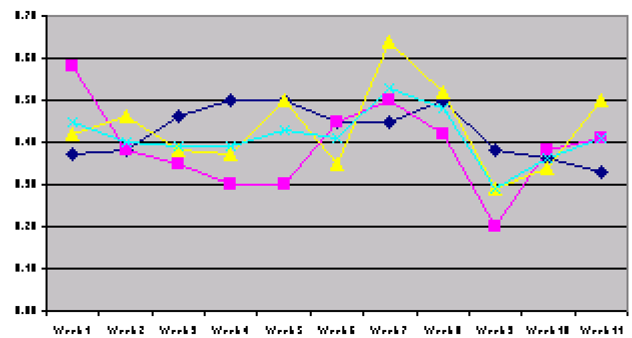
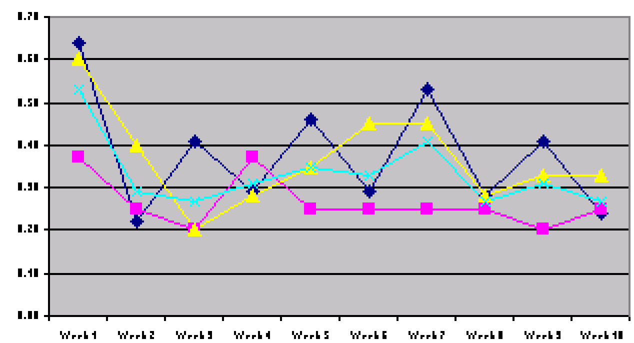
Subject # 8	
Subject # 10	
Subject # 2	

Figure 3 Less Skilled Subjects

A high degree of consistency was found between the groupings based on the spectrographic data, as shown in Table 1, and the instructor/investigator's grouping of students based on performance in studio lessons and recitals. The following summary of the instructor's observations was based on individual student profiles and lesson records (see Appendix A).

The advanced students—Subject #7, Subject #9, and Subject #6—had, in the investigator's opinion, achieved reliable consistency in producing resonant sounds. Subject #7's sound was well-balanced and strong, by far the most professional in the group. Subject #9, too, had strength and balance, though less well developed than Subject #7's. Subject #6's sound was somewhat less well balanced and not quite as strong.

Although the students whose chiaroscuro levels placed them in the intermediate group were quite different from one another, in the investigator's assessment all had reached about the same level. Subject #1 often produced a sound that equaled Subject #7's, but her production was not yet consistent. The investigator observed well-developed dark qualities in Subject #5's and Subject #4's voices, and both had learned to add brilliance to their sounds. Subject #4 achieved a more professional sound at times, but Subject #5's was more consistent, though less strong. Subject #3 showed consistent and rapid improvement even though her sound was not very strong and not always balanced.

Among the three subjects placed in the less-skilled group on the basis of their chiaroscuro levels, Subject #8 and Subject #10 were still having balance problems, and Subject #2' sound was quite weak.

Subquestion 2b: Will the objective data derived from the spectrographic wave files be consistent with the instructor's subjective assessment of the student's progress during the period of the study?

A comparison of the objective and subjective data related to this subquestion showed little consistency. The weekly chiaroscuro levels recorded for each student provided the objective data for this subquestion (see Table 2 and the individual graphs of chiaroscuro levels included in Appendix A).

Table 2. Weekly Chiaroscuro Levels, by Student

Student	Chiaroscuro Level, by Week									
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Subject #1	.35	.79	.37	.51	.43	.52	.49	.45	.52	.45
Subject #2	.53	.29	.27	.31	.35	.33	.41	.27	.31	.27
Subject #3	.34	.46	.48	.40	.54	.54	n/a	.43	.53	.46
Subject #4	.40	.50	.45	.47	.36	.50	.40	.43	.60	.51
Subject #5	.42	.38	.45	.42	.61	.44	.62	.29	.37	.59
Subject #6	.48	.49	.54	.51	.56	.46	.61	.50	.52	.64
Subject #7	.70	.55	.55	.58	.76	.72	.76	.83	.78	.78
Subject #8	.37	.46	.44	.49	.46	.41	.49	.39	.37	.32
Subject #9	.42	.54	.52	.48	.71	.51	.54	.58	.45	.70
Subject #10	.45	.40	.39	.39	.43	.41	.53	.48	.29	.36

The subjective data were provided by the instructor's assessment of each student's progress, as reflected in the answers to Questions 10 ("Compare the student's wave file today with last week's") and 11 ("Compare the student's wave file today with those over the study period so far") on the instrument entitled "Teacher's Weekly Lesson Evaluations of Spectrography" (see Tables 3 and 4). The instrument used a Likert-type scale ranging from 1 ("Much better") to 5 ("Much worse").

Table 3. Instructor's Weekly Assessment of Subjects' Progress: Responses to Teacher Questionnaire Item 10, "Compare the Student's Wave File This Week with Last Week's"

Student	Instructor's Assessment (1 = "Much better" to 5 = "Much Worse")									
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Subject #1	n/a	2	2	4	2	2	2	2	2	2
Subject #2	n/a	2	3	2	3	3	2	3	4	2
Subject #3	n/a	2	3	2	2	2	2	2	3	2
Subject #4	n/a	2	2	3	2	3	2	2	2	3
Subject #5	n/a	3	3	3	2	2	2	4	2	2
Subject #6	n/a	3	3	3	3	3	2	4	3	3
Subject #7	n/a	2	3	3	3	2	2	3	2	2
Subject #8	n/a	n/a	3	3	3	3	2	3	3	3
Subject #9	n/a	2	2	3	3	3	3	4	3	3
Subject #10	n/a	2	4	4	2	2	3	2	2	3

Table 4. Instructor's Weekly Assessment of Subjects' Progress: Responses to Teacher Questionnaire Item 11, "Compare the Student's Wave File This Week over the Study Period So Far"

Student	Instructor's Assessment (1 = "Much better" to 5 = "Much Worse")									
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Subject #1	n/a	2	2	4	2	2	2	2	2	2
Subject #2	n/a	2	3	2	3	3	2	3	4	2
Subject #3	n/a	2	3	2	2	2	2	2	3	2
Subject #4	n/a	2	2	3	2	3	2	2	2	3
Subject #5	n/a	3	3	3	2	2	2	2	2	2
Subject #6	n/a	3	2	2	2	3	2	3	2	2
Subject #7	n/a	2	3	3	3	2	2	3	2	2
Subject #8	n/a	n/a	3	3	3	3	2	3	3	3
Subject #9	n/a	2	3	3	3	3	3	4	3	3
Subject #10	n/a	2	4	4	2	2	3	2	2	3

Each student's weekly lesson grades can be found in Appendix A, but these grades were not used to answer this subquestion because they represented the student's overall lesson preparation and performance rather than the performance in that part of the lesson (i.e., the warm-ups) which was subjected to spectrographic analysis.

The following remarks are based on the instructor/investigator's written summary of each student's strengths and weaknesses as indicated in the weekly spectrograms and as perceived aurally by the instructor. The students are discussed in groups according to skill levels, as established by chiaroscuro levels and instructor judgment. Supporting materials are provided in Appendix A.

For advanced students (in this study, Subject #7, Subject #9, and Subject #6), balance—one of the factors most easily addressed by the spectrograph—is not an issue; most have also learned to use resonance techniques and breath management to strengthen the voice. Of the vocal issues that advanced students face, the spectrograph is more likely to provide information about vibrato, glottal attacks, uneven breath, and vocal styles.

Subject #7, who had the highest average chiaroscuro level, was the only subject who had studied with a teacher other than the researcher for an extended period of time. Her age (23) and extra training may partially account for the higher chiaroscuro level numbers that she achieved, as may her use of [e] rather than [o] as her second vowel. Nevertheless, a comparison of her chiaroscuro levels with Subject #9's shows that Subject #7's levels were higher for all her vowels. Subject #7's greatest concern about her vocal production was a too-wide, uneven vibrato, which was an unattractive feature of an otherwise beautiful sound. Spectrogram 1 (see Appendix A) shows a straight tone that opens to a wide and uneven vibrato as pitch ascends. This was a result of her unsuccessful attempts to reduce her vibrato by holding the larynx still. In her second and third spectrograms she can be seen producing a somewhat more even vibrato, but in the fourth and fifth she returned to her old patterns. In the sixth spectrogram, the extra breath pressure that she was accustomed to adding to the top of her voice is clearly visible. The seventh spectrogram shows better balance except for the force applied to the top, and in spectrograms 8, 9, and 10 Subject #7 showed skill in handling her whole voice without tension or forcing.

Subject #9's spectrograms were remarkably consistent. Her difficulties were nonvocal, arising from a lack of musicianship skills. The spectrograph did, however, bring to light one interesting facet of Subject #9's singing: her thorough grounding in musical theatre styles occasionally slipped into her vocalises. All 10 spectrograms show a break at the same place in the [si] exercise. The break did not affect the frequencies under 2000 Hz, but occurred in the 2000-4000 Hz range. It can be attributed to the fact that that Subject #9 was singing the first four notes of the exercise on a continued vowel but was aspirating an [h] before singing the fifth vowel with a released larynx that was free to produce vibrato. The spectrograms heightened Subject #9's awareness of her use of this procedure, which is quite acceptable in musical theatre but less appropriate for other vocal styles.

Subject #6, the third member of the advanced group, had a very consistent set of spectrograms. The data confirm the instructor's opinion that Subject #6, like many young lyric coloraturas, had learned to use the upper frequencies as a tool to increase her speed and flexibility and to ease the many high notes that her repertoire required.

For the intermediate group (Subject #5, Subject #1, Subject #3, and Subject #4), the spectrographic evidence indicated that the subjects had learned many of the skills requisite for professional singing but were not applying this knowledge consistently.

Subject #5's spectrograms show her reliance on the lower level frequencies, which produced a dark, warm voice but not the voice of a professional singer. When she did add the upper level frequencies, her sound instantly became full and resonant. In her fourth spectrogram she showed more consistency in adding the upper frequencies but had not yet reached a professional level. Spectrograms 5-10 make particularly apparent Subject #5's tendency to avoid upper level frequencies at high pitches.

Subject #1's spectrograms confirm the instructor's assessment of her as a a young singer who was rapidly learning to control a large and naturally well-balanced voice. From her first recordings to her last, she showed an increase in frequencies in both her upper and lower ranges. By the time of the fifth spectrogram, she was beginning to control her voice very well; at the sixth, however, she was not quite able to maintain control while exploring the possibilities of her voice. The last four spectrograms show her beginning to grasp the uses of resonant vowels, although not with complete consistency.

Subject #3's spectrograms show weakness and lack of upper frequencies, which are common problems for freshman voice students. In addition, a weakness was detected in lower frequencies and a straight tone, which may be related to body tension, especially around the larynx; tension issues are not always visible on the spectrograph, except as characteristics (such as straight tone) that can be related to body tension. By her sixth spectrogram Subject #3 seemed to be grasping some of the resonance techniques, but in the eighth spectrogram the nearly straight tone indicated severe tension problems. Spectrograms 9 and 10 show considerable improvement.

Subject #4, in contrast, had few if any tension problems. Her greatest difficulty was controlling a very large mezzo-soprano voice weighted toward the lower frequencies. By her seventh spectrogram she was beginning to produce a very resonant tone without sounding over-resonated, but in her eighth spectrogram she had lost focus. The frequency balance in the ninth and tenth spectrograms again shows her progressing toward a resonant sound.

The sound characteristics that relegate students like Subject #8, Subject #10, and Subject #2 to the less skilled group are visible on the spectrograph, but the reasons for producing these sounds are not. The machine indicates only *what* singers are doing, not *why*. For example, Subject #2's spectrograms 1-7 are discouragingly similar, showing a moderate level in the under 2000 Hz range and hardly any indications above 2000 Hz except those from the [i] vowel. Even in the [i] vowel the upper frequencies are extremely weak. In the eighth spectrogram it is possible to identify an attempt to increase sound, but Subject #2 was not employing resonance techniques, she was pushing more breath against the vocal folds. Spectrograms 9 and 10 show some strengthening of lower frequencies, but upper frequencies are almost altogether missing. Not visible on the spectrogram is Subject #2's rejection of the professional sound, which prevented her from accepting the use of resonant vowels.

Subject #8 tended to weight her voice toward the lower frequencies. Spectrograms 1-5 show lower strength that was not balanced by upper strength. There was better balance in spectrograms 6-10, but still the comparison of Subject #8's spectrograms with Subject #7's or Subject #9's shows less strength in both areas.

Subject #10's spectrograms support the instructor's assessment of her voice as a young instrument bound by a very tight, gospel-style soprano sound. A minimal degree of vibrato indicates tension around the larynx. Upper level frequencies were present, and lower level frequencies needed to be increased to balance them. In spectrogram 5 a greater degree of lower frequency strength is apparent, as is also true in spectrograms 7 and 9. Tension in the voice is apparent in spectrogram 7, where nearly straight tone singing is visible. Glottal attacks are visible at the beginning of the [a] vowel in all the spectrograms except numbers 2 and 8.

A comparison of the objective and subjective data related to this subquestion shows both consistencies and inconsistencies. As noted above (Subquestion 2a), the instructor's informal professional assessment of the student's voice tended to be consistent with the spectrographic data. The relationship between the Likert-scale questionnaire data and the spectrographic data, however, is less clear (see Tables 2-4). As noted, comparisons on a week-to-week basis were made problematic by the presence of extraneous variables. For this reason, the discussion that follows concerns only the subjects' progress over the entire course of the study—that is, the objective data are drawn from Table 2, weeks 1 and 10 only; subjective data are drawn from Table 4, week 10 only.

In the instructor's judgment, as reflected in the responses to Question 11 of the instructor questionnaire (Table 4 and Appendix A), 6 students—Subject #3, Subject #6, Subject #1, Subject #5, Subject #7, and Subject #2—performed "better" (2 on the Likert-type scale) on the study task at the end of the 10-week period than at the beginning; 4 students—Subject #9, Subject #8, Subject #4, and Subject #10— performed "the same" (3 on the Likert-type scale). No student was rated "much better," "worse," or "much worse."

To make a quantitative comparison between students' performance in the first and last weeks of the study, the chiaroscuro level from week 1 was subtracted from that for week 10. According to these data, the students can be divided into 3 groups. Those who showed the most improvement were Subject #9 (W10 – W1 = .28), Subject #5 (.17), and

Subject #6 (.16). Showing moderate improvement were Subject #3, (.12), Subject #4 (.11), Subject #1 (.10), and Subject #7 (.8). No improvement was shown by Subject #8 (–.05), Subject #10 (– .09), and Subject #2 (–.26); even discounting Subject #2's unusually high week 1 score, her chiaroscuro level still dropped by .02 from week 2.

In summary, several marked inconsistencies were found between the spectrographic data and the instructor's evaluations of student progress (see Table 5). Most notably, Subject #9's performance, which showed the greatest improvement as measured by chiaroscuro levels, was rated "the same" by the instructor. Conversely, Subject #2, who failed to show any improvement by the objective measure, was considered by the instructor to have performed "better" at the end of the study period than at the beginning. This latter discrepancy may perhaps be explained by Subject #2's poor performance at week 9 (as assessed by the instructor); this may have had the effect of inflating the instructor's assessment of her relatively better performance the next week. Subject #7, whose improvement as measured by chiaroscuro level was quite modest, was judged by the instructor to be "better." Subject #7's seemingly lackluster progress by objective measure may be attributable to her advanced skill level: since her chiaroscuro levels were far higher at the beginning of the study than those of the other students, quantifiable gains would be proportionately more difficult to demonstrate. It is also possible that more specific questions on the teacher's questionnaire would have created data more consistent with the objective spectrographic results.

Table 5. Comparison of 10-Week Change in Chiaroscuro Levels and Instructor's Rating of Improvement

Student	Chiaroscuro Level			Instructor Rating	Consistency
	W1	W10	Change		
Subject #1	.35	.45	+.10	better	moderate
Subject #2	.53	.31	–.26	better	low
Subject #3	.34	.46	+.12	better	high
Subject #4	.40	.51	+.11	same	moderate
Subject #5	.42	.59	+.17	better	high
Subject #6	.48	.64	+.16	better	high
Subject #7	.70	.78	+.08	better	moderate
Subject #8	.37	.32	–.05	same	high
Subject #9	.42	.54	+.28	same	low

Subject #10	.45	.36	–.09	same	high

Subquestion 2c: Will the objective data derived from the spectrographic wave files be consistent with the subject's subjective assessment of her own progress during the period of the study?

No consistent agreement was found between the spectrographic data and the students' assessment of progress over the 10-week period.

Objective spectrographic data in the form of 10-week change in chiaroscuro level were compared with several subjective data based on the Likert-type student questionnaire. These were: (a) responses to item 2 ("I sang well today") for weeks 1 and 10; (b) the 10-week mean of responses to questions 6 ("I think that my wave file this week showed improvement from last week"), 7 ("I think that my wave file this week showed improvement since the beginning of the semester"), and 8 ("I think that studying technique is helping me become a better performer"), all of which attempt to assess the student's view of her own progress. (See Table 6 and Appendix 1.)

With regard to item 2, it should be noted that the student questionnaire was completed immediately after the warm-ups, during which the spectrographic data were collected. The responses thus reflect the student's assessment of her performance during that part of the lesson only.

Table 6. Comparison of 10-Week Change in Chiaroscuro Levels and Students' Rating of Improvement[a]

Student	Chiaroscuro 10-wk. Change	Question 2 10-wk. Change[b]	Questions 6-8 Mean	Est. Consistency
Subject #1	+.10	0	1.55	moderate
Subject #2	–.26	0	1.00	low
Subject #3	+.12	+2	1.40	low
Subject #4	+.11	0	1.25	moderate

Subject #5	+.17	+1	1.10	moderate
Subject #6	+.16	0	1.40	low
Subject #7	+.08	–3[c]	4.46[c]	n/a
Subject #8	0	+1	3.00	moderate
Subject #9	+.28	+1	1.33	moderate
Subject #10	–.09	0	1.30	low

[a] Because the items were worded positively and the range of the Likert-type scale was from 1 ("strongly agree) to 5 ("strongly disagree"), lower means represent more positive assessments.
[b] Because the range of the Likert-type scale was from 1 ("very good") to 5 ("unacceptable"), the week 10 score was subtracted from the week 1 score so that positive assessments of progress could be indicated by a positive numerical equivalent.
[c] It is likely that this student interpreted the scale backward.

It is clear from the data in Table 6 that, overall, the subjects' assessment of their own progress was less consistent with the objective data of the wave files than was the instructors' assessment. In this case as well as in the teacher's questionnaire it is possible that more specific questions on the student's questionnaire could have created data more consistent with the objective spectrographic results.

The dichotomy between student and teacher results is probably related to one or more of three hearing issues. Students' ears are usually not as well trained as their teachers' ears. Since students hear their own sound filtered through the bones of the head, their assessment of their own sound is not as reliable as their teacher's. Students may have a faulty concept of the best possible sounds for their own voices.

The 10-week averages of the questionnaire data, along with the ten-week chiaroscuro levels and a quantification of the students' written reactions, are included in Table 7 and Figure 4 below. The 10-week chiaroscuro levels are not directly supported by any of the student reactions. The two most enthusiastic written responses were from Subject #7, who had the best chiaroscuro level, and Subject #10, who had the next to lowest chiaroscuro level. The least enthusiastic written response was from Subject #6, who was third in the chiaroscuro levels.

Table 7. Ten-Week Means for Chiaroscuro Levels, Student Questionnaire Data, Teacher Questionnaire Data, and Quantified Student Written Assessments

Student	Chiaroscuro Level	Student Questionnaire[a]	Teacher Questionnaire[b]	Student Written Assessment[c]
Subject #1	.33	1.55	2.39	2
Subject #2	.33	1.00	2.66	2
Subject #3	.46	1.40	2.22	2
Subject #4	.46	1.25	2.33	2
Subject #5	.46	1.10	2.61	2
Subject #6	.53	1.40	3.00	2
Subject #7	.70	4.46[d]	2.77	1
Subject #8	.43	3.00	2.75	2
Subject #9	.54	1.33	2.94	2
Subject #10	.42	1.30	2.40	1

[a] Questions 6-8 only; 5-point Likert-type scale, 1 = agree strongly, 5 = disagree strongly
[b] Questions 10 and 11 only; 5-point Likert-type scale, 1 = very good, 5 = unacceptable
[c] Scale: 1 = enthusiastic; 2 = positive; 3 = neutral; 4 = hesitant; 5 = negative
[d] It is probable that this student responded to the Likert-scale questions backward; i.e., 5 = agree strongly

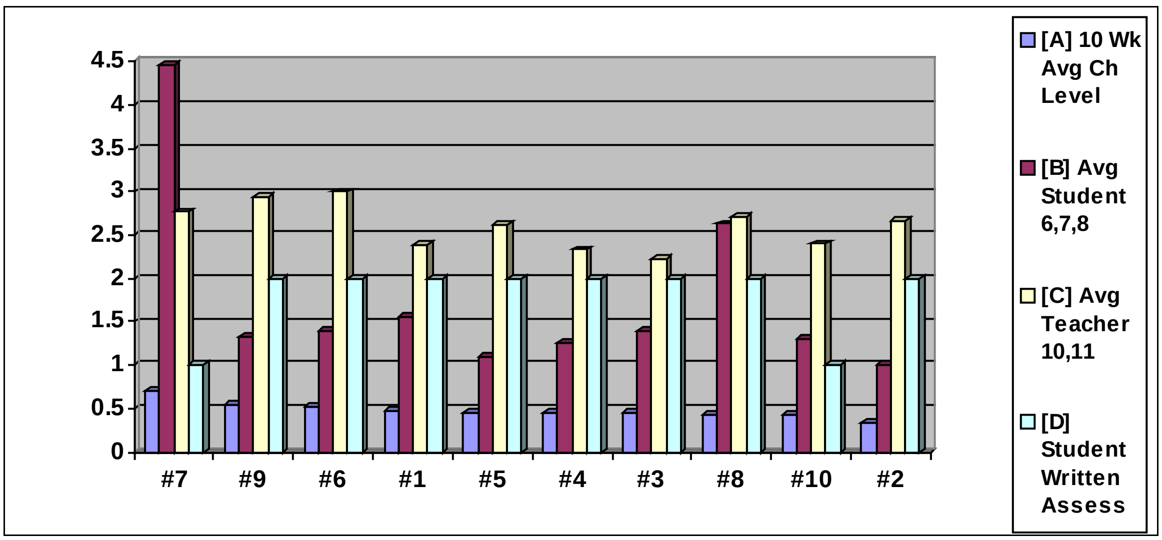


Figure 4 Ten Week Comparisons

Further information about the relative consistency of the objective and subjective data obtained during this study may be gained from an examination of the individual graphs entitled "Comparison of Weekly Likert Scale and Chiaroscuro Levels," which are included in the student profiles in Appendix A. These graphs, one of which is included for each subject, compare a mean of all the answers on the subject's questionnaires and all the answers except those to questions 4-7 on the teacher questionnaires with the subject's weekly chiaroscuro levels. Questions 4-7 on the teacher questionnaires seek information about what areas of the voice were addressed at a lesson. A zero answer in questions 4-7 merely meant that an area was not addressed at a particular lesson, but zero answers to those questions skewed the weekly average, and it was decided to exclude those questions from the average. Comparisons visible in the line graph indicate that there are some instances of positive correlation between student and teacher averages, but that neither teacher nor student means tend to correlate with the chiaroscuro levels.

The second graph in the student profiles (Appendix A) compares the student's and teacher's weekly perceptions of progress with the chiaroscuro level for that week. Questions 6-8 in the student questionnaire and questions 10 and 11 in the teacher questionnaire seek information about the student's and the teacher's perception of progress since the preceding week and in the study overall. On these graphs there are even more instances of positive correlation between student and teacher data, but again correlation with the weekly chiaroscuro levels is not consistent.

Research Question #3:

Will the subjects find the use of the spectrograph helpful?

This question was directly addressed by items 11 and 12 on the student questionnaire (Likert-type scale from 1 (strongly agree) to 5 (strongly disagree). The responses are tabulated individually for each student in Appendix A. The mean for all responses (excluding those of Subject #7, who had apparently misinterpreted the scale) to item 11 ("I noticed something today on the spectrograph display that gave me some insight into how I can improve my singing") was 1.43. The mean for all responses (again excluding Subject #7's) to item 12 ("I think the spectrograph is helping me improve my tone quality" was 1.21.

An important indicator of the subjects' attitude toward the use of the spectrograph was provided by the written reactions elicited at the end of the study. Without exception, these evaluations were positive. All the subjects seemed to feel that it added a level of understanding to their study of voice. The complete text of each written reaction can be found in Appendix A; representative selections appear below.

Subject #1

I found myself looking forward to working with the spectrograph. Each time I would use it, I would try to sing "better" than the time before. . . .I think the spectrograph is a great experience that everyone should have. It has helped me become a better singer.

Subject #2

I began to learn from watching the spectrograph. I began to see how the resonant sounds work and how I could modify my vowels to produce different sounds. . . . I think that the spectrograph was extremely helpful and interesting.

Subject #3

I felt that the spectrograph was extremely helpful in enabling me to better my singing technique. . . .I was able to easily understand what I was watching at every lesson. And because it was used during every lesson, I was able to see my steady progress, as well as which techniques worked for my voice and which did not.

Subject #4

I enjoyed working with the spectrograph from the very first time we used it. . . . As the semester continued, I could actually see the changes in tone quality. It was exciting to have a visual representation of the changes in my voice.

Subject #5

In the beginning there was not a continuous line [on the spectrogram] like there should be in singing. . . . I learned to use my diaphragm and correct breathing to make sure that lines were connected. As time went on, those lines began to get thicker as my voice got larger and more secure. I can say that the spectrograph has improved my technique and my sound immensely.

Subject #6

[The spectrograph] enables me to discover the areas of my voice that are strong and healthy, as well as the ones that could use improvement. . . .I have thoroughly enjoyed watching the spectrograph and recording wave files every week in my lessons. They help with the discouragement that often comes to someone entering the music field.

Subject #7

I am, after some lingering hesitations, glad that [the instructor] is using her spectrograph—it provides a picture of the voice with which to work. . . . Though I cringe at times at the honesty with which the computer translates my sound, it is useful. . . . I finally have a more tangible image of what my voice is, and using it isn't so scary after all. All in all, whoever came up with the engineering ideas to bring a singer's sound to a visual point is a compassionate genius.

Subject #8

For me the spectrograph has helped my singing immensely. Before we began using the spectrograph in class, I would know that I had poor breath control, however I did not know why. I am a visual learner and the spectrograph allowed me to visualize where I began to stop using my breath support. . . . In my opinion every voice class should be able to have the use of a spectrograph.

Subject #9

I have found the spectrograph to be very helpful and a learning experience. I have found my voice and the overall tone have improved during the past ten weeks. . . . The best part would have to be the actual viewing of the voice and its progress. . . . [T]he spectrograph was not only a great learning tool, but documentation [of progress] as well.

Subject #10

> The spectrograph tells me what I need to do if I want to make my voice sound different. . . . The spectrograph is an excellent teaching tool and is very understandable to read. . . . Not only does the student learn, it helps the teacher learn about the student. Keep using the spectrograph. It works!

Research Question #4:
Will the use of spectrographic technology prove to be compatible with traditional teaching techniques?

The subjective data gathered in this study clearly indicate that the use of spectrographic technology is compatible with teaching techniques traditionally employed in the voice studio.

As the comments above indicate, the subjects, once they became acclimated to the use of the spectrograph, found it to be an "excellent teaching tool" (Appendix A: Subject #10, "Student's Written Reaction to Use of Spectrograph"). After the initial adjustment period (in most instances only two or three lessons) no subject reported discomfort with the technology. In fact, the mean response to item 9 on the student questionnaire ("I enjoy watching the spectrograph") was 1.17 on a 5-point Likert-type scale where 1 = "strongly agree." In terms of students' level of comfort with the technology, then, the spectrograph is compatible with the traditional vocal studio.

On the teacher's questionnaire, items 8 ("How often does the student interact with the spectrograph?") and 9 ("How much did you refer to the spectrograph during warm-ups today?") provide an indication of the instructor's level of success in integrating the technology into the vocal lesson.

Response choices for item 8 were "often and enthusiastically," "positively," "neutral," "rarely," and "not at all." For tabulation, these choices were assigned Likert-type values from 1 (for "often and enthusiastically") through 5 ("not at all"). The mean of all responses was 1.78, indicating that, in the instructor's opinion, most students interacted with the spectrograph quite positively.

Response choices for item 9 were also tabulated on a Likert-type scale: 1, "frequently pointing out occurrences"; 2, "occasionally"; 3, "only a few overall remarks"; 4, "only responding to student questions"; and 5, "only while setting up to make the wave file"). The mean of all responses was 2.24, indicating that in most lessons the instructor referred to the spectrograph occasionally during the warm-ups.

The use of the spectrograph changed the instructor's lesson plan only minimally; after the 10-15-minute warm-up period, the lesson proceeded normally, with the remainder of the time devoted to technical instruction and work on literature. It was not necessary to modify the pacing or content of the instruction to accommodate the use of the spectrograph.

CHAPTER 5

CONCLUSIONS

In Chapter One four research questions were designated as the focus of this work. The findings indicated that:

(1) A rich variety of information may be gleaned from wave files. This information includes, but is not limited to, the strength of upper and lower level frequencies and the presence of vibrato, glottal attacks, uneven breath, and diction problems. Teachers of beginning students will find that the most significant information is the dynamic balance between upper and lower frequencies as the student learns to produce a resonant sound.

(2) The spectrographic data were consistent with the instructor's overall assessment of each subject, but little consistency was observed between that data and either the instructor's or the subjects' assessment of their weekly or long-term progress.

(3) The subjects found the spectrograph helpful and interesting to use. They particularly appreciated its ability to provide a visual picture of vocal strengths and weaknesses.

(4) The use of the spectrograph was compatible with traditional voice teaching techniques.

On the basis of these findings, the following conclusions may be drawn.

(1) Both students and teachers may find that the use of the spectrograph improves communication, in that it provides objective, visual confirmation of the teacher's professional judgment.

(2) Because the spectrograph is a helpful tool in the voice teaching process and is more readily available than in the past, it has a place in the traditional collegiate vocal studio.

(3) The spectrograph would also be well suited to use by students in the practice room. Students at universities with vocal arts laboratories are able to analyze audio and video tapes of lessons in the labs, and even to create overlays on video tapes that show the spectrographic analysis along with the video of the lesson, but this type of technology costs tens of thousands of dollars. The technology used in this study, however, is quite inexpensive.

(4) Written self-evaluation of voice lessons, such as the subjects in this study completed, may be useful in the voice studio. Many teachers have students keep a practice journal, but thoughtful evaluation of lessons might be a valuable addition to the journaling process. If indeed students had access to a spectrograph in the practice room, journaling would be a method of keeping track of questions to ask in the next lesson.

(5) The spectrograph could be used in the assessment of students over a period of years. As data storage technology continues to improve, it may be possible to save wave files of entire songs or entire lessons, and doing so

at regular intervals offers an objective measurement for assessing students' progress.

Recommendations for Further Study

Because this study was conducted at a women's college, the subjects were all female. In many ways a limited population is an asset because the limitation allows deeper exploration of similar subjects. A corresponding study at a men's college is to be desired, along with studies of men and women at co-educational institutions. It is recommended that a larger population be studied and that populations in which students are all at the same level, for example beginners, be studied.

Some of the data collection methods might be changed to good effect. Wave files could be made later in the lesson time, rather than during the warm-up exercises. More specific questionnaire items would elicit more pertinent responses from students and allow the instructor to report his or her observations and reactions more accurately. Although the chiaroscuro levels seem to correlate with aural assessment of the students in this study, it should be possible to achieve better correlation between weekly assessments by students and teacher with the wave file information.

To keep the scope of this study manageable, it was necessary to exclude a large portion of the wealth of information that the spectrograph provides. It is recommended that further studies explore other aspects and uses of spectrographic data.

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APPENDIX A

SUBJECT PROFILES AND DATA

Appendix A1: Subject #1

Subject #1 was an 18-year-old African-American freshman majoring in vocal performance. Her home town was Augusta, Georgia. She was exceptionally advanced vocally, sounding more like a junior voice major than a freshman. Her background in music was not strong, but she was determined to overcome any deficiencies. She was conscientious about asking questions whenever she did not understand any aspect of music or voice training, and she worked very hard. Subject #1 was hoping for an operatic career, and she had a good chance because of her lovely lyric soprano voice, innate musicality, ability to sing expressively, good appearance, and work ethic.

Because freshmen in this program do not perform on the midterm or Broadway recitals, Subject #1's first performance, other than in voice major class, was in the end of semester student recital. When she did perform, she was completely successful.

Subject #1's vocal production was naturally very good. It was important that she understoond why what she did instinctively was good vocal technique. At the end of the semester she was leaning a little too heavily on resonance techniques, probably because she had heard them discussed with reference to other students' voices. What was necessary in other cases was not necessary for Subject #1. Her challenges were developing musicianship, improving her language skills, and singing repertoire carefully chosen to be incrementally more difficult. Developing range and flexibility were the goals, along with not allowing her to sing music that is too heavy for her. Vocally she was ready for some of the light lyric Mozart arias.

The spectrograph was an asset in Subject #1's lessons because she could see how well-balanced her voice was. She tended to magnify her flaws and minimize her superiorities, and the spectrograph helped her to see her abilities more objectively.

Fall Semester 2000 Repertoire – Subject #1`

Caldara	Sebben crudele
Giordani	Caro mio ben
Duke	Lovliest of Trees
Gladys Rich	American Lullaby
Blas de Laserna	La Tirana de Tripili
Bellini	Dolente imagine mia Filla
Mozart	Vedrai carino

Lesson record over the data collection period – Subject #1

Date	Grade	Repertoire Studied during Lesson	Student Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	Wave File Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, 8; and Teacher Questions 10-11
8/24	A	Assigned rep	Good	Very sweet voice – MR says she sounds like Kathleen Battle – she's undersigning today – short on background – long on determination	#1 E flat	Chiaroscuro - .35 Student – n/a, n/a, 2; Teacher n/a, n/a
8/31	A+	Giodani, Rich, Caldara, Duke	Excellent	Has learned first two and started solidyly on next two – sure of giordani, she really sang today – first class voice! – no limits – if she continues to work, she can sing anywhere – asked today who Kathleen Battle is – listened to some CD's	#2 E flat	Chiaroscuro - .79 Student 2, n/a, 2 Teacher 2, 2
9/7	A+	Duke, Laserna	Excellent	I will not address resonance beyod good vowels – when she has a passagio problem, we'll analyze vowels – she naturally does it right – needs attention to breathing, but again she is nearly perfect, and I don't want to do too much.	#3 E flat	Chiaroscuro - .37 Student 1, 1, 1 Teacher 2, 2
9/14	A	Giordani, Caldara, Duke – sent her with book to look at several Bellini songs	Excellent	She is getting sick – saved voice – coached diction and rhythm in Duke	#4 E flat	Chiaroscuro - .51 Student 4, 3, 2 Teacher 4, 4
9/21	A+	Giordani, Caldara, Rich, Duke, Lasema, she has chosen a Bellini	Excellent	She is better and working hard – Very little vocal coaching required – I'm doing mostly diction	#5 E flat	Chiaroscuro - .43 Student 1, 1, 1 Teacher 2, 2
9/28				Lesson cancelled because of Brenau recital		
9/29	A+	Bellini, Caldara	Excellent	Make-up lesson – coached diction – her tone quality is so even and beautiful that there is little to do except carefully select repertoire – she wants an aria, and I have promised one as soon as she's memorized her assigned repertoire	#6 E flat	Chiaroscuro - .52 Student 1, 1, 1 Teacher 2, 2
10/5	A	Bellini, Lasema	Excellent	She is struggling a little with diction and musical issues, but working hard and improving steadily. This was mostly diction coaching. She asked today how far I think she can go. I said no limits if she keeps on working this hard.	#7 E flat	Chiaroscuro - .49 Student 3, 0, 2 Teacher 2, 2
10/12	A+	Bellini, Lasema, Duke	Excellent	Everything working well – diction	#8 E flat	Chiaroscuro - .45 Student 4, 2, 1 Teacher 2, 2
10/19	A+	Caldara, Duke, Lesema	Excellent	Disappointed not to sing on midterm recital – quite ready, but dept policy allowed no exceptions	#9 E flat	Chiaroscuro - .52 Student 1, 1, 1 Teacher 2, 2
10/26	A+	Bellini, Rich	Excellent	Voice fine – working well – everything going well – nearly all repertoire memorized – remember that she is promised an aria when it's all memorized	#10 E flat	Chiaroscuro - .45 Student 1, 1, 1 Teacher 2, 2
11/2	A	Bellini, Lesema	Excellent	Working on phrasing in this repetitive song		

11/9	A+	Bellini, Caldara, Lesema	Excellent	She is doing everything right – walked through recital procedure		
11/16	A+	Sang all repertoire by memory	Excellent	All is well – she's ready to perform – selected Zerlina's Act I aria		
11/19	A+	Bellini	Excellent	Student recital – excellent work		
Ten week average Chiaroscuro Level						**.48**

Responses to student questionnaires – Subject #1

Question	8/24	8/31	9/7	9/14	9/21	9/29	10/5	10/12	10/19	10/26	**Total of weekly answers to questions 6, 7, 8**
1	4	2	2	4	2	1	3	4	2	3	
2	4	2	2	4	3	2	4	4	2	3	
3	2	2	2	2	2	1	2	3	2	2	
4	2	2	2	1	2	1	1	1	1	1	
5	2	2	1	1	1	1	1	1	1	1	
6	N/A	2	1	4	1	1	3	4	1	1	**2**
7	N/A	N/A	1	3	1	1	0	2	1	1	**1.25**
8	2	2	1	2	1	1	2	1	1	1	**1.4**
9	2	2	1	0	1	1	1	1	1	1	**Average over ten week period**
10	N/A	2	1	2	1	1	1	1	1	1	
11	2	2	1	2	1	1	1	3	1	1	
12	N/A	2	1	4	1	1	1	1	1	1	
Weekly Average	2.5	2	1.33	2.63	1.41	1.08	1.66	2.16	1.25	1.41	**1.55**

0 indicates no answer recorded on the student questionnaire

Responses to teacher questionnaires – Subject #1

Quantification of the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)

2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)

3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)

4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)

5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

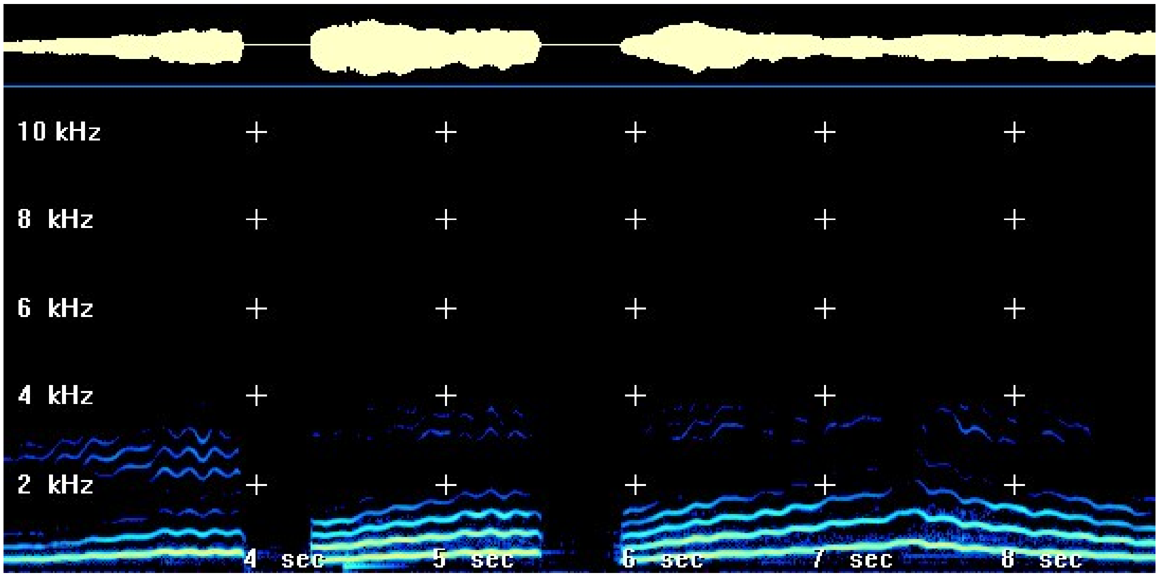
Question	8/24	8/31	9/7	9/14	9/21	9/29	10/5	10/12	10/19	10/26	**Totals and Average of questions 10 & 11**
1	2	2	2	2	2	2	2	2	2	2	
2	2	1	2	3	2	2	1	1	1	2	
3	2	2	2	2	2	2	2	2	2	2	
4	2	1	1	3	3	3	2	4	3	4	
5	5	5	4	4	3	4	2	4	3	3	
6	4	3	5	5	5	5	5	4	3	3	
7	5	5	5	5	5	5	5	5	5	5	
8	1	1	1	1	1	1	2	1	2	2	
9	1	1	2	3	2	2	2	2	2	3	
10	N/A	2	2	4	2	2	2	2	2	2	**2.39**
11	N/A	2	2	4	2	2	2	2	2	2	**2.39**
Weekly Average excluding questions 4-7	1.6	1.57	1.85	2.71	1.85	1.85	1.85	1.71	1.85	2.14	**2.39**

Student's Written Reaction to Use of Spectrograph – Subject #1

I enjoyed using the spectrograph this semester. I not only learned a lot from it, the spectrograph made me aware of all the work that goes into singing correctly. At first, the spectrograph was just something I had to do for my voice lessons. Soon, however, I found myself looking forward to working with the spectrograph. Each time I would use it, I would try to sing "better" than the time before; sometimes, I would wish to do my whole lesson on the spectrograph. Not only have I enjoyed the spectrograph, I've learned so much from it. I have learned what vowels make better sounds and are easier to sing on, where my forward placement is, and what really happens when I'm singing. I also learned how to make "more sound" without working any harder than I have to. I think the spectrograph is a great experience that everyone should have. It has helped me become a better singer.

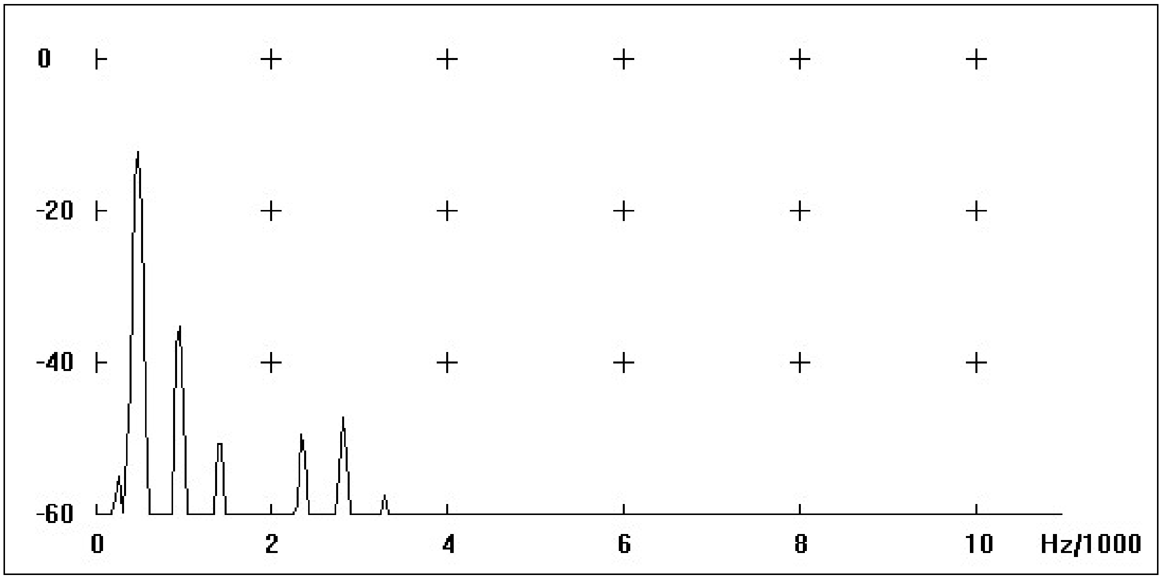
Analysis of Wave Files

Wave File Number 1 – August 24, 2000 - Subject #1

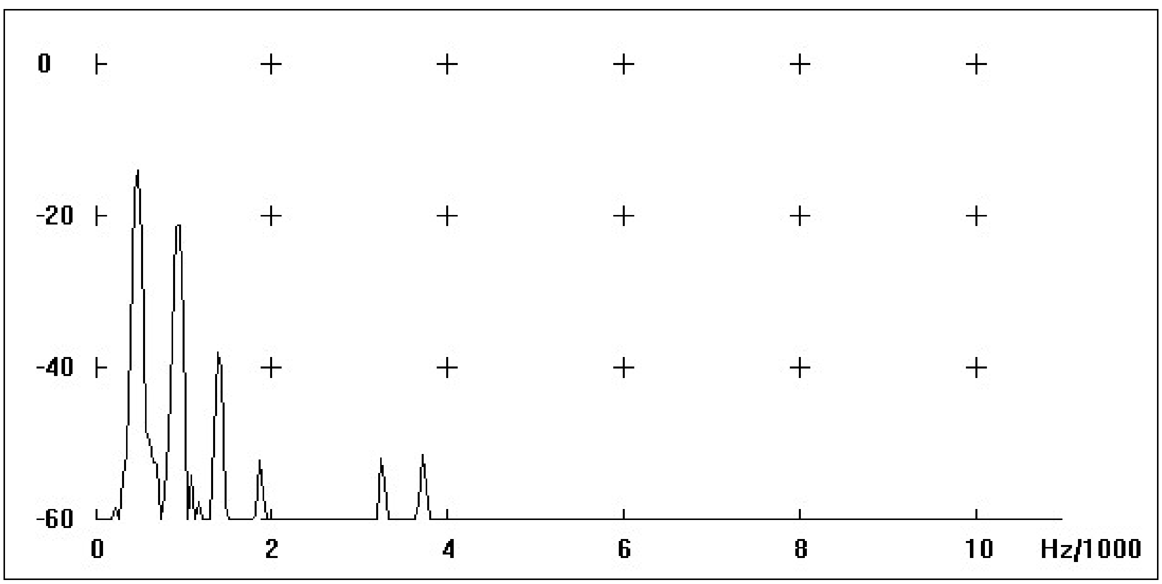


Subject #1 – Analysis of Wave File #1 – August 24, 2000 – D major				
		[si] (2-4sec)	[o] (4.3-5.5 sec)	[a] (6-10 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	3 partial bands	2 partial bands clearer at higher pitches	2 partial bands and some parts of a third – even throughout scale
2nd Formant Area (Vowel Definition)		Vowel is clear but under-resonated	Better vowel but not fully resonated	Better vowel but not fully resonated
1st Formant Area		Clear but weak	Clear but weak	Clear but weak
Chiaroscuro Balance		Voice is light in both aspects	Voice is light in both aspects, but somewhat firmer in the lower areas	Voice is light in both aspects
Power Spectrum		Increases from about 15% to about 30%	30%-60%	Initial increase to about 50%, declines to about 20%
First wave file for freshman soprano: light, somewhat uncertain of what is expected of her. Sound is promising, but not fully realized because vowels are not well resonated. Even vibrato indicates freedom of laryngeal function.				

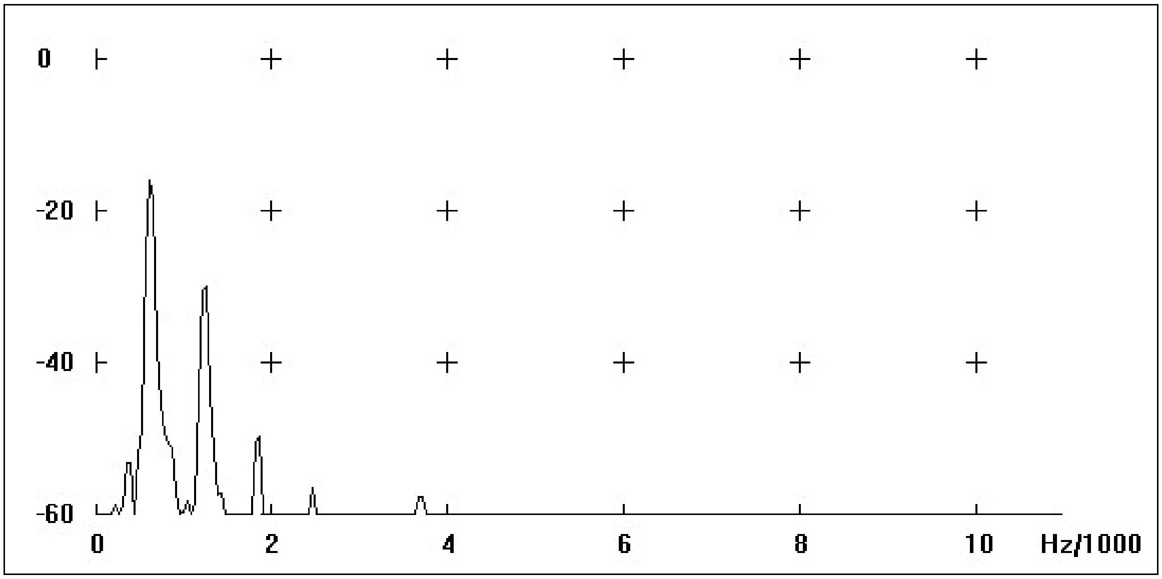
Power Spectrum from Spectrogram #1, Subject #1 at 3.65 seconds [i]



Power Spectrum from Spectrogram #1, Subject #1 at 5.2 seconds [o]

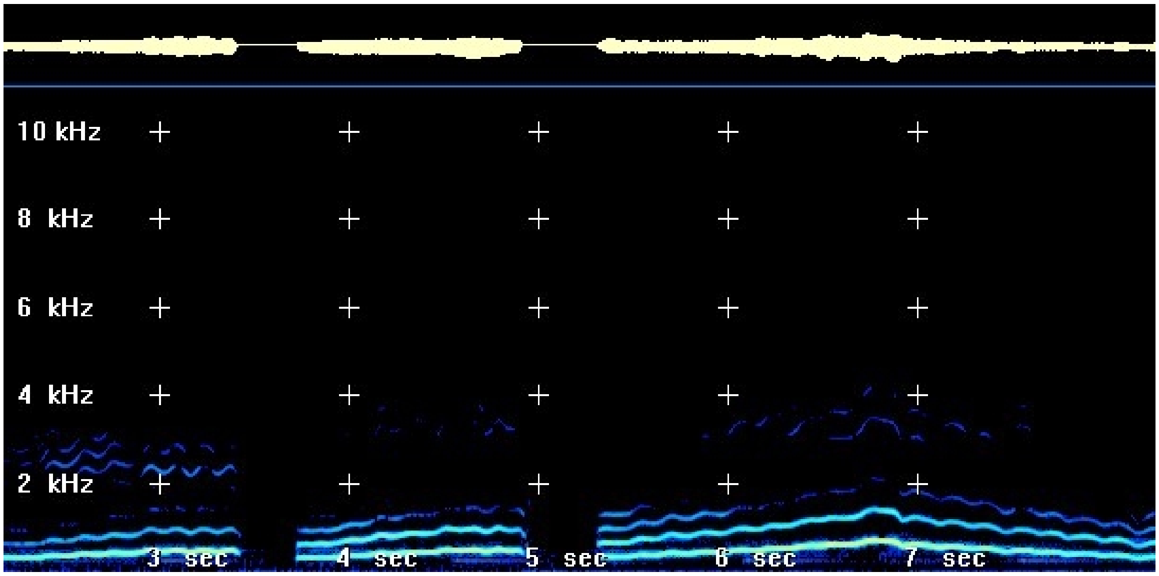


Power Spectrum from Spectrogram #1, Subject #1 at 7.62 seconds [a]



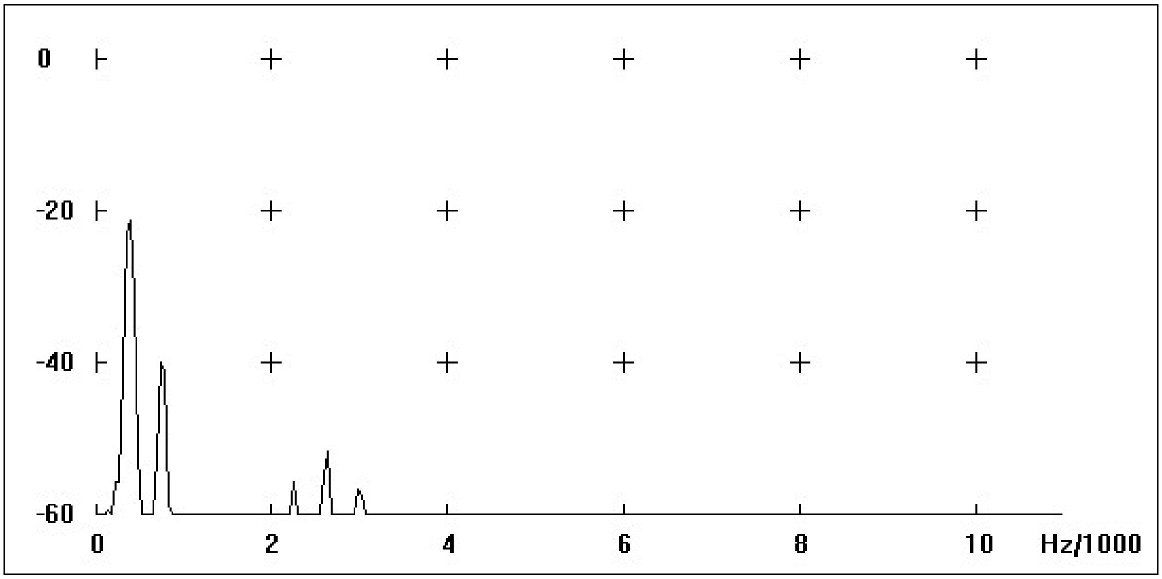
Analysis of Power Spectra from Spectrogram #1 for Subject #1 – August 24, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.65	4	2	.5	3	7	.42	.46
5.2	7	3	.42	2	9	.22	.32
7.62	6	2	.33	2	8	.25	.29
Average of three chiaroscuro levels							.35

Wave File Number 2 – August 31, 2000 – Subject #1

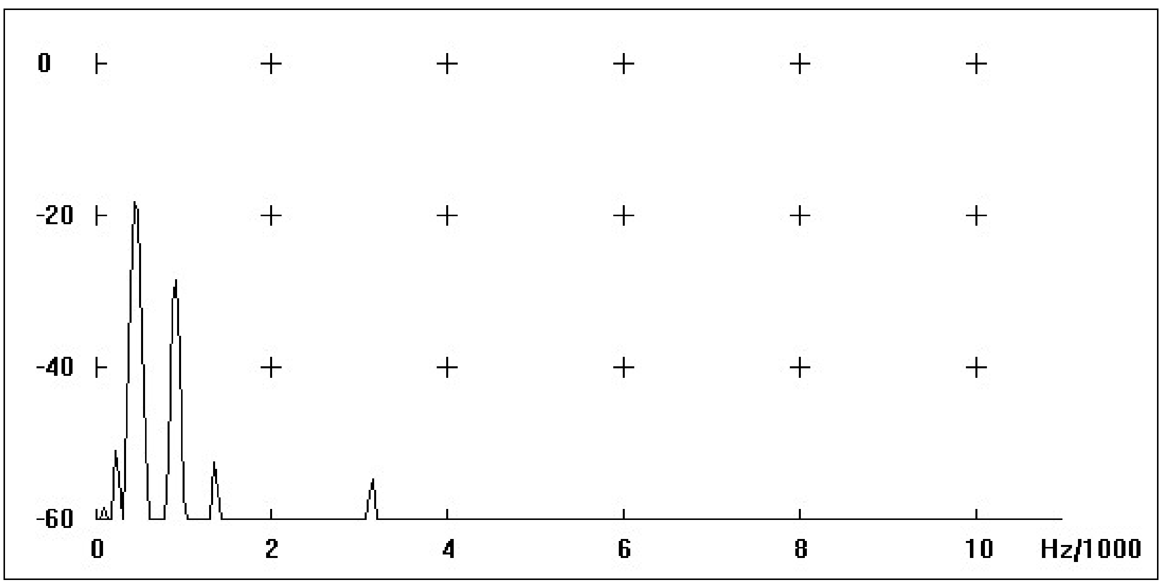


Subject #1 – Analysis of Wave File #2 – August 31, 2000 – E-flat major				
		[si] (2-3.4 sec)	[o] (3.8-5 sec)	[a] (5.4-9 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	3 partial bands of moderate strength	Scattering of light indications	Practically no indications except in higher registers (6-7.25 sec)
2nd Formant Area (Vowel Definition)		Vowel is clear but under-resonated	Better vowel but not fully resonated	Better vowel but not fully resonated
1st Formant Area		Clear but weak	Clear but weak	Clear but weak
Chiaroscuro Balance		Voice is light in both aspects	Voice is light in both aspects, but somewhat firmer in the lower areas	Voice is light in both aspects, but lower frequencies are stronger than #1
Power Spectrum		Increases from about 10% to about 20%	Increases from about 15% to about 20%	Increases from about 15% to about 25% and declines to about 10%
Second wave file for freshman soprano: shows some improvement				

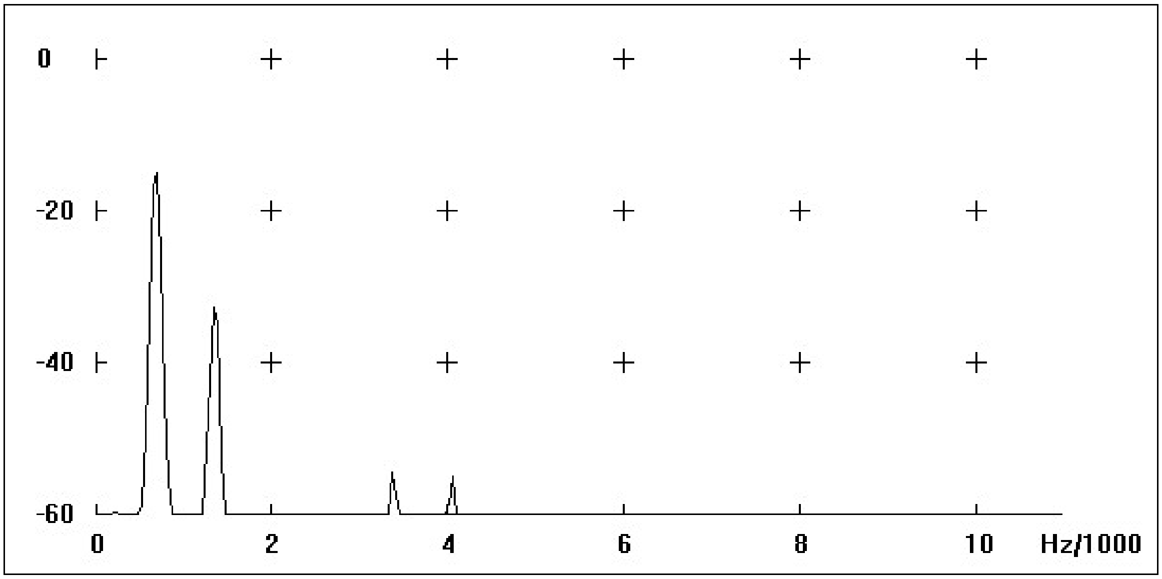
Power Spectrum from Spectrogram #2, Subject #1 at 2.69 seconds [i]



Power Spectrum from Spectrogram #2, Subject #1 at 4.73 seconds [o]

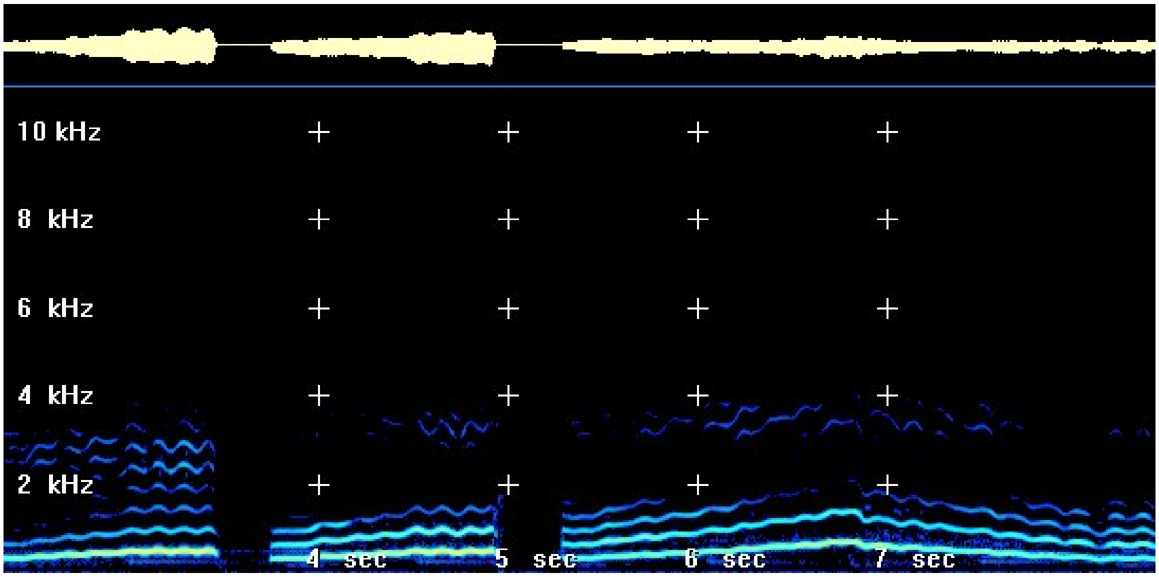


Power Spectrum from Spectrogram #2, Subject #1 at 6.74 seconds [a]



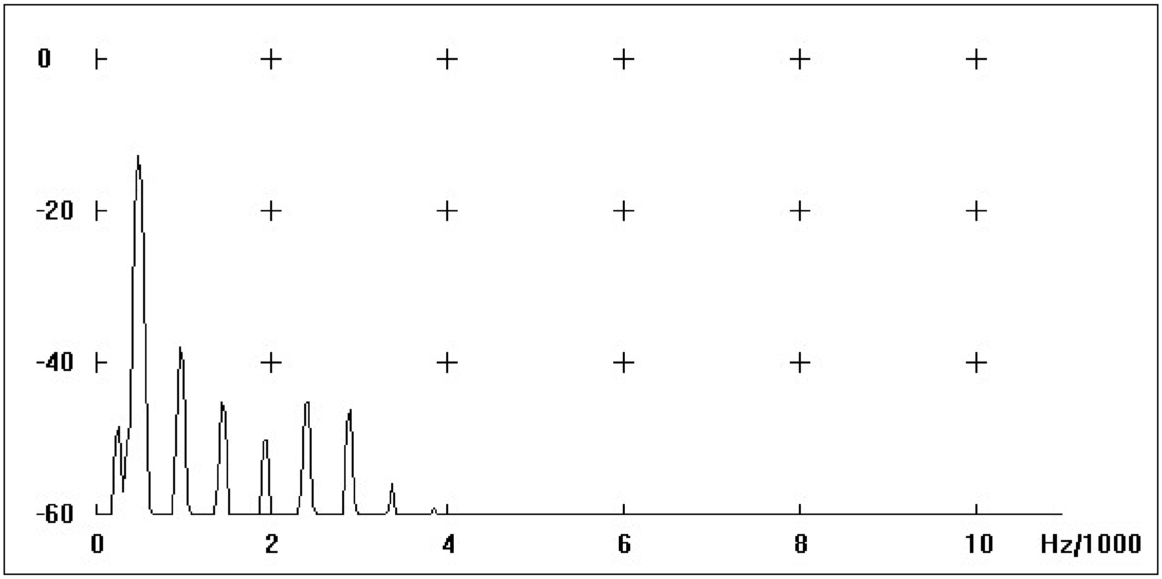
Analysis of Power Spectra from Spectrogram #2 for Subject #1 – August 31, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.69	2	2	1	3	5	.6	.8
4.73	5	2	.4	1	6	.16	.28
6.74	3	2	.6	2	5	.4	.5
Average of three chiaroscuro levels							.79

Wave File Number 3 – September 7, 2000 – Subject #1

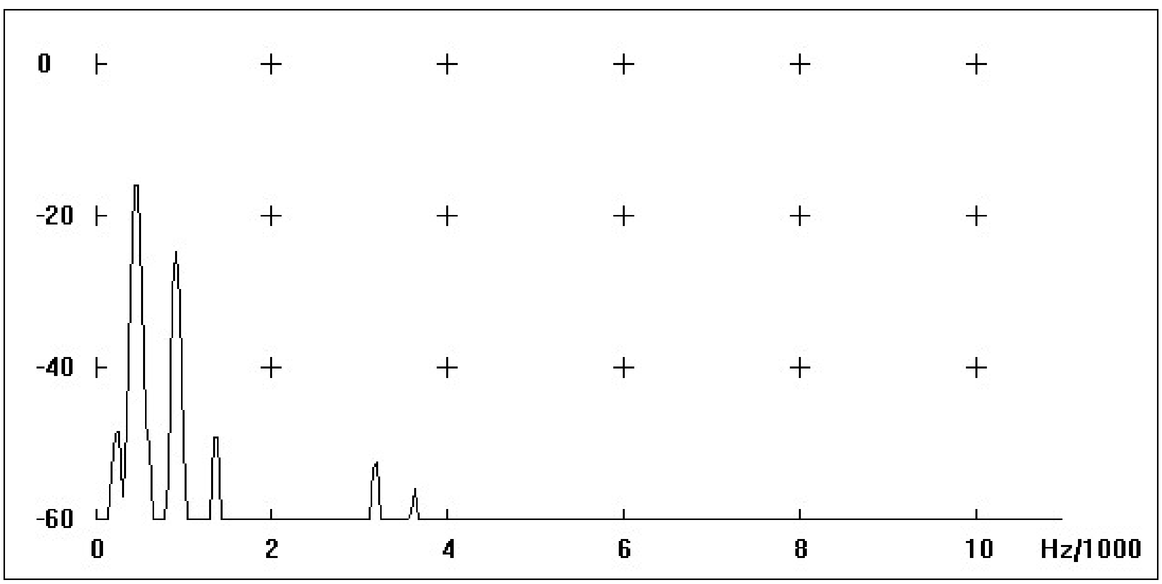


Subject #1 – Analysis of Wave File #3 – September 7, 2000 – E-flat major				
		[si] (2.3-3.5 sec)	[o] (3.8-5 sec)	[a] (5.3-8.7 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	3 nearly solid bands	One partial band with some scattering	3 partial bands
2nd Formant Area (Vowel Definition)		Clear vowel formation	Not as strong as [si] but stronger than #2	Clear vowel formation
1st Formant Area		Gaining strength	Gaining strength	Gaining strength
Chiaroscuro Balance		Increasing strength in lower areas is somewhat balanced in upper areas	Increasing strength in lower area	Increasing strength in lower areas somewhat balanced, but not consistently
Power Spectrum		Increases from about 10% to about 50%	Increases from about 10% to a little less than 50%	Stays within about 20% throughout
Young voice gaining confidence. The more familiar lower frequencies are gaining strength, but especially in the [i] vowel upper frequencies are beginning to gain strength. Note the noisy cut-off of [o] at 5 seconds. At the beginning of the wave file, which is not shown on this screen, it is also possible to see the consonant [s]. Student may have stood somewhat closer to microphone for this recording.				

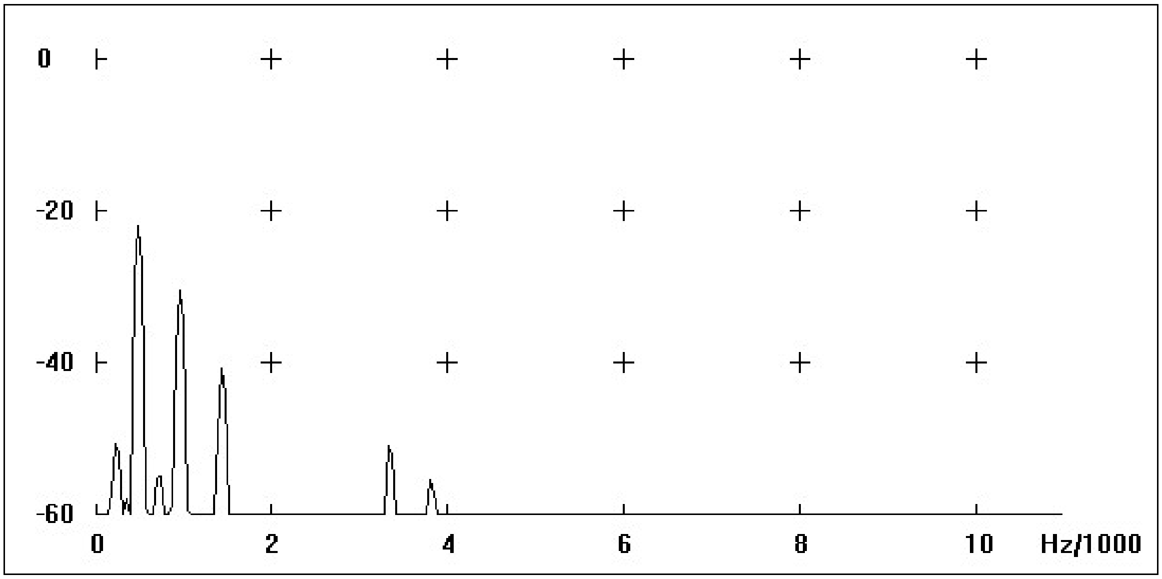
Power Spectrum from Spectrogram #3, Subject #1 at 3 seconds [i]



Power Spectrum from Spectrogram #3, Subject #1 at 4.58 seconds [o]

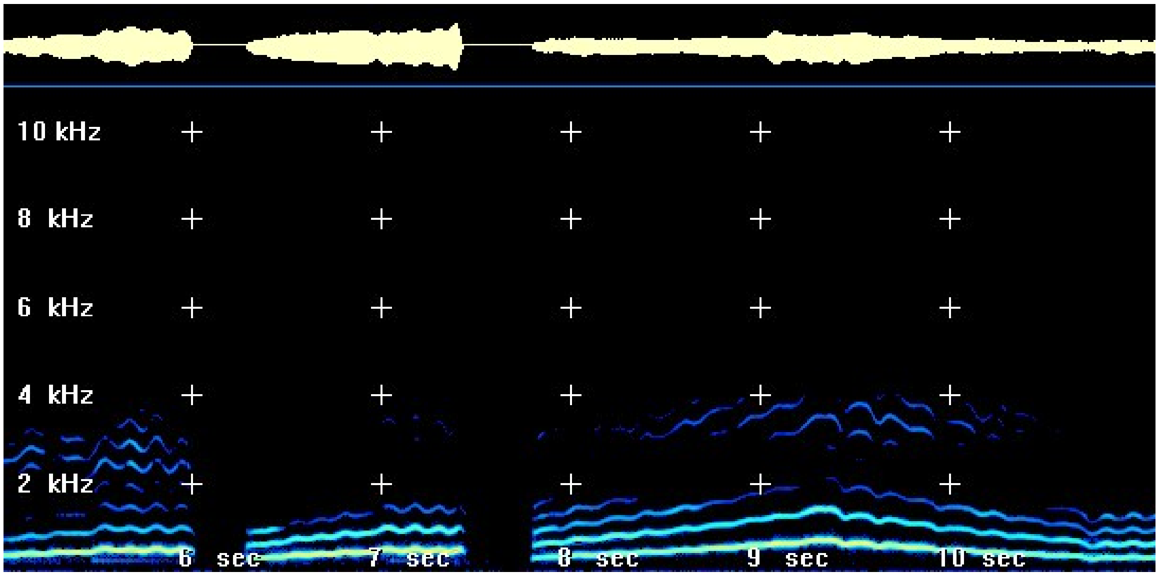


Power Spectrum from Spectrogram #3, Subject #1 at 6.15 seconds [a]



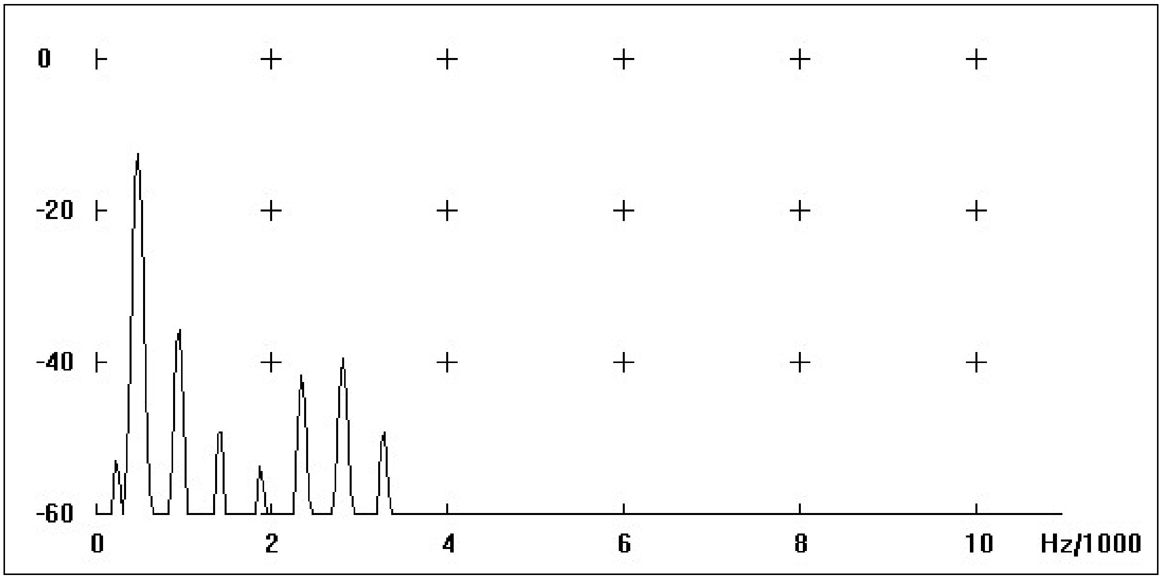
Analysis of Power Spectra from Spectrogram #3 for Subject #1 – September 7, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.0	5	2	.4	4	9	.44	.42
4.58	4	2	.5	2	6	.33	.41
6.15	6	2	.33	2	8	.25	.29
Average of three chiaroscuro levels							.37

Wave File Number 4 – September 14, 2000 - Subject #1

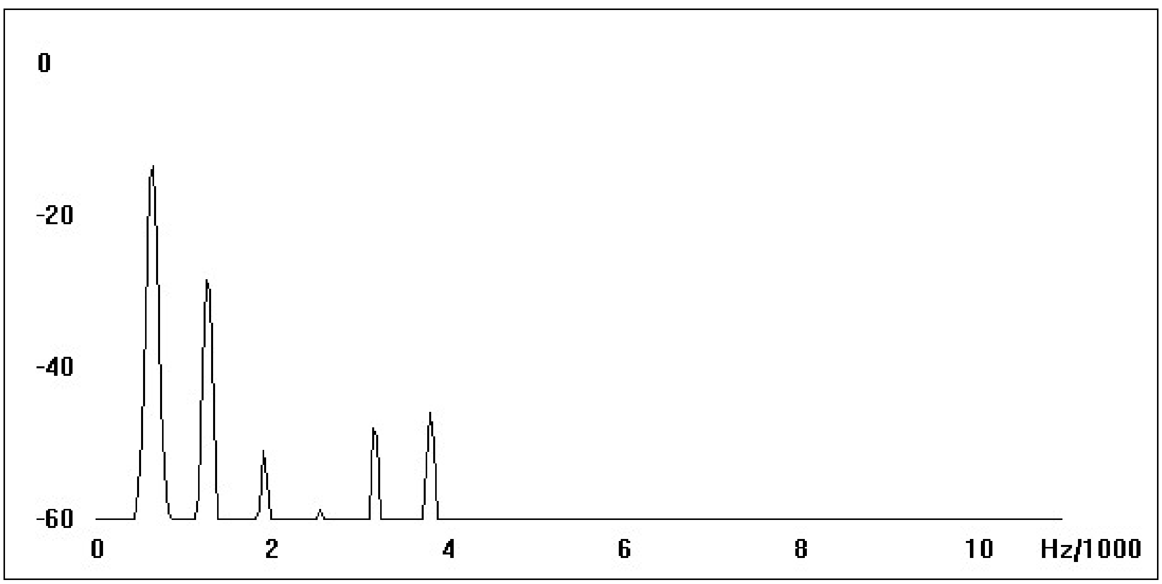


Subject #1 – Analysis of Wave File #4– September 14, 2000 – E-flat major				
		[si] (4.72-6 sec)	[o] (6.3-7.4 sec)	[a] (7.8-11.5 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	3 bands nearly solid increasing strength	Only slight scattered indications	3 bands increasing strength
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Increasing strength	Increasing strength	Increasing strength
Chiaroscuro Balance		Increasing strength in lower areas is somewhat balanced in upper areas	Increasing strength in lower area	Increasing strength in lower areas somewhat balanced, better consistency
Power Spectrum		Increases from about 15% to about 40%	Increases from about 20% to about 40%	Increases from about 10% to about 30% and declines to about 10%
Gaining strength in lower frequencies but still damping the top.				

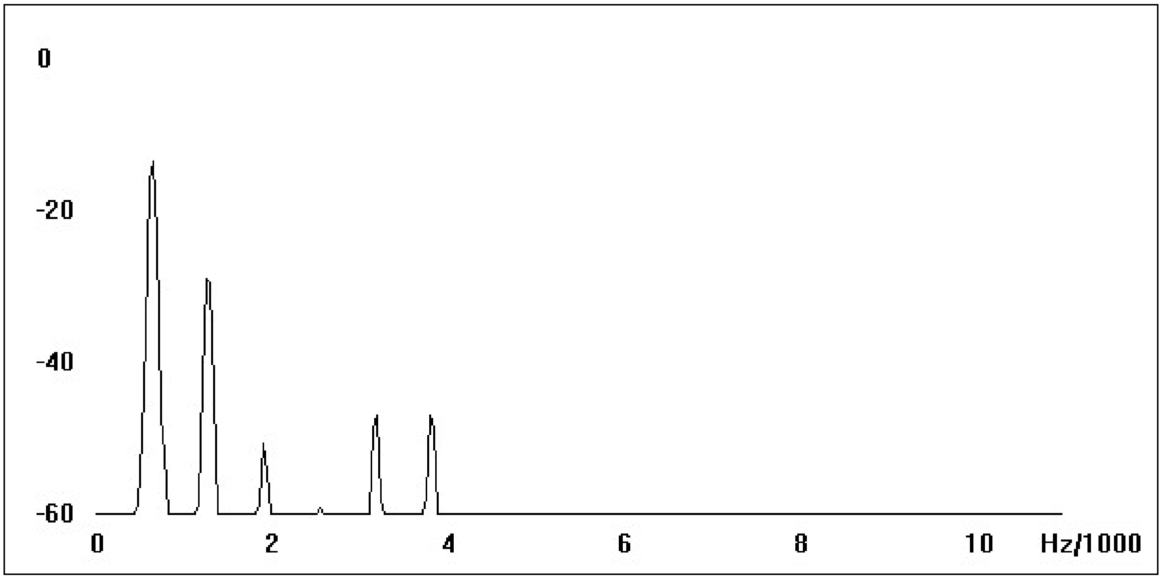
Power Spectrum from Spectrogram #4, Subject #1 at 5.73 seconds [i]



Power Spectrum from Spectrogram #4, Subject #1 at 7.18 seconds [o]

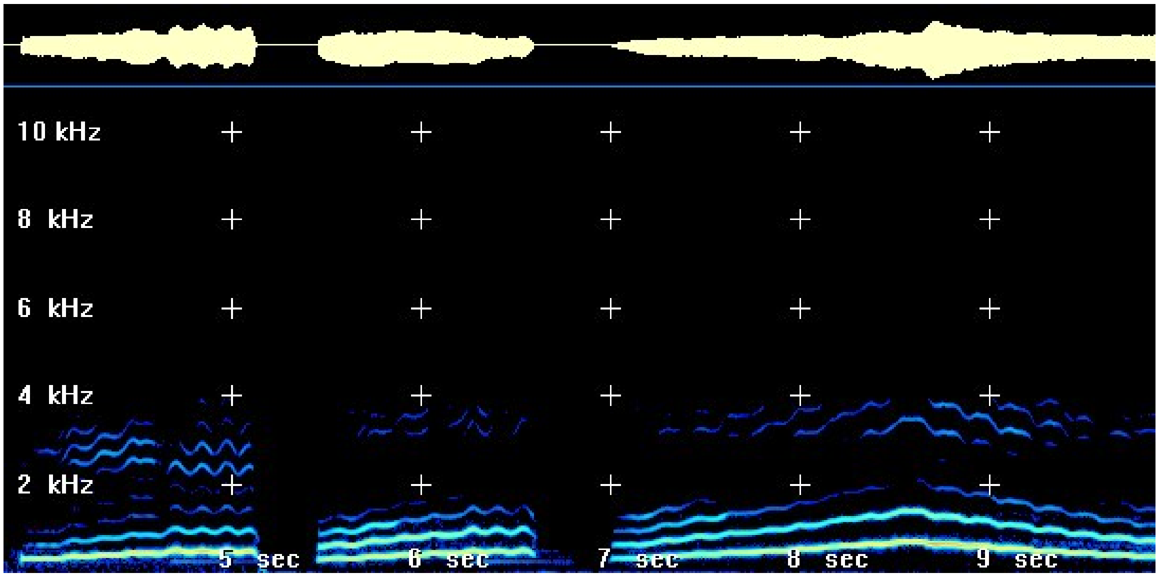


Power Spectrum from Spectrogram #4, Subject #1 at 9.53 seconds [a]



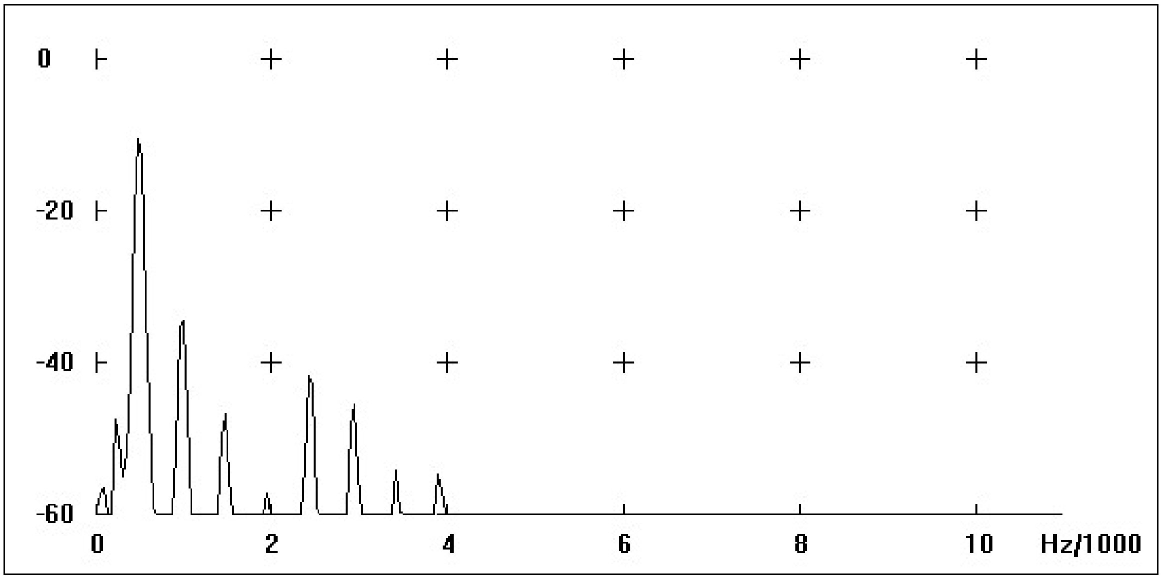
Analysis of Power Spectra from Spectrogram #4, Subject #1 – September 14, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.73	5	2	.4	3	8	.37	.38
7.18	3	2	.66	3	6	.5	.58
9.53	3	2	.66	3	6	.5	.58
Average of three chiaroscuro levels							.51

Wave File Number 5 – September 21, 2000 - Subject #1

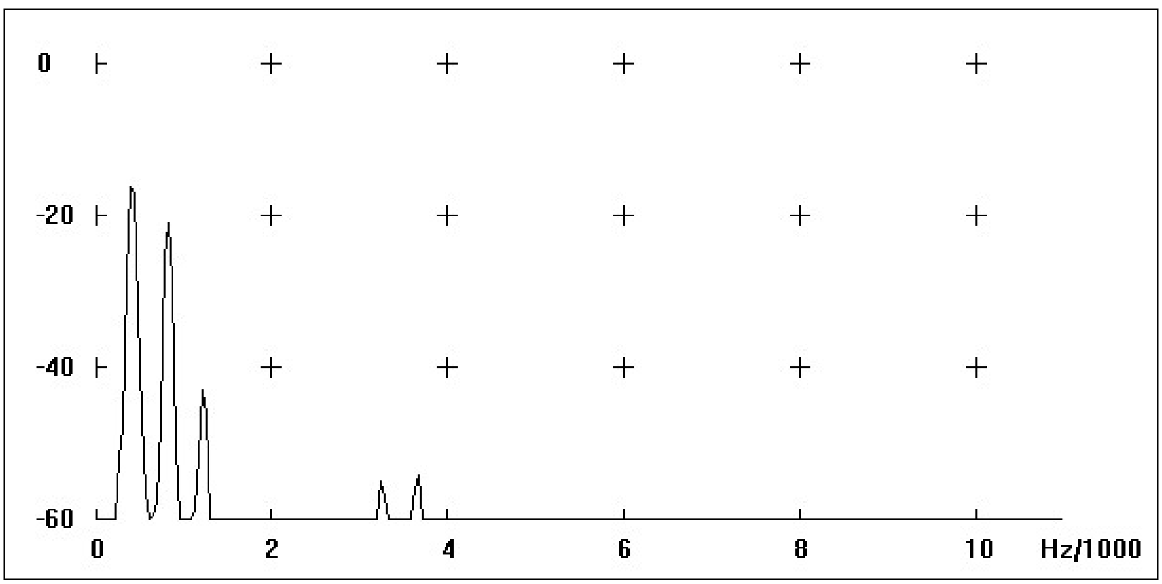


Subject #1 – Analysis of Wave File #5 – September 21, 2000 – E-flat major				
		[si] (3.91-5.12 sec)	[o] (5.47-6.58 sec)	[a] (7.0-10.8 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	3 nearly solid bands, plus partial 4th band -increasing strength- PS sample shows 10 peaks, although some are very weak	Two partial bands – increasing strength – same 5 peaks in PS sample, but their decibel reading is higher	3 partial bands – increasing strength and consistency
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Increasing strength	Increasing strength	Increasing strength
Chiaroscuro Balance		Improving balance	Improving balance, lower frequencies still considerably stronger	Improving balance, tendency to damp top still visible
Power Spectrum		Increase from about 20% to about 50%	Increase from about 30% to about 40% and decline to about 20%	Increase from less than 10% to about 60% and decline
Power Spectrum (PS) samples are beginning to show more peaks, which indicate that the young singer is beginning to add more complexity to her sound. As she continues to add these peaks more consistently, the sound will be perceived by hearers as a larger and fuller sound.				

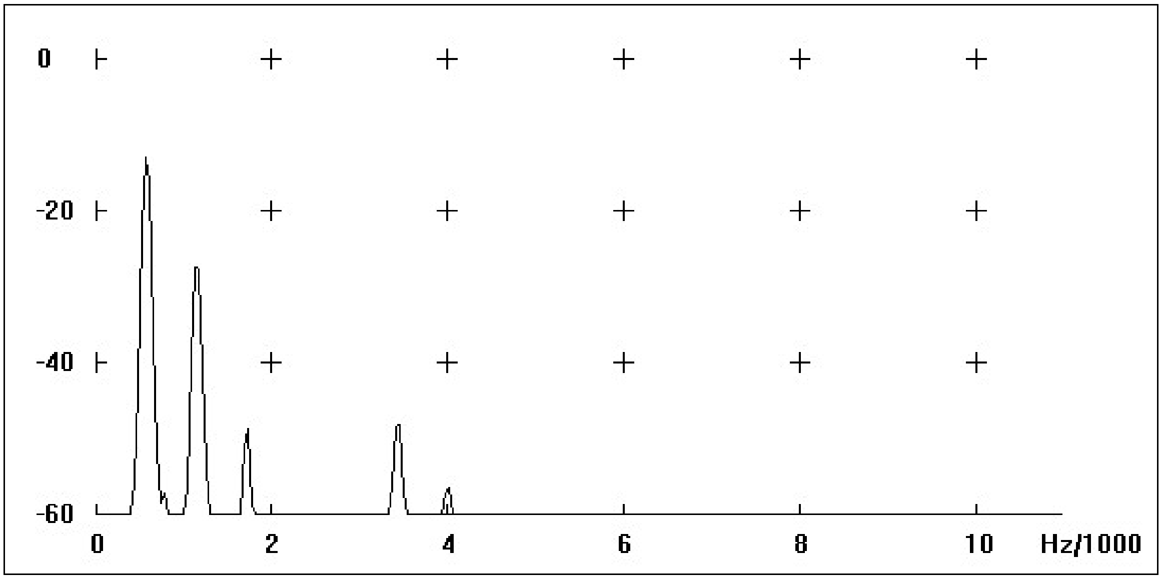
Power Spectrum from Spectrogram #5, Subject #1 at 4.85 seconds [i]



Power Spectrum from Spectrogram #5, Subject #1 at 6.04 seconds [o]

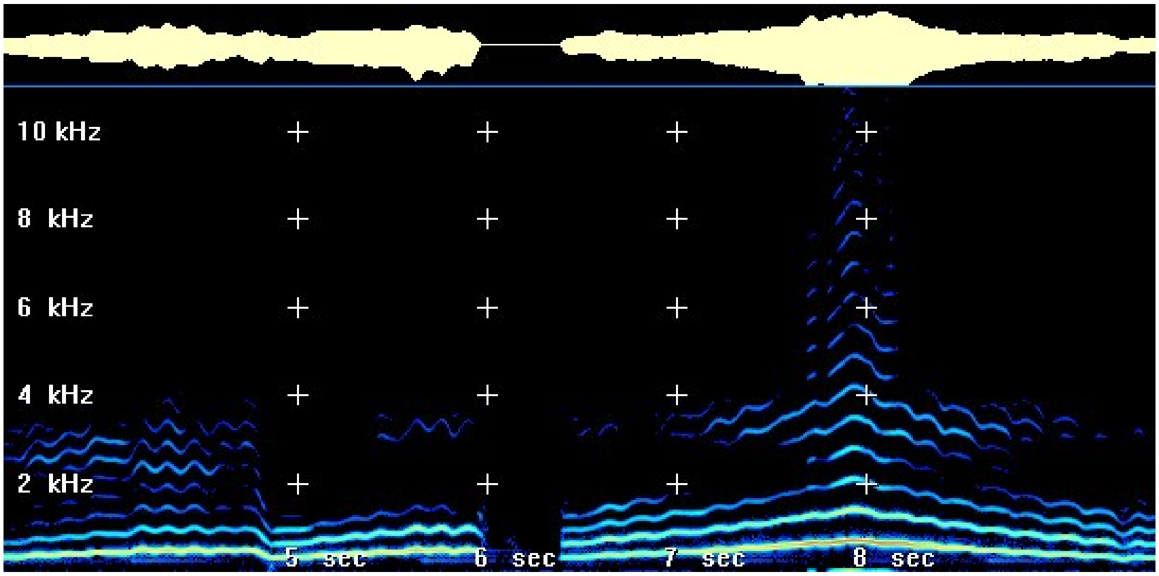


Power Spectrum from Spectrogram #5, Subject #1 at 9.03 seconds [a]



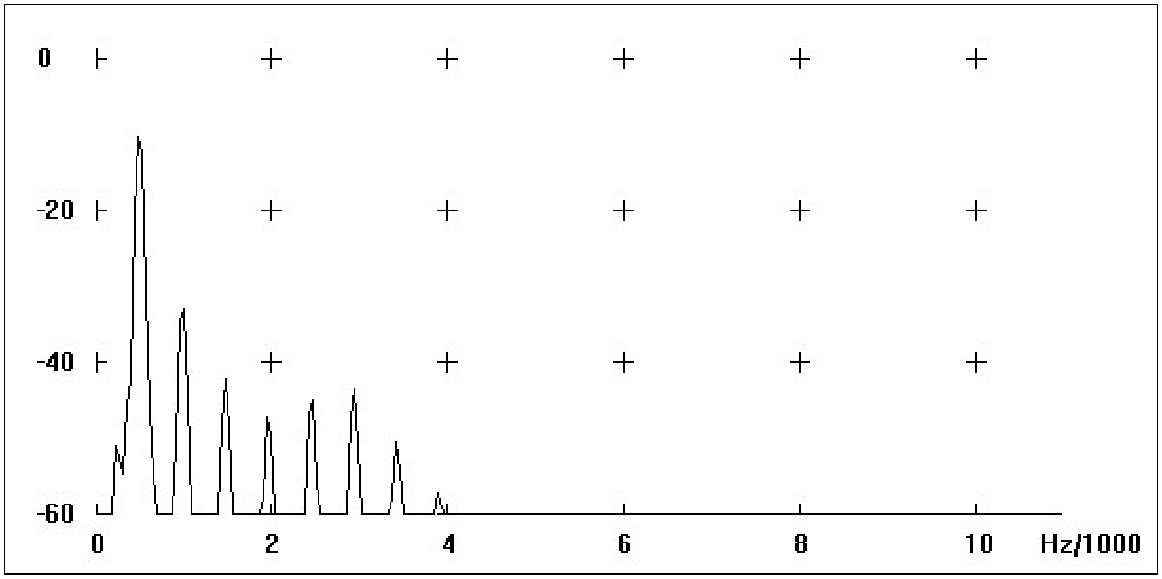
Analysis of Power Spectra from Spectrogram #5, Subject #1 – September 21, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.85	6	2	.33	4	10	.4	.36
6.04	3	2	.66	2	5	.4	.53
9.03	4	2	.5	2	6	.33	.41
Average of three chiaroscuro levels							.43

Wave File Number 6 – September 29, 2000 – Subject #1

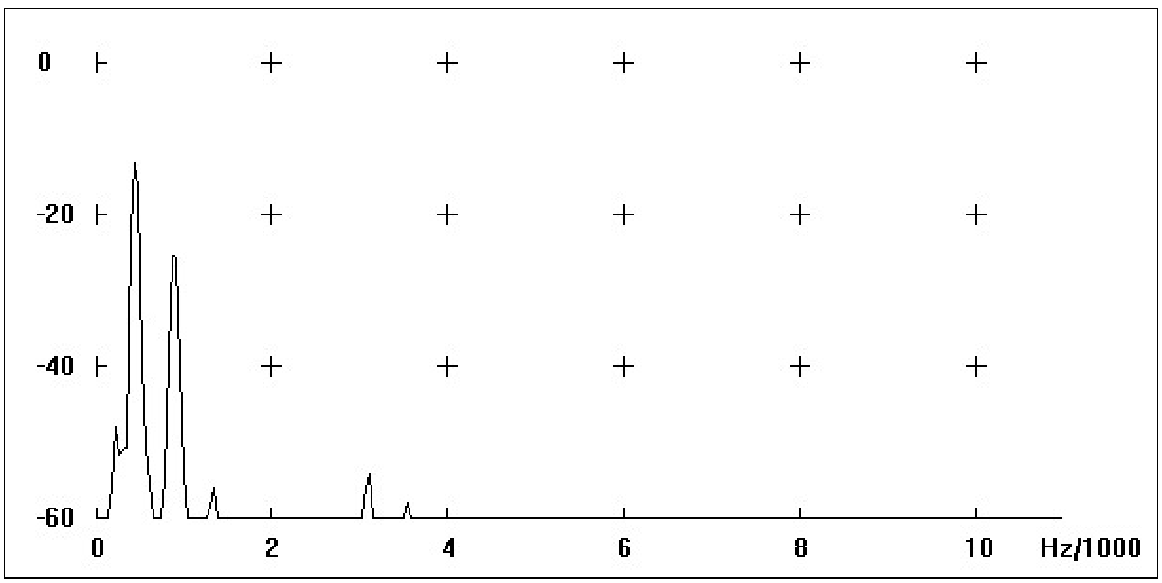


Subject #1 – Analysis of Wave File #6 – September 29, 2000 – E-flat major				
		[si] (3.36-4.76 sec)	[o] (4.87-5.97 sec)	[a] (6.4-10 sec)
Singer's Formant Area	4000+ Hz			Large spike over 10,000 Hz probably due to sudden increase of air pressure
	2000-4000 Hz	4 nearly solid bands plus additional partial bands – 7 peaks in PS sample	Increasing strength and consistency	Increasing strength and consistency
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Clearly stronger	Clearly stronger	Clearly stronger
Chiaroscuro Balance		Well balanced	Balance improving	Better overall balance
Power Spectrum		Increase from about 15% to about 50%	Increase from about 20% to about 60%	Increase from about 20% to 100% and decline to about 25%
As this young singer is beginning to understand the possibilities of her voice, she occasionally looses control. Her chiaroscuro is much more balanced, but in the course of achieving this kind of balance, she overdid her muscular support at the top of the [a] vowel.				

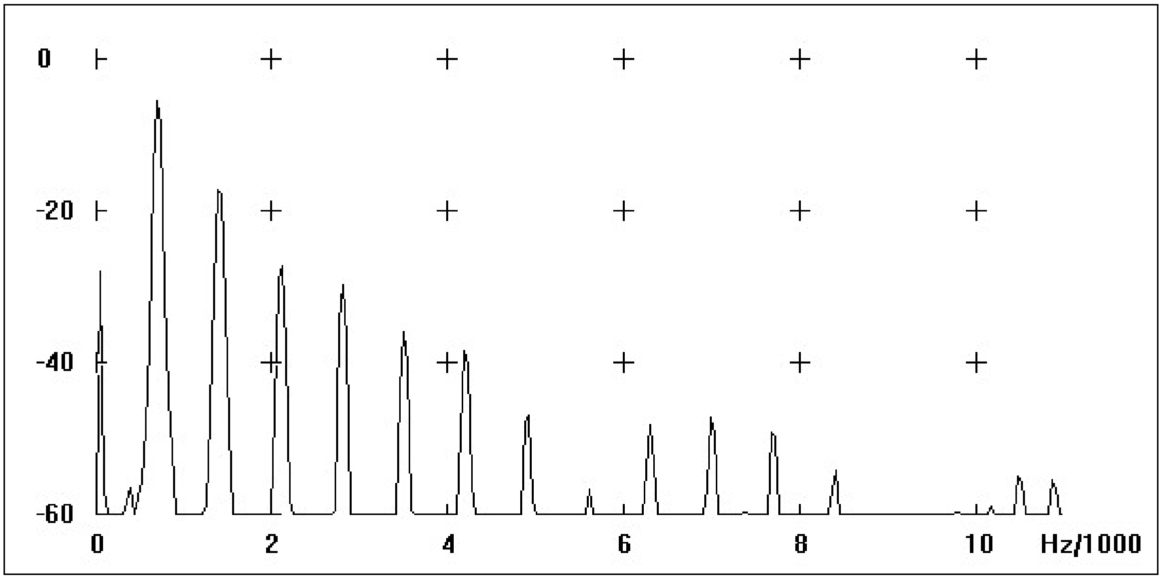
Power Spectrum from Spectrogram #6, Subject #1 at 4.32 seconds [i]



Power Spectrum from Spectrogram #6, Subject #1 at 5.84 seconds [o]

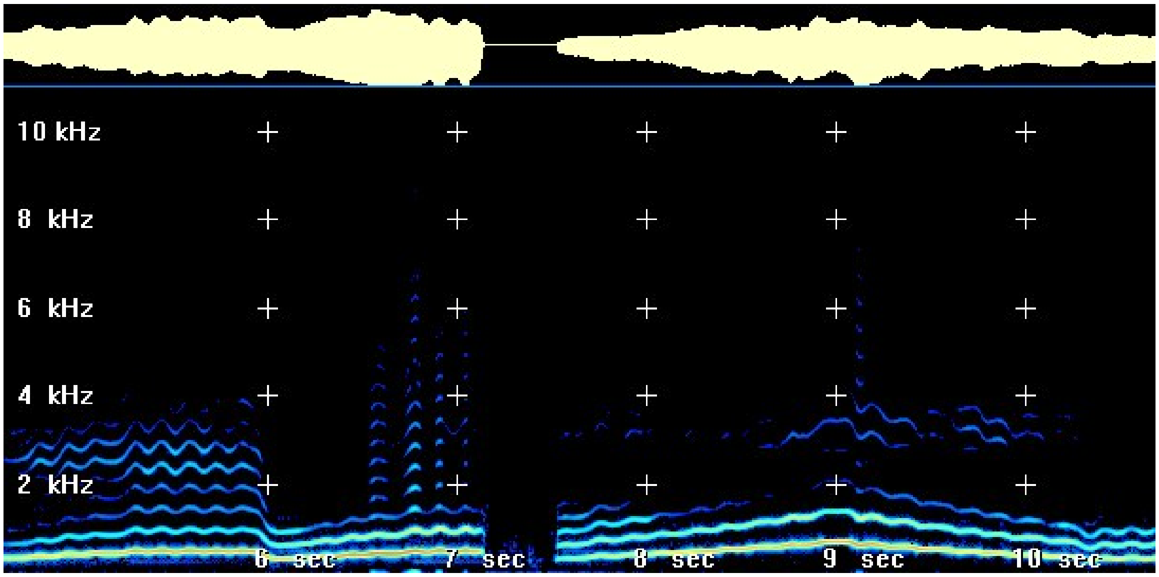


Power Spectrum from Spectrogram #6, Subject #1 at 7.94 seconds [a]



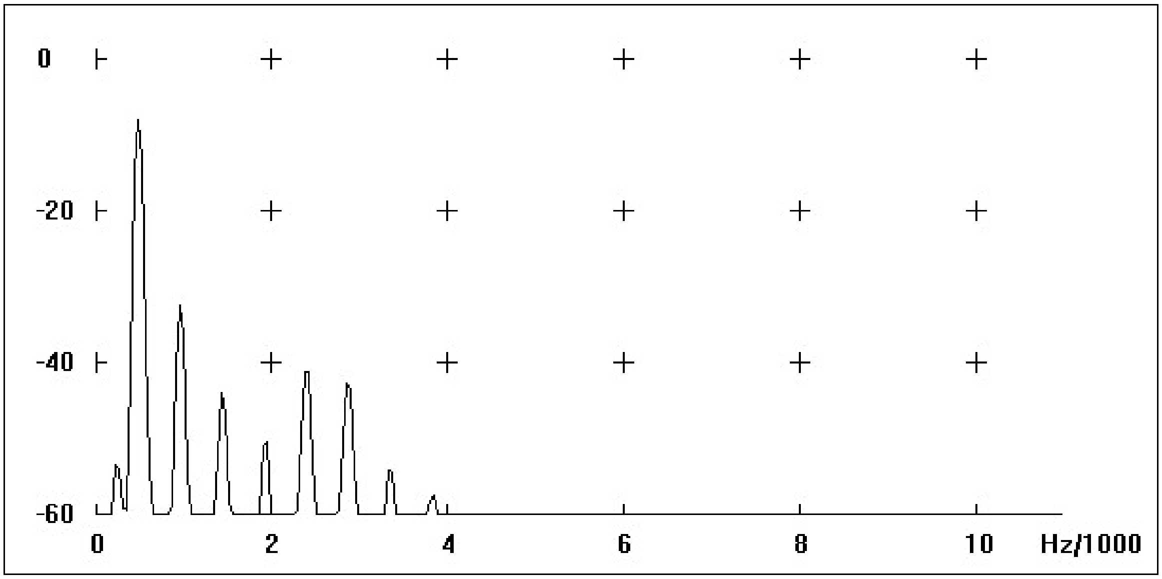
Analysis of Power Spectra from Spectrogram #6, Subject #1 – September 29, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	b/a	c	d	c/d	(b/a+c/d)/2
4.32	5	2	.4	4	9	.44	.42
5.84	4	2	.5	2	6	.33	.41
7.94	4	3	.75	13	17	.76	.75
Average of three chiaroscuro levels							.52

Wave File Number 7 – October 5, 2000 – Subject #1

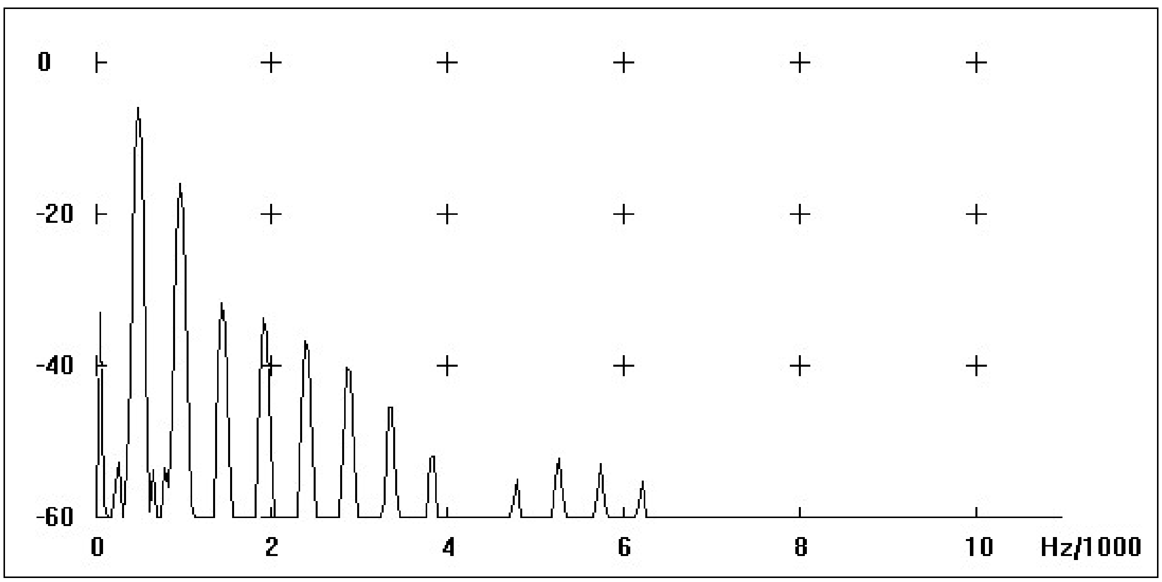


Subject #1 – Analysis of Wave File #7 – October 5, 2000 – E-flat major				
		[si] (4.6-6 sec)	[o] (6.2-7.12 sec)	[a] (7.56-11.2 sec)
Singer's Formant Area	4000+ Hz		Peaks up to 6000+ Hz	Peak over 6000 Hz at top pitch
	2000-4000 Hz	Solid indications	Indications in upper half of exercise	More consistent throughout
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Continuing to strengthen	Continuing to strengthen	Continuing to strengthen
Chiaroscuro Balance		Good balance	Improving balance	Consistency improving
Power Spectrum		Increase from about 30% to about 80%	Increase from about 50% to 100%	Much steadier increase from about 20% to about 100%
The singer is beginning to use resonance more consistently. There are still a few spikes as she over sings, but she is gaining control.				

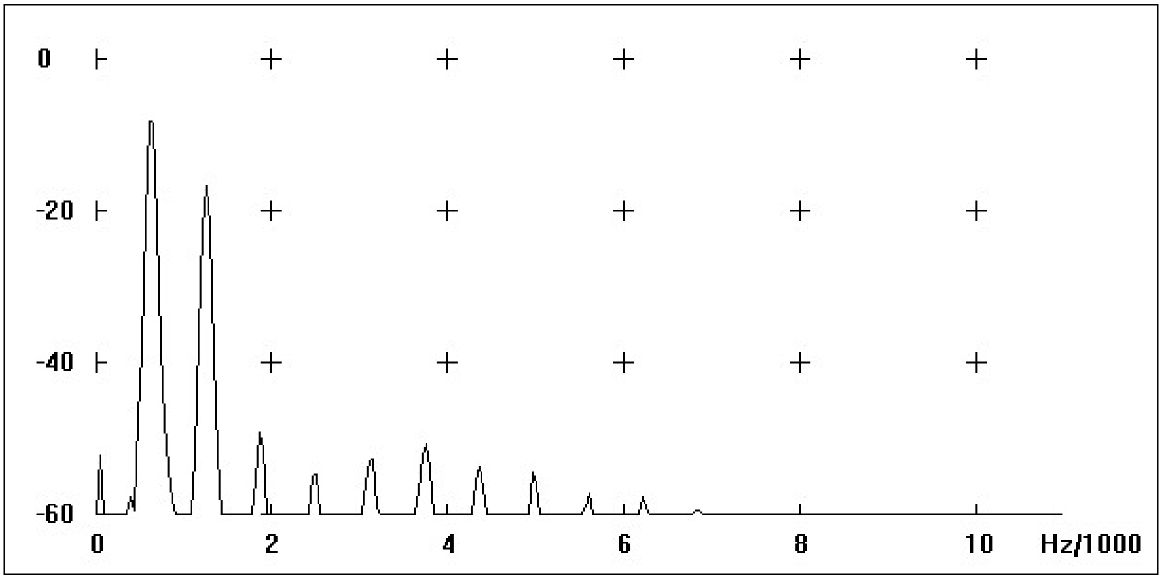
Power Spectrum from Spectrogram #7 Subject #1 at 5.57 seconds [i]



Power Spectrum from Spectrogram #7, Subject #1 at 6.78 seconds [o]

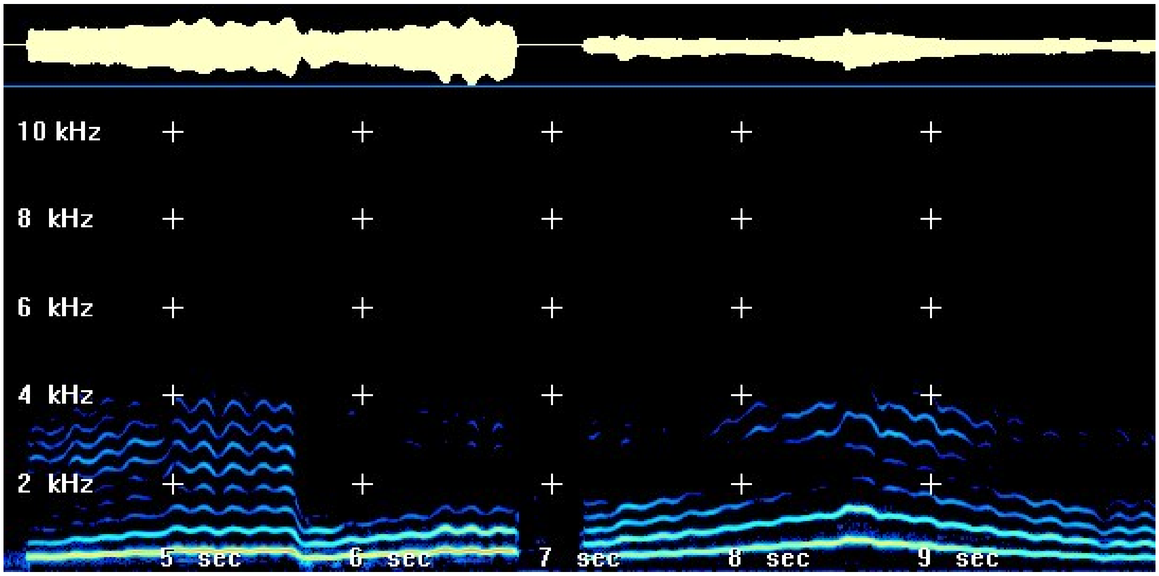


Power Spectrum from Spectrogram #7, Subject #1 at 9.13 seconds [a]



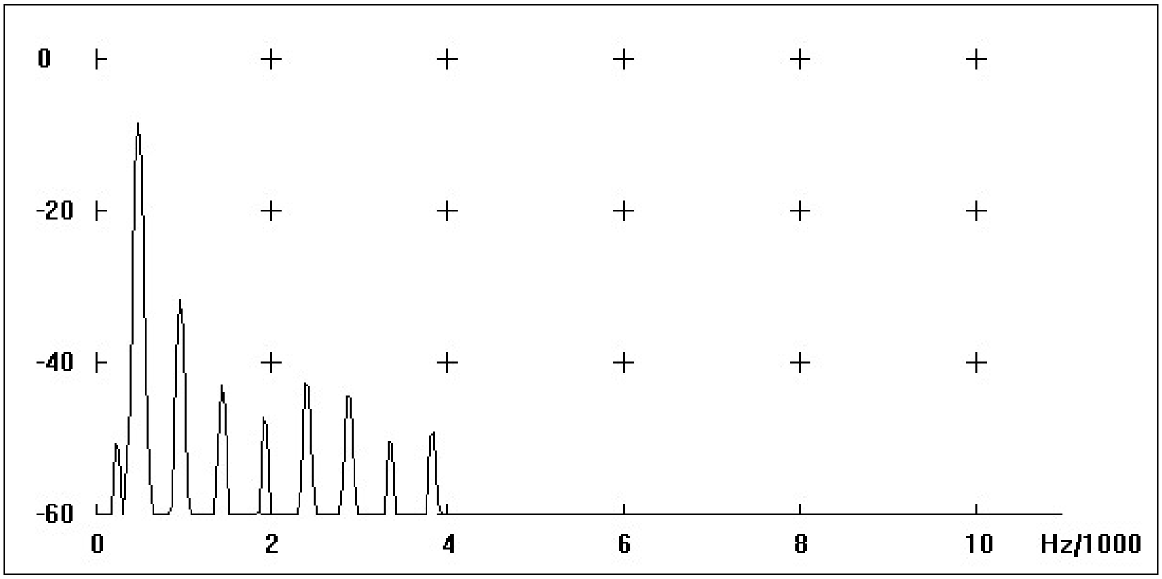
Analysis of Power Spectra from Spectrogram #7, Subject #1 – October 5, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.57	5	2	.4	4	9	.44	.42
6.78	8	5	.62	8	16	.5	.56
9.13	5	2	.4	8	13	.61	.5
Average of three chiaroscuro levels							.49

Wave File Analysis #8 – October 12, 2000 – Subject #1

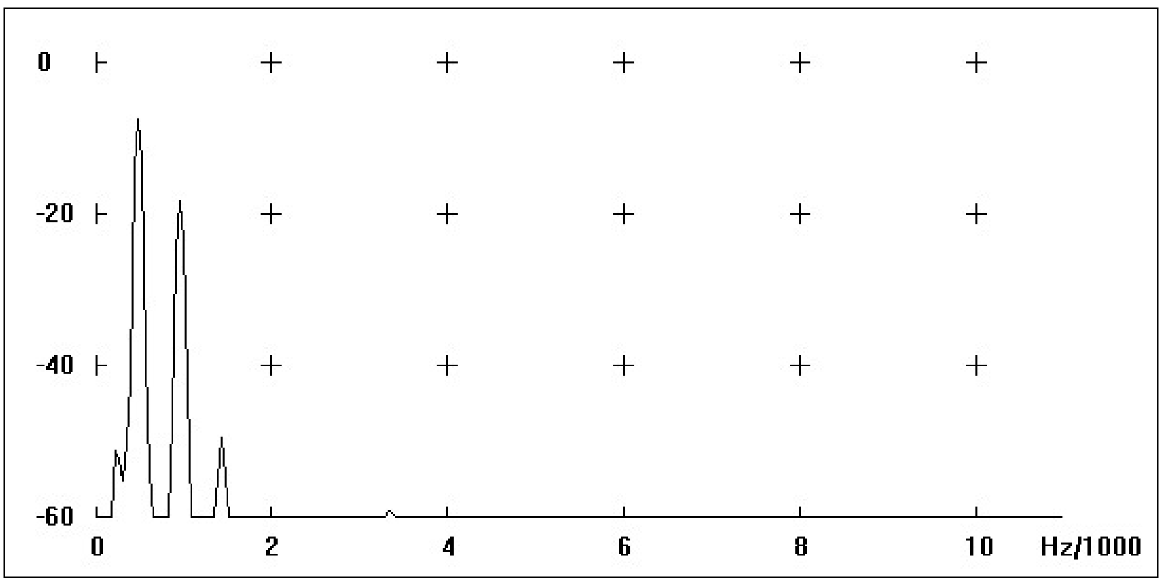


Subject #1 – Analysis of Wave File #8 – October 12, 2000 – E-flat major				
		[si] (4.23-5.6 sec)	[o] (5.73-6.82 sec)	[a] (7.1-10.5 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Solid and consistent	Not as good as #7, but continuing to improve	Not as good as #7, but continuing to improve
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Continuing to strengthen	Continuing to strengthen	Continuing to strengthen
Chiaroscuro Balance		Good balance	Still weighted toward lower area	Consistency continuing to improve
Power Spectrum		Increase from about 40% to about 80%	Increase from about 40% to about 80%	Increase from about 10% to about 30% and decline to 10%
The singer's [o] and [ɑ] vowels continue to be weighted toward the lower frequencies because she needs to adjust the vowels for more resonance toward [ɒ] and [a].				

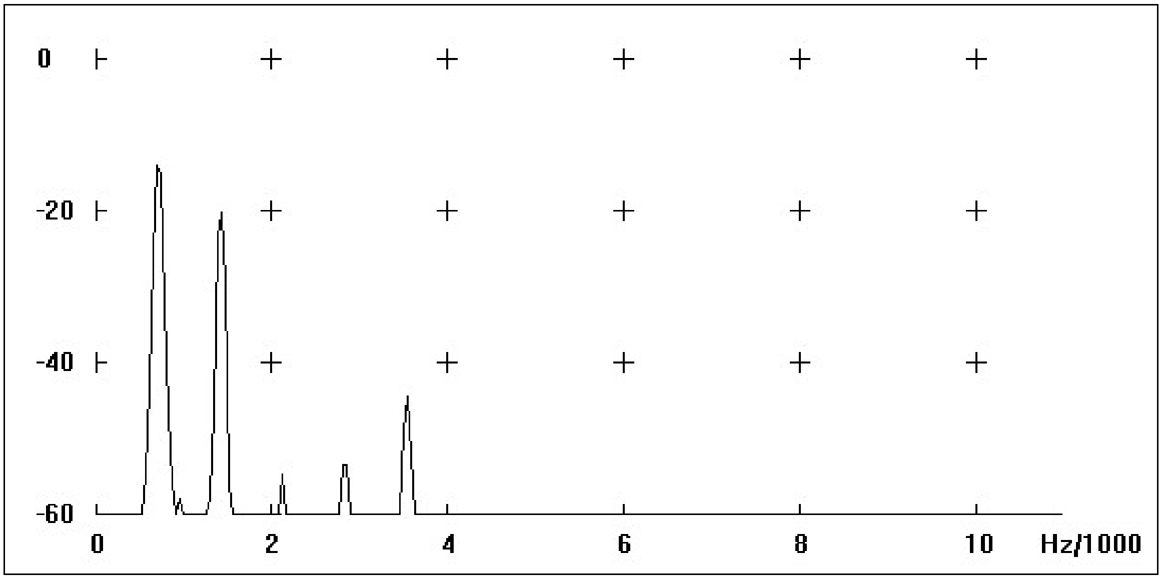
Power Spectrum from Spectrogram #8, Subject #1 at 5.15 seconds



Power Spectrum from Spectrogram #8, Subject #1 at 6.57 seconds

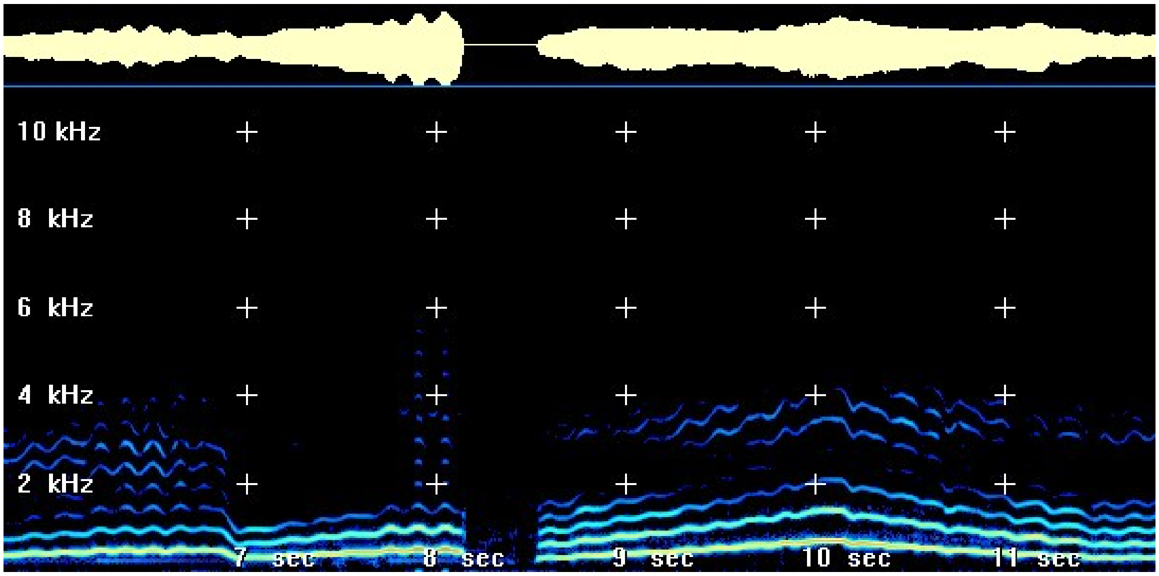


Power Spectrum from Spectrogram #8, Subject #1 at 8.65 seconds



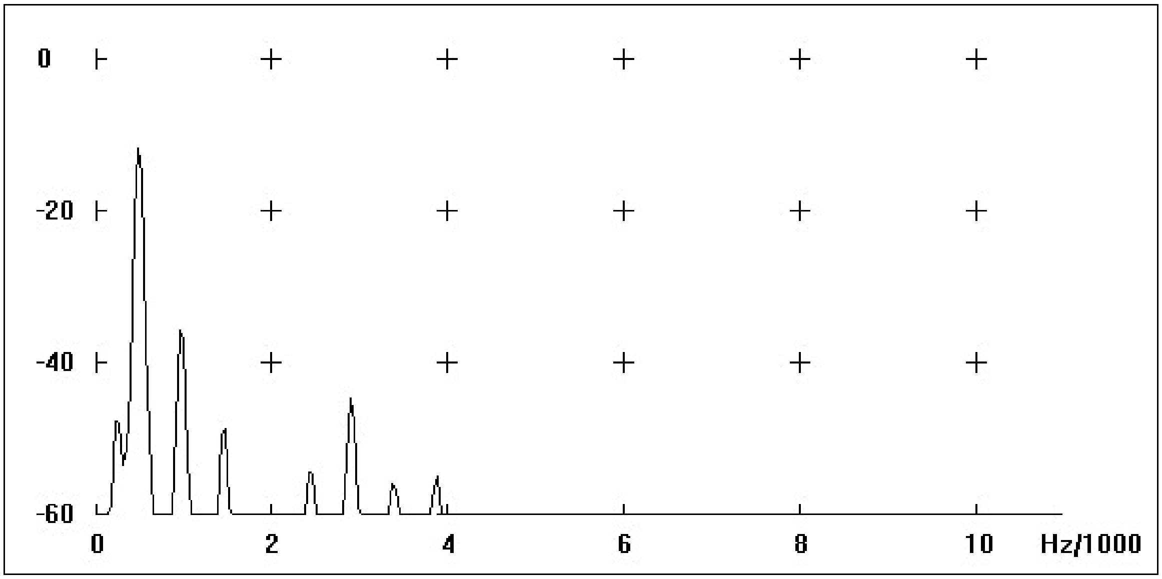
Analysis of Power Spectra from Spectrogram #8, Subject #1 – October 12, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.15	5	2	.4	4	9	.44	.42
6.57	4	2	.5	1	5	.2	.35
8.65	3	2	.66	3	6	.5	.58
Average of three chiaroscuro levels							.45

Wave File Analysis #9 – October 19, 2000 – Subject #1

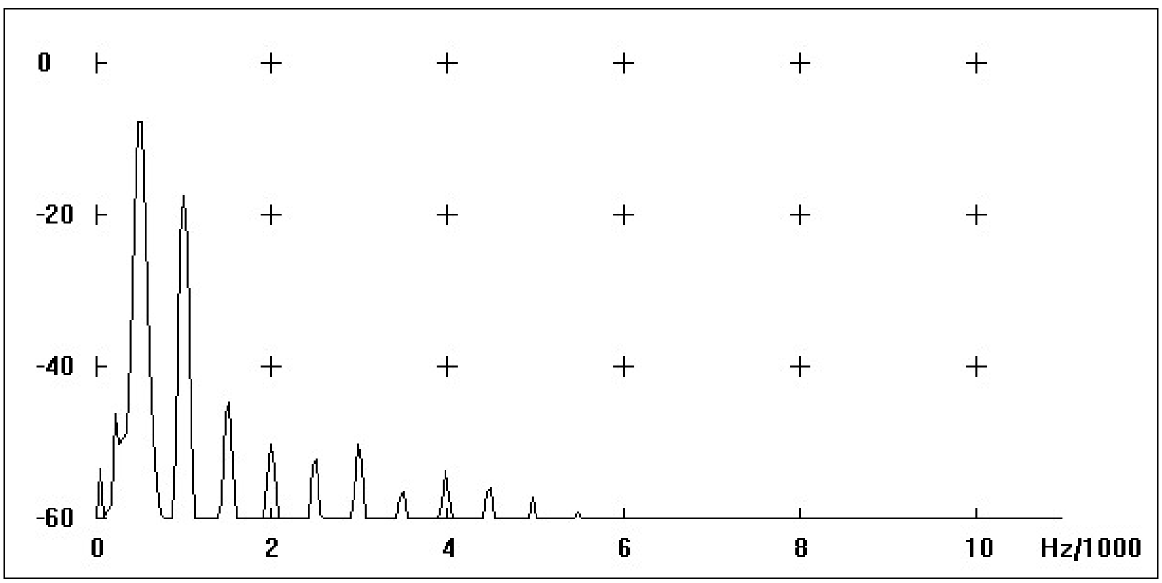


Subject #1 – Analysis of Wave File #9 – October 19, 2000 – E-flat major				
		[si] (5.4-6.77 sec)	[o] (7-8.13 sec)	[a] (8.55-12.24 sec)
Singer's Formant Area	4000+ Hz		7.9-8.1 (5.5 Hz)	Slight spike at 10.17
	2000-4000 Hz	4 nearly solid bands	Less indication until the end when the audible vowel change to [u] brings in upper level frequencies	2 full bands and 1 partial band continuing to improve consistency
2nd Formant Area (Vowel Definition)		Clarity in vowel	Clarity in vowel	Clarity in vowel
1st Formant Area		Strength in first two bands continues to increase	Strength in first two bands continues to increase	Strength in first two bands continues to increase
Chiaroscuro Balance		Balanced	Weighted toward darker sound	More even balance than in #8 – tendency to damp the highest pitches is decreasing
Power Spectrum		Increases from about 15% to about 30%	Increases from about 20% to about 90%	Increases from about 20% to about 90% then declines to about 25%
This wave file shows a young voice that is well balanced in spite of a tendency toward a naturally dark sound. The addition of upper frequency resonance by adjustments in [o] and [a] will not decrease natural darkness, but will increase brilliance and amplitude of sound.				

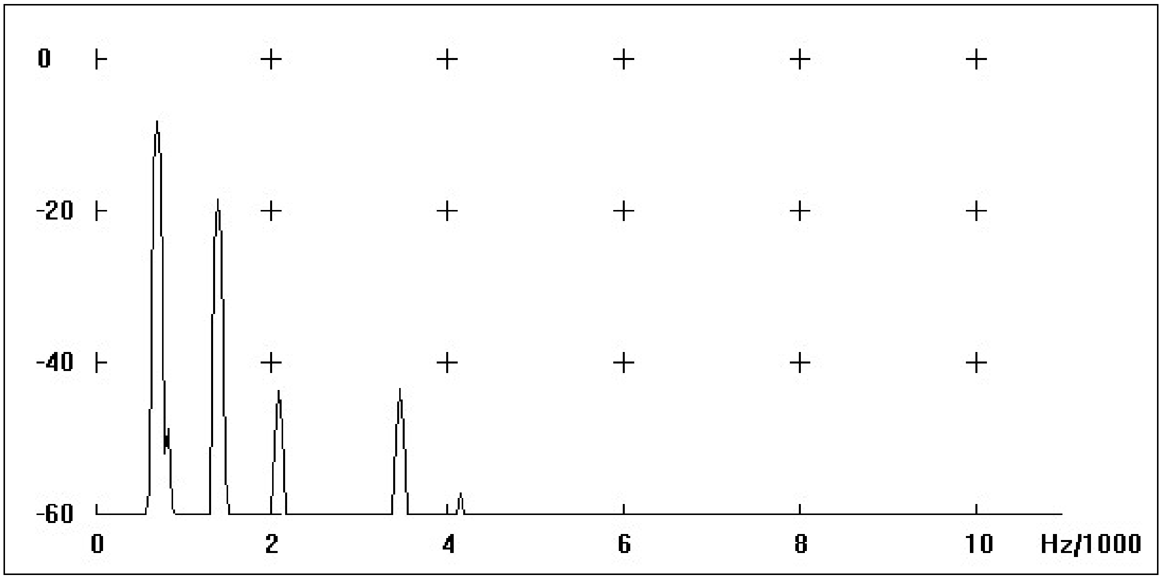
Power Spectrum from Spectrogram #9, Subject #1 at 6.36 seconds



Power Spectrum from Spectrogram #9, Subject #1 at 7.91 seconds

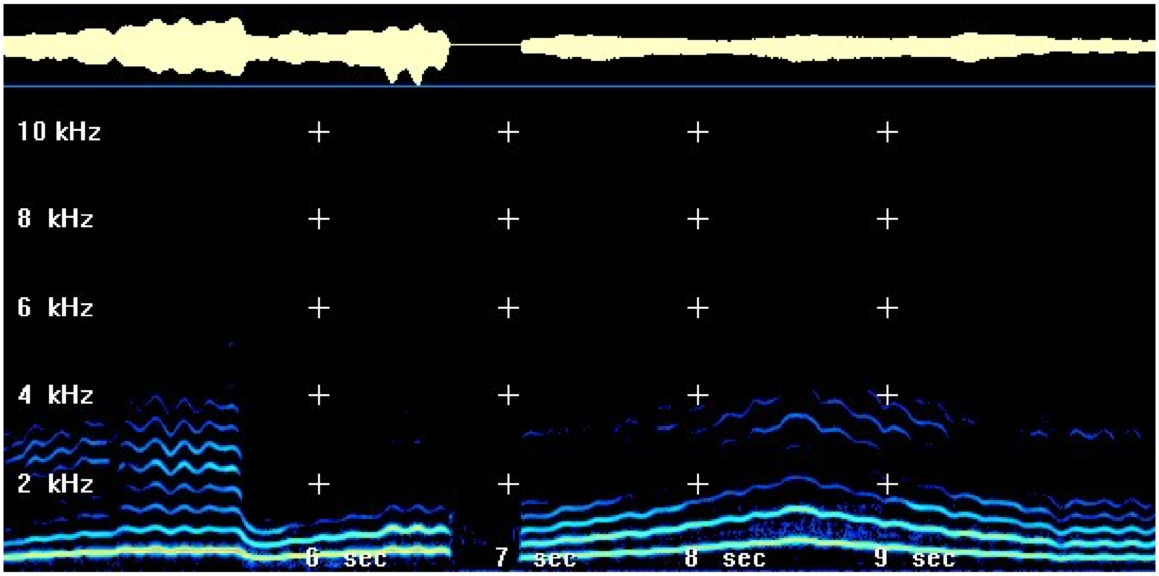


Power Spectrum from Spectrogram #9, Subject #1 at 10.14 seconds



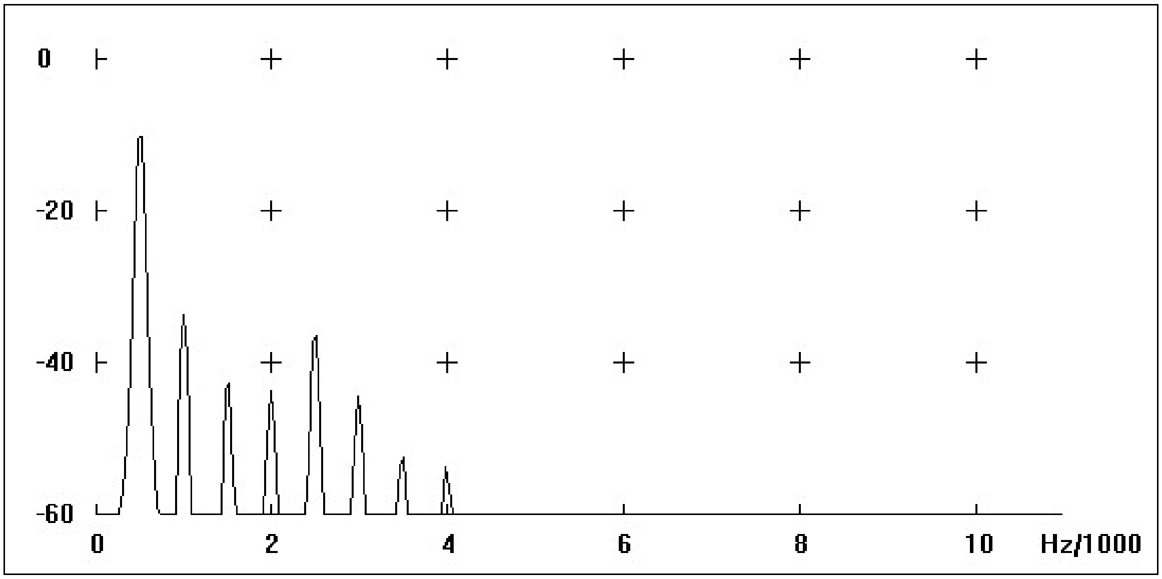
Analysis of Power Spectra from Spectrogram #9, Subject #1 – October 192000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
6.36	4	2	.5	4	8	.5	.5
7.91	5	2	.4	8	13	.61	.5
10.14	3	2	.66	3	6	.5	.58
Average of three chiaroscuro levels							.52

Wave File Analysis #10 – October 26, 2000 – Subject #1

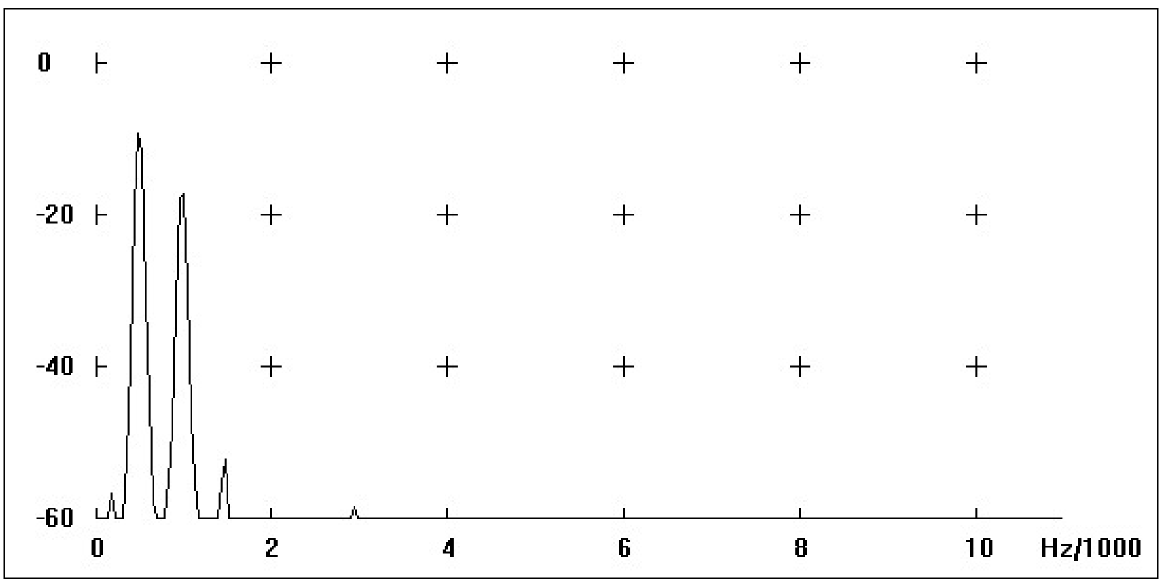


Subject #1 – Analysis of Wave File #10 – October 26, 2000 – E-flat major				
		[si] (4.3-5.58 sec)	[o] (5.74-6.71 sec)	[a] (7.07-10.6 sec)
Singer's Formant Area	4000+ Hz	One small indication at about 5.7 – noisy cutoff using extra breath		
	2000-4000 Hz	Strong indications	Slight indications	Somewhat less consistent than #8 and #9
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Continuing to strengthen	Continuing to strengthen	Continuing to strengthen
Chiaroscuro Balance		Good balance	Strength of lower frequencies enough to bring power spectrum near to that for [si]	Weighted toward lower frequencies
Power Spectrum		Increase from about 20% to about 80%	Increase from about 20% to about 70%	Increase from about 15% to about 30% and decline to about 15%
Although this young voice is not equally balanced throughout the three vowels, there is evidence that she is beginning to use resonance techniques rather than extra breath to achieve a fuller tone. Her voice is developing well, and there is no rush to enforce balance. Gradual development should be the goal.				

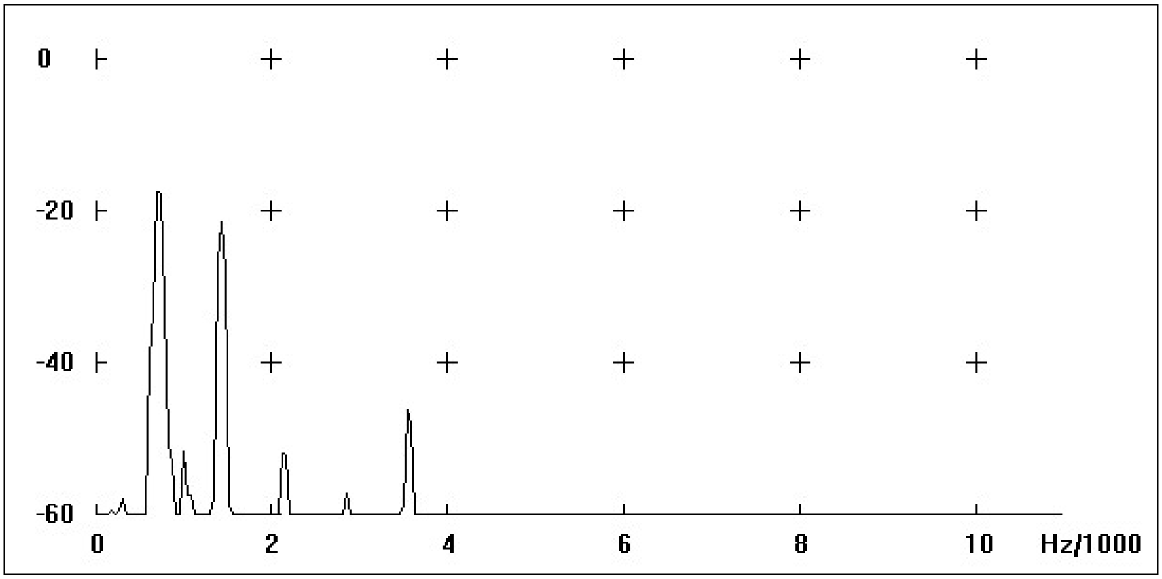
Power Spectrum from Spectrogram #10, Subject #1 at 5.15 seconds



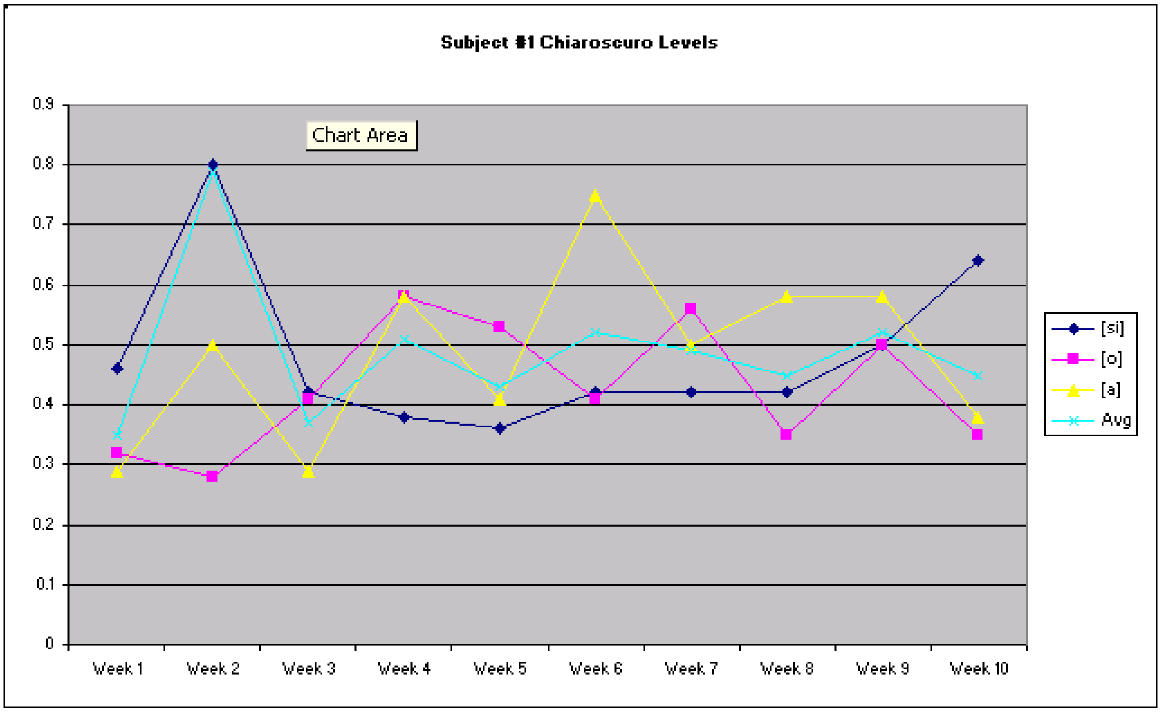
Power Spectrum from Spectrogram #10, Subject #1 at 6.52 seconds



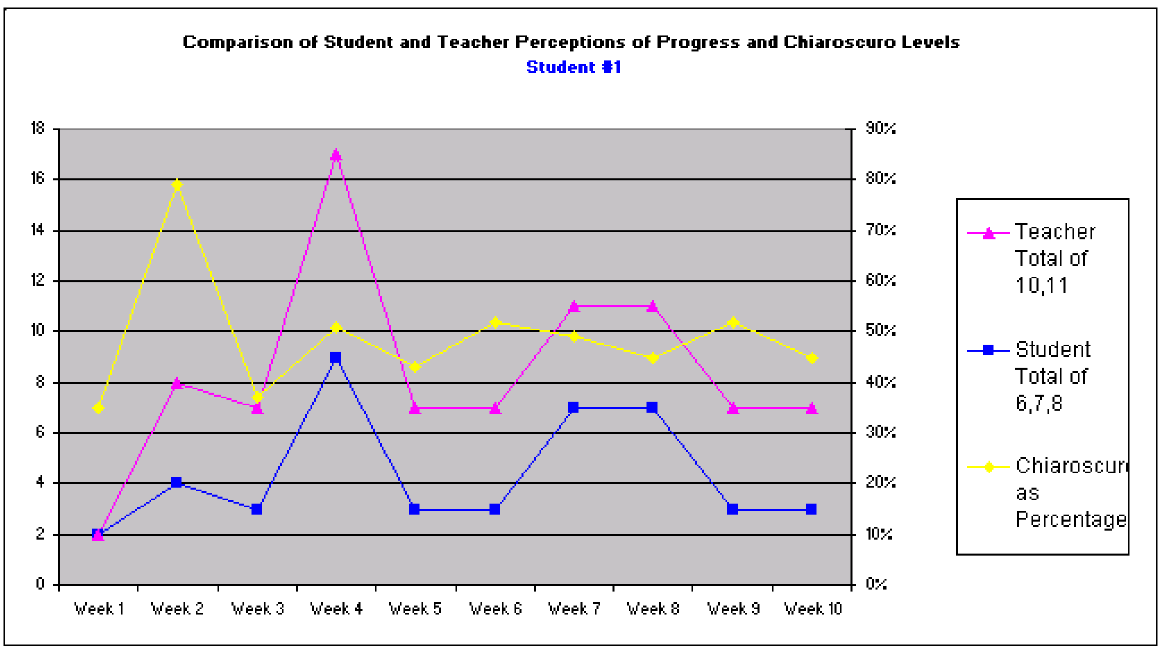
Power Spectrum from Spectrogram #10, Subject #1 at 8.54 seconds



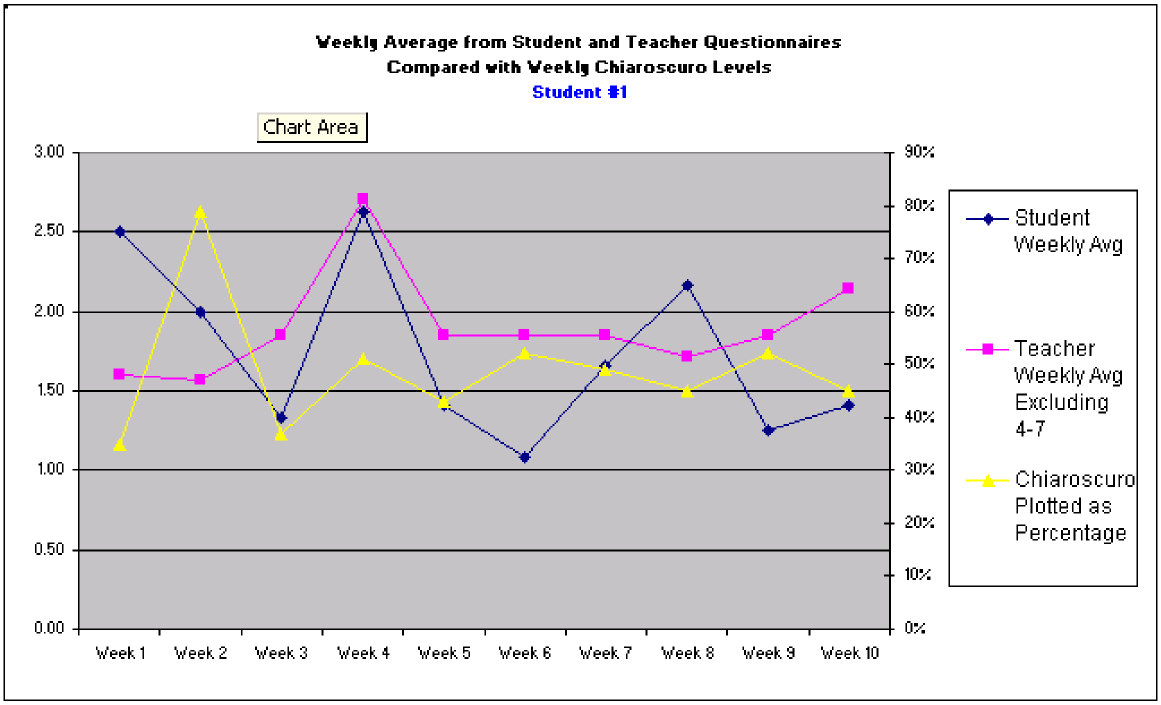
Analysis of Power Spectra from Spectrogram #10, Subject #1 - October 26, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.15	3	2	.66	5	8	.62	.64
6.52	4	2	.5	1	5	.2	.35
8.54	5	2	.4	3	8	.37	.38
Average of three chiaroscuro levels							.45



Subject #1 Chiaroscuro Levels
Chart Area
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg



Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Student #1
18
16
14
12
10
8
6
4
2
0
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Student #1
Chart Area
3.00
2.50
2.00
1.50
1.00
0.50
0.00
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A2: Subject #2

Subject #2 was an 18-year-old Caucasian freshman majoring in music education. She was from Conyers, Georgia. In her first semester Subject #2 had not yet decided whether to choose voice or piano as her major instrument, and she had difficulty learning all the music she was assigned in two majors. Finally she settled on piano. Aesthetic convictions made it difficult for her to accept the harsh sound heard by a singer who is producing a resonant sound. These difficulties delayed her acceptance of the spectrograph in her voice lessons.

Because freshmen in this program do not perform on the midterm or Broadway recitals, Subject #2's first performance, other than in voice major class, was in the end of semester student recital. Feedback from students in voice major class encouraged her to sing with a resonant sound, but she continued to resist the idea until very late in the semester. When she finally attempted to sing with a resonant sound, her tone quality and audibility improved, but she did not make the kind of progress throughout the semester that she might have.

Subject #2's vocal production was very small and child-like. Her voice was pretty, but lacked resonance and expression. Voice teachers rarely find it productive to force a student to accept a vocal ideal with which the student does not agree. Therefore, after several weeks of focusing on changing the student's sound, the issue was deemphasized. The subject was never completely dropped, however, and finally the student, on her own, began to consider the possibility of change. She did well enough on the end-of-semester recital, but was surpassed by nearly all the other freshmen.

The spectrograph was clearly a graphic representation of the lack of upper resonance in Subject #2's sound. Because she rejected the idea of producing a resonant sound, the information from the spectrograph was not useful in helping her improve. When she finally did accept the concept of producing a full sound, thanks to the encouragement of the other voice majors, she quickly became interested in seeing what she was doing.

Fall Semester 2000 Repertoire – Subject #2

Carissimi	Vittoria mio core
Parisotti	Se tu m'ami
Vacci	Exercise #7: Come il candare
Morley	It was a lover and his lass
Purcell	Let us dance and sing
Hundley	Bartholomew Green

Lesson record over the data collection period – Subject #2

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10 and 11
8/22	A	Assigned rep Parisotti	Good – had come by before classes began to ask about music and pick up her syllabus	Worked on basics of how the voice works – how the study is being conducted – syllabus – began Parisotti - basics of Italian diction – I don't think she's sung in foreign languages very much – quite intimidated by Italian	#1 D	Chiaroscuro - .53 Student n/a, n/a, 1 Teacher n/a, n/a
8/29	A	Parisotti, Hundley, Vaccai	On time – had worked	Taped Italian texts, worked musically on Vaccai – talked about resonant sound – It's a small, clear voice – very musical, but not very brave – astounded by resonance	#2 D	Chiaroscuro - .29 Student 1, n/a, 1 Teacher 2, 2
9/5	A	Parisotti, Carissimi	Good	Hard day: spent 20 minutes trying to get the stereo to tape her Italian – it didn't work last week either	#3 E flat	Chiaroscuro - .27 Student 1, 1, 1 Teacher 3,.3
	A	Carissimi	Good	Voice major class performance – Jennifer gave her the speech about having been the tiny voice last year – good for Jennifer!		
9/12	A	All rep with acc	Excellent	Made her an accompaniment tape – was able to talke about breathing – she catches on fast	#4 E flat	Chiaroscuro - .31 Student 1, 1, 1 Teacher 2, 2
9/19	B	Purcell, Parisotti, Hundley	Okay	She is not learning the music as quickly as I though she would. Trouble with rhythm in Purcell – took a long time to work out – unwilling to accept resonant sound	#5 E flat	Chiaroscuro - .35 Student 1, 1, 1 Teacher 3, 3
9/26				Lesson cancelled because of Tennessee trip		
9/29	B	Purcell, Parisotti	Better prep	Make up lesson – finally has Purcell rhythm – I am going to let up on resonance and try breath management. She gets a better sound, but still not colorful.	#6 E flat	Chiaroscuro - .33 Student 1, 1, 1 Teacher 3, 3
10/4	B	Hundley, Purcell	Better prep	Still having surprising musical difficulties – most of lesson was coaching – encouraged her to support – tried to talk a little resonance	#7 E flat	Chiaroscuro - .41 Student 1, 1, 1 Teacher 2, 2
10/10	A	Everything except Morley	Good	Breakthrough day! Asking her to imitate caricature of opera singer led to a focused sound. She has an opera singer aunt who's sound she hates and wants to avoid at all costs – source of difficulty	#8 E flat	Chiaroscuro - .27 Student 1, 1, 1 Teacher 3, 3
10/17	B	Everything except Morley	Good	Make up lesson – doesn't feel good – voice weaker than usual	#9 E flat	Chiaroscuro - .31 Student 1, 1, 1 Teacher 4, 4
10/24	B	Purcell, Parisotti, Hundley	Okay	She is doing okay, but taking a long time to learn her music, longer than I expected. I wonder how well she practices?	#10 E flat	Chiaroscuro - .27 Student 1, 1, 1 Teacher 2, 2
10/31				Lesson rescheduled – Career Day		
11/7	B	Parisotti, Hundley, Carissimi	Okay	Slow progress musically and vocally – still does not accept the professional sound		
11/14	B	Morley, Parisotti, Vaccau, Purcell	Okay	Still struggling musically – still uncommitted vocally – not uncooperative, just not progressing		

11/19	B	Parisotti	Good	Student Recital		
11/21				Lesson rescheduled so she could get home		
11/28	B	All rep with acc	Good	She is a sweet girl, and I'll miss her next semester, but I won't have work as hard with another student. She is very hard to teach.		
12/1	B	Jury	Good	She did fine. Not stellar, but okay.		

Responses to student questionnaires – Subject #2

Question	8/22	8/29	9/5	9/12	9/19	9/29	10/4	10/10	10/17	10/24	
1	1	1	2	1	1	1	1	1	2	1	**Total of weekly answers to questions 6, 7, 8**
2	2	1	2	1	1	1	1	1	2	2	
3	1	1	2	2	1	1	1	1	2	2	
4	1	1	1	1	1	1	1	1	1	1	
5	1	1	1	1	1	1	1	1	1	1	
6	N/a	1	1	1	1	1	1	1	1	1	**1**
7	N/a	N/a	1	1	1	1	1	1	1	1	**1**
8	1	1	1	1	1	1	1	1	1	1	**1**
9	1	1	1	1	1	1	1	1	1	1	**Average over ten week period**
10	1	1	1	1	1	1	1	1	1	1	
11	1	2	1	1	1	1	1	1	2	2	
12	1	2	1	1	1	1	1	1	1	1	
Weekly Average	1.1	1.18	1.25	1.08	1	1	1	1	1.33	1.25	**1**

Responses to teacher questionnaires – Subject #2

Quantification of the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)

2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)

3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)

4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)

5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

Question	8/22	8/29	9/5	9/12	9/19	9/29	10/4	10/10	10/17	10/24	
1	2	2	2	2	2	2	2	2	2	2	**Totals and Average of Questions 10 & 11**
2	2	2	3	2	3	3	3	2	3	2	
3	2	2	2	2	2	2	2	2	2	2	
4	1	2	2	1	1	3	2	3	3	3	
5	5	5	5	5	3	5	5	5	5	5	
6	3	3	3	3	5	5	4	5	3	3	
7	5	5	5	5	5	5	5	5	5	5	
8	2	1	3	2	3	3	2	3	2	2	
9	1	2	2	2	2	2	2	3	4	2	
10	N/a	2	3	2	3	3	2	3	4	2	**2.66**
11	N/a	2	3	2	3	3	2	3	4	2	**2.66**
Weekly Average excluding questions 4-7	1.8	1.85	2.57	2	2.57	2.57	2.14	2.57	3	2	**2.66**

Student's Written Reaction to Use of Spectrograph – Subject #2

I thought that the spectrograph was extremely interesting. At first, I thought that it wasn't going to be very beneficial to me. However, as my voice lessons went on, I began to learn from watching the spectrograph. I began to see how the resonant sounds work and how I could modify my vowels to produce different sounds.

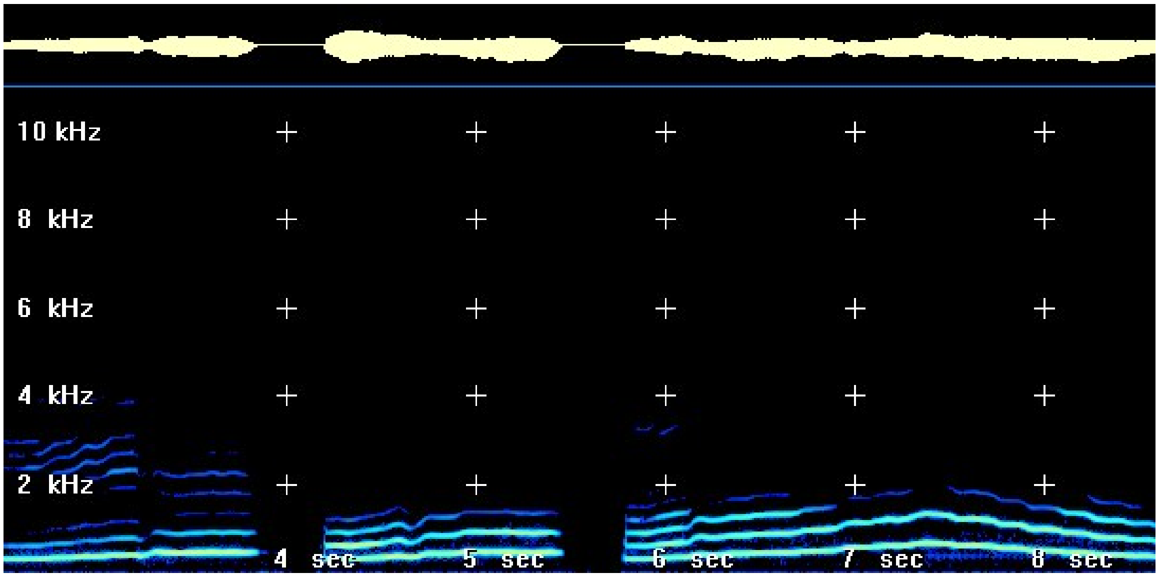
When I first started working with Mrs. Callaway, my voice was extremely soft and I was not producing a very big sound at all. But, as I became more familiar with the spectrograph, I learned that I could use the resonant sounds to my advantage. I began to modify my vowels and sure enough, I had a much larger sound. It didn't take any more effort on my part; all I had to do was learn to change my vowels.

Another thing that I learned from the spectrograph was that the resonant sounds and modified vowels didn't always sound good to me. What Mrs. Callaway pointed out was that it didn't matter what I had to listen to in my head. All that mattered was what the audience was hearing. And what they were hearing was a nice, rich sound. The spectrograph helped me realize that by showing the level of resonance that I was producing. So when I didn't believe that the sound I was producing was a nice sound, Mrs. Callaway would just point to the spectrograph. And, sure, enough, the lines were indicating a resonant sound.

I think that the spectrograph was extremely helpful and beneficial. I know that it would have been much harder to learn how to make a more resonant sound if I had not had the spectrograph. And, I can definitely tell a difference in my voice since the beginning of the semester. I am now producing a much bigger and much nicer sound.

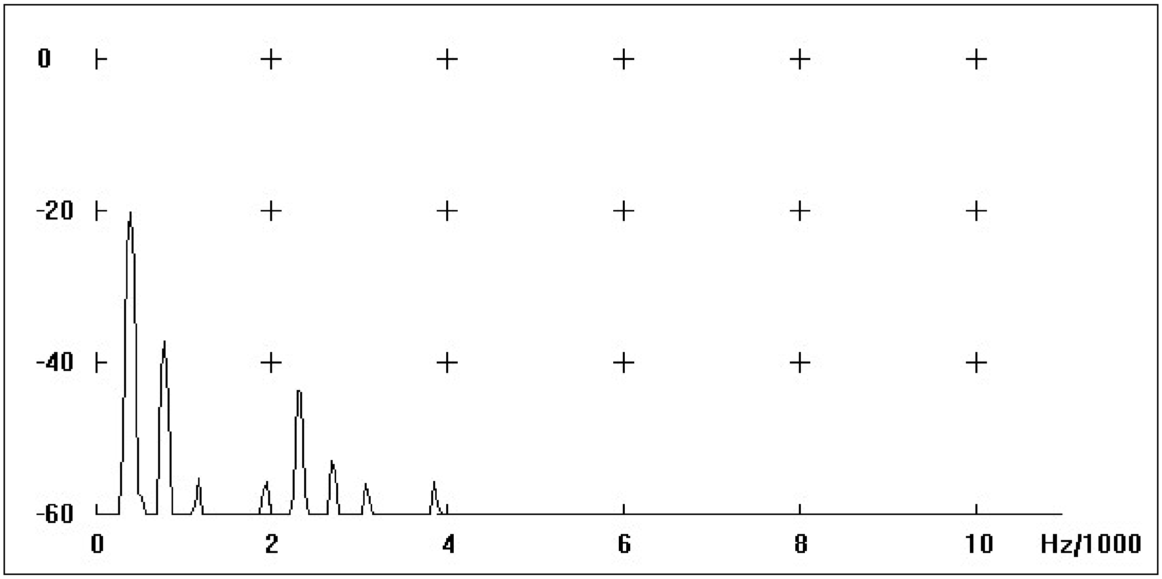
Analysis of Wave Files

Wave File Number 1 – August 22, 2000 – Subject #2

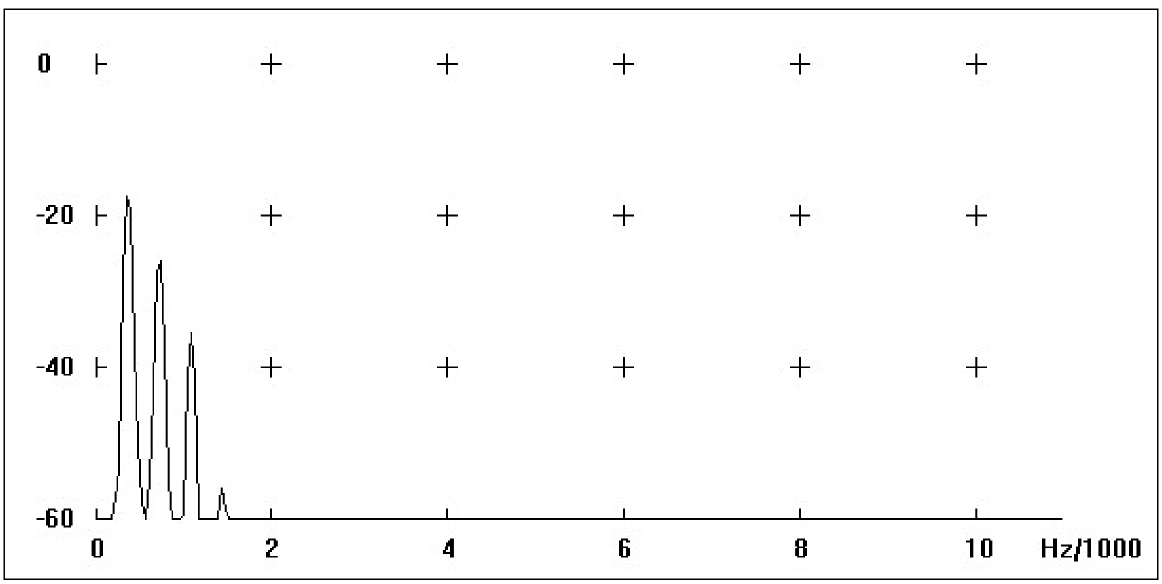


Subject #2 – Analysis of Wave File #1 – August 22, 2000 – D major				
		[si] (2.52-3.8 sec)	[o] (4.2-5.43 sec)	[a] (5.79-9.64 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Vowel is producing some indications		Slight indication at beginning of vowel
2nd Formant Area (Vowel Definition)		Break in vowel at 3.2 shows audible change in vowel	Less distinct break visible at 4.6 is also audible change in vowel – note noisy beginning of vowel, nearly a glottal	Fairly clear vowel, but another noisy, nearly glottal attack
1st Formant Area		Not strong	Not strong	Not strong
Chiaroscuro Balance		Weakness in upper frequencies balanced by weakness in lower frequencies	Weakness in upper frequencies balanced by weakness in lower frequencies	Weakness in upper frequencies balanced by weakness in lower frequencies
Power Spectrum		Increase from about 10% to about 20%	Noisy opening at about 40% decreases to about 20% then increases to about 30%	Relatively even varying from 10% to 30%
Young voice that is unfocused and unsupported shows several variances in vowel that seem to be accidental. Very little that is purposeful in this voice production.				

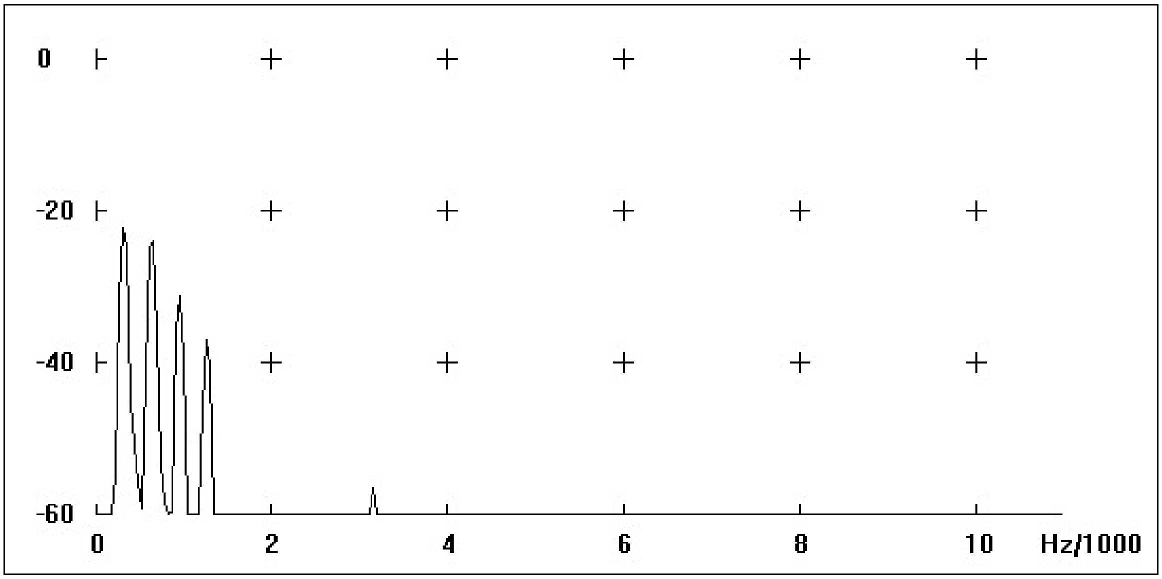
Power Spectrum from Spectrogram #1, Subject #2 at 3.15 seconds [i]



Power Spectrum from Spectrogram #1, Subject #2 at 4.58 seconds [o]

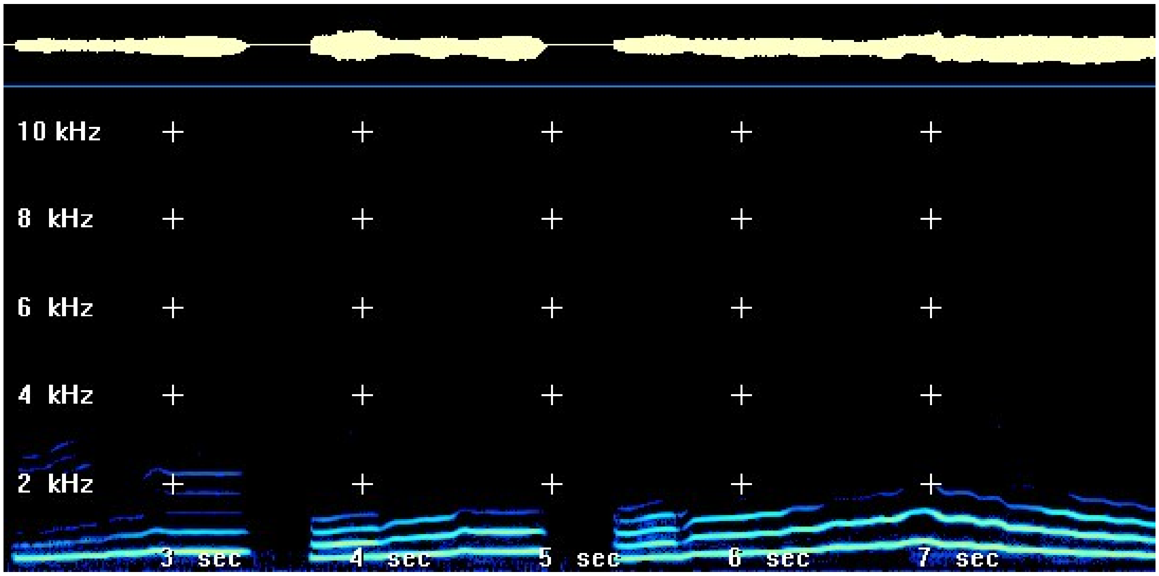


Power Spectrum from Spectrogram #1, Subject #2 at 5.99 seconds [a]



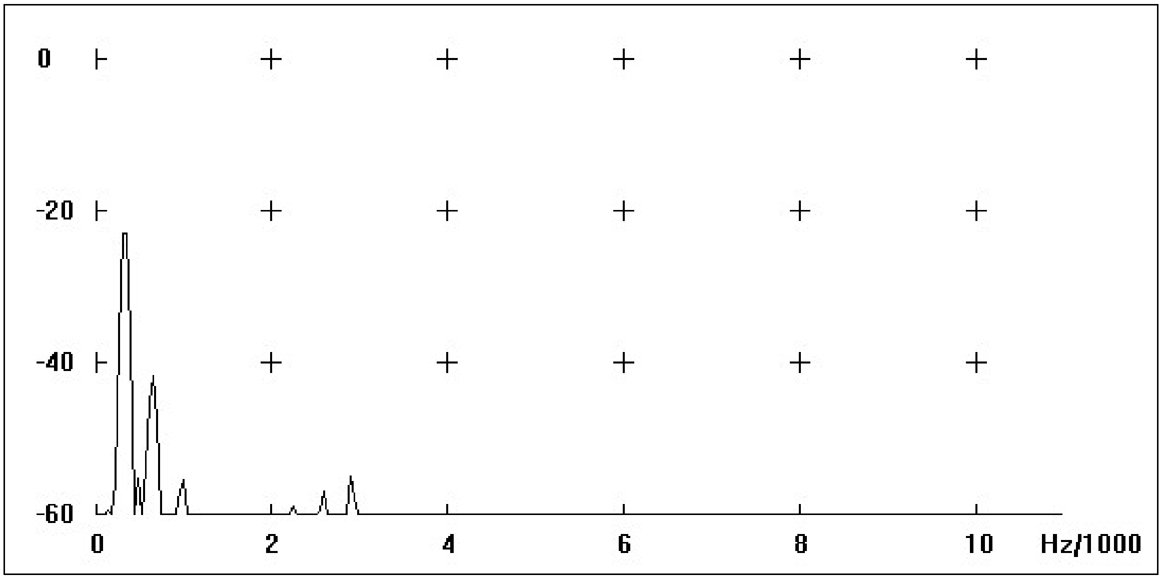
Analysis of Power Spectra from Spectrogram #1, Subject #2 – August 22, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.15	3	2	.66	5	8	.62	.64
4.58	4	3	.75	0	4	0	.37
5.99	4	4	1	1	5	.2	.6
Average of three chiaroscuro levels							.53

Wave File Number 2 – August 29, 2000 – Subject #2

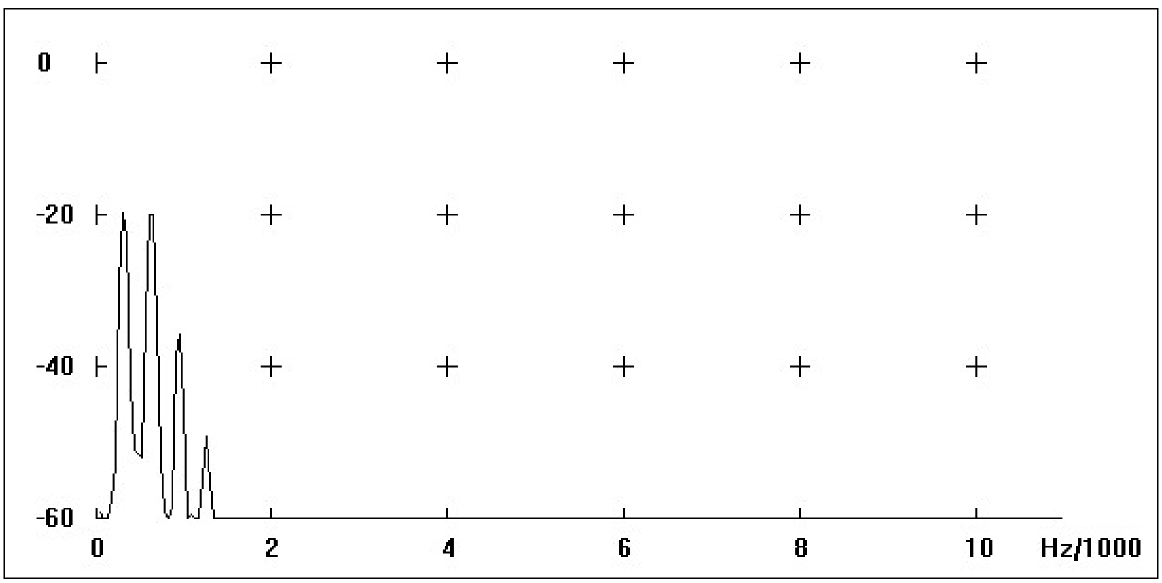


<table>
<tr><td colspan="5">Subject #2 – Analysis of Wave File #2 – August 29, 2000 – D major</td></tr>
<tr><td colspan="2"></td><td>[si] (2.2-3.4 sec)</td><td>[o] (3.7-5 sec)</td><td>[a] (5.3-9 sec)</td></tr>
<tr><td rowspan="2">Singer’s Formant Area</td><td>4000+ Hz</td><td></td><td></td><td></td></tr>
<tr><td>2000-4000 Hz</td><td>Vowel is producing some indications</td><td></td><td></td></tr>
<tr><td colspan="2">2nd Formant Area (Vowel Definition)</td><td>Weak vowel definition– break at (2.75 sec) at audible vowel change</td><td>Weak vowel definition - slight break at 4.2 – audible vowel change with aspirant</td><td>Weak vowel definition - break at 5.8 – audible vowel change with aspirant</td></tr>
<tr><td colspan="2">1st Formant Area</td><td>Not strong</td><td>Not strong</td><td>Not strong</td></tr>
<tr><td colspan="2">Chiaroscuro Balance</td><td>Weakness in upper frequencies balanced by weakness in lower frequencies</td><td>Weakness in upper frequencies balanced by weakness in lower frequencies</td><td>Weakness in upper frequencies balanced by weakness in lower frequencies</td></tr>
<tr><td colspan="2">Power Spectrum</td><td>Increase from about 10% to about 20%</td><td>Varying around 25%</td><td>Varying around 30%</td></tr>
<tr><td colspan="5">Young voice that is unfocused and unsupported shows several variances in vowel that seem to be accidental. The breaks are much like a small yodel with an aspirated sound.</td></tr>
</table>

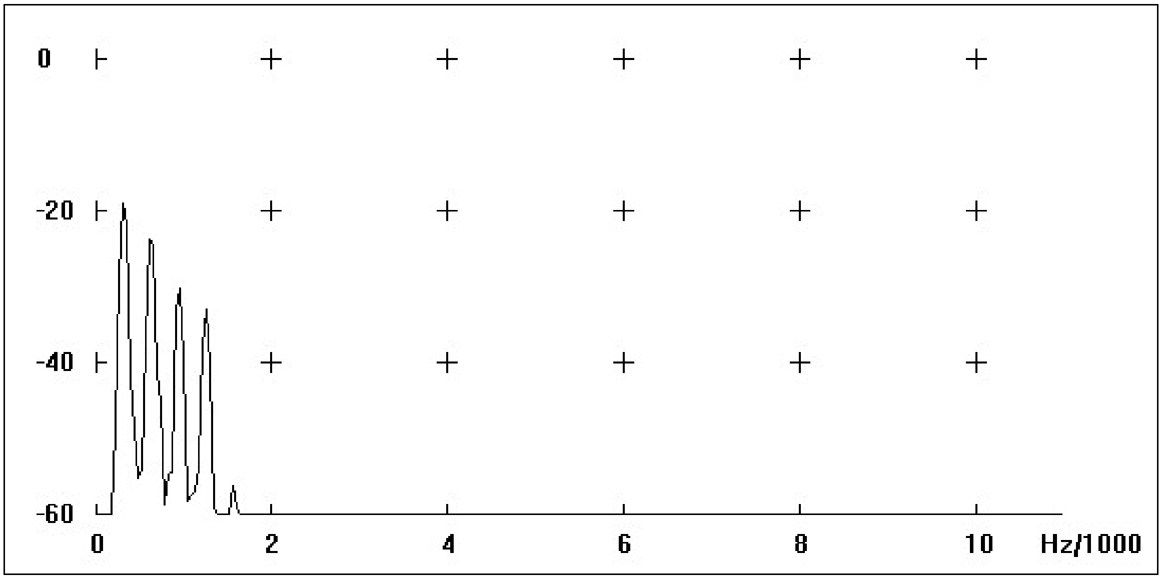
Power Spectrum from Spectrogram #2, Subject #2 at 2.44 seconds [i]



Power Spectrum from Spectrogram #2, Subject #2 at 3.93 seconds [o]

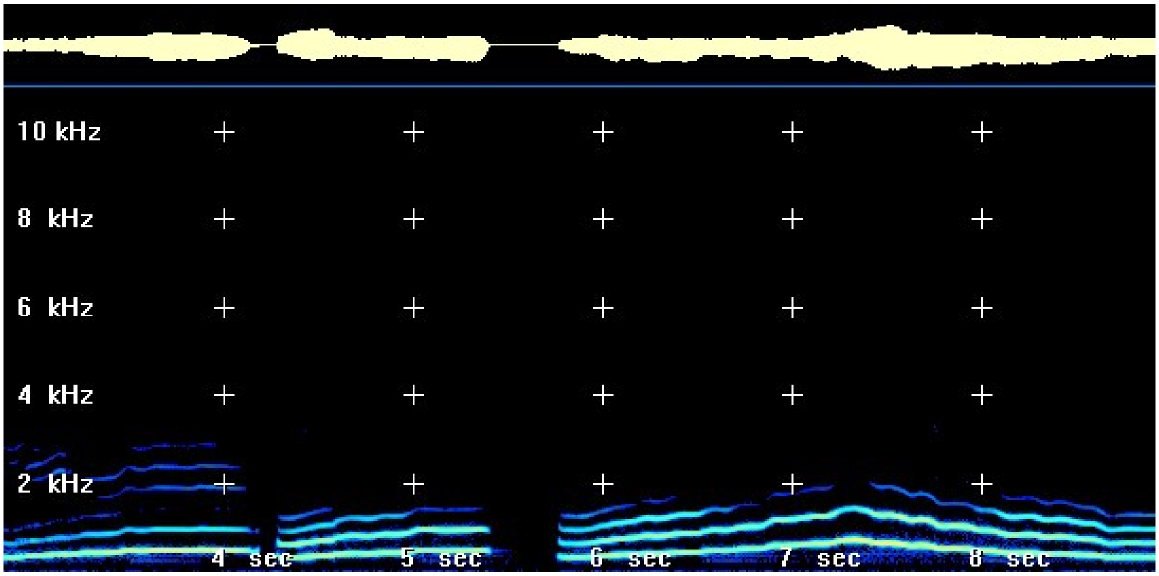


Power Spectrum from Spectrogram #2, Subject #2 at 5.55 seconds [a]



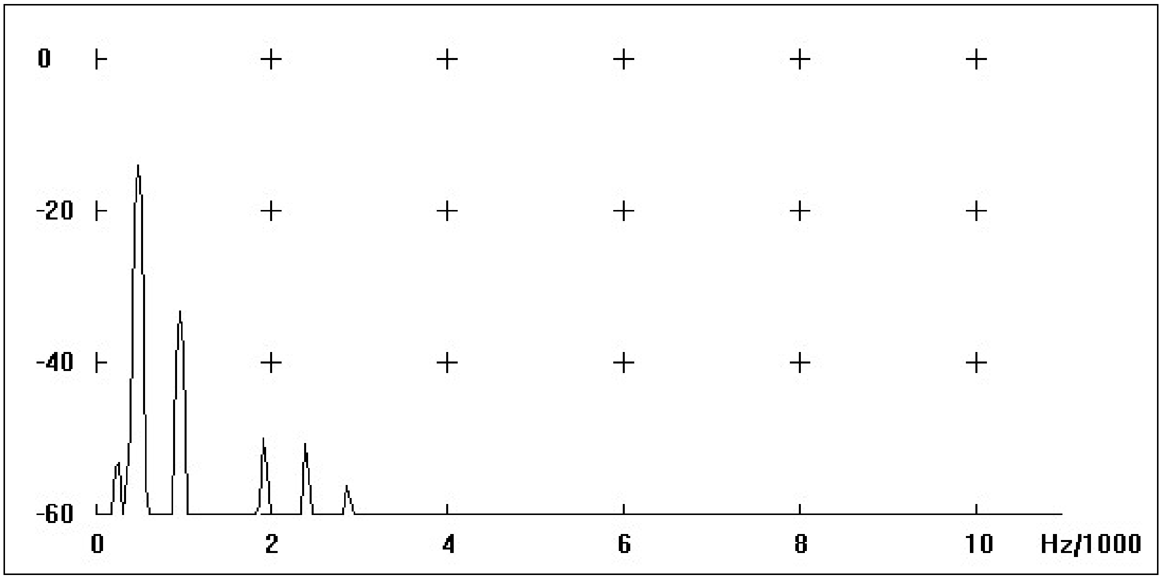
Analysis of Power Spectra from Spectrogram #2, Subject #2 – August 29, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.44	4	1	,25	1	5	.2	.22
3.93	4	2	.5	0	4	0	.25
5.55	5	4	,8	0	5	0	.4
Average of three chiaroscuro levels							.29

Wave File Number 3 – September 6, 2000 – Subject #2

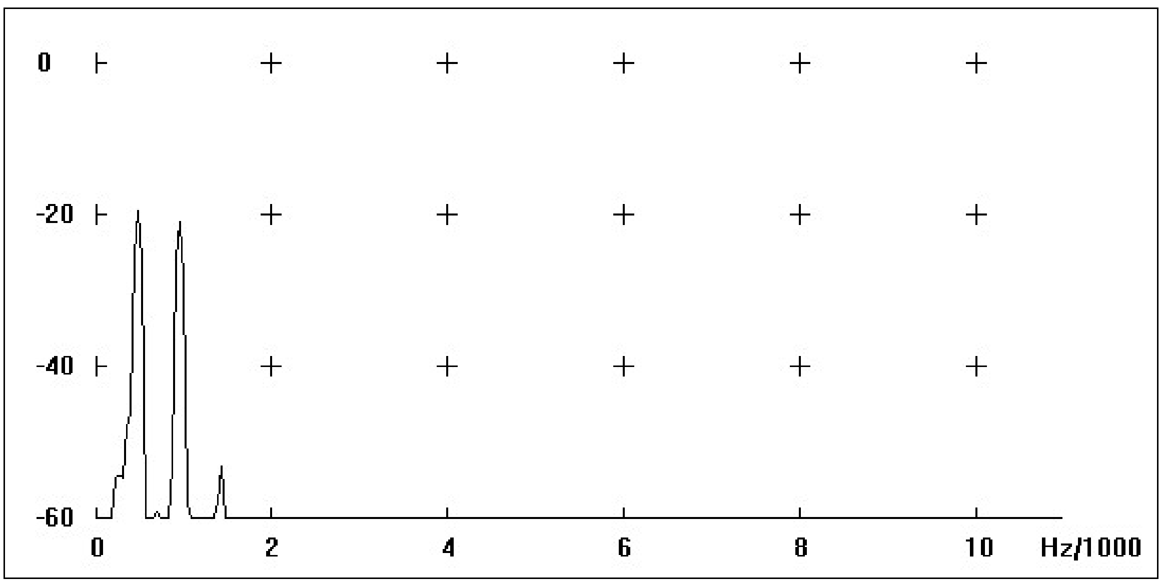


<table>
<tr><td colspan="5">Subject #2 – Analysis of Wave File #3 – September 5, 2000 – E flat major</td></tr>
<tr><td colspan="2"></td><td>[si] (2.83-4.1 sec)</td><td>[o] (4.28-5.4 sec)</td><td>[a] (5.78-9.3 sec)</td></tr>
<tr><td rowspan="2">Singer's Formant Area</td><td>4000+ Hz</td><td></td><td></td><td></td></tr>
<tr><td>2000-4000 Hz</td><td>Vowel is producing some indications</td><td></td><td></td></tr>
<tr><td colspan="2">2nd Formant Area (Vowel Definition)</td><td>Weak vowel definition – less break than in #2</td><td>Weak vowel definition – less break than in #2 though still audible and visible at 4.5</td><td>Weak vowel definition – less break than in #2</td></tr>
<tr><td colspan="2">1st Formant Area</td><td>Not strong</td><td>Not strong</td><td>Not strong – some increase at higher pitches</td></tr>
<tr><td colspan="2">Chiaroscuro Balance</td><td>Somewhat balanced</td><td>Weighted toward lower frequencies</td><td>Weighted toward lower frequencies</td></tr>
<tr><td colspan="2">Power Spectrum</td><td>Increase from about 10% to about 30%</td><td>Varying around 30%</td><td>Varying around 25% with increase to about 50% at higher pitches</td></tr>
<tr><td colspan="5">The key change made to facilitate entry into upper frequencies did not have that effect. Wave file #3 is very similar to wave file #2. Little progress.</td></tr>
</table>

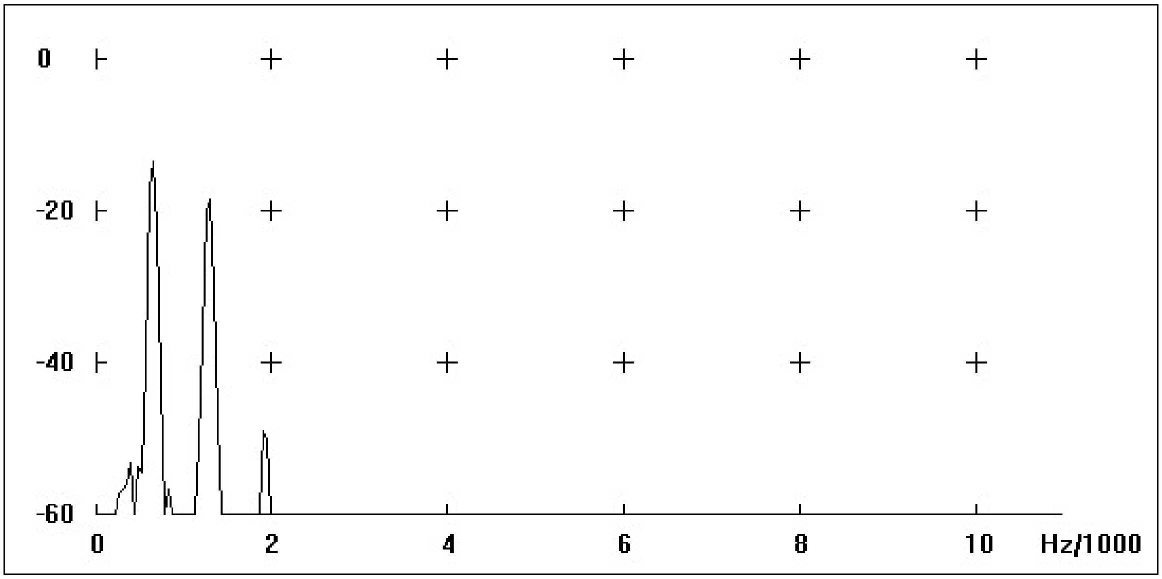
Power Spectrum from Spectrogram #3, Subject #2 at 3.65 seconds [i]



Power Spectrum from Spectrogram #3, Subject #2 at 5.06 seconds [o]

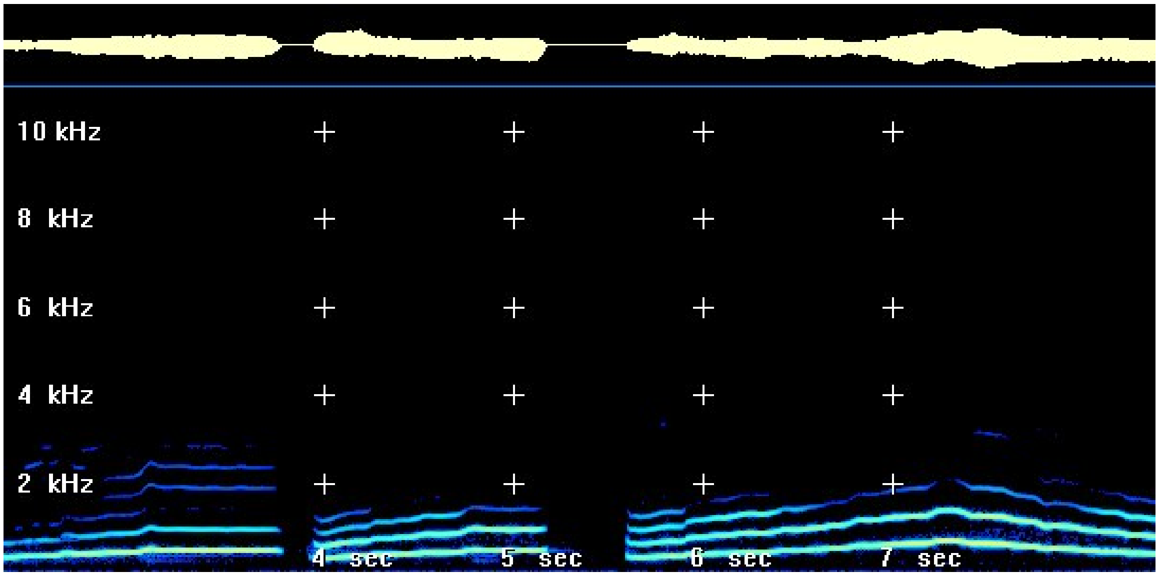


Power Spectrum from Spectrogram #3, Subject #2 at 7.47 seconds [a]



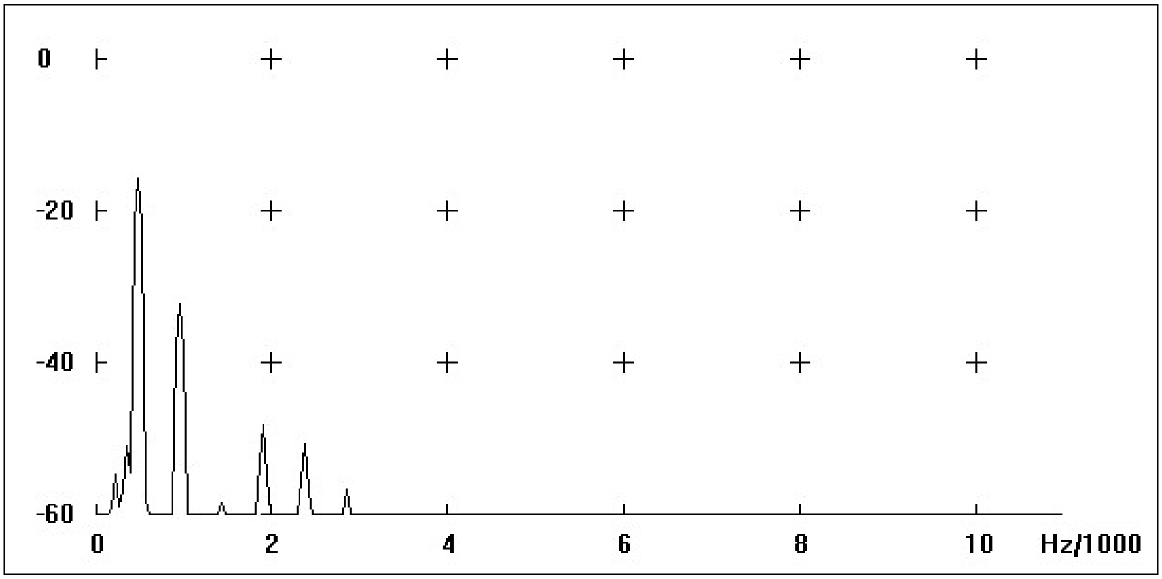
Analysis of Power Spectra from Spectrogram #3, Subject #2 – September 5, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.65	4	2	.5	2	6	.33	.41
5.06	5	2	.4	0	5	0	.2
7.47	5	2	.4	0	5	0	.2
Average of three chiaroscuro levels							.27

Wave File Number 4 – September 12, 2000 – Subject #2

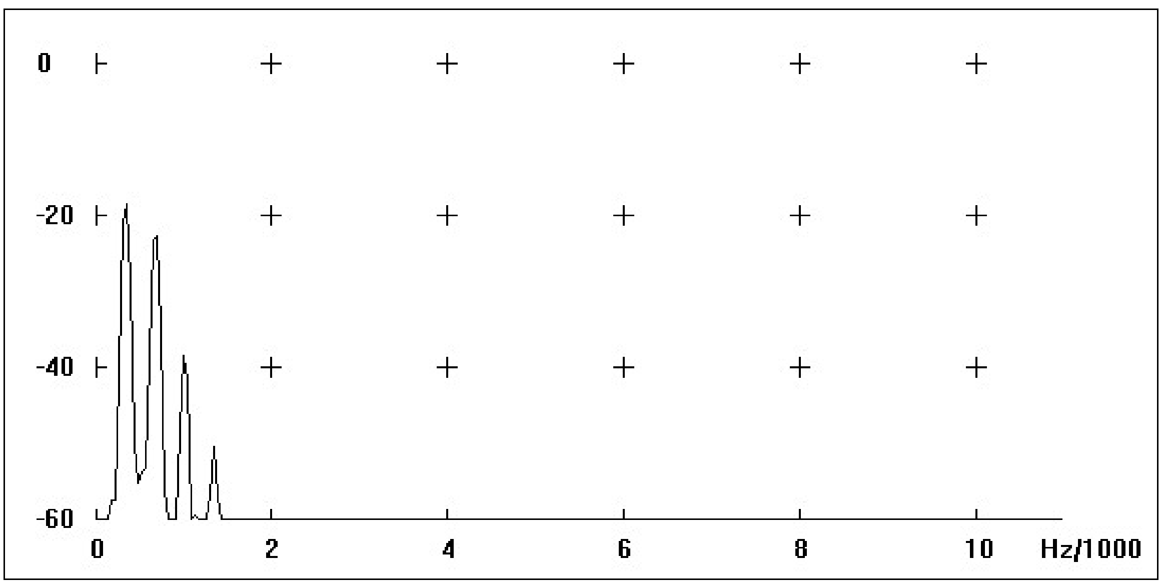


Subject #2 – Analysis of Wave File #4 – September 12, 2000 – E flat major				
		[si] (2.26-3.77 sec)	[o] (3.9-5.18 sec)	[a] (5.6-9.5 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Somewhat more consistent than heretofore, shows effort by singer		Slight indications at beginning of vowel and at highest pitches
2nd Formant Area (Vowel Definition)		Continues to show breaks caused by inserting aspirants as she changes pitches (2.6)	Breaks at 4.3 and 4.7 are clearly audible – note the loss of an upper frequency at 4.3	Similar loss of upper frequency at 5.95
1st Formant Area		Some strengthening – power spectrum shows increase from to decibels	Some strengthening – power spectrum shows increase from to decibels	Some strengthening – power spectrum shows increase from to decibels
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 10% to about 25%	Varying around 20%	Varying around 20% with increase at high pitches to about 40%
Singer is trying to add some upper frequencies, but is not convinced enough to change her tonal ideal. Changing the sound to please the teacher is not a successful plan. The singer's tonal ideal must also change.				

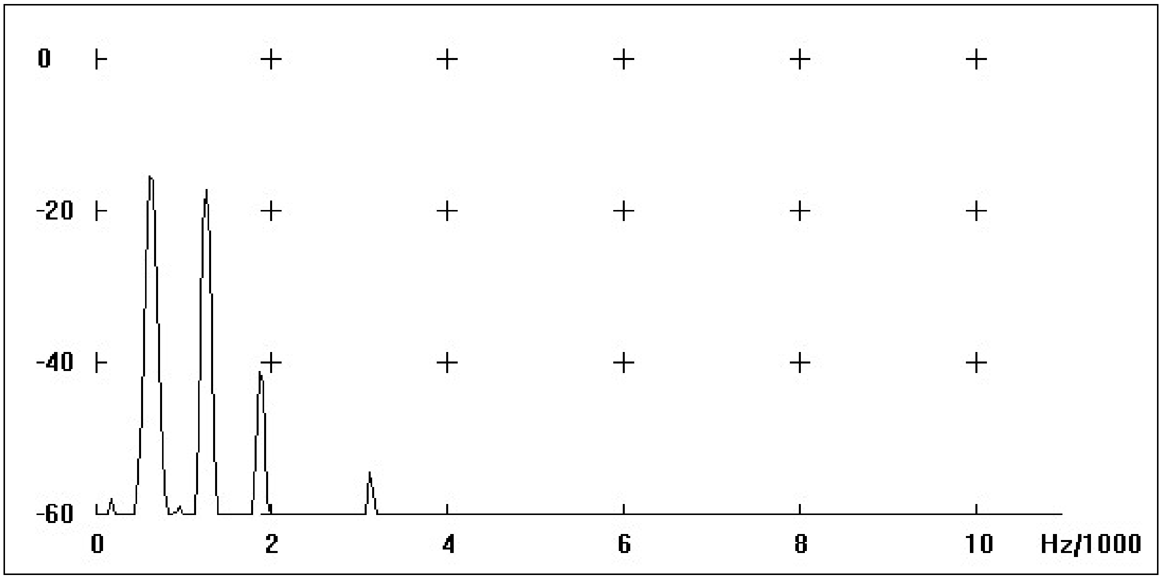
Power Spectrum from Spectrogram #4, Subject #2 at 3.3 seconds [i]



Power Spectrum from Spectrogram #4, Subject #2 at 4.17 seconds [o]

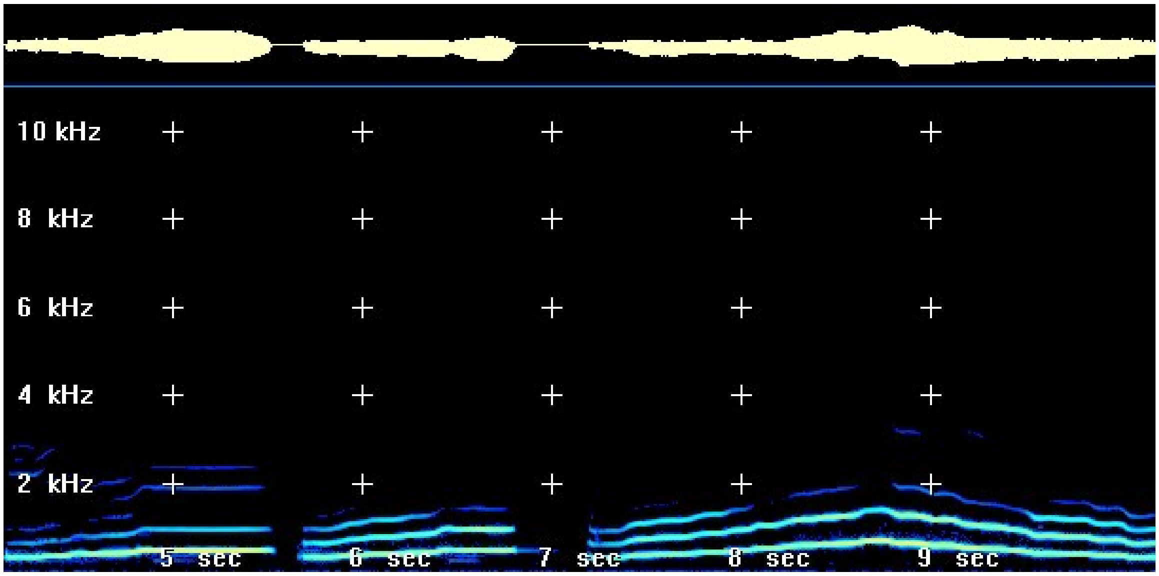


Power Spectrum from Spectrogram #4, Subject #2 at 7.54 seconds [a]



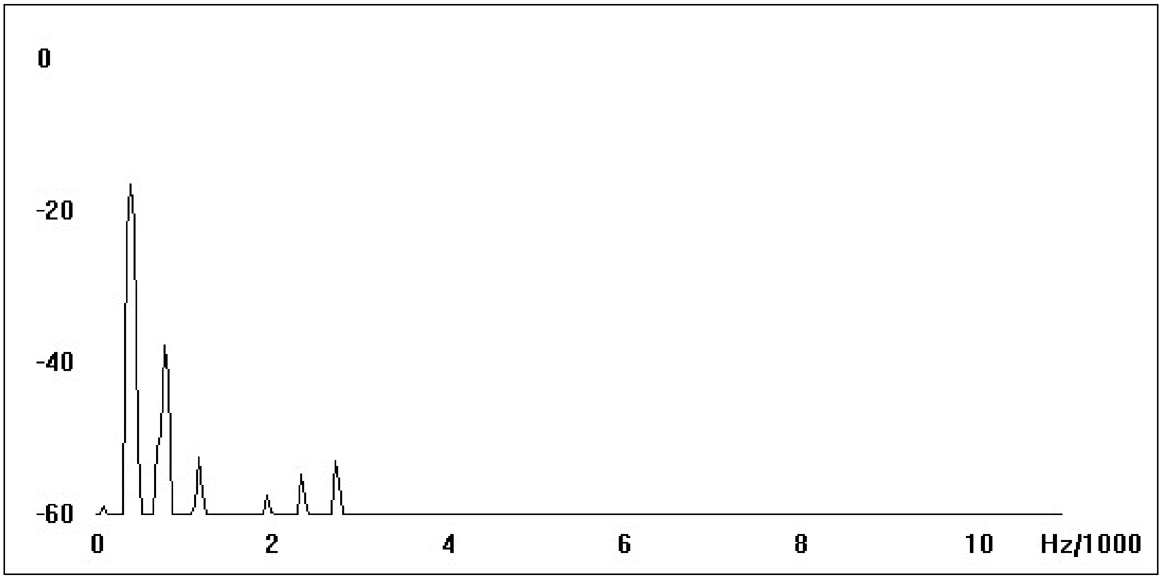
Analysis of Power Spectra from Spectrogram #4, Subject #2 – September 12, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.3	6	2	.33	2	8	.25	.29
4.17	4	3	.75	0	4	0	.37
7.54	5	2	.4	1	6	.16	.28
Average of three chiaroscuro levels							.31

Wave File Number 5 – September 19, 2000 – Subject #2

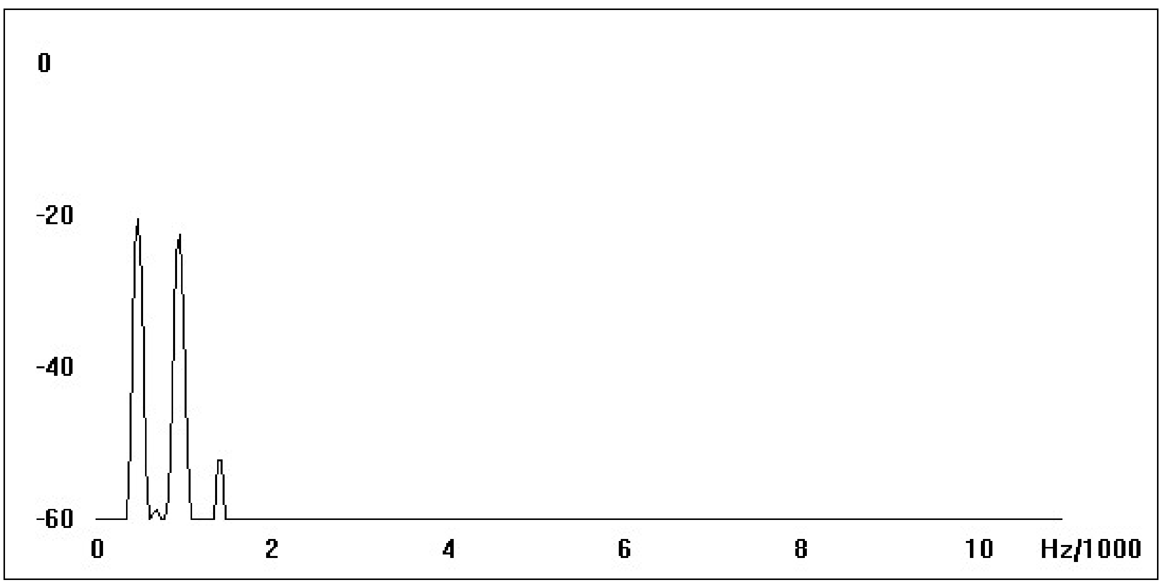


Subject #2 – Analysis of Wave File #5 – September 19, 2000 – E flat major				
		[si] (4.0-5.3 sec)	[o] (5.5-6.79sec)	[a] (7.18-10.8 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Slight indications from vowel		Two scattered indications
2nd Formant Area (Vowel Definition)		No visible or audible aspirated breaks	No visible or audible aspirated breaks	No visible or audible aspirated breaks
1st Formant Area		Some strengthening at end of vowel	Some strengthening at end of vowel	Slight strengthening at highest pitches
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increasing from about 10% to about 40%	Varying around 20%	Varying around 20% except for increase to about 40% at highest pitches
There is improvement since the singer is not breaking up her line with aspirated vowel changes, and there is some strengthening in the first formant area, but lack of upper frequencies continue to keep the power spectra low.				

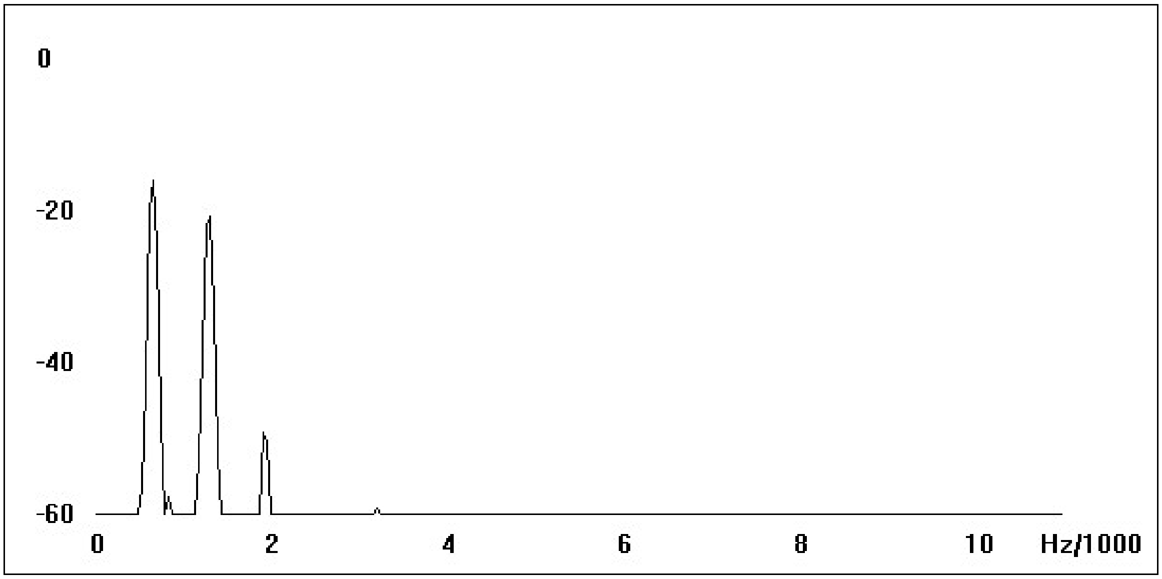
Power Spectrum from Spectrogram #5, Subject #2 at 4.35 seconds [i]



Power Spectrum from Spectrogram #5, Subject #2 at 6.58 seconds [o]

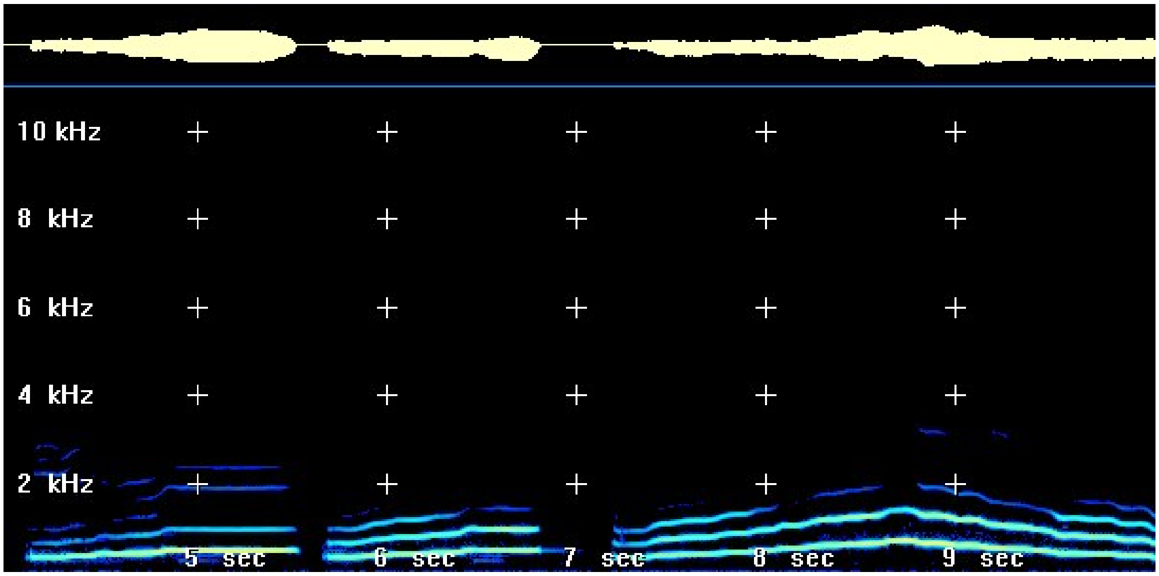


Power Spectrum from Spectrogram #5, Subject #2 at 9.0 seconds [a]



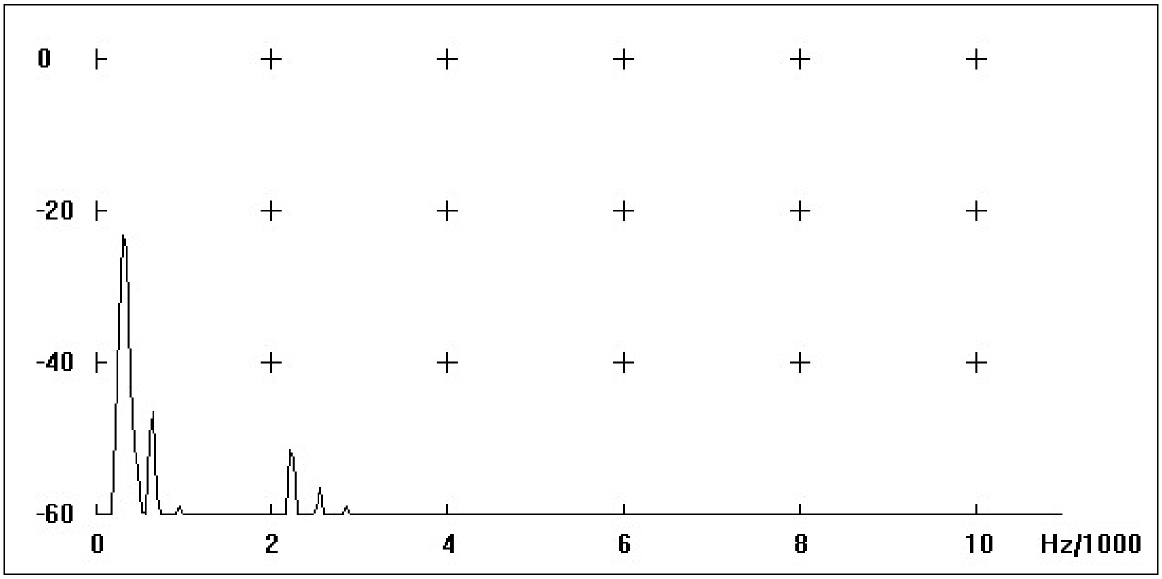
Analysis of Power Spectra from Spectrogram #5, Subject #2 – September 19, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.35	4	2	.5	3	7	.42	.46
6.58	4	2	.5	0	4	0	.25
9.0	4	2	.5	1	5	.2	.35
Average of three chiaroscuro levels							.35

Wave File Number 6 – September 29 – Subject #2

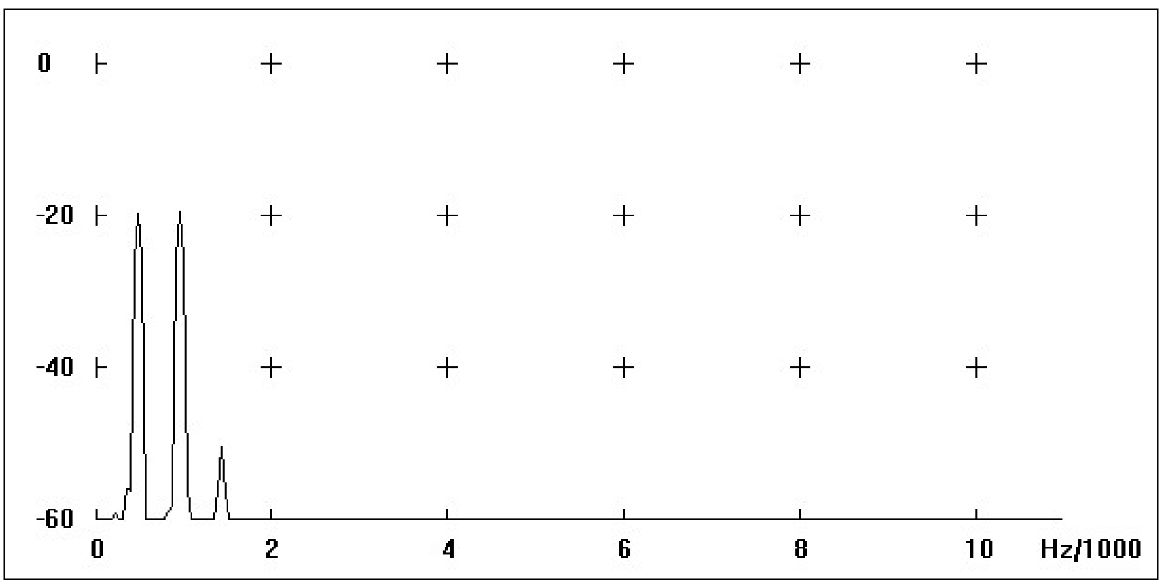


Subject #2 – Analysis of Wave File #6 – September 29, 2000 – E flat major				
		[si] (4.12-5.5 sec)	[o] (5.68-6.8 sec)	[a] (7.25-10.7 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Slight indications from vowel, mostly at beginning – vowel changes to less resonant sound almost immediately		Two slight indications at highest pitches
2^{nd} Formant Area (Vowel Definition)		Vowel definition still weak, but breaks seem to be gone	Vowel definition still weak, but breaks seem to be gone	Vowel definition still weak, but breaks seem to be gone
1^{st} Formant Area		Some strengthening at higher pitches	Some strengthening at higher pitches	Some strengthening at higher pitches
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 10% to about 40%	Varying around 20%	Varying around 20% except for increase to about 40% at highest pitches
Wave file #6 is almost identical to wave file #5. Not much progress.				

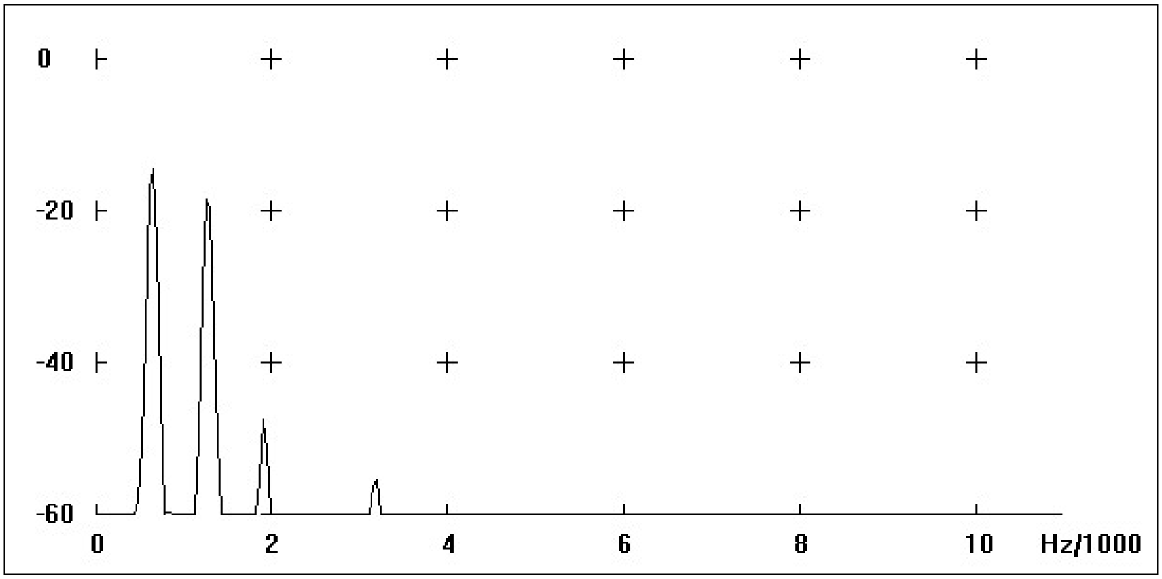
Power Spectrum from Spectrogram #6, Subject #2 at 4.19 seconds [i]



Power Spectrum from Spectrogram #6, Subject #2 at 6.64 seconds [o]

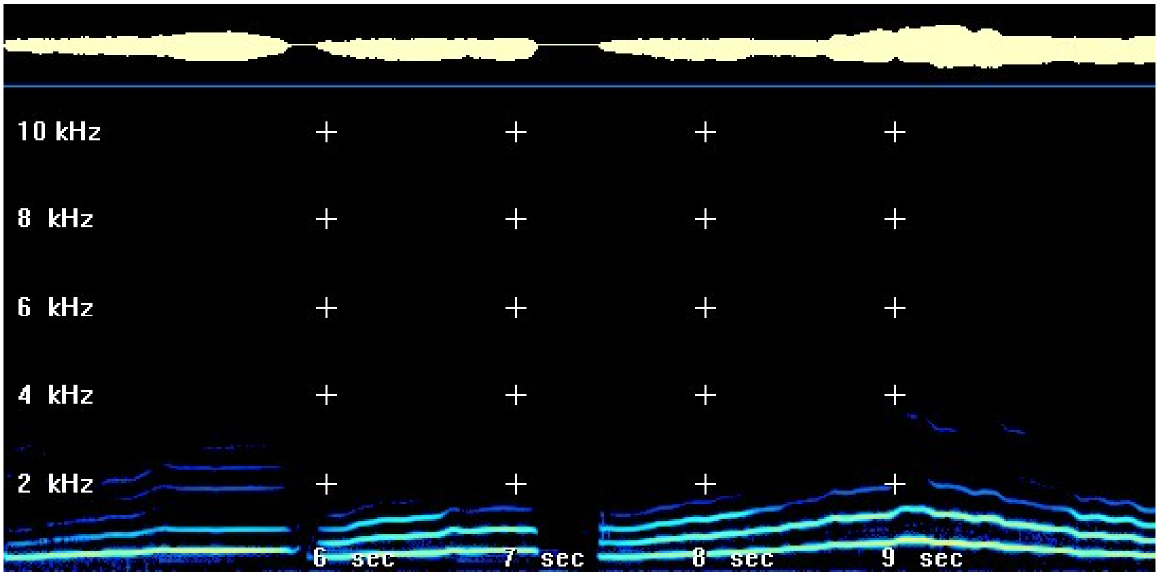


Power Spectrum from Spectrogram #6, Subject #2 at 8.88 seconds [a]



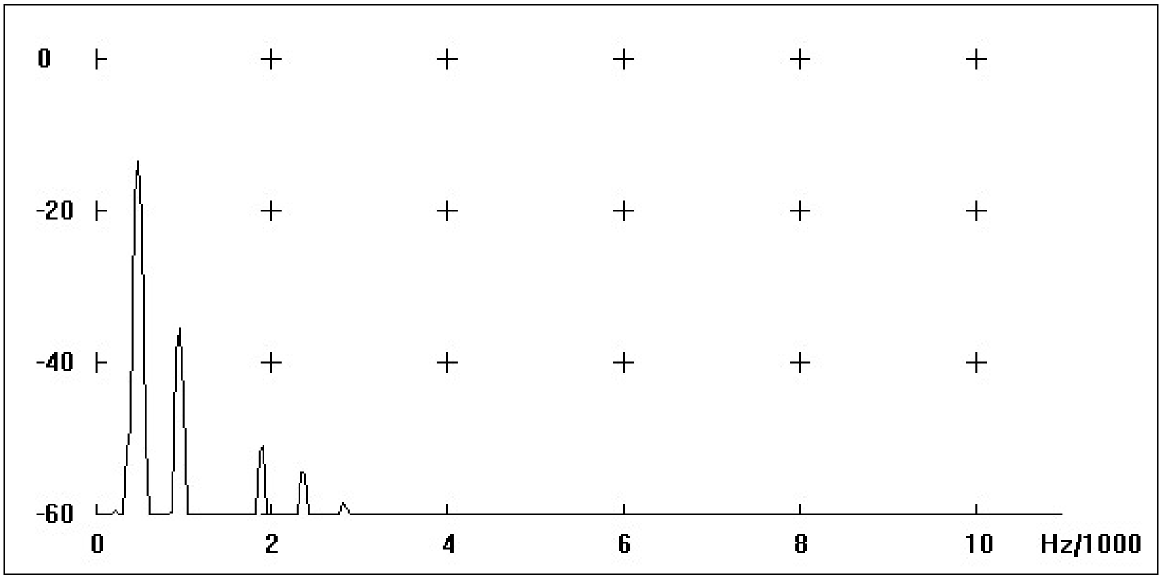
Analysis of Power Spectra from Spectrogram #6, Subject #2 – September 29, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.48	3	1	.33	1	4	.25	.29
6.69	4	2	.5	0	4	0	.25
8.88	3	2	.66	1	4	.25	.45
Average of three chiaroscuro levels							.33

Wave File Number 7 – October 4, 2000 – Subject #2

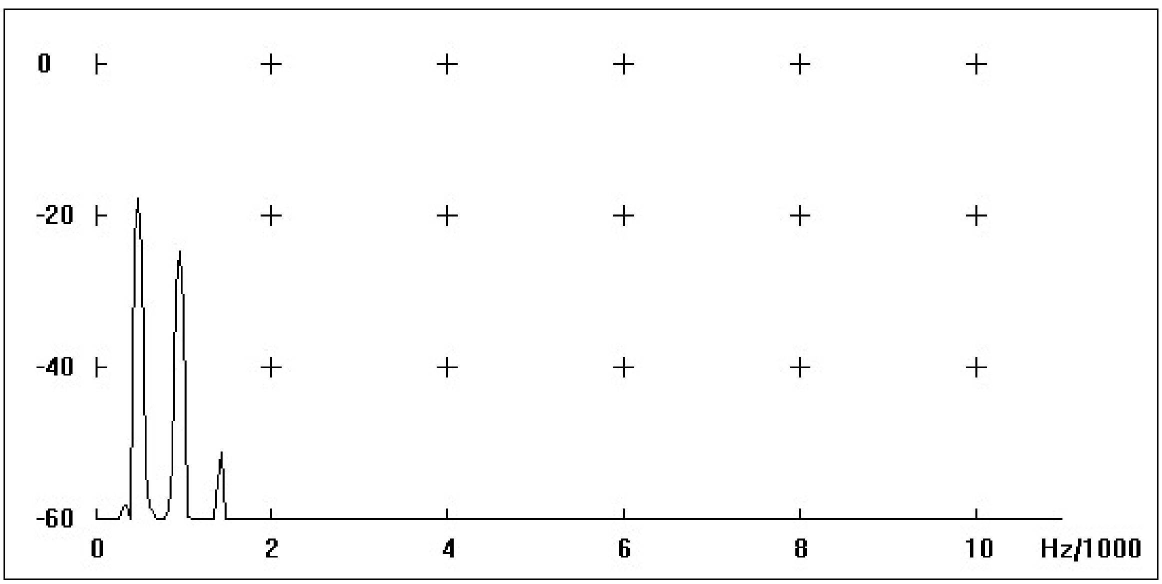


Subject #2 – Analysis of Wave File #7 – October 4, 2000 – E flat major				
		[si] (4.33-5.8 sec)	[o] (6-7.13 sec)	[a] (7.5-11.2 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Slight indications from vowel		Three scattered indications
2nd Formant Area (Vowel Definition)		No visible or audible aspirated breaks	No visible or audible aspirated breaks	No visible or audible aspirated breaks
1st Formant Area		Some strengthening at end of vowel	Some strengthening at end of vowel	Slight strengthening at highest pitches
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increasing from about 10% to about 30%	Varying around 20%	Varying around 20% except for increase to about 50% at highest pitches
Wave file #7 is almost identical to wave file #6. Not much progress.				

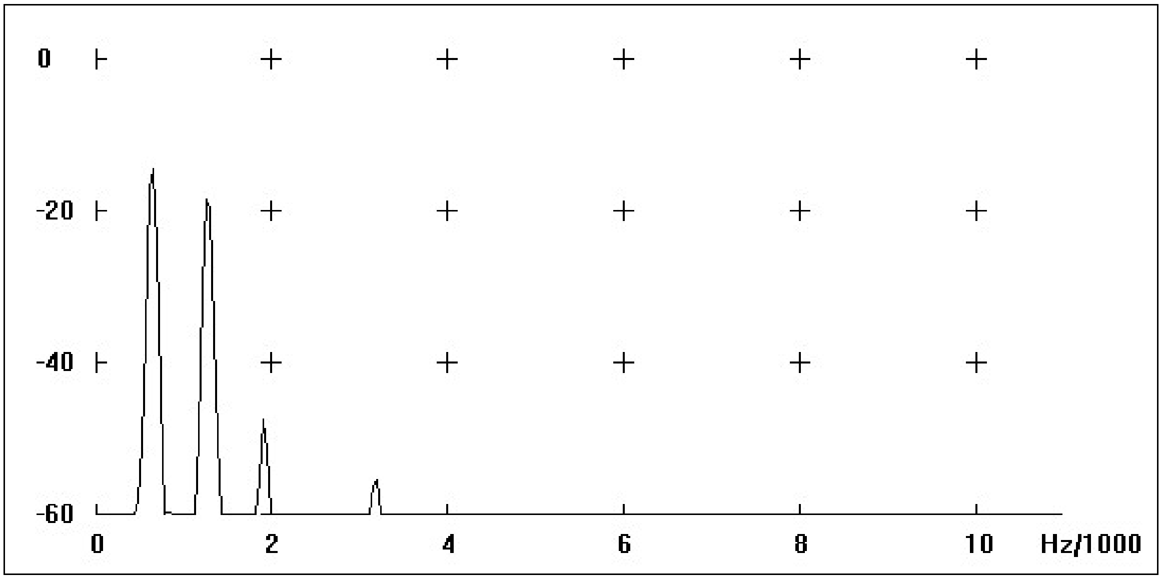
Power Spectrum from Spectrogram #7, Subject #2 at 5.48 seconds [i]



Power Spectrum from Spectrogram #7, Subject #2 at 6.69 seconds [o]

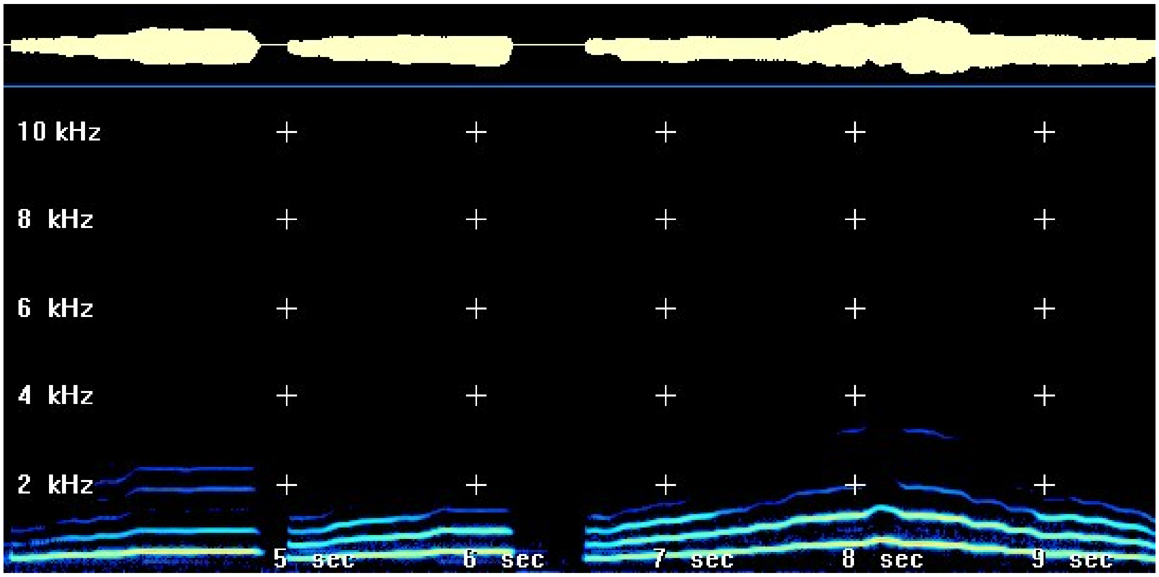


Power Spectrum from Spectrogram #7, Subject #2 at 8.88 seconds [a]



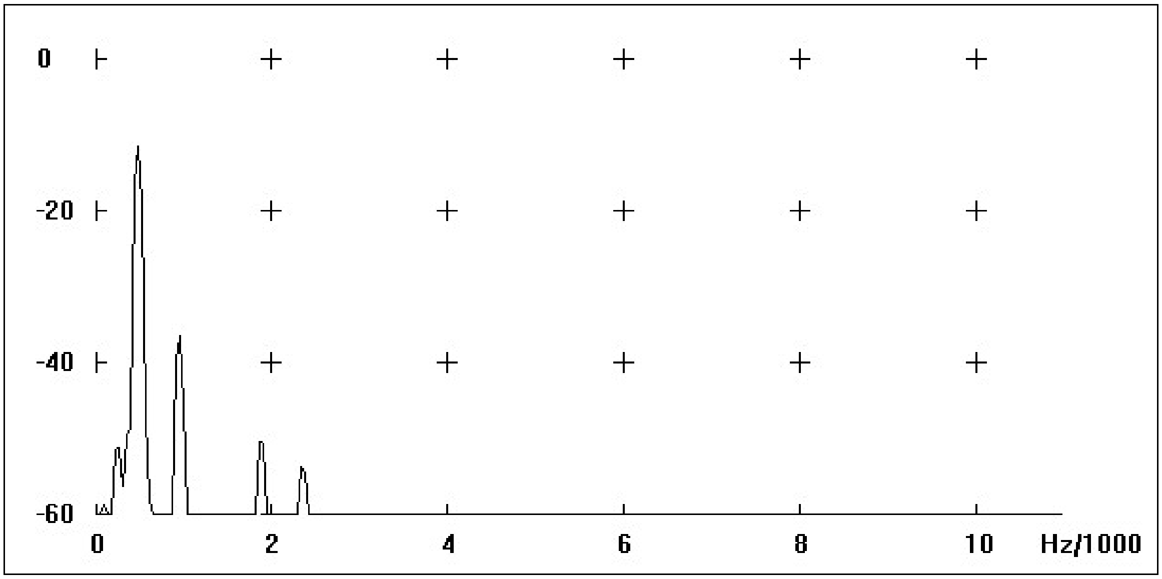
Analysis of Power Spectra from Spectrogram #7, Subject #2 – October 4, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.48	3	2	.66	2	5	.4	.53
6.69	4	2	.5	0	4	0	.25
8.88	3	2	.66	1	4	.25	.45
Average of three chiaroscuro levels							.41

Wave File Number 8 – October 10, 2000 – Subject #2

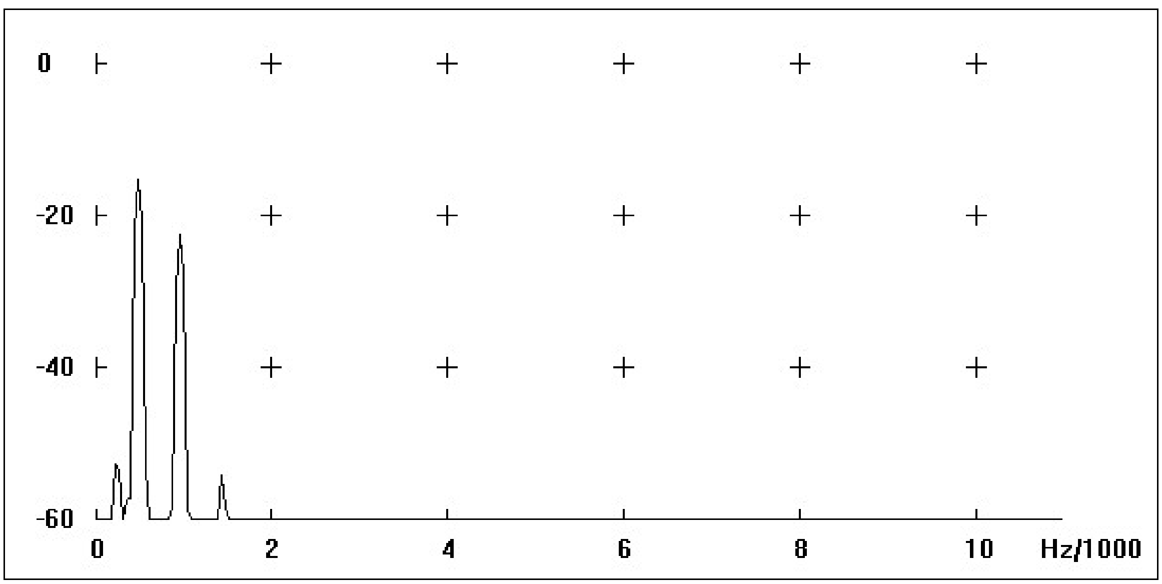


Subject #2 – Analysis of Wave File #8 – October 10, 2000 – E flat major				
		[si] (3.56-4.83 sec)	[o] (5.01-6.2 sec)	[a] (6.56-10.4 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Two nearly solid band		One pair at highest pitch that seem to be part of the same band
2nd Formant Area (Vowel Definition)		Better vowel definition	Better vowel definition	Better vowel definition
1st Formant Area		Some strengthening at higher pitches	Some strengthening at higher pitches	Some strengthening at higher pitches
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 20% to about 50%	Increase from about 20% to about 40%	Varying around 30% with increase to about 80% at highest pitches
This wave file indicates more intent on the singer's part to achieve a resonant sound. There is also some evidence that in making the effort the singer is pushing the voice to a degree: the slight vibrato that had been evident is nearly straight in the [si] and [o] exercises. Even so, the upper frequencies are more consistent, the movement of the voice is less interrupted, and the vowel definition is better.				

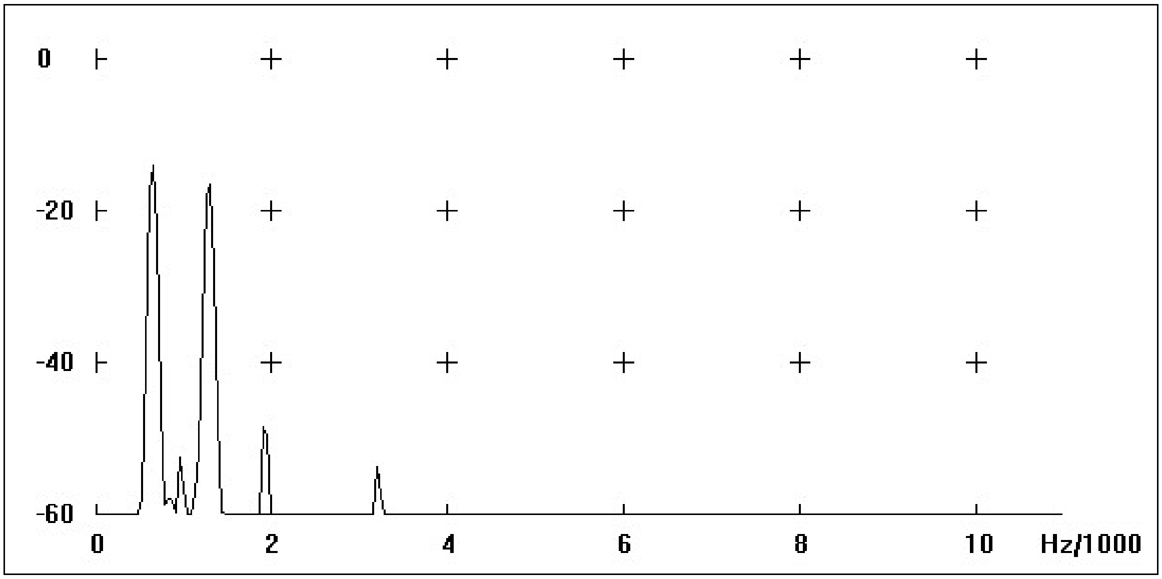
Power Spectrum from Spectrogram #8, Subject #2 at 4.28 seconds [i]



Power Spectrum from Spectrogram #8, Subject #2 at 5.58 seconds [o]

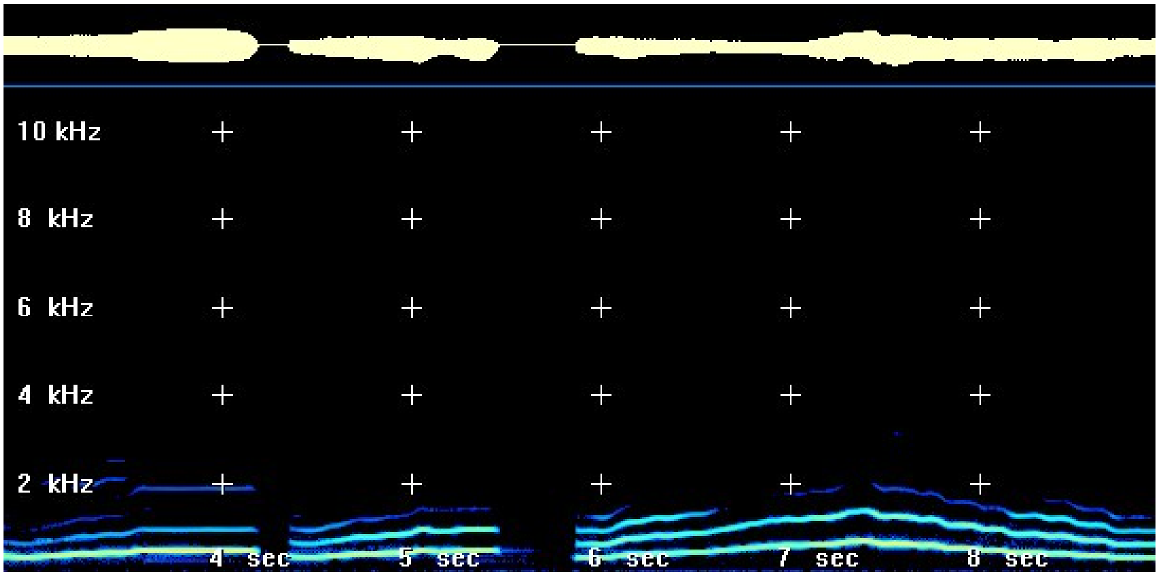


Power Spectrum from Spectrogram #8, Subject #2 at 7.99 seconds [a]



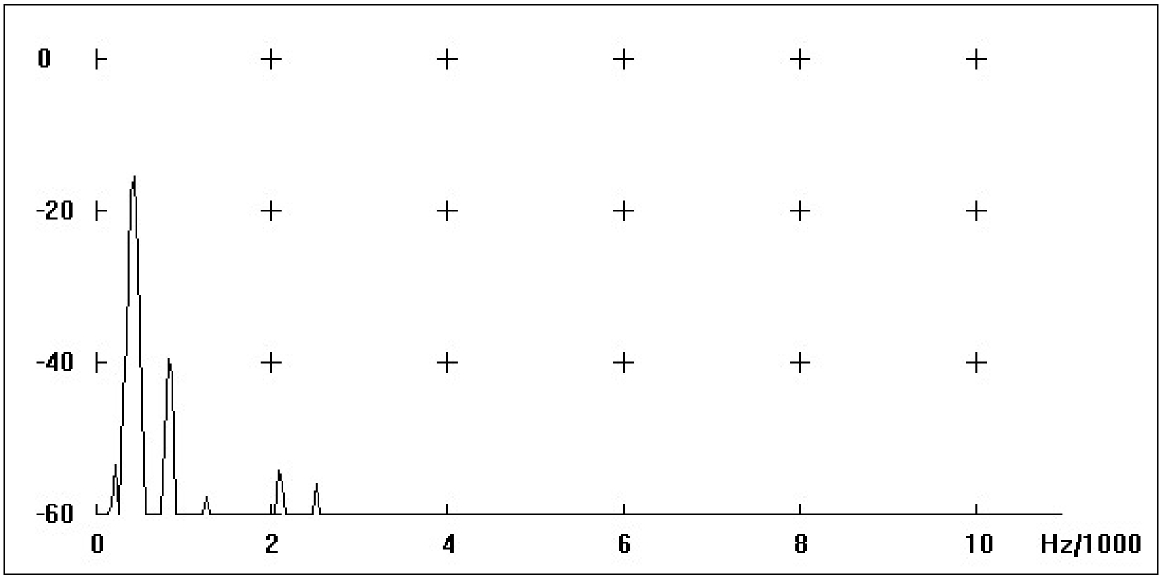
Analysis of Power Spectra from Spectrogram #8, Subject #2 - October 10, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.28	5	2	.4	1	6	.16	.28
5.85	4	2	.5	0	4	0	.25
7.99	5	2	.4	1	6	.16	.28
Average of three chiaroscuro levels							.27

Wave File Number 9 – October 17, 2000 – Subject #2

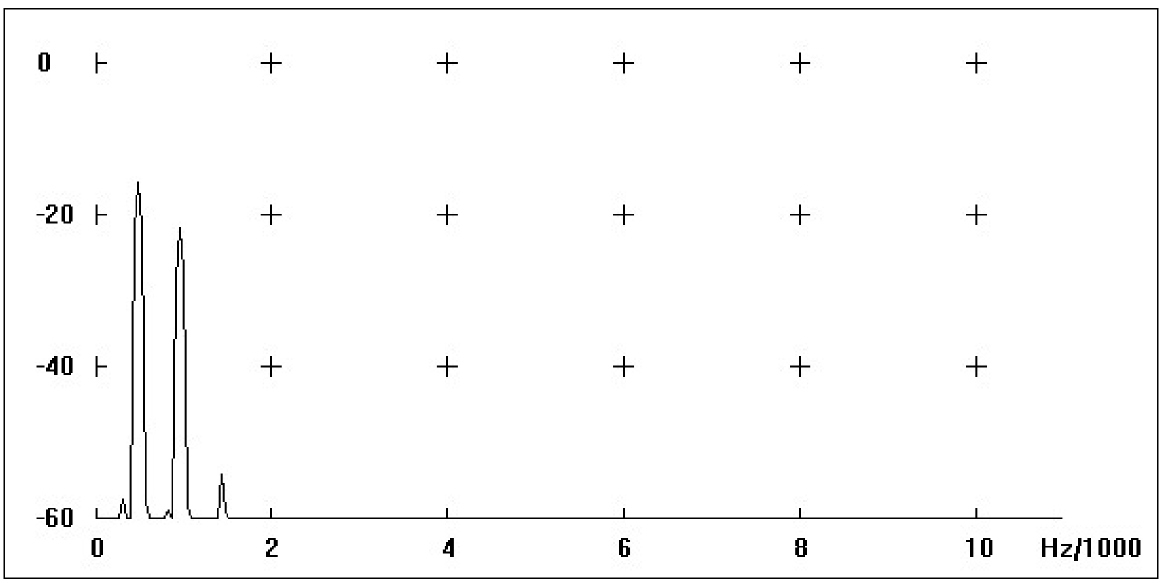


Subject #2 – Analysis of Wave File #9 – October 17, 2000 – E flat major				
		[si] (2.85-4.16 sec)	[o] (4.36-5.45 sec)	[a] (5.88-9.4 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Very slight, scattered indications		
2nd Formant Area (Vowel Definition)		Weak vowel definition	Weak vowel definition	Weak vowel definition
1st Formant Area		Some strengthening at higher pitches		
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 20% to about 30%	Varying around 25%	Varying around 30%
This wave file does not indicate the progress show in Wave File #8. The same damping of high frequencies and disorganized approach to a resonant tone are visible as in earlier wave files.				

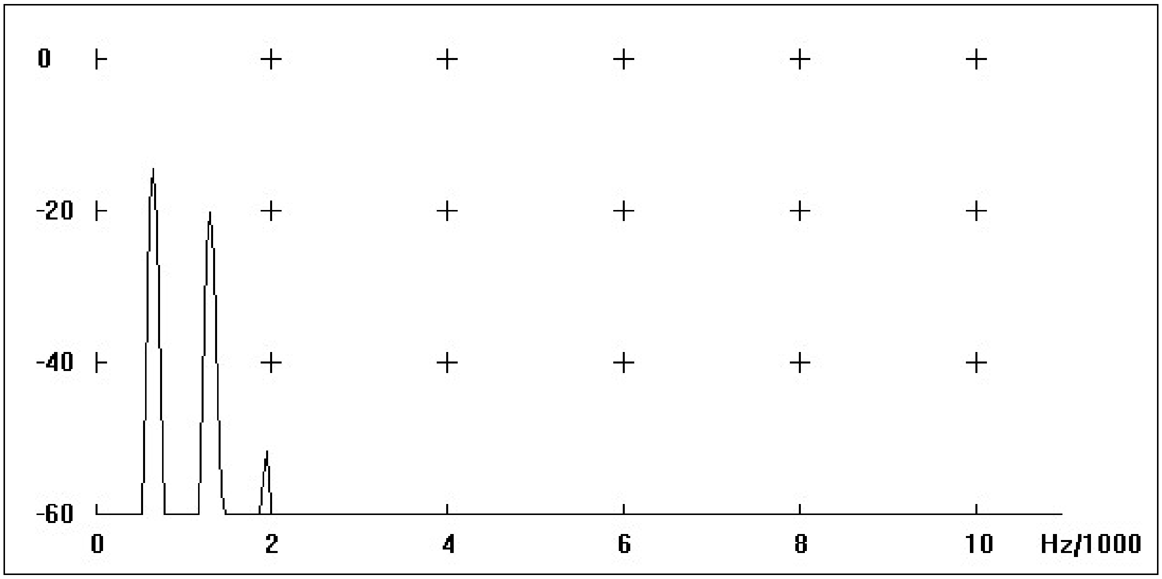
Power Spectrum from Spectrogram #9, Subject #2 at 3.41 seconds [i]



Power Spectrum from Spectrogram #9, Subject #2 at 5.07 seconds [o]

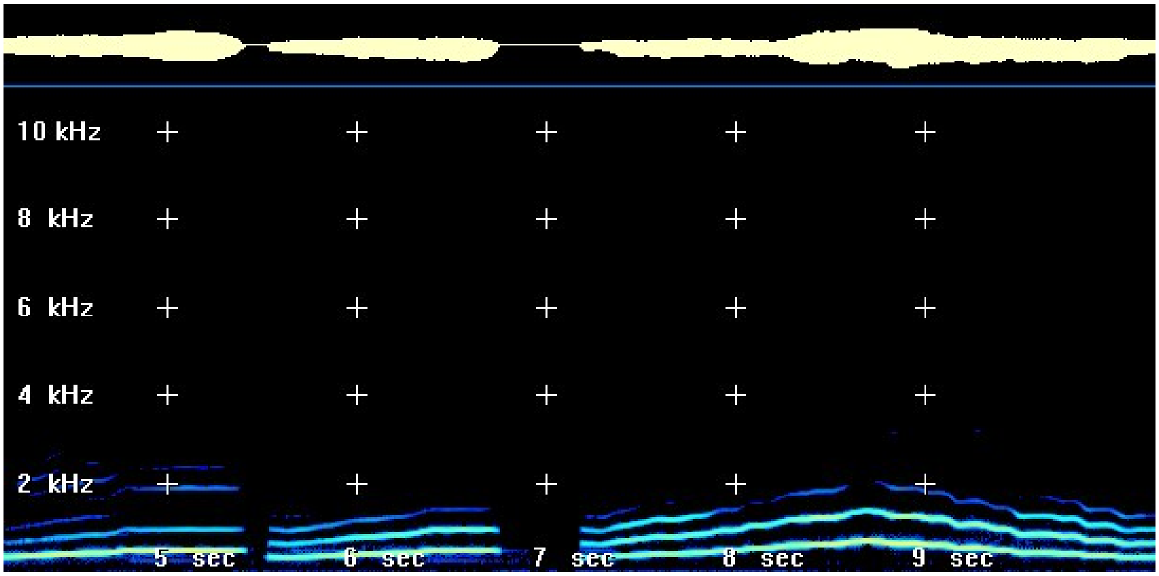


Power Spectrum from Spectrogram #9, Subject #2 at 7.47 seconds [a]



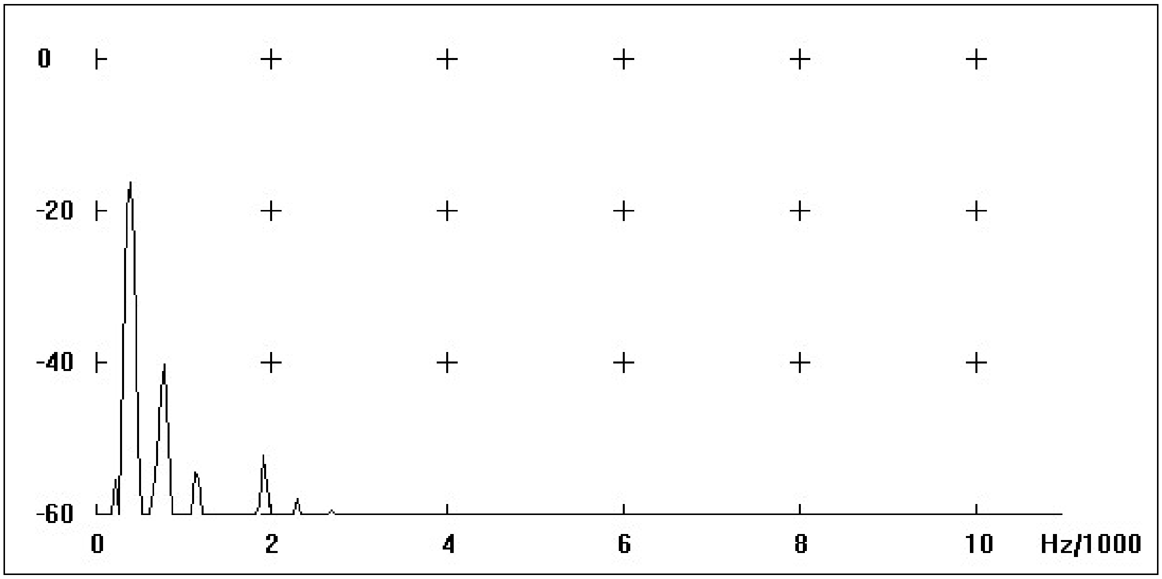
Analysis of Power Spectra from Spectrogram #9, Subject #2 – October 17, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.41	4	2	.5	2	6	.33	.41
5.07	5	2	.4	0	5	0	.2
7.47	3	2	.66	0	3	0	.33
Average of three chiaroscuro levels							.31

Wave File Number 10 – October 24, 2000 – Subject #2

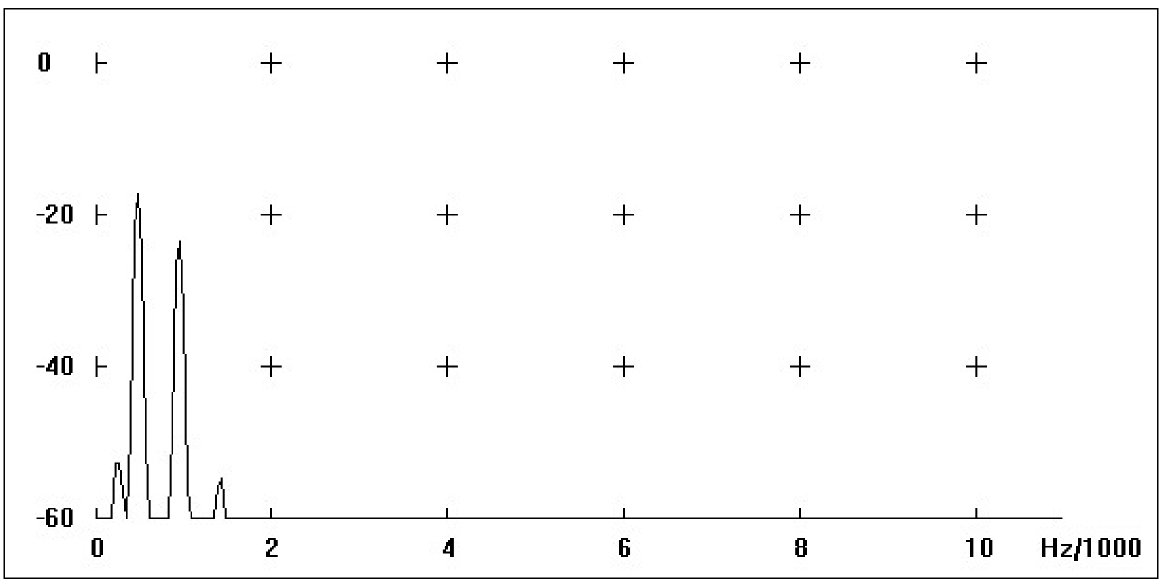


Subject #2 – Analysis of Wave File #10 – October 24, 2000 – E flat major				
		[si] (4.17-5.4 sec)	[o] (5.54-6.76 sec)	[a] (7.18-10.64 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Some slight, scattered indications		One faint indication
2nd Formant Area (Vowel Definition)		Weak vowel definition	Weak vowel definition	Weak vowel definition
1st Formant Area		Some strengthening at highest pitches	Some strengthening at highest pitches	Some strengthening at highest pitches
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 20% to about 40%	Increase from about 20% to about 30%	Varying around 20% with increase to about 40% at highest pitches
Disappointing overall lack of improvement. This wave file is very much like most of the earlier ones.				

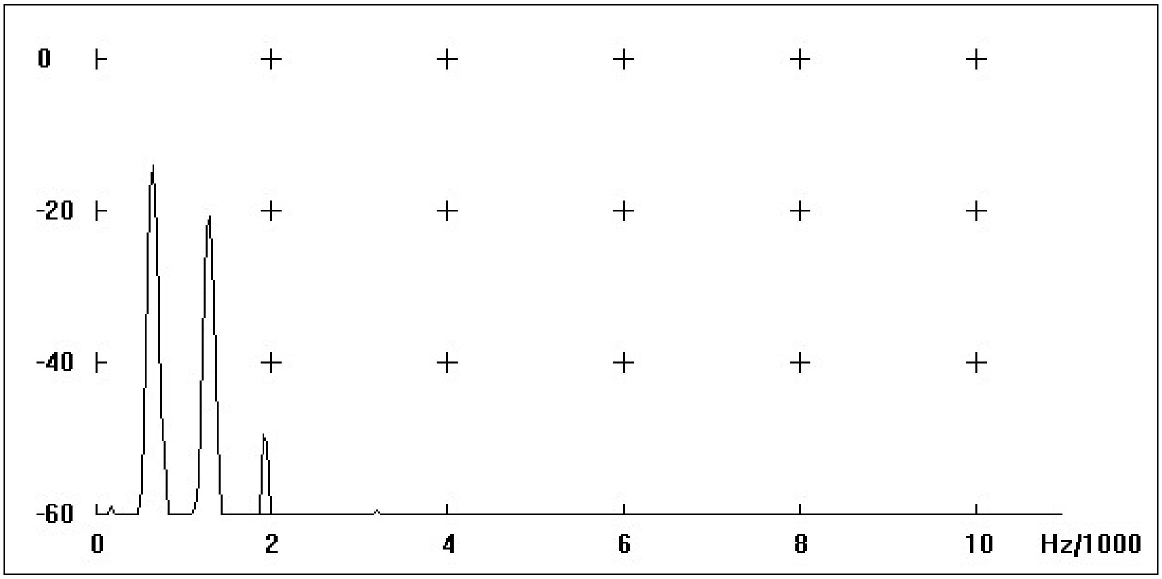
Power Spectrum from Spectrogram #10, Subject #2 at 4.43 seconds [i]



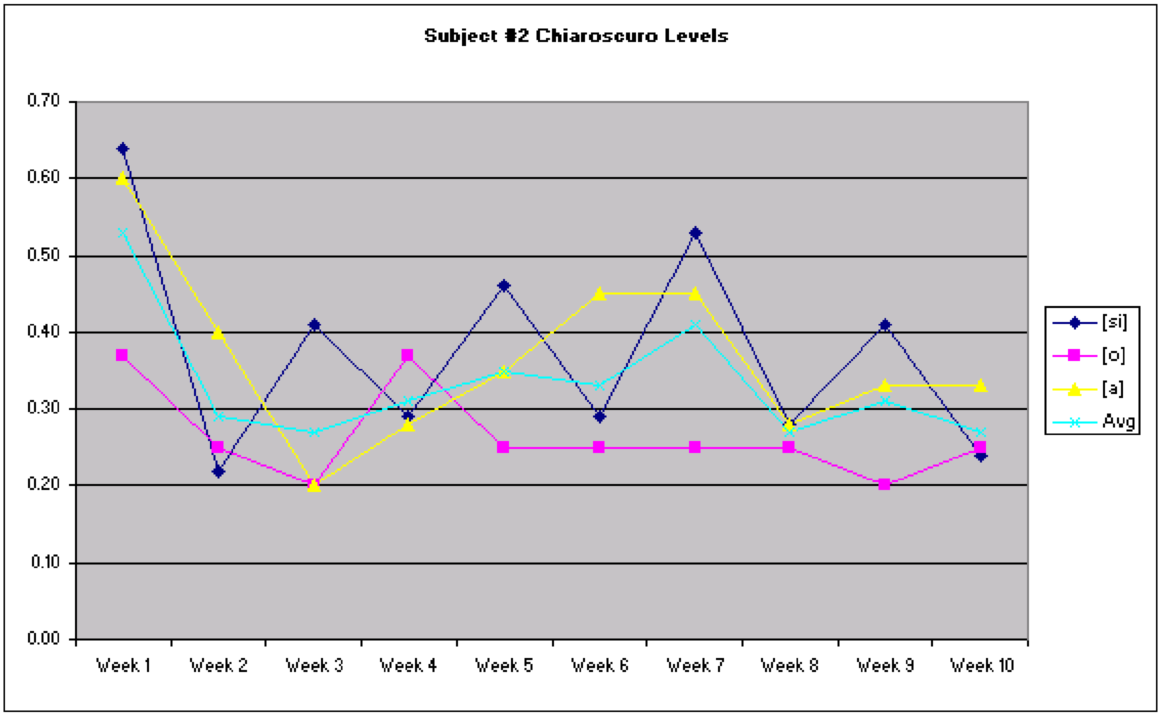
Power Spectrum from Spectrogram #10, Subject #2 at 6.45 seconds [o]

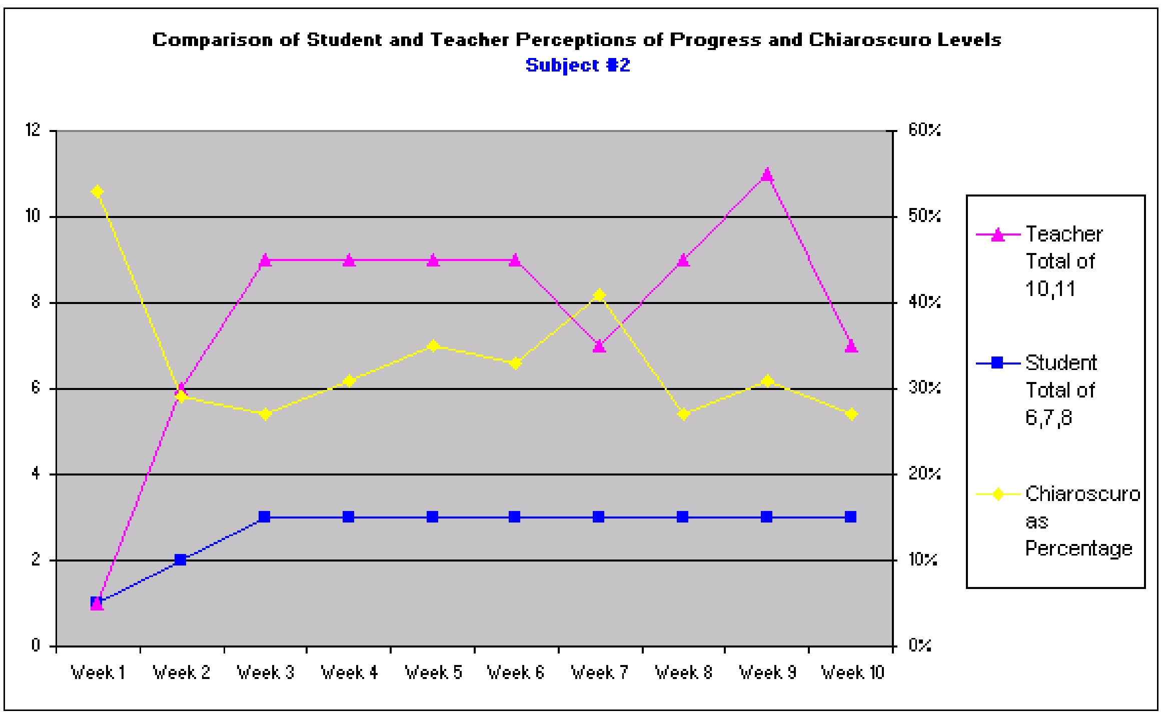


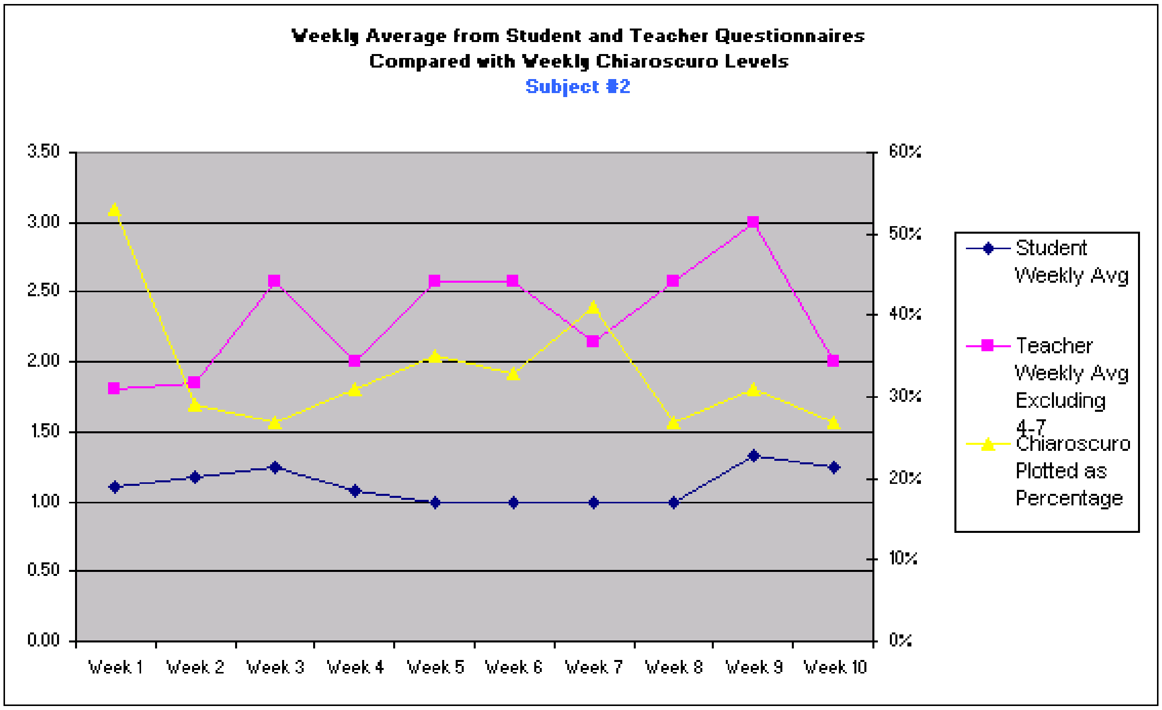
Power Spectrum from Spectrogram #10, Subject #2 at 8.83 seconds [a]



Analysis of Power Spectra from Spectrogram #10, Subject #2 – October 24, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.43	5	1	.2	2	7	.28	.24
6.45	4	2	.5	0	4	0	.25
8.83	4	2	.5	1	6	.16	.33
Average of three chiaroscuro levels							.27


Subject #2 Chiaroscuro Levels
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg


Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #2
12
10
8
6
4
2
0
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #2
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A3: Subject #3

Subject #3 was an 18-year-old Caucasian freshman majoring in vocal performance. Her home was in Gwinnett County, in the northeast part of metropolitan Atlanta. She was exceptionally intelligent, very intense, and very thin. She was a dancer and a gymnast, and her physical intensity tended to have a tension producing effect on her singing. She was conscientious about practicing and made good progress during the semester.

At the beginning of the semester her voice, while not large, was very clear, with a range from a to c^3 and little vibrato. The lack of vibrato was due not to unsupported singing, but rather to tension in the muscles around the larynx. She was inclined to over-support, which caused her to sing flat in the second passaggio area. Her challenge during the semester in which data were collected was to learn to use skill instead of strength to achieve good vocal quality and good tuning. Her intonation problems were caused by physical aspects of her technique, not by a lack of musicianship.

Because freshmen in this program do not perform on the midterm or Broadway recitals, Subject #3's first performance, other than in voice major class, was in the end of semester student recital. She had worked very hard on perfecting her song for the recital, and she was successful in her performance.

The spectrograph was an effective tool for Subject #3. Her intellectual approach to singing made her want to understand the mechanics of the voice. Thinking of her sound in terms of frequencies that she could control was a liberating idea for her and seemed to help her take control of her voice.

Fall Semester 2000 Repertoire – Subject #3

Beethoven	Ich liebe dich
Purcell	Nymphs and shepherds
Monteverdi	Lasciatemi morire
Scarlatti	Le violette
Britten	O Ca Ye Sew Cushions (low key)
Campian	Oft have I sighed
Schubert	An die Musik (previously studied – asked to coach)

Lesson record over the data collection period – Subject #3

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10-11
8/22	A	Assignment of rep	Good	Basics of warm-up, how the study will be operated, nice voice – tendency to open nasal port in lower register – clear sound – no problems	#1 E flat	Chiaroscuro - .34 Student n/a, n/a, 1 Teacher n/a, n/a
8/28	A	Beethoven	Good	German diction – she has pretty much learned the Beethoven – sang it with accompaniment	#2 D	Chiaroscuro - .46 Student 3, 3, 1 Teacher 2, 2
9/5	B	Beethoven	Sick with sinus infection	Too sick to sing much – used Singer's Voice video (Vocal Tract) and worked on Beethoven diction	#3 D flat	Chiaroscuro - .48 Student 5, 4, 1 Teacher 3, 3
	B	Scarlatti	Had learned the song very well	I was not expecting her to sing in voice major class, but she did. She had learned the whole song with ornaments and sang very musically, but the voice was not there for her because she is ill. She was very flat, and I've not heard her flat before.		
9/11	A	Scarlatti, Beethoven	Excellent	Voice is nearly healthy – has learned both songs quite well – she is having problems learning to control her large voice to take care of pitch in pasaggio – Beethoven is giving her fits – also holding at larynx level to strengthn tone (wrong!) and working way too hard		
9/12	A	Beethoven, Purcell w/acc	Good prep – 2-part lesson before and after Formal Convocation	Tunig is her issue – dance/athletics = strength and that can mean oversupporting and tension – she is learning to use resonance instead of forcing – finds spectrograph revealing		
9/14	A	Britten, Schubert	On time and prepared	Make-up (rest of 9/12) – worked on breathing – she has been taugh staumitode, and I will not insist she change, but I want to transfer her attention dynamic muscular opposition and concentrating on maintaining the position of inspiration	#4 E-flat	Chiaroscuro - .40 Student 1, 1, 1 Teacher 2, 2
9/19	A	Beethoven, Scarlatti	On time, prepared	She is beginning to see that what I tell her helps her to stay in tune – becoming increasingly willing to try – not that she ever was unwilling – just not too trusting – likes the spectrograph	#5 E flat	Chiaroscuro - .54 Student 1, 1, 1 Teacher 2, 2
9/26				Lesson cancelled because of Tennessee trip		
9/29	A	Beethoven, Purcell	On time, well prepared	Make-up lesson – she is replacing strength with skill – tuning continues to improve	#6 E flat	Chiaroscuro - .54 Student 1, 1, 1 Teacher 2, 2
10/5	A	Scarlatti, Beethovan, Campion	Excellent	She is making remarkable progress in overcoming her pitch problems – uses excellent brains to advantage – diction rapidly improving – very interest in VoPed – mentioned Miller today	#7 E flat	Damaged disc – no wave file data available Chiaroscuro n/a Student 1, 1, 1 Teacher 2, 2

10/10	A	Monteverdi, Schubert, Beethoven	Excellent	Schubert gave her fits because the tuning went out (old song-old habits) – the Beethoven was like changing to a new instrument – she is coming along – worked passaggio for resonance and brilliance	#8 E flat	Chiaroscuro - .43 Student 1, 1, 1 Teacher 2, 2
10/17	A	Beethoven, Purcell, Scharlatti	Excellent	Scarlatti is memorized – wish she were working a little faster with the memory work – otherwise she is working like a dream – sharping is a problem, but she is able to understand and apply the technique that fixes it	#9 E flat	Chiaroscuro - .53 Student 1, 1, 1 Teacher 3, 3
10/24	A	Beethoven, Monteverdi, Campian	Excellent	Good work – working on centering tone	#10 E flat	Chiaroscuro - .46 Student 1, 1, 1 Teacher 2, 2
10/31				Career Day – lesson rescheduled for 11/9		
11/7	A	Beethoven, Purcell, Onteverdi, Campian	Excellent	Purcell memorized – working on Monteverdi and Campian – whole body singing – chest must not collapse – tongue must not clench		
11-9				She forgot – try again 11/16		
11/14	A	Beethoven	Excellent	Walked through recital – working on tuning and phrasing – she has nearly grasped her tuning – her intelligence is physical as well as intellectual		
11/16	A	Beethoven	Excellent	Student recital		
11/21	A	All rep by memory	Excellent	She really has progressed, especially learning to control pitch in passaggio		

Responses to student questionnaires – Subject #3

Question	8/22	8/28	9/5	9/14	9/19	9/29	10/5	10/10	10/17	10/24	**Total of weekly answers to questions 6, 7, 8**
1	2	1	5	1	1	1	2	2	2	1	
2	3	3	4	2	1	1	2	2	2	1	
3	3	1	2	1	1	1	1	1	1	1	
4	1	1	1	1	1	1	1	1	1	1	
5	1	1	1	1	1	1	1	1	1	1	
6	N/A	3	5	1	1	1	1	1	1	1	**1.66**
7	N/A	3	4	1	1	1	1	1	1	1	**1.55**
8	1	1	1	1	1	1	1	1	1	1	**1**
9	1	1	1	1	1	1	1	1	1	1	**Average over ten-week period**
10	1	1	1	1	1	1	1	1	1	1	
11	1	1	3	1	1	1	1	1	1	1	
12	2	1	1	1	1	1	1	1	1	1	
Weekly Average	1.6	1.5	2.41	1.08	1	1	1.16	1.16	1.16	1	**1.40**

Responses to teacher questionnaires – Subject #3

Quantification of the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)

2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)

3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)

4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)

5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

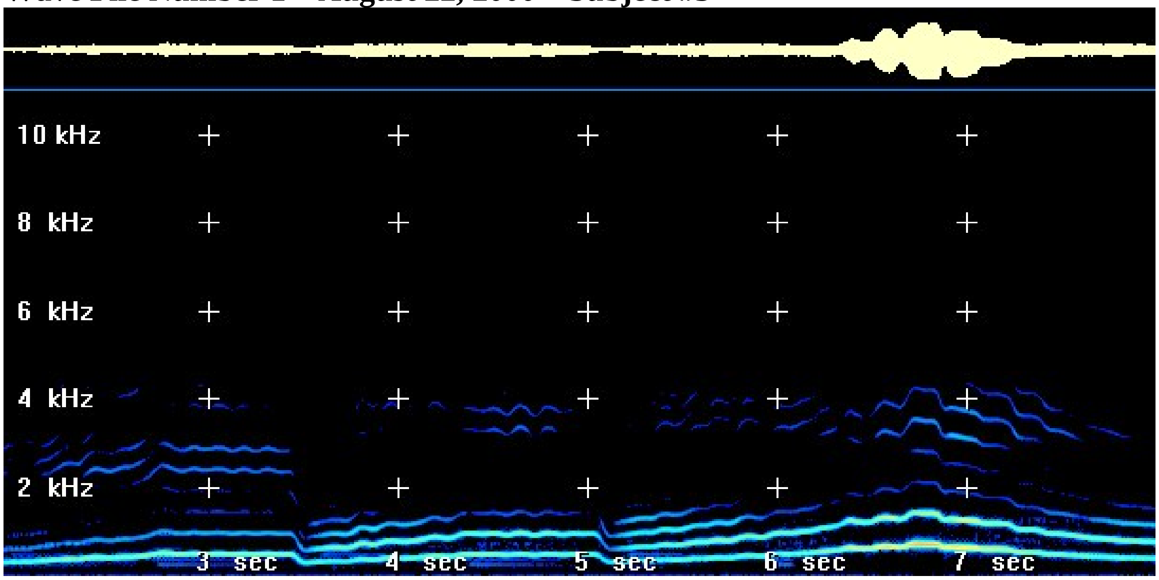
Question	8/22	8/28	9/5	9/14	9/19	9/29	10/5	10/10	10/17	10/24	**Totals and Average of questions 10 & 11**
1	2	2	2	2	2	2	2	2	2	2	
2	2	2	4	2	2	1	1	2	1	2	
3	2	2	2	2	2	2	2	2	2	2	
4	3	3	5	1	2	2	2	4	3	3	
5	5	5	5	4	4	4	4	5	5	5	
6	2	3	5	3	4	5	4	4	4	5	
7	5	5	5	5	5	5	5	5	5	5	
8	2	2	2	1	1	1	1	2	2	2	
9	1	2	5	3	2	1	1	2	1	2	
10	N/A	2	3	2	2	2	2	2	3	2	**2.22**
11	N/A	2	3	2	2	2	2	2	3	2	**2.22**
Weekly Average excluding questions 4-7	1.8	2	3	2	1.85	1.57	1.57	2	2	2	**2.22**

Student's Written Reaction to Use of Spectrograph – Subject #3

I felt that the spectrograph was extremely helpful in enabling me to better my singing technique. It allowed me to see the slight variations in my voice as I progressed in my private lessons. Because the technicalities of what the spectrograph does were explained to me so well, I was able to easily understand what I was watching at every lesson. And because it was used during every lesson, I was able to see my steady progress, as well as which technique's worked for my voice and which did not. I enjoyed using the spectrograph very much and I fell that it has done me a world of good in my pursuit of singing.

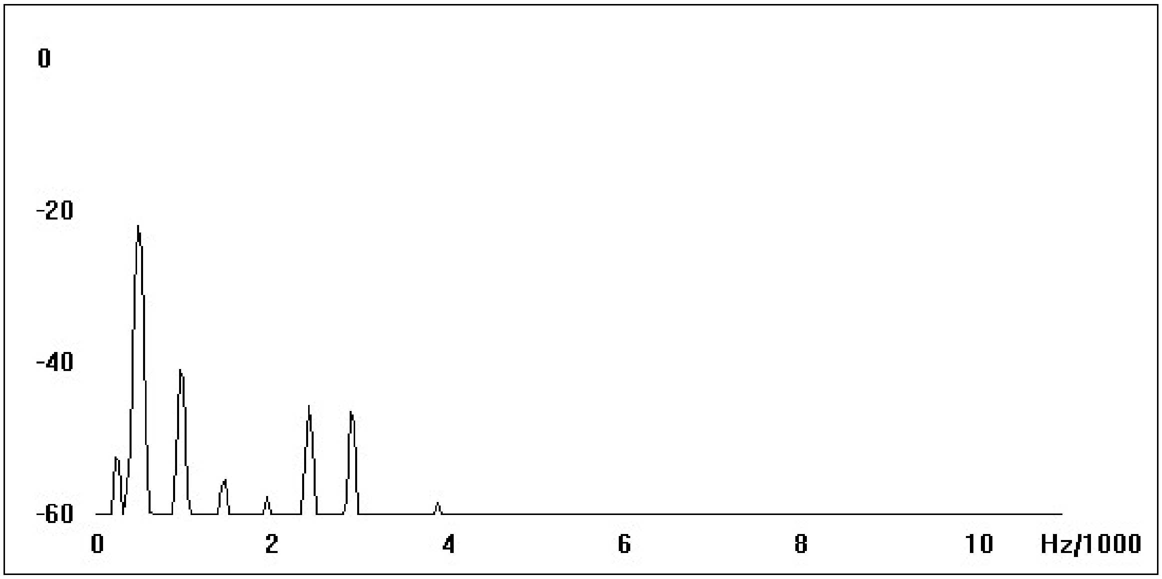
Analysis of Wave Files

Wave File Number 1 – August 22, 2000 – Subject #3

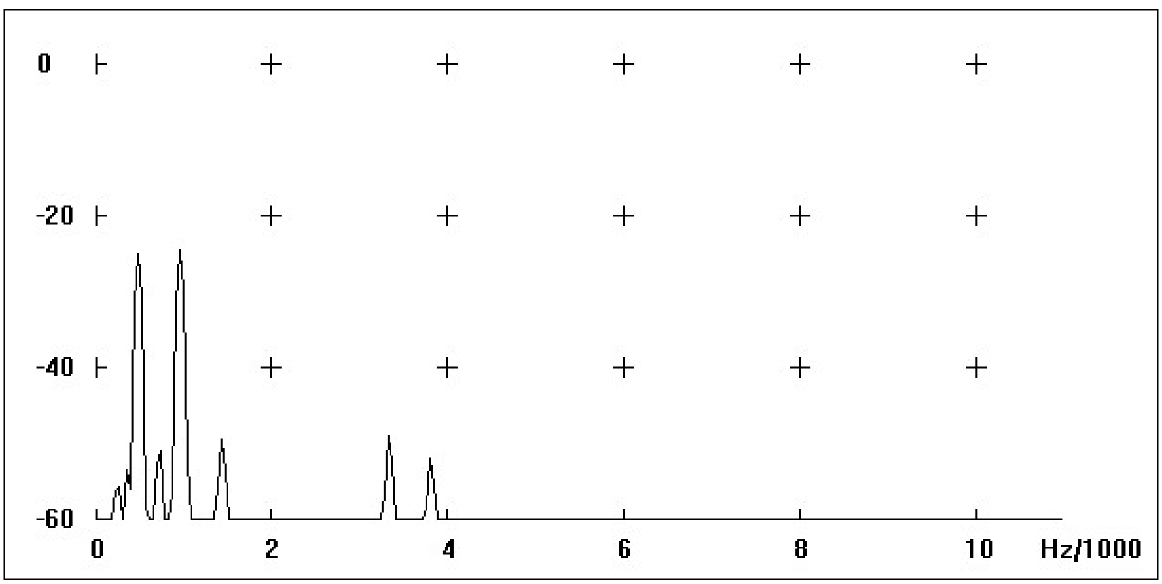


Subject #3 – Analysis of Wave File #1 – August 22, 2000 – E flat major				
		[si] (1.94-3.92 sec)	[o] (3.56-5.01 sec)	[a] (5.17-9.05 sec)
Singer's Formant Area	4000+ Hz	Some indications approaching this level		Some indications approaching this level
	2000-4000 Hz	Two nearly solid bands – not strong	Two nearly solid bands – not strong	Two nearly solid bands increasing to three at highest pitches – not strong
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Weak	Weak	Weak, but strengthens at highest pitches
Chiaroscuro Balance		Somewhat balanced	Somewhat balanced	Somewhat balanced
Power Spectrum		Varying around 10%	Varying around 20%	Varying around 20% with increase to about 80% at highest pitches
Good young voice with beginnings of a resonant sound. Some concern over weakness of lower frequencies, since development of upper and lower frequencies must be balanced to avoid undesirable qualities in the voice. Another concern is the tendency to start each vowel with a nearly straight tone, since this may indicate lack of freedom in the larynx area. Finally, the decision on the part of the singer to sing the entire exercise without a breath may indicate a tendency to try too hard.				

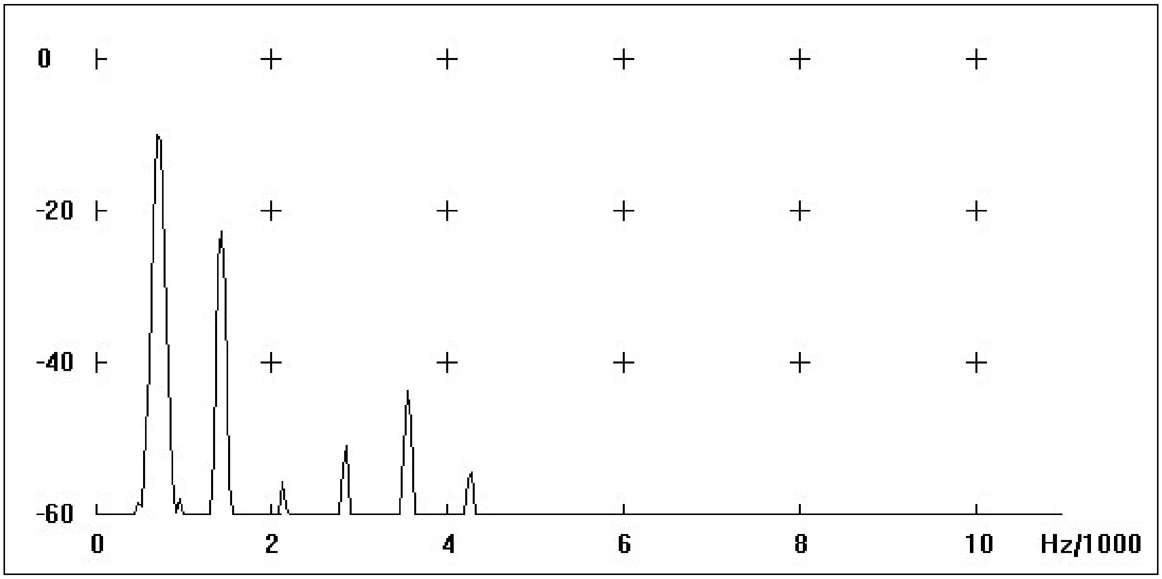
Power Spectrum from Spectrogram #1, Subject #3 at 2.94 seconds [i]



Power Spectrum from Spectrogram #1, Subject #3 at 4.63 seconds [o]

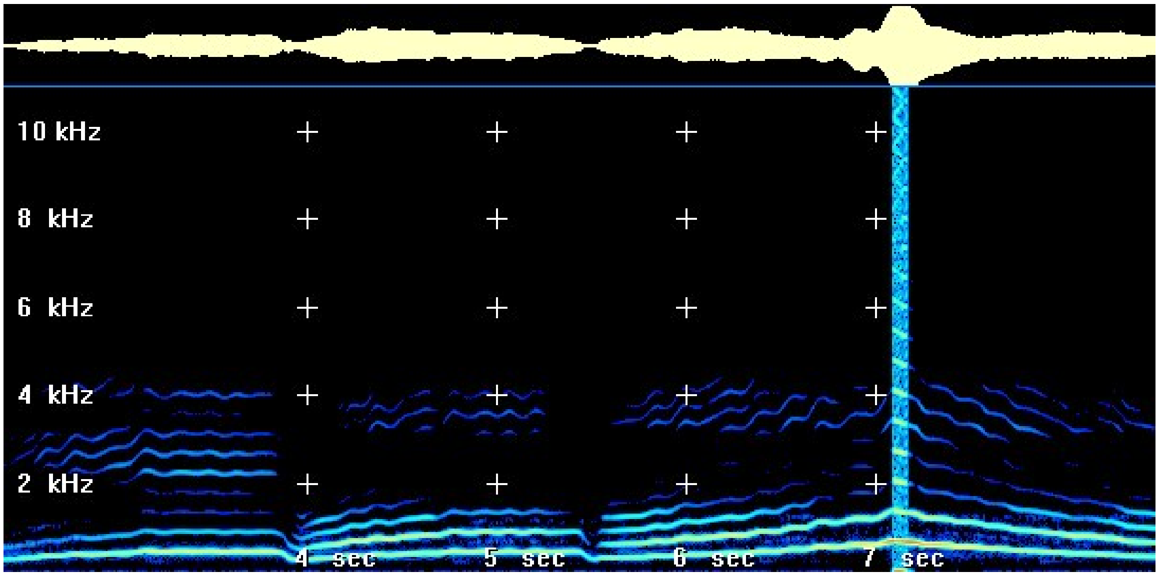


Power Spectrum from Spectrogram #1, Subject #3 at 6.75 seconds [a]



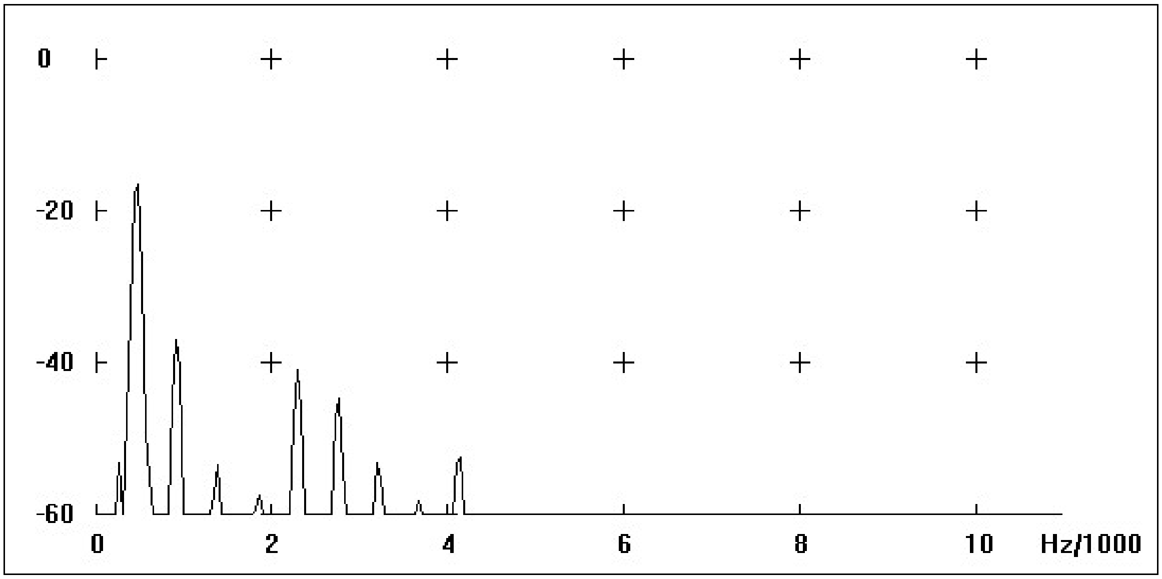
Analysis of Power Spectra from spectrogram #1, Subject #3 – August 22, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.94	5	1	.2	2	7	.28	.24
4.63	6	2	.33	2	8	.25	.29
6.75	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.34

Wave File Number 2 – September 29, 2000 – Subject #3

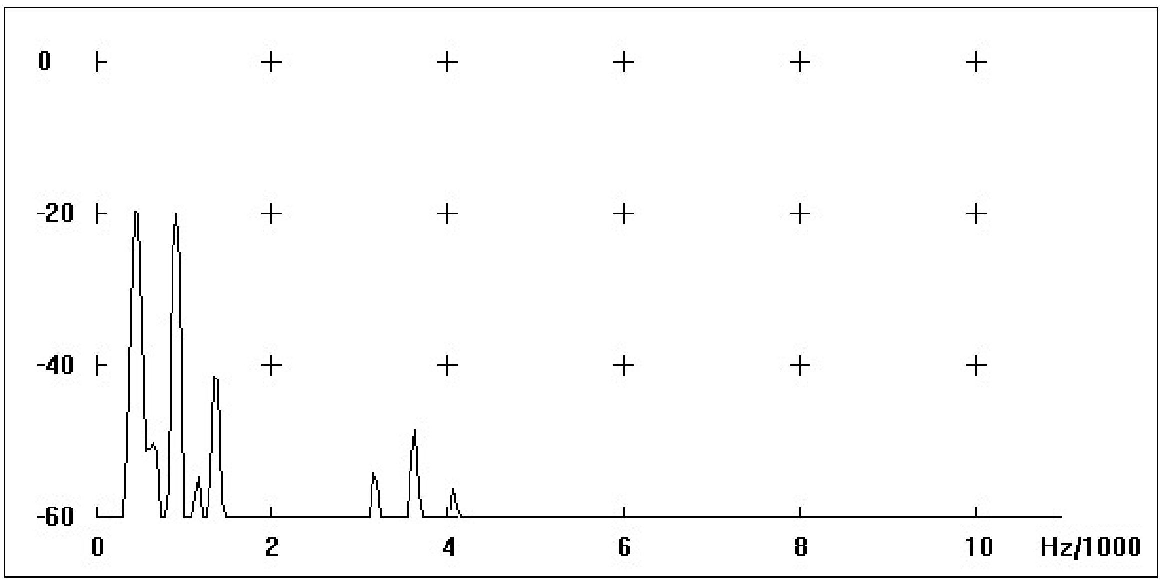


Subject #3 – Analysis of Wave File #2 – August 28, 2000 – D major				
		[si] (2.43-3.82 sec)	[o] (4-5.41 sec)	[a] (5.53-9.48 sec)
Singer's Formant Area	4000+ Hz	Some indications approaching this level		Some indications approaching this level – accidental peak at 7.14 perhaps from bumping microphone
	2000-4000 Hz	3 nearly solid bands – somewhat stronger than in wave file #1	2 nearly solid bands and one partial band – not strong	Two nearly solid bands increasing to three at highest pitches – not strong
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Stronger	Stronger	Stronger – continues to strengthen at highest pitches
Chiaroscuro Balance		Somewhat balanced	Somewhat balanced	Somewhat balanced
Power Spectrum		Increasing from about 10% to about 30%	Varying around 30%	Varying around 40% with increase to 100% at highest pitches
The singer clearly is trying to apply resonance techniques and is showing improvement over Wave File #1. The noisy peak at 7.14 could be caused by her bumping the microphone or by standing too close to the microphone. At that point a sudden punch with the breath can be heard, and the noise may be extra breath.				

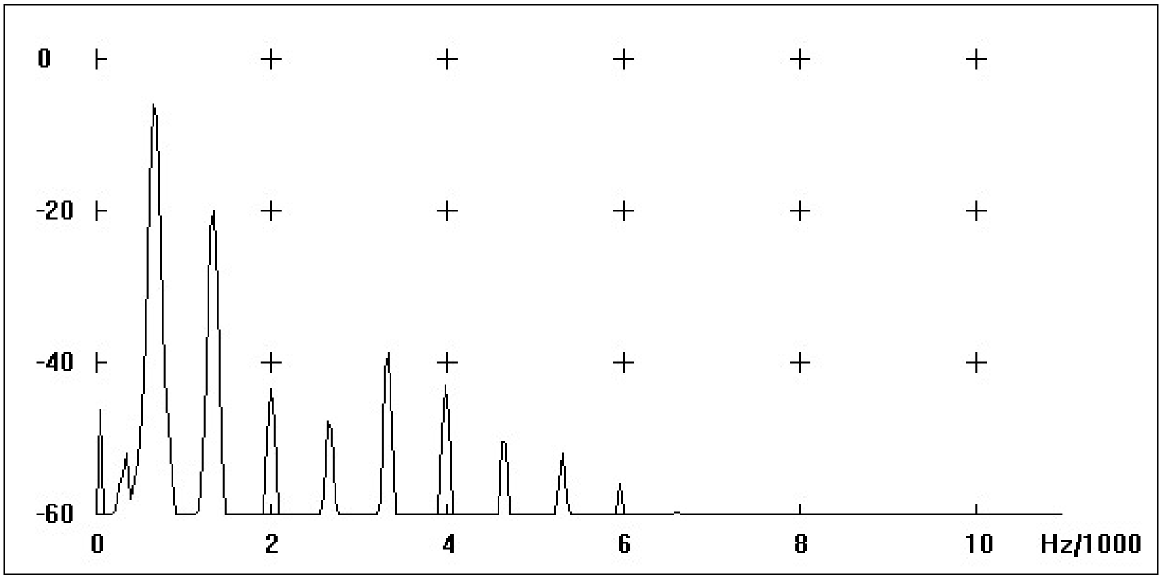
Power Spectrum from Spectrogram #2, Subject #3 at 3.17 seconds [i]



Power Spectrum from Spectrogram #2, Subject #3 at 5.06 seconds [o]

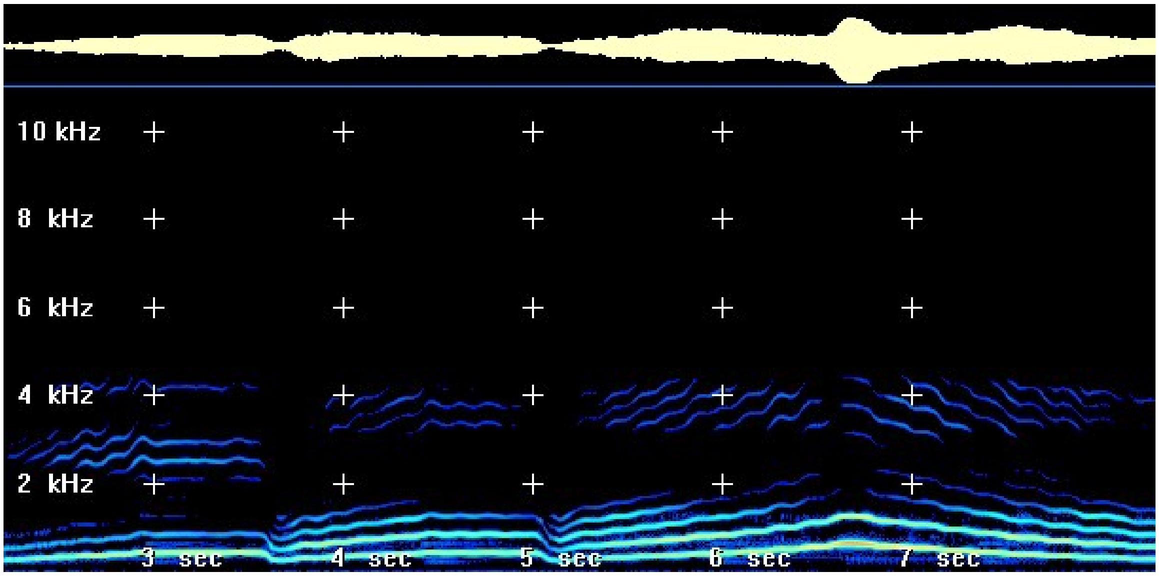


Power Spectrum from Spectrogram #2, Subject #3 at 7.2 seconds [a]



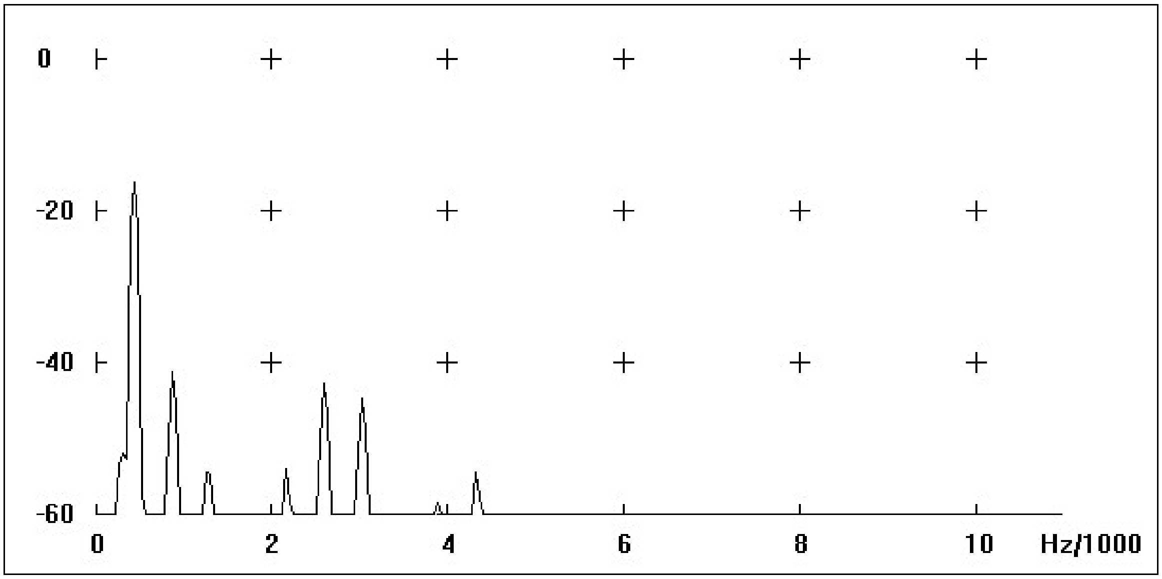
Analysis of Power Spectra from Spectrogram #2, Subject #3 – August 28, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.17	5	2	.4	5	10	.5	.45
5.06	5	2	.4	3	8	.37	.38
7.2	4	2	.5	7	11	.63	.56
Average of three chiaroscuro levels							.46

Wave File Number 3 – September 9, 2000 – Subject #3

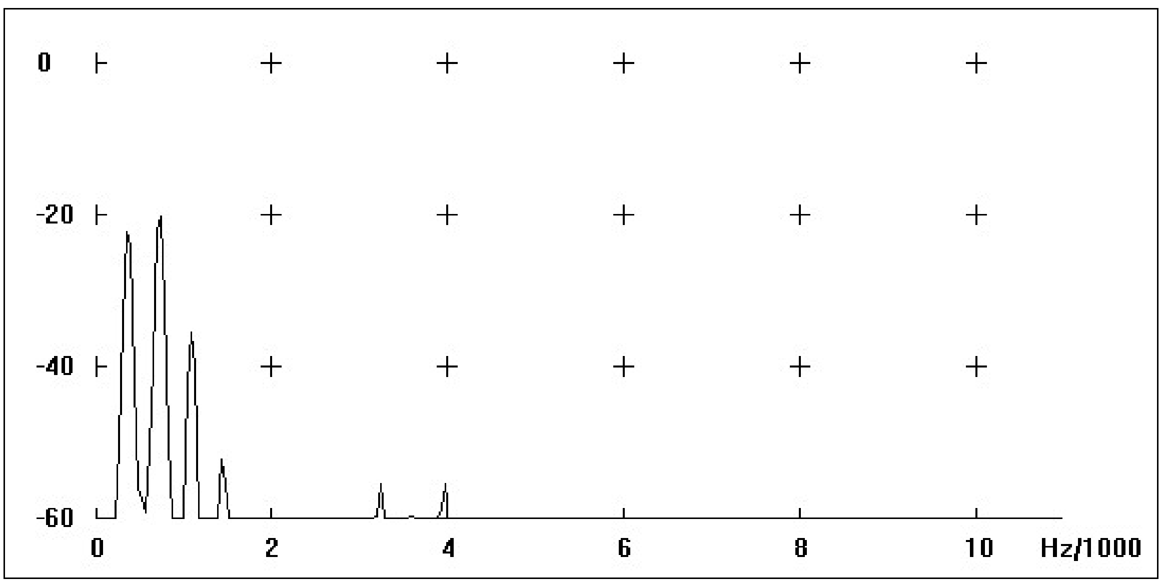


Subject #3 – Analysis of Wave File #3 – September 9, 2000 – D major				
		[si] (2.25-3.54 sec)	[o] (3.76-5.03 sec)	[a] (5.27-8.97 sec)
Singer's Formant Area	4000+ Hz	Some indications approaching this level		Some indications approaching this level
	2000-4000 Hz	Two nearly solid bands – third partial	Two nearly solid bands – third partial	3-4 nearly solid bands– not strong
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Stronger	Stronger	Stronger
Chiaroscuro Balance		Somewhat balanced	Somewhat balanced	Somewhat balanced
Power Spectrum		Increasing from about 10% to about 30%	Varying around 30%	Increasing from about 10% to about 40% with surge to about 80% at highest pitches
Continuing her progress in trying to apply resonance techniques.				

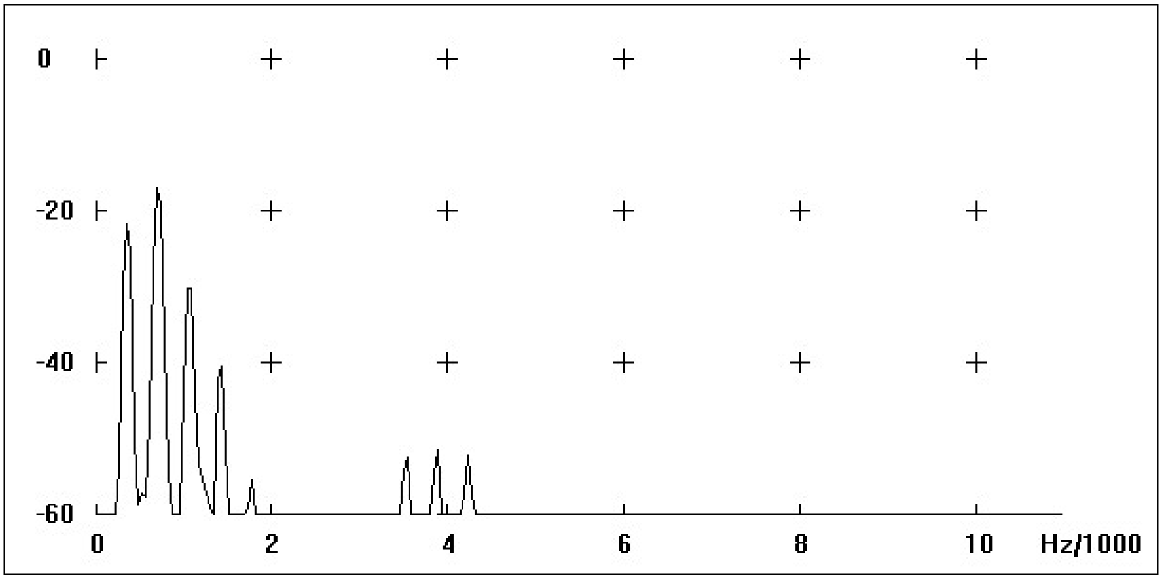
Power Spectrum from Spectrogram #3, Subject #3 at 2.54 [i]



Power Spectrum from Spectrogram #3, Subject #3 at 4.94 [o]

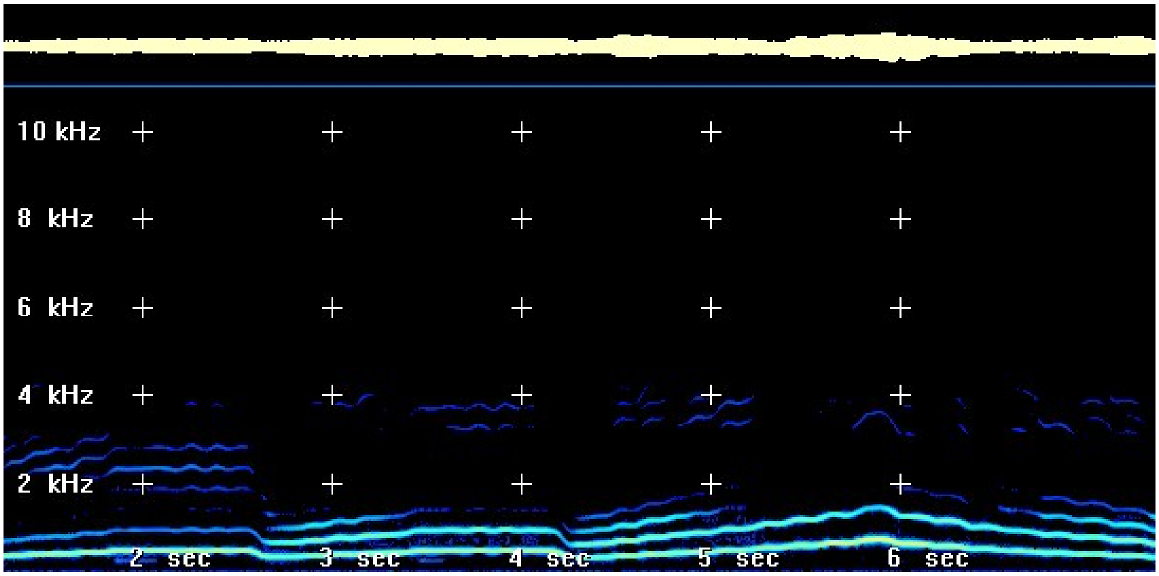


Power Spectrum from Spectrogram #3, Subject #3 at 5.7 [a]



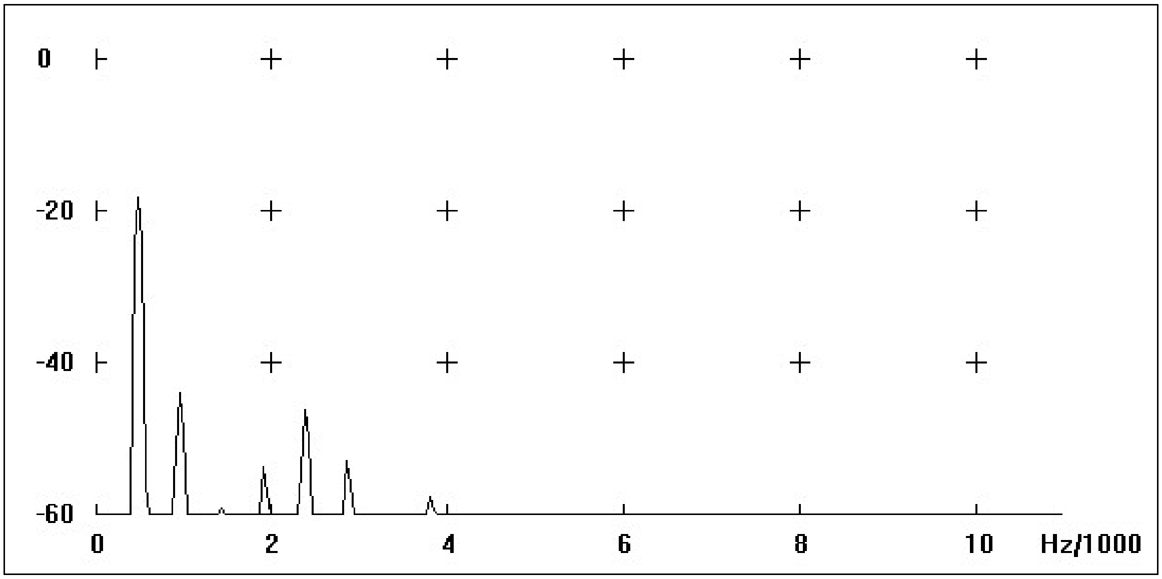
Analysis of Power Spectra from Spectrogram #3, Subject #3 – September 9, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.54	4	1	.25	5	9	.55	.4
4.94	4	3	.75	3	7	.42	.58
5.7	5	3	.6	3	8	.37	.48
Average of three chiaroscuro levels							.48

Wave File Number 4 – September 14, 2000 – Subject #3

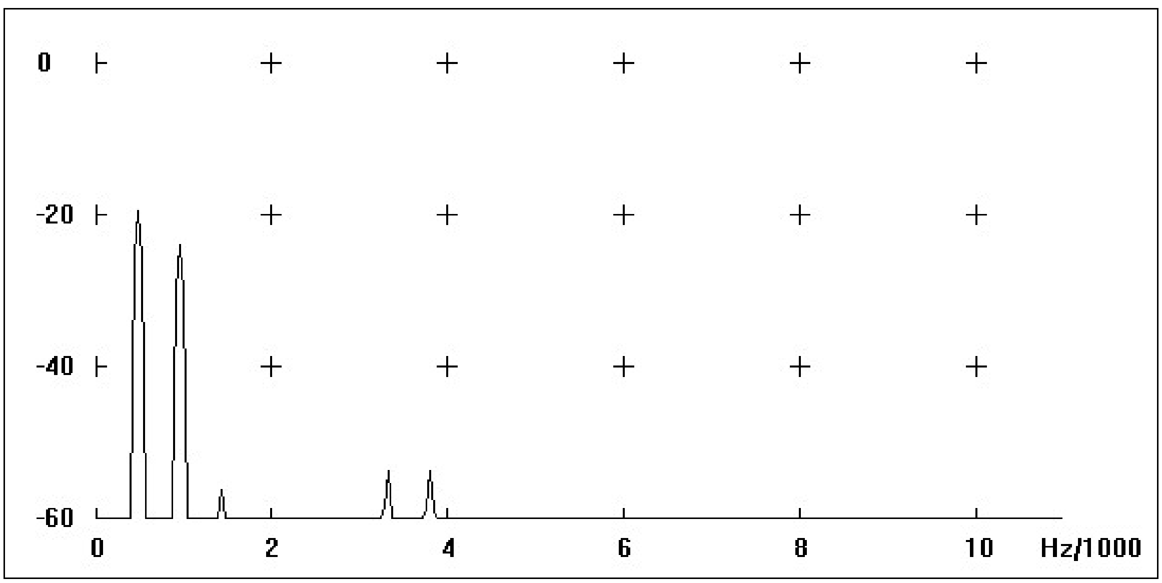


Subject #3 – Analysis of Wave File #4 – September 14, 2000 – E flat major				
		[si] (1.32-2.56 sec)	[o] (2.73-4.17 sec)	[a] (4.32-8 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	2 partial bands	2 partial bands	Scattered indications
2nd Formant Area (Vowel Definition)		Less vowel definition than in wave file #3	Less vowel definition than in wave file #3	Less vowel definition than in wave file #3
1st Formant Area		Not as strong as in wave file #3	Not as strong as in wave file #3	Not as strong as in wave file #3
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 20%	Varying around 20%	Varying around 205 with increase to about 30% at highest pitches
Much less strength in the voice all together. Looks as if the singer might be getting sick.				

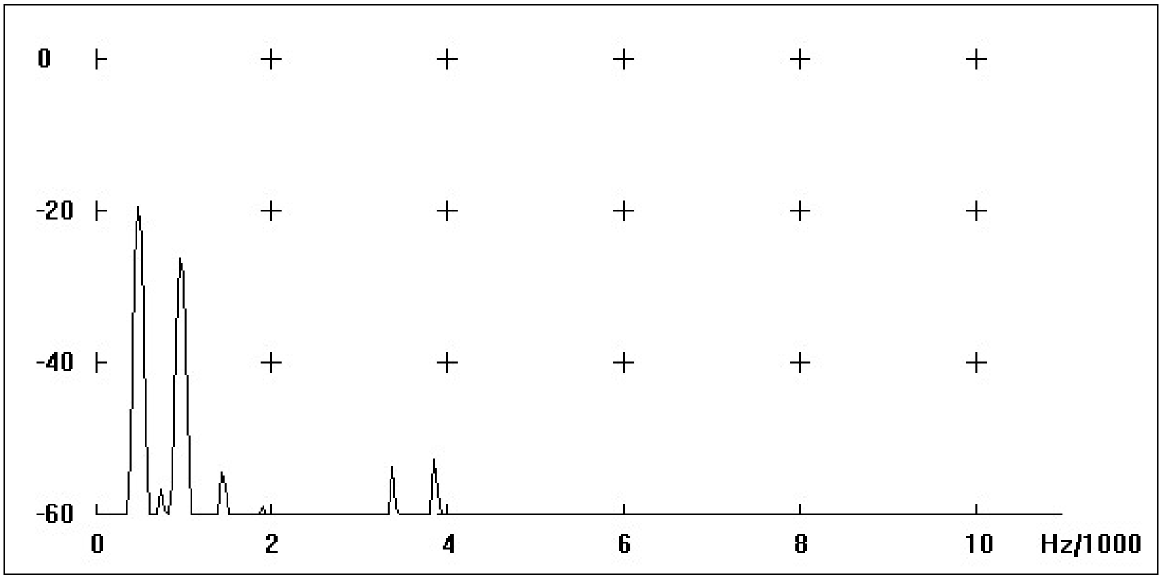
Power Spectrum from Spectrogram #4, Subject #3 at 2.25 seconds [i]



Power Spectrum from Spectrogram #4, Subject #3 at 3.79 seconds [o]

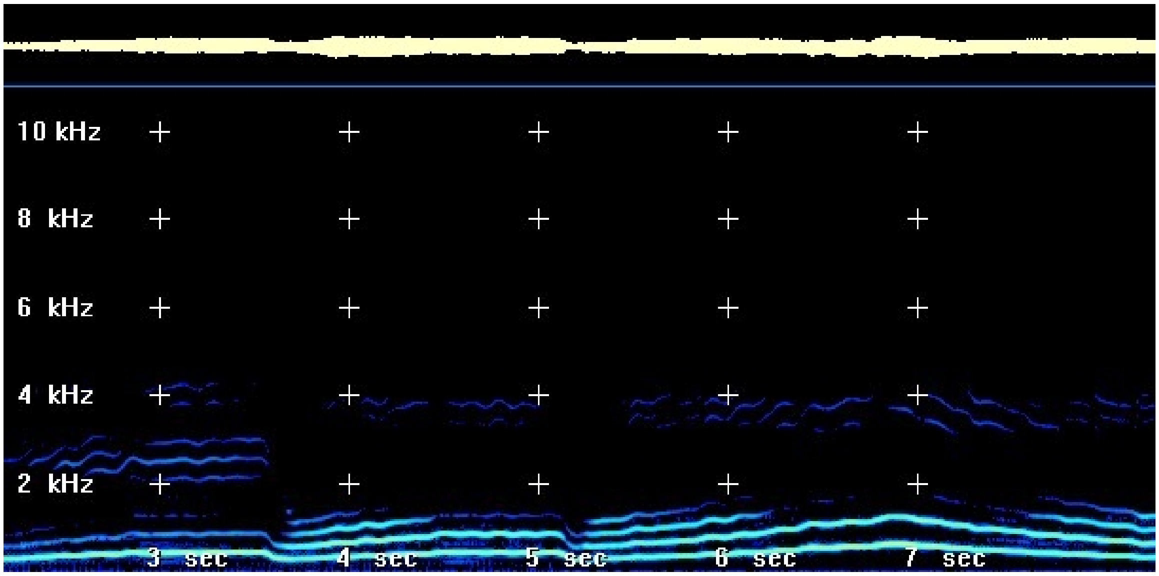


Power Spectrum from Spectrogram #4, Subject #3 at 5.09 seconds [a]



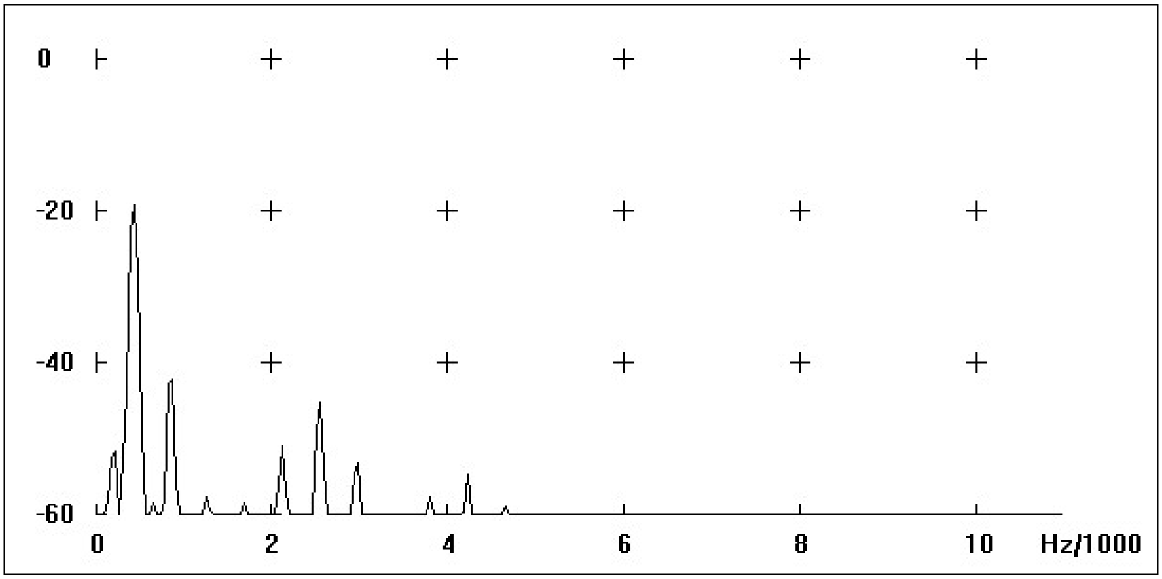
Analysis of Power Spectra from Spectrogram #4, Subject #3 – September 14, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.25	4	1	.25	3	7	.42	.33
3.79	3	2	.66	2	5	.4	.53
5.09	5	2	.4	2	7	.28	.34
Average of three chiaroscuro levels							.4

Wave File Number 5 – September 19, 2000 – Subject #3

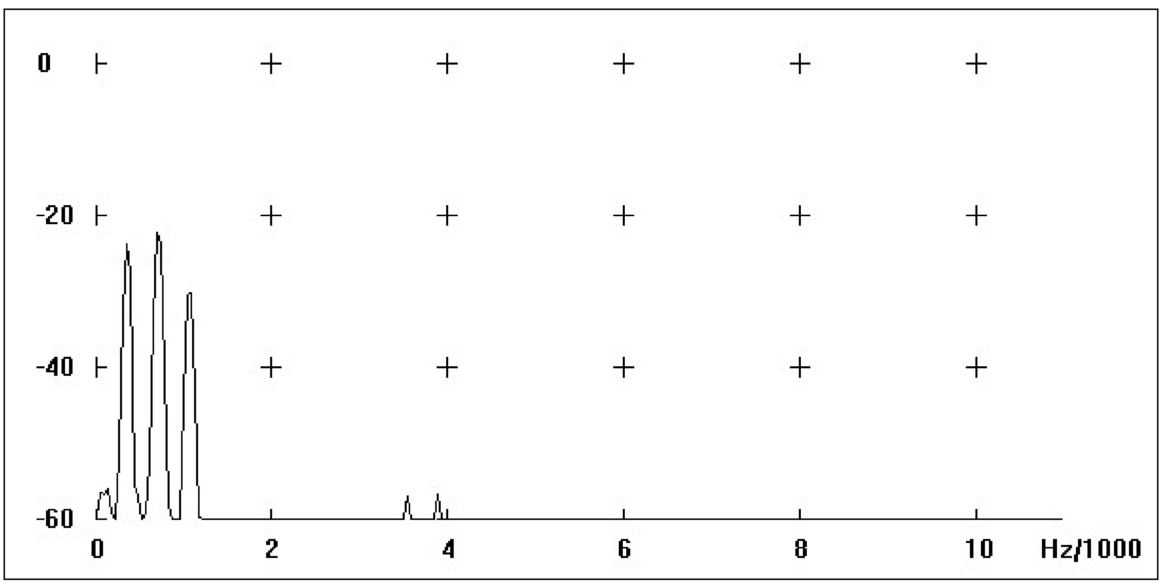


Subject #3 – Analysis of Wave File #5 – September 19, 2000 – D major				
		[si] (2.19-3.54 sec)	[o] (3.66-5.1 sec)	[a] (5.27-9.16 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	2 small indications above vowel	1 partial indication	2 partial bands
2nd Formant Area (Vowel Definition)		Good vowel definition	Weak vowel definition	Good vowel definition, but show damping at high pitches
1st Formant Area		Weak	Weak	Weak
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 15%	Varying around 20%	Varying around 20%
Little change from wave file #4				

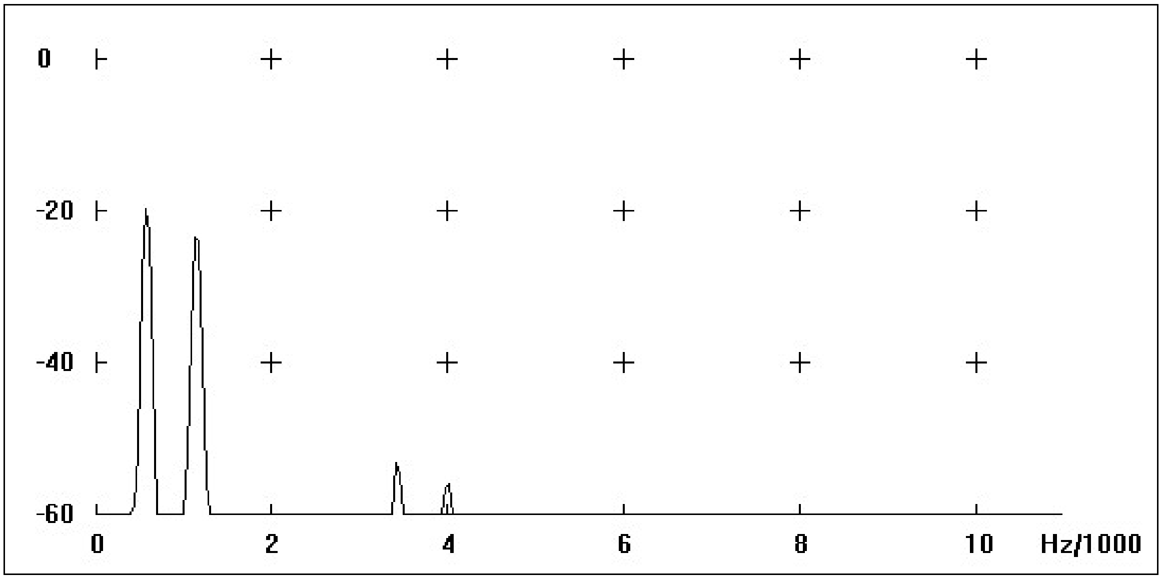
Power Spectrum from Spectrogram #5, Subject #3 at 3.1 seconds [i]



Power Spectrum from Spectrogram #5, Subject #3 at 4.12 seconds [o]

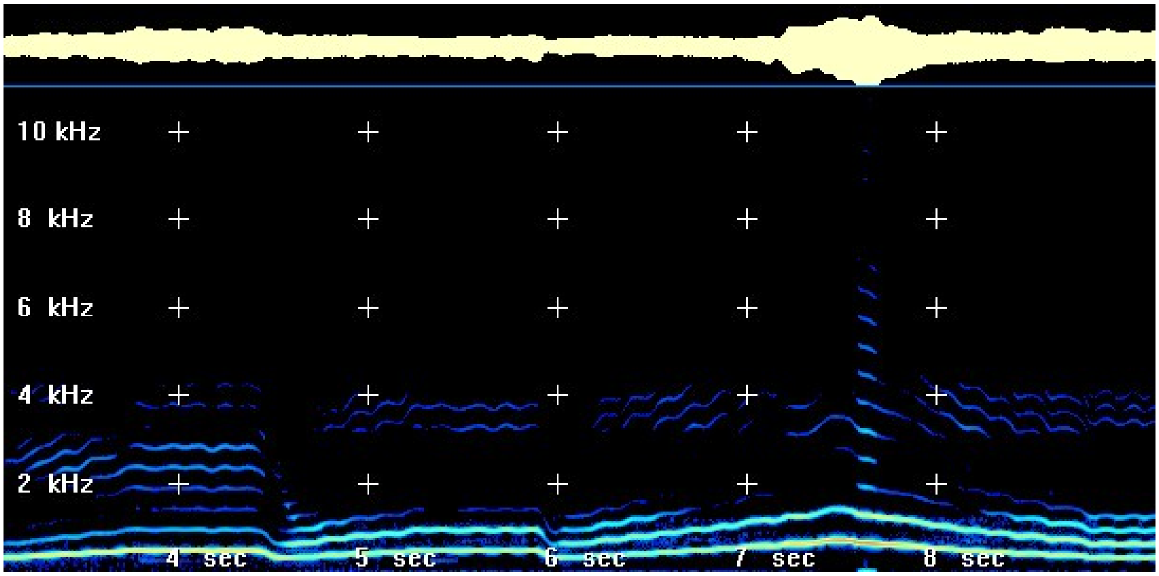


Power Spectrum from Spectrogram #5, Subject #3 at 7.08 seconds [a]



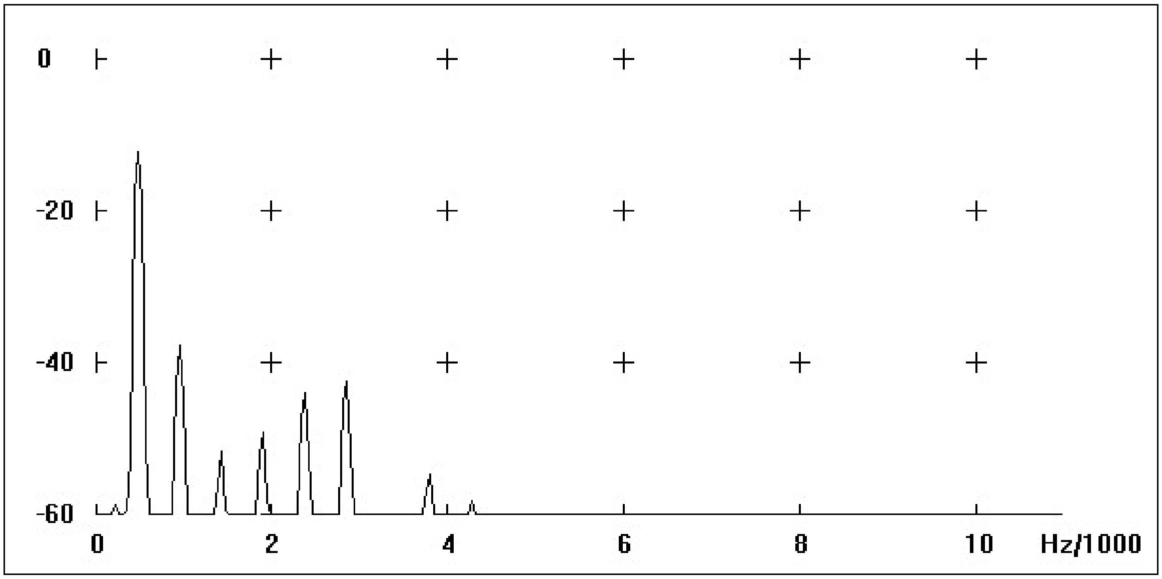
Analysis of Power Spectra from Spectrogram #5, Subject #3 – September 19, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.1	6	1	.16	6	12	.5	.33
4.12	4	3	.75	2	6	.33	.54
7.08	2	2	1.0	2	4	.5	.75
Average of three chiaroscuro levels							.54

Wave File Number 6 – September 29, 2000 – Subject #3

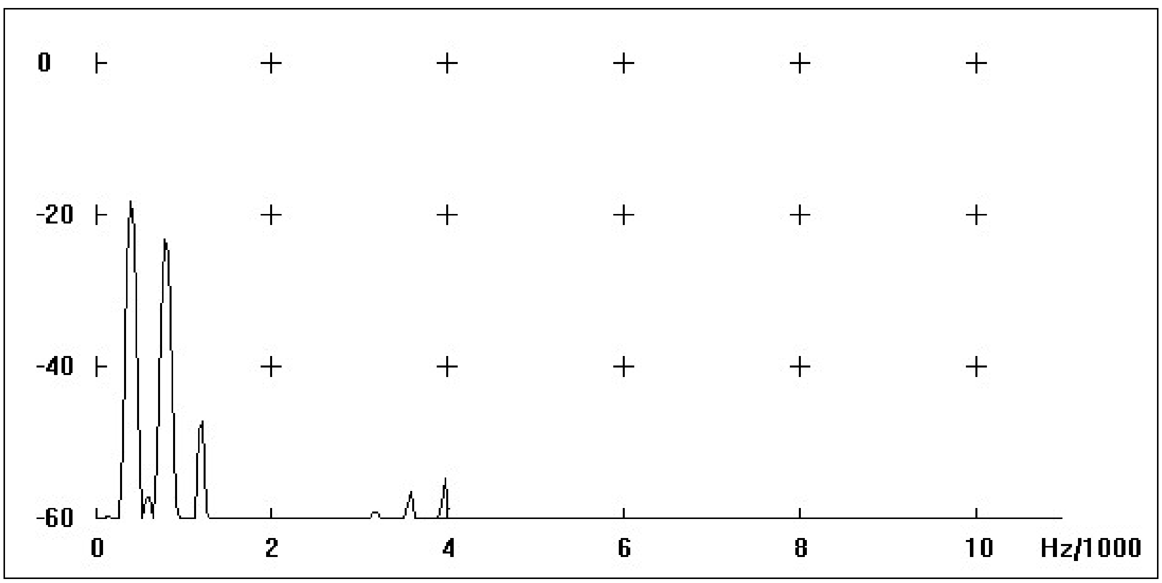


Subject #3 – Analysis of Wave File #6 – September 29, 2000 – E flat major				
		[si] (3.1-4.44 sec)	[o] (4.56-5.88 sec)	[a] (6.07-9.53 sec)
Singer's Formant Area	4000+ Hz			Spike at 7.6 is just after highest note – possibly indicates late breath support
	2000-4000 Hz	One nearly solid band above vowel	2 nearly solid bands	3 nearly solid bands
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Considerably stronger	About the same as in wave file #5	Stronger at high pitches
Chiaroscuro Balance		Nearly balanced	Better balance	Better balance
Power Spectrum		Varying around 30%	Varying around 20%	Varying around 30% with increase to about 90% at highest pitches
This wave file shows another good day at working on resonance techniques. The spike in the upper part of the [a] vowel is an audible extra effort for the high note. It comes later than it should; the increase in air pressure should occur gradually leading up to the highest note and decrease gradually.				

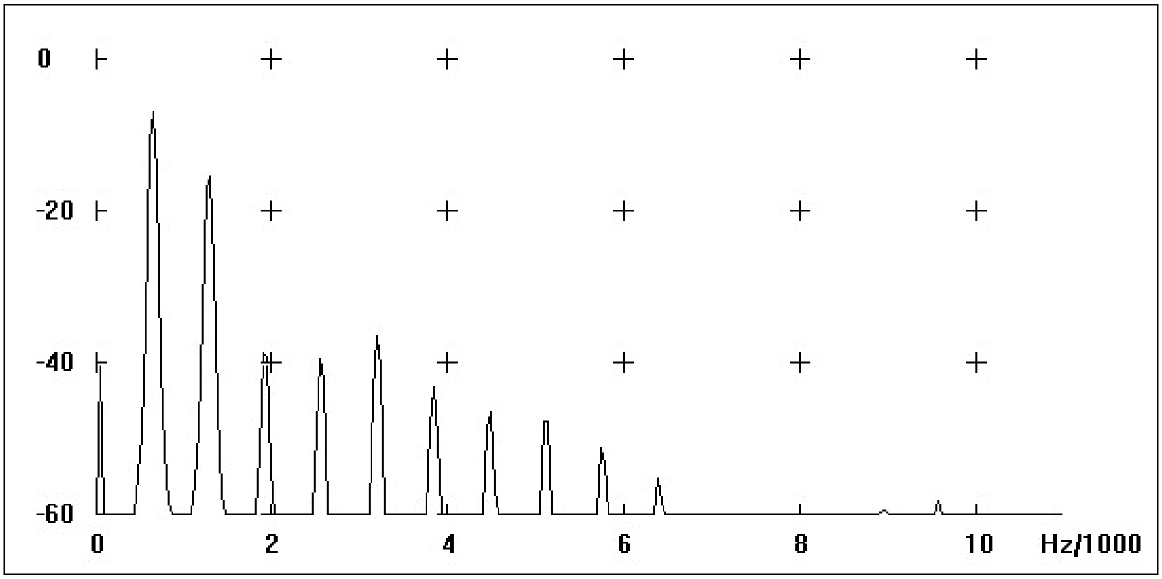
Power Spectrum from Spectrogram #6, Subject #3 at 4.24 seconds [i]



Power Spectrum from Spectrogram #6, Subject #3 at 4.93 seconds [o]

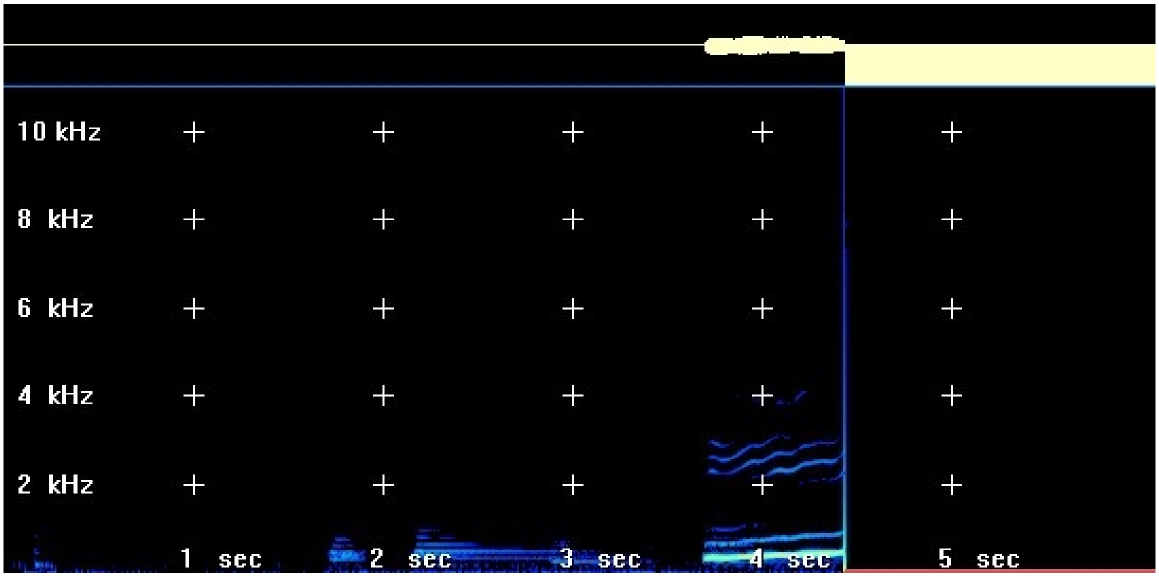


Power Spectrum from Spectrogram #6, Subject #3 at 7.63 seconds [a]



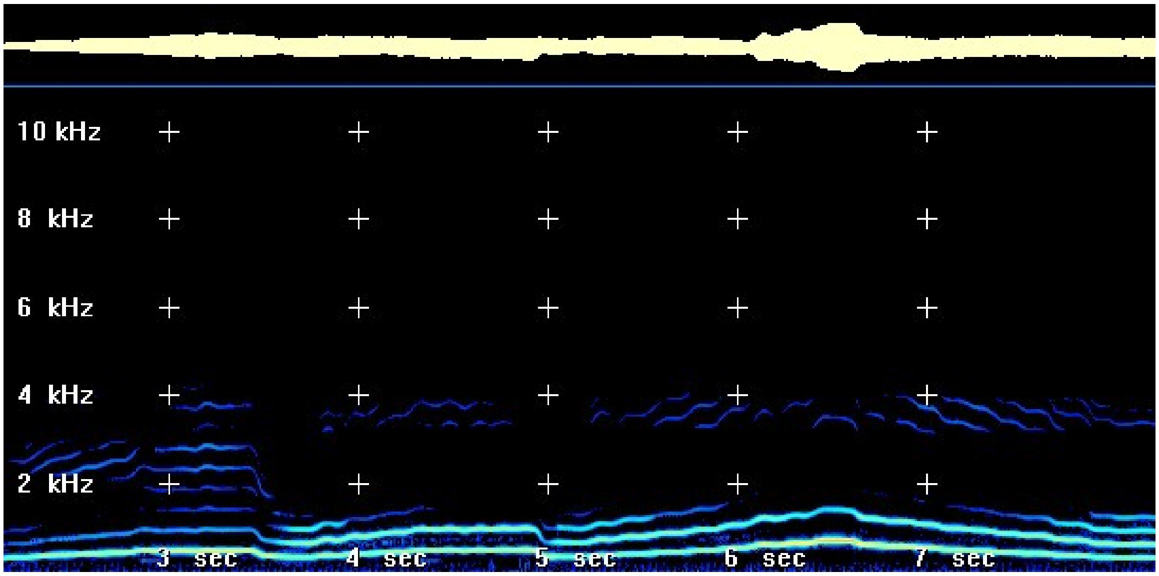
Analysis of Power Spectra from spectrogram #6, Subject #3 – September 29, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	b/a	c	d	c/d	(b/a+c/d)/2
4.24	5	2	.4	4	9	.44	.42
4.93	5	2	.4	3	8	.37	.38
7.63	4	4	1.0	9	13	.69	.84
Average of three chiaroscuro levels							.54

Wave File Number 7 – October 5, 2000 – Subject #3



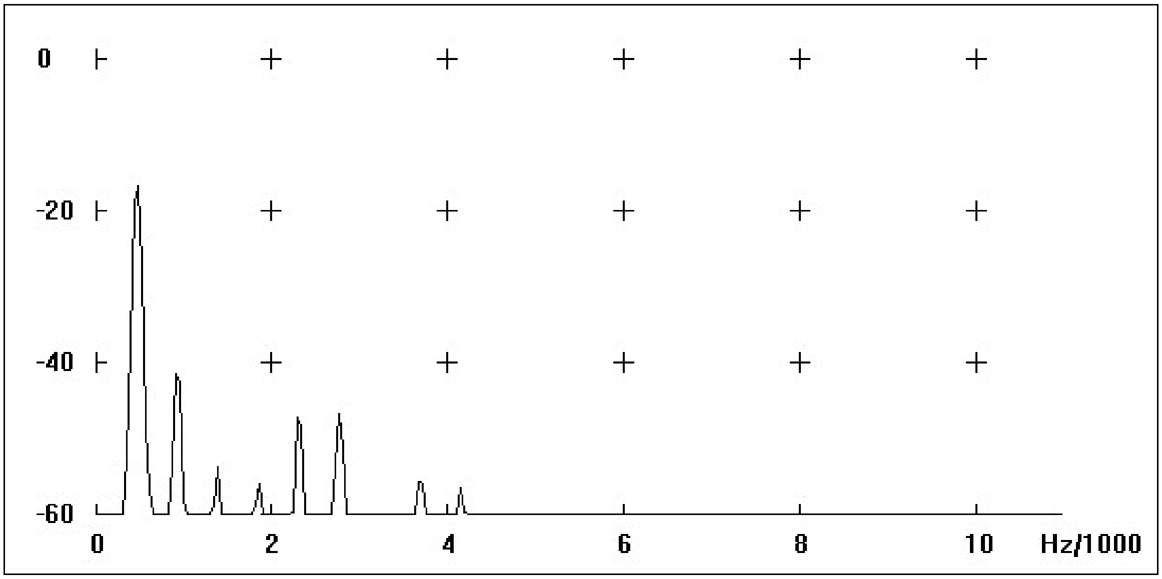
Subject #3 – Analysis of Wave File # 7 – October 5, 2000 – E flat major				
		[si] (sec)	[o] (sec)	[a] (sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz			
2nd Formant Area (Vowel Definition)				
1st Formant Area				
Chiaroscuro Balance				
Power Spectrum				
The data on the floppy disc made October 5 was damaged. Only this small section of this wave file was recoverable. Analysis is not possible from this amount of data.				

Wave File Number 8 – September 6, 2000 – Subject #3

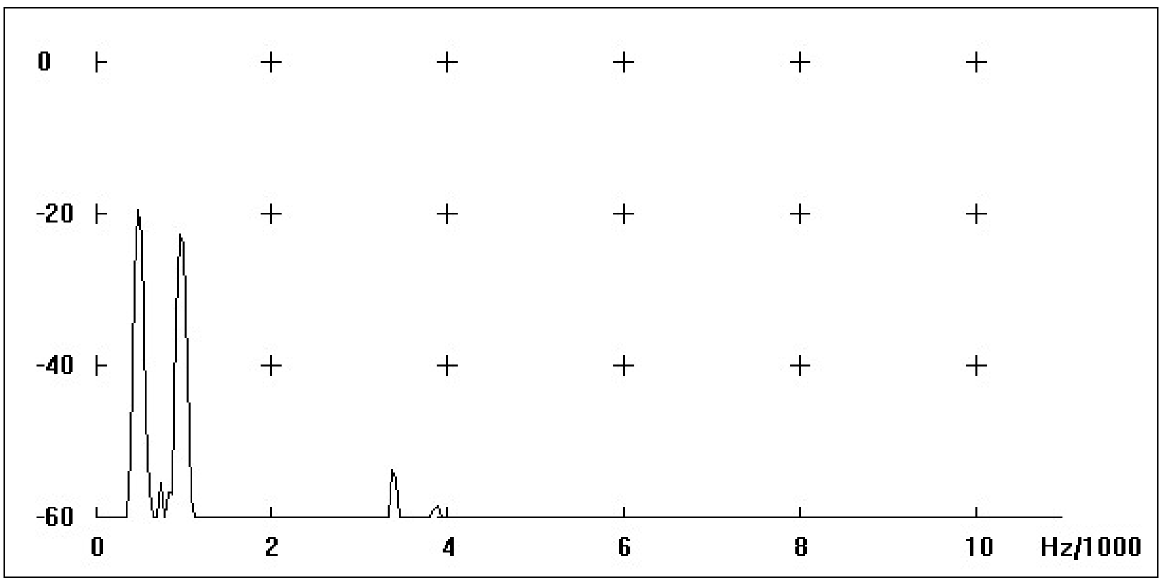


Subject #3 – Analysis of Wave File #8 – October 10, 2000 – E flat major				
		[si] (2.15-3.42 sec)	[o] (3.67-4.9 sec)	[a] (5.09-8.6 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	2 partial bands above vowel	2 partial bands	2-3 partial bands
2^{nd} Formant Area (Vowel Definition)		Clear vowel definition	Weak vowel definition	Weak vowel definition
1^{st} Formant Area		Continuing to strengthen	Continuing to strengthen	Continuing to strengthen
Chiaroscuro Balance		Somewhat balanced	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 25%	Varying around 25%	Varying around 25% with increase to about 60% at highest pitches
Progress toward a resonant tone is uneven. It is often inhibited by the student's ever-present body tension. The indication in this wave file of a tense day is the almost total lack of vibrato. Healthy vibrato occurs when the larynx is free to move. Tension in the muscles around the larynx often decreases vibrato. The same tension also occurs from holding the larynx still to sing with a straight tone, a practice that is discouraged in healthy singing.				

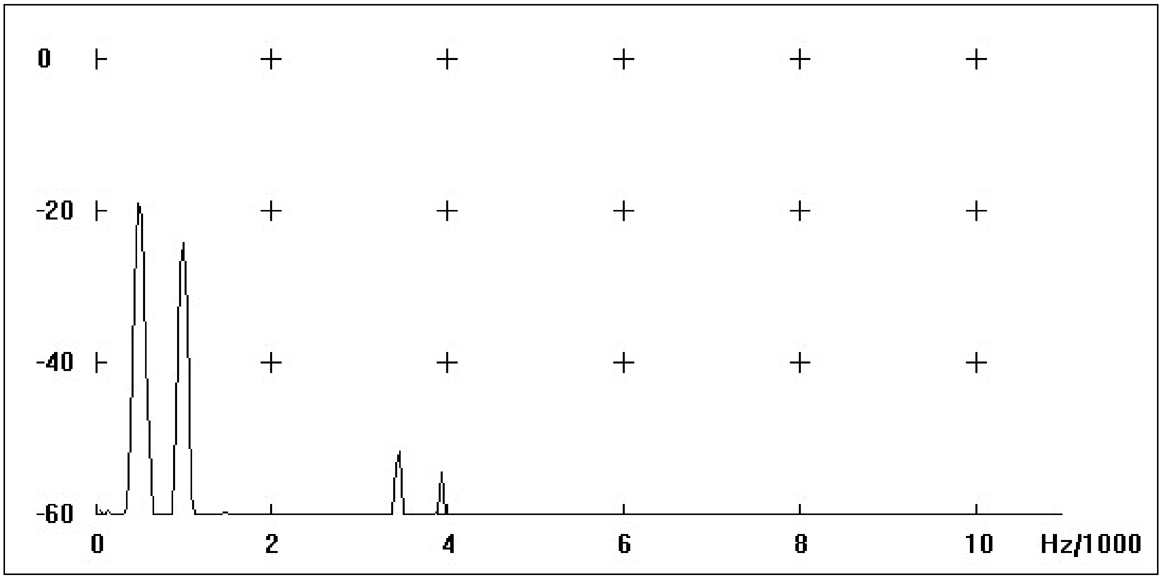
Power Spectrum from Spectrogram #8, Subject #3 at 3.13 seconds [i]



Power Spectrum from Spectrogram #8, Subject #3 at 4.49 seconds [o]

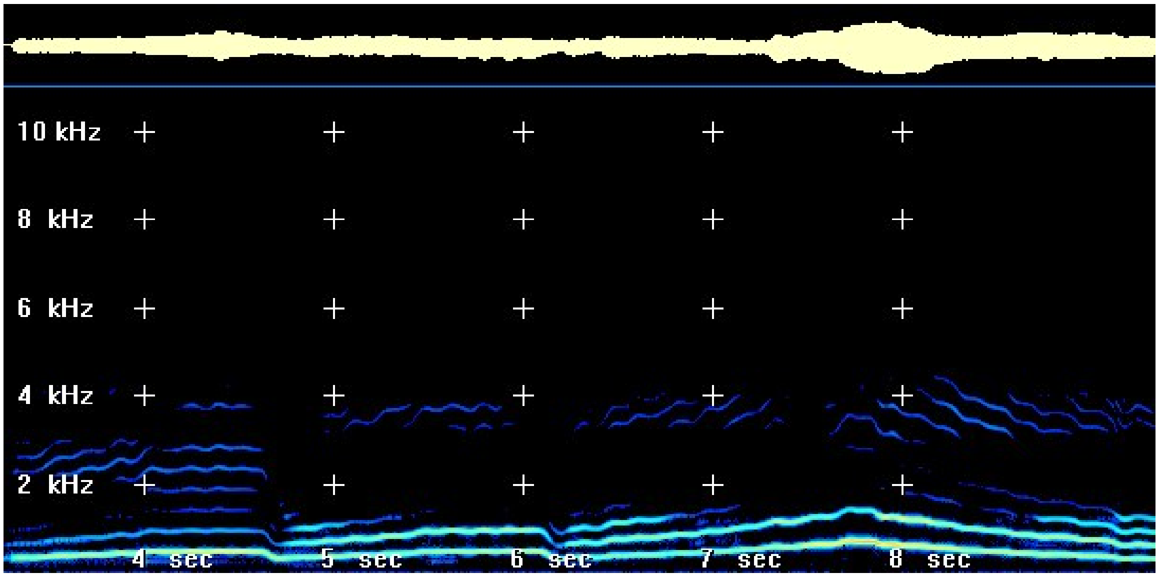


Power Spectrum from Spectrogram #8, Subject #3 at 7.11 seconds [a]



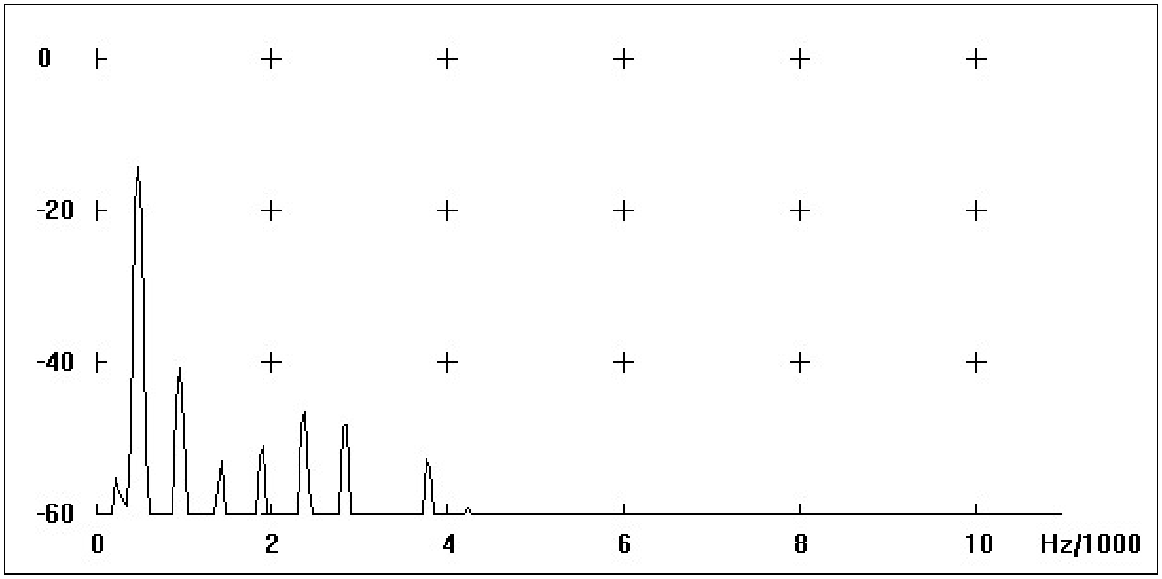
Analysis of Power Spectra from Spectrogram #8, Subject #3 – October 10, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.13	4	1	.25	4	8	.5	.37
4.49	3	2	.66	2	5	.4	.53
7.11	4	2	.5	2	6	.33	.41
Average of three chiaroscuro levels							.43

Wave File Number 9 – October 17, 2000 – Subject #3

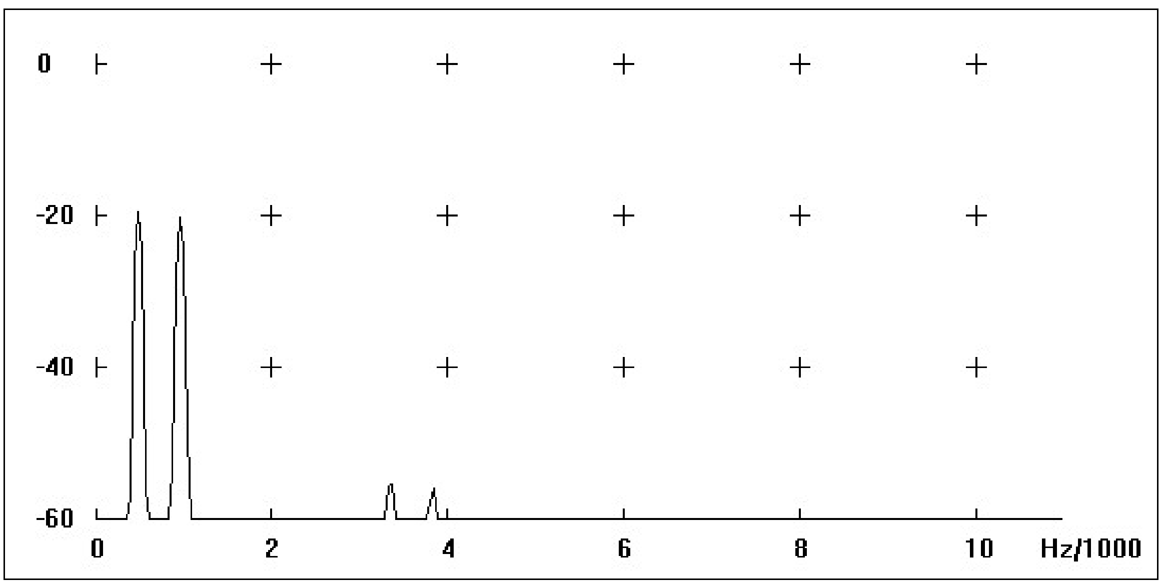


Subject #3 – Analysis of Wave File #9 – October 17, 2000 – E flat major				
		[si] (3.32-4.63 sec)	[o] (4.82-6.07 sec)	[a] (6.24-10 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Somewhat stronger than in Wave File 8	Somewhat stronger than in Wave File 8	Somewhat stronger than in Wave File 8
2nd Formant Area (Vowel Definition)		Good vowel definition	Good vowel definition	Good vowel definition
1st Formant Area		Somewhat stronger than in Wave File 8	Somewhat stronger than in Wave File 8	Somewhat stronger than in Wave File 8 especially at highest pitches
Chiaroscuro Balance		Somewhat balanced	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 25%	Varying around 25%	Varying around 25% with increase to about 75% at highest pitches
First formant area is stronger, as are the singer's formant area. Some degree of relaxation shows in slightly increased vibrato.				

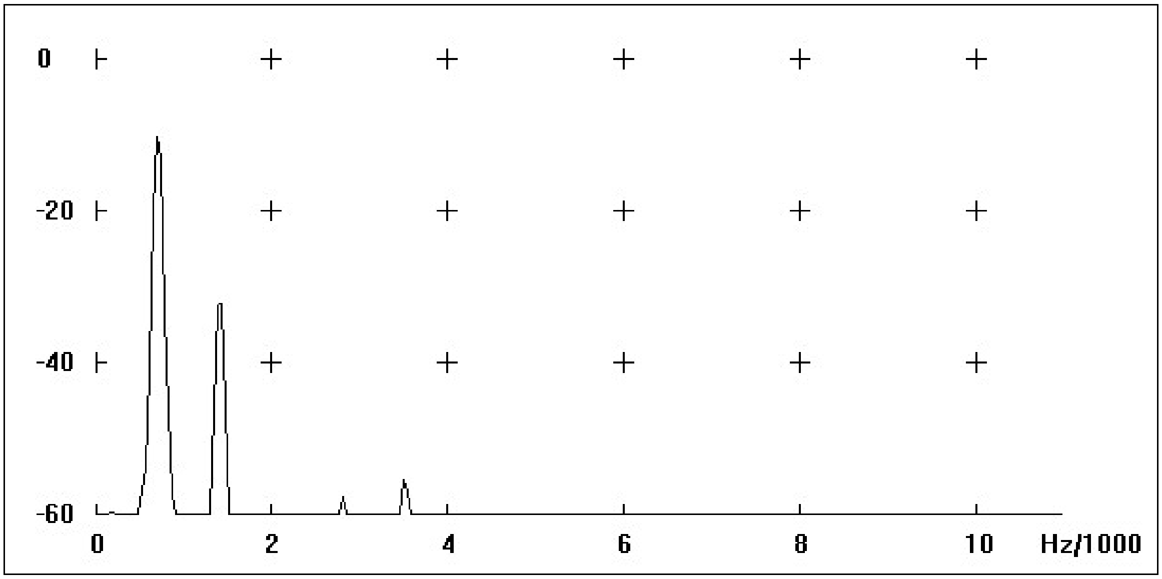
Power Spectrum from Spectrogram #9, Subject #3 at 4.44 seconds [i]



Power Spectrum from Spectrogram #9, Subject #3 at 5.8 seconds [o]

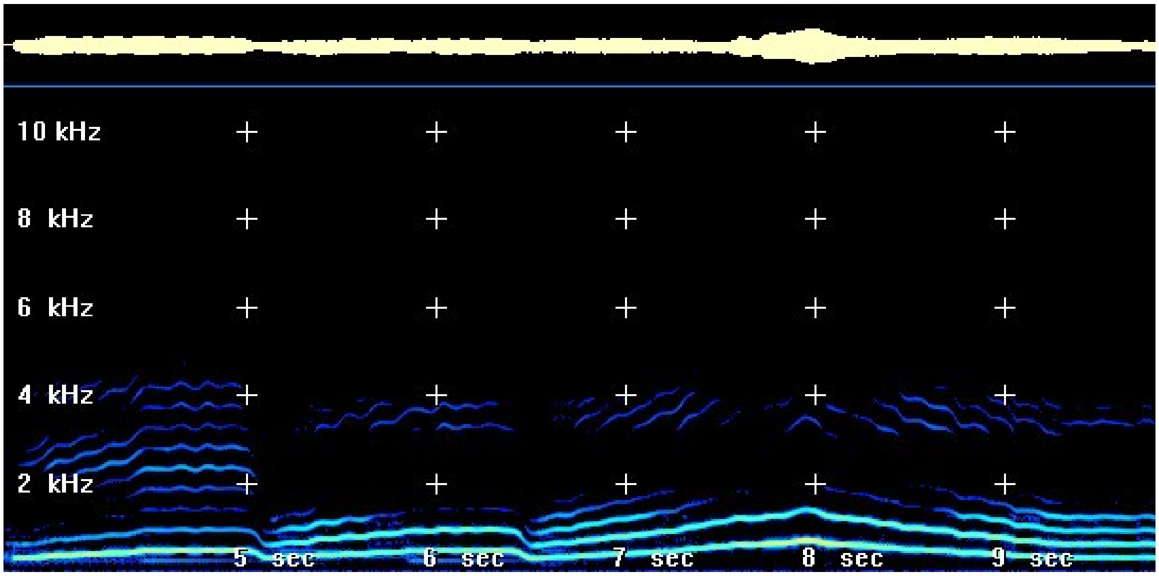


Power Spectrum from Spectrogram #9, Subject #3 at 7.78 seconds [a]



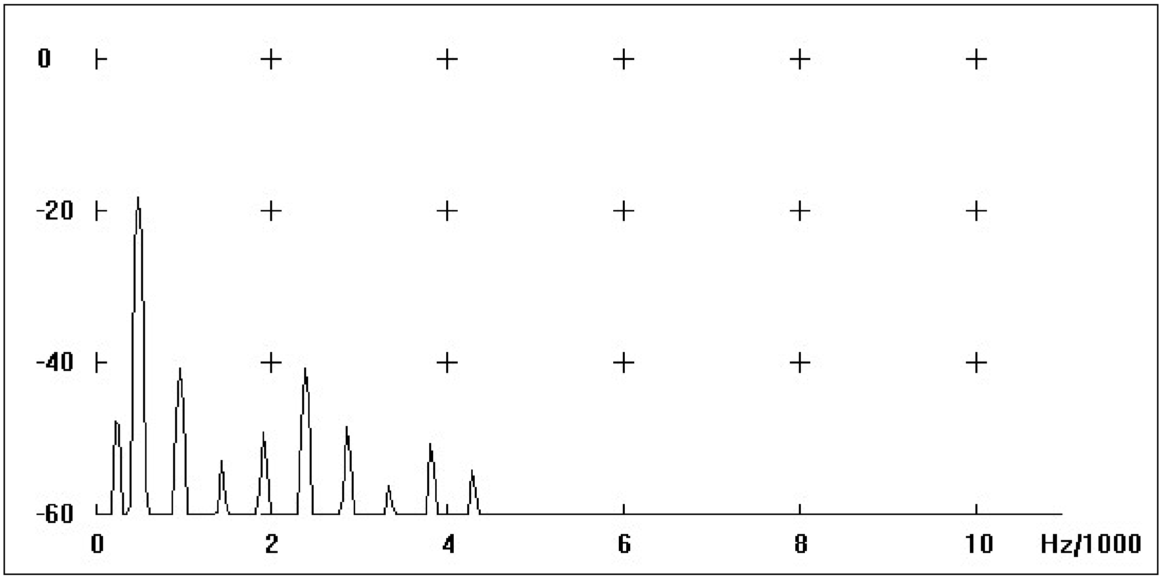
Analysis of Power Spectra from Spectrogram #9, Subject #3 – October 17, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.44	5	1	.2	4	9	.44	.32
5.8	2	2	1.0	2	4	.5	.75
7.78	3	2	.66	2	5	.4	.53
Average of three chiaroscuro levels							.53

Wave File Number 10 – October 24, 2000 – Subject #3

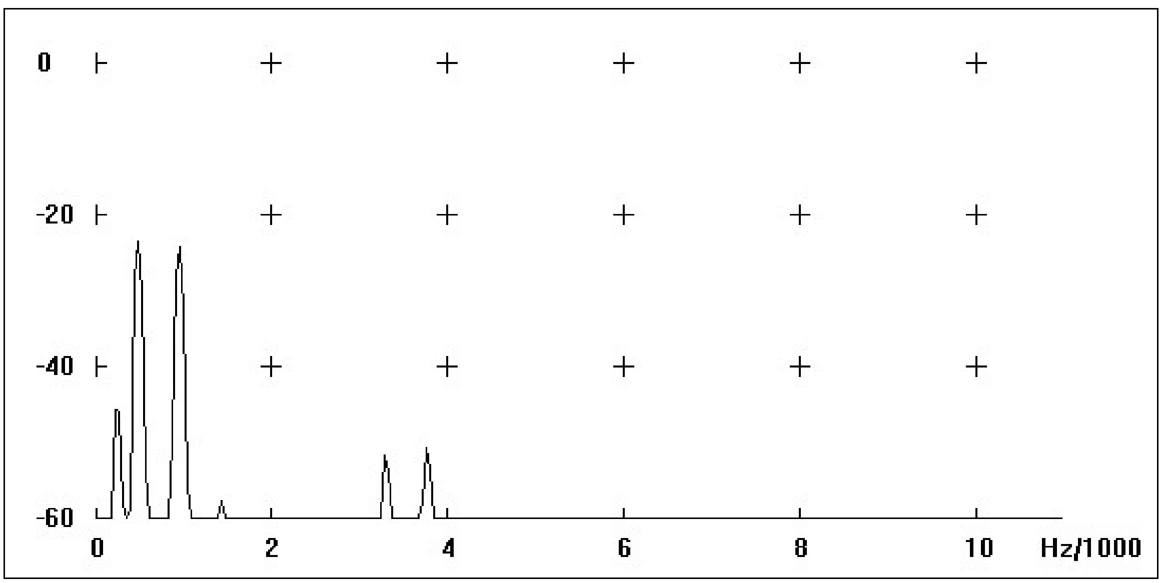


<table>
<tr><td colspan="5">Subject #3 – Analysis of Wave File #10 – October 24, 2000 – E flat major</td></tr>
<tr><td colspan="2"></td><td>[si] (3.81-5.02 sec)</td><td>[o] (5.15-6.4 sec)</td><td>[a] (6.54-9.95 sec)</td></tr>
<tr><td rowspan="2">Singer's Formant Area</td><td>4000+ Hz</td><td>Some indications approaching this area</td><td>Some indications approaching this area</td><td>Some indications approaching this area</td></tr>
<tr><td>2000-4000 Hz</td><td>About the same moderate strength as in wave file #9</td><td>About the same moderate strength as in wave file #9</td><td>About the same moderate strength as in wave file #9</td></tr>
<tr><td colspan="2">2nd Formant Area (Vowel Definition)</td><td>Good vowel definition</td><td>Good vowel definition</td><td>Good vowel definition</td></tr>
<tr><td colspan="2">1st Formant Area</td><td>About the same as in Wave File #9</td><td>About the same as in Wave File #9</td><td>About the same as in Wave File #9</td></tr>
<tr><td colspan="2">Chiaroscuro Balance</td><td>Somewhat balanced</td><td>Weighted toward lower frequencies</td><td>Weighted toward lower frequencies</td></tr>
<tr><td colspan="2">Power Spectrum</td><td>Varying around 25%</td><td>Varying around 20%</td><td>Varying around 20% with increase to about 40% at highest pitches</td></tr>
<tr><td colspan="5">The student's body tension is a difficult problem to overcome. It continues to interfere with voice production. Note that the vibrato has again decreased.</td></tr>
</table>

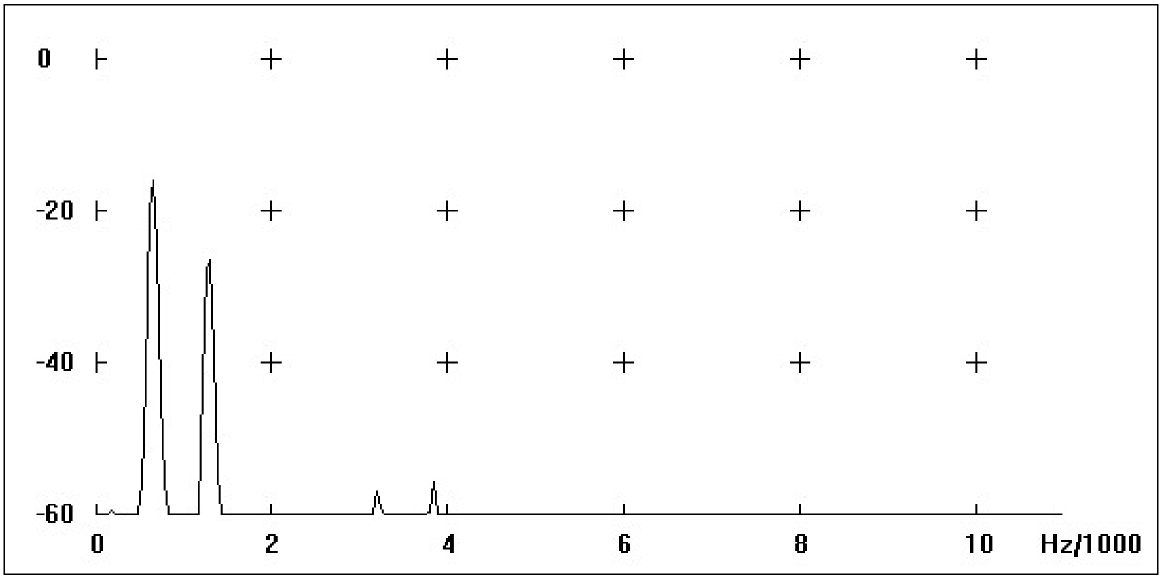
Power Spectrum from Spectrogram #10, Subject #3 at 4.66 seconds [i]



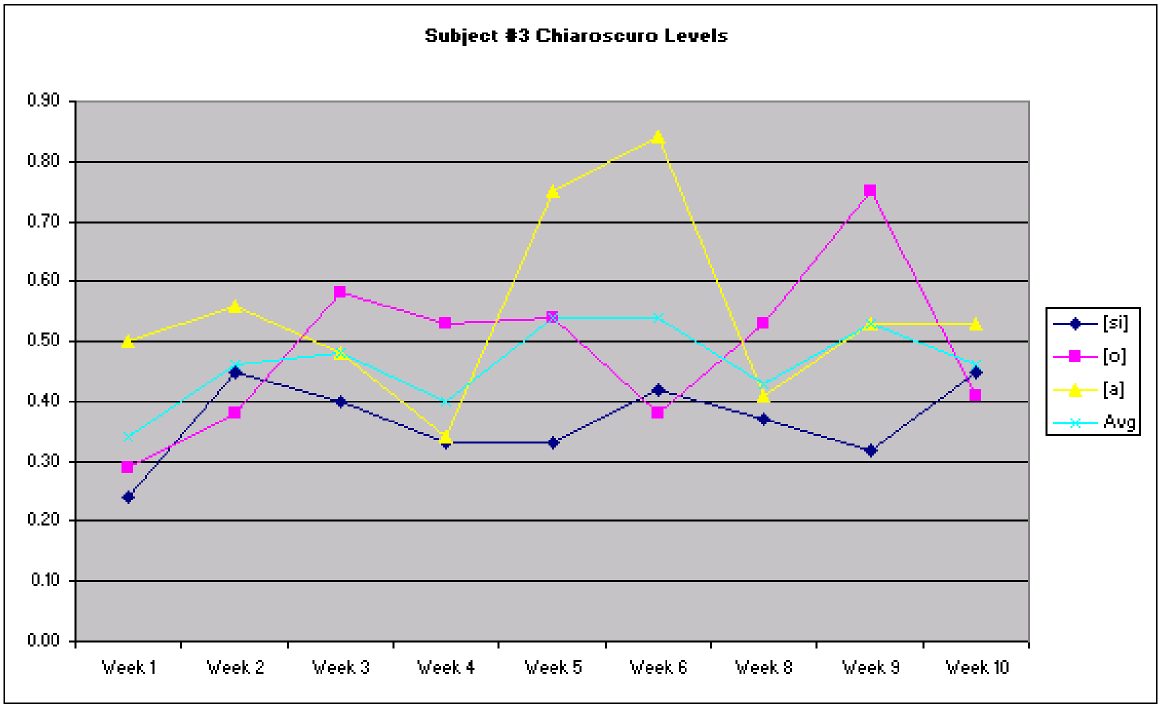
Power Spectrum from Spectrogram #10, Subject #3 at 6.03 seconds [o]



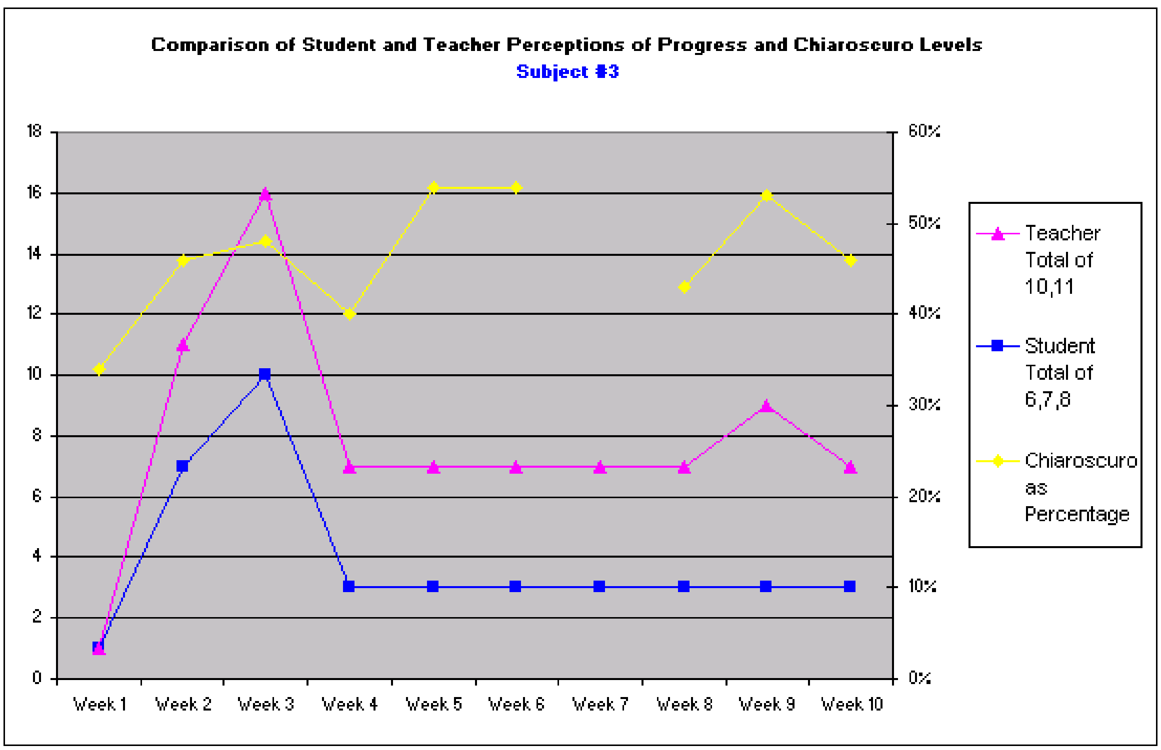
Power Spectrum from Spectrogram #10, Subject #3 at 7.87 seconds [a]



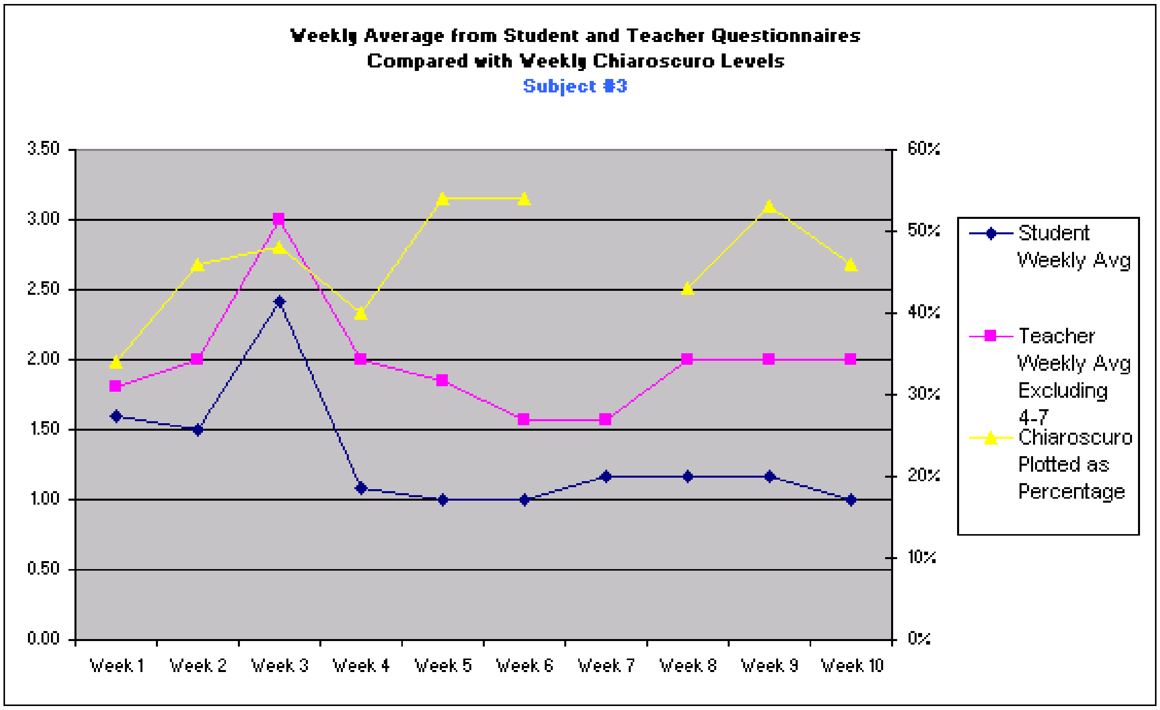
Analysis of Power Spectra from Spectrogram #10, Subject #3 – October 24, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.66	5	2	.4	5	10	.5	.45
6.03	4	2	.5	2	6	.33	.41
7.87	3	2	.66	2	5	.4	.53
Average of three chiaroscuro levels							.46



Subject #3 Chiaroscuro Levels
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg



Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #3
18
16
14
12
10
8
6
4
2
0
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage



Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #3
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A4: Subject #4

Subject #4 was a 19-year-old African-American sophomore majoring in vocal performance. Her home was in Gwinnett County, in the northeastern metropolitan Atlanta area. During the semester in which data were gathered, she made enormous strides in vocal technique and self-confidence. She discovered that she had an ear for languages and presented several successful performances. She was vocally healthy all semester.

At the time of the data collection she had been a student in the researcher's studio for one year. She first entered the studio as a freshman vocal performance major, but her background was almost entirely nonclasssical. Using a familiar pop style, she had a successful performance in the Broadway recital during the fall semester. Because her self-confidence was so low, it seemed best not to work on changing her vocal production until after that performance. After two semesters of work on vocal production, as well as introductory work on diction during the data collection semester, Subject #4 demonstrated marked improvement. She was chosen for one of the major solos in the chamber choir's December program, and she gave an excellent performance.

Subject #4's vocal production was never harmful, but tended toward an unresonated microphone style. Along with an innate musicality and sensitivity to text, Subject #4 had a beautiful mezzo-soprano voice of operatic proportions. Her range increased rapidly along with the dynamic power of her voice. She found singing in French to be particularly productive, since French vowels lend themselves to singing well-resonated tones. At the end of the semester she was singing *Cantique de Noël* in the soprano key, which requires a b-flat^2.

The spectrograph was a little confusing to Subject #4 initially. She seemed to see it as a test or criticism. As she became more familiar with it, she began to see it as a visual reflection of her sound that could help her learn to control her large instrument.

Fall Semester 2000 Repertoire – Subject #4

Fauré	Les Berceaux
Schubert	Frühlingsglaube
Britten	The Ash Grove
Quilter	Damask Roses
Menotti	Lullaby from *The Consul*
Martini	Piacer d'Amor
Adam	Cantique de Noël
Fats Waller	Ain't Misbehavin'

Lesson record over the data collection period – Subject #4

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10-11
8/23	A	Rep assigned last spring – Martini, Menotti, Waller	Good	Voice is in good shape – she needs to trust her resonant sound more and use more elegant diction	#1 E-flat	Chiaroscuro - .4 Student n/a, n/a, 1 Teacher n/a, n/a
8/29	B	Fauré, Britten, Schubert	Not as good as I would like; needs to learn music faster	Voice excellent – worked diction and coaching (no accompanist)	#2 E flat	Chiaroscuro - .5 Student 1, 1, 1 Teacher 2, 2
8/29	A	Britten	VMC	Did excellent job on first time trying the Ash Grove with the accompaniment		
9/6	A	Fauré, Schubert, Quilter, Menotti, Waller	Good – she's been working	Coaching	#3 E flat	Chiaroscuro - .45 Student 1, 1, 1 Teacher 2, 2
9/13	A	Fauré, Schubert, Waller	Good	Coaching, especially diction – she is working hard and trying for elegance in diction		
9/20	A	Britten, Schubert, Waller	Good	Voice is in excellent shape – she is just blooming – continues to work well	#4 E flat	Chiaroscuro - .47 Student 1, 1, 1 Teacher 3, 3
9/27	A	Fauré, Britten, Schubert, Waller	Excellent	She is working well and the voice is blooming	#5 E flat	Chiaroscuro - .36 Student 1, 1, 1 Teacher 2, 2
10/4	A	Fauré, Britten, Schubert, Waller	Excellent	She's worked hard on her French and it's coming along – did Tuesday hearing with Ash Grove	#6 E-flat	Chiaroscuro - .5 Student 1, 1, 1 Teacher 3, 3
10/11	A	Fauré	Excellent	Concerned that she has too much vibrato – analyzed her WF and counted the cycles (5-6/sec) – well within normal!	#7 E-flat	Chiaroscuro - .4 Student 1, 1, 1 Teacher 2, 2
10/16	A	Fauré	Excellent	Midterm recital – very successful		
10/18	A	Schubert, Martini, Menotti	Good	Voice coming along with siz and strength developing – works hard – excellent German – she's a natural mimic	#8 E flat	Chiaroscuro - .43 Student 3, 1, 1 Teacher 2, 2
10/25	A	Schubert, Menotti	Good	She is such a natural mimic! Her German vowels are very good when she hears and copies – has worked hard on Schubert – coached Menotti w/ accompanist	#9 E flat	Chiaroscuro - .6 Student 1, 1, 1 Teacher 2, 2
11/1	A	Adam, Schubert	Excellent	She wanted to add the Adam to her rep, and sing it in E flat - vocal progress escellent – high B flat is coming in	#10 E flat	Chiaroscuro - .51 Student 3, 1, 1 Teacher 3, 3
11/7	A	Schubert	Excellent	Pre-recital hearing – very successful		
11/8	A	Martini, Britten, Schubert	Excellent	Voice is growing in size and range – her confidence improves with each success.		
11/15	A	Schubert	Good	She is concentrating on her performance rep and neglecting some of the other rep, but her vocal gains are extraordinary		
11/19	A	Schubert	Excellent	Another success		
11/29	B	Quilter, Britten, Martini	Panic stricken	She is not prepared to sing this rep at her jury on Friday – trying to cram – putting off Menotti until spring		

12/1	B	Britten, Martini	Tried hard, but had memory lapses	She was so nervous about not having learned her music that she did not sing as well as she should have – recital card has only 7 concerts! – She will make a B for the semester in spite of all her fine vocal progress.		

Responses to student questionnaires – Subject #4

Question	8/23	8/29	9/6	9/20	9/27	10/4	10/11	10/18	10/25	11/1	**Total of weekly answers to questions 6, 7. 8**
1	1	1	1	1	1	1	1	1	1	1	
2	1	1	1	1	1	1	1	1	1	1	
3	3	1	1	1	1	1	1	2	1	1	
4	1	1	1	1	1	1	1	1	1	1	
5	1	1	1	1	1	1	1	1	1	1	
6	N/a	1	1	1	1	1	1	3	1	3	**1.77**
7	N/a	1	1	1	1	1	1	1	1	1	**1**
8	1	1	1	1	1	1	1	1	1	1	**1**
9	1	1	1	1	1	1	1	1	1	1	**Average over ten week period**
10	1	1	2	1	1	1	1	1	1	1	
11	3	2	1	2	1	1	1	1	1	1	
12	3	1	1	2	1	1	1	1	1	1	
Weekly Average	1.6	1.08	1.08	1.16	1	1.25	1	1.25	1	1.16	**1.25**

Responses to teacher questionnaires – Subject #4

Quantification of the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)

2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)

3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)

4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)

5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

Question	8/23	8/29	9/6	9/20	9/27	10/4	10/11	10/18	10/25	11/1	
1	2	3	2	2	2	2	2	2	2	2	**Totals and average of questions 10 & 11**
2	2	2	1	2	2	1	1	2	2	2	
3	2	3	2	2	2	2	2	2	2	2	
4	3	1	1	4	4	4	2	3	3	3	
5	5	4	2	5	3	5	2	3	4	4	
6	3	5	2	5	4	5	5	4	3	4	
7	5	5	5	5	5	5	5	5	5	5	
8	2	1	1	2	2	2	2	2	2	2	
9	2	1	1	2	2	3	2	2	2	3	
10	N/a	2	2	3	2	3	2	2	2	3	**2.33**
11	N/a	2	2	3	2	3	2	2	2	3	**2.33**
Weekly Average excluding questions 4-7	2	2	1.57	2.28	2	2.28	1.85	2	2	2.42	**2.33**

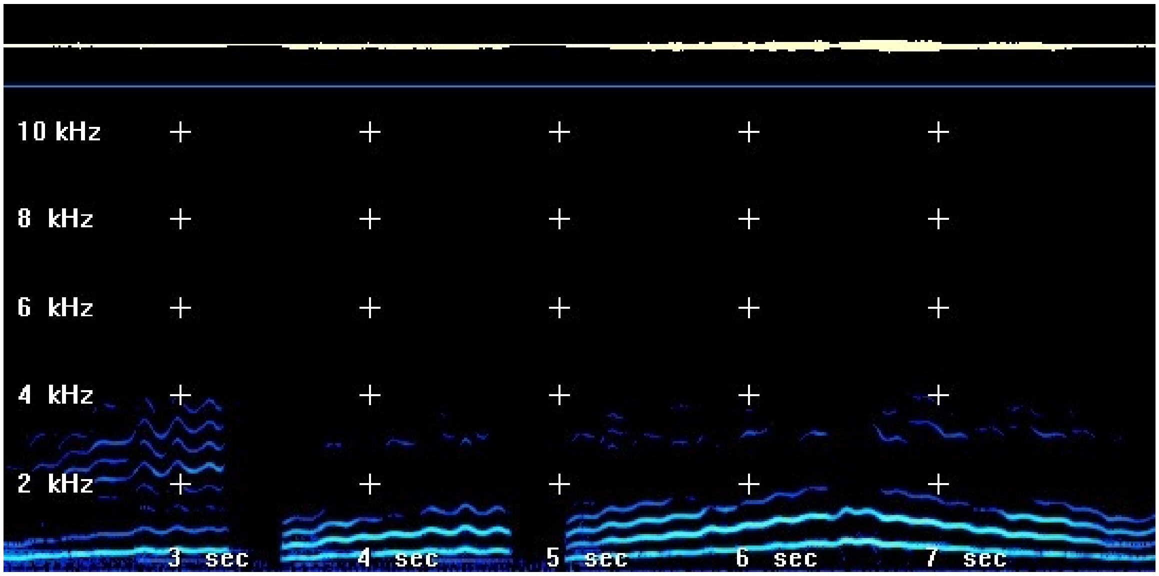
Student’s Written Reaction to Use of Spectrograph – Subject #4

I enjoyed working with the spectrograph from the very first time we used it in my voice lesson. However, my appreciation for the device grew as I began to further understand the visual representation of what I was singing. As the semester continued, I could actually see the changes in tone quality. It was exciting to have a visual representation of the changes in my voice.

The spectrograph was very helpful once I understood how it worked. It might be nice to have a little bit more explanation during voice lessons. Overall, I found working with the spectrograph enjoyable and informative.

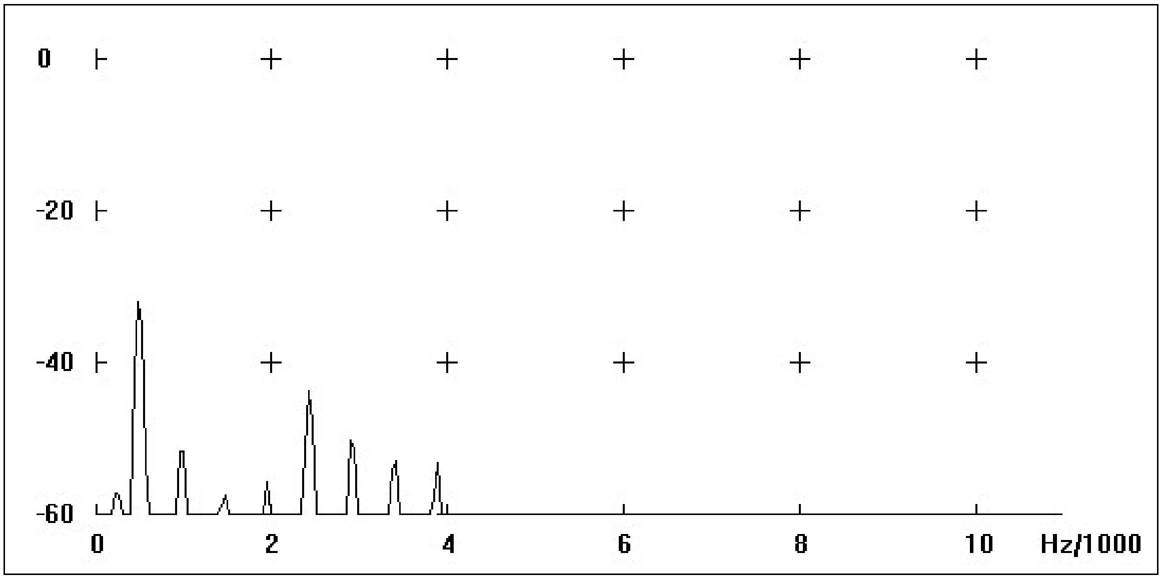
Analysis of Wave Files

Wave File Number 1 – August 23, 2000 – Subject #4

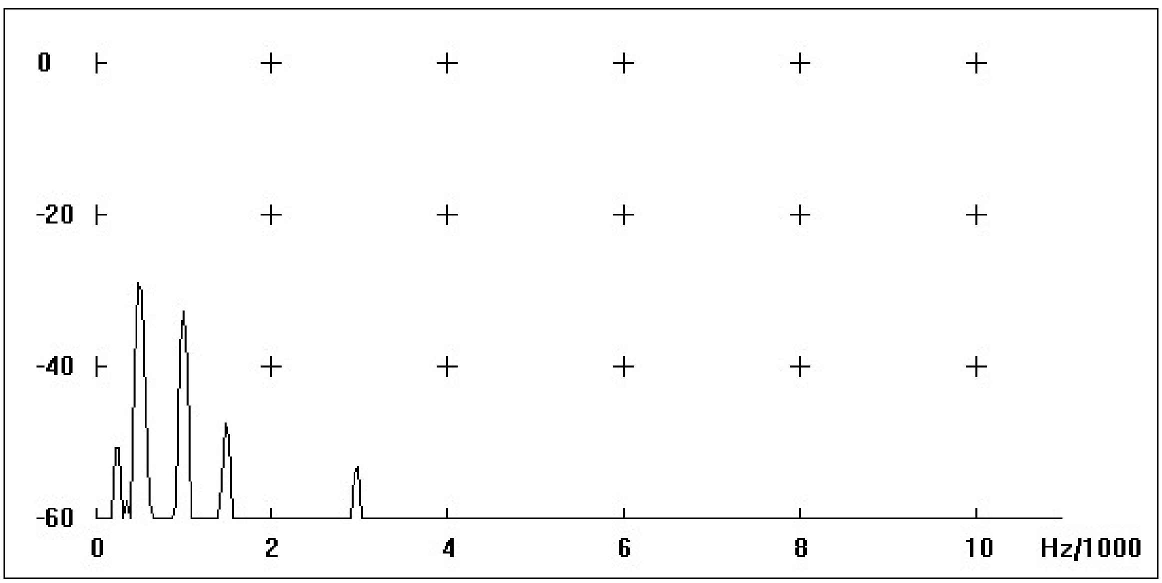


Subject #4 – Analysis of Wave File #1 – August 23, 2000 – E flat major				
		[si] (2.0-3.23 sec)	[o] (3.55-4.76 sec)	[a] (5.05-8.8 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Good indications	Slight indications	Slight indications – tendancy to damp higher frequencies
2nd Formant Area (Vowel Definition)		Good vowel definition	Good vowel definition	Good vowel definition
1st Formant Area		Shows strength	Shows strength	Shows strength
Chiaroscuro Balance		Nearly balanced – could be stronger in both areas	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 5%	Varying around 10%	Varying around 15%
Surprising weakness in power spectrum may be due to student standing too far back from microphone. Excellent young voice (sophomore) working on resonance techniques that she learned as a freshman.				

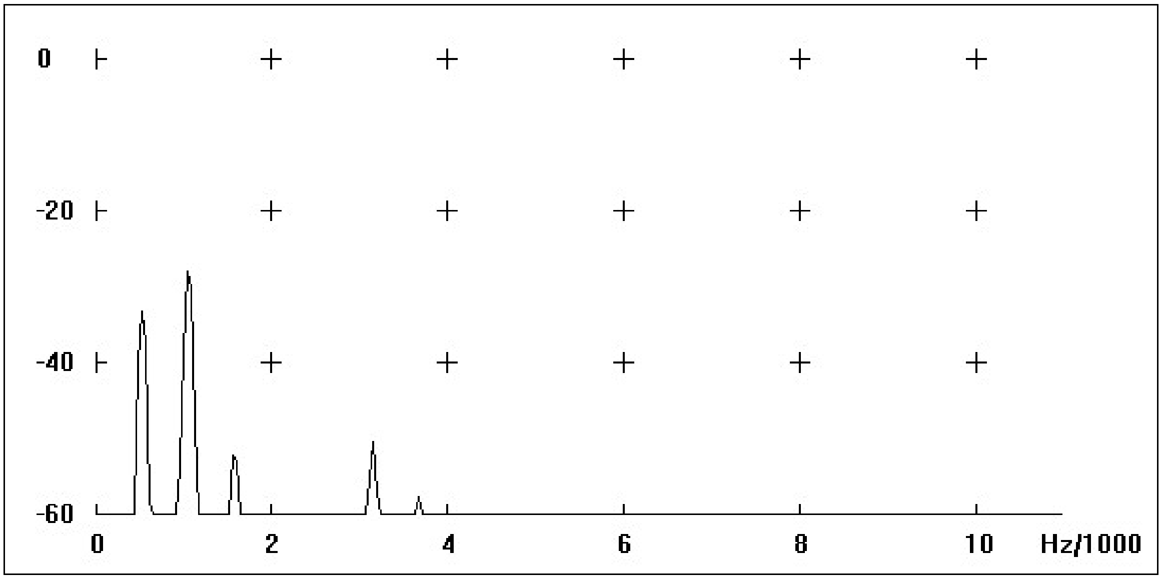
Power Spectrum from Spectrogram #1, Subject #4 at 3.15 seconds [i]



Power Spectrum from Spectrogram #1, Subject #4 at 4.5 seconds [o]

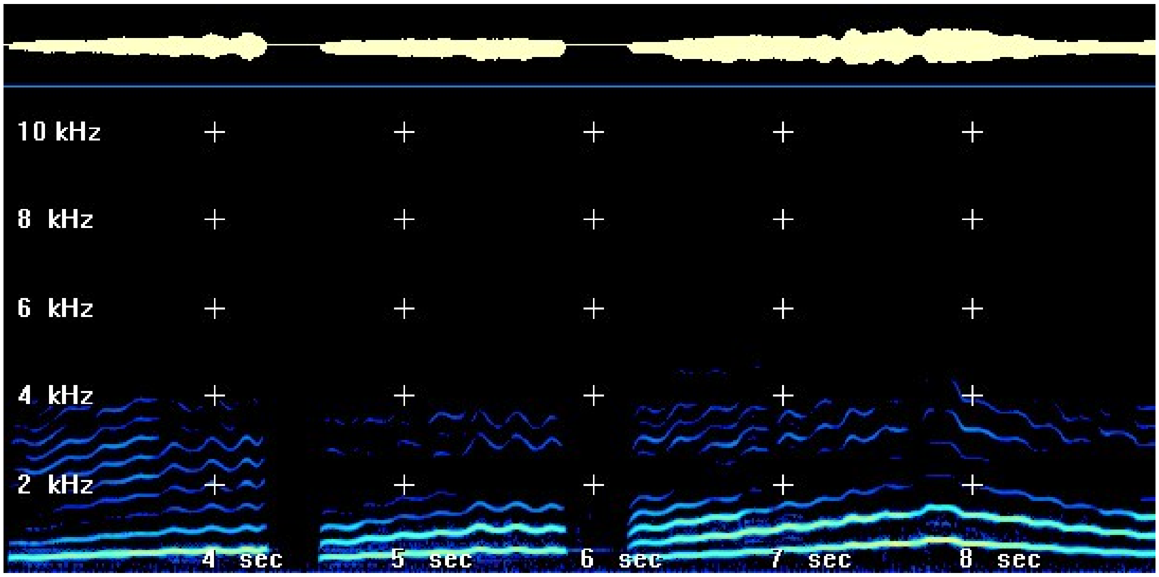


Power Spectrum from Spectrogram #1, Subject #4 at 6.0 seconds [a]



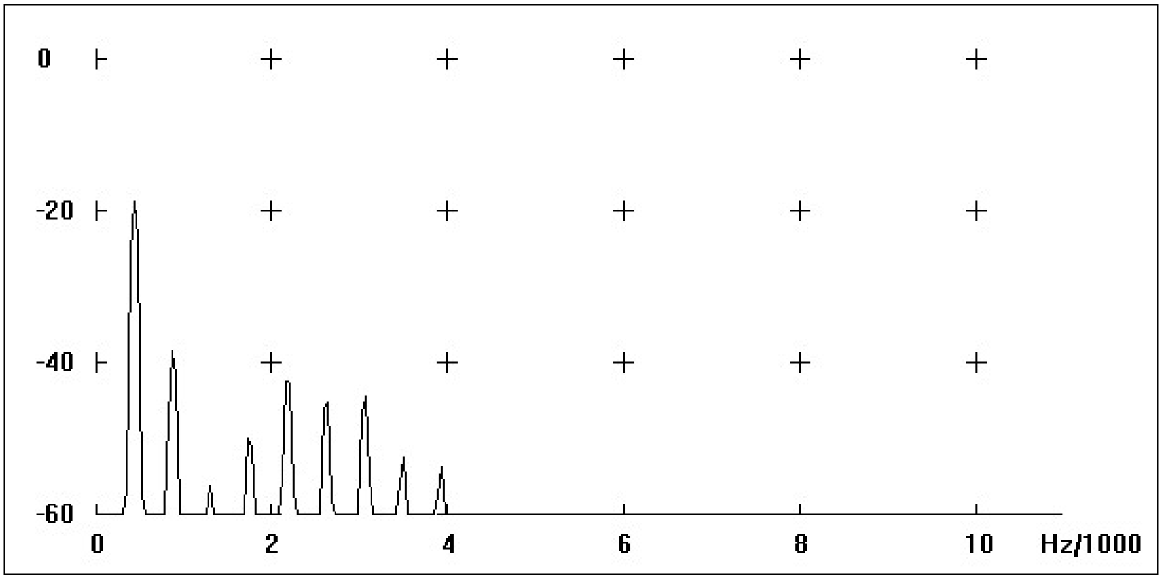
Analysis of Power Spectra from Spectrogram #1, Subject #4 – August 23, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.15	4	1	.25	5	9	.55	.4
4.5	5	2	.4	1	6	.16	.28
6.0	3	2	.66	2	5	.4	.53
Average of three chiaroscuro levels							.4

Wave File Number 2 – August 29, 2000 – Subject #4

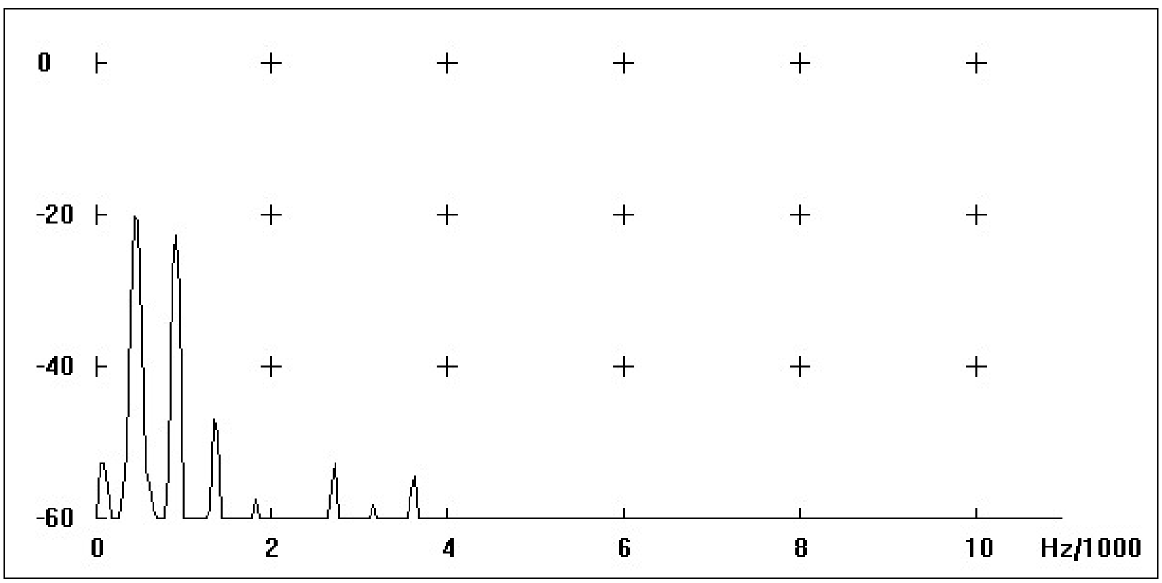


Subject #4 – Analysis of Wave File #2 – August 29, 2000 – E flat major				
		[si] (2.94-4.23 sec)	[o] (4.57-5.84 sec)	[a] (6.2-9.98 sec)
Singer's Formant Area	4000+ Hz			Slight indication in this area indicates less damping of high notes
	2000-4000 Hz	Solid indications above the vowel	Two nearly solid bands	Three nearly solid bands
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Stronger	Stronger	Stronger
Chiaroscuro Balance		Balanced	Nearly balanced	Nearly balanced
Power Spectrum		Increase from about 10% to about 30%	Varying around 20%	<> from about 10% to about 40% and back
This power spectrum is more in line with the upper frequencies that are visible in this wave file. Note the clarity of beginnings and endings of exercises. All the frequencies begin and end together; there is no "easing into" the vowel that could lead to poor diction.				

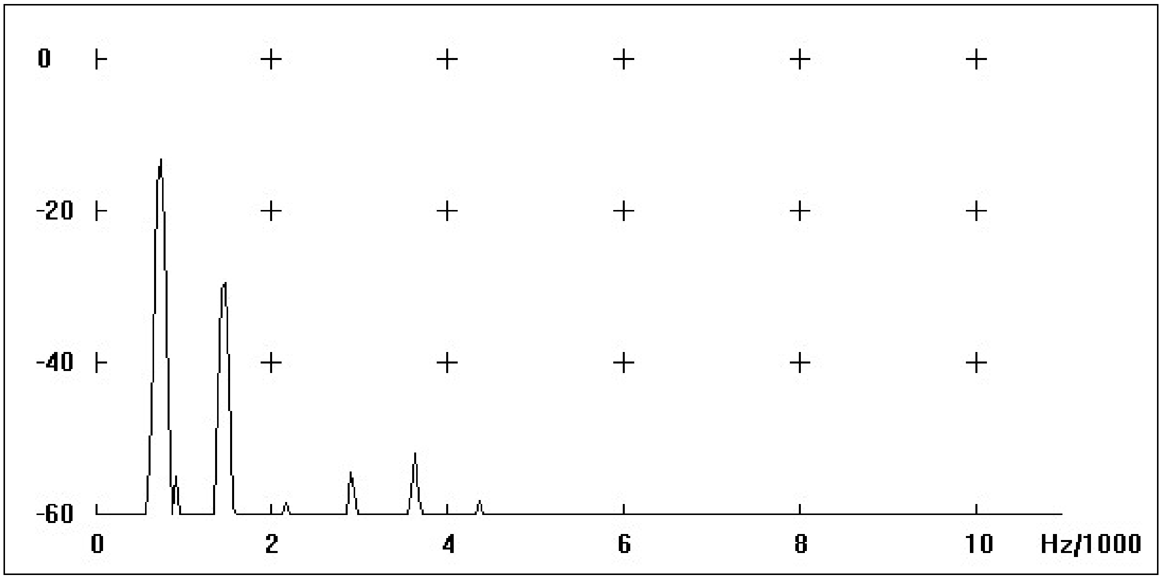
Power Spectrum from Spectrogram #2, Subject #4 at 3.63 [i]



Power Spectrum from Spectrogram #2, Subject #4 at 5.21 [o]

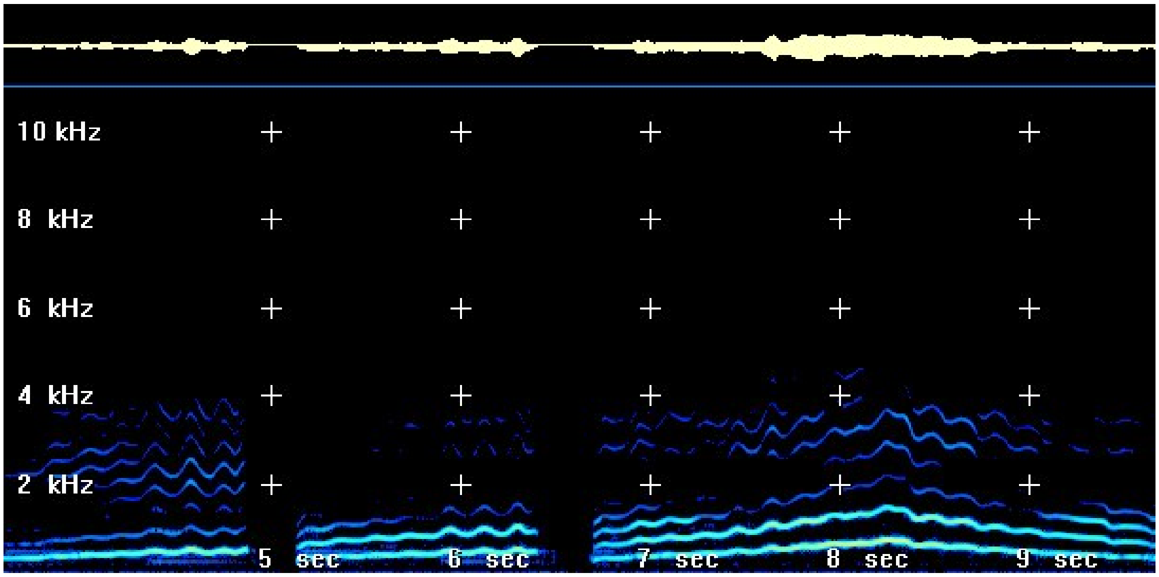


Power Spectrum from Spectrogram #2, Subject #4 at 7.91 [a]



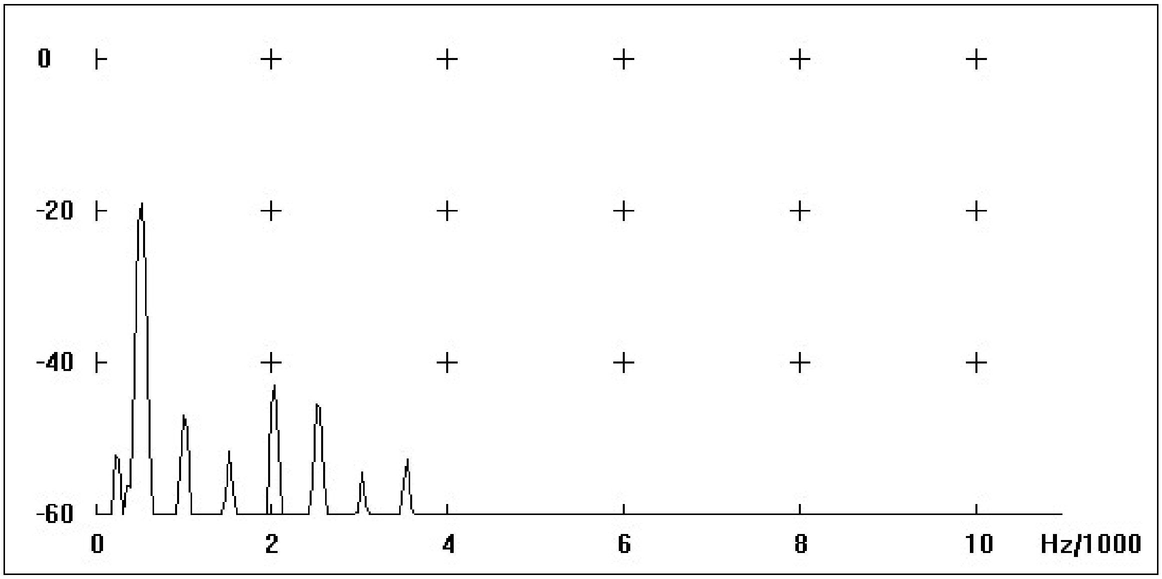
Analysis of Power Spectra from Spectrogram #2, Subject #4 – August 29, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.63	4	2	.5	5	9	.55	.52
5.21	5	2	.4	3	8	.37	.38
7.91	3	2	.66	4	7	.57	.61
Average of three chiaroscuro levels							.5

Wave File Number 3 – September 2 – Subject #4

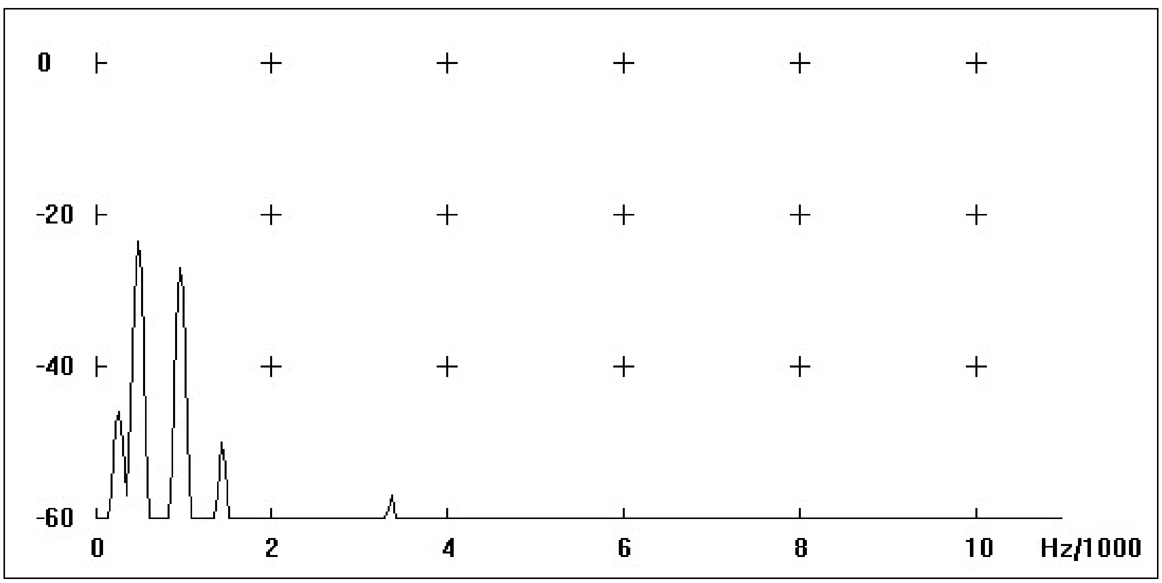


Subject #4 – Analysis of Wave File #3 – September 2, 2000 – E flat major				
		[si] (3.61-4.86 sec)	[o] (5.13-6.4 sec)	[a] (6.71-10.1 sec)
Singer's Formant Area	4000+ Hz			Slight indications
	2000-4000 Hz	Indications above vowel not quite as strong as in Wave File #2	Indications above vowel not quite as strong as in Wave File #2	Indications above vowel not quite as strong as in Wave File #2, but less indication of damping the top
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Good	Good	Good
Chiaroscuro Balance		Nearly balanced	Weighted toward lower frequencies	Nearly balanced
Power Spectrum		Verying around 10%	Varying around 10%	Varying around 10% with increase to about 25% at highest pitches
Power spectrum is again not what would be expected. Perhaps microphone placement is a problem.				

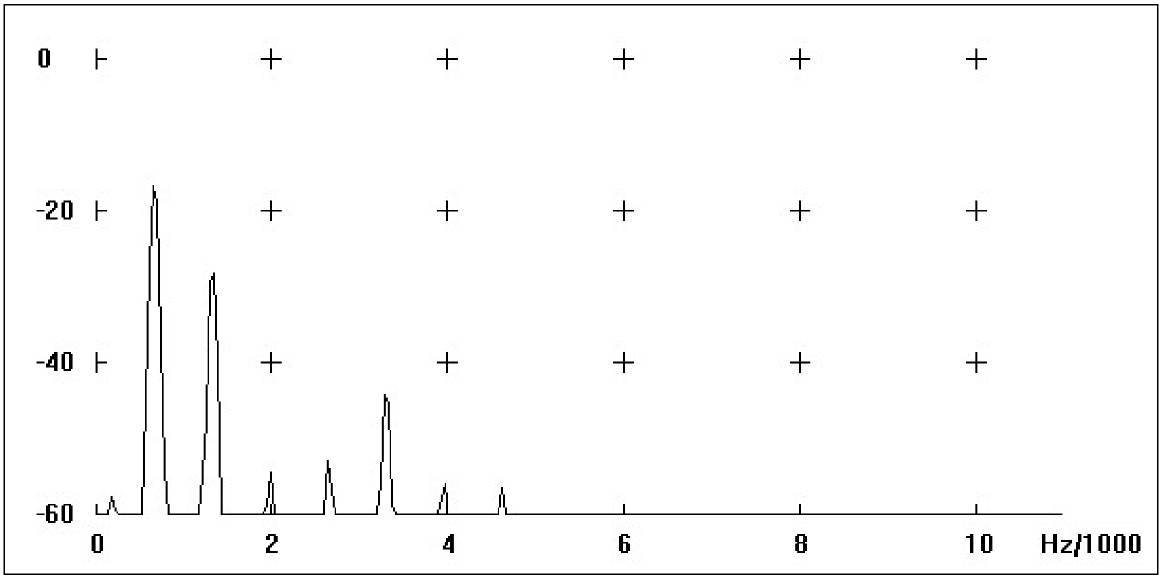
Power Spectrum from Spectrogram #3, Subject #4 at 4.6 seconds [i]



Power Spectrum from Spectrogram #3, Subject #4 at 5.94 seconds [o]

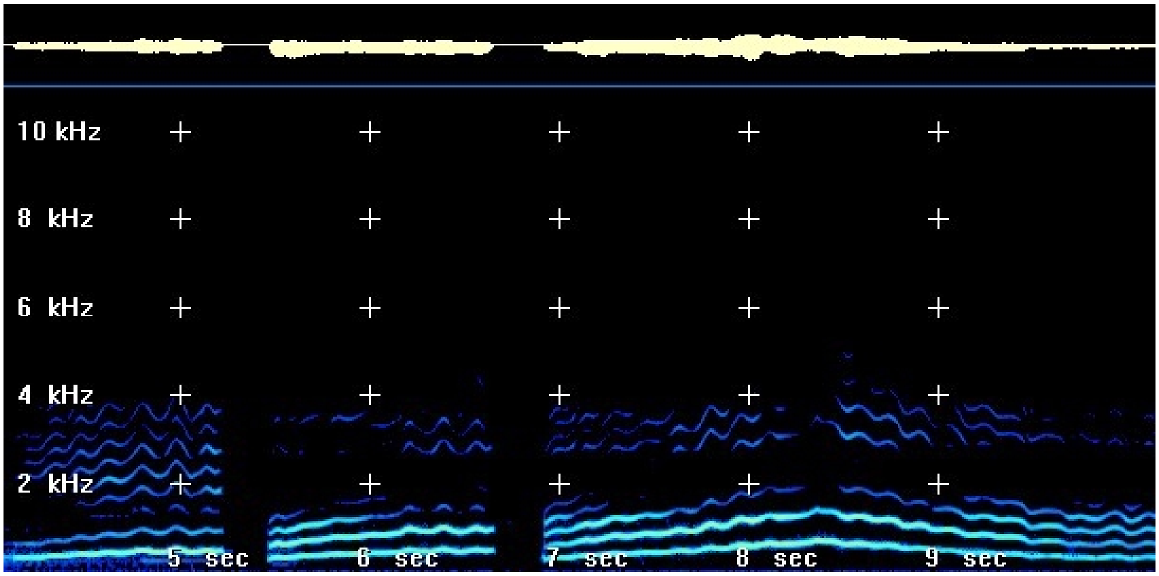


Power Spectrum from Spectrogram #3, Subject #4 at 8.12 seconds [a]



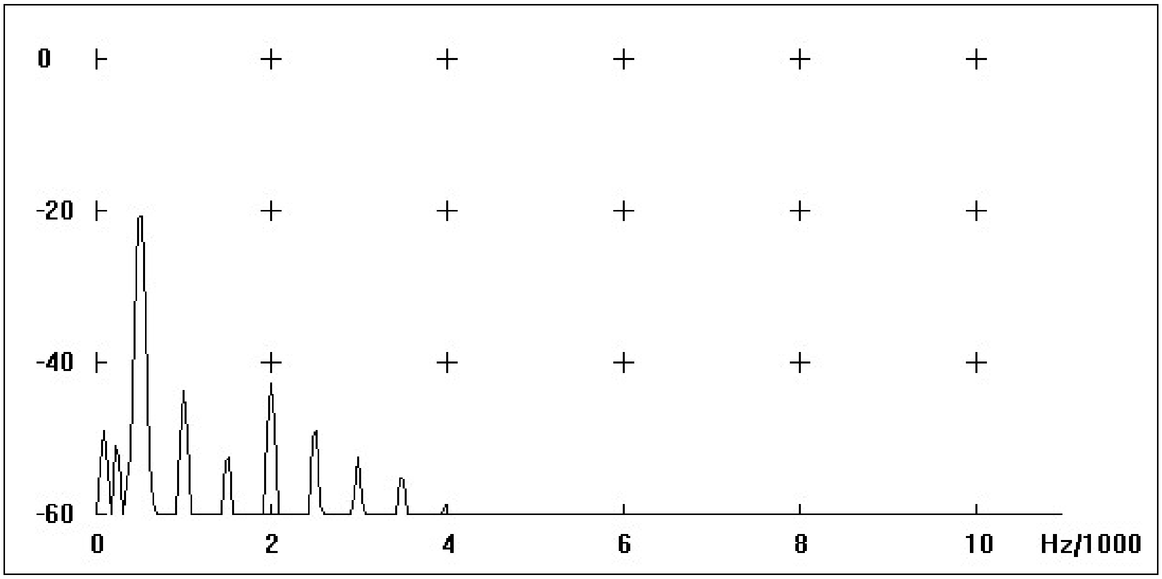
Analysis of Power Spectra from Spectrogram #3, Subject #4 – September 2, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.6	4	1	.25	4	8	.5	.37
5.94	4	2	.5	1	5	.2	.35
8.12	3	2	.66	5	8	.62	.64
Average of three chiaroscuro levels							.45

Wave File Number 4 – September 20 – Subject #4

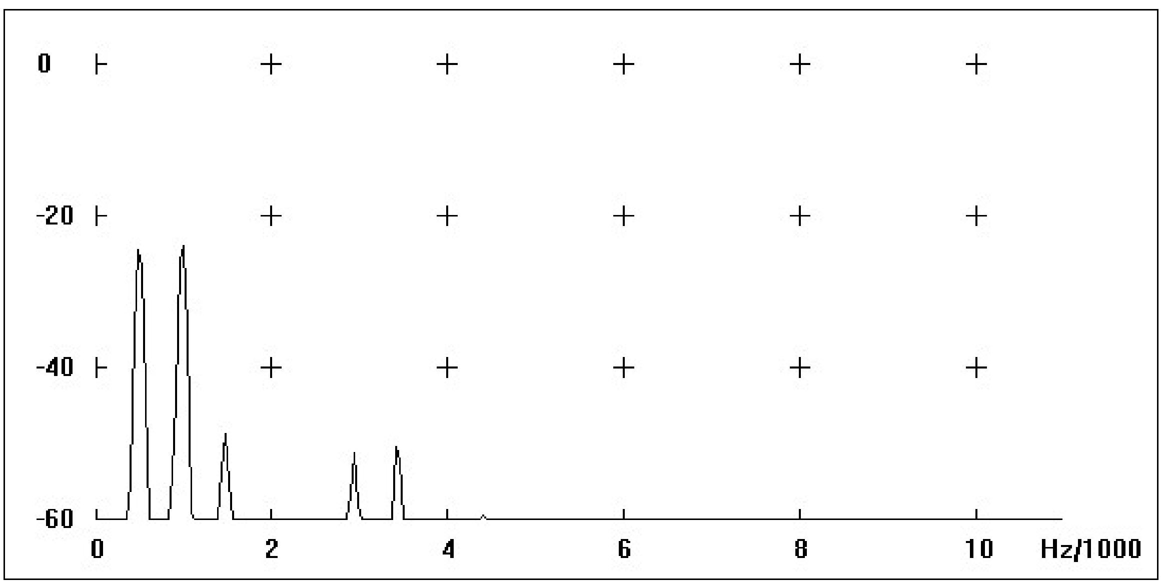


<table>
<tr><td colspan="5">Subject #4 – Analysis of Wave File #4 – September 20, 2000 – E flat major</td></tr>
<tr><td colspan="2"></td><td>[si] (4.16-5.2 sec)</td><td>[o] (5.46-6.67 sec)</td><td>[a] (6.93-10.3 sec)</td></tr>
<tr><td rowspan="2">Singer's Formant Area</td><td>4000+ Hz</td><td></td><td></td><td></td></tr>
<tr><td>2000-4000 Hz</td><td>Firm indications above the vowel</td><td>2 partial bands</td><td>2-3 firm bands</td></tr>
<tr><td colspan="2">2nd Formant Area (Vowel Definition)</td><td>Clear vowels</td><td>Clear vowels</td><td>Clear vowels</td></tr>
<tr><td colspan="2">1st Formant Area</td><td>Strong</td><td>Strong</td><td>Strong</td></tr>
<tr><td colspan="2">Chiaroscuro Balance</td><td>Well balanced</td><td>Nearly balanced</td><td>Nearly balanced</td></tr>
<tr><td colspan="2">Power Spectrum</td><td>Varying around 10%</td><td>Varying around 20%</td><td>Varying around 30%</td></tr>
<tr><td colspan="5">The student's voice is coming into focus as she begins to rely on resonance techniques. Note the even vibrato and the strength of the lower frequencies. A singer who's voice is naturally weighted toward lower frequencies can make a substantial addition of upper frequencies before the voice will become unbalanced. This young singer can still go further.</td></tr>
</table>

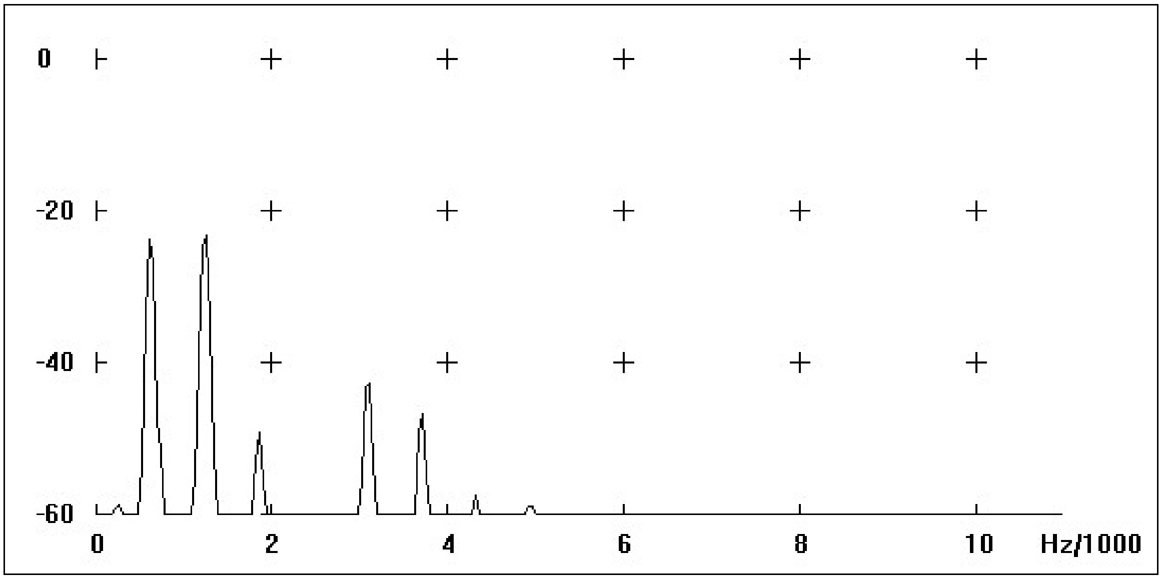
Power Spectrum from Spectrogram #4, Subject #4 at 4.98 seconds [i]



Power Spectrum from Spectrogram #4, Subject #4 at 6.58 seconds [o]

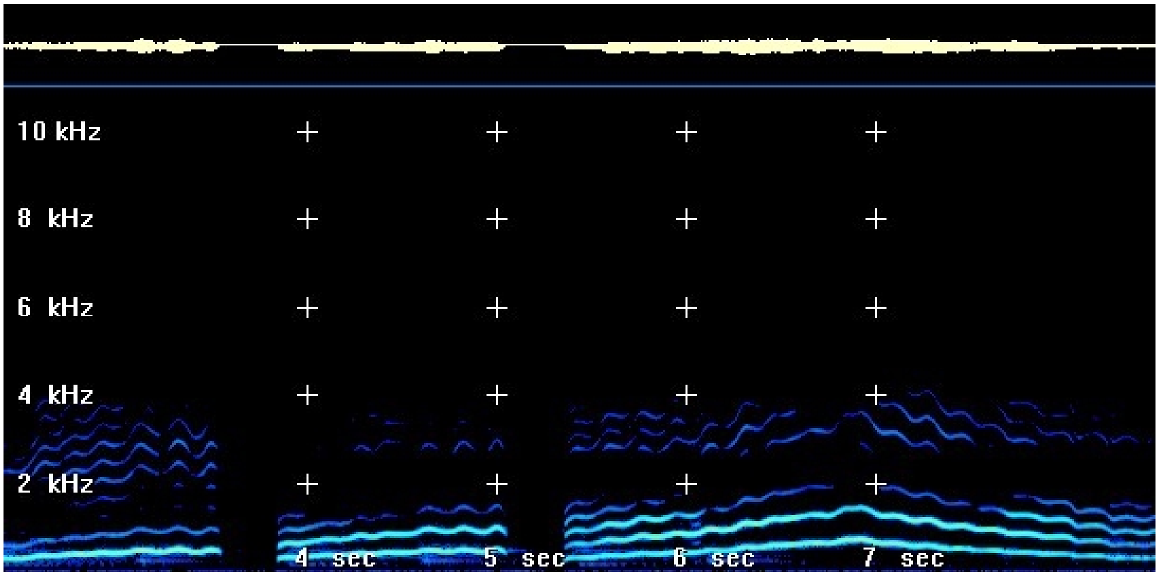


Power Spectrum from Spectrogram #4, Subject #4 at 8.52 seconds [a]



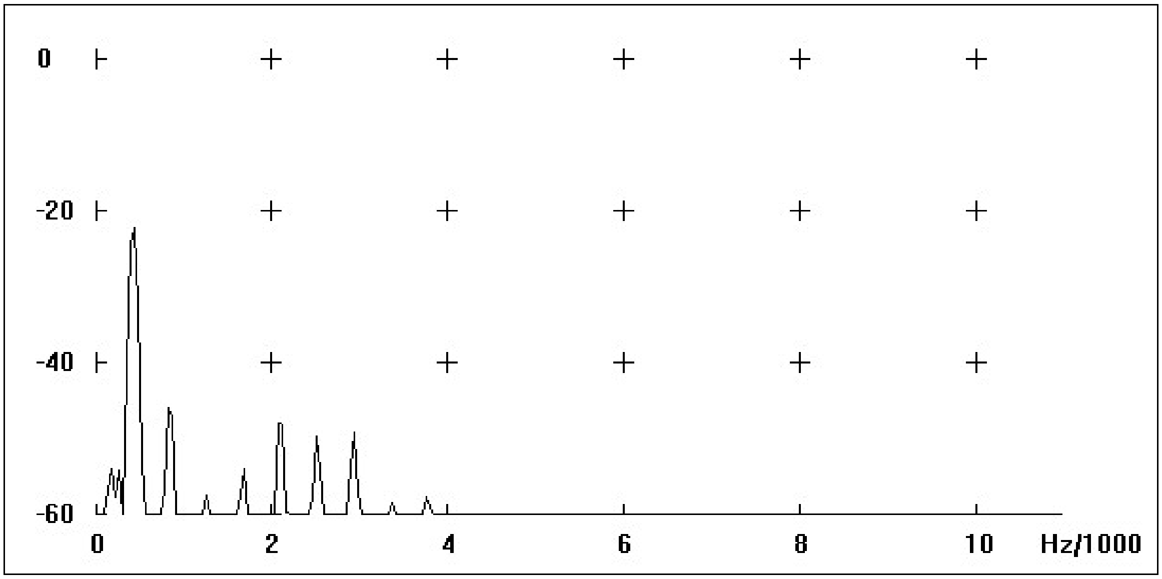
Analysis of Power Spectra from Spectrogram #4, Subject #4 – September 20, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.98	5	1	.2	5	10	.5	.35
6.58	3	2	.66	3	6	.5	.58
8.52	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.47

Wave File Number 5 – September 27 – Subject #4

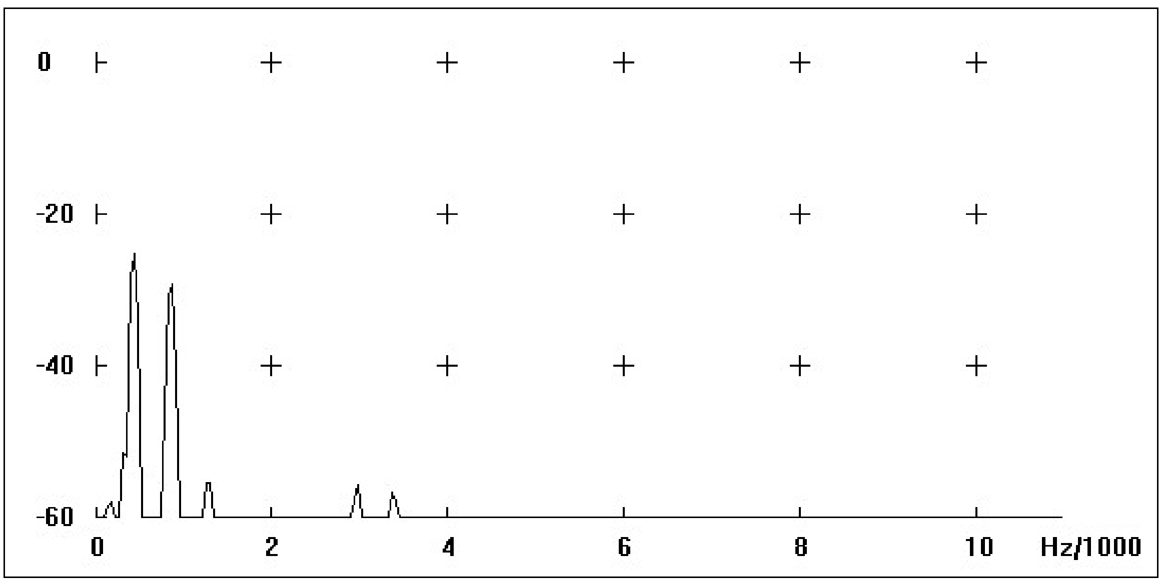


Subject #4 – Analysis of Wave File #5 – September 27, 2000 – E flat major				
		[si] (2.41-3.52 sec)	[o] (3.86-8.92 sec)	[a] (5.35-8.92 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Firm indications above the vowel	2 partial bands	2-3 firm bands
2nd Formant Area (Vowel Definition)		Clear vowels	Clear vowels	Clear vowels
1st Formant Area		Strong	Strong	Strong
Chiaroscuro Balance		Well balanced	Slightly less well balanced than in wave file #4	Nearly balanced – still damping top just slightly
Power Spectrum		Varying around 10%	Varying around 10%	Varying around 20%
Again the power spectrum is weaker than would be expected from a wave file that shows good upper frequencies, as this one does. Only the [o] vowel shows a decrease in power from wave file #4.				

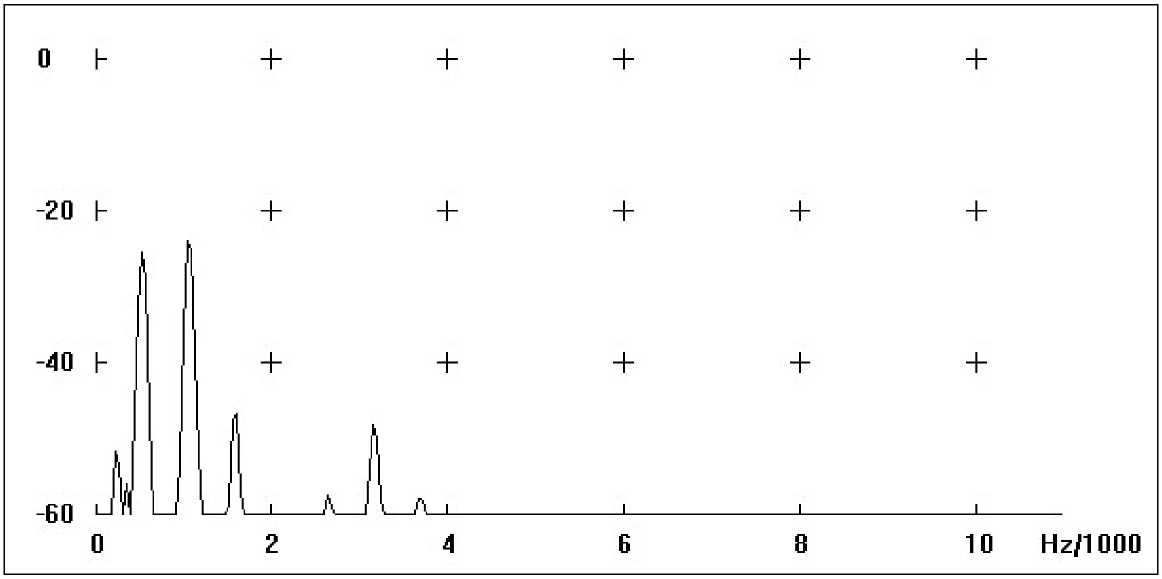
Power Spectrum from Spectrogram #5, Subject #4 at 2.93 seconds [i]



Power Spectrum from Spectrogram #5, Subject #4 at 4.43 seconds [o]

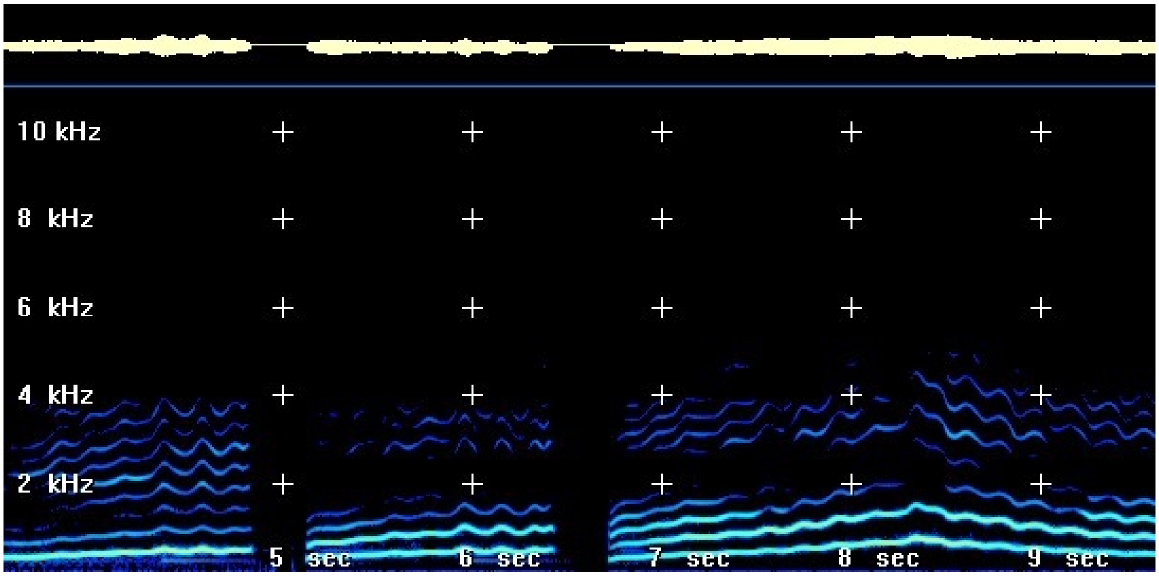


Power Spectrum from Spectrogram #5, Subject #4 at 6.3 seconds [a]



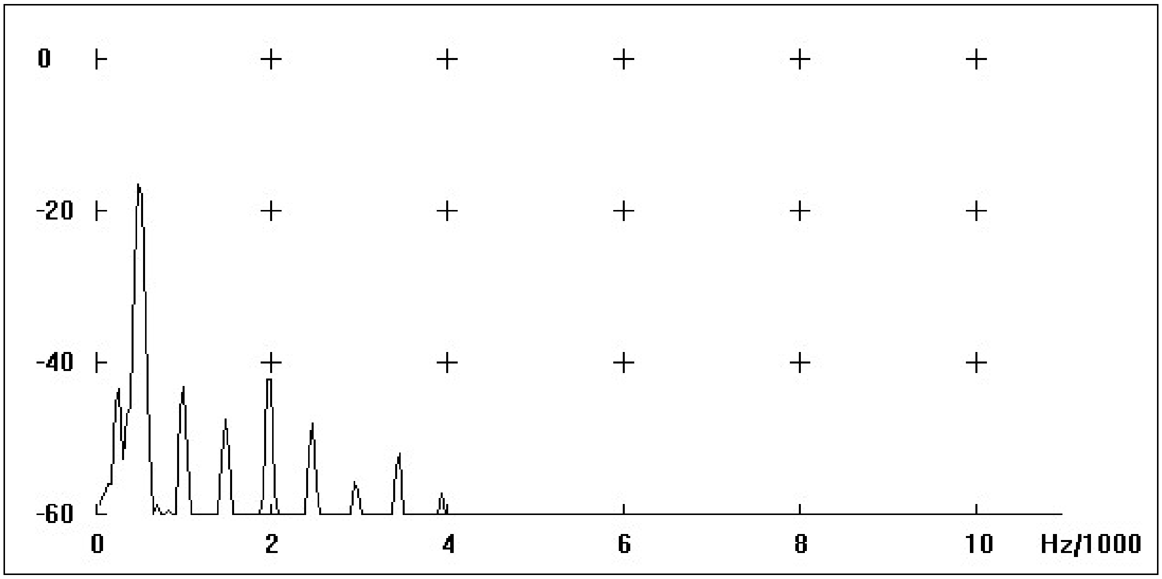
Analysis of Power Spectra from Spectrogram #5, Subject #4 – September 27, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	b/a	c	d	c/d	(b/a+c/d)/2
2.93	6	1	.16	5	11	.45	.3
4.43	4	2	.5	2	6	.33	.41
6.3	5	2	.4	3	8	.37	.38
Average of three chiaroscuro levels							.36

Wave File Number 6 – October 4, 2000 – Subject #4

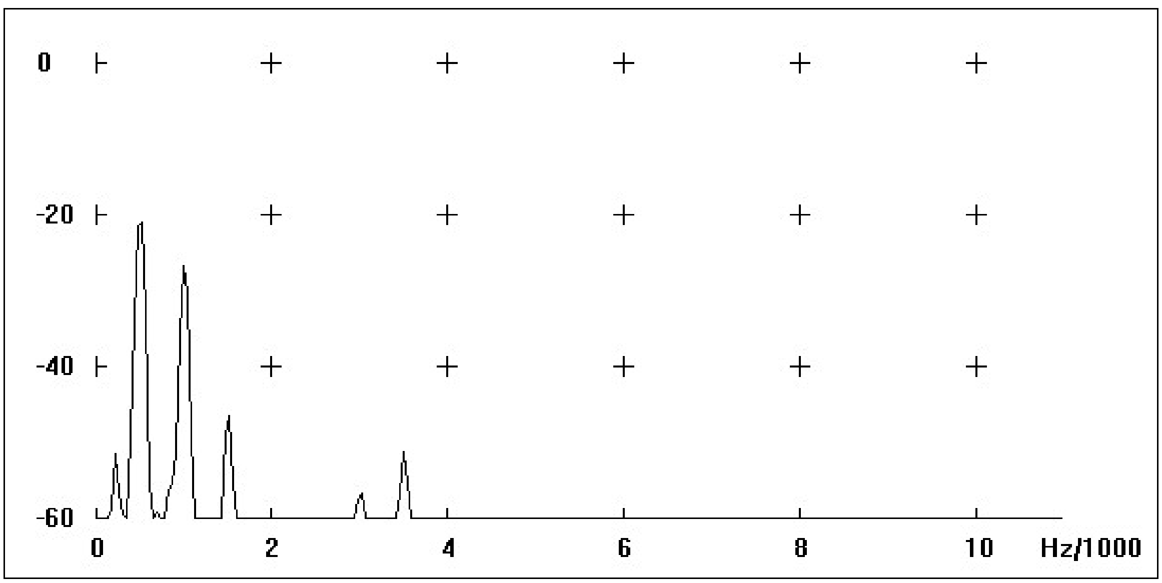


Subject #4 – Analysis of Wave File #6 – October 4, 2000 – E flat major				
		[si] (3.55-4.81 sec)	[o] (5.11-6.42 sec)	[a] (6.74-10.5 sec)
Singer's Formant Area	4000+ Hz			Some scattered indications
	2000-4000 Hz	Bands above vowel are present but weaker than in wave file #5	2 nearly solid bands - weaker than in wave file #5	3-4 nearly solid bands, but weaker than in wave file #5 – continues to decrease damping of top
2nd Formant Area (Vowel Definition)		Good vowel definition	Good vowel definition	Good vowel definition
1st Formant Area		Stronger than in wave file #5	Stronger than in wave file #5	Stronger than in wave file #5
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 20%	Varying around 20%	Varying around 20%
This wave file indicates less emphasis on upper frequencies and more on the lower; the resultant singing would be somewhat "throatier" or "darker".				

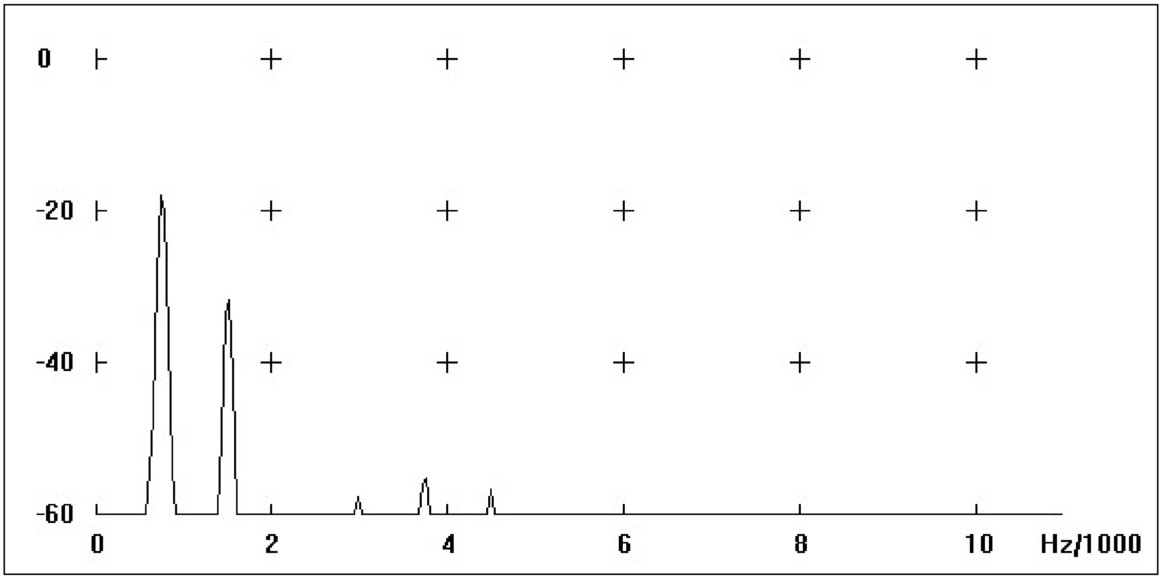
Power Spectrum from Spectrogram #6, Subject #4 at 4.38 seconds [i]



Power Spectrum from Spectrogram #6, Subject #4 at 5.96 seconds [o]

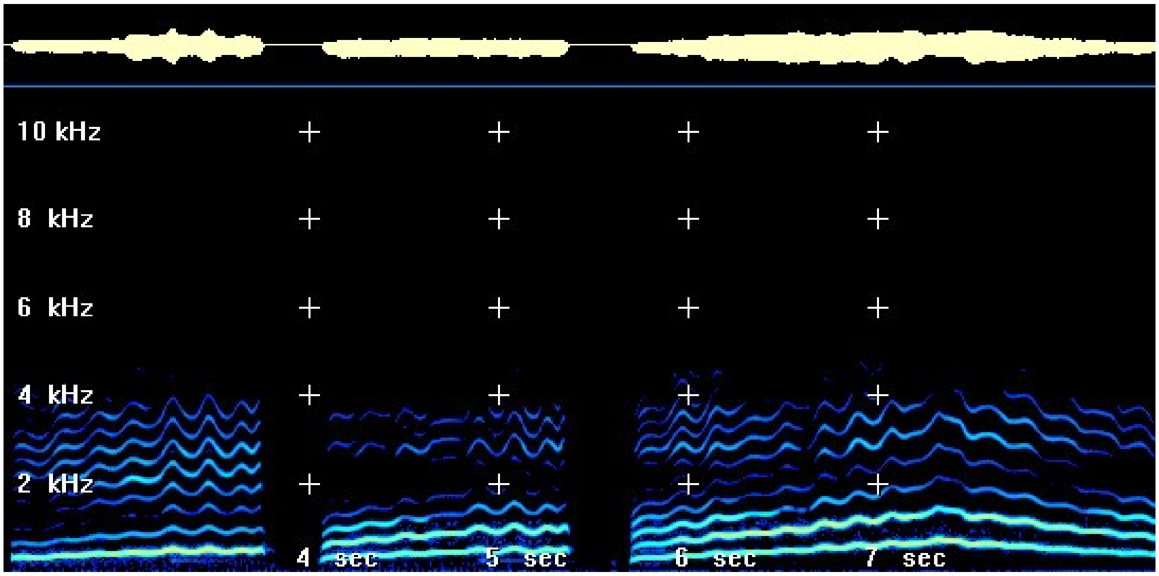


Power Spectrum from Spectrogram #6, Subject #4 at 8.35 seconds [a]



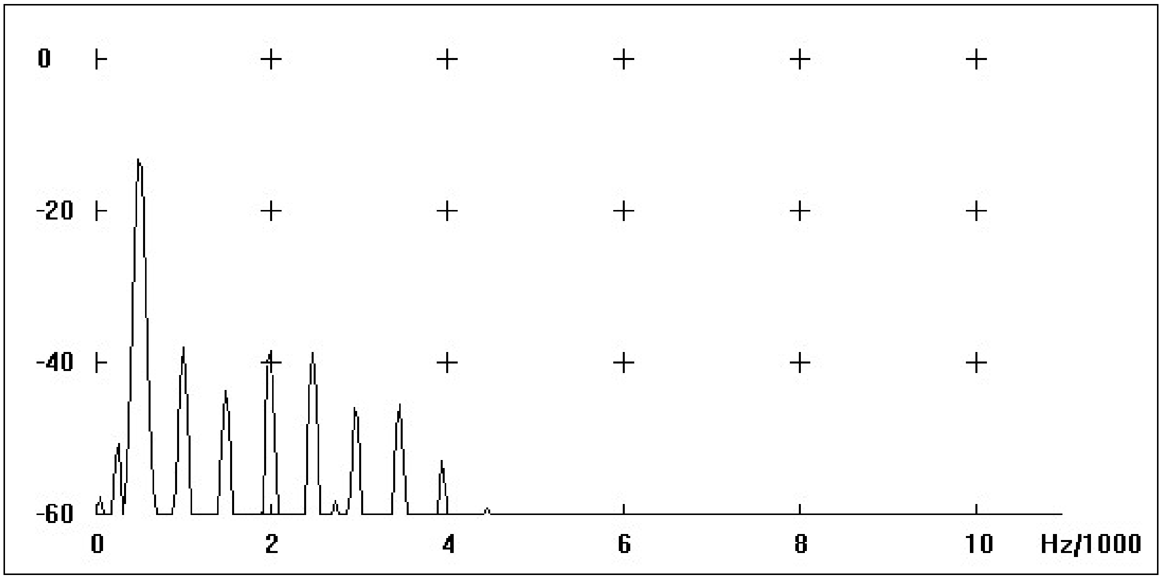
Analysis of Power Spectra from Spectrogram #6, Subject #4 – October 4, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.38	6	1	.16	5	11	.45	.3
5.96	4	2	.5	2	6	.33	.41
8.35	2	2	1.0	3	5	.6	.8
Average of three chiaroscuro levels							.5

Wave File Number 7 – October 11 – Subject #4

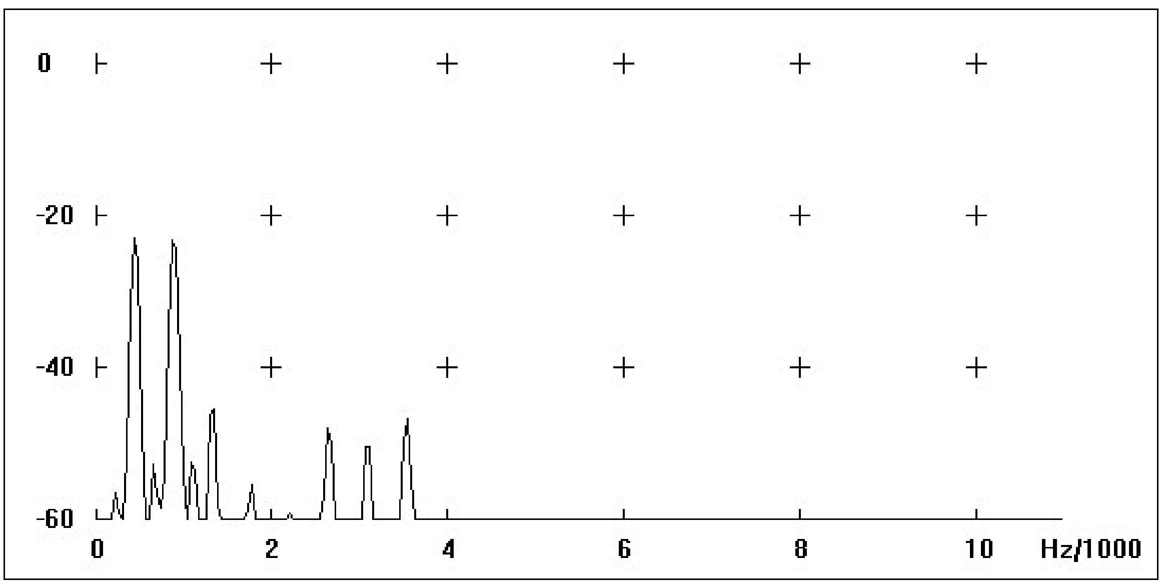


<table>
<tr><td colspan="5">Subject #4 – Analysis of Wave File #7 – October 11, 2000 – E flat major</td></tr>
<tr><td colspan="2"></td><td>[si] (2.45-3.73 sec)</td><td>[o] (4.07-5.36 sec)</td><td>[a] (5.7-9.61 sec)</td></tr>
<tr><td rowspan="2">Singer’s Formant Area</td><td>4000+ Hz</td><td></td><td></td><td>Scattering of indications</td></tr>
<tr><td>2000-4000 Hz</td><td>Strengthening and increasingly consistent</td><td>Strengthening and increasingly consistent</td><td>Strengthening and increasingly consistent</td></tr>
<tr><td colspan="2">2nd Formant Area (Vowel Definition)</td><td>Clear vowel formation</td><td>Clear vowel formation</td><td>Clear vowel formation</td></tr>
<tr><td colspan="2">1st Formant Area</td><td>Stronger</td><td>Stronger</td><td>Stronger</td></tr>
<tr><td colspan="2">Chiaroscuro Balance</td><td>Well balanced</td><td>Nearly balanced</td><td>Well balanced and without damping of top</td></tr>
<tr><td colspan="2">Power Spectrum</td><td>Increasing from about 20% to about 40%</td><td>Varying around 20%</td><td>Increasing from about 20% to about 50%</td></tr>
<tr><td colspan="5">The student is singing a well-balanced sound and beginning to increase both the upper and lower frequencies as she discovers the strength of her sound. The increasing consistency of upper frequencies indicates the growing complexity and consequent fullness of her sound.</td></tr>
</table>

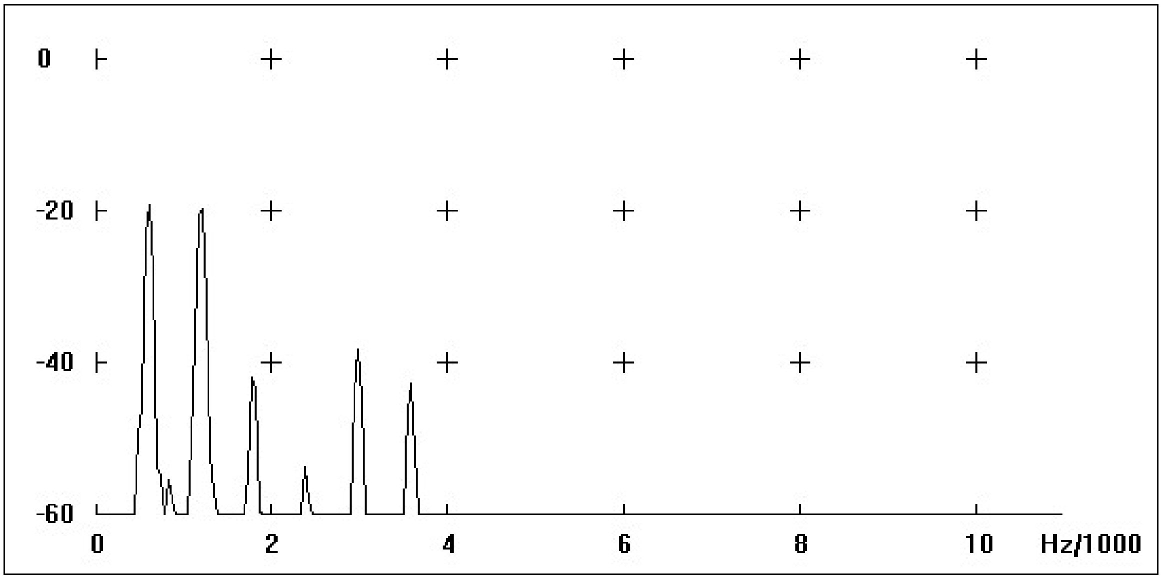
Power Spectrum from Spectrogram #7, Subject #4 at 3.28 seconds [i]



Power Spectrum from Spectrogram #7, Subject #4 at 5.18 seconds [o]

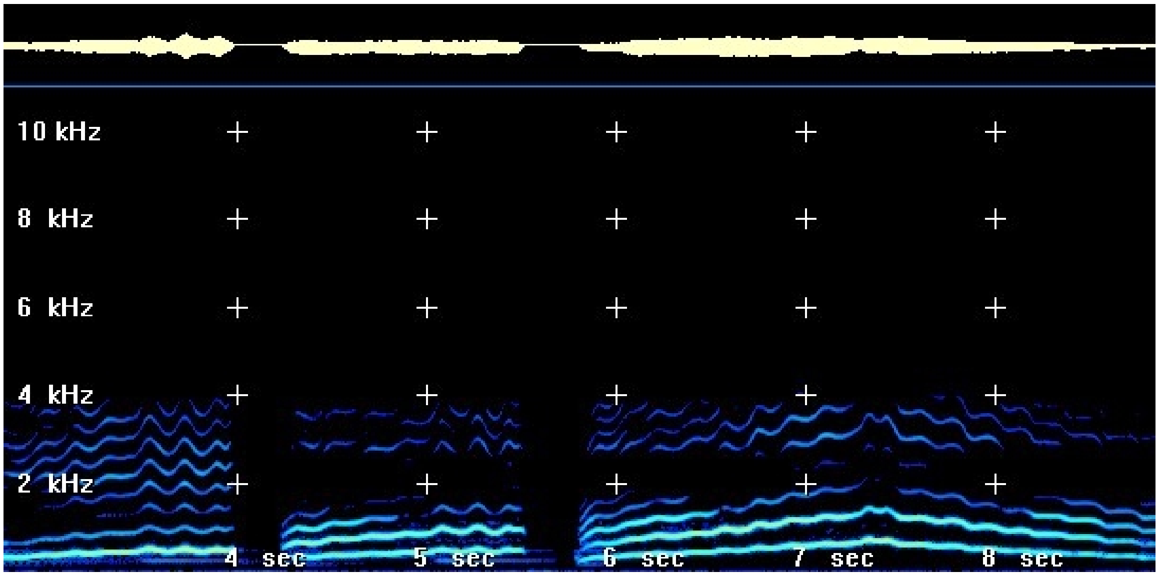


Power Spectrum from Spectrogram #7, Subject #4 at 6.92 seconds [a]



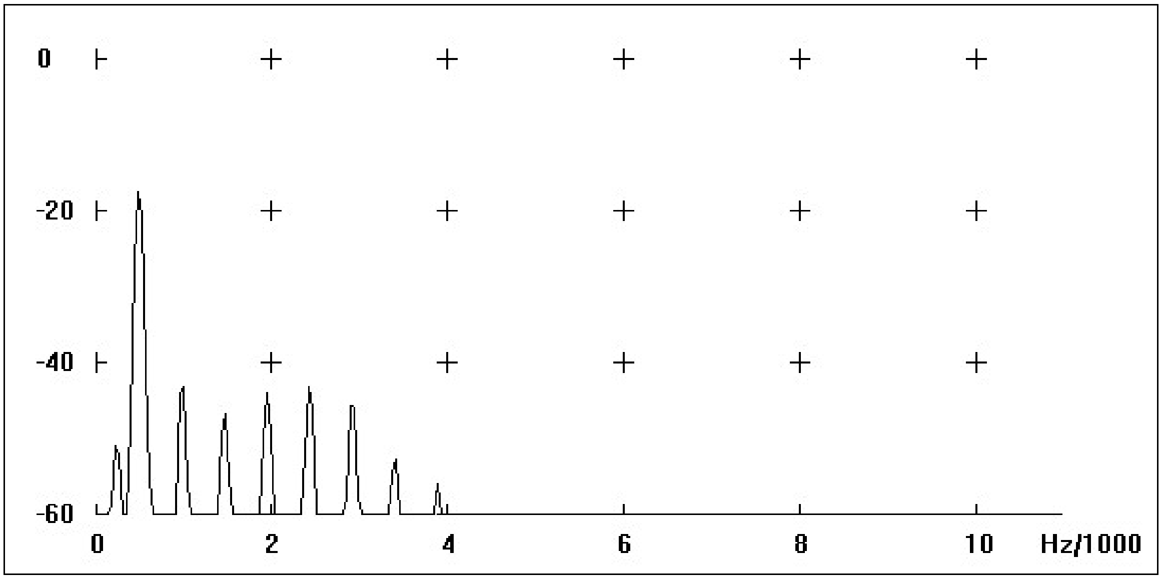
Analysis of Power Spectra from Spectrogram #7, Subject #4 – October 11, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area $\geq$ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks $\geq$ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{b/a+c/d}{2}$
3.28	5	2	.4	6	11	.54	.47
5.18	7	2	.28	3	10	.3	.29
6.92	4	2	.5	3	7	.42	.46
Average of three chiaroscuro levels							.4

Wave File Number 8 – October 18 – Subject #4

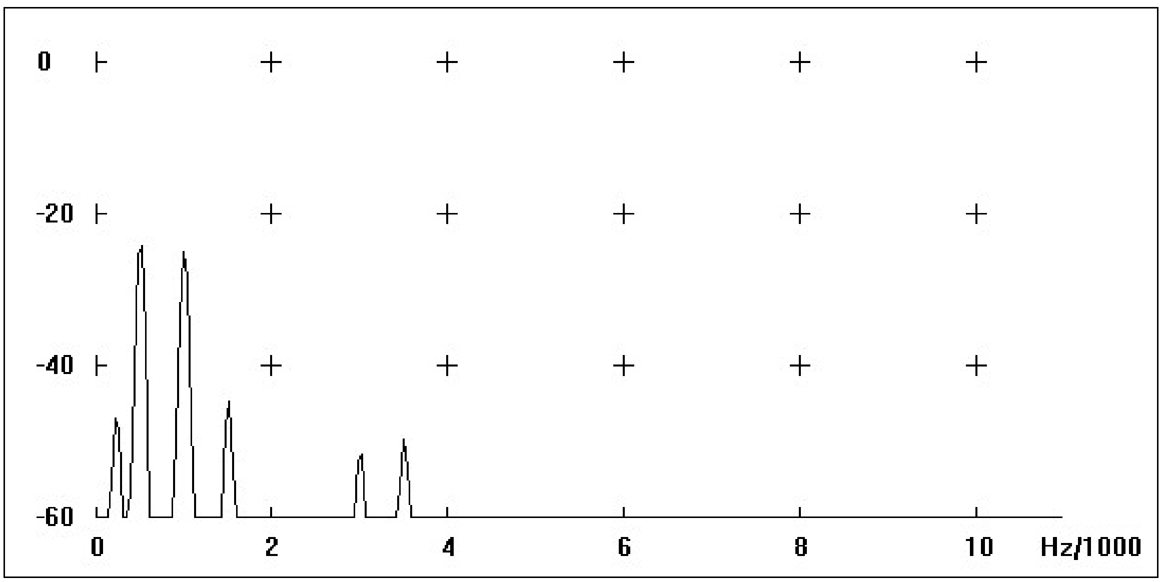


Subject #4 – Analysis of Wave File #8 – October 18, 2000 – E flat major				
		[si] (2.77-3.97 sec)	[o] (4.26-5.51 sec)	[a] (5.81-9.51 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Still good, but not as consistent as in wave file #7	Still good, but not as consistent as in wave file #7	Still good, but not as consistent as in wave file #7
2nd Formant Area (Vowel Definition)		Good	Good	Good
1st Formant Area		Quite strong	Quite strong	Quite strong
Chiaroscuro Balance		Continues to be balanced	Weighted toward lower frequencies	Nearly balanced
Power Spectrum		Increase from about 20% to about 30%	Varying around 20%	Varying around 30%
Progress is never linear. This wave file is less consistent and strong than wave file #7. It indicates that the singer was singing with less concentration, almost casually. Note the scoop into the [a] vowel at 5.81-5.88.				

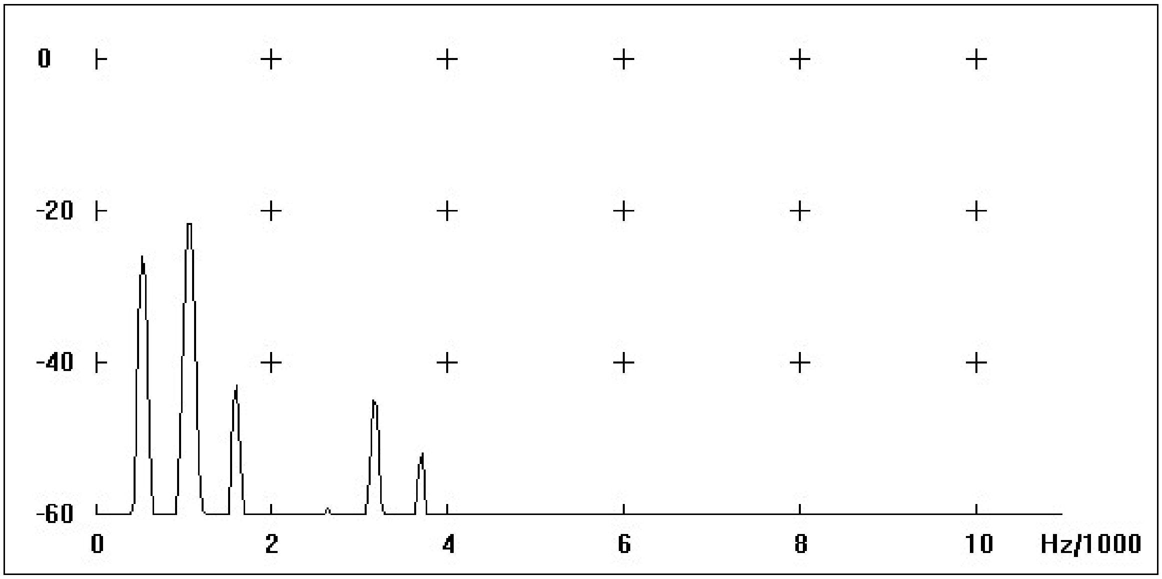
Power Spectrum from Spectrogram #8, Subject #4 at 3.89 seconds [i]



Power Spectrum from Spectrogram #8, Subject #4 at 5.27 seconds [o]

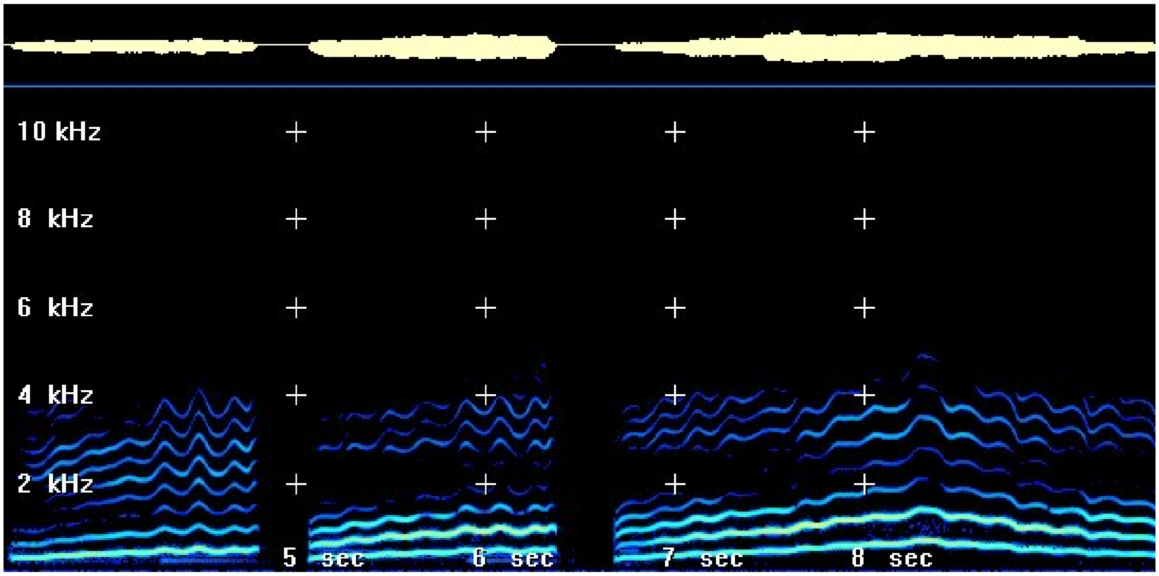


Power Spectrum from Spectrogram #8, Subject #4 at 6.8 seconds [a]



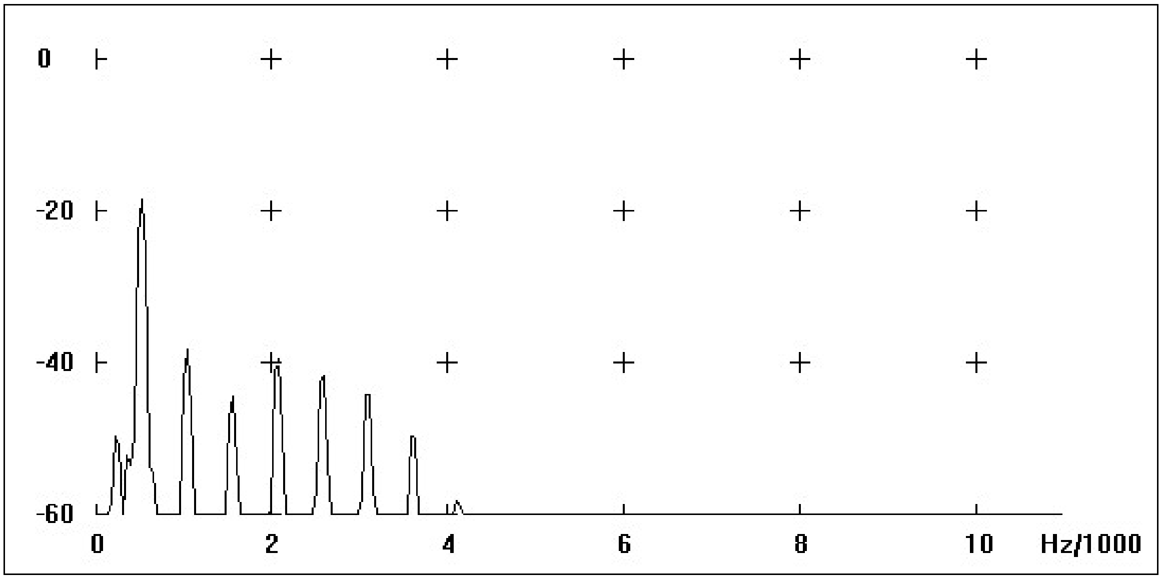
Analysis of Power Spectra from Spectrogram #8, Subject #4 – October 18, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.89	5	1	.2	4	9	.44	.32
5.27	4	2	.5	2	6	.33	.41
6.8	3	2	.66	3	6	.5	.58
Average of three chiaroscuro levels							.43

Wave File Number 9 – October 25 – Subject #4

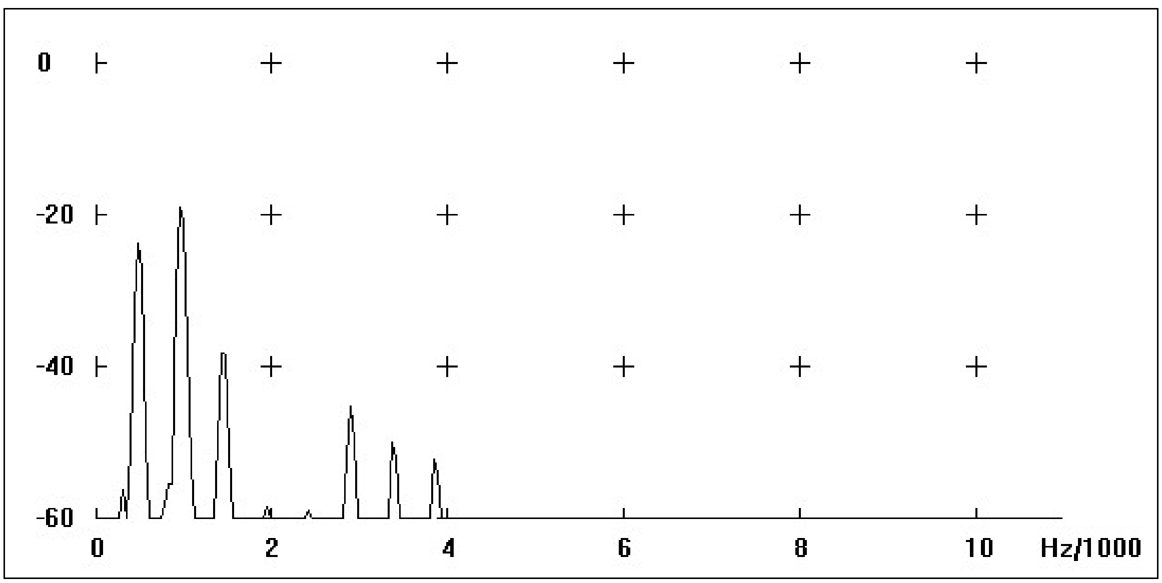


Subject #4 – Analysis of Wave File #9 – October 25, 2000 – E flat major				
		[si] (3.94-4.77 sec)	[o] (5.05-6.36 sec)	[a] (6.69-10.5 sec)
Singer's Formant Area	4000+ Hz		Scattering	Scattering
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strengthening	Strengthening	Strengthening
Chiaroscuro Balance		Well balanced	Nearly balanced	Well balanced
Power Spectrum		Varying around 20%	Varying around 30%	<> from about 20% to about 40%
Indicates progress.				

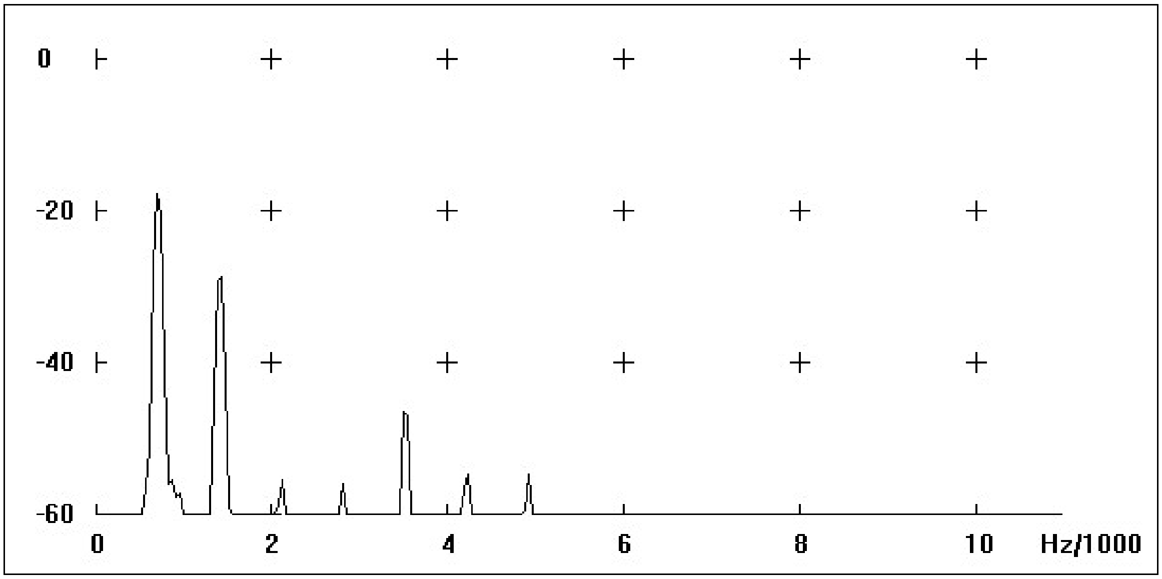
Power Spectrum from Spectrogram #9, Subject #4 at 4.49 seconds [i]



Power Spectrum from Spectrogram #9, Subject #4 at 5.9 seconds [o]

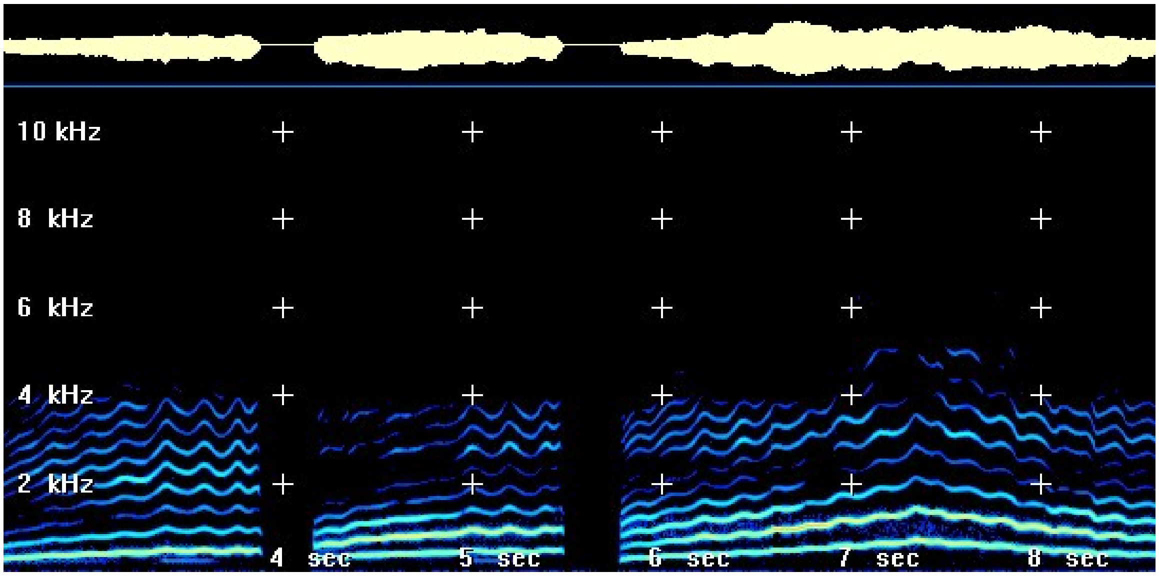


Power Spectrum from Spectrogram #9, Subject #4 at 8.32 seconds [a]



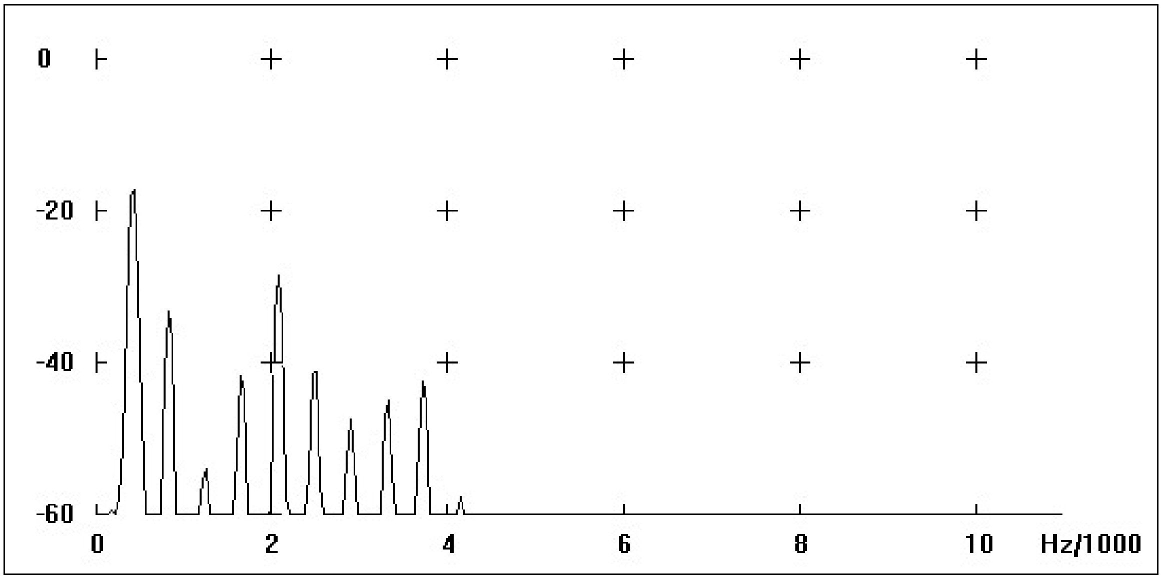
Analysis of Power Spectra from Spectrogram #9, Subject #4 – October 25, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.49	5	2	.4	5	10	.5	.45
5.9	5	3	.6	4	9	.44	.52
8.32	2	2	1.0	5	7	.71	.85
Average of three chiaroscuro levels							.6

Wave File Number 10 – November 1, 2000 – Subject #4

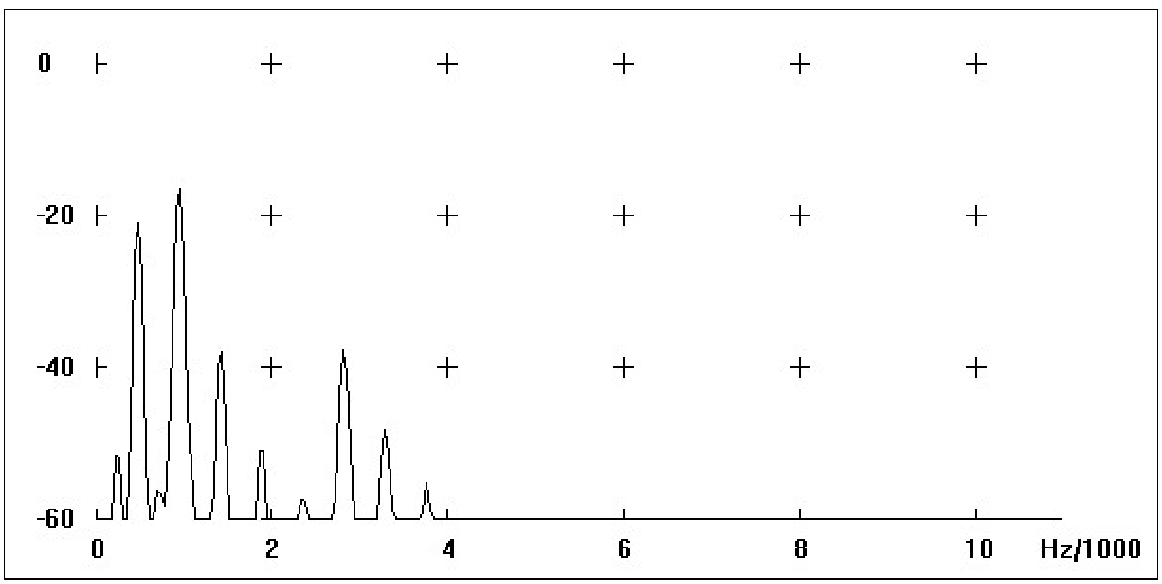


Subject #4 – Analysis of Wave File #10 – November 1, 2000 – E flat major				
		[si] (2.53-8.86 sec)	[o] (4.16-5.48 sec)	[a] (5.79-9.51 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area		Beginning to enter this area
	2000-4000 Hz	Strong, consistent indications	Nearly solid indications	Strong, consistent indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Partially balanced
Power Spectrum		Increase from about 15% to about 30%	Varying around 40%	Varying around 605 with especially strong low section between 6.5 and 7 sec
Continuing good progress.				

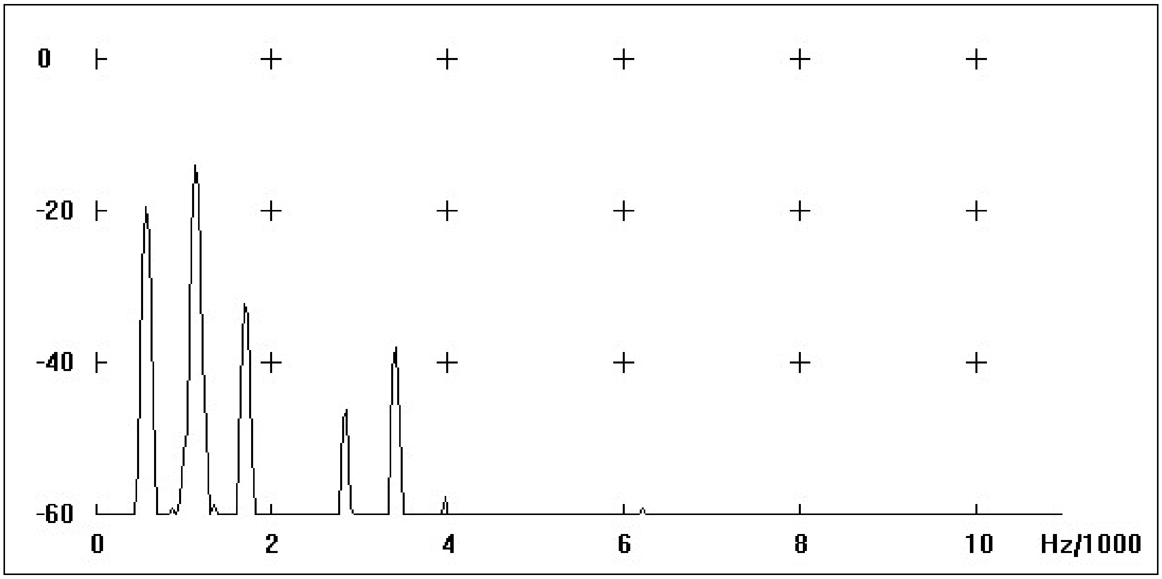
Power Spectrum from Spectrogram #10, Subject #4 at 3.24 seconds [i]



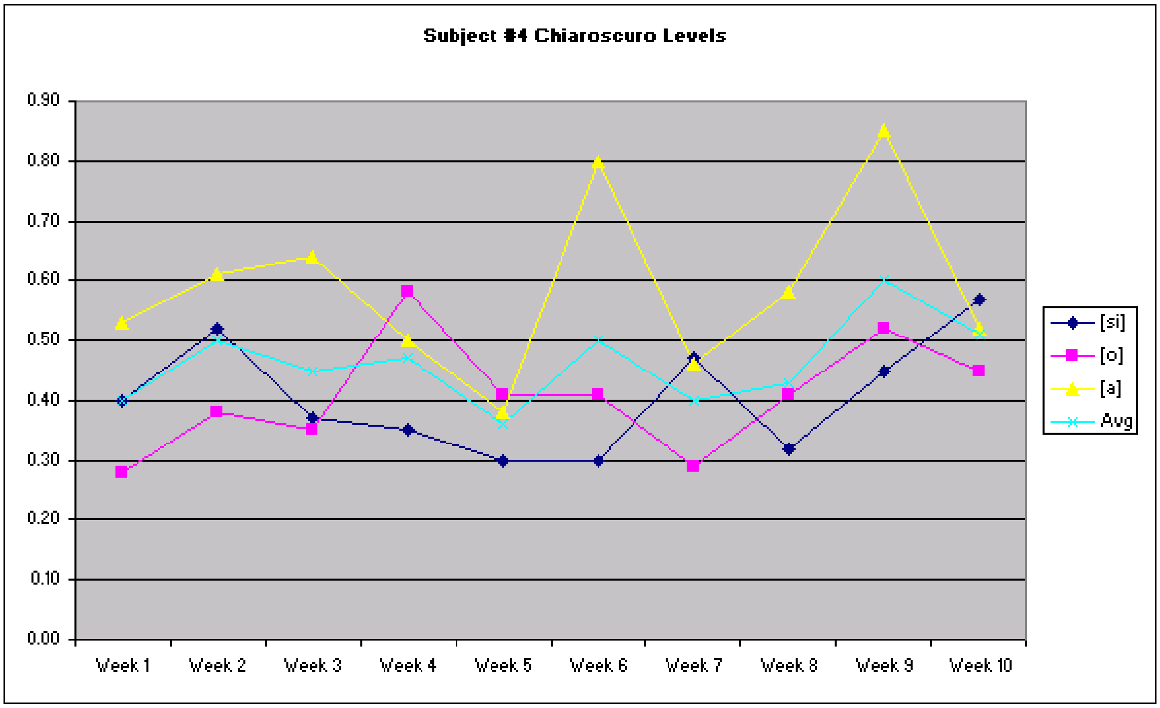
Power Spectrum from Spectrogram #10, Subject #4 at 5.18 seconds [o]

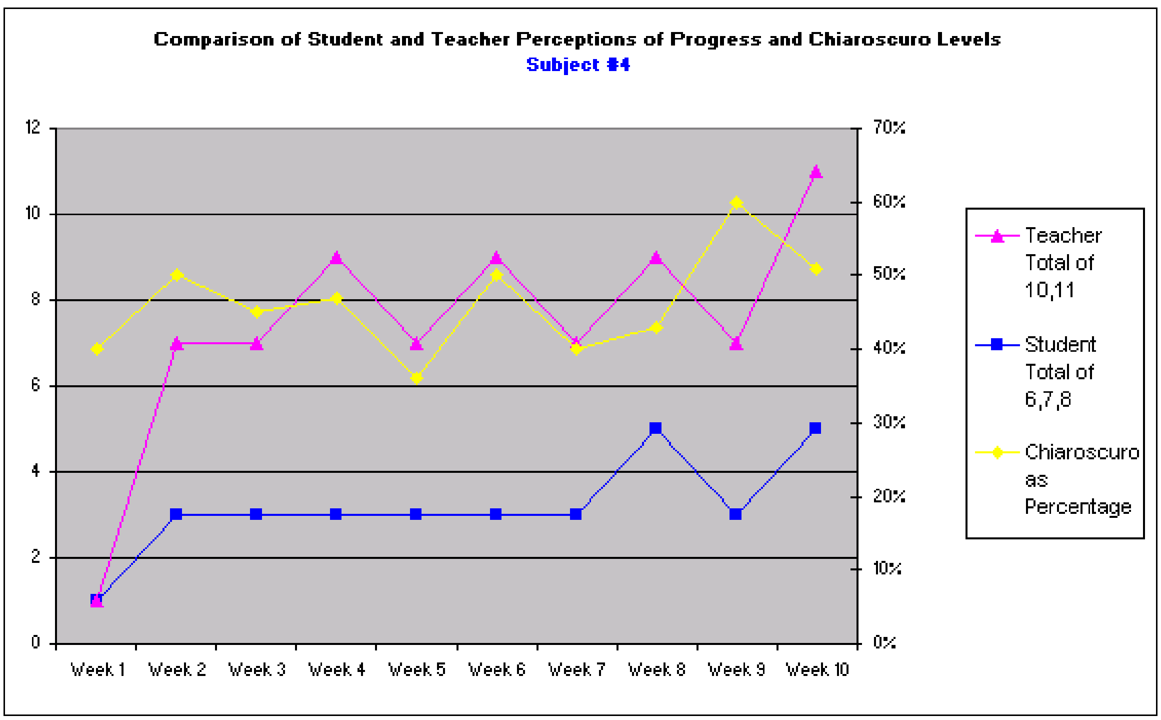


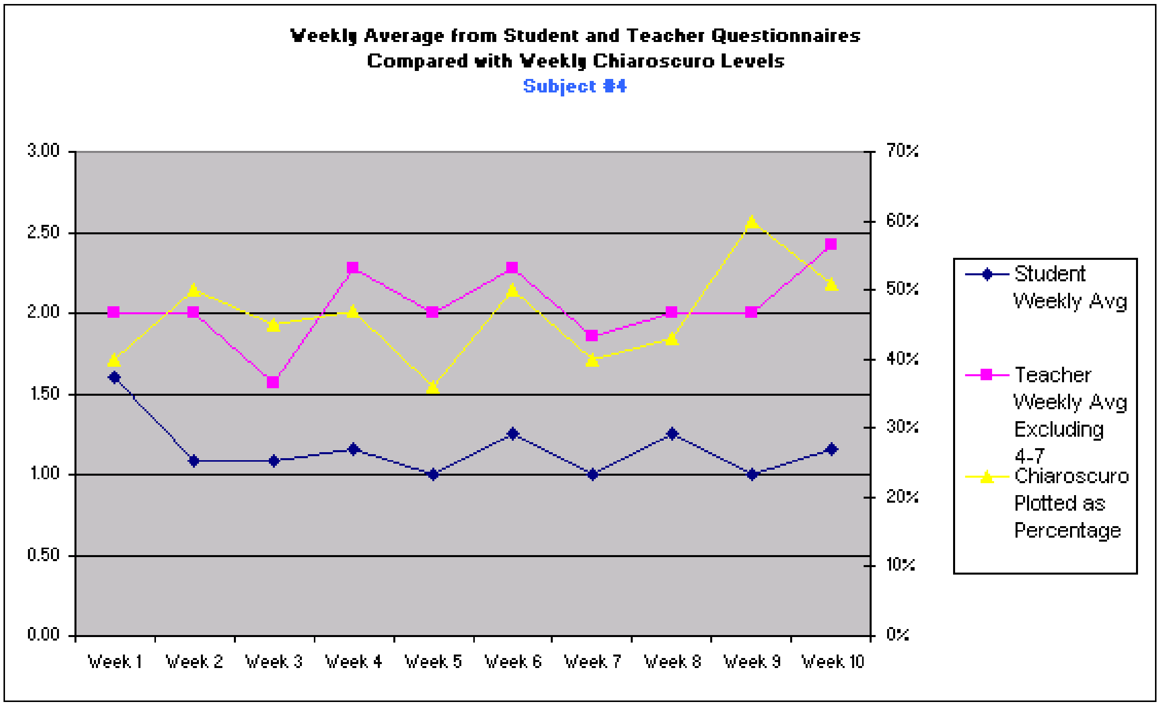
Power Spectrum from Spectrogram #10, Subject #4 at 7.05 seconds [a]



Analysis of Power Spectra from Spectrogram #10, Subject #4 – November 1, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.24	5	3	.6	6	11	.54	.57
5.18	6	3	.5	4	10	.4	.45
7.05	5	3	.6	4	9	.44	.52
Average of three chiaroscuro levels							.51


Subject #4 Chiaroscuro Levels
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg


Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #4
12
10
8
6
4
2
0
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #4
3.00
2.50
2.00
1.50
1.00
0.50
0.00
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A5: Subject #5

Subject #5 is a 20-year-old African-American junior majoring in arts management. Her home town is Birmingham, Alabama. At the time of the data collection she had been a student in the researcher's studio for two years. Voice was her concentration, and she made excellent progress from an inauspicious beginning.

As a freshman she had very diffuse vocal production. Although the basic sound was pretty, it was nearly inaudible, lacking energy and focus. Subject #5 had to learn all the resonance techniques. She did not, however, have to overcome problems stemming from singing popular styles, and she had a good background in music and French. She had to learn and consciously practice breath management techniques

Subject #5's voice was a medium-sized, warm, dark-colored lyric mezzo-soprano, heard to advantage in her favorite genres of *lieder* and *mélodies*. Her voice might best be described as "velvety." She had internalized all the resonance and breath management techniques to the point that she could sing expressively throughout her entire range, as long as she was singing a song. She rarely showed the quality of her voice in exercises. She normally vocalized from a to a^2, with even vocal production throughout.

In her junior year she began to sing with conviction and skill, and agreed to perform duets in several productions and recitals. The only problem for Subject #5 was that she had completed all of her music courses, and her business courses were interfering with her practice time. At the beginning of the semester she was not practicing as consistently as had been her habit, but she managed to improve her schedule. Aside from a two-week siege of bronchitis, she was healthy throughout the data collection period.

The spectrograph was a tool of enlightenment for Subject #5. During her first two years, she tended to believe that her voice was not as good as some of the other students' voices. Along with her shy personality, a lack of self-confidence made her regard herself as a "chorus only" singer. Seeing a spectrographic picture of her voice helped her to value it, particularly as she came to understand that her vocal quality was under her own control.

Fall Semester 2000 Repertoire – Subject #5

Hugo Wolf	Auf ein altes bild
	Mögen alle bösen Zungern
	Der Musikant
	Morgentau
Offenbach	The Letter Aria from *La Perichole*
Hailstock	I Loved You
Debussy	Chevaux de Bois
Chausson	Le Charme
	La derniére feuille
	Le Colibri
Arr. Brown	O Redeemed!
Quilter	The Widflower's Song
	Dream Valley
Mozart	The Heart duet from *Cosi fan tutte*
Herman	Bosom Buddies from *Mame*

Lesson record over the data collection period – Subject #5

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10-11
8/21	B	Repertoire assigned last spring – some progress Quilters	Good	Copying music for accompanist – check Quilter – nice ease in top voice has developed over the summer – she's putting everything together	#1 E flat	Chiaroscuro - .42 Student 1, 1, 1 Teacher n/a, n/a
8/22	A	Wildflower's Song	Good	VMC – nice job		
8/28	A	Auf ein altes Bild, Mozart, Hailstock	Good	In good voice working well – coaching	#2 D	Chiaroscuro - .38 Student 1, 1, 1 Teacher 3, 3
9/4			Holiday			
9/11	A	Auf ein altes Bild, Quilters, Der Musikant	Starting to get sick – voice okay so far – excellent preparation	Has nearly memorized the Quilters – working our dissonances in Auf ein altes Bild – tried Der Musikant and loved it – her voice is working, but the drainage is making her nauseous – hard to support	#3 E flat	Chiaroscuro - .45 Student 1, 1, 1 Teacher 3, 3
9/18			Lesson cancelled for guest artist			
9/19	A	Quilters, Hailstock	Good – make up lesson	Voice is working beautifully – she is working steadily on her music – all is well - Coaching	#4 E flat	Chiaroscuro - .42 Student 1, 1, 1 Teacher 3, 3
9/25				Lesson cancelled for TN trip		
10/2				Lesson cancelled – sick teacher		
10/5				Make up lesson scheduled – she forgot		
10/9	A	Auf ein altes Bild, Wildflowers Song, Le Charm	Good	She is coming along with superb sounds - Coaching	#5 D	Chiaroscuro - .61 Student 2, 1, 1 Teacher 2, 2
10/12	A	Quilter, 3 Chausson	Excellent	Has worked all the Chausson's – Coaching	#6 E flat	Chiaroscuro - .44 Student 1, 1, 1 Teacher 2, 2
10/16	A	Quilter, 3 Chausson	Excellent	Vocally in good shape – confidence is not so good – someone in her sorority said something nasty	#7 E flat	Chiaroscuro - .62 Student 1, 1, 1 Teacher 2, 2
	B+	Wildflower Song	Good	Student recital – she got scared and her tuning and tone quality were not what I expected		
10/23			Sick – bronchitis			
10/26			Sick - bronchitis			
10/30	B	Der Musikant Auf ein altes Bild	Okay, but she's not well yet	Almost recovered – warmed up and made wave file – voice is weak and ragged, but she wants to sing – dryness is a big problem	#8 E flat	Chiaroscuro - .29 Student 3, 1, 1 Teacher 4, 2
11/6	B	Le Charm for VMC recital check – make up lesson	Okay	Wave file recording had some problems: Margie's and a false start are on this recording – Le Charm needed lots of coaching to be ready – lost ground while sick	#9 E flat	Chiaroscuro - .37 Student 1, 1, 1 Teacher 3, 21
11/7	A	Le Charm, Der Musikant, Auf ein altes Bild	Excellent	Coaching	#10 E flat	Chiaroscuro - .59 Student 1, 1, 1 Teacher 3, 2
11/13				Lesson cancelled for Scholarship Auditions		
11/14	A	Cosi duet	Excellent	Blocking and coaching		

11/20	A	Le Charme, Le Colibri, Auf ein altes Bild, Der Musikant	Excellent	Coaching – she has a real feel for lieder and melodies – is exploring recordings on her own		
11/21	A	4 Chausson., 4 Wolf, Debussy	Excellent	Most memorized, all learned, incuding 3/5 of Debussy		

Responses to student questionnaires – Subject #5

(Note: From 8/21 through 10/12 Subject #5 had misread the scale and was using it in reverse, 5 meaning "strongly agree" and 1 meaning "strongly disagree". Her responses have been changed in this chart to indicate her actual answer with the original answer in parentheses in the same cell.)

Question	8/21	8/28	9/11	9/19	10/9	10/12	10/16	10/30	11/6	11/7	**Total of weekly answers to questions 6, 7,. 8**
1	2 (4)	1 (5)	2 (4)	2 (4)	1 (5)	2	1	3	1	1	
2	2 (4)	1 (5)	2 (4)	2 (4)	2 (4)	2	1	3	1	1	
3	1 (5)	1 (5)	2 (4)	2 (4)	2 (4)	1	1	2	2	1	
4	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	
5	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	
6	1 (5)	1 (5)	1 (5)	1 (5)	2 (4)	1	1	3	1	1	**1.3**
7	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	**1**
8	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	**1**
9	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	**Average over ten week period**
10	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	
11	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	
12	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1	1	1	1	1	
Weekly Average	1.16	1	1.25	1.25	1.25	1.16	1	1.58	1.08	1	**1.1**

Responses to teacher questionnaires – Subject #5

Quantification of the verbal categories on the form will be as follows:

1	=	Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)
2	=	Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)
3	=	Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)
4	=	Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)
5	=	Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all

(Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

Question	8/21	8/28	9/11	9/19	10/9	10/12	10/16	10/30	11/6	11/7	**Total and Average of questions 10 & 11**
1	1	2	2	2	2	2	2	2	2	2	
2	2	1	3	2	2	1	1	4	2	2	
3	2	2	2	2	2	2	2	2	2	2	
4	3	1	2	3	3	3	2	5	3	4	
5	5	2	5	4	5	3	4	5	4	4	
6	1	2	4	4	5	3	3	5	5	5	
7	5	5	5	5	3	5	5	5	5	5	
8	2	1	1	1	2	2	1	2	2	2	
9	1	2	2	2	3	1	2	4	2	2	
10	N/A	3	3	3	2	2	2	4	3	3	**2.9**
11	N/A	3	3	3	2	2	2	2	2	2	**2.33**
Weekly average excluding questions 4-7	1.6	2	2.28	2.14	2.14	2	1.71	2.85	2.14	2.14	**1.61**

Student's Written Reaction to Use of Spectrograph – Subject #5

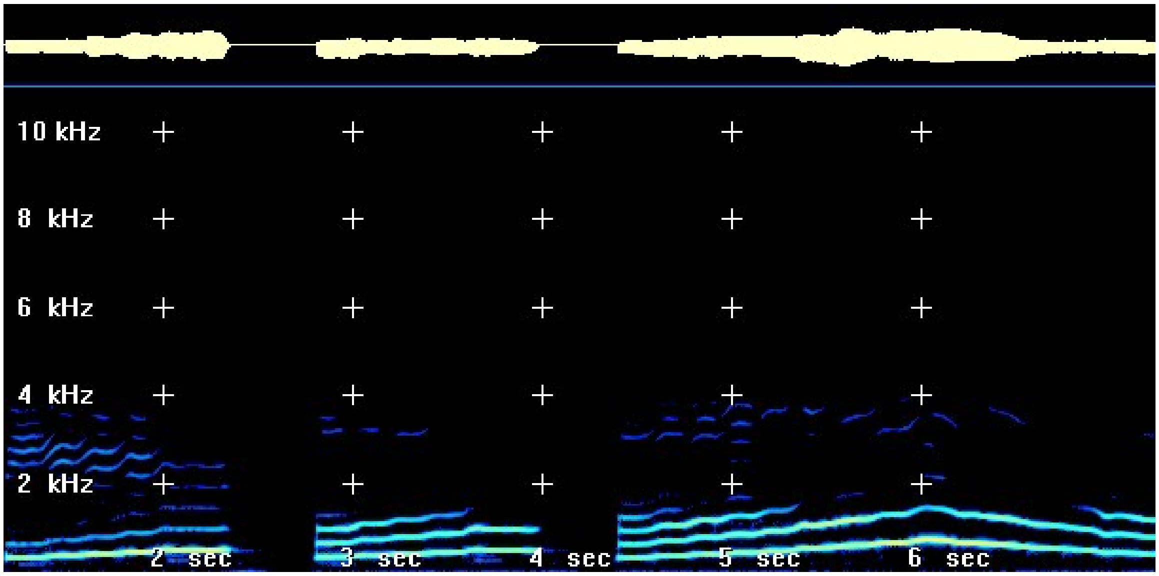
When I first encountered the spectrograph, I had no idea what I was getting into. I thought the idea of being able to see what my voice was doing while I sang was going to be interesting. My first experience was amazement, but I still did not know what it was I was supposed to be looking for when I sang different ways. As I continued to do the spectrograph in my lesson, however, I came to realize what the squiggly lines meant and what they said about my singing.

The first thing that I began to understand was the top, yellow line on the spectrograph. I found out that it measured my vibrato. I noticed that when I first began singing, I did not have very much action in that line. However, as I learned to manipulate my voice to get the spectrograph to do the correct things, I began to see that same yellow line move and grow thicker as my vibrato got better.

The bottom lines were the ones that changed significantly as I used the spectrograph more. In the beginning there was not a continuous line like there should be in singing. Instead there was an occasional line amidst several broken lines. I learned to use my diaphragm and correct breathing to make sure that lines were connected. As time went on, those lines began to get thicker as my voice got larger and more secure. I can say that the spectrograph has improved my technique and my sound immensely.

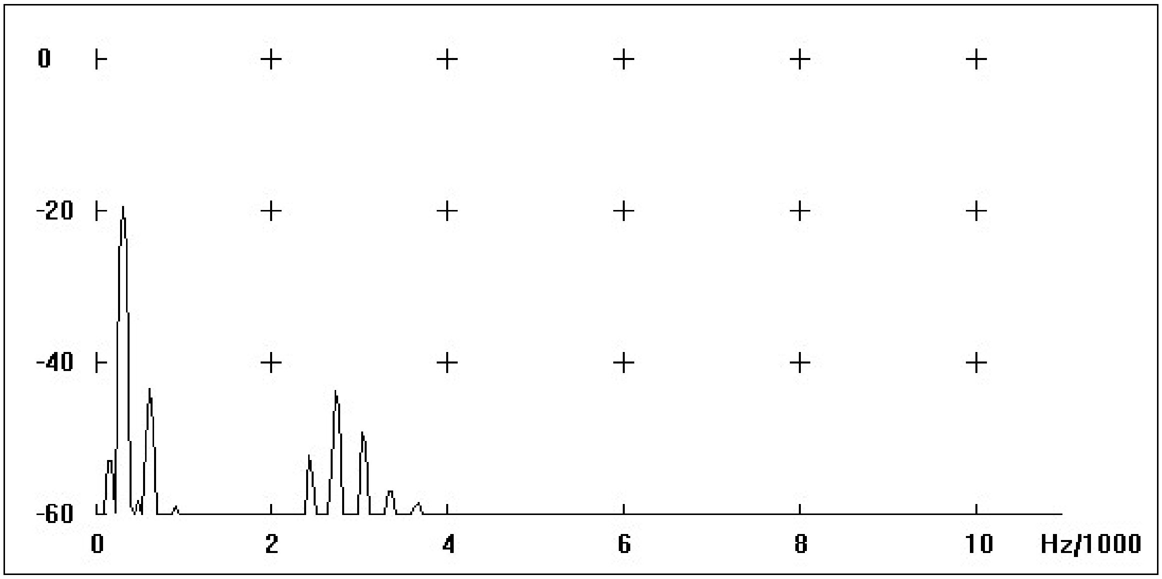
Analysis of Wave Files

Wave File Number 1 – August 21, 2000 – Subject #5

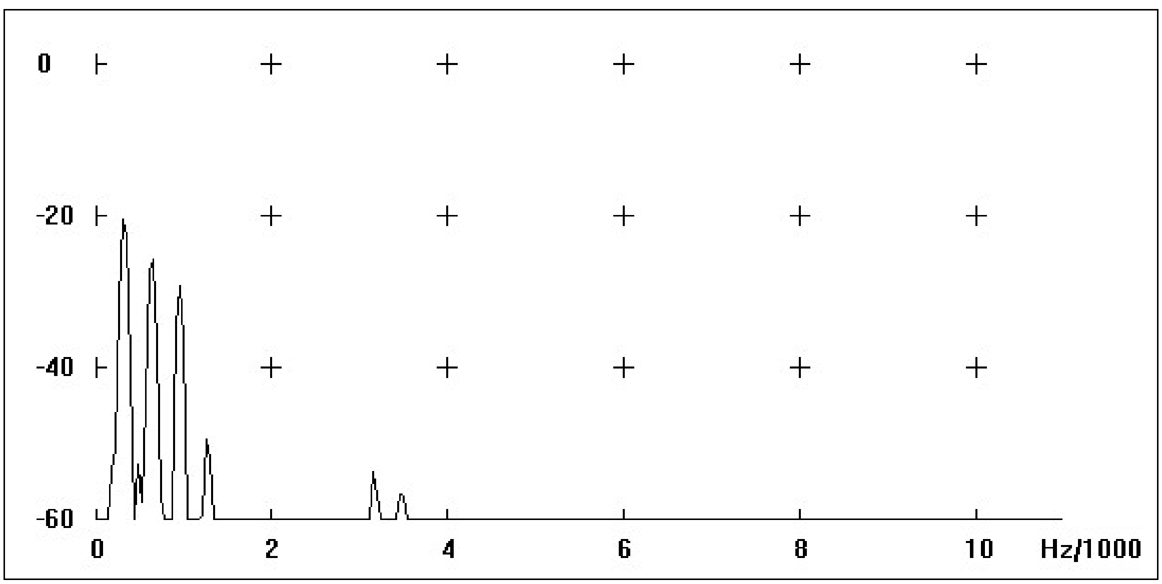


Subject #5 – Analysis of Wave File #1 – August 21, 2000 – E flat major				
		[si] (1.19-2.33 sec)	[o] (2.8-4.0 sec)	[a] (4.39-8.5 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Begins with some indications, but looses them halfway	Begins with some indications, but looses them halfway	Begins with some indications, but looses them halfway
2nd Formant Area (Vowel Definition)		Good vowel formation	Good vowel formation	Somewhat weak vowel formation
1st Formant Area		Moderately strong	Moderately strong	Moderately strong
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increases from about 10% to about 30%	Varies around 20%	<> from about 10% to about 30%
A lack of commitment to producing the sound is evident here. The skill to produce a resonant sound is evident at the beginning of each vowel but is not consistent. Lack of consistency could be attributed to inconsistent breath management.				

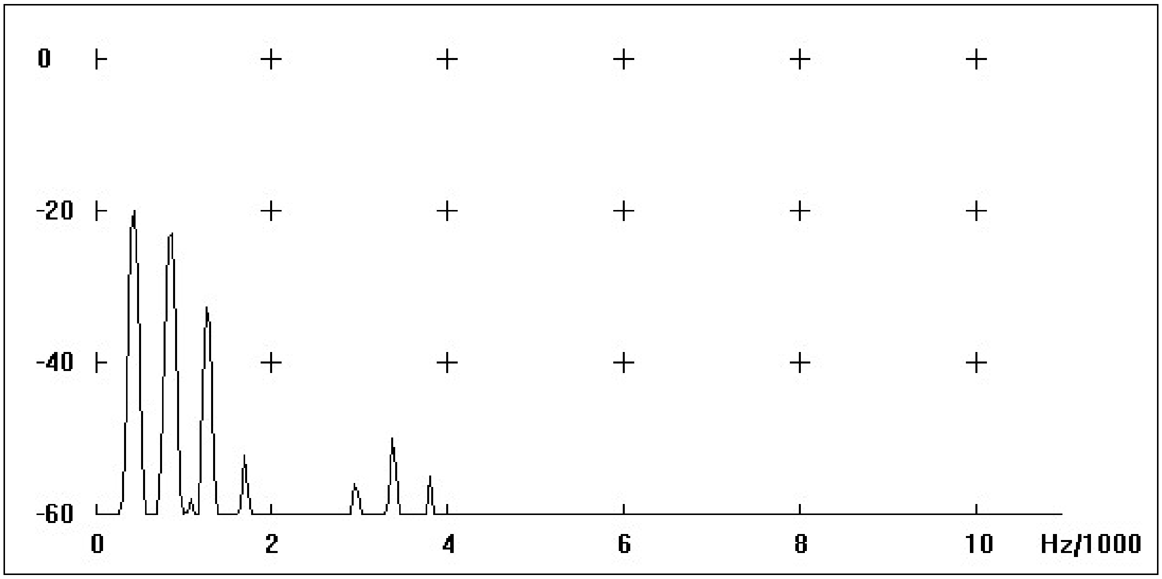
Power Spectrum from Spectrogram #1, Subject #5 at 1.28 seconds [i]



Power Spectrum from Spectrogram #1, Subject #5 at 2.88 seconds [o]

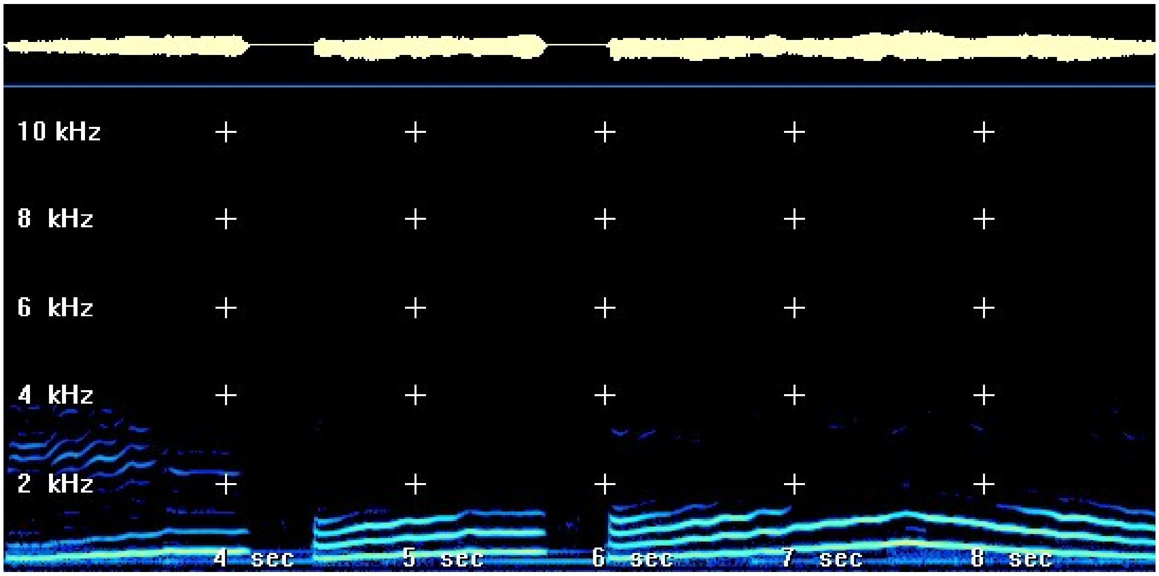


Power Spectrum from Spectrogram #1, Subject #5 at 5.05 seconds [a]



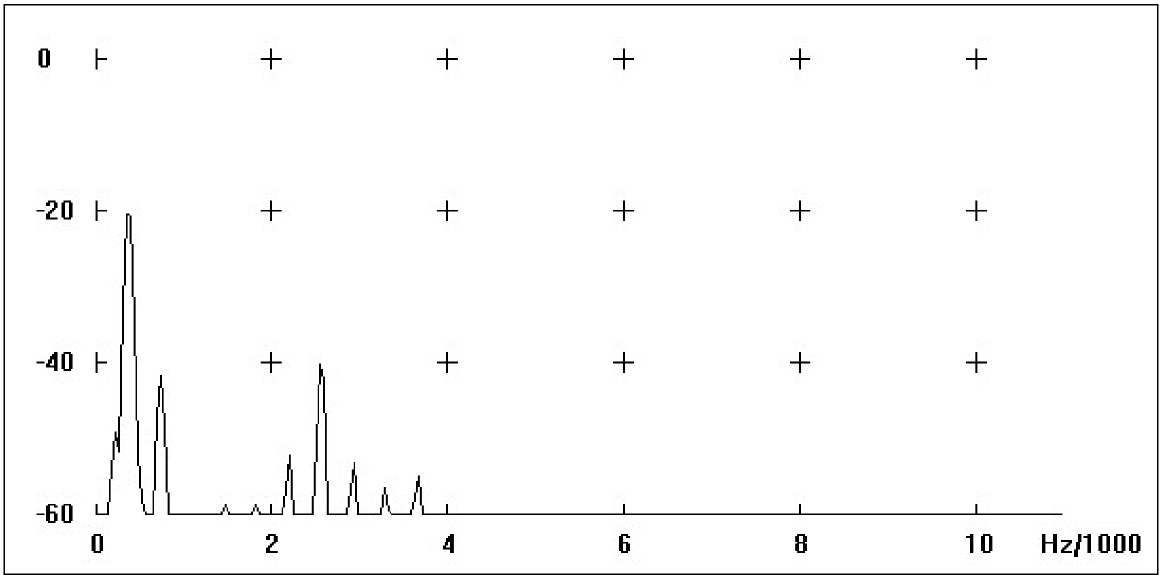
Analysis of Power Spectra from Spectrogram #1, Subject #5 – August 21, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	b/a	c	d	c/d	(b/a+c/d)/2
1.28	5	1	.2	5	10	.5	.35
2.88	5	3	.6	2	7	.28	.44
5.05	5	3	.6	3	8	.37	.48
Average of three chiaroscuro levels							.42

Wave File Number 2 – August 28, 2000 – Subject #5

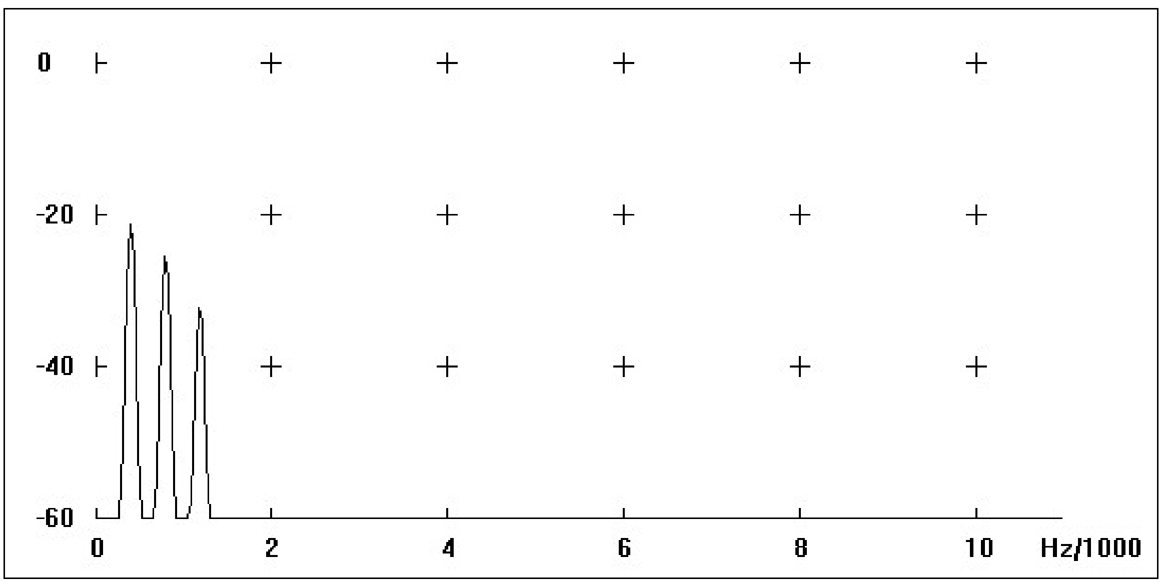


Subject #5 – Analysis of Wave File #2 – August 28, 2000 – D major				
		[si] (2.85-4.09 sec)	[o] (4.49-5.68 sec)	[a] (6.03-9.61 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications		Scattered indications
2nd Formant Area (Vowel Definition)		Good vowel formation	Good vowel formation	Good vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increasing from about 10% to about 20%	Varying around 30%	Varying around 40%
Tends to rely on lower frequencies.				

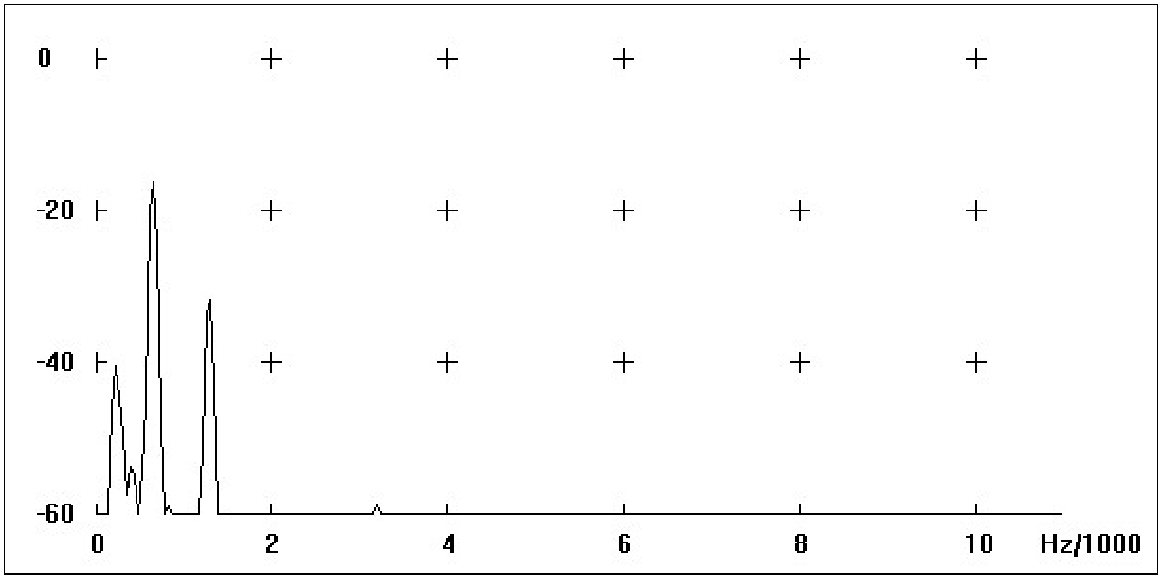
Power Spectrum from Spectrogram #2, Subject #5 at 3.37 seconds [i]



Power Spectrum from Spectrogram #2, Subject #5 at 5.11 seconds [o]

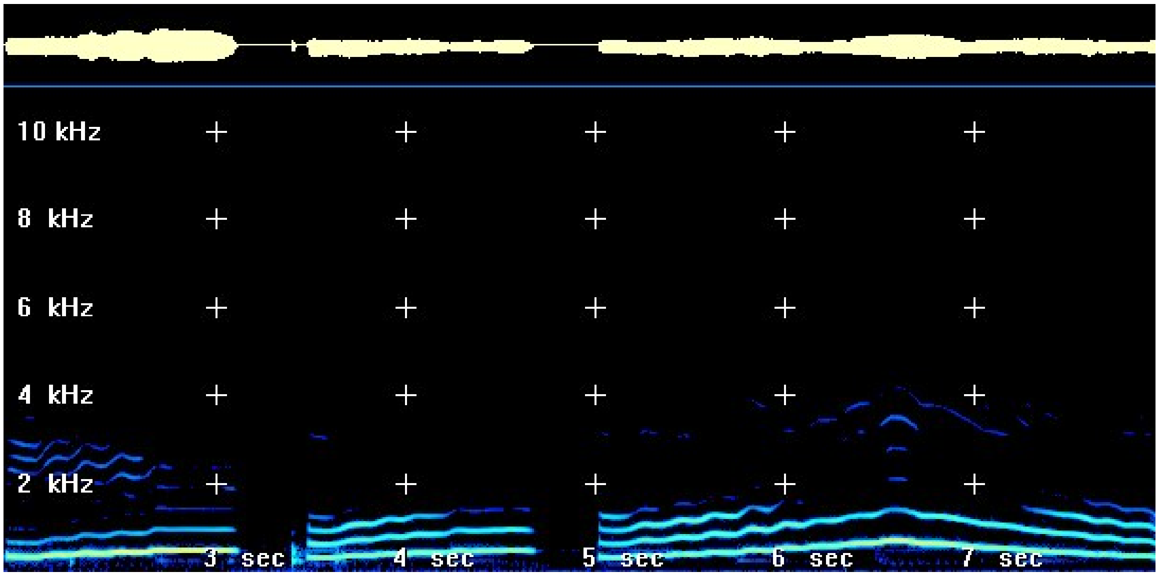


Power Spectrum from Spectrogram #2, Subject #5 at 7.56 seconds [a]



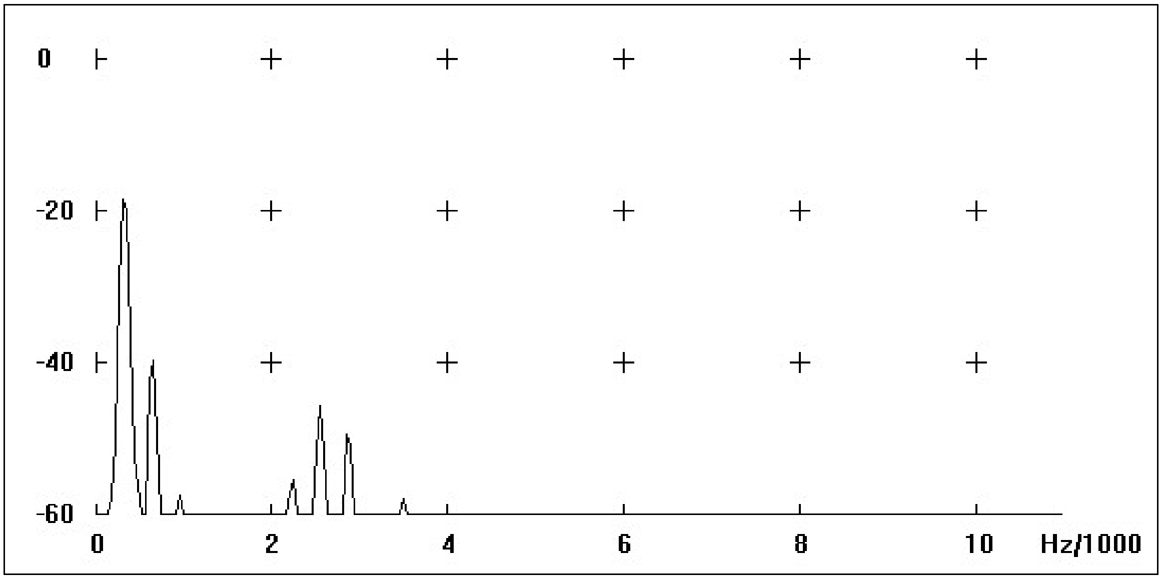
Analysis of Power Spectra from Spectrogram #2, Subject #5 – August 28, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.69	5	1	.2	5	10	.5	.3
4.73	3	3	1.0	0	3	0	.5
6.74	4	2	.5	1	5	.2	.35
Average of three chiaroscuro levels							.38

Wave File Number 3 – September 11, 2000 – Subject #5

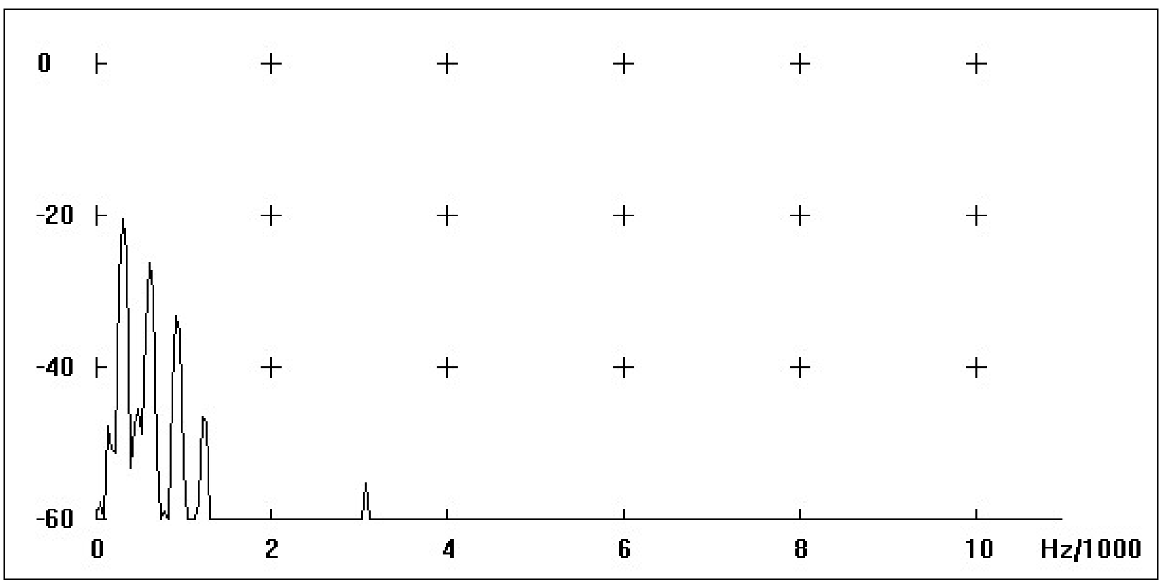


Subject #5 – Analysis of Wave File #3 – September 11, 2000 – E flat major				
		[si] (1.92-3.1 sec)	[o] (3.5-4.66 sec)	[a] (5.04-8.98 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Two nearly consistent bands	Scattered indications	Mainly during highest pitches
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Moderately strong and consistent	Moderately strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 20% to about 40%	Varying around 20%	Varying around 20%
Continues to rely on lower frequencies.				

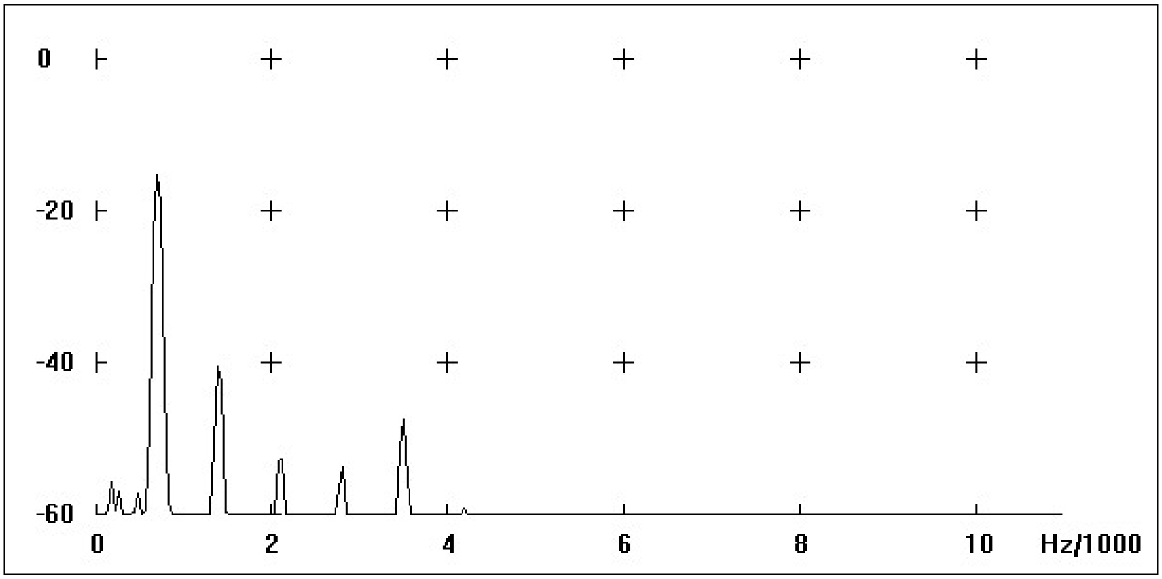
Power Spectrum from Spectrogram #3, Subject #5 at 2.02 seconds [i]



Power Spectrum from Spectrogram #3, Subject #5 at 3.54 seconds [o]

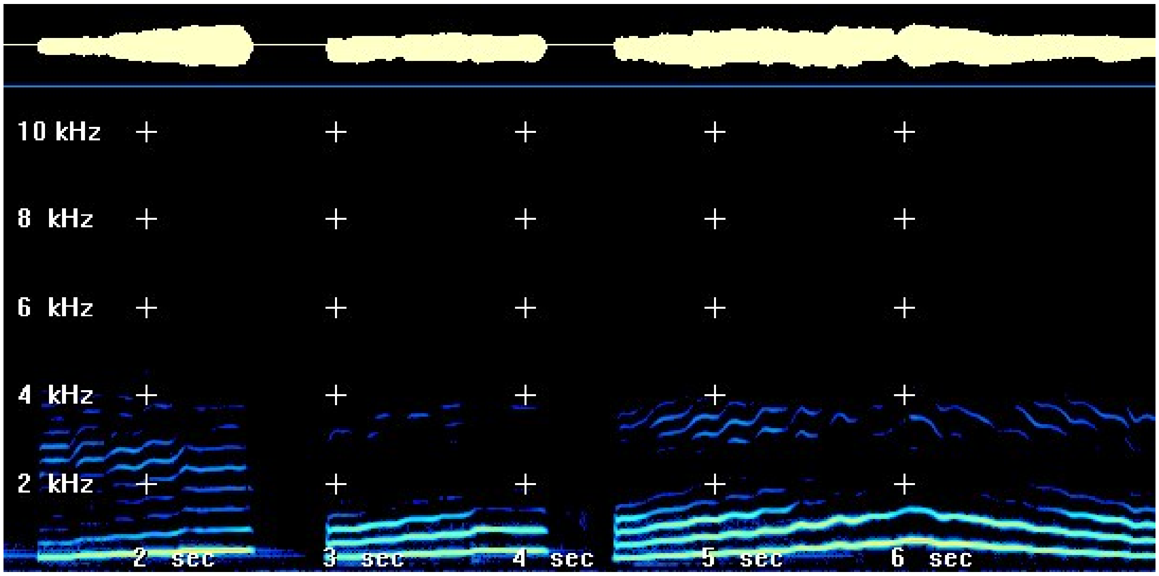


Power Spectrum from Spectrogram #3, Subject #5 at 6.63 seconds [a]



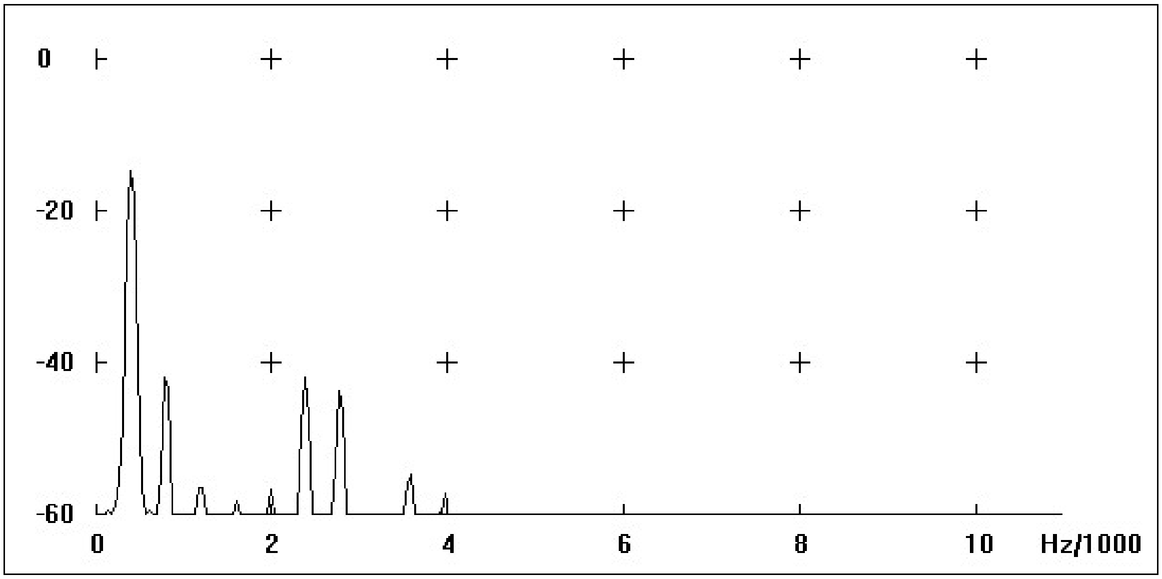
Analysis of Power Spectra from Spectrogram #3, Subject #5 – September 11, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.02	3	2	.66	4	7	.57	.61
3.54	6	3	.5	1	7	.14	.32
6.63	5	2	.4	4	9	.44	.42
Average of three chiaroscuro levels							.45

Wave File Number 4 – September 19, 2000 – Subject #5

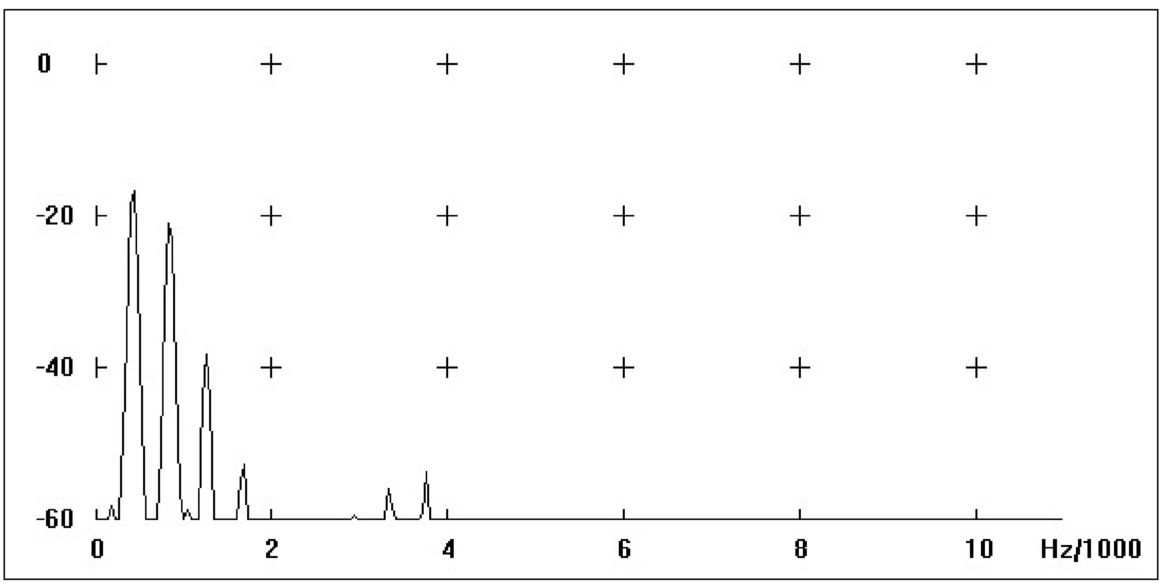


Subject #5 – Analysis of Wave File #4 – September 19, 2000 – E flat major				
		[si] (1.44-2.52 sec)	[o] (2.94-4.1 sec)	[a] (4.46-8.43 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Scattered indications	2-3 bands stronger at 4.5-5.5
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Better balance	Better balance	Better balance
Power Spectrum		Increase from about 20% to about 60%	Varying around 30%	Varying around 40%
Much better balance in this wave file. Lower frequencies still strong, but more indications of upper frequencies.				

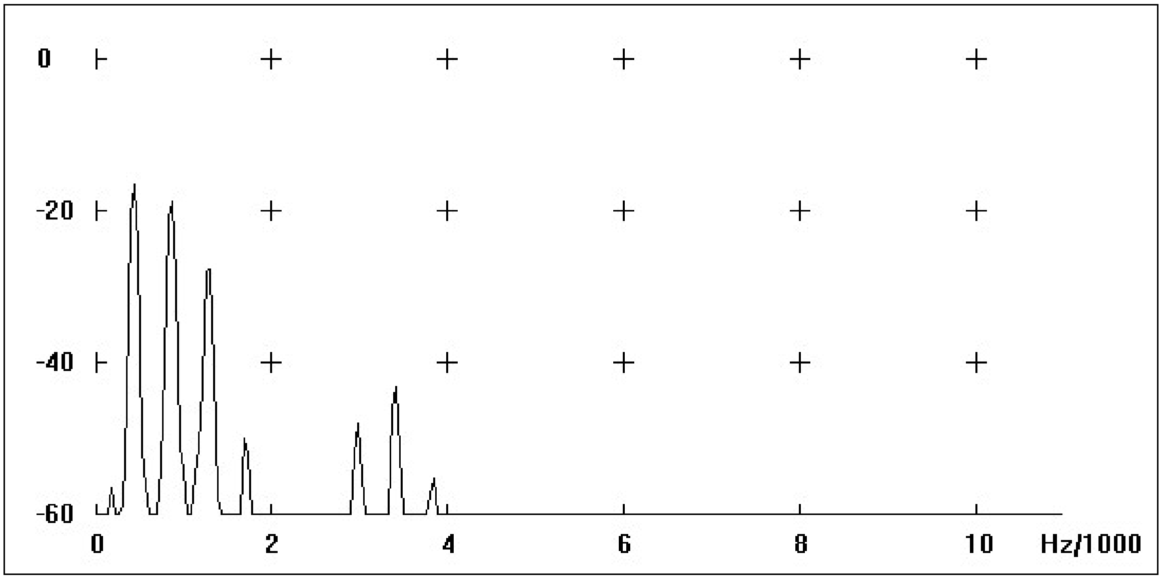
Power Spectrum from Spectrogram #4, Subject #5 at 1.88 seconds [i]



Power Spectrum from Spectrogram #4, Subject #5 at 3.61 seconds [o]

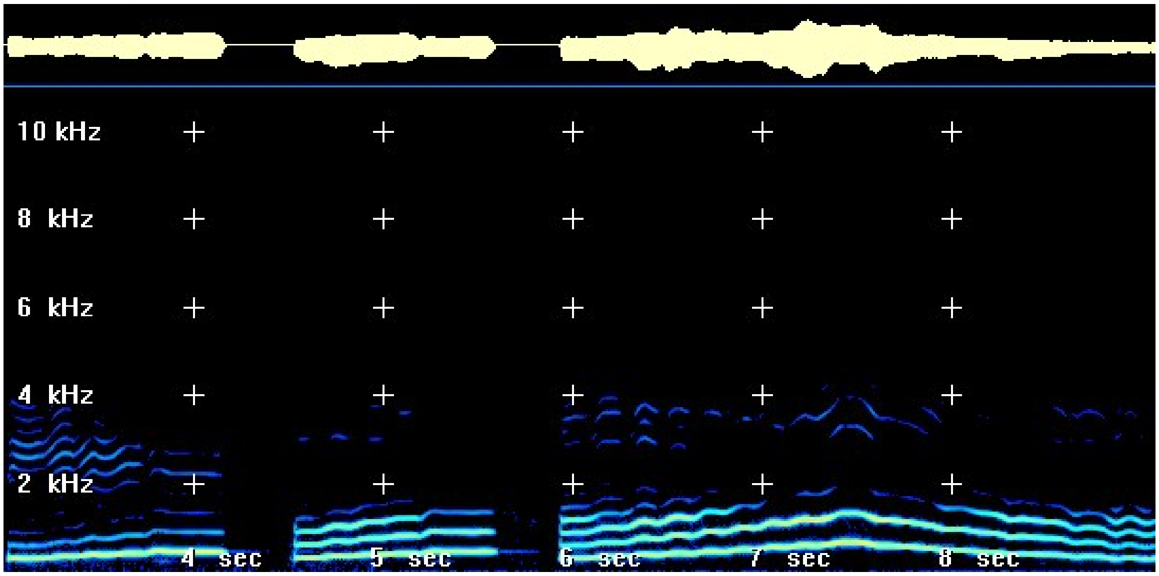


Power Spectrum from Spectrogram #4, Subject #5 at 5.1 seconds [a]



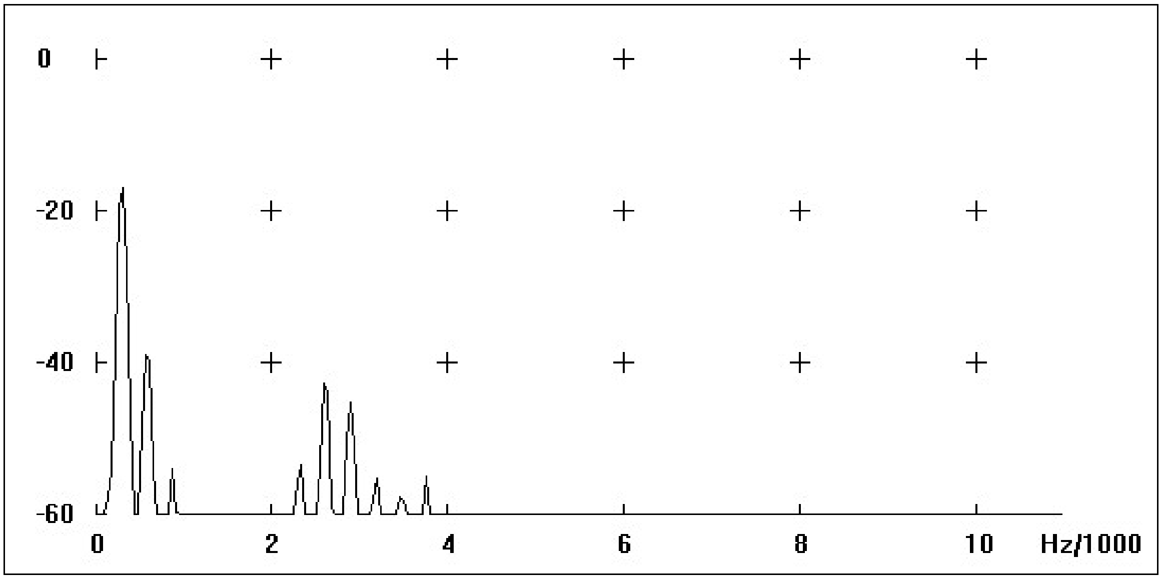
Analysis of Power Spectra from Spectrogram #4, Subject #5 – September 19, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
1.88	6	2	.33	5	11	.45	.39
3.61	6	3	.5	3	9	.33	.41
5.1	5	3	.6	3	8	.37	.48
Average of three chiaroscuro levels							.42

Wave File Number 5 – October 9, 2000 – Subject #5

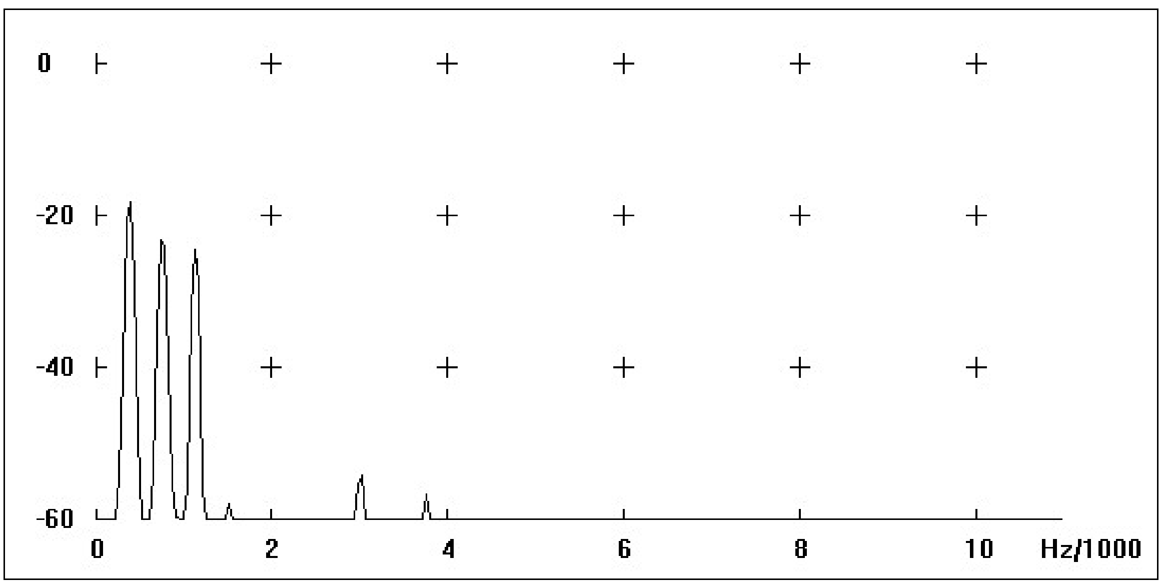


Subject #5 – Analysis of Wave File #5 – October 9, 2000 – D major				
		[si] (3.04-4.14 sec)	[o] (4.52-5.58 sec)	[a] (5.95-9.82 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Scattered indications	Scattered indications – most consistent at highest pitches
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 30%	Varying around 30%	<> from about 20% to about 80%
This wave file is a picture of something often called "backing away" from the sound. The student tends to decrease upper level frequencies as she increases pitch, effectively lightening the voice at higher pitches rather than keeping it full and consistent.				

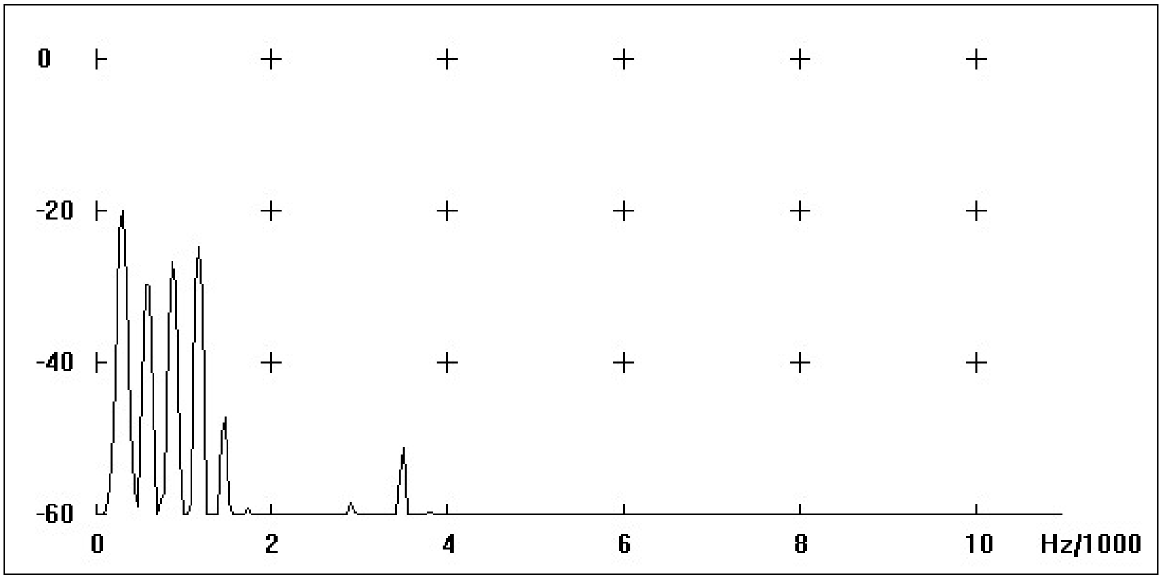
Power Spectrum from Spectrogram #5, Subject #5 at 3.09 seconds [i]



Power Spectrum from Spectrogram #5, Subject #5 at 4.97 seconds [o]

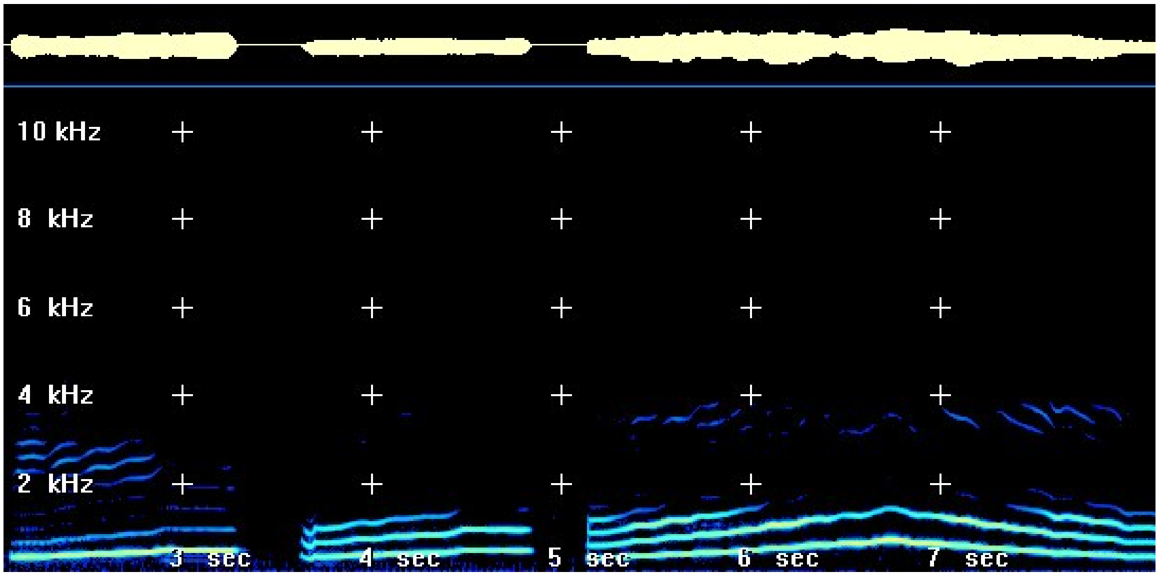


Power Spectrum from Spectrogram #5, Subject #5 at 6.0 seconds [a]



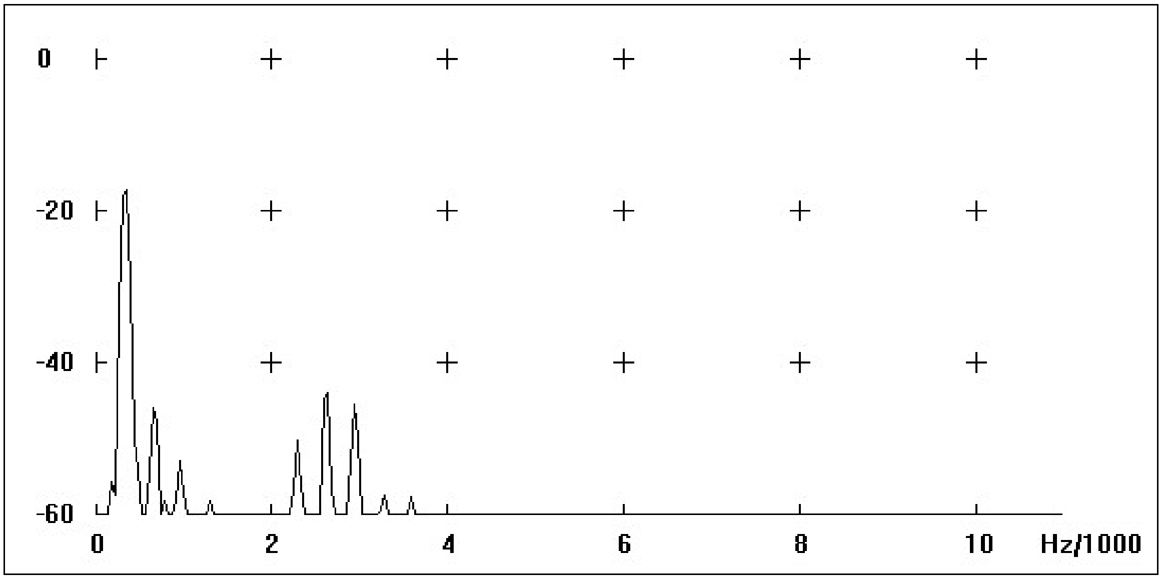
Analysis of Power Spectra from Spectrogram #5, Subject #5 – October 9, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.09	3	2	.66	6	9	.66	.66
4.97	4	3	.75	2	6	.66	.7
6.0	6	4	.66	3	9	.33	.49
Average of three chiaroscuro levels							.61

Wave File Number 6 – October 12, 2000 – Subject #5

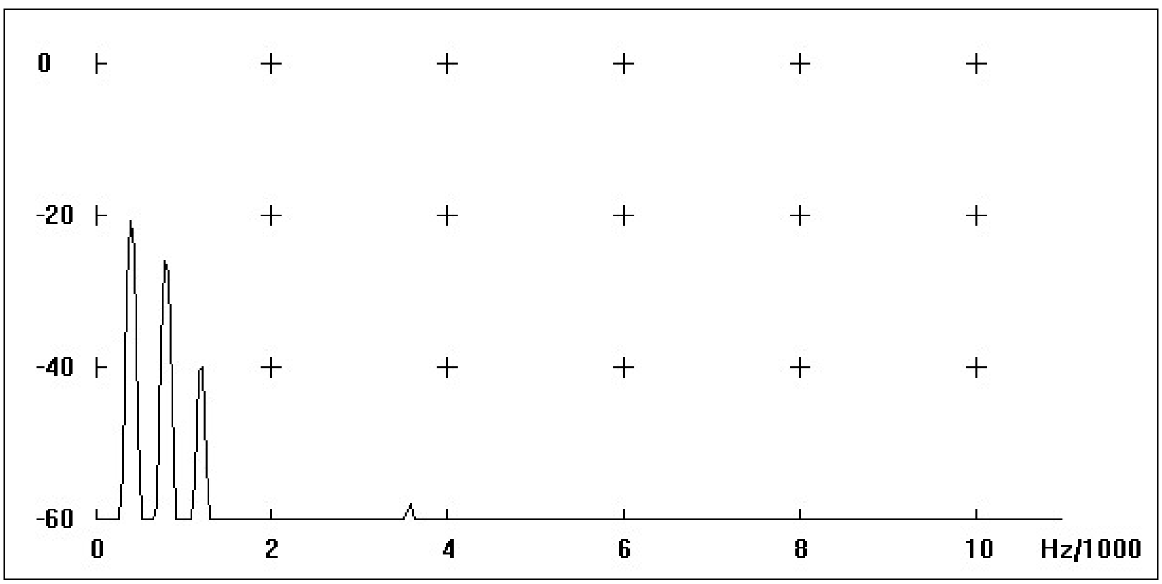


Subject #5 – Analysis of Wave File #6 – October 12, 2000 – E flat major				
		[si] (2.14-3.28 sec)	[o] (3.63-4.83 sec)	[a] (5.14-9.07 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Scattered indications	Scattered indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 20%	Varying around 10%	Varying around 30%
Student continues to "back away" from upper frequencies.				

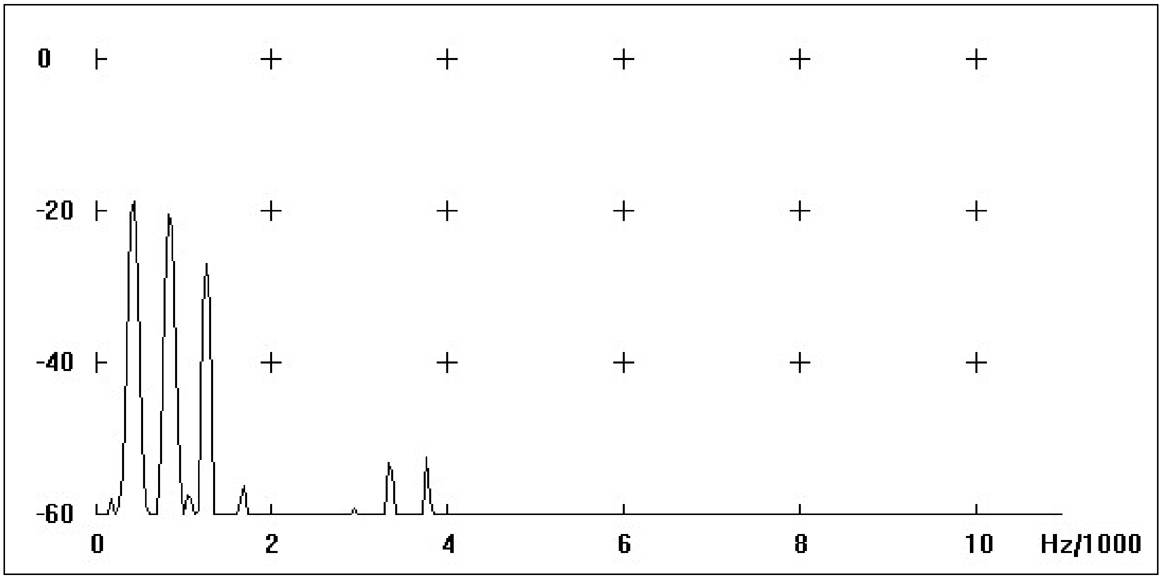
Power Spectrum from Spectrogram #6, Subject #5 at 2.21 seconds [i]



Power Spectrum from Spectrogram #6, Subject #5 at 4.18 seconds [o]

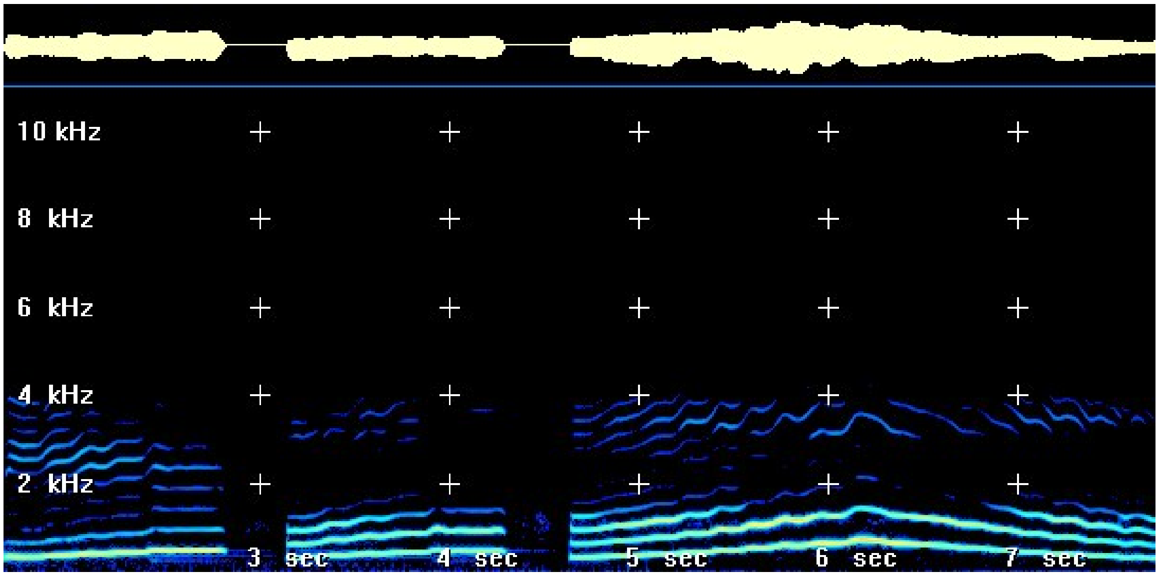


Power Spectrum from Spectrogram #6, Subject #5 at 5.8 seconds [a]



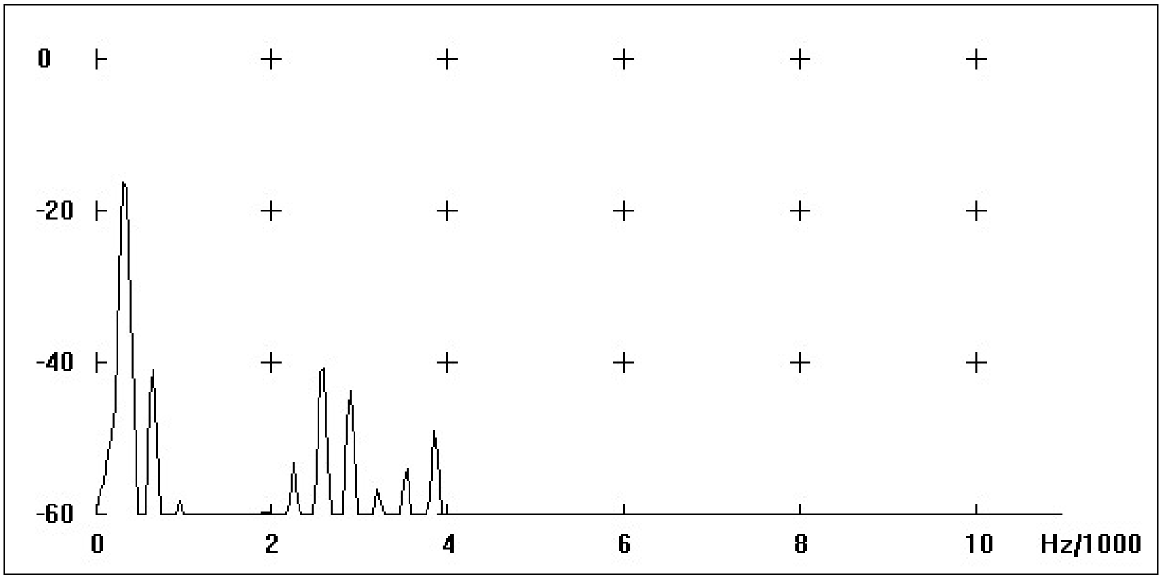
Analysis of Power Spectra from spectrogram #6, Subject #5 – October 12, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.21	6	1	.16	5	11	.45	.3
4.18	3	3	1.0	1	4	.25	.62
5.8	6	3	.5	3	9	.33	.41
Average of three chiaroscuro levels							.44

Wave File Number 7 – October 16, 2000 – Subject #5

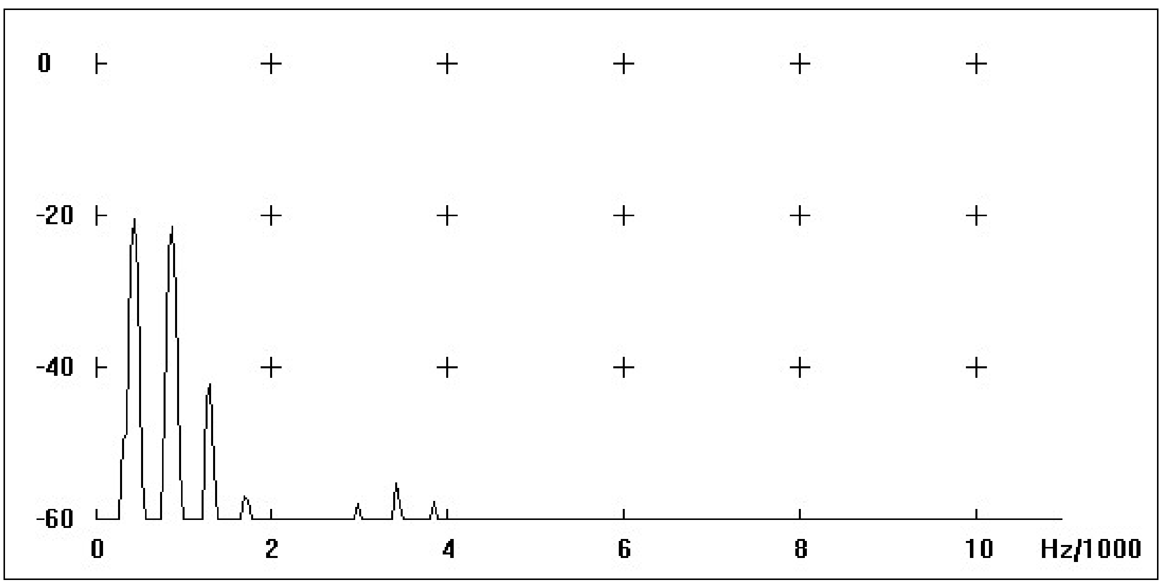


Subject #5 – Analysis of Wave File #7 – October 16, 2000 – E flat major				
		[si] (2.14-3.28 sec)	[o] (3.15-4.3 sec)	[a] (5.14-9.07 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Several indications above the vowel – continue to lessen as pitch rises	Scattered indications – continue to lessen as pitch rises	Nearly solid indications – lessen as exercise ends
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Better balanced	Weighted toward lower frequencies	Better balanced
Power Spectrum		Varying around 30%	Varying around 20%	<> from about 20% to about 70%
Although this wave file shows much more consistency in upper frequencies, the "backing off" effect continues. This effect may result from releasing muscular effort (breath management) before the end of the exercise.				

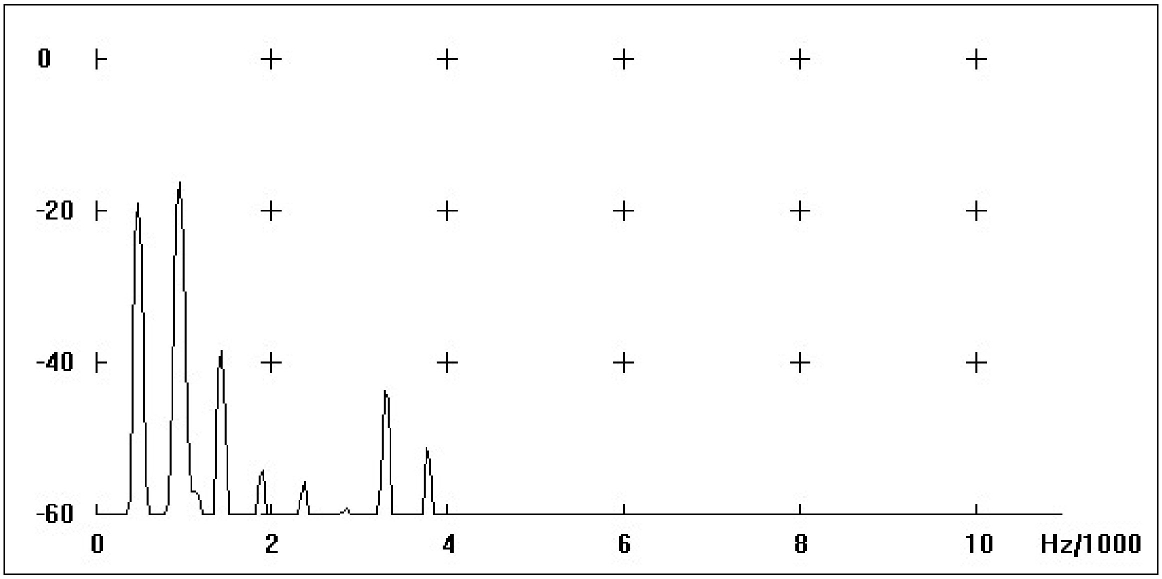
Power Spectrum from Spectrogram #7, Subject #5 at 1.72 seconds [i]



Power Spectrum from Spectrogram #7, Subject #5 at 3.76 seconds [o]

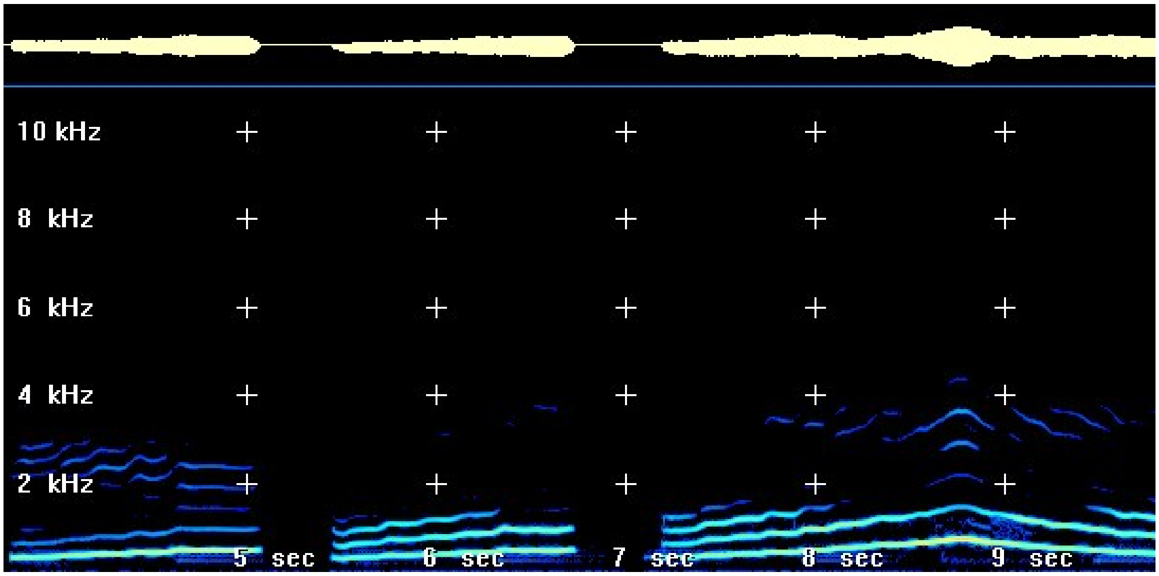


Power Spectrum from Spectrogram #7, Subject #5 at 5.48 seconds [a]



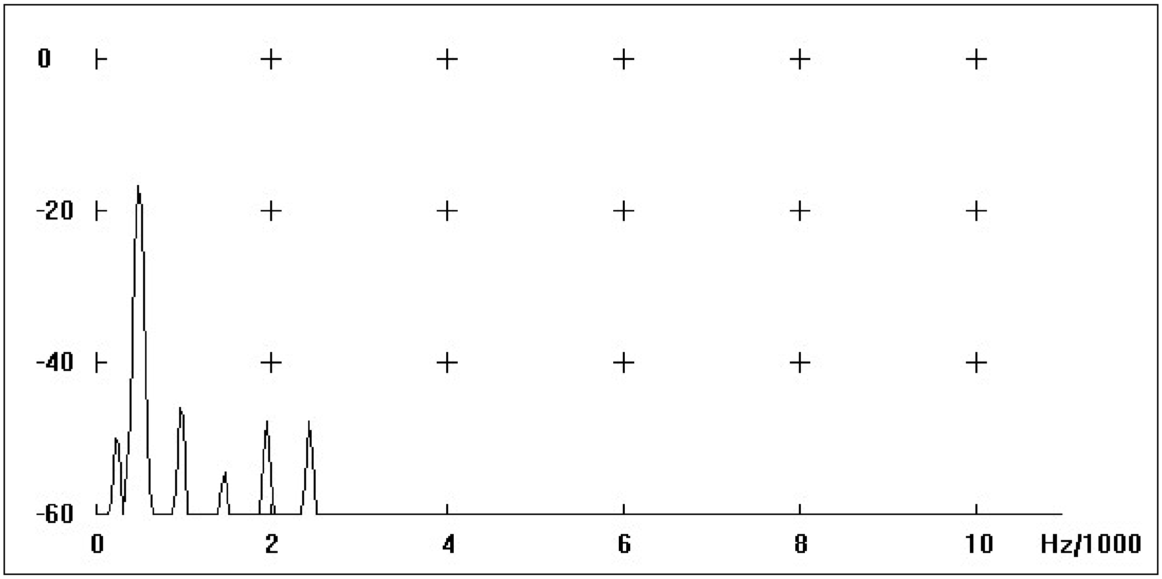
Analysis of Power Spectra from Spectrogram #7, Subject #5 – October 16, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{b/a+c/d}{2}$
1.72	3	2	.66	6	9	.66	.66
3.76	4	3	.75	3	7	.42	.58
5.48	4	3	.75	4	8	.5	.62
Average of three chiaroscuro levels							.62

Wave File Number 8 – October 30, 2000 – Subject #5

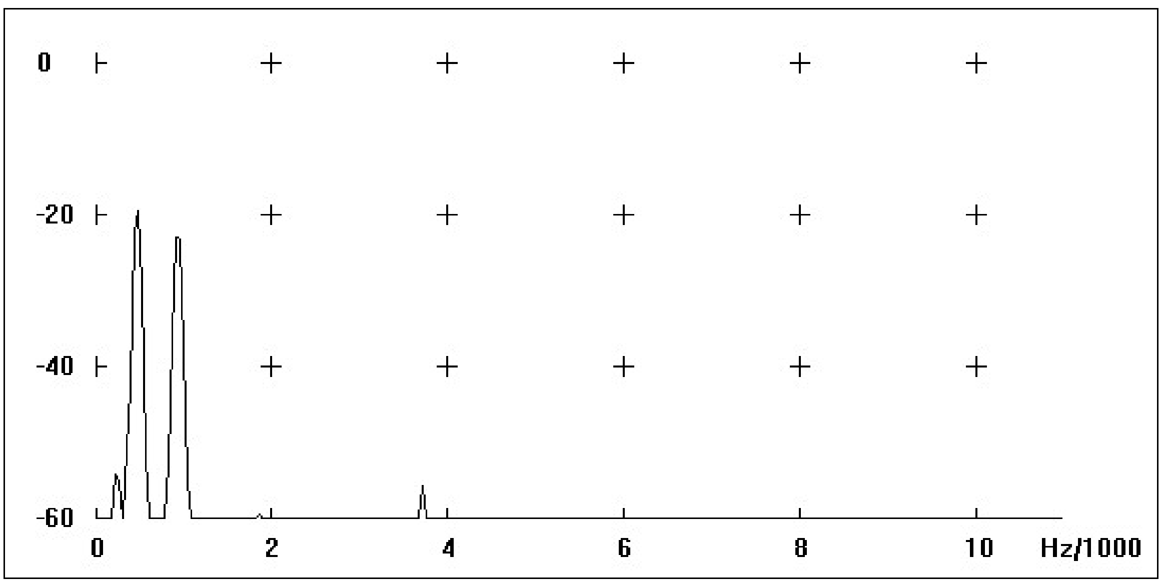


Subject #5 – Analysis of Wave File #8 – October 30, 2000 – E flat major				
		[si] (3.75-5.04 sec)	[o] (5.46-6.72 sec)	[a] (7.21-11.0 sec)
Singer's Formant Area	4000+ Hz			One indication
	2000-4000 Hz	Scattered indications	Scattered indications	Scattered indications, especially at highest pitches
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increasing from about 10% to about 20%	Increasing from about 10% to about 20%	<> from about 20% to about 40%
The high frequencies occurring in the [a] vowel at the highest pitches resulted from an audible sudden increase of air pressure. Note the noise visible between 8.6 and 9.1 seconds in the first formant area.				

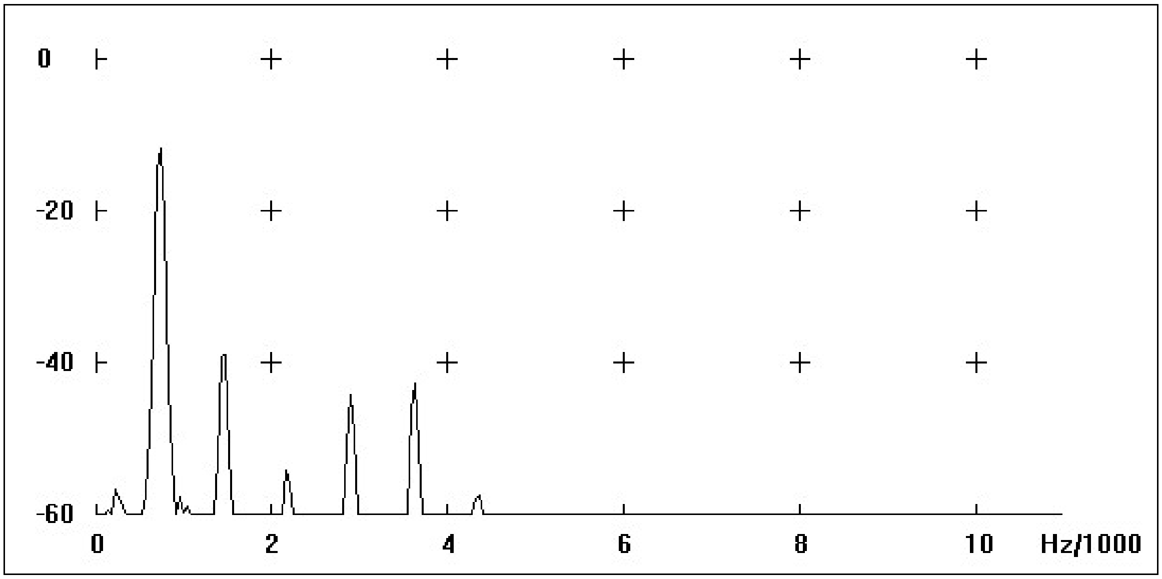
Power Spectrum from Spectrogram #8, Subject #5 at 4.68 seconds [i]



Power Spectrum from Spectrogram #8, Subject #5 at 6.59 seconds [o]

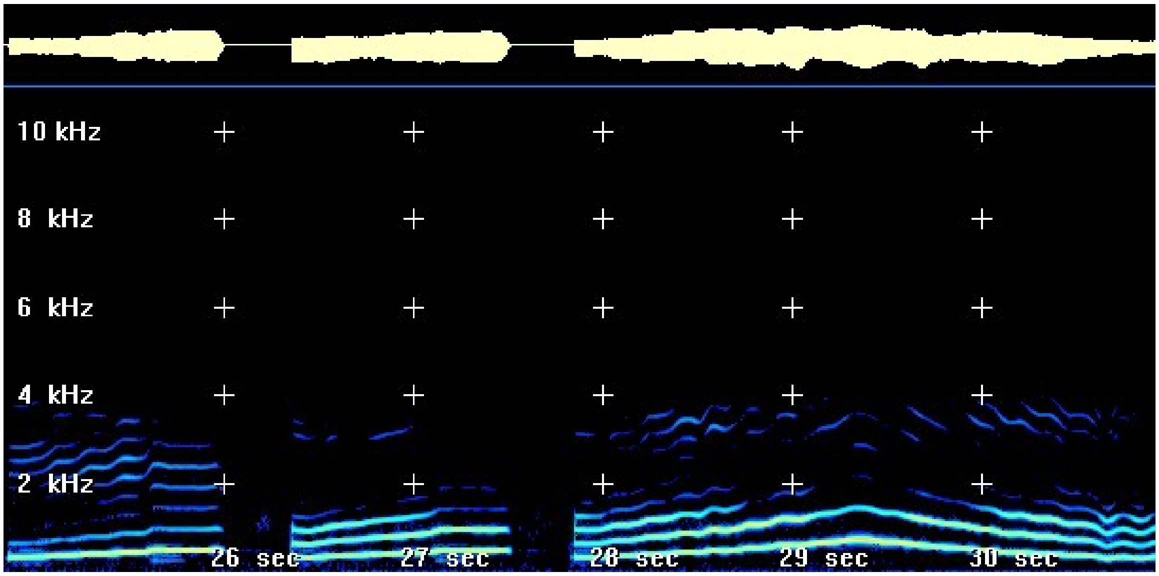


Power Spectrum from Spectrogram #8, Subject #5 at 8.75 seconds [a]



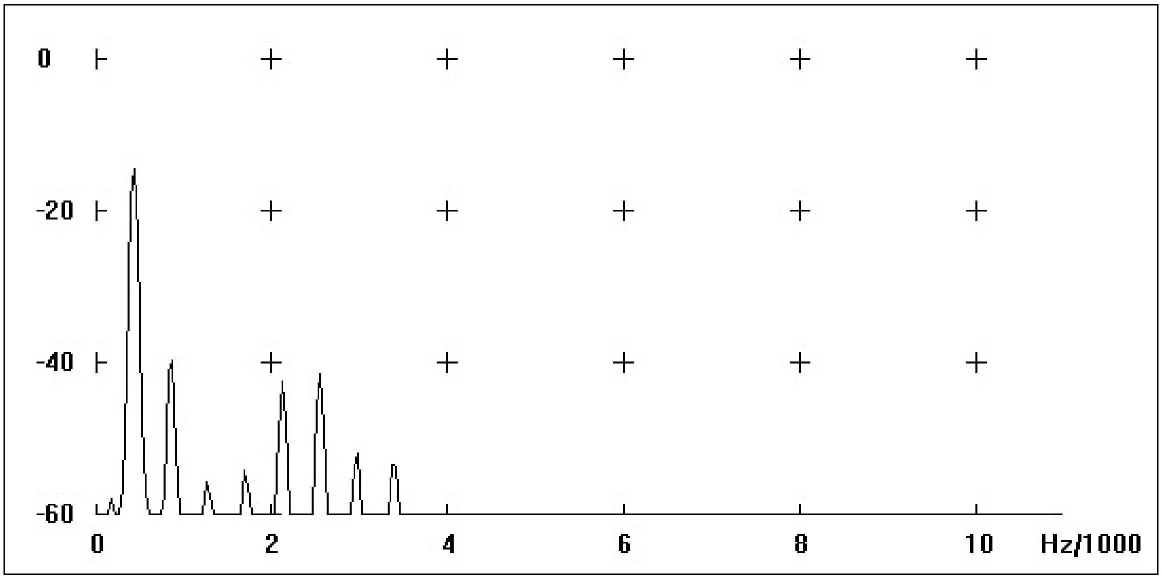
Analysis of Power Spectra from spectrogram #8, Subject #5 – October 30, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.68	5	1	.2	1	6	.16	.18
6.59	4	2	.5	1	5	.2	.35
8.75	6	2	.33	4	10	.4	.36
Average of three chiaroscuro levels							.29

Wave File Number 9 – November 6, 2000 – Subject #5

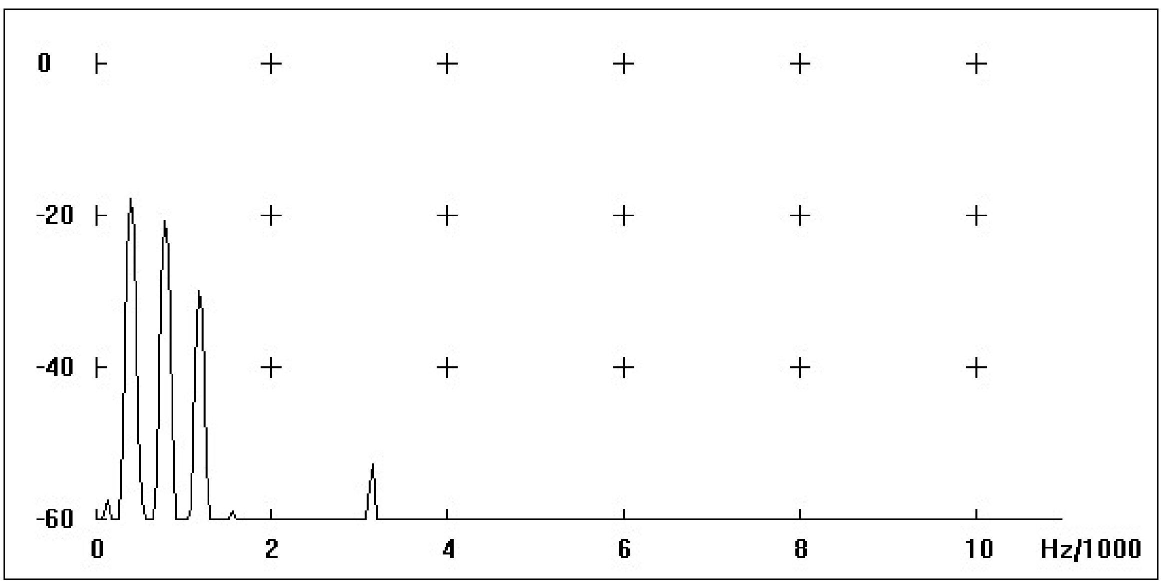


Subject #5 – Analysis of Wave File #9 – November 6, 2000 – E flat major				
		[si] (24.87-25.9 sec)	[o] (26.36-27.5 sec)	[a] (27.85-28.5 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Scattered indications	Scattered indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 10% to about 30%	Varying around 30%	<> from about 15% to about 40%
The timing on this wave file are much larger than on others in this study because another student's file was inadvertently transferred into the beginning of this recording. After a wait of several seconds and one false start this wave file was completed satisfactorily.				

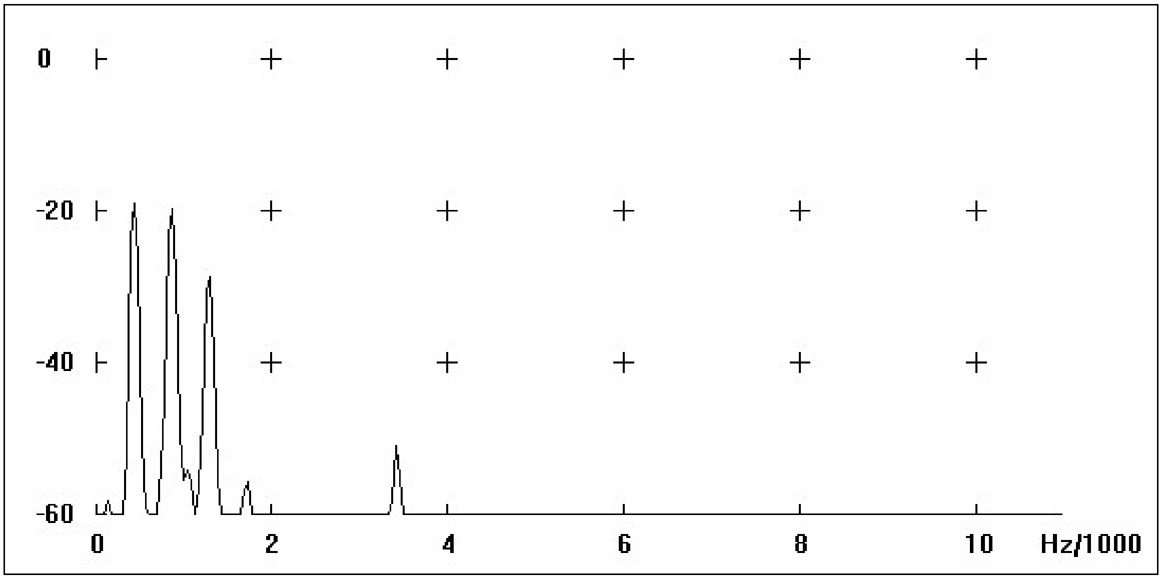
Power Spectrum from Spectrogram #9, Subject #5 at 25.5 seconds [i]



Power Spectrum from Spectrogram #9, Subject #5 at 26.95 seconds [o]

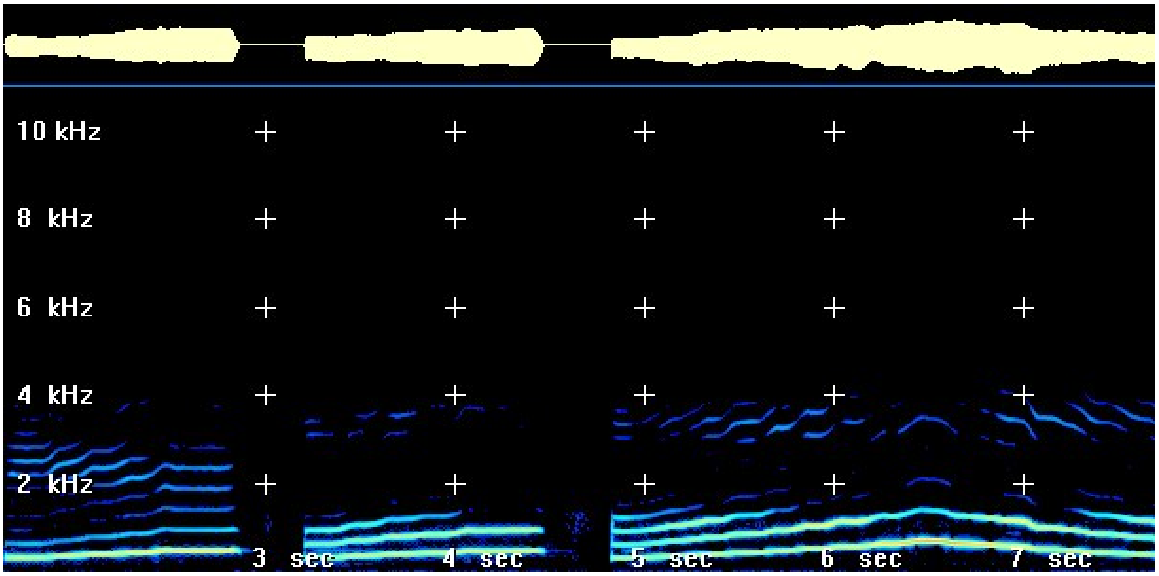


Power Spectrum from Spectrogram #9, Subject #5 at 28.58 seconds [a]



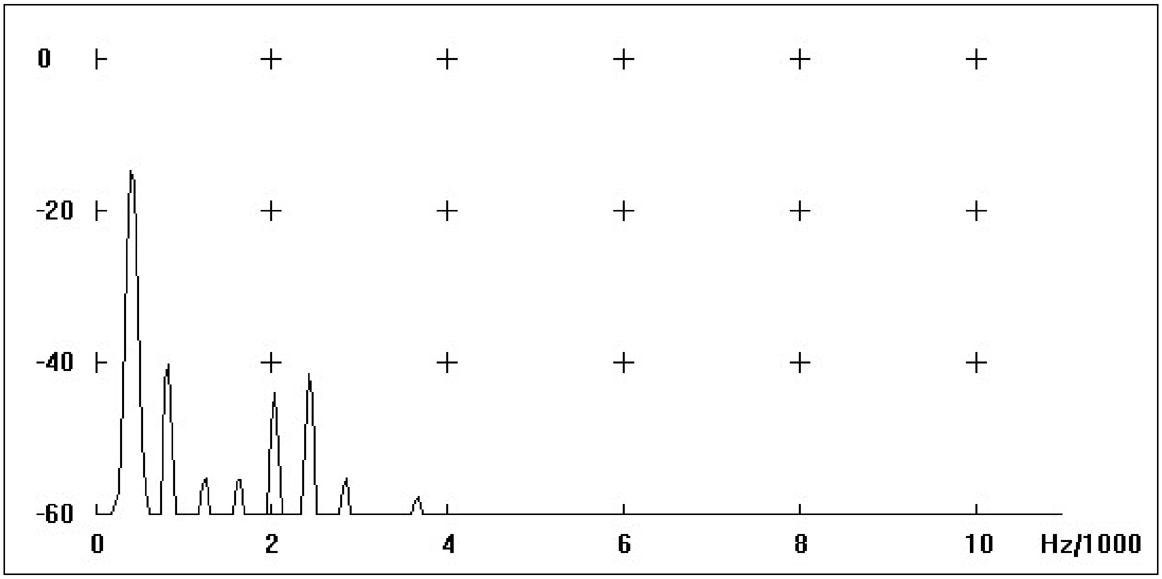
Analysis of Power Spectra from Spectrogram #9, Subject #5 – November 6, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
25.5	5	2	.4	4	9	.44	.42
26.9	5	3	.6	1	6	.16	.38
28.6	6	3	.5	1	7	.14	.32
Average of three chiaroscuro levels							.37

Wave File Number 10 – November 7, 2000 – Subject #5

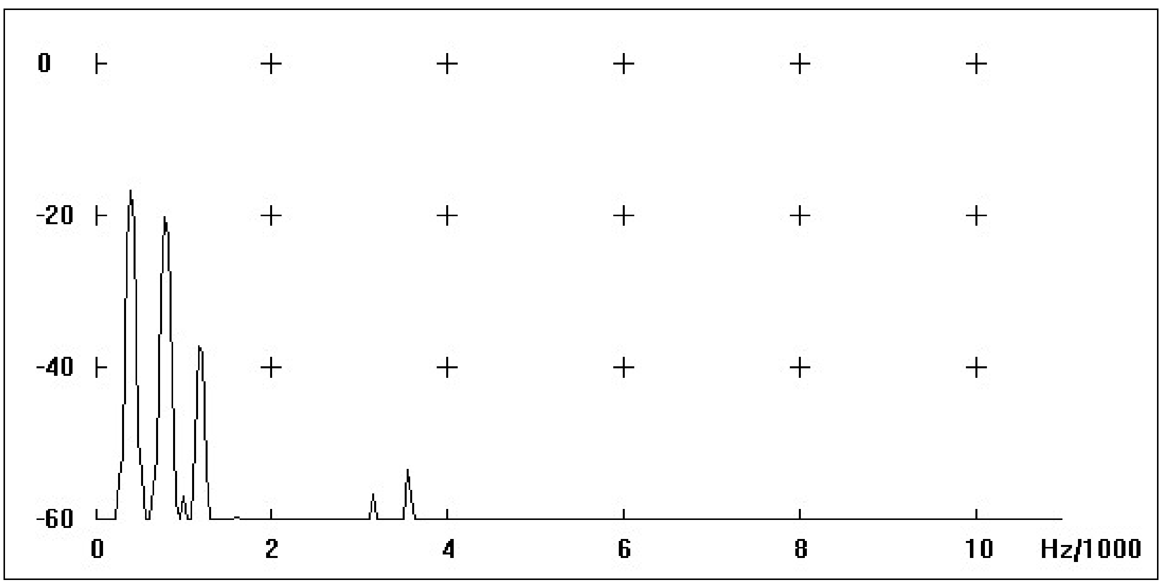


Subject #5 – Analysis of Wave File # 10 – November 7, 2000 – E flat major				
		[si] (1.65-2.79 sec)	[o] (3.2-4.47 sec)	[a] (4.82-8.91 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications, but more consistent	Scattered indications, but more consistent	Nearly consistent indications 2-3 bands
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Nearly balanced
Power Spectrum		Increasing from about 25% to about 40%	Increasing from about 30% to about 40%	<> from about 20% to about 80%
Although there is not a large change from wave file #9, this wave file does show more consistency in using upper frequencies. The "backing off" effect is lessened.				

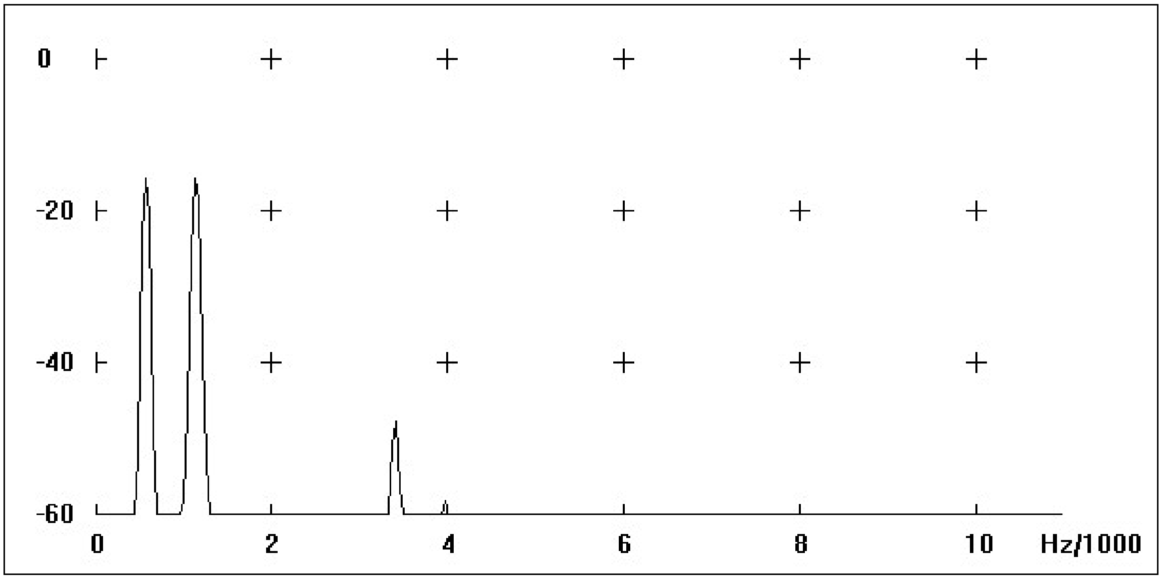
Power Spectrum from Spectrogram #10, Subject #5 at 2.23 seconds [i]



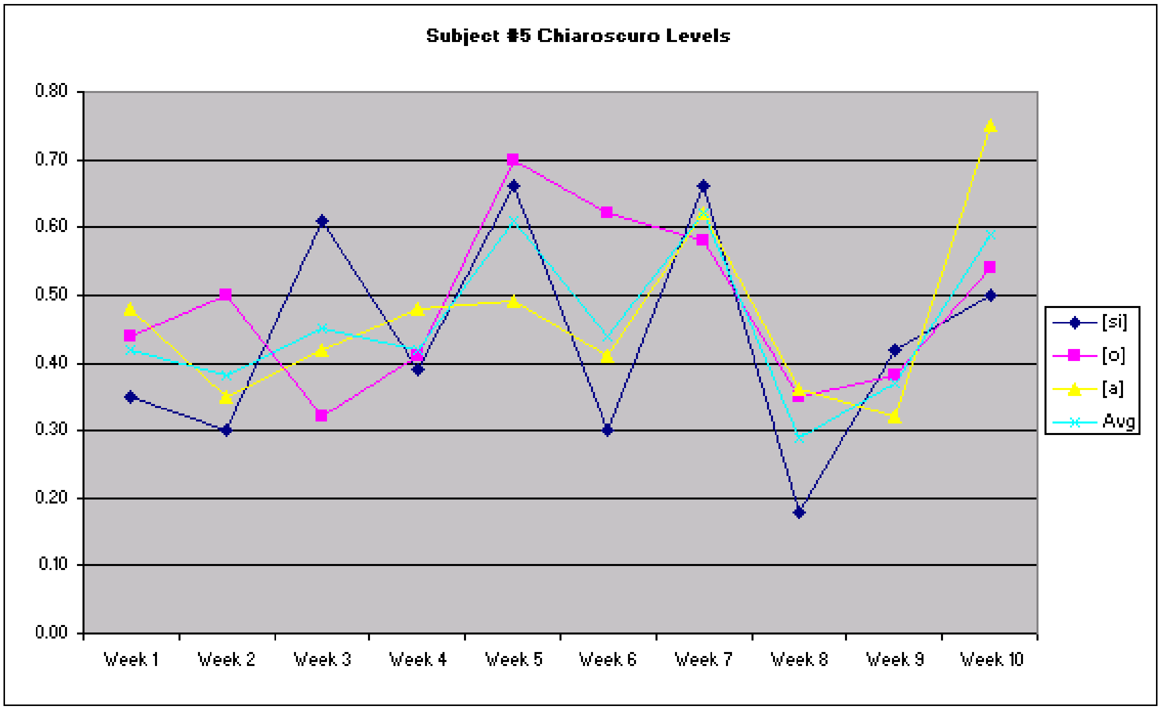
Power Spectrum from Spectrogram #10, Subject #5 at 3.67 seconds [o]

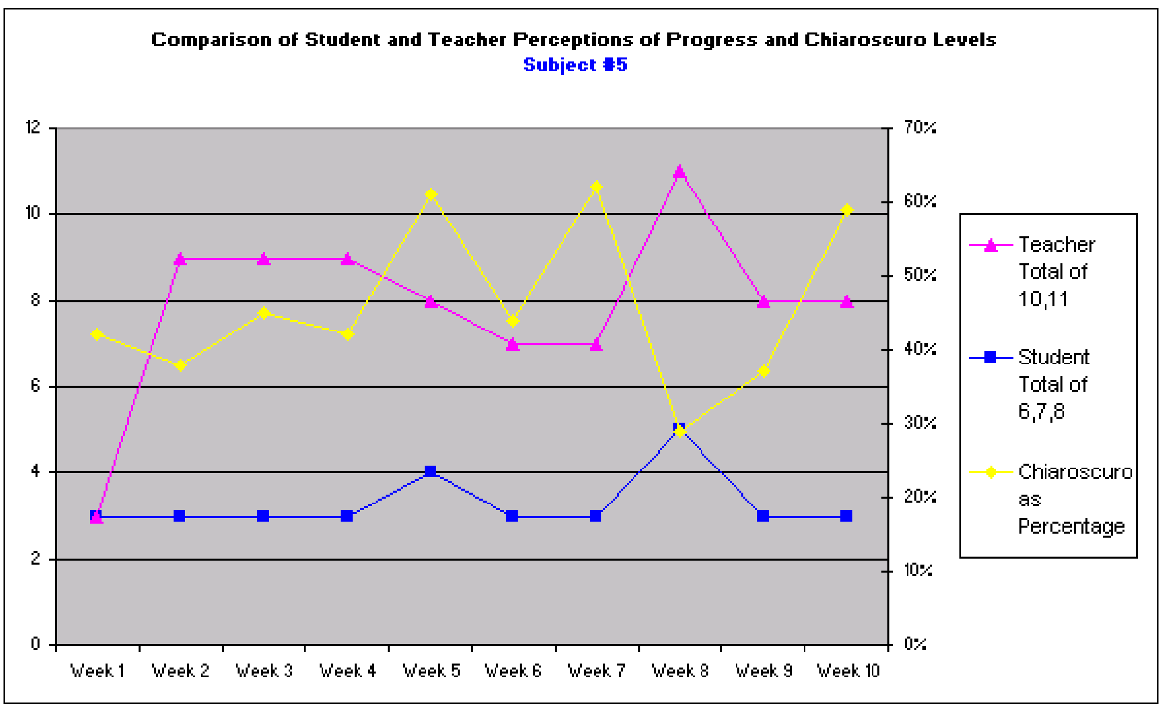


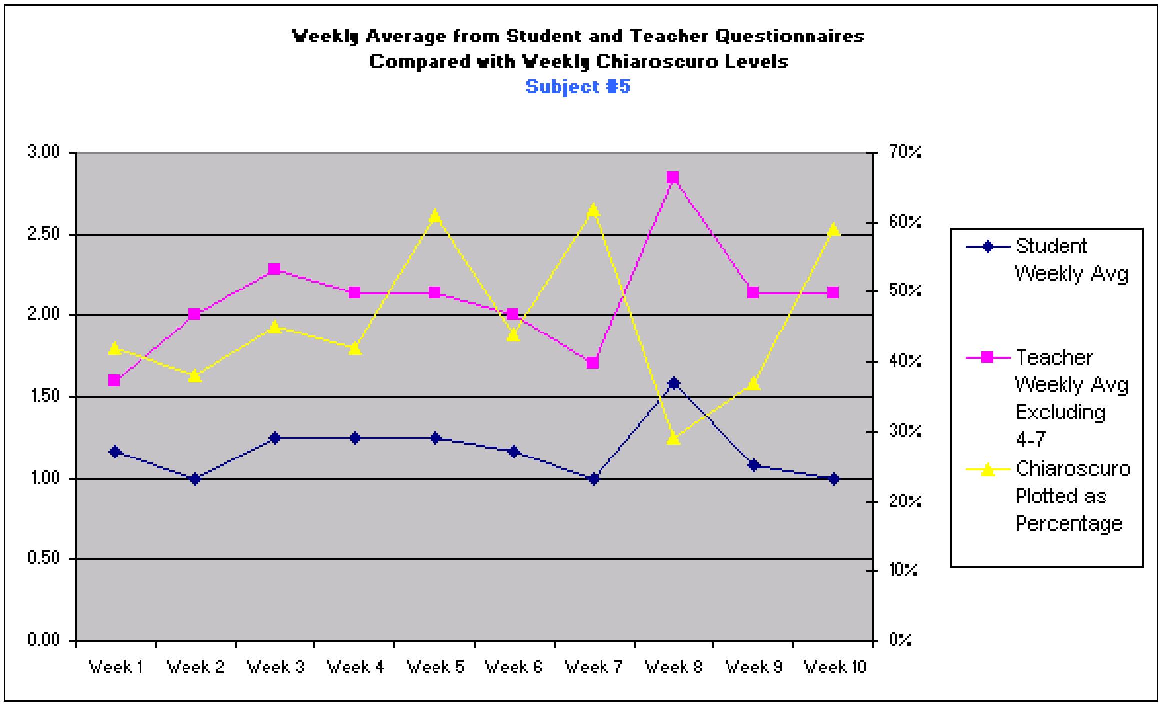
Power Spectrum from Spectrogram #10, Subject #5 at 6.1 seconds [a]



Analysis of Power Spectra from Spectrogram #10, Subject #5 – November 7, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.23	4	2	.5	4	8	.5	.5
3.67	4	3	.75	2	6	.33	.54
6.1	2	2	1.0	2	4	.5	.75
Average of three chiaroscuro levels							.59


Subject #5 Chiaroscuro Levels
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg


Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #5
12
10
8
6
4
2
0
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage



Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #5
3.00
2.50
2.00
1.50
1.00
0.50
0.00
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A6: Subject #6

Subject #6 was a 20-year-old Caucasian junior majoring in music performance major with a concentration in voice. Her home was in Sylacauga, Alabama. At the time of the data collection she had been a student in the researcher's studio for two years. Because she was preparing for a junior recital, she had voice twice weekly.

Her vocal production had been good since she was a freshman, except for a too-fast vibrato, tongue tension, breath management issues, and a tendency to try too hard. Before her breath issues were overcome, she developed a tendency to sing sharp, which disappeared as she concentrated on better breath management.

Subject #6's voice was a medium-sized, lyric soprano with enough flexibility to sing much of the coloratura repertoire. She vocalized from a to c^3, and her voice seemed to be expanding upward toward f^3. The middle register of her voice developed a warm quality, and her lower voice solidified over the last year. She was a hard worker and conscientious about learning her music and performing in voice major class. She had been somewhat tentative in artistic interpretation, preferring to try for perfection in notes and words before experimenting, but as she became more comfortable with her upper voice, she grew more willing to try for expressiveness in addition to correctness.

Subject #6 had a series of health problems since she arrived in college. Both her freshman and sophomore years she experienced serious bronchial infections that left her unable to sing from late November until January or February. The year before the study, she had further serious health problems during spring semester. She was much healthier during data collection except for a cyst that required emergency surgery early in the semester.

Vocally, Subject #6 was doing very well. Her voice worked as it should and was reliable in the upper register. During the data collection semester she continued to develop her upper register and produced several excellent performances.

It is possible that the spectrograph has been of assistance in Subject #6's becoming more at ease in the top voice. Being able to see that maximum effort is not always required to produce a full sound in the upper register allowed her to sing with more skill. Since her resonance issues were already mostly resolved before the spectrograph entered the studio, it was not of assistance in that area.

Fall Semester 2000 Repertoire – Subject #6

Bizet	Ouvre ton coeur
Dell'Aqua	Villanelle
Sergeant	Stopping By the Woods On a Snowy Evening
Donizetti	O luce di quest'anima from *Linda di Chamounix*
Mozart	Deh vieni non tardar from *Le Nozze di Figaro*
	Die Zufriedenheit, K. 349
	Trio from *The Impresario*
Poulenc	Les Chemins de l'amour
Delibes	Les Filles de Cadix
Beethoven	Der treue Johnie
Hoiby	Where the Music Comes From
Rebecca Clarke	Shy One
Gilbert & Sullivan	Poor Wandering One
Lucy Simon	How Could I Ever Know from *The Secret Garden*

Lesson record over the data collection period – Subject #6

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10-11
8/21	A	Donizetti, Sergeant	Good - Student accompanist can attend both lessons	Finished copying music for accompanist – worked on repertoire from last semester to use for student recitals this semester	#1 F	Chiaroscuro - .48 Student – n/a, n/a, 1 Teacher – n/a, n/a
8/22	B	Donizetti	Okay	VMC – Donizetti not quite ready		
8/23	A	Donizetti, Bizet, Dell'Aqua	Good	Coached French diction – she fell and hurt her back, so I am not pushing her too hard.		
8/28			Back causing lots of pain	Sent her back to sorority house to rest		
8/29	C	Donizetti	Not good	Did not sing well at VMC – much pain from back – decided to go to the emergency room		
8/30				Surgery on colon for cyst causing back pain		
9/4				Holiday		
9/6	A	Zufriedenheit, Simon	Has caught a bad cold	Worked very gently and stopped early – made wave file, but forgot the questionnaires		
9/11	A	Deh vieni, Clarke, Hoiby	Good – student accompanist injured-faculty will fill in Thurs 10:30	Voice is nearly back – still being careful of top – worked through Deh vieni for musical and stylistic issues (appoggiaturas) – Hoiby or Clarke for VMC	#2 E-flat	Chiaroscuro - .49 Student – 1, 1, 1 Teacher – 3, 3
9/13	A	Poulenc, Delibes	Good, but may be getting sick	Worked diction on French songs – voice very tender – switch to T-Th with Practicum on M-W to accommodate student accompanist	#3 E flat	Chiaroscuro - .54 Student – 3, 2, 1 Teacher – 3, 2
9/21	A	Hoiby, Clarke, Mozart lied, Beethoven	Good	Still not well, but singing okay – mostly coaching and ensemble	#4 E flat	Chiaroscuro - .51 Student – 2, 2, 1 Teacher – 3, 2
9/26				Lesson cancelled for TN trip		
9/27	A	Donizetti	Good	Nenirt abd accyract vert giid 0 wirjubg fir ograsubgm ductuib abd style	#5 E flat	Chiaroscuro - .56 Student – 2, 1, 1 Teacher – 3, 2
10/5	A	Donizetti , Bizet	Good	Made tape to apply for NATS Workshop	#6 E flat	Chiaroscuro - .46 Student – 2, 2, 1 Teacher – 3, 3
10/10	A	Beethoven, Poulence, Mozart aria, Simon	Good	Excellent lesson – she has figured out how to time the top – not consistent yet, but she's got it	#7 E flat	Chiaroscuro - .61 Student – 1, 1, 1 Teacher – 2, 2
10/13	A+	Simon	Excellent	Terrible costume – beautiful singing		
10/16	A+	Donizetti	Excellent	Student recital: scared, but sang excellently well – ensemble issues and too-fast tempo		
10/17	A	Poulenc	Good	Voice tired, high notes not ready at 10 a.m. – they certainly were there last night	#8 E flat	Chiaroscuro - .50 Student – 3, 2, 1 Teacher – 4, 3
10/19	A	Deh vieni	Excellent	Coaching and ensemble – needs to work on phrasing and diction		
10/24	A	Sergeant, Beethoven, Poulenc	Excellent	Coaching	#9 E flat	.52
10/26	A	Mozart lied & aria Hoiby, Delibes	Excellent	Coaching and ensemble		
10/31				Lesson cancelled for Career Day		
11/2	A	Sergeant, Poulenc, Hoiby Delibes	Excellent	Coaching	#10 E flat	Chiaroscuro - .64 Student – 1, 1, 1 Teacher – 3, 2

11/7	A	Sergeant, Mozart aria	Excellent	Coaching – she is coming along and working hard, but not having a committee accompanist is making it hard for her		
11/9	A	Sergeant, Hoiby, Delibes	Excellent	Coaching and ensemble		
11/14	A	Sergeant, G&S, Clarke	Excellent	Coaching		
11/16	A	Mozart aria, Sergeant	Excellent	She talked our guest artist into coming to her lesson, and he worked on her diction and dramatic presentations – she is starting to see how much more work there is to life as a musician and is thinking of going into politics		
11/19	A	Sergeant	Excellent	Student recital		
11/21	A	Delibes, Poulenc, Clarke	Excellent	Coaching, especially French diction		

Responses to student questionnaires – Subject #6

Question	8/21	9/11	9/13	9/21	9/27	10/5	10/10	10/17	10/24	11/2	**Total of weekly answers to questions 6, 7, 8**
1	1	2	4	3	1	3	1	3	1	3	
2	2	2	3	2	1	4	2	3	2	2	
3	1	1	2	2	1	1	2	2	3	2	
4	1	1	1	1	1	1	1	1	1	1	
5	1	1	1	1	1	1	1	2	1	1	
6	N/A	1	3	2	2	2	1	3	1	1	**1.77**
7	N/A	1	2	2	1	2	1	2	1	1	**1.44**
8	1	1	1	1	1	1	1	1	1	1	**1**
9	1	1	1	1	1	1	1	1	1	1	**Average over ten week period**
10	1	1	1	1	1	1	1	1	1	1	
11	3	1	1	2	1	1	1	2	1	1	
12	1	1	1	1	1	1	1	1	1	1	
Weekly Average	1.3	1.16	1.75	1.58	1.08	1.58	1.16	1.83	1.25	1.33	**1.4**

Responses to teacher questionnaires – Subject #6

Quantification of the verbal categories on the form will be as follows:

1	=	Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)
2	=	Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)
3	=	Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)
4	=	Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)
5	=	Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

Question	8/21	9/11	9/13	9/21	9/27	10/5	10/10	10/17	10/24	11/2	**Totals and average of questions 10 & 11**
1	1	2	2	2	2	2	2	2	2	2	
2	1	2	3	3	2	3	1	3	2	2	
3	2	2	2	2	2	2	2	2	2	2	
4	4	4	4	4	4	4	3	4	4	3	
5	5	5	4	5	5	4	3	5	4	5	
6	3	5	5	3	3	4	3	5	4	5	
7	1	5	5	5	5	5	5	5	5	5	
8	2	1	2	2	2	2	1	2	2	2	
9	2	5	2	2	3	3	2	4	3	2	
10	N/A	3	3	3	3	3	2	4	3	3	**3**
11	N/A	3	2	2	2	3	2	3	2	2	**3**
Weekly Average excluding questions 4-7	1.6	2.57	2.28	2.28	2.28	1.5	1.71	2.85	2.28	2.14	**3**

Student's Written Reaction to Use of Spectrograph – Subject #6

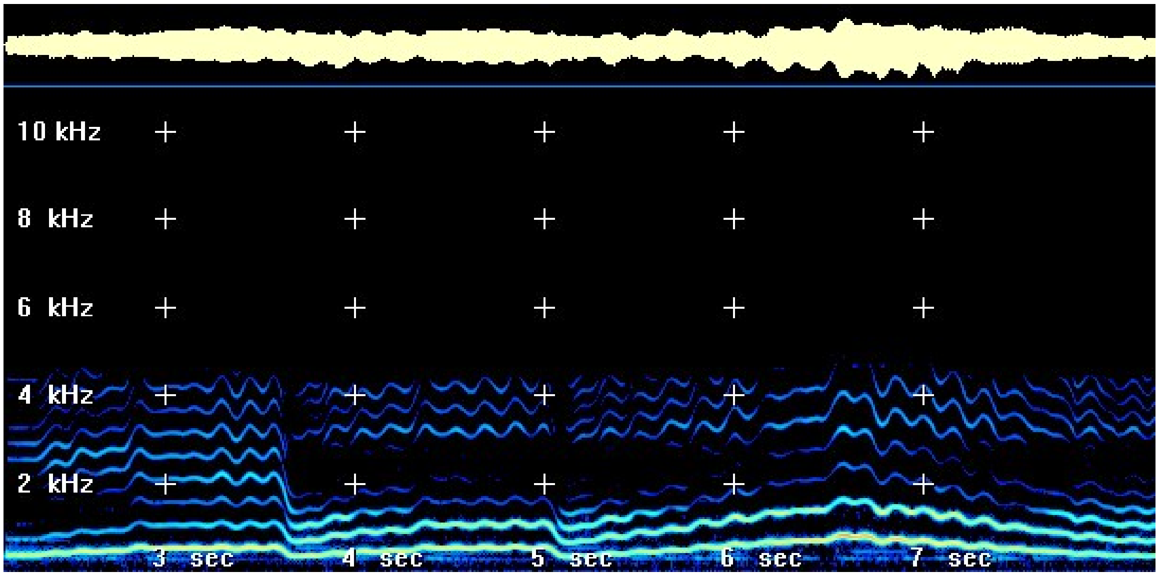
During the past two and half years, I have studied voice with Ms. Patricia Callaway at Brenau University. In the past year we have used a program in my lessons that has allowed us to view the different characteristics of my voice. As a junior vocal performance major, the spectrograph enables me to view the things my voice is doing. Each week, we record on disk me as I sing into the spectrograph; so Ms. Callaway and I can look and compare the progress of my voice from lesson to lesson. It enables me to discover the areas of my voice that are strong and healthy, as well as the ones that could use improvement.

By viewing the spectrograph throughout my lessons, I have been able to determine the amount of pressure I am applying to the vocal cords. That way I know when to apply more air and when I am straining too much, which will help prevent me from causing damage to the vocal cords. The power of the voice can be viewed at the top of the computer screen. This makes it possible to see the strong areas of the voice and the differences between passagio and chest voice. As I sing, a wave, line, etc. goes across the screen and fills the bottom to the middle of the screen. Within these lines I can view the different qualities of my voice from its strength to the natural vibrato.

I have thoroughly enjoyed watching the spectrograph and recording wave files every week in my lessons. They help with the discouragement that often comes to someone entering the music field. The wave files show the improvement I have made throughout the year. Like I said before, I have been recording wave files for almost a year now, and I can see dramatic improvement between last semester's wave files and the current semester's wave files. I would encourage anyone teaching voice, or even teachers of other instruments to use the spectrograph system and record weekly wave files. They really do help me as a student, but especially as a performer. This is a great way for students and even professionals to see what they are doing right and wrong.

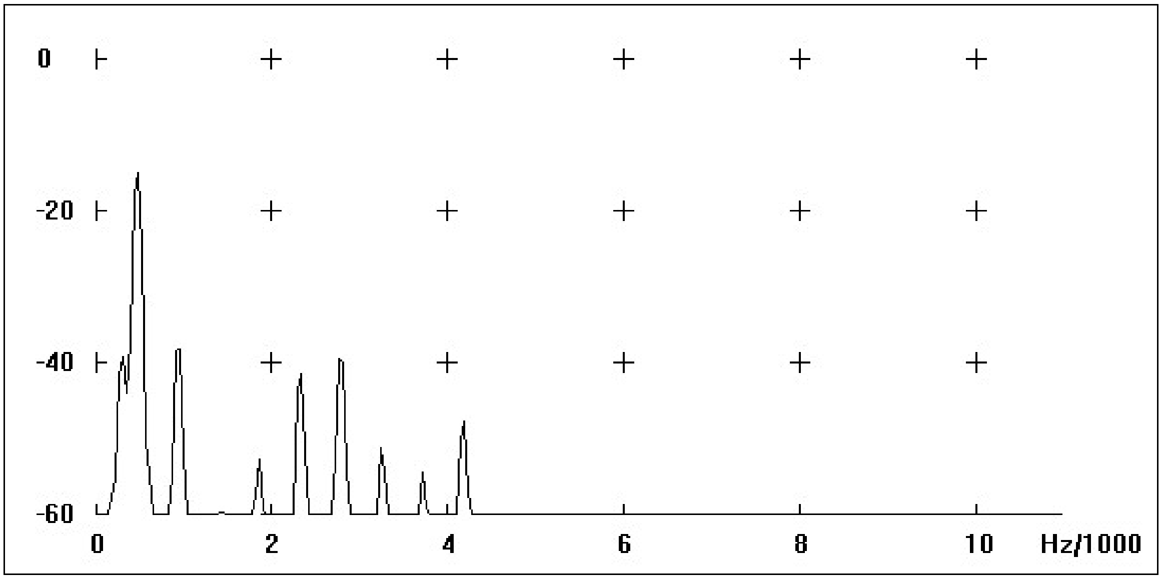
Analysis of Wave Files

Wave File Number 1 - August 21, 2000 – Subject #6

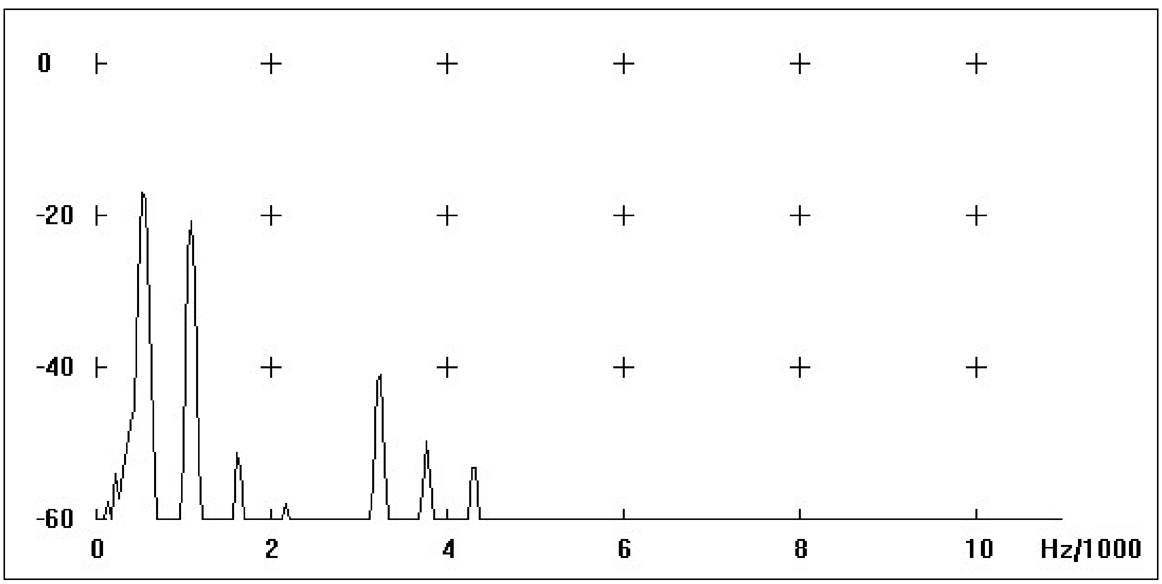


Subject #6 – Analysis of Wave File #1 – August 21, 2000 – F major				
		[si] (2.16-3.56 sec)	[o] (3.7-5.0 sec)	[a] (5.13-9.17 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2^{nd} Formant Area (Vowel Definition)		Good vowel definition	Good vowel definition	Good vowel definition
1^{st} Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 40%	Varying around 50%	Varying around 50% with increase to about 80% at highest pitches
This is a young, bright, well-used voice with few flaws.				

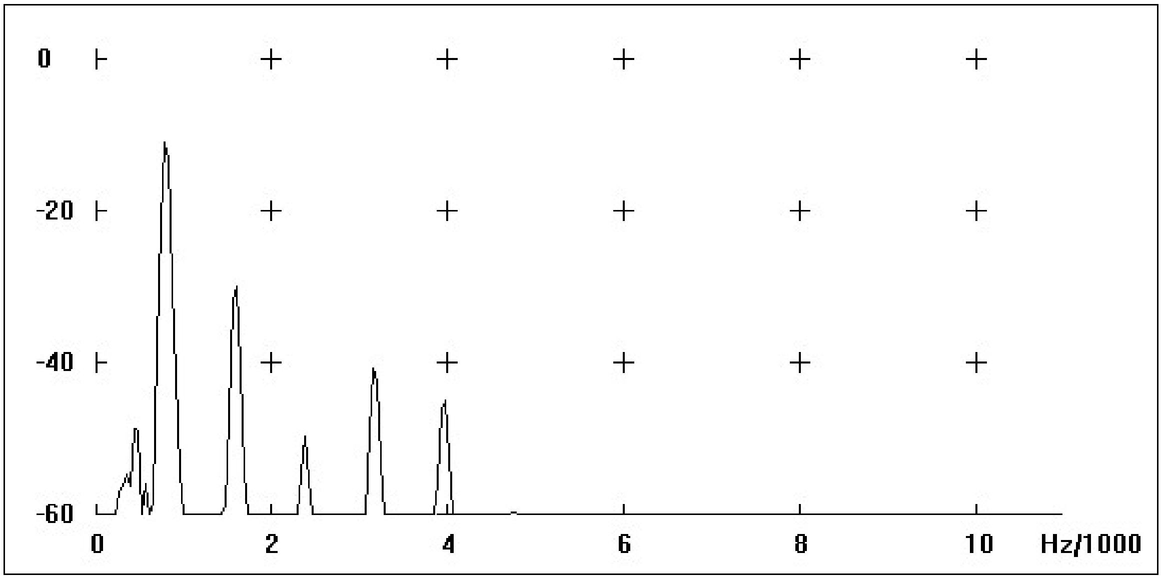
Power Spectrum from Spectrogram #1, Subject #6 at 2.73 seconds [i]



Power Spectrum from Spectrogram #1, Subject #6 at 4.53 seconds [o]

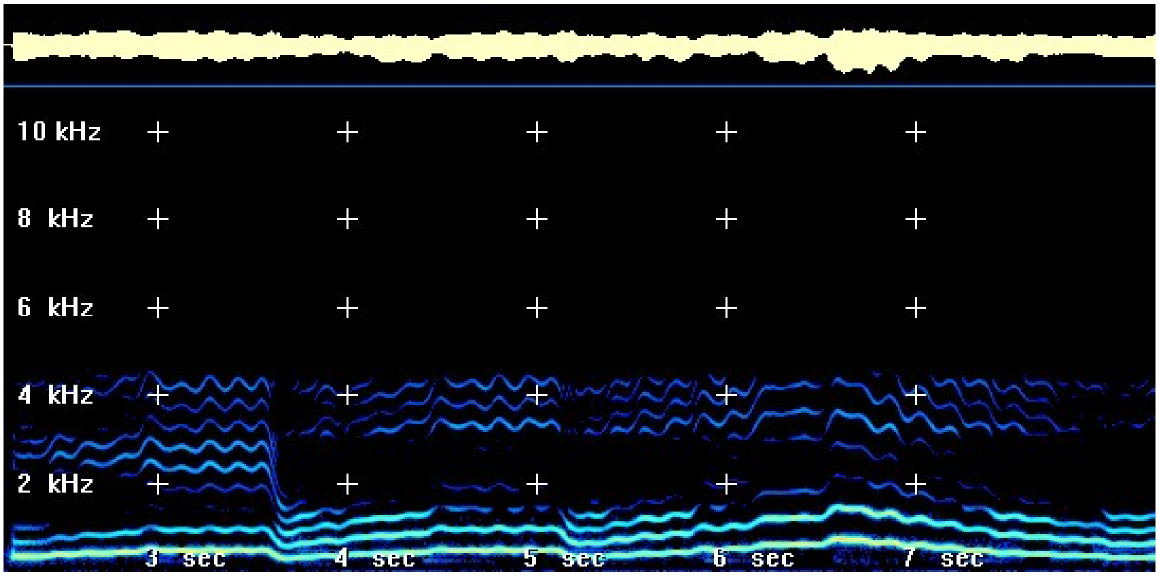


Power Spectrum from Spectrogram #1, Subject #6 at 6.56 seconds [a]



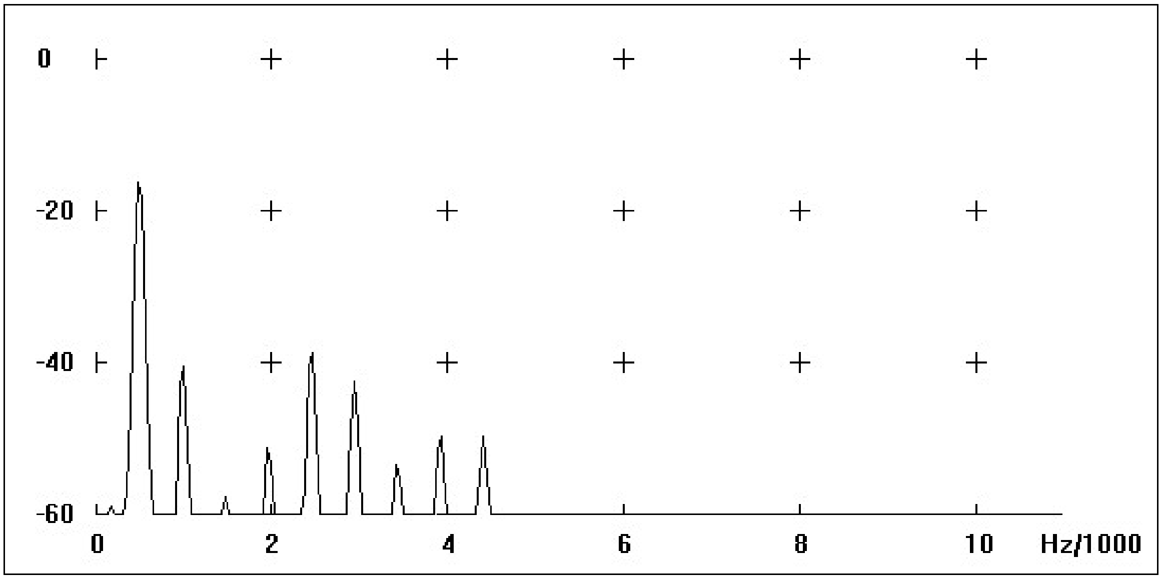
Analysis of Power Spectra from Spectrogram #1, Subject #6 – August 21, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	b / a	c	d	c / d	(b/a+c/d) / 2
2.73	4	3	.75	5	9	.55	.65
4.53	5	2	.4	4	9	.44	.42
6.56	5	2	.4	3	8	.37	.38
Average of three chiaroscuro levels							.48

Wave File Number 2 – September 11, 2000 – Subject #6

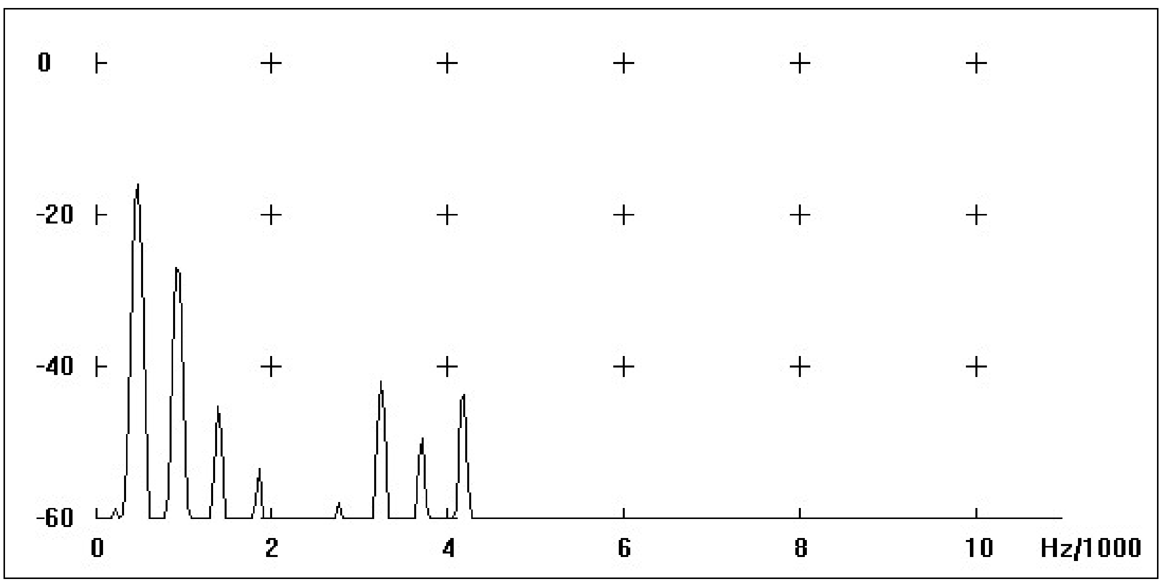


Subject #6 – Analysis of Wave File #2 – September 11, 2000 – E flat major				
		[si] (2.24-3.55 sec)	[o] (3.73-5.09 sec)	[a] (5.22-9.14 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 40%	Varying around 40%	Varying around 40% with increase to 6-% at highest pitches
The consistency found in this singer's wave files is to be expected in a junior music major who has successfully learned good vocal technique.				

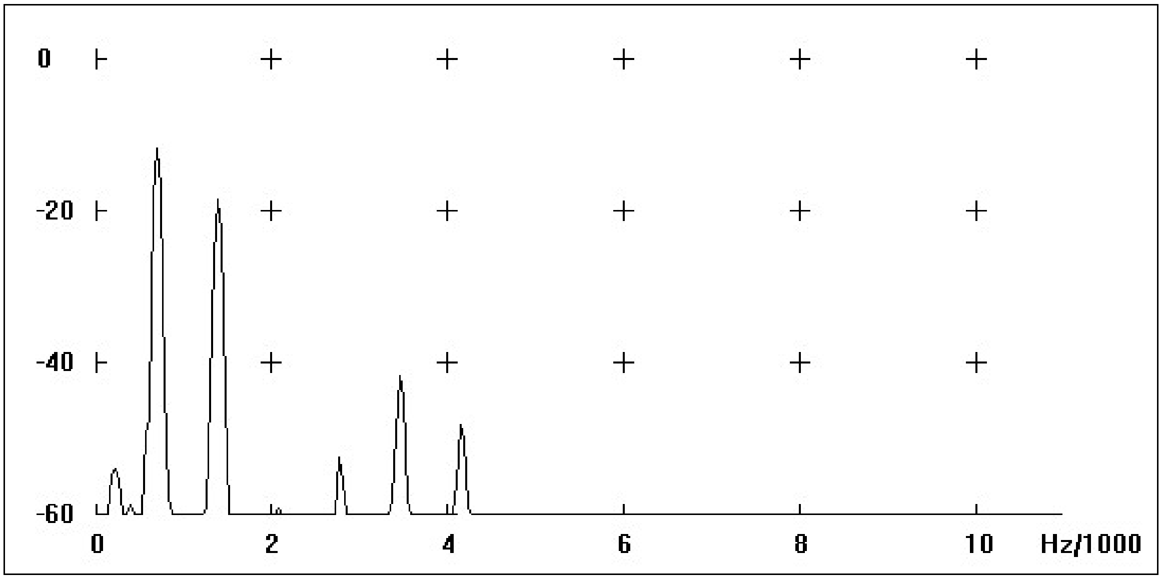
Power Spectrum from Spectrogram #2, Subject #6 at 3.27 seconds [i]



Power Spectrum from Spectrogram #2, Subject #6 at 4.73 seconds [o]

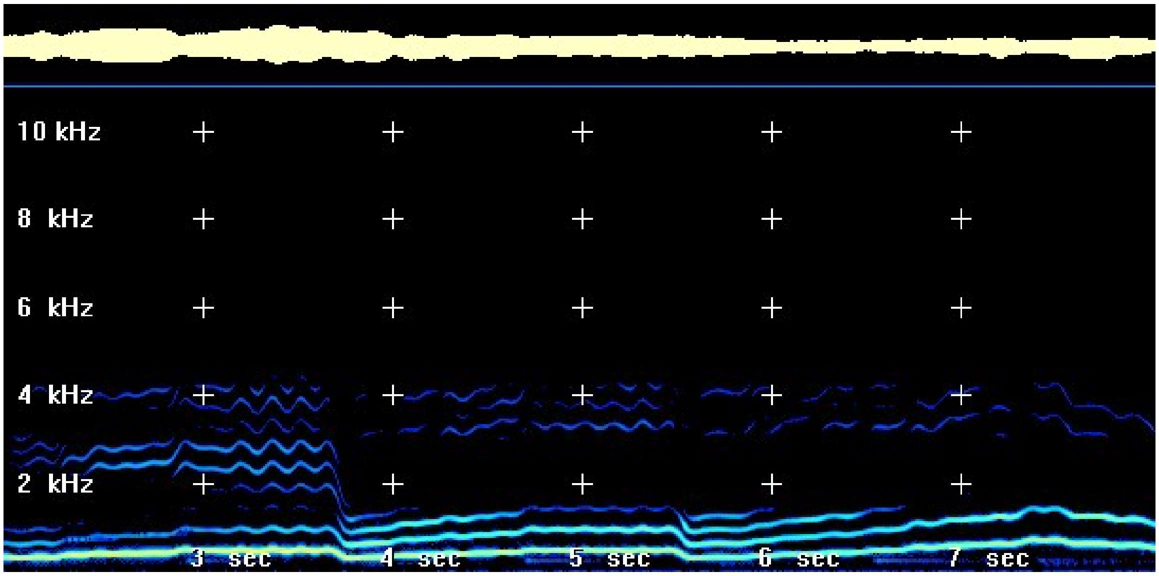


Power Spectrum from Spectrogram #2, Subject #6 at 6.75 seconds [a]



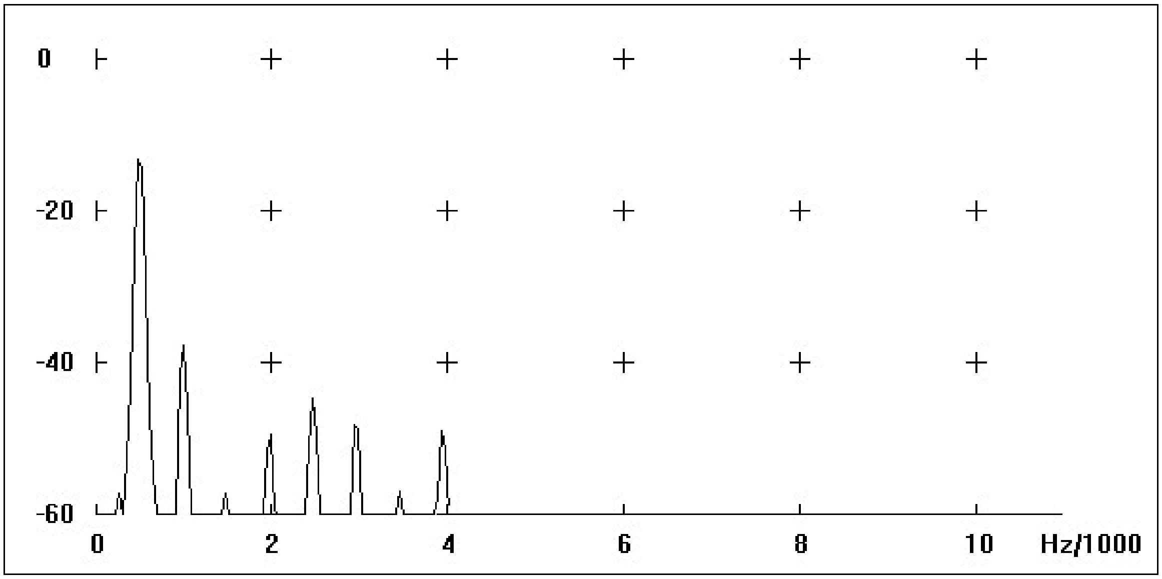
Analysis of Power Spectra from Spectrogram #2, Subject #6 – September 11 , 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.27	4	2	.5	6	10	.6	.55
4.73	5	2	.4	4	9	.44	.42
6.75	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.49

Wave File Number 3 – September 13, 2000 – Subject #6

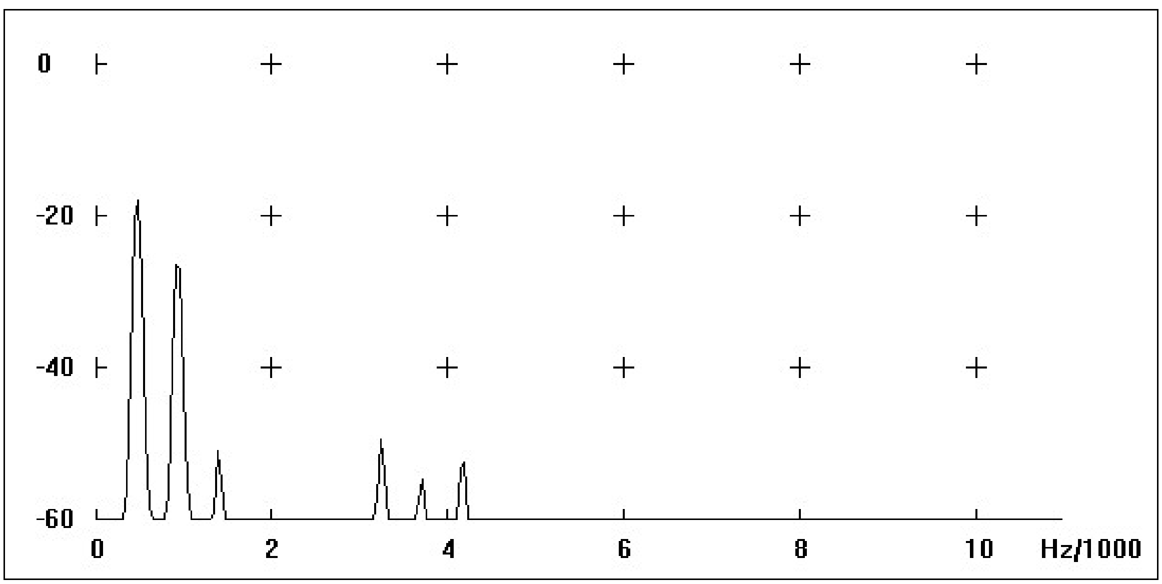


Subject #6 – Analysis of Wave File #3 – September 13, 2000 – E flat major				
		[si] (1.94-3.65 sec)	[o] (3.84-5.44 sec)	[a] (5.65-10.3 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Somewhat weaker than wave file #2	Somewhat weaker than wave file #2	Somewhat weaker than wave file #2
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 40%	Varying around 30%	Varying around 20%
Indications here are that the singer is singing somewhat less strongly than usual. Any number of reasons are possible from illness to a frivolous mood.				

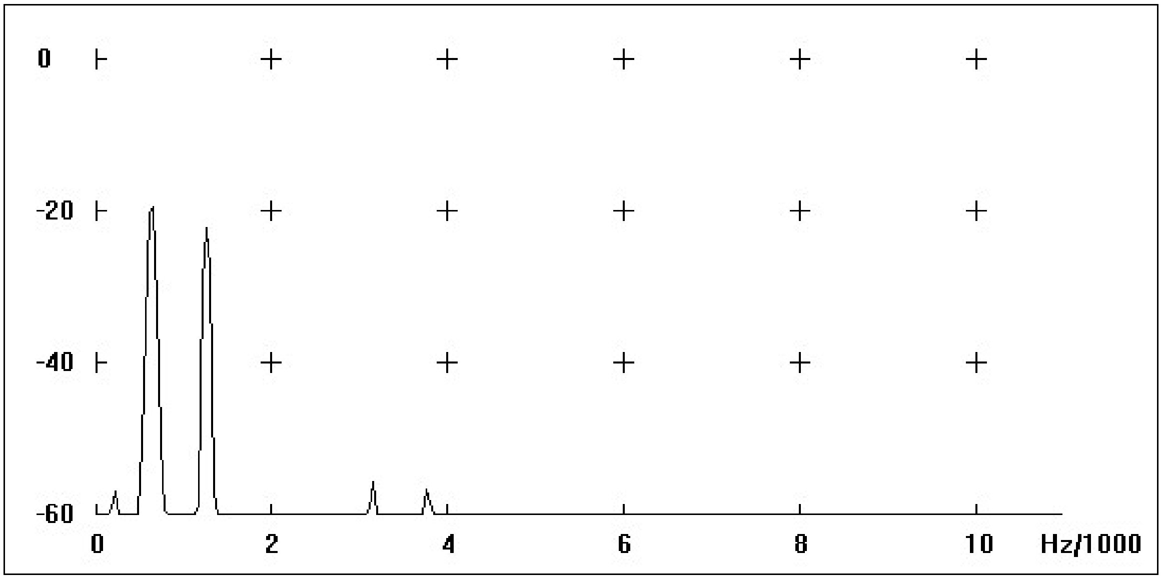
Power Spectrum from Spectrogram #3, Subject #6 at 3.36 seconds [i]



Power Spectrum from Spectrogram #3, Subject #6 at 5.24 seconds [o]

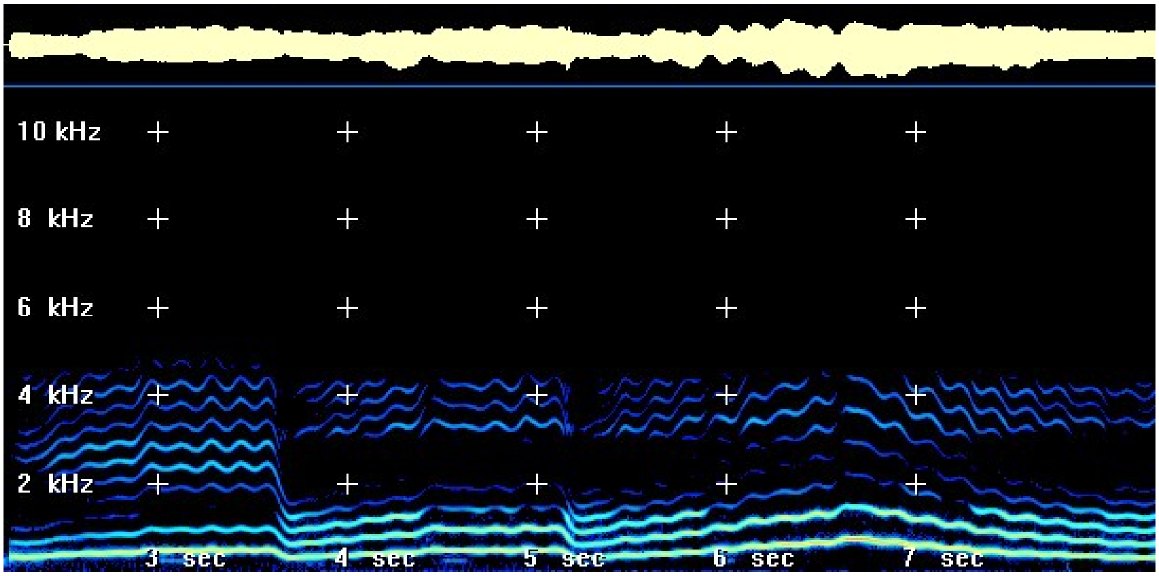


Power Spectrum from Spectrogram #3, Subject #6 at 7.68 seconds [a]



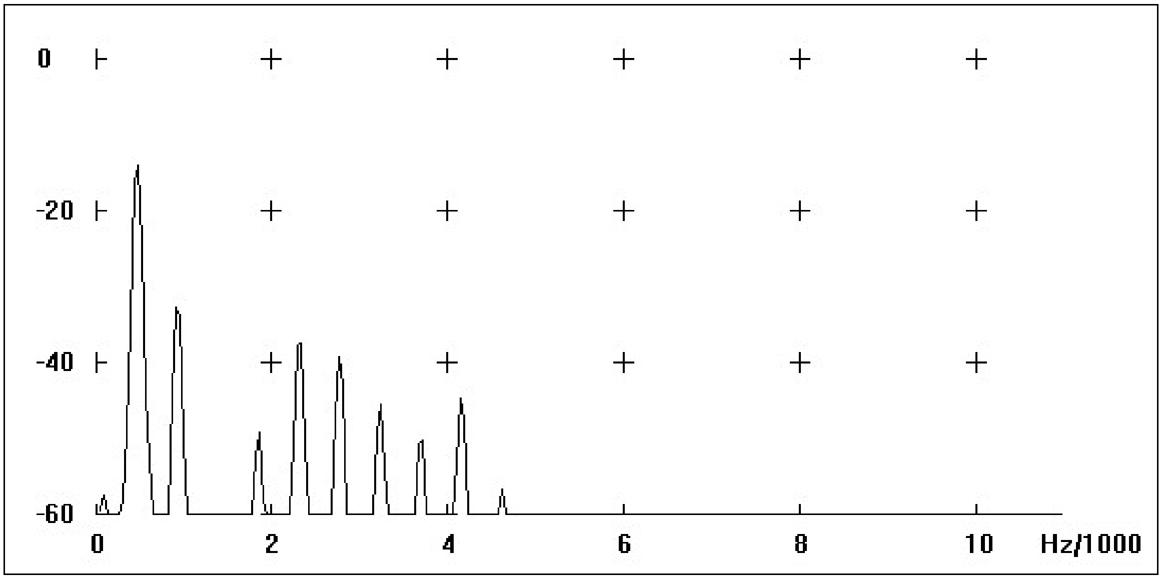
Analysis of Power Spectra from Spectrogram #3, Subject #6 – September 13 , 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.36	4	2	.5	5	9	.55	.52
5.24	3	2	.66	3	6	.5	.58
7.68	3	2	.66	2	5	.4	.53
Average of three chiaroscuro levels							.54

Wave File Number 4 – September 21, 2000 – Subject #6

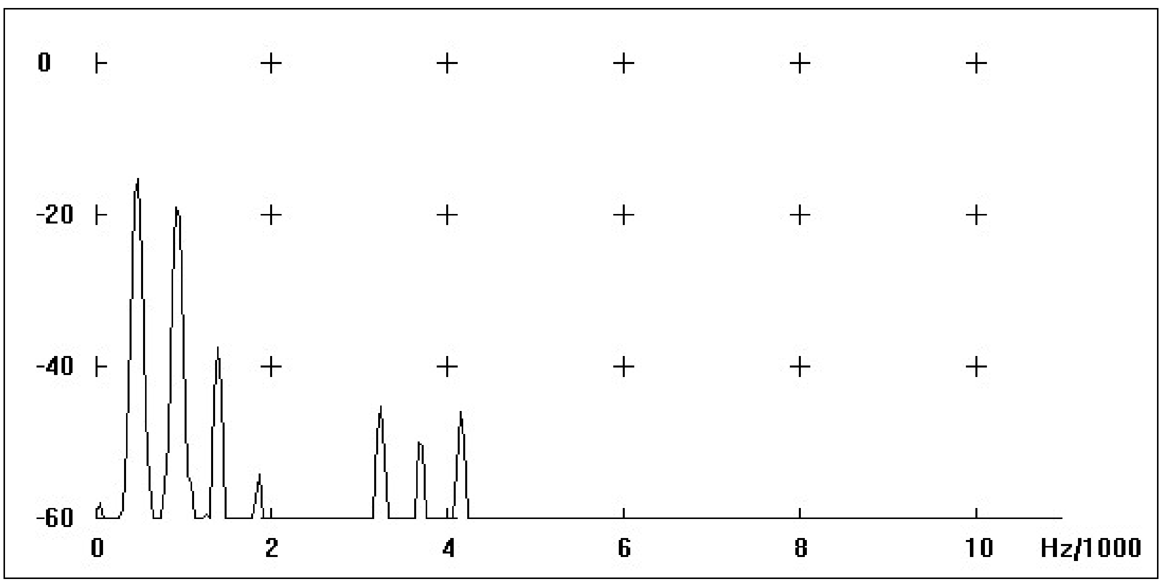


Subject #6 – Analysis of Wave File #4 – September 21, 2000 – E flat major				
		[si] (2.22-3.59 sec)	[o] (3.73-5.12 sec)	[a] (5.28-9.05 sec)
Singer's Formant Area	4000+ Hz	Beginning to move into this area	Beginning to move into this area	Beginning to move into this area
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 40%	Varying around 40%	Varying around 40% with increase to 70% at highest pitches
Increases in singer's formant area show movement into frequencies above 4000 Hz with corresponding strength in lower frequencies.				

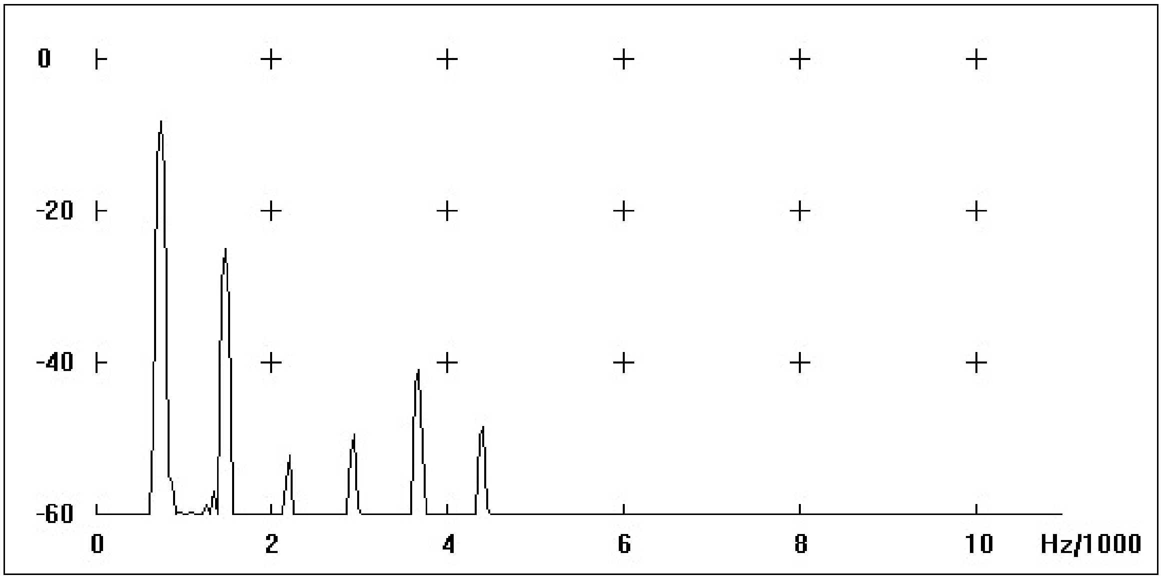
Power Spectrum from Spectrogram #4, Subject #6 at 3.36 seconds [i]



Power Spectrum from Spectrogram #4, Subject #6 at 4.86 seconds [o]

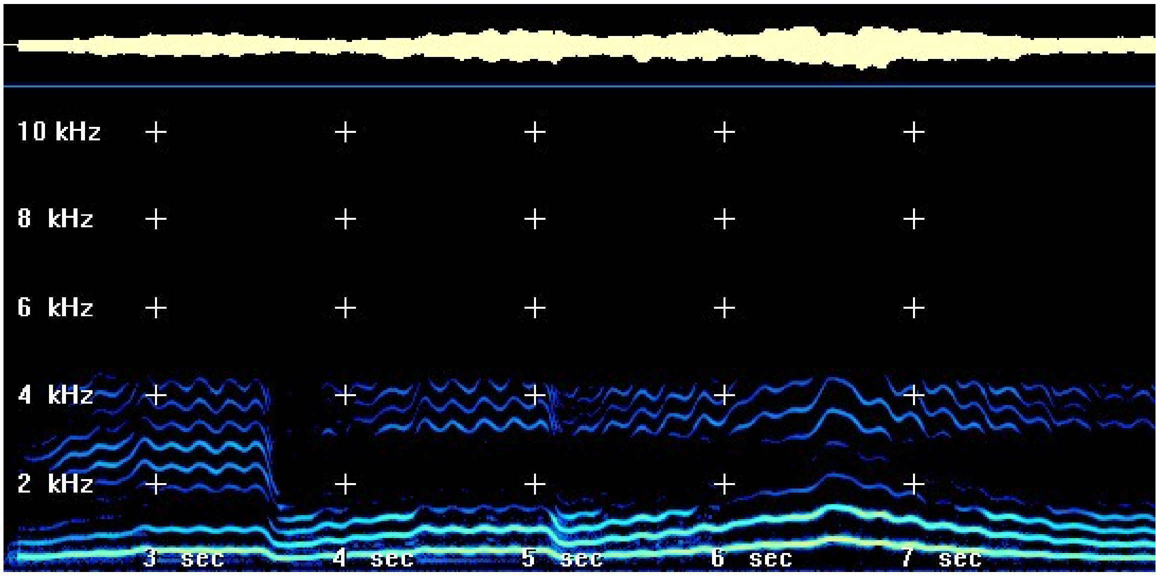


Power Spectrum from Spectrogram #4, Subject #6 at 6.71 seconds [a]



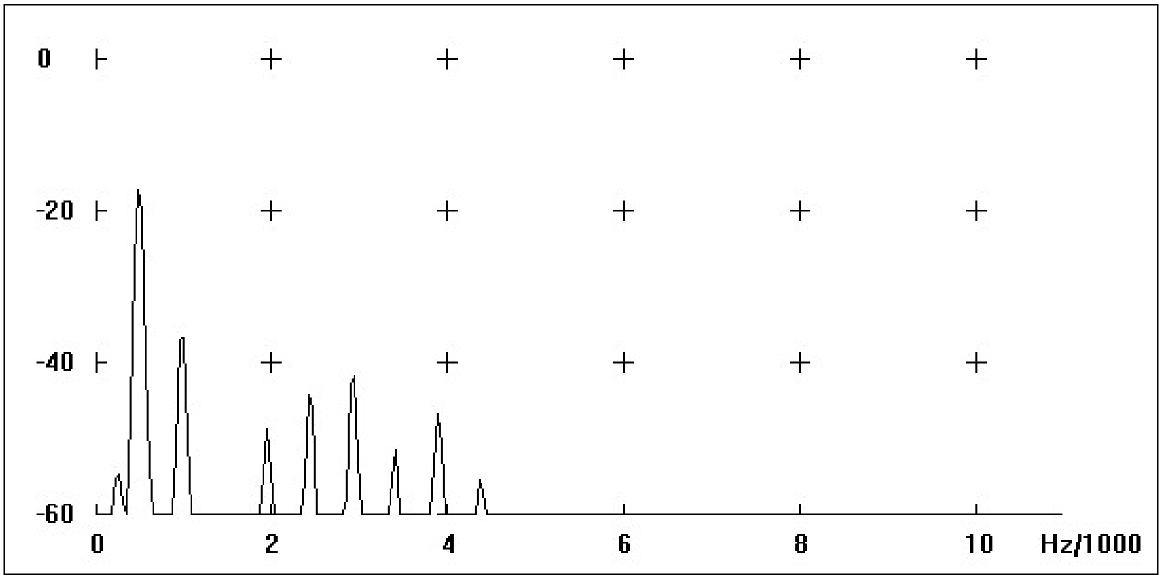
Analysis of Power Spectra from Spectrogram #4, Subject #6 – September 21, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{b/a+c/d}{2}$
3.36	4	2	.5	6	10	.6	.55
4.86	5	3	.6	3	8	.37	.48
6.71	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.51

Wave File Number 5 – September 27 – Subject #6

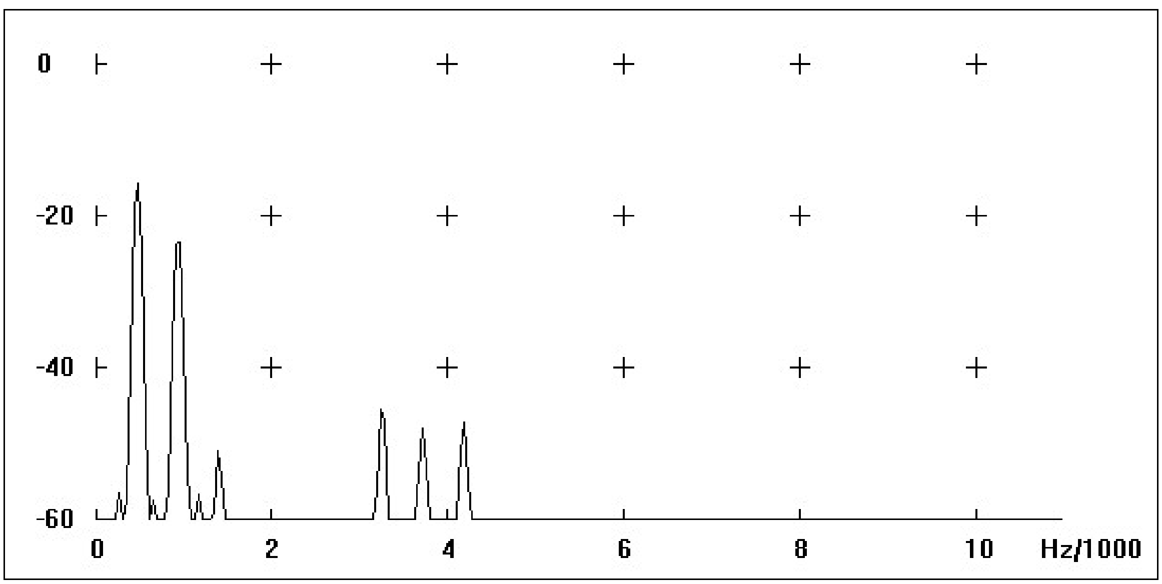


Subject #6 – Analysis of Wave File #5 – September 27, 2000 – E flat major				
		[si] (2.28-3.53 sec)	[o] (3.87-5.03 sec)	[a] (5.22-8.84 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 25%	Varying around 30%	Varying around 30% with increase to about 40% at highest pitches
Indicates solid and consistent technique.				

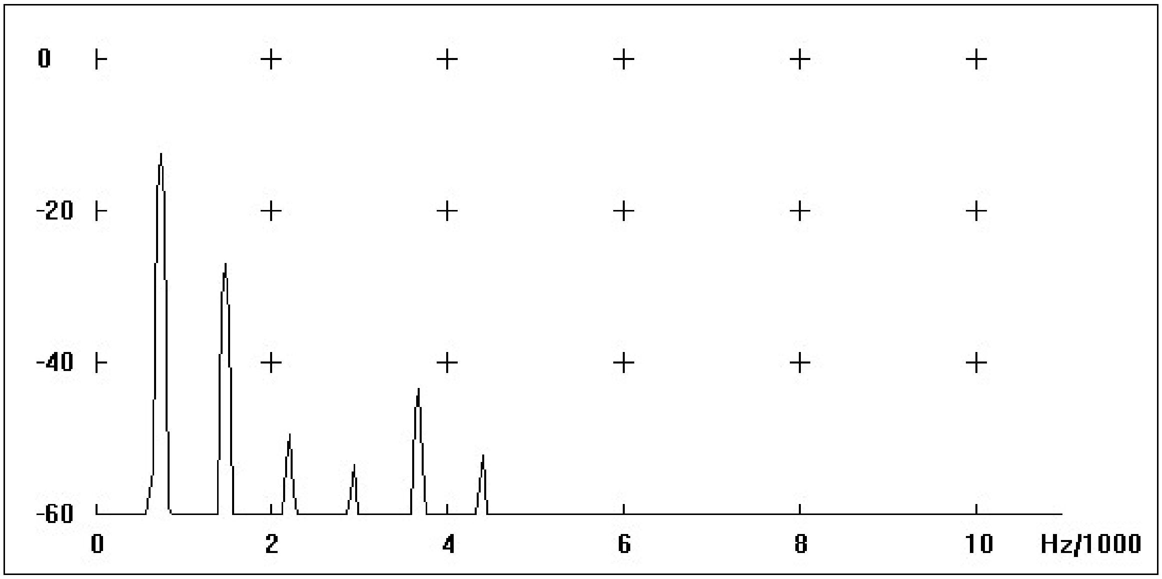
Power Spectrum from Spectrogram #5, Subject #6 at 3.23 seconds [i]



Power Spectrum from Spectrogram #5, Subject #6 at 4.81 seconds [o]

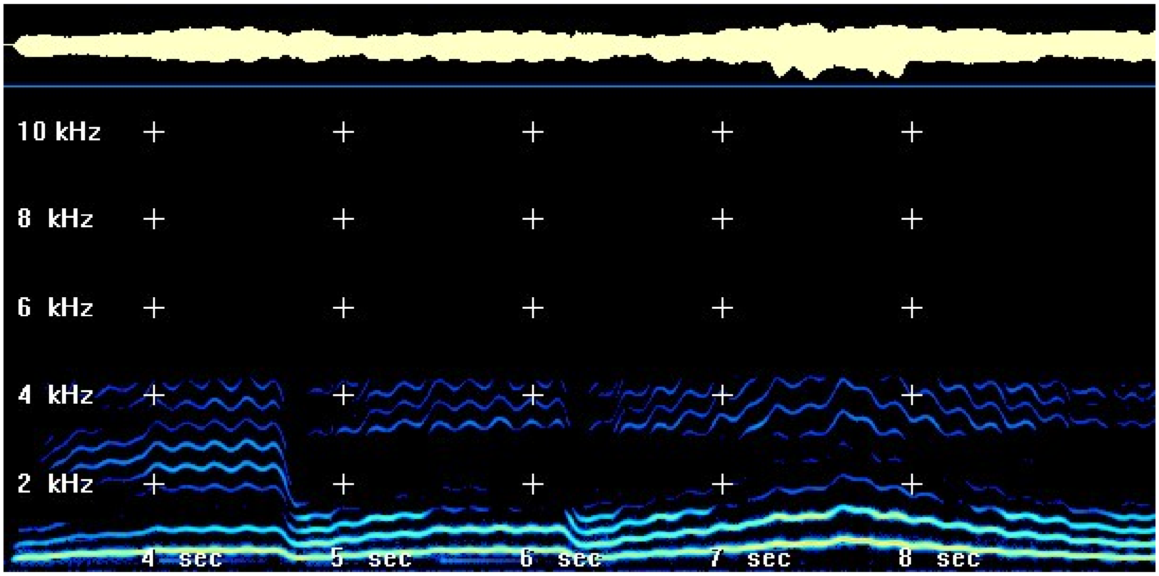


Power Spectrum from Spectrogram #5, Subject #6 at 6.59 seconds [a]



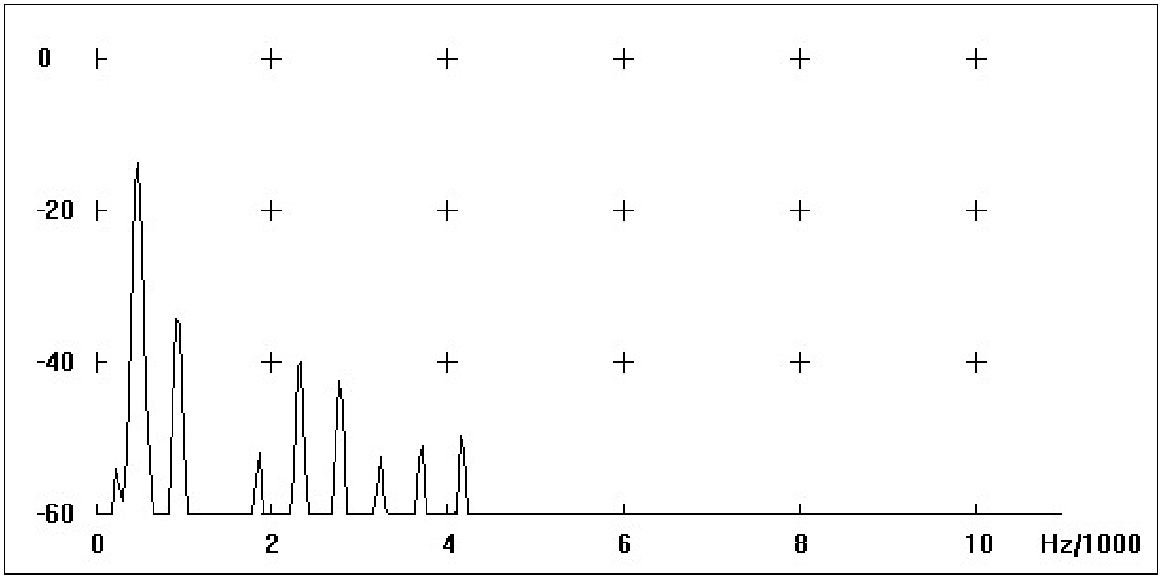
Analysis of Power Spectra from Spectrogram #5, Subject #6 – September 27, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.23	4	2	.5	5	9	.55	.52
4.81	6	2	.33	3	9	.33	.33
6.59	2	2	1.0	4	6	.66	.83
Average of three chiaroscuro levels							.56

Wave File Number 6 – October 5, 2000 – Subject #6

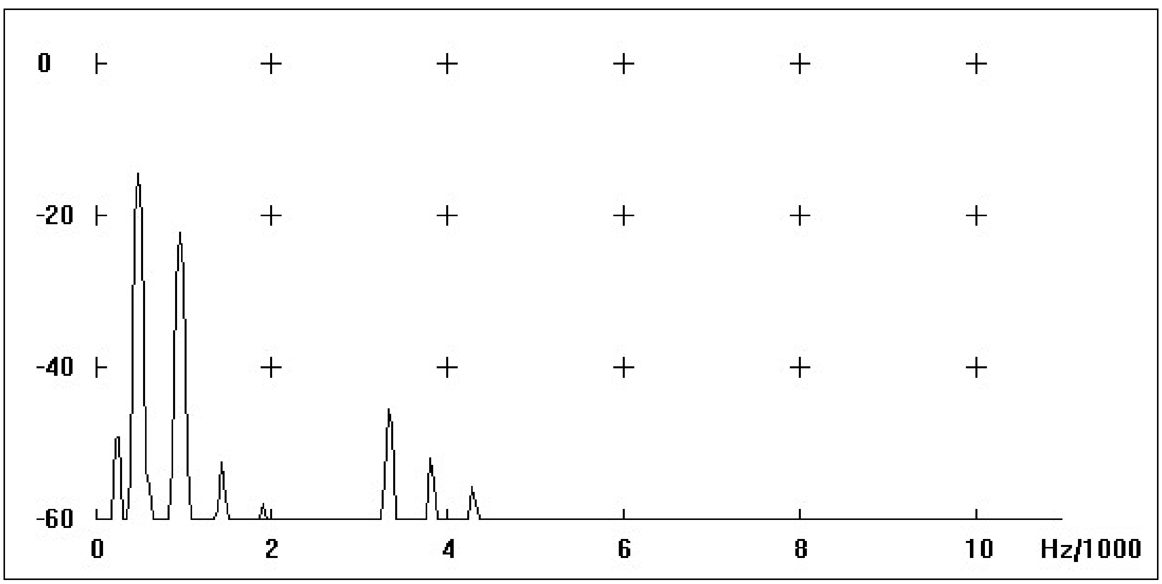


Subject #6 – Analysis of Wave File #6 – October 5, 2000 – E flat major				
		[si] (3.4-4.6 sec)	[o] (4.84-6.14 sec)	[a] (6.31-10.14 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 30%	Varying around 30%	Varying around 30% with increase to about 70%
Indicates solid and consistent technique.				

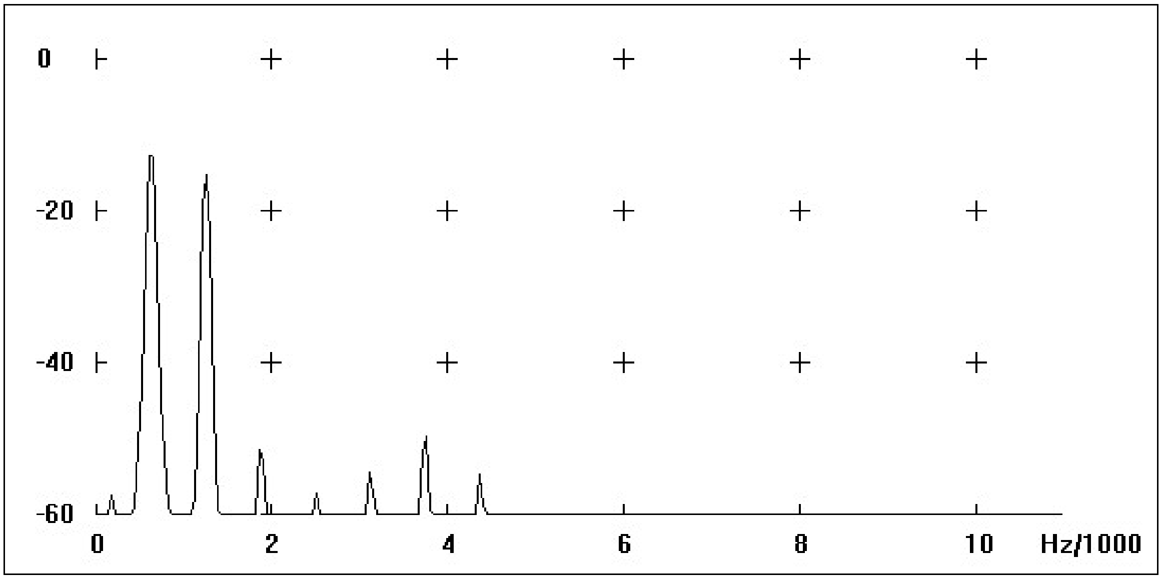
Power Spectrum from Spectrogram #6, Subject #6 at 4.4 seconds [i]



Power Spectrum from Spectrogram #6, Subject #6 at 5.71 seconds [o]

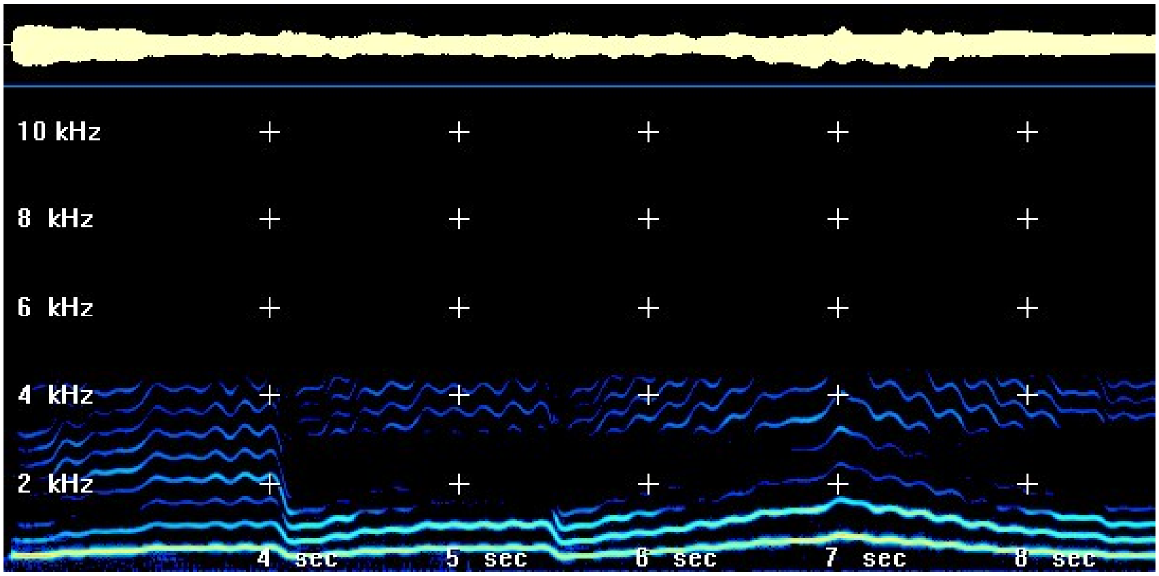


Power Spectrum from Spectrogram #6, Subject #6 at 7.45 seconds [a]



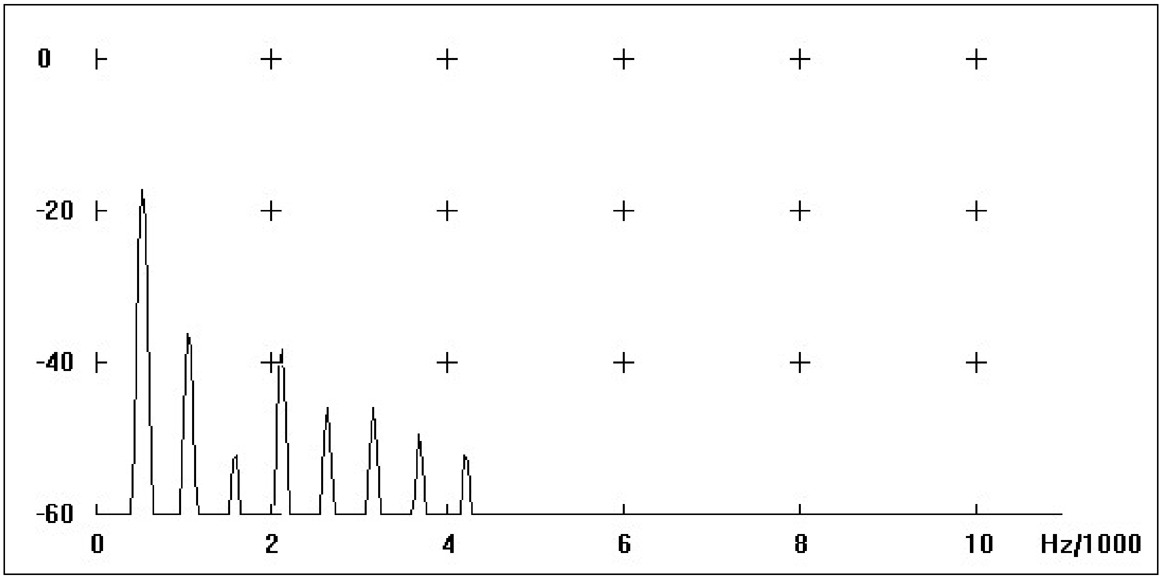
Analysis of Power Spectra from Spectrogram #6, Subject #6 - October 5, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.4	4	2	.5	5	9	.55	.52
5.71	5	2	.4	3	8	.37	.38
7.45	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.46

Wave File Number 7 – October 10, 2000 – Subject #6

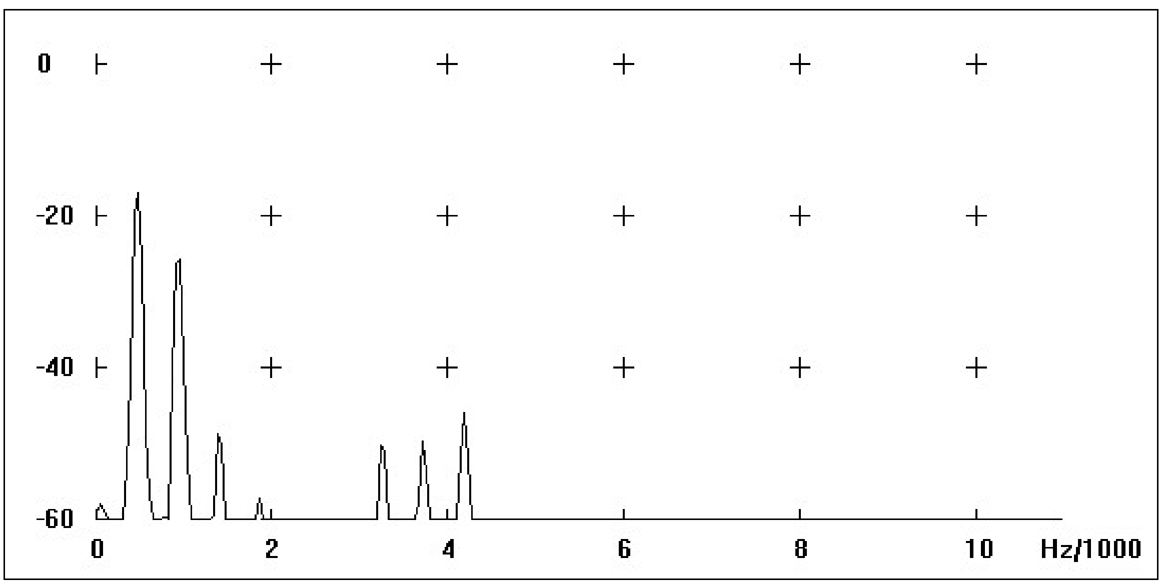


Subject #6 – Analysis of Wave File #7 – October 10, 2000 – F major				
		[si] (2.69-4.0 sec)	[o] (4.19-5.43 sec)	[a] (5.6-9.29 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 40%	Varying around 30%	Varying around 30%
Indicates solid and consistent technique.				

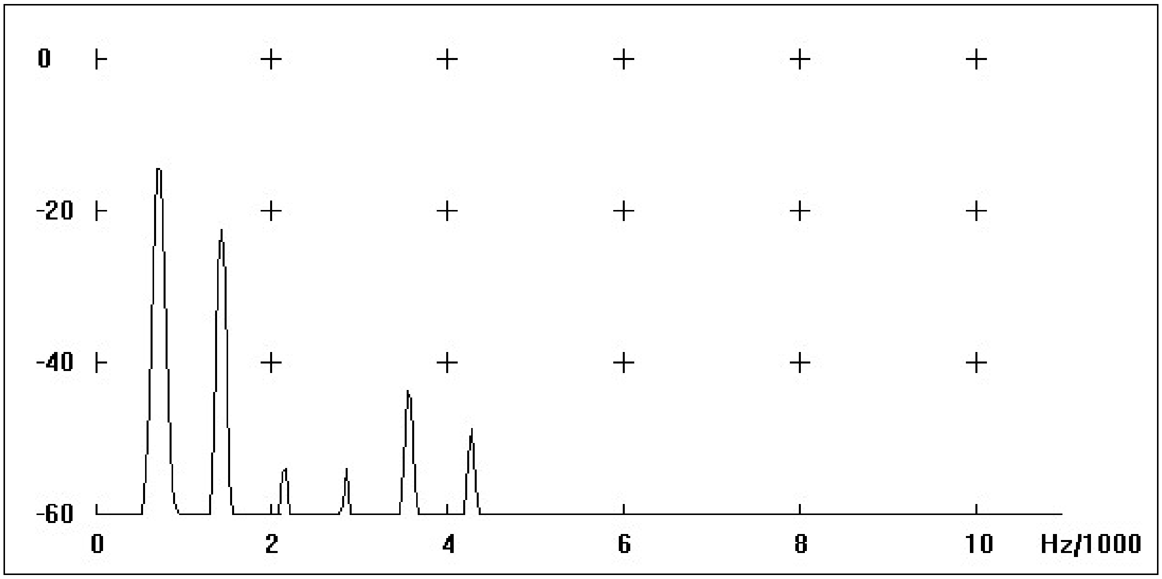
Power Spectrum from Spectrogram #7, Subject #6 at 3.93 seconds [i]



Power Spectrum from Spectrogram #7, Subject #6 at 4.71 seconds [o]

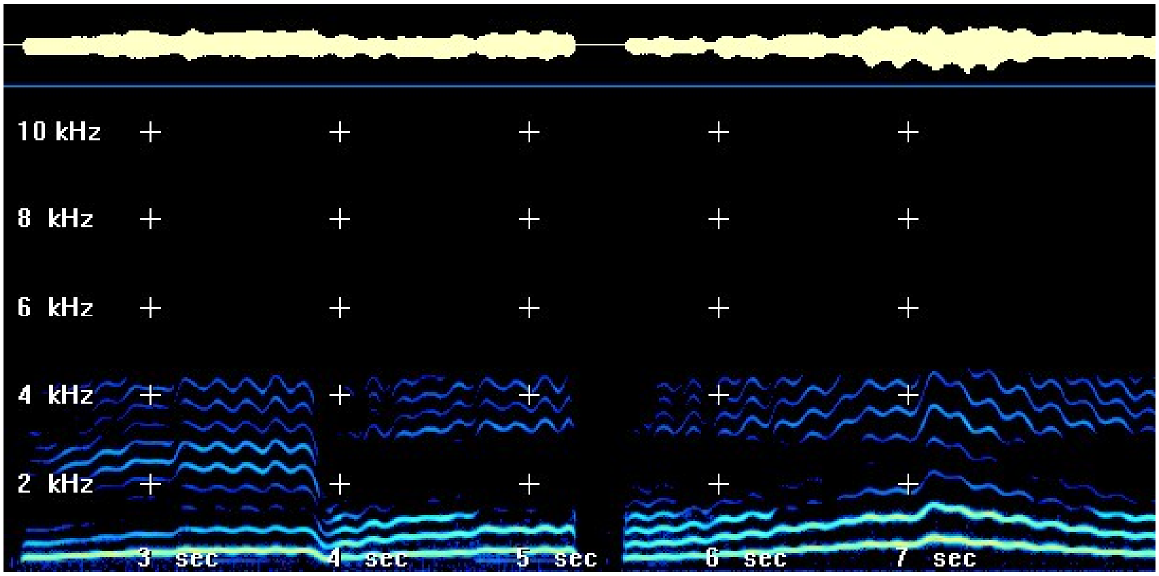


Power Spectrum from Spectrogram #7, Subject #6 at 6.93 seconds [a]



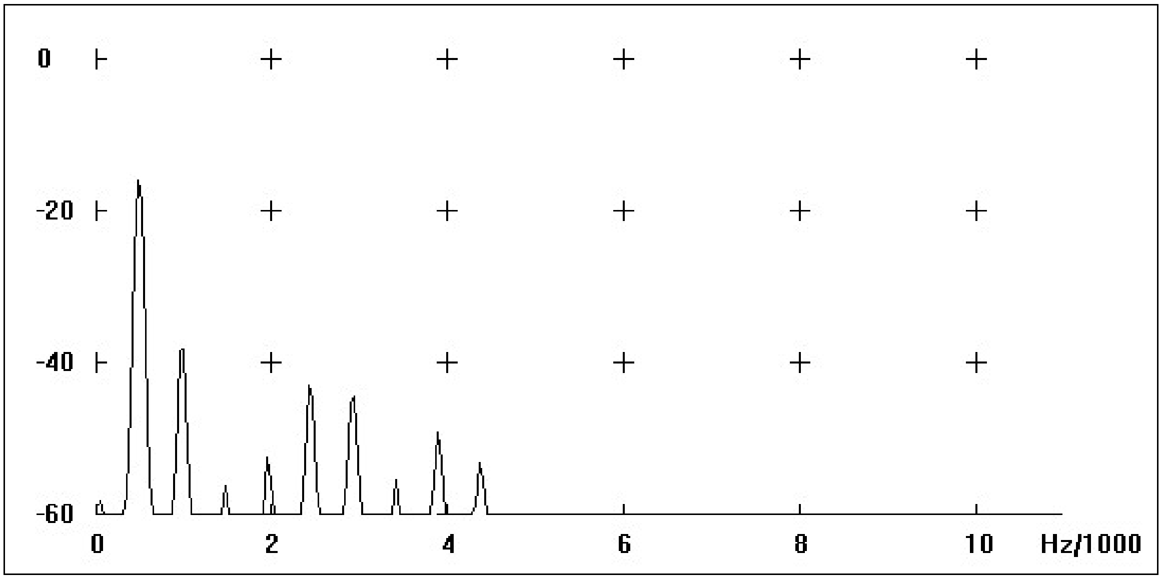
Analysis of Power Spectra from spectrogram #7, Subject #6 - October 10, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.93	3	2	.66	5	8	.62	.64
4.71	5	2	.4	3	8	.37	.38
6.93	2	2	1.0	4	6	.66	.83
Average of three chiaroscuro levels							.61

Wave File Number 8 – October 17, 2000 – Subject #6

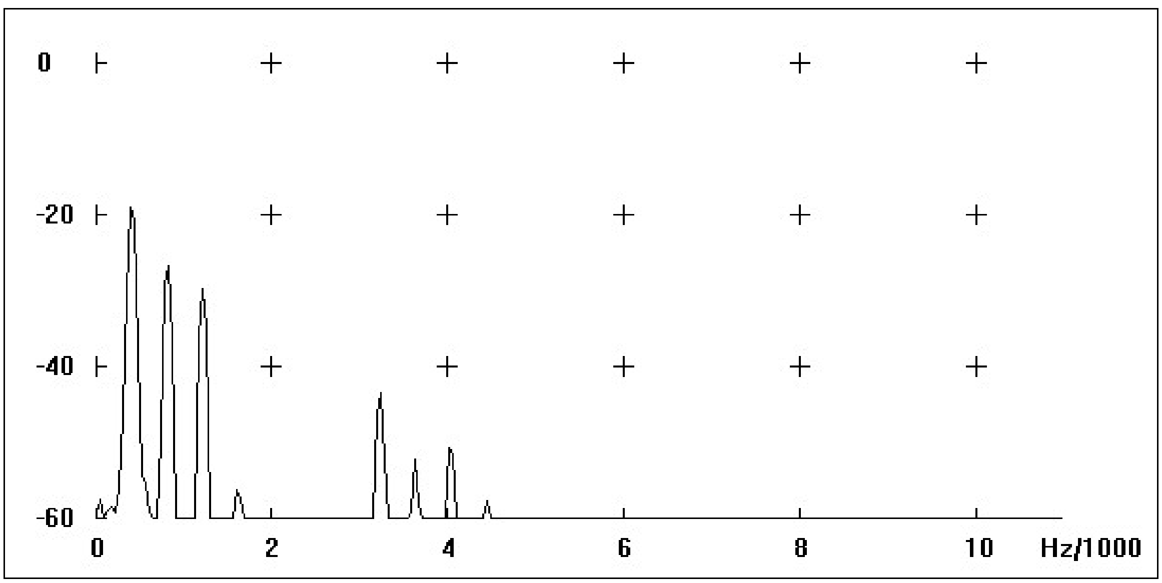


Subject #6 – Analysis of Wave File #8 – October 17, 2000 – E flat major				
		[si] (2.35-3.8 sec)	[o] (4.03-5.19 sec)	[a] (5.5-9.95 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 30%	Varying around 30%	Varying around 30% with increase to about 60% at highest pitches
Indicates solid and consistent technique.				

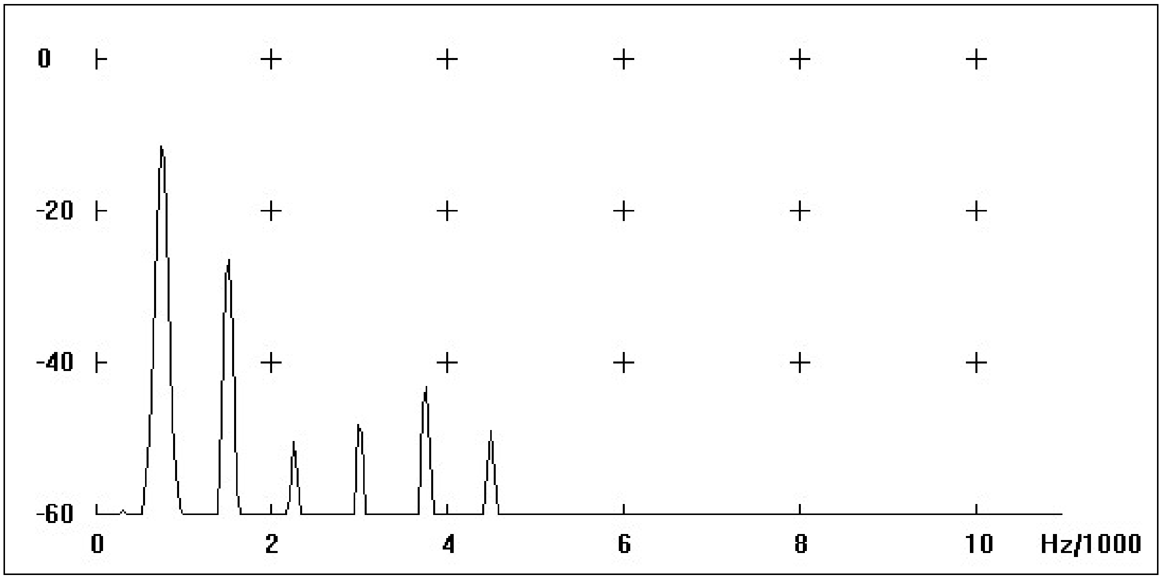
Power Spectrum from Spectrogram #8, Subject #6 at 3.65 seconds [i]



Power Spectrum from Spectrogram #8, Subject #6 at 4.51 [o]

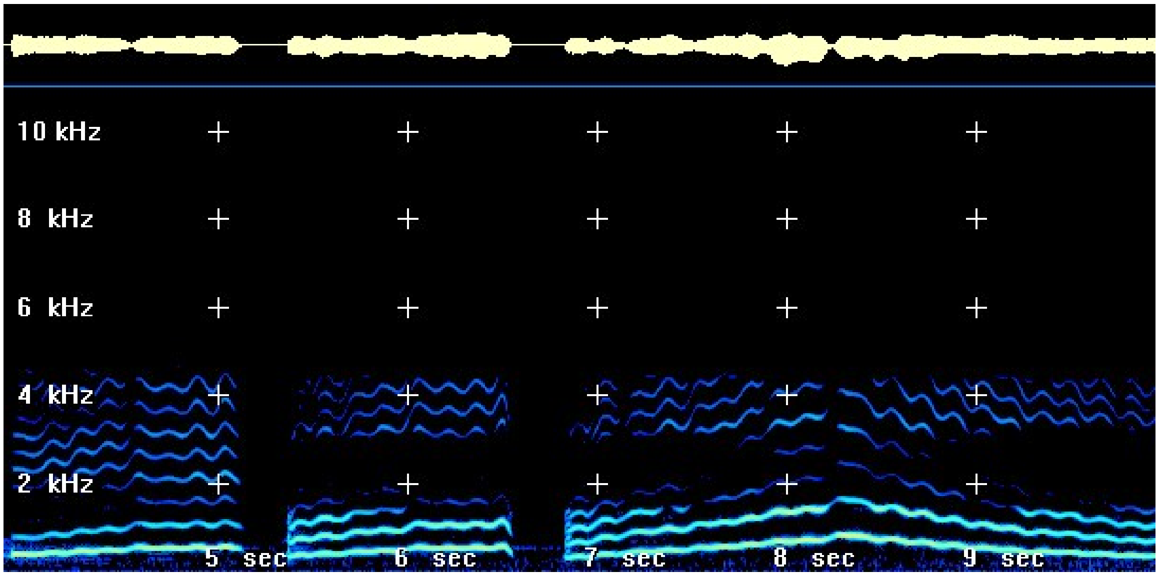


Power Spectrum from Spectrogram #8, Subject #6 at 7.14 seconds [a]



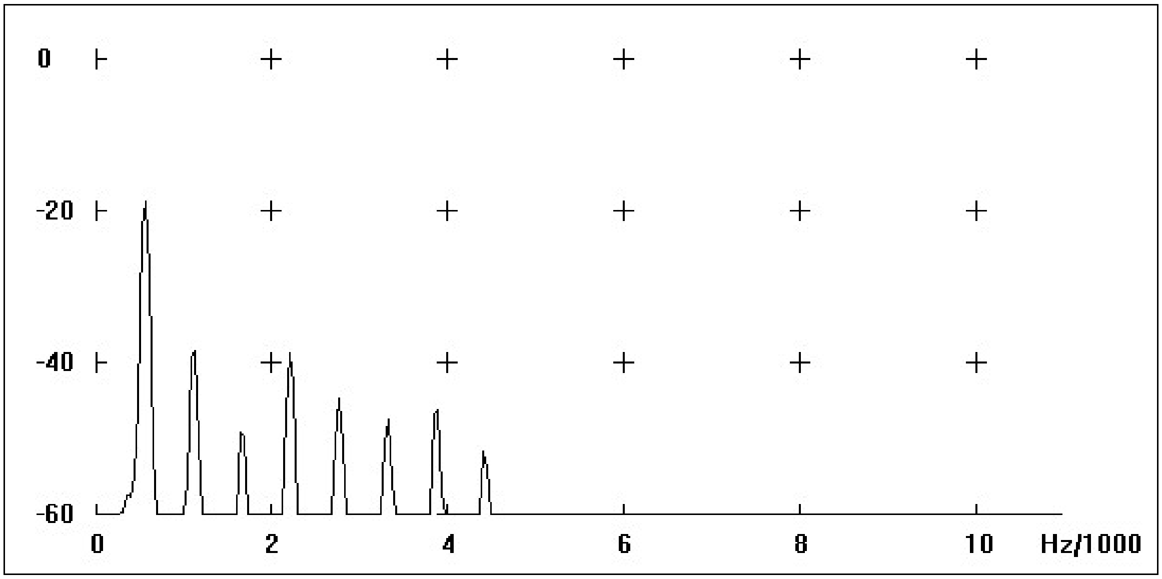
Analysis of Power Spectra from Spectrogram #8, Subject #6 October 17, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{b/a+c/d}{2}$
3.65	5	2	.4	5	10	.5	.45
4.51	6	3	.5	4	10	.4	.45
7.14	3	2	.66	4	7	.57	.61
Average of three chiaroscuro levels							.5

Wave File Number 9 – October 24, 2000 – Subject #6

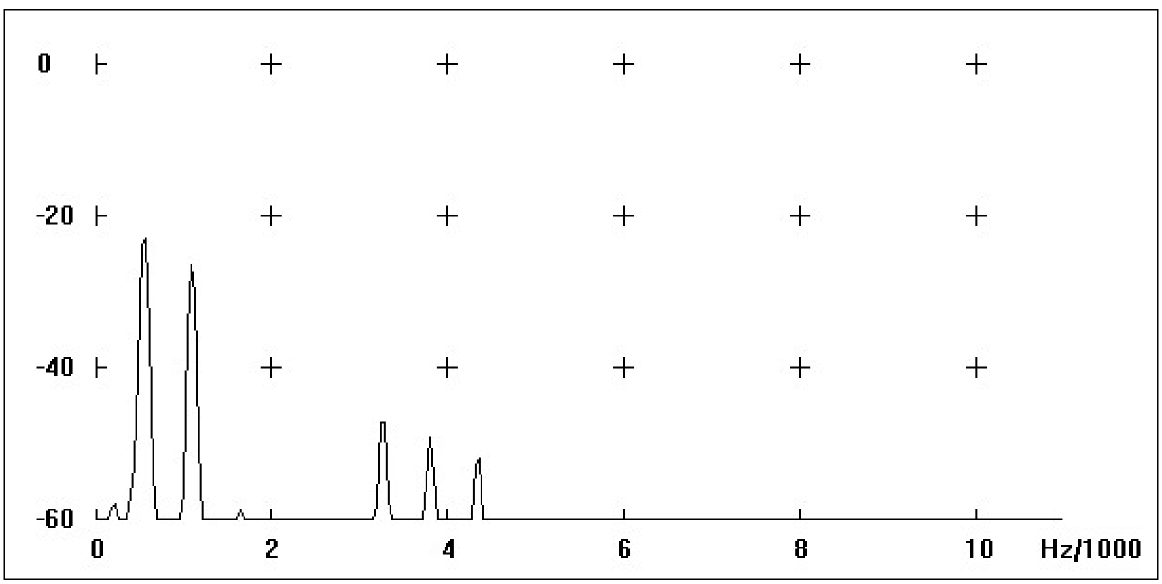


Subject #6 – Analysis of Wave File #9 – October 24, 2000 – F major				
		[si] (3.93-5.1 sec)	[o] (5.38-6.52 sec)	[a] (6.83-10.5 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Not as strong as in wave file #8	Not as strong as in wave file #8	Not as strong as in wave file #8
Chiaroscuro Balance		Slightly over-resonated	Slightly over-resonated	Slightly over-resonated
Power Spectrum		Varying around 20%	Varying around 25%	Varying around 30%
Slightly over-resonated sound caused by entering upper frequencies without enough strength in the first formant area.				

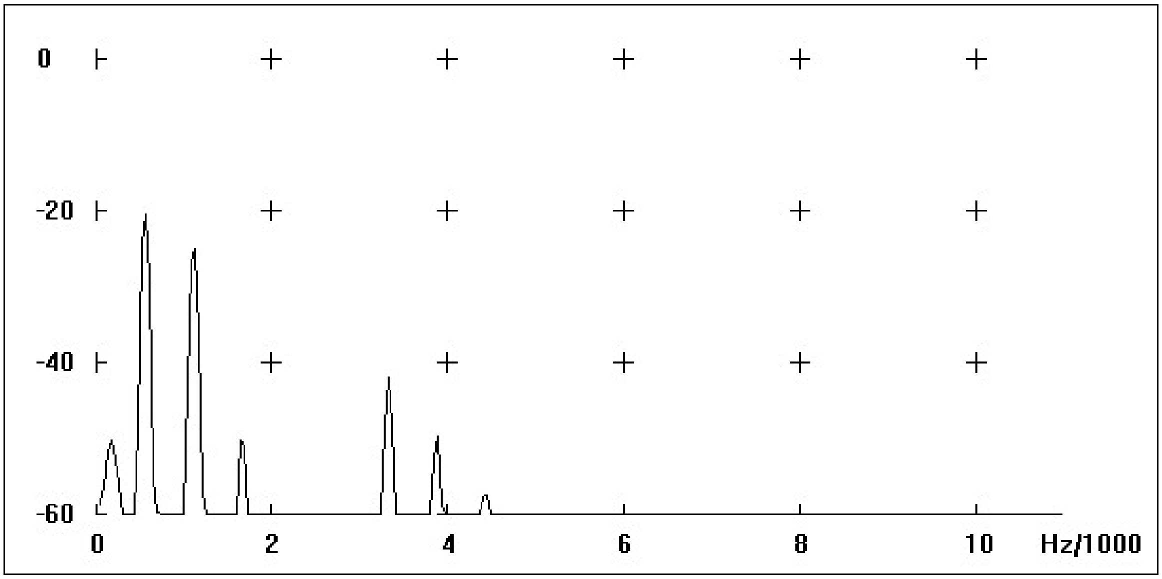
Power Spectrum from Spectrogram #9, Subject #6 at 4.89 seconds [i]



Power Spectrum from Spectrogram #9, Subject #6 at 6.06 seconds [o]

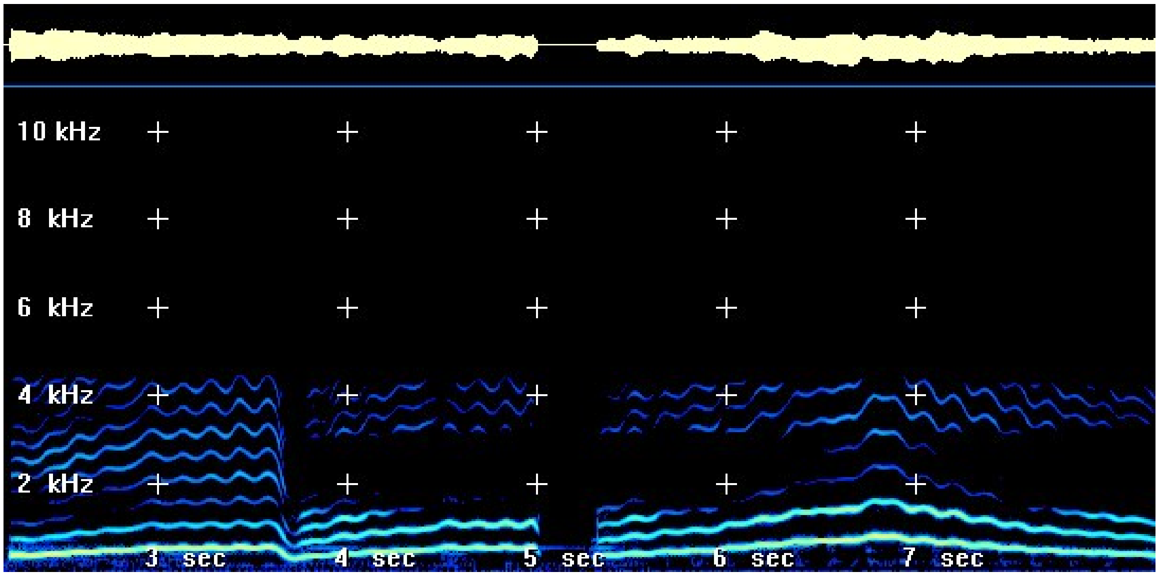


Power Spectrum from Spectrogram #9, Subject #6 at 7.72 seconds [a]



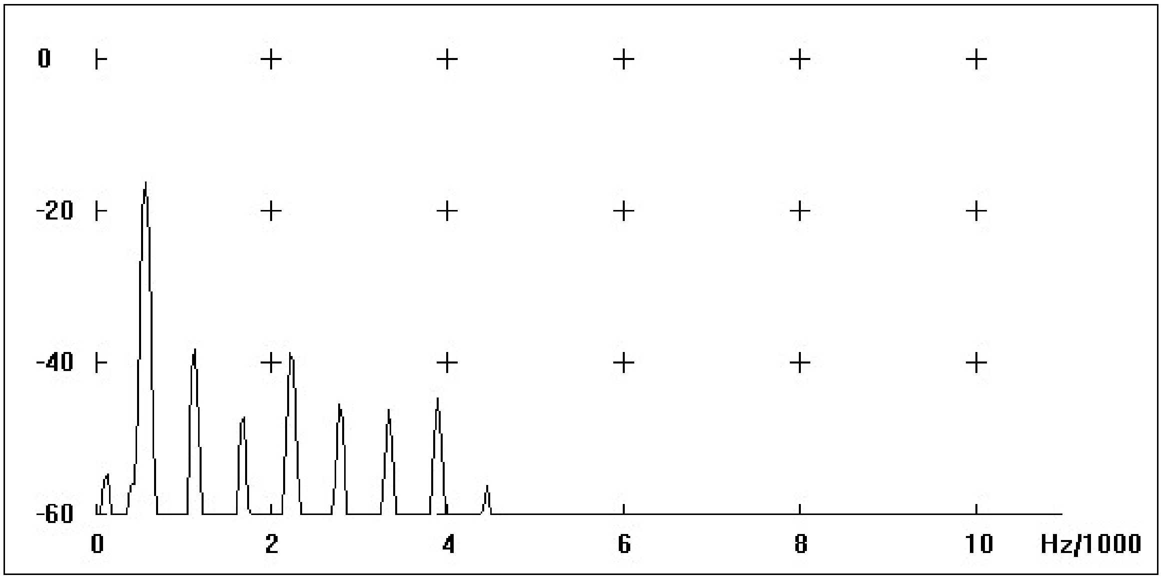
Analysis of Power Spectra from Spectrogram #9, Subject #6 - October 24, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.89	3	2	.66	5	8	.62	.64
6.06	4	2	.5	3	7	.42	.46
7.72	4	2	.5	3	7	.42	.46
Average of three chiaroscuro levels							.52

Wave File Number 10 – November 3, 2000 – Subject #6

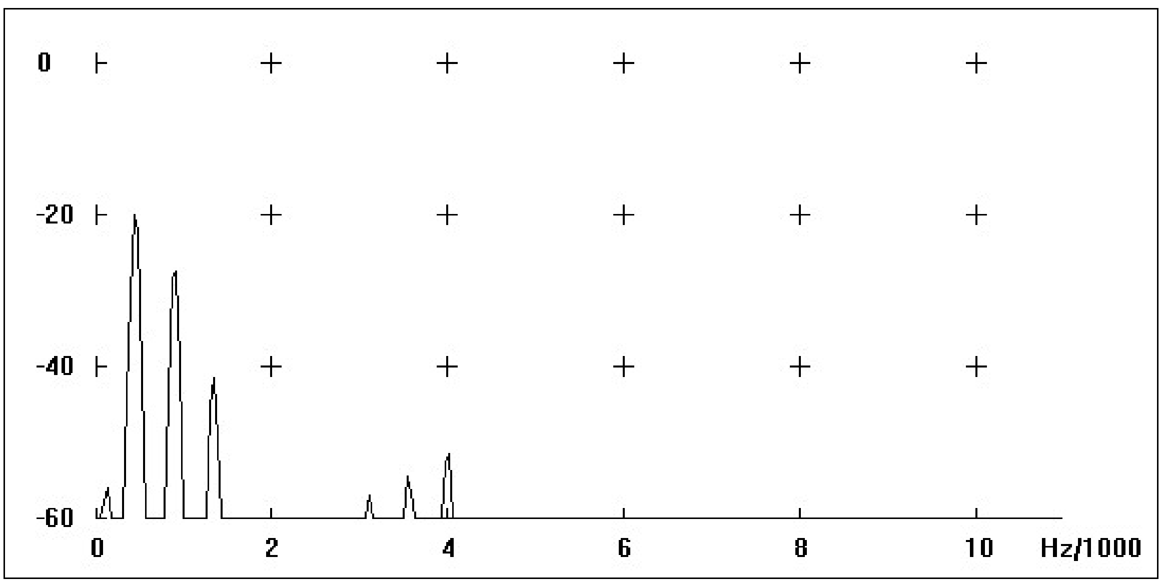


Subject #6 – Analysis of Wave File #10 – November 3, 2000 – F major				
		[si] (2.22-3.57 sec)	[o] (3.79-4.98 sec)	[a] (5.32-9.14 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 30%	Varying around 30%	Varying around 30%
Indicates solid and consistent technique.				

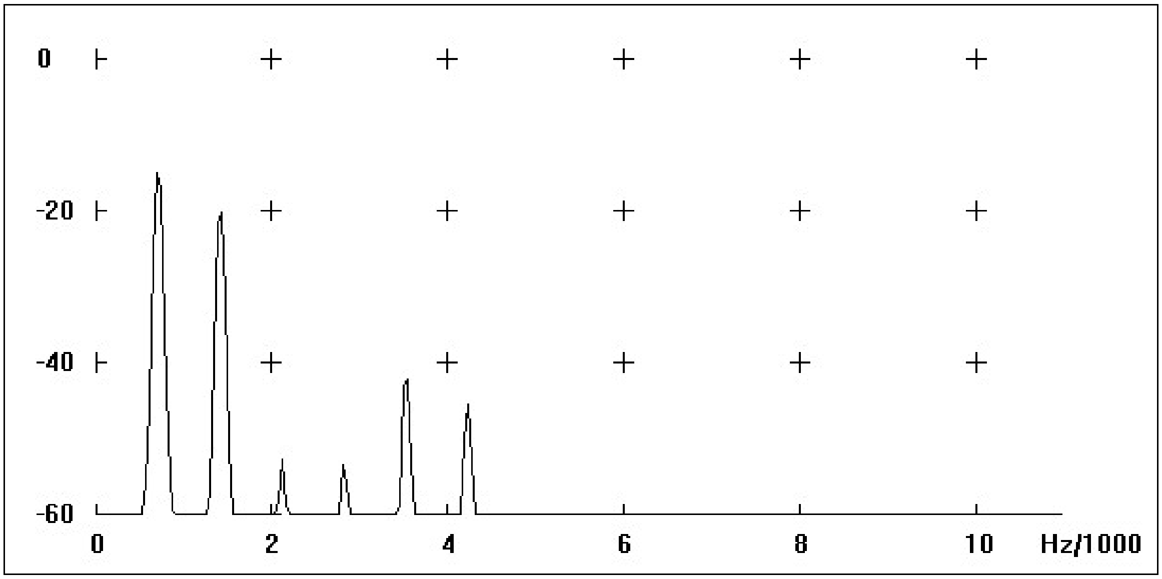
Power Spectrum from Spectrogram #10, Subject #6 at 3.43 seconds [i]



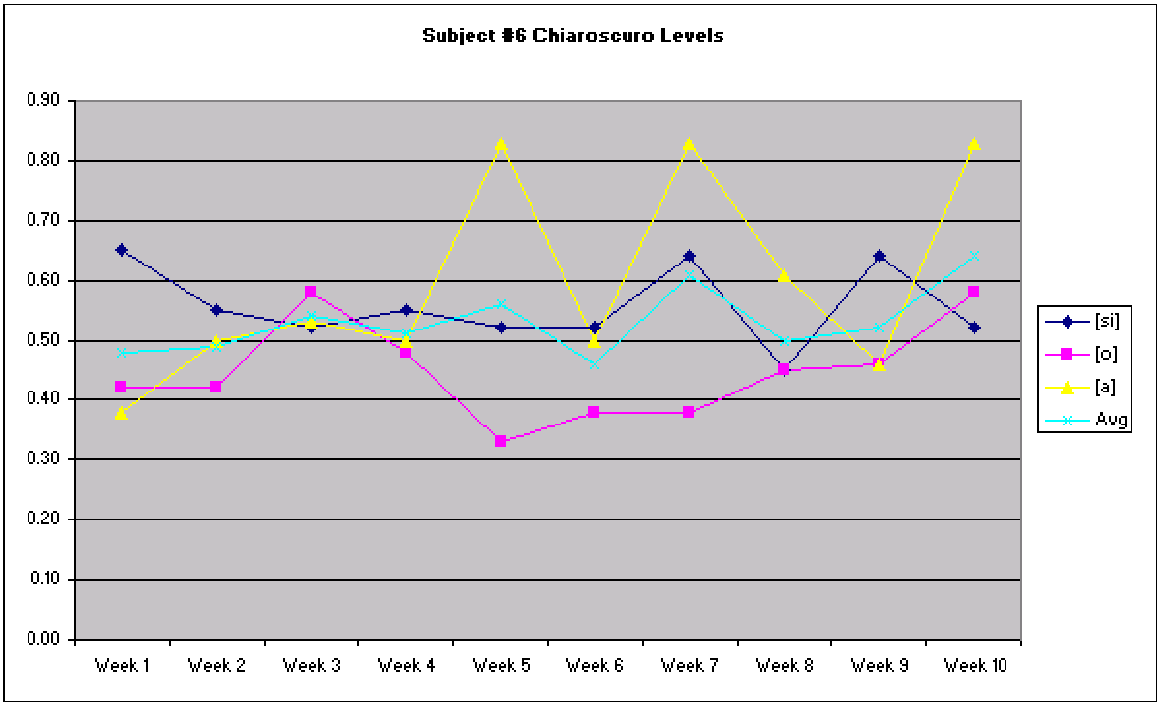
Power Spectrum from Spectrogram #10, Subject #6 at 4.14 seconds [o]

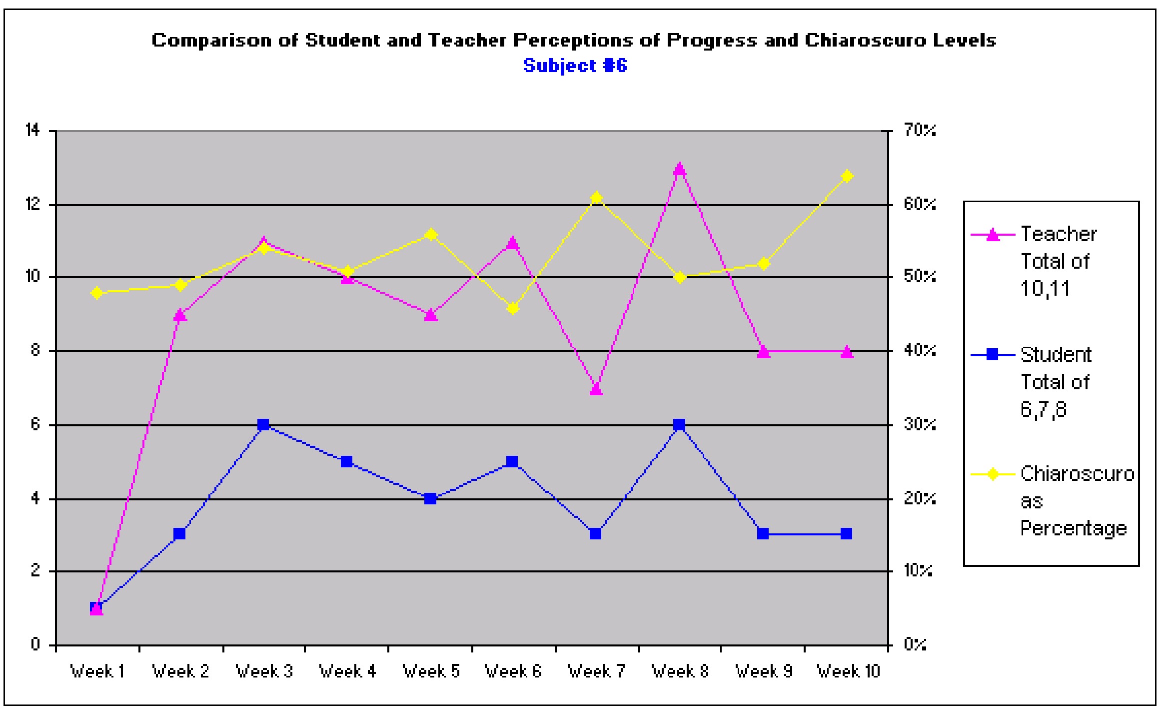


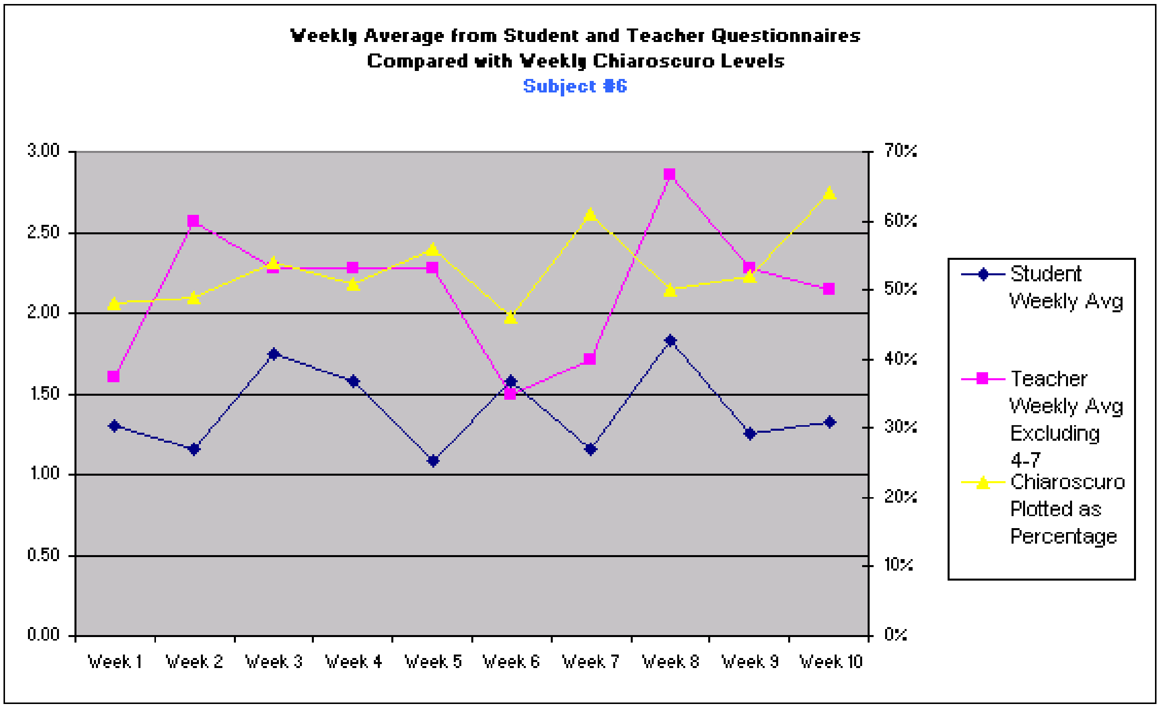
Power Spectrum from Spectrogram #10, Subject #6 at 6.67 seconds [a]



Analysis of Power Spectra from Spectrogram #10, Subject #6 - November 3, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.43	4	2	.5	5	9	.55	.52
4.14	4	3	.75	3	7	.42	.58
6.67	2	2	1.0	4	6	.66	.83
Average of three chiaroscuro levels							.64


Subject #6 Chiaroscuro Levels
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg


Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #6
14
12
10
8
6
4
2
0
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #6
3.00
2.50
2.00
1.50
1.00
0.50
0.00
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A7: Subject #7

Subject #7 is a 23-year-old African-American senior majoring in musical theatre. She was from DeKalb County in Atlanta. The semester in which data were gathered was her first after she decided to change her major from voice performance to musical theatre. Subject #7 transferred to this program in January 2000, after spending three years in three different colleges studying music. Her goal was musical theatre performance, but she was not sure in which area she wanted to perform. She enjoyed opera and musical theatre equally and was planning a recital that would include repertoire from both. She had a leading role in a musical theatre production based on the music of George Gershwin and was vocally healthy during the data collection semester.

Subject #7's vocal production was very impressive at her scholarship audition. She had a wonderful lyric spinto sound with a long range from f to e^3 and a lovely high pianissimo, but her vocal production was marred by tension in the jaw and tongue that caused an extreme vibrato. Her dramatic and linguistic abilities along with a beautiful natural voice brought her quite a few performance opportunities, including Donna Elvira in *Don Giovanni*, but her tension issues and disorganized approach to understanding her voice were standing in her way.

Subject #7 was a very intelligent singer who took good care of her voice. As she learned to release the jaw and tongue, she became able to produce her wonderful sound without the enormous effort she was putting into voice production. She learned to balance breath management with resonance techniques and to trust that her voice would work for her when she called upon it. She also found that it was possible to sing with the richness she liked in her lower voice for musical theatre without losing her upper register.

Ease in the notes above c^3 came with this process, and her vibrato relaxed to normal levels. One interesting feature of her vocal improvement was an exploration of the mezzo-soprano repertoire. Subject #7 may have the option of choosing soprano or mezzo-soprano roles at some point.

The spectrograph did not play a big role in Subject #7's improvement at first. She tended to find it intrusive until she discovered that resonance techniques could take some of the pressure off her voice. She could see both upper frequencies and vibrato rate as she learned to manipulate each to her advantage.

Fall Semester 2000 Repertoire – Subject #7

Mozart	Dove sono
	Porgi amor
	Trio from *The Impresario*
Rossini	Una voce poco fa
Gershwin	My Man's Gone Now
Tchaikowsky	Adieu forêt
Sondheim	Broadway Baby
	The Glamorous Life
	Children Will Listen
	Loosing My Mind
Obrados	Seven Classical Songs
Billie Holiday	Carnival

Lesson record over the data collection period – Subject #7

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10-11
8/21	A	Dove sono	Good	Worked on Dove sono over the summer – nearly has it		
8/28	A	Dove sono	Good	Voice is good – there is still a tension level that I don't understand – why won't she release?	#1 F	Chiaroscuro - .70 Student 3, 3, 2 Teacher n/a, n/a
9/11	A	Dove sono, Gershwin, trio	Very good	Worked hard on Dove sono with accompanist – talked about change to more mezzo quality and how it will affect her top – trying to release tension and vibrato – hangs up just entering passaggio (B flat-C) – tried mush-mouth with great success – she says it feels like a massage – sound is A+ - I think this is what she needs and it will work with her repertoire.	#2 F	Chiaroscuro - .55 Student 5, 5, 5 Teacher 2, 2
9/18				Lesson cancelled for guest artists		
9/22	A	Gershwin – tried O beau forêt	Good	Make up lesson – she is definitely sick – we worked on exploring mezzo rep – her voice is so calm in the Tchaikowskyd	#3 F	Chiaroscuro - .55 Student 5, 4, 5 Teacher 3, 3
9/25				Lesson cancelled for Tennessee trip		
9/29	A	Dove sono, Gershwin	Good	Worried about staying in school – wants to go to London, but decided to finish degree – voice is back – tension in Dove sono – less in Gershwin – gorgeous sound at all times	#4 F	Chiaroscuro - .58 Student 1, 1, 1 Teacher 3, 3
10/2				Lesson cancelled – teacher sick		
10/6				Lesson cancelled – administrative duties		
10/9	A	Dove sono, Sondheim, Billie Holiday	Excellent	Struggling with what her own sound is and how to vary what she does – asked her to spend daily time just with the physicality of producing her sound	#5 F	Chiaroscuro - .76 Student 5, 5, 5 Teacher 3, 3
10/13	A	Impresario Trio, Rossini, Porgi amor	Excellent	Starting to find her way – must release	#6 F	Chiaroscuro - .72 Student 5, 5, 5 Teacher 2, 2
10/16	A	Trio	Good	She is settling on the lower middle to an extent because of her change in rep – I'm glad she has the trio for balance. She has started working on it, and Ashlee read it with her	#7 F	Chiaroscuro - .76 Student 3, 4, 3 Teacher 2, 2
10/25	A	Dove sono	Good	Understands dramatically and can do it vocally, but is working way too hard, which makes her voice almost uncontrollable	#8 F	Chiaroscuro - .83 Student 4, 5, 5 Teacher 3, 3
11/6	A	Dove sono	Good	The aria is so difficult that she has to use less force to make it through – I think she believes me!	#9 F	Chiaroscuro - .78 Student 5, 5, 5 Teacher 2, 2
11/9	A	Dove sono	Good	Sang for Chamber Choir since she can't come to VMC – got lost in the recitative, but sang smoothly and well without forcing – a breakthrough!		
11/10				Just vocalized and made wave file – I had to audition an adjunct	#10 F	Chiaroscuro - .78 Student 5, 4, 4 Teacher 2, 2

11/17	A	Dove sono, Rossini	Good	She is gaining control by forcing less – finds the voice cooperative when she takes it easy		.
11/19	A	Dove sono	Excellent	Student recital – very successful		
11/20	A	Una voce poco fa	Good	Exultant over success in student recital – recit and area word and note perfect – dramatically exciting- vocally easy – good, she's learning – Una voce is the next challenge – can she keep her ease when singing rapid notes		

Responses to student questionnaires – Subject #7

Question	8/28	9/11	9/23	9/29	10/9	10/13	10/16	10/25	11/6	11/10	**Total of weekly answers to questions 6, 7, 8**
1	1	2	3	1	4	5	5	5	5	4	
2	1	1	2	1	4	5	4	4	4	4	
3	1	1	2	1	3	4	5	4	3	3	
4	5	5	5	5	2	5	5	5	5	5	
5	4	5	5	4	4	5	4	5	5	4	
6	3	5	5	1	5	5	3	4	5	5	4.4
7	3	5	4	1	5	5	4	5	5	4	4.5
8	2	5	5	1	5	5	3	5	5	4	4.5
9	5	1*	4	1	4	1	3	1	3	5	**Average over ten week period**
10	5	5	5	1	4	2	3.5**	4	5	4	
11	2	5	2	1	4	4	4	4	4	5	
12	1	5	1	2	4	1	2	4	4	5	
Weekly Average	2.75	3.75	3.56	1.66	4	3.91	3.75	4.16	4.41	4.33	**4.46**

*Note on this answer: "Just 'cause I don't like my voice much"
**Subject #7 checked both 3 and 4
It is very likely that Subject #7 used the 1-5 scale backwards

Responses to teacher questionnaires – Subject #7
Quantification of the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)
2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)
3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)
4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)
5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

Question	8/28	9/11	9/22	9/29	10/9	10/13	10/16	10/25	11/6	11/10	**Total and Average of questions 10 & 11**
1	2	2	2	2	2	2	2	2	2	2	
2	2	2	3	2	3	2	1	2	2	2	
3	2	2	2	2	2	2	2	2	2	2	
4	4	2	4	4	4	4	3	5	5	5	
5	1	1	4	3	3	2	3	2	3	5	
6	3	5	4	4	4	5	5	3	3	4	
7	5	5	5	5	5	5	5	5	5	5	
8	2	1	2	2	2	2	1	1	1	2	
9	2	1	2	2	2	2	1	2	1	3	
10	N/a	2	3	3	3	2	2	3	2	2	2.77
11	N/a	2	3	3	3	2	2	3	2	2	2.77
Weekly average excluding questions 4-7	2	1.71	2.42	2.28	2.42	2	1.57	2.14	1.71	2.14	**2.77**

Student's Written Reaction to Use of Spectrograph – Subject #7

I have been singing for most of my life, and it has not always been frustrating. As a child it was fun and comforting in some indescribable way when I learned a catchy tune or sang in one of the choirs I was a member of. As I grew older, it became more serious and, consequently, more frustrating: to sing the phrasing just so, with the pitch and range being unforced but supported and making sure your "instrument" was in good working order. It wasn't until I grew older that I began to think about what being a singer was, apart from being a good singer. My analysis has changed in a few ways, but one characteristic that remains the same frustrating reality is that being a singer means controlling an "instrument" that one will never be able to see. Unlike any other musician, a singer is naked in every artistic and technical way, and the tuning cannot be seen with the naked eye; it must be heard and felt by singers themselves. This may be one of the reasons that singers are stereotyped as "difficult" or "self-centered". We do not take our instruments out of a box or tune it with a fork, no matter how much one may want to at certain times. It is for these reasons that I am, after some lingering hesitations, glad that Mrs. Callaway is using her spectrograph – it provides a picture of the voice with which to work.

On the first day that Ms. Callaway brought in her machine for my voice lesson, I was a bit skeptical about how useful it would be to my technique. It was a foreign and intrusive object that seemed to threaten the tried and true method of vocal production of teacher-student rapport. I eyed it with nothing less than contempt and was not willing to make friends with it very easily. We vocalized and when we arrived at the proper recording key for the machine, Mrs. Callaway would tell me to click on the computer's button so that it could record my sound. Of course the first few times I was astounded at the colors and waves that were produced on the screen. They were senseless to me and it wasn't decipherable. After a few months it began to make a bit more sense: the height and widths of the lines were translating my frequency and range. What the waves were indicating about my voice had grown informative as well as fascinating. Over the course of time my voice has become stronger when I am practicing on my own as well as when I am recording on the spectrograph for Mrs. Callaway. No longer is it a contemptuous machine for me; now it is a photographer that shows me what my "instrument" can look like.

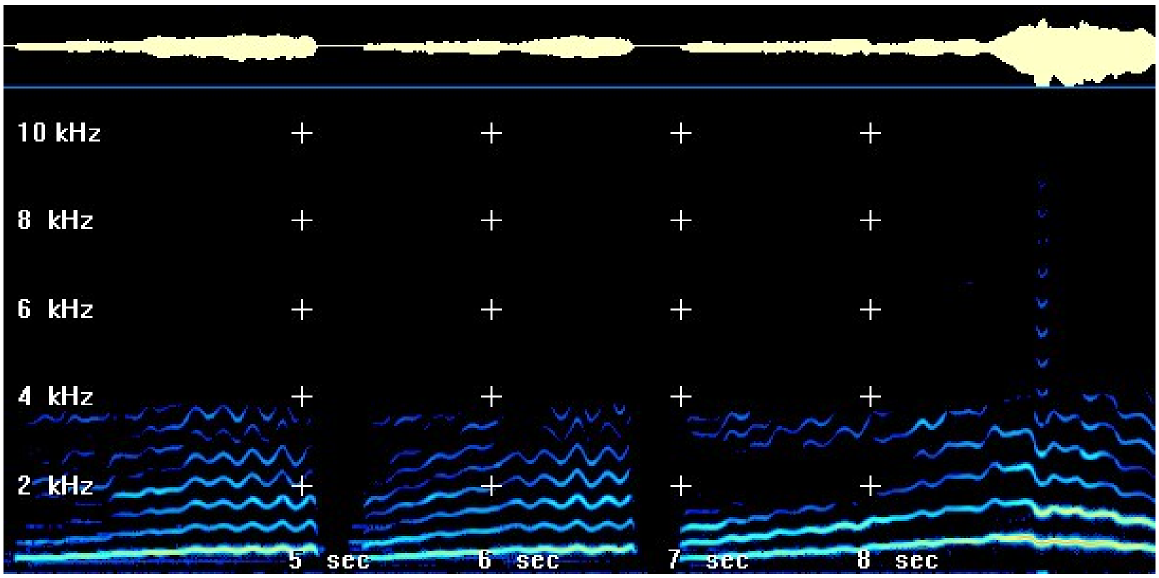
With this experimental part of Mrs. Callaway's research, I am reassured in my voice. Being a visual and auditory learner it is helpful for me to have an image in my head of what my sound looks like when I sing certain ways. Through I cringe at times at the honesty with which the computer translates my sound, it is useful for showing me what I should release in order to make the picture more even in frequency and shape. Since I am unable to hear my voice as others hear it and don't quite grasp the size of my voice, it is nice for me to see how "big" my voice is in a picture frame. This tool helps me to identify in another way with exactly what I am steering in the body of mine. I finally have a more tangible image of what my voice is and using it isn't so scary after all.

All in all whomever came up with the engineering ideas to bring a singer's sound to a visual point is a compassionate genius and I am fortunate enough to have a teacher who is smart enough to bring this technology and understanding to her students.

Analysis of Wave Files

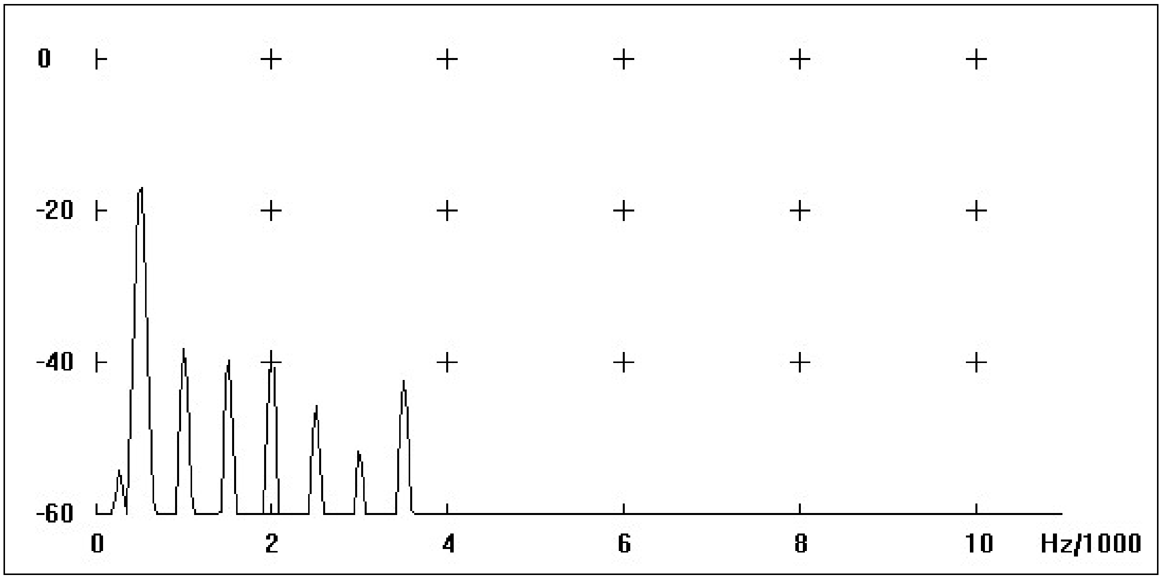
Wave File Number 1 – August 28, 2000 – Subject #7

Note that throughout the data gathering process Subject #7 used the vowels [i], [ɛ], [a] which she was accustomed to using for warm-ups rather than [si], [o], [a] used by the other students.

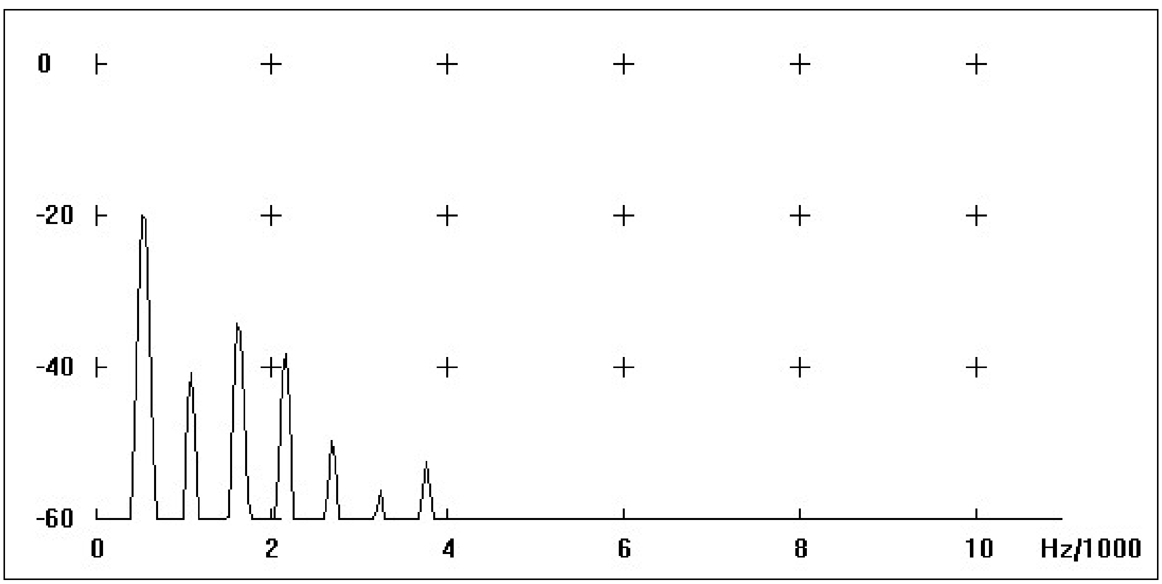


Subject #7 – Analysis of Wave File #1 – August 28, 2000 – F major				
		[si] (3.47-5.07 sec)	[ɛ] (5.26-6.75 sec)	[a] (7.0-11.2 sec)
Singer's Formant Area	4000+ Hz			Spike at 8.9 probably due to sudden increase in air pressure
	2000-4000 Hz	Good indications above vowel	Good indications	Good indications, but ragged vibrato indicates tension
2nd Formant Area (Vowel Definition)		Good vowel definition	Good vowel definition	Good vowel definition
1st Formant Area		Strong	Strong	Strong
Chiaroscuro Balance		Nearly balanced	Nearly balanced	Nearly balanced
Power Spectrum		Increases from about 10% to about 30%	Increases from about 10% to about 20%	Varying around 15% until surge to about 90% at highest pitches
This is a very fine voice with good resonation, but the singer has serious reservations about her vibrato. She begins with a straightened tone, and her attempt to retain the straightened tone at high pitches results in a very ragged, tense vibrato.				

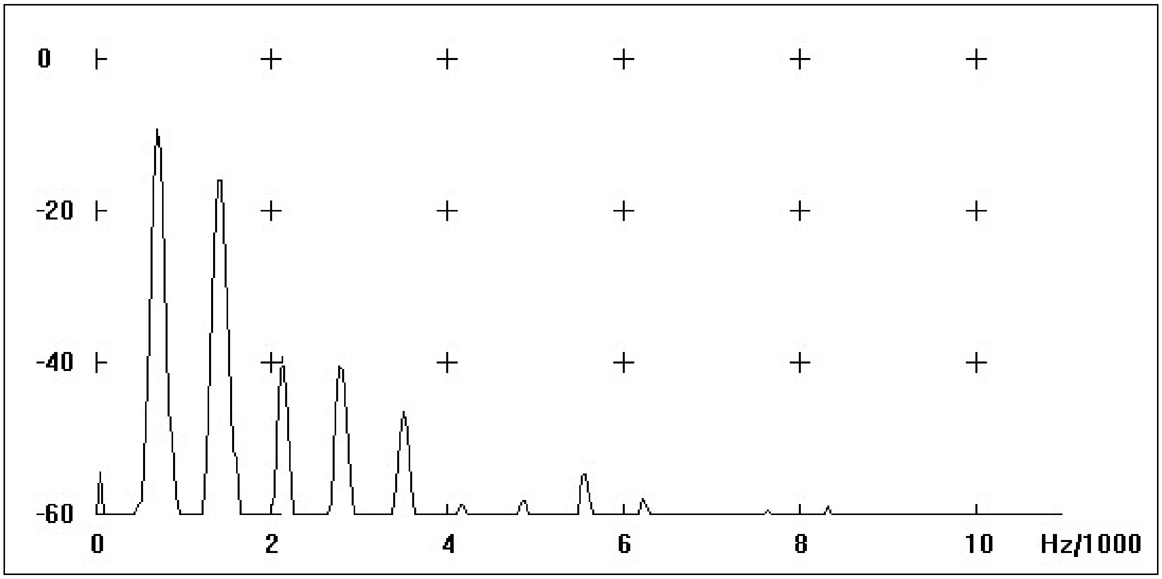
Power Spectrum from Spectrogram #1, Subject #7 at 4.66 seconds [i]



Power Spectrum from Spectrogram #1, Subject #7 at 6.67 seconds [ɛ]

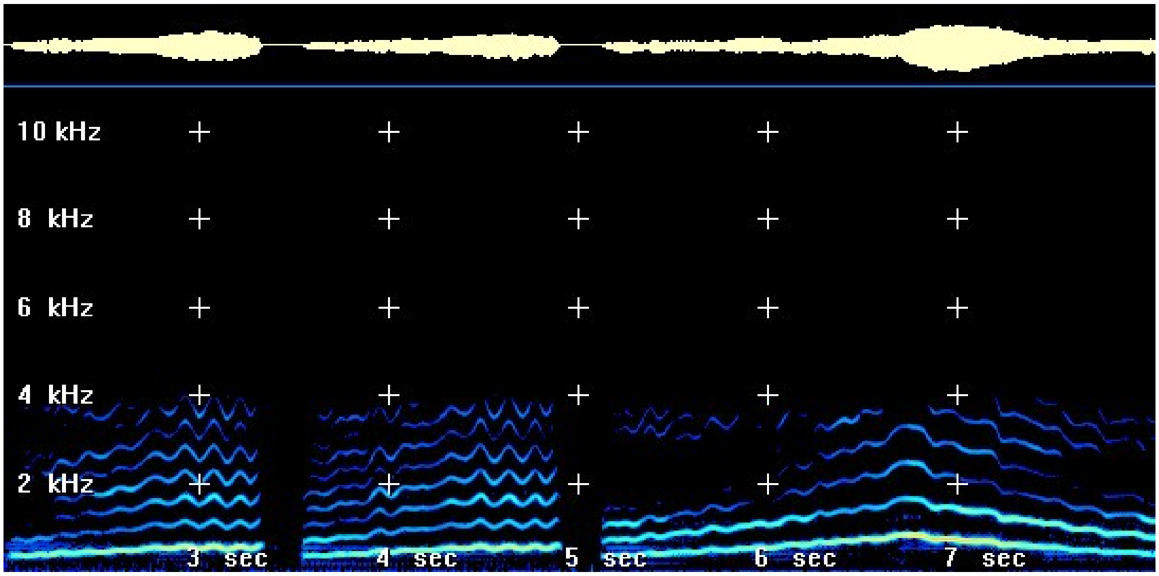


Power Spectrum from Spectrogram #1, Subject #7 at 8.9 seconds [a]



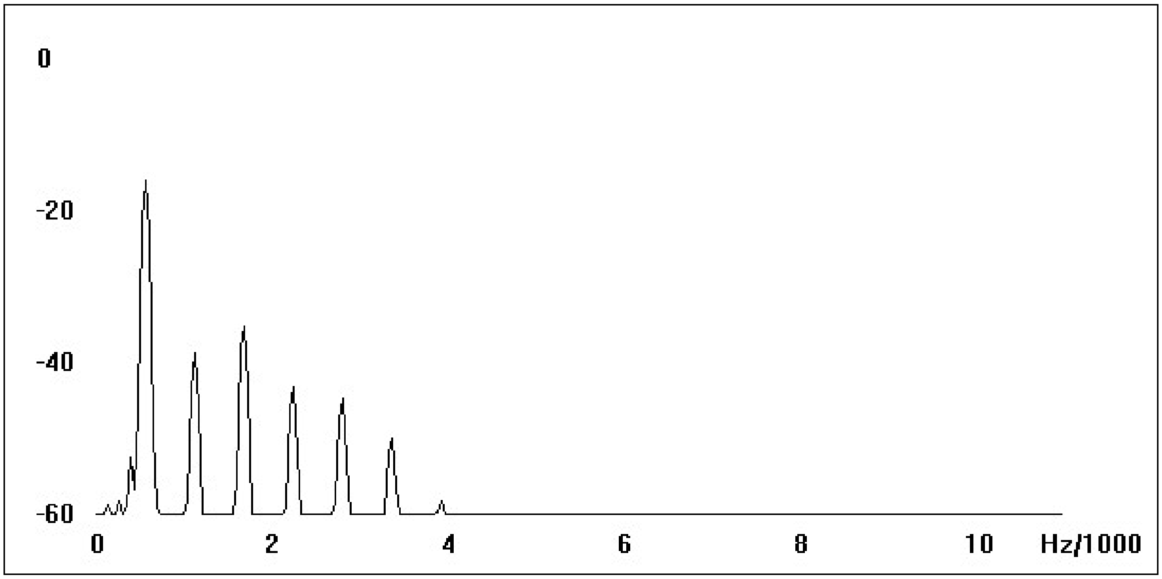
Analysis of Power Spectra from Spectrogram #1, Subject #7 – August 28, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.66	4	3	.75	4	8	.5	.62
6.67	3	3	1.0	4	7	.57	.78
8.9	3	2	.66	9	12	.75	.7
Average of three chiaroscuro levels							

Wave File Number 2 – September 11, 2000 – Subject #7

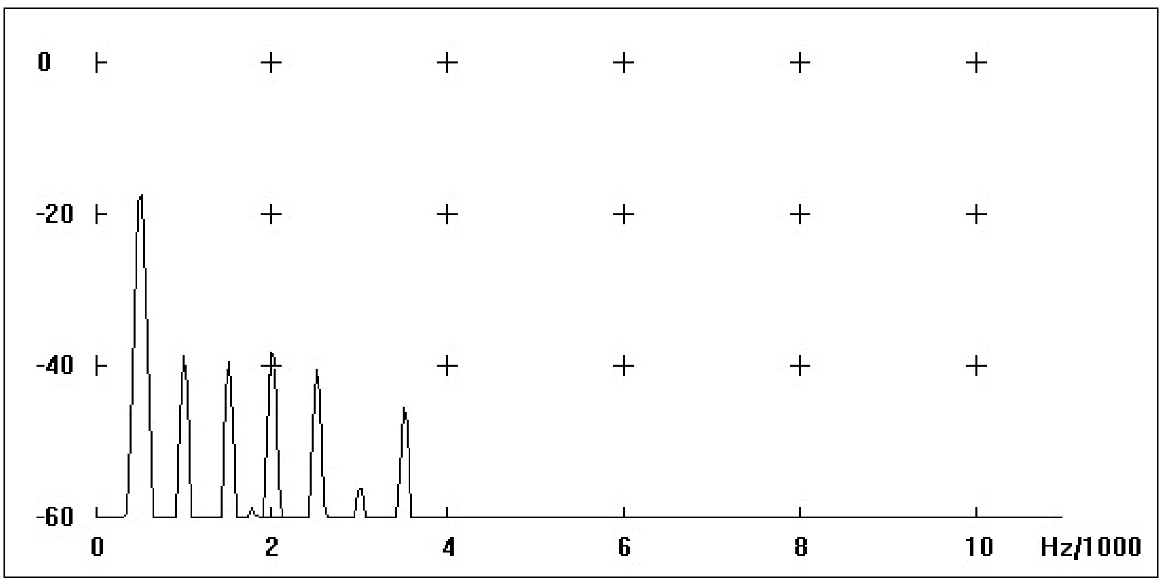


Subject #7 – Analysis of Wave File #2 – September 11, 2000 – F major				
		[si] (2.07-3.29 sec)	[ɛ] (3.55-4.88 sec)	[a] (5.14-9.24 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Solid indications above vowel	Continues all the bands produced in [si] without help from the vowel	Not quite as strong
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Somewhat less clear vowel formation
1st Formant Area		Strong	Strong	Extra strength here seems to be compensating for fewer upper frequencies
Chiaroscuro Balance		Well balanced	Well balanced	Weighted toward lower frequencies
Power Spectrum		Increases from about 10% to about 30%	Increases from about 10% to about 25%	Varies around 20% until increase to about 70% at highest pitches
The power spectra in this wave file are much more controlled; increases are more gradual than in wave file #1. The voice overall is showing good strength and balance. Note the complexity of the tone shown by the many frequencies accessed throughout.				

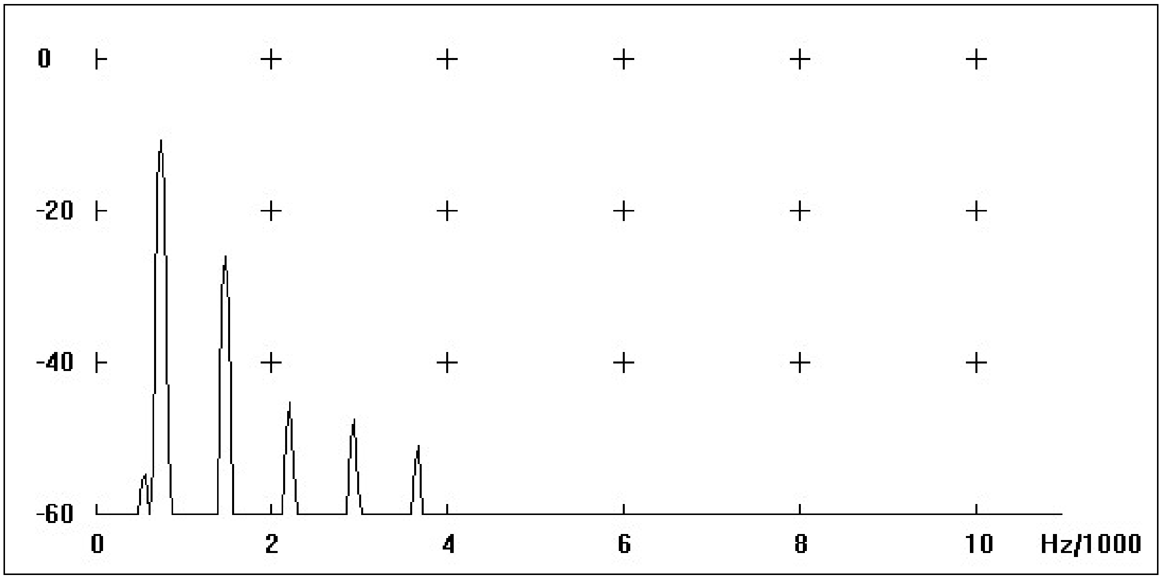
Power Spectrum from Spectrogram #2, Subject #7 at 2.91 seconds [i]



Power Spectrum from Spectrogram #2, Subject #7 at 4.56 seconds [ɛ]

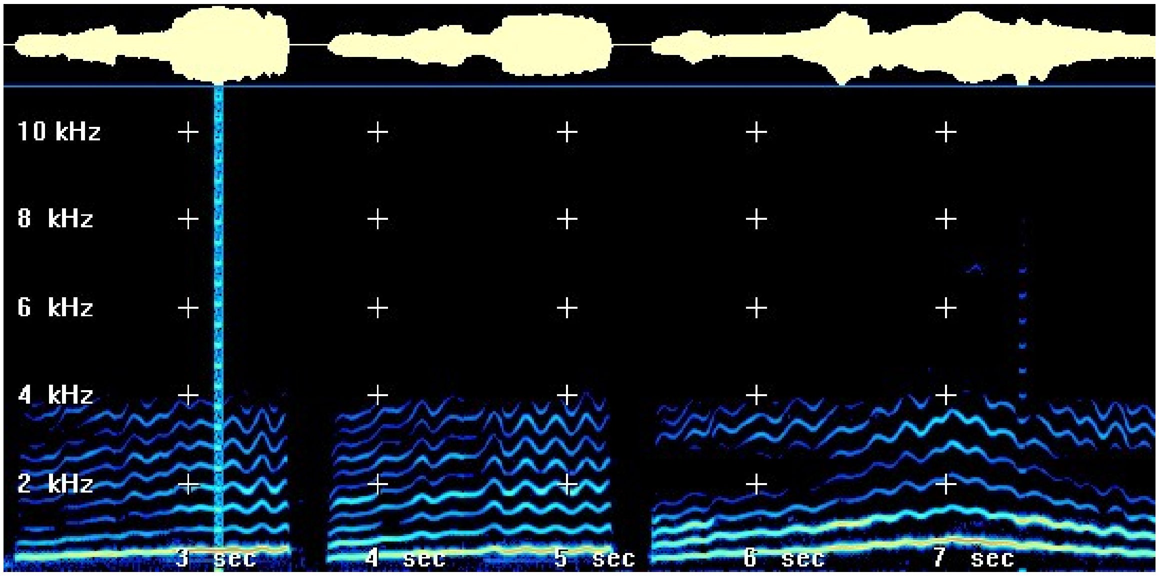


Power Spectrum from Spectrogram #2, Subject #7 at 6.95 seconds [a]



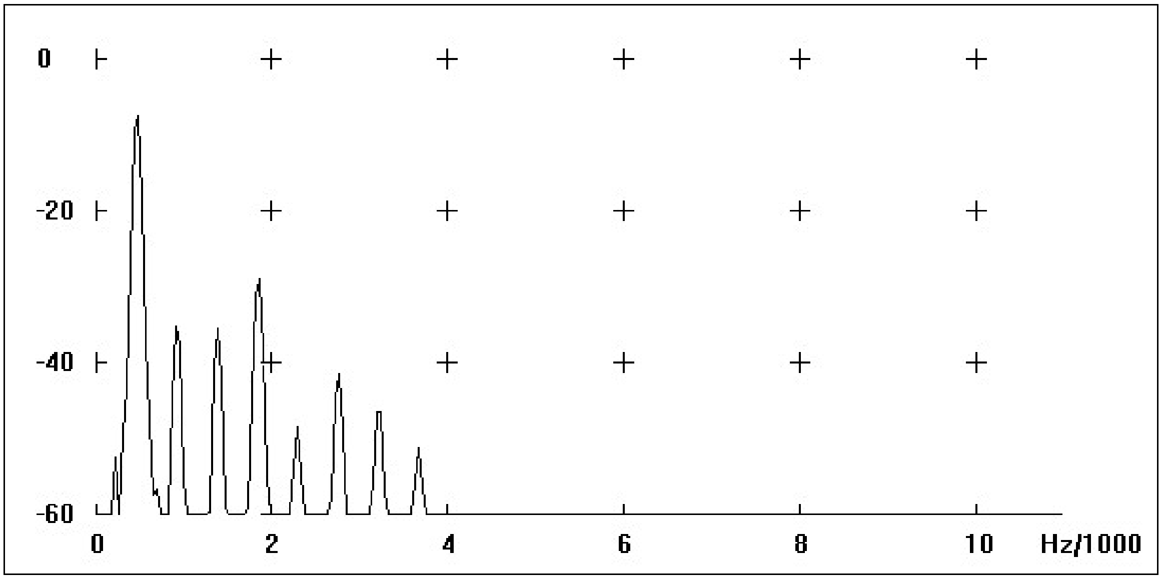
Analysis of Power Spectra from Spectrogram #2, Subject #7 – September 11, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.91	6	3	.5	4	10	.4	.45
4.56	4	3	.75	4	8	.5	.62
6.95	3	2	.66	3	6	.5	.58
Average of three chiaroscuro levels							.55

Wave File Number 3 – September 22 – Subject #7

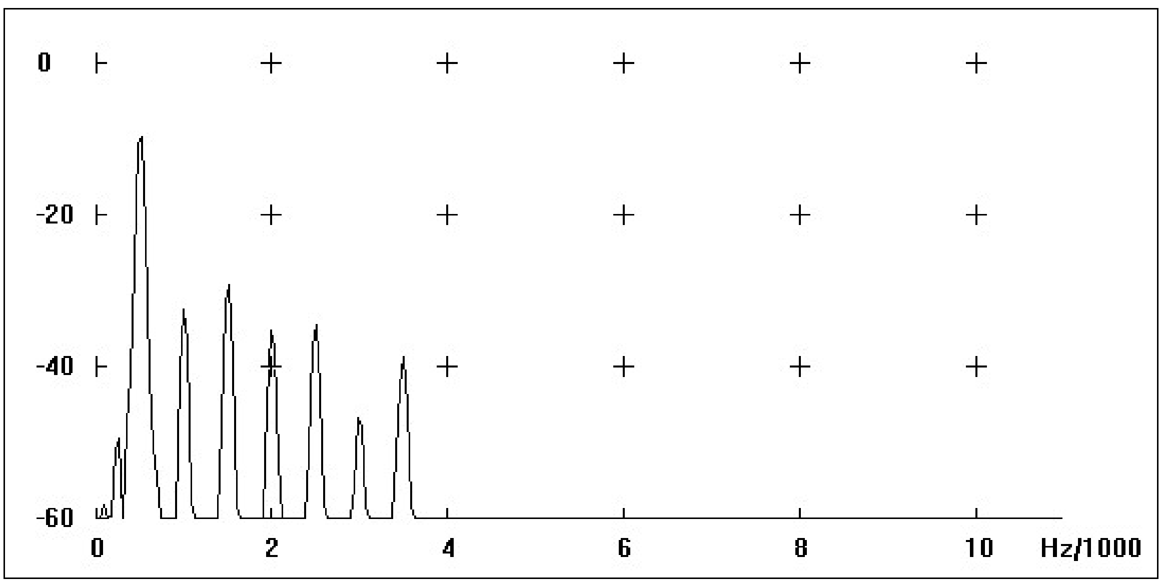


Subject #7 – Analysis of Wave File #3 – September 22, 2000 – E flat major				
		[si] (2.13-3.51 sec)	[ɛ] (3.74-5.22 sec)	[a] (5.45-9.72 sec)
Singer's Formant Area	4000+ Hz	Noise at 3.15 is not part of the voice – mike may have been bumped		Two indications – spike at 7.4 seems more controlled than spike in wave file #1
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong; improved consistency
2nd Formant Area (Vowel Definition)		Clear vowels	Clear vowels	Clear vowels
1st Formant Area		Strong	Strong	Strong
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Bumpy increase from about 25% to 100%	Bumpy increase from about 25% to about 90%	Bumpy increases from about 25% to about 90%
Each of the power spectra shows one or more sudden increases that match with an audible increase of air pressure. The voice otherwise seems even and consistent, although the vibrato is a little fast, reaching a rate of 8 cycles per second between 4.5 and 5.2 seconds. Average pleasant vibrato speed is usually between 5.5-7.5 cycles per second.				

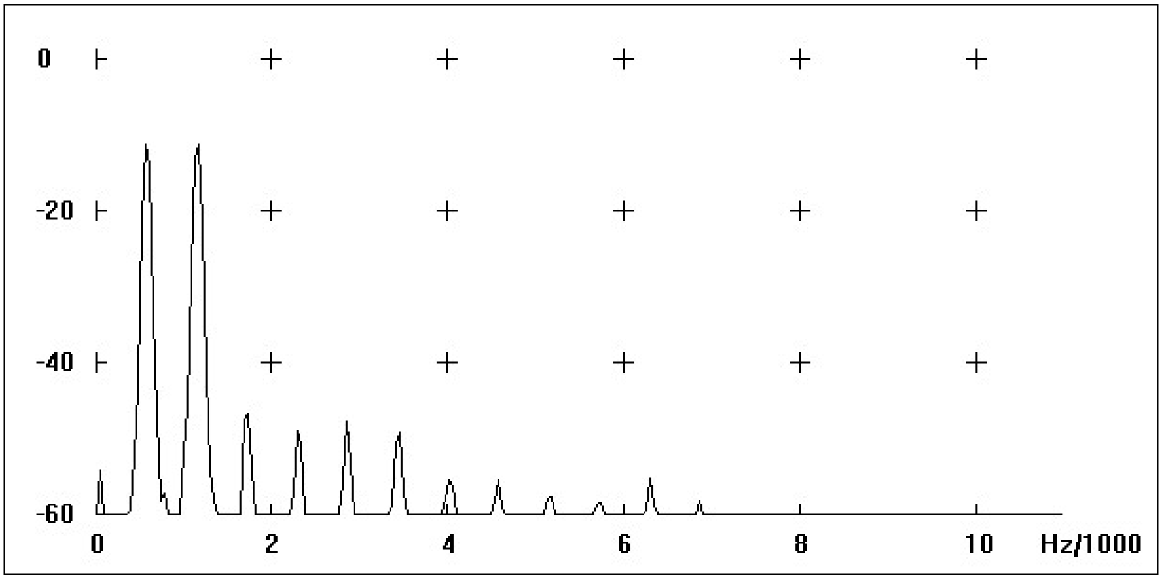
Power Spectrum from Spectrogram #3, Subject #7 at 3.3 seconds [i]



Power Spectrum from Spectrogram #3, Subject #7 at 4.78 seconds [ε]

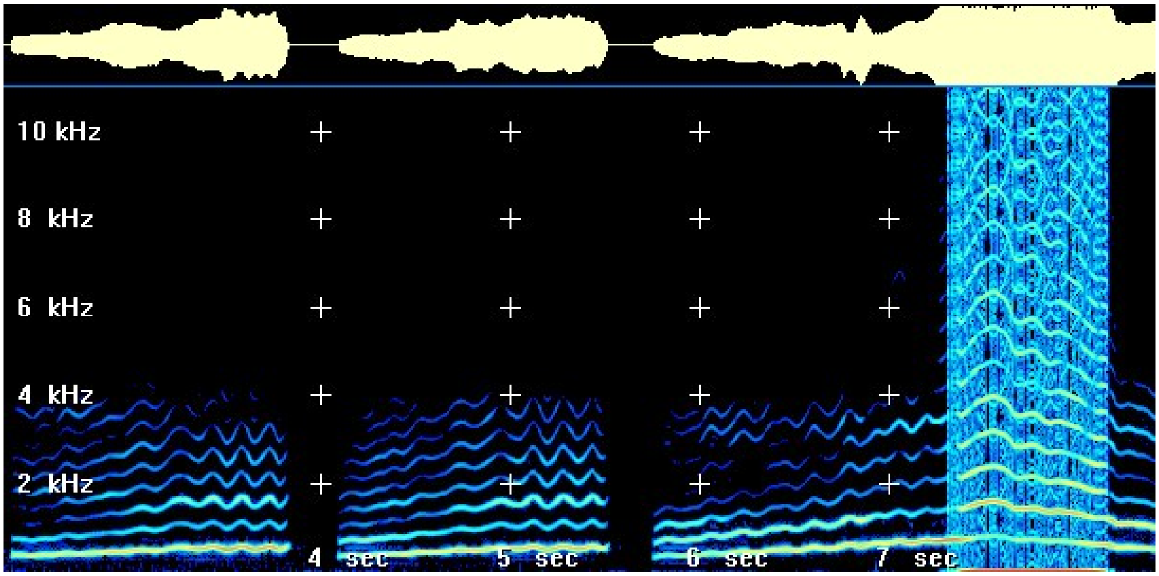


Power Spectrum from Spectrogram #3, Subject #7 at 7.4 seconds [a]



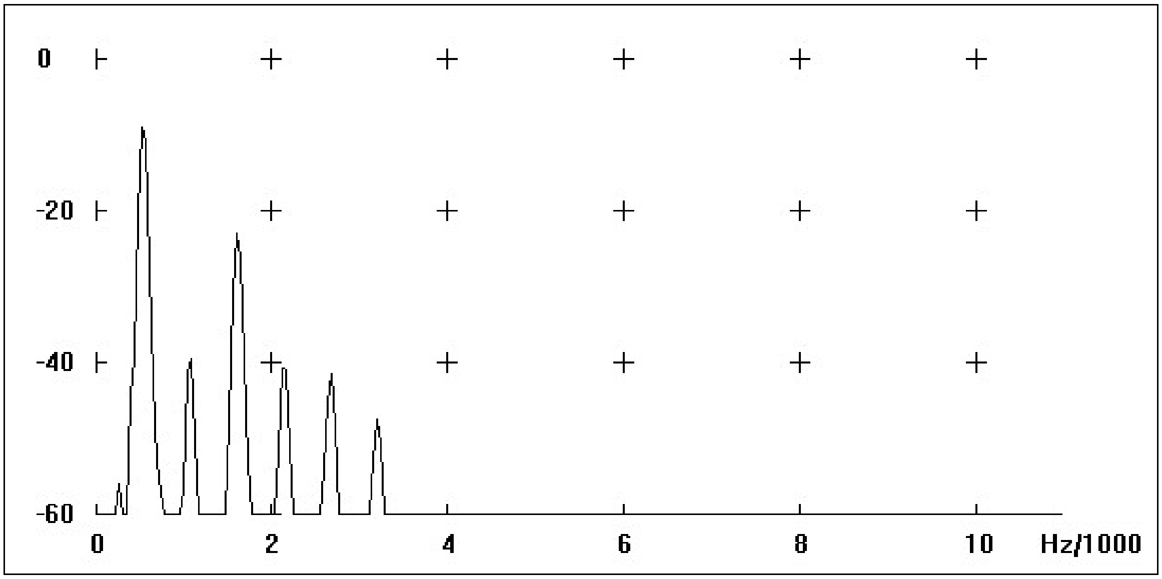
Analysis of Power Spectra from Spectrogram #3, Subject #7 – September 22, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.3	5	4	.8	4	9	.44	.62
4.78	5	3	.6	4	9	.44	.52
7.4	5	2	.4	9	14	.64	.52
Average of three chiaroscuro levels							.55

Wave File Number 4 – September 29, 2000 – Subject #7

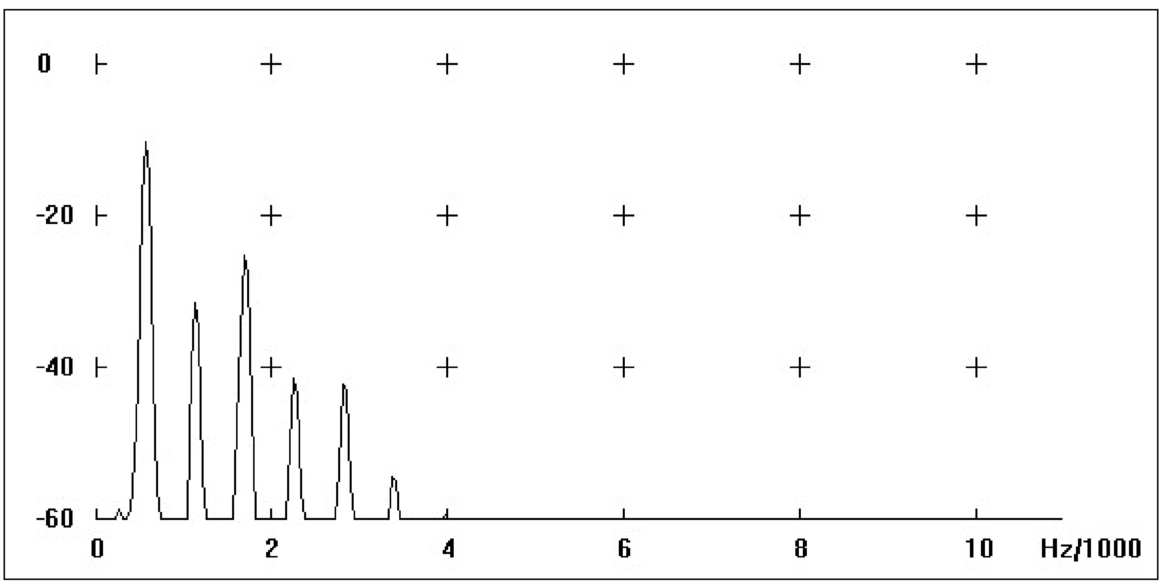


<table>
<tr><td colspan="5">Subject #7 – Analysis of Wave File #4 – September 29, 2000 – F major</td></tr>
<tr><td colspan="2"></td><td>[si] (2.37-3.81 sec)</td><td>[ɛ] (4.07-5.49 sec)</td><td>[a] (5.76-10.04 sec)</td></tr>
<tr><td rowspan="2">Singer’s Formant Area</td><td>4000+ Hz</td><td></td><td></td><td>Large band of noise caused by voice peaking the microphone</td></tr>
<tr><td>2000-4000 Hz</td><td>Strong and consistent</td><td>Strong and consistent</td><td>Strong and consistent</td></tr>
<tr><td colspan="2">2nd Formant Area (Vowel Definition)</td><td>Clear vowels</td><td>Clear vowels</td><td>Clear vowels</td></tr>
<tr><td colspan="2">1st Formant Area</td><td>Strong</td><td>Strong</td><td>Strong</td></tr>
<tr><td colspan="2">Chiaroscuro Balance</td><td>Well balanced</td><td>Well balanced</td><td>Nearly balanced</td></tr>
<tr><td colspan="2">Power Spectrum</td><td>Increase from about 20% to about 80%</td><td>Increase from about 20% to about 80%</td><td>Increase from about 20% to about 80% with peak to 100%</td></tr>
<tr><td colspan="5">The limitations of the equipment used in this data gathering process are evident here. A large voice that tends to push the top has in this case peaked the microphone. The spectrograph is recording vibrations from the metal mike in addition to those of the voice. The result is noise as seen in the third power spectrum below.</td></tr>
</table>

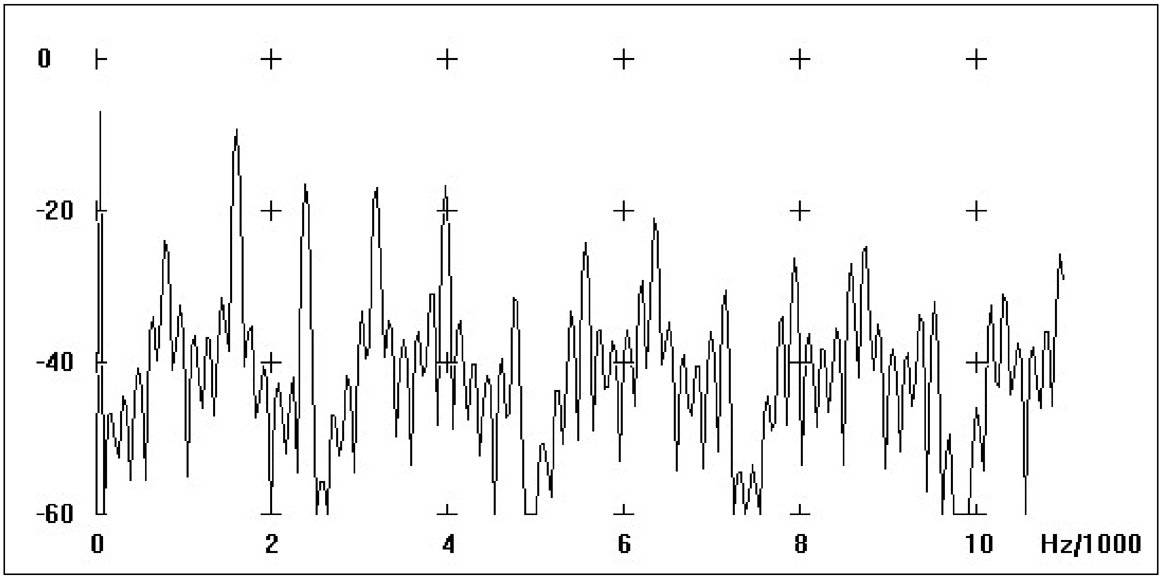
Power Spectrum from Spectrogram #4, Subject #7 at 3.47 seconds [i]



Power Spectrum from Spectrogram #4, Subject #7 at 5.3 seconds [ε]

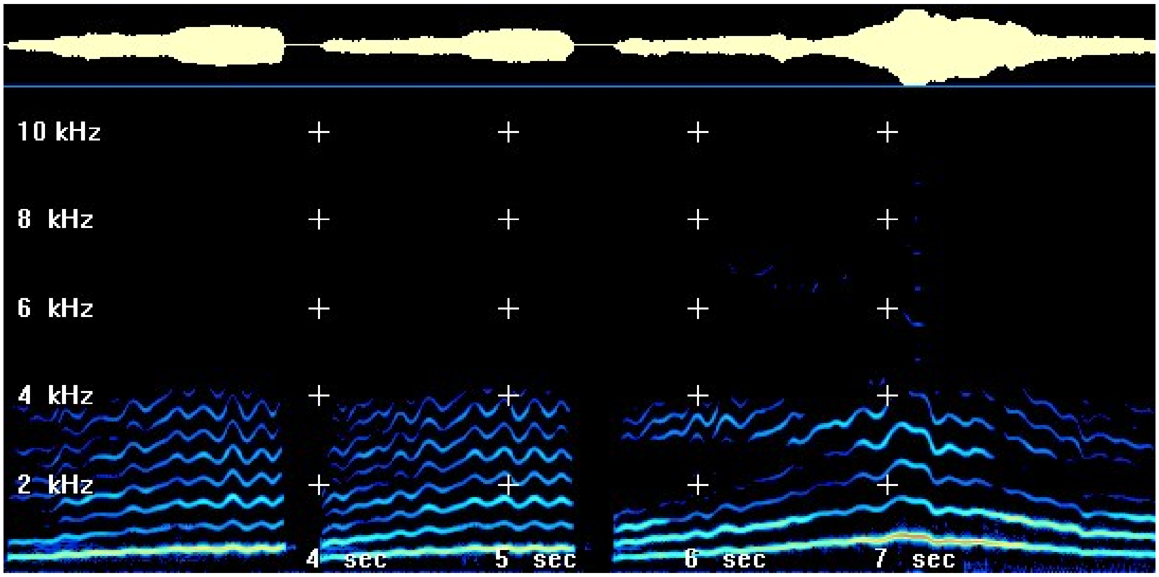


Power Spectrum from Spectrogram #4, Subject #7 at 7.55 seconds [a]



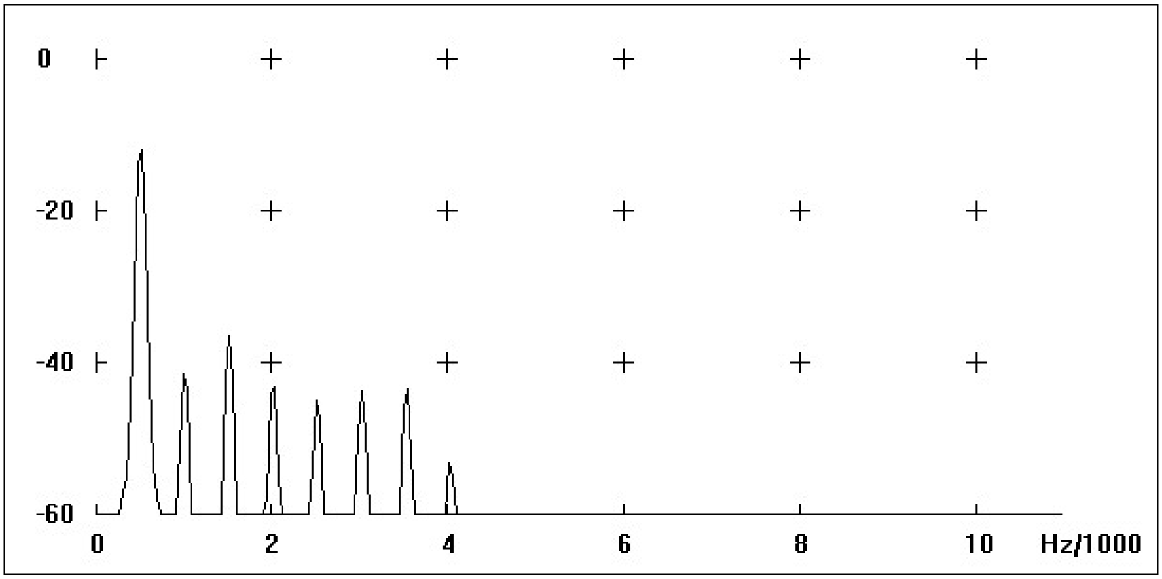
Analysis of Power Spectra from Spectrogram #4, Subject #7 – September 29, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.47	4	3	.75	3	7	.42	.58
5.3	4	3	.75	3	7	.42	.58
7.55	Recording data from less than the “best” section of this vowel would skew the average, as would recording data from the “peaked” microphone.						
Average of two chiaroscuro levels							.58

Wave File Number 5 – October 9, 2000 – Subject #7

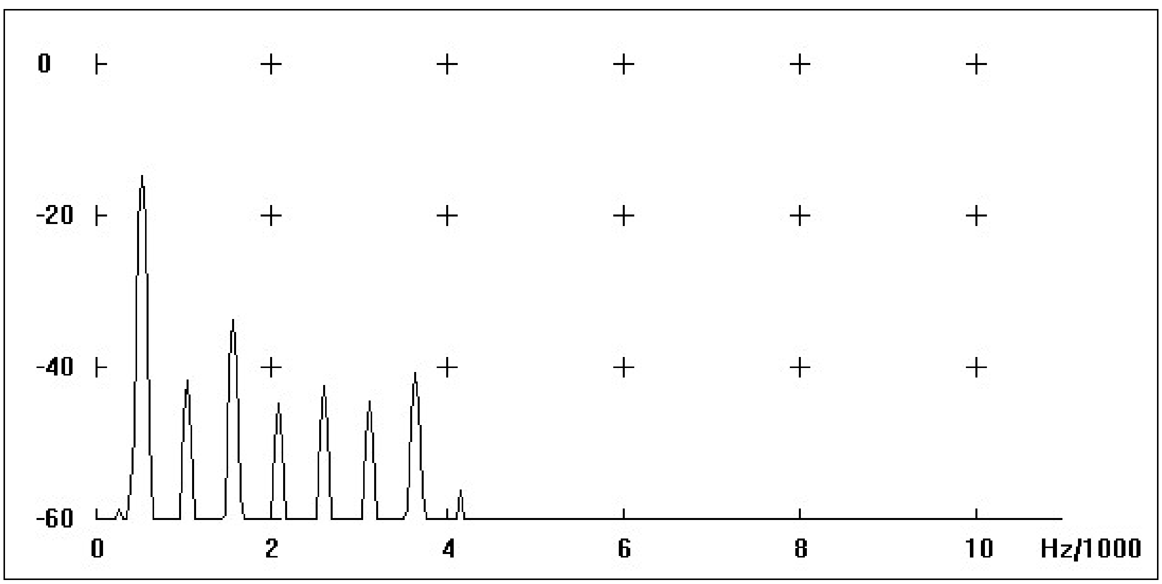


Subject #7 – Analysis of Wave File #5 – October 9, 2000 – F major				
		[si] (2.37-3.81 sec)	[ɛ] (4.03-5.34 sec)	[a] (5.57-9.51 sec)
Singer's Formant Area	4000+ Hz			Scattered indications
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong	Strong	Strong
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Increases from about 10% to about 60%	Increases from about 10% to about 40%	Varying around 20% with increase to 90% at highest pitches
Chiaroscuro balance is quite good, but tension issues obscure the beauty of the voice.				

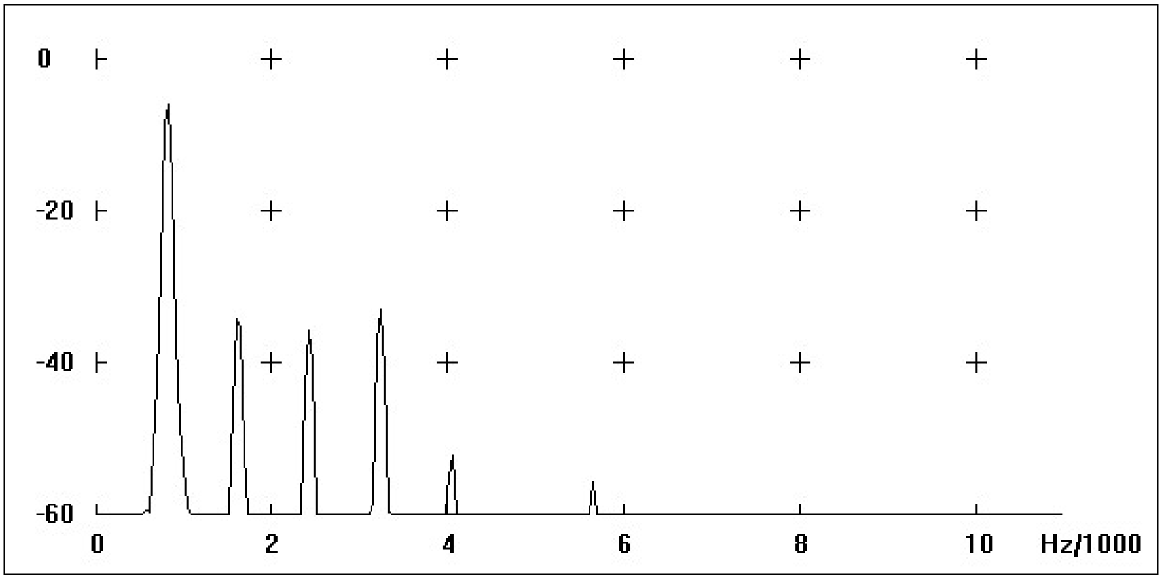
Power Spectrum from Spectrogram #5, Subject #7 at 3.46 seconds [i]



Power Spectrum from Spectrogram #5, Subject #7 at 4.88 seconds [ɛ]

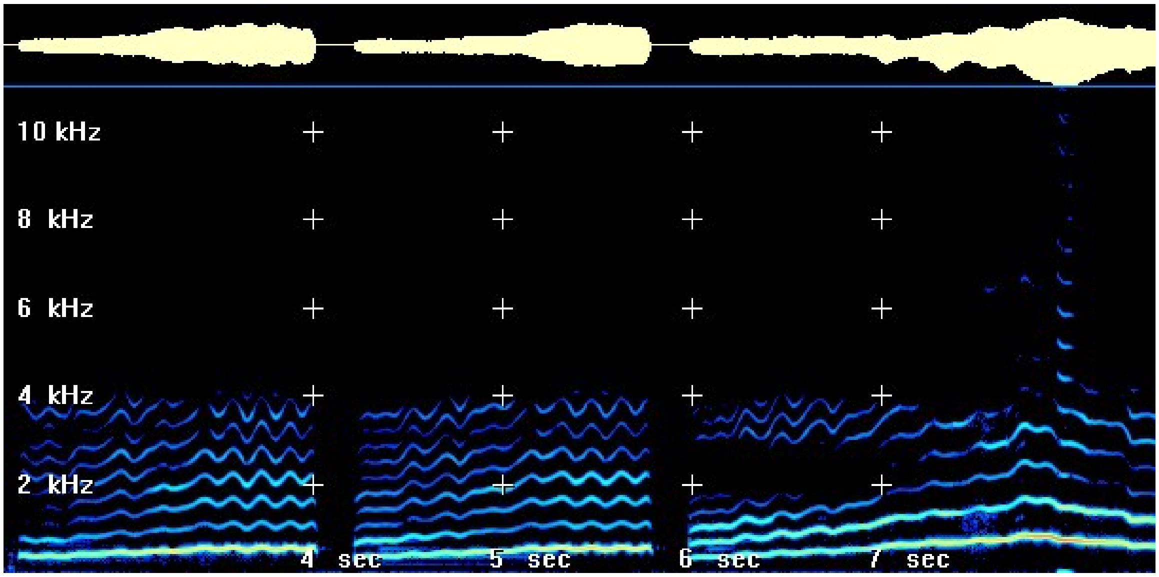


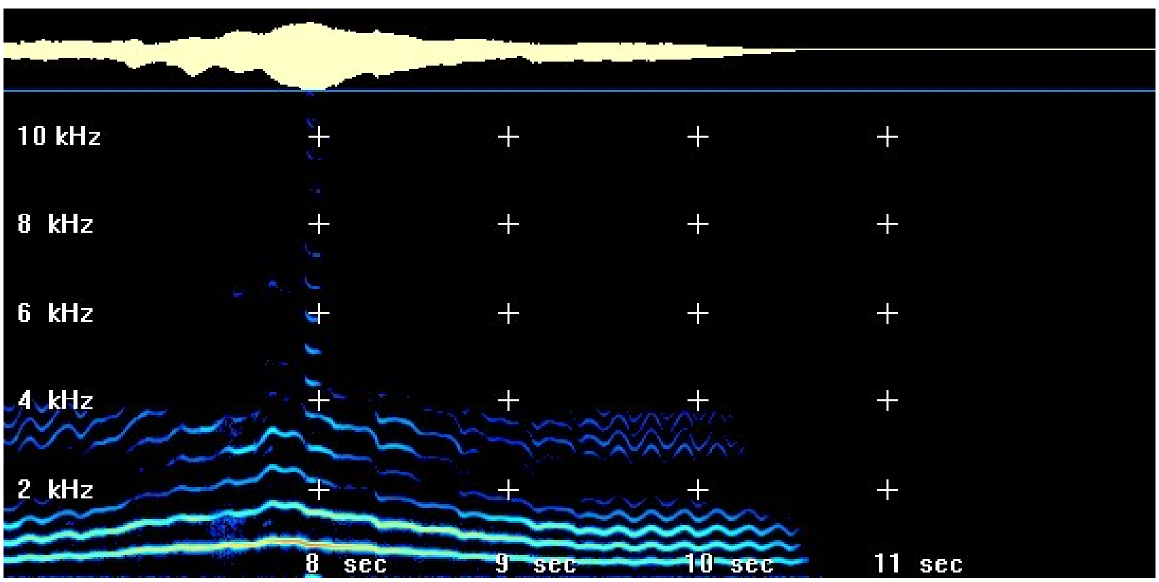
Power Spectrum from Spectrogram #5, Subject #7 at 7.15 seconds [a]



Analysis of Power Spectra from Spectrogram #5, Subject #7 – October 9, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.46	3	3	1.0	5	8	.62	.81
4.88	4	3	.75	5	9	.55	.65
7.15	2	2	1.0	4	6	.66	.83
Average of three chiaroscuro levels							.76

Wave File Number 6 – October 13, 2000 – Subject #7

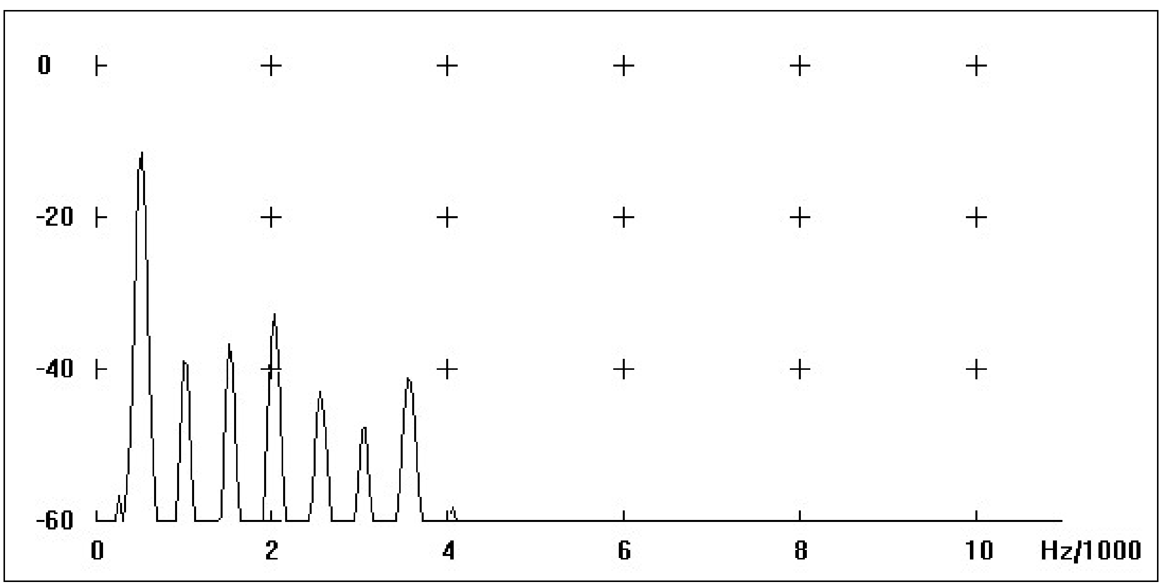




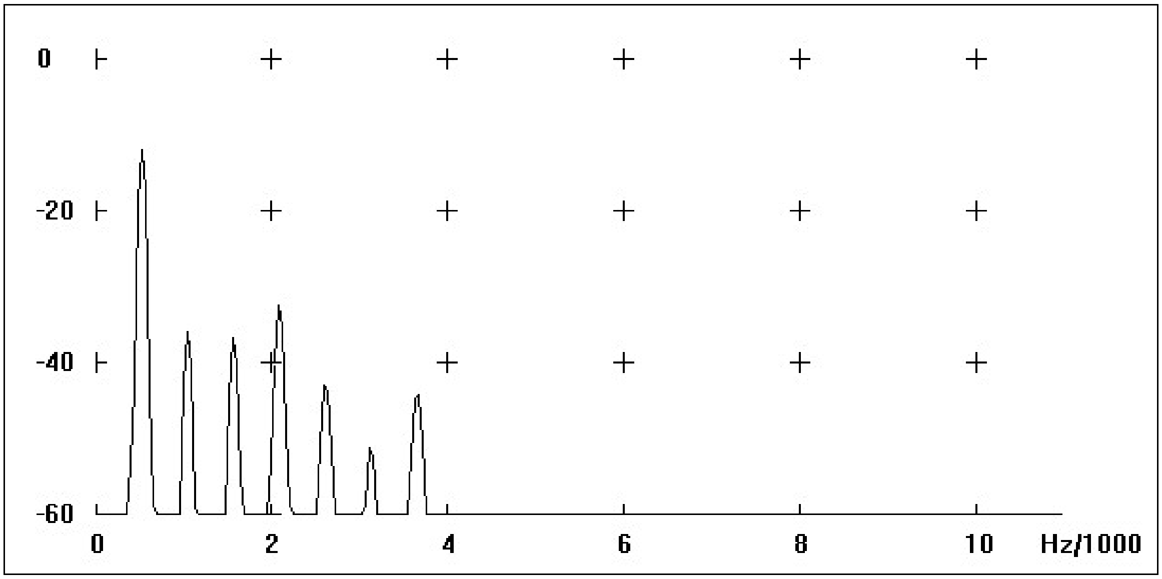
<table>
<tr><td colspan="5">Subject #7 – Analysis of Wave File #6 – October 13, 2000 – F major</td></tr>
<tr><td colspan="2"></td><td>[si] (2.46-4.02 sec)</td><td>[ɛ] (4.24-5.76 sec)</td><td>[a] (5.96-10.5 sec)</td></tr>
<tr><td rowspan="2">Singer's Formant Area</td><td>4000+ Hz</td><td></td><td></td><td>Spike results from an audible sudden increase of air pressure</td></tr>
<tr><td>2000-4000 Hz</td><td>Strong and consistent</td><td>Strong and consistent</td><td>Strong and consistent</td></tr>
</table>

Subject #7 – Analysis of Wave File #6 – October 13, 2000 – F major			
	[si] (2.46-4.02 sec)	[ɛ] (4.24-5.76 sec)	[a] (5.96-10.5 sec)
2nd Formant Area (Vowel Definition)	Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area	Strong with extra effort made at the end	Strong with extra effort made at the end	Strong with extra effort made at the highest pitches
Chiaroscuro Balance	Well balanced	Well balanced	Nearly balanced
Power Spectrum	Increase from about 10% to about 30%	Increase from about 10% to about 30%	<> from about 20% to about 90%
In the [i] and [ɛ] vowels the singer is adding extra pressure at the end of each exercise. Note the weight added to the first formant area and the increase in vibrato. In the [a] vowel the extra pressure is added at the high notes. In all three cases the singer would do better to force the voice less and allow a more natural production. At the end of the [a] vowel (second wave file picture) one can see the audible difference at the end of the exercise. If extra sound actually were required, equalizing additional air pressure with additional resonation probably would be the better solution.			

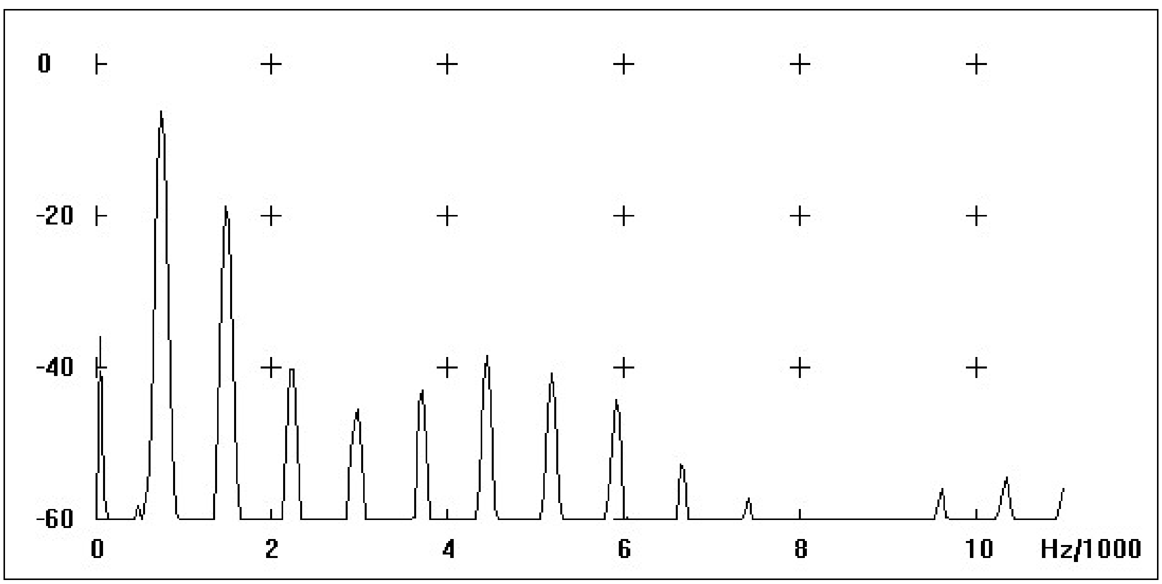
Power Spectrum from Spectrogram #6, Subject #7 at 3.64 seconds [i]



Power Spectrum from Spectrogram #6, Subject #7 at 5.38 seconds [ɛ]

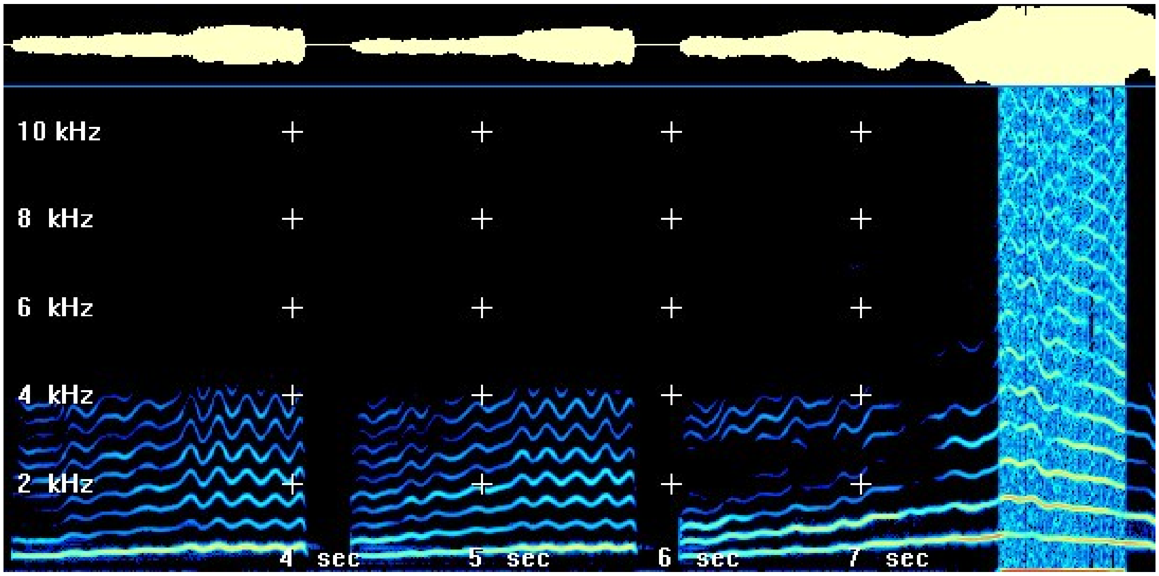


Power Spectrum from Spectrogram #6, Subject #7 at 7.96 seconds [a]



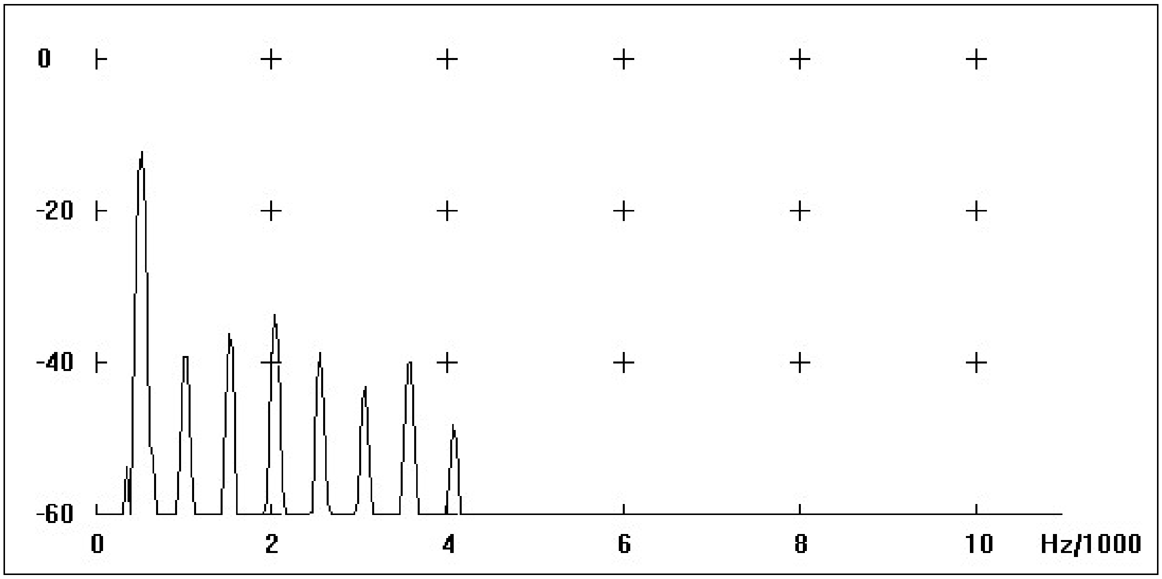
Analysis of Power Spectra from Spectrogram #6, Subject #7 – October 13, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.64	4	3	.75	5	9	.55	.65
5.38	3	3	1.0	4	7	.57	.78
7.96	4	3	.75	11	15	.73	.74
Average of three chiaroscuro levels							.72

Wave File Number 7 – October 16, 2000 – Subject #7

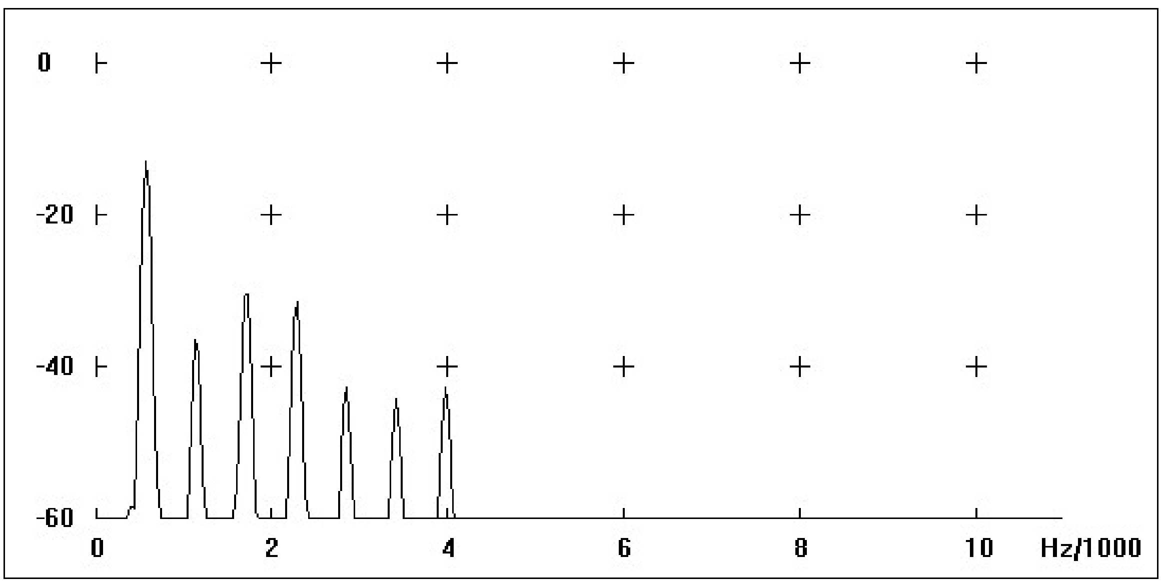


Subject #7 – Analysis of Wave File #7 – October 16, 2000 – F major				
		[si] (2.54-4.05 sec)	[ɛ] (4.3-5.79 sec)	[a] (6.06-10.4 sec)
Singer's Formant Area	4000+ Hz			Scattering of indications – spike is again because of limitations of equipment
	2000-4000 Hz	Strong and consistent	Strong and consistent	Nearly consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong	Strong	Strong
Chiaroscuro Balance		Well balanced	Well balances	Nearly balanced
Power Spectrum		Increase from about 10% to about 30%	Increase from about 10% to about 30%	Varying around 30% until peak
The voice is functioning well in spite of the tendency to push the top. The equipment was not equal to the force applied in the [a] vowel, and the microphone peaked.				

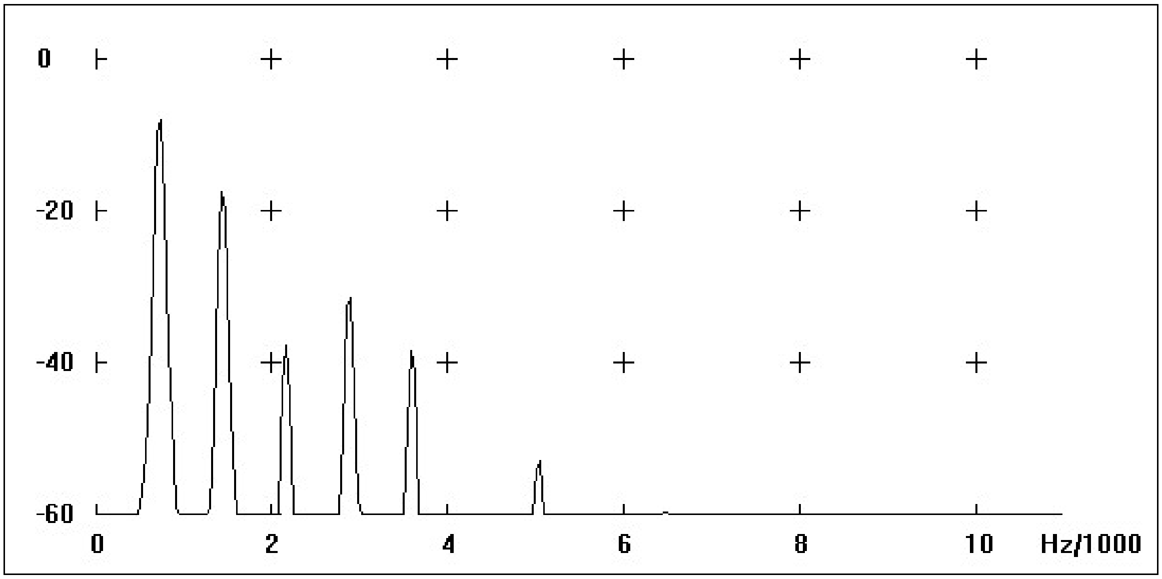
Power Spectrum from Spectrogram #7, Subject #7 at 3.68 seconds [i]



Power Spectrum from Spectrogram #7, Subject #7 at 5.66 seconds [ɛ]

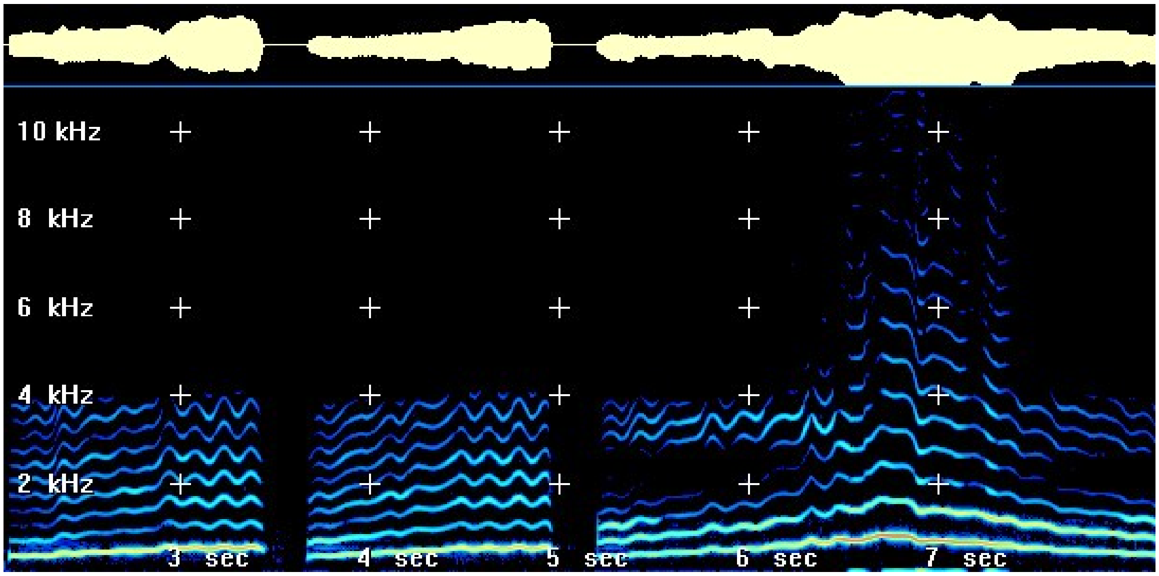


Power Spectrum from Spectrogram #7, Subject #7 at 7.59 seconds [a]



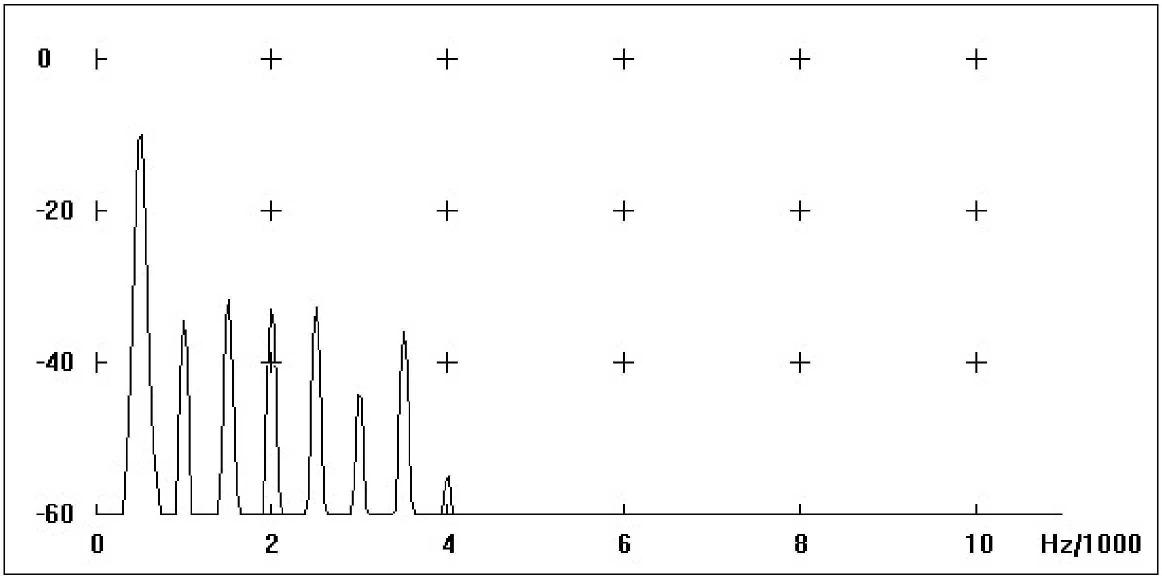
Analysis of Power Spectra from Spectrogram #7, Subject #7 – October 16, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.68	4	3	.75	5	9	.55	.65
5.66	3	3	1.0	4	7	.57	.78
7.59	2	2	1.0	5	7	.71	.85
Average of three chiaroscuro levels							.76

Wave File Number 8 – October 25, 2000 – Subject #7

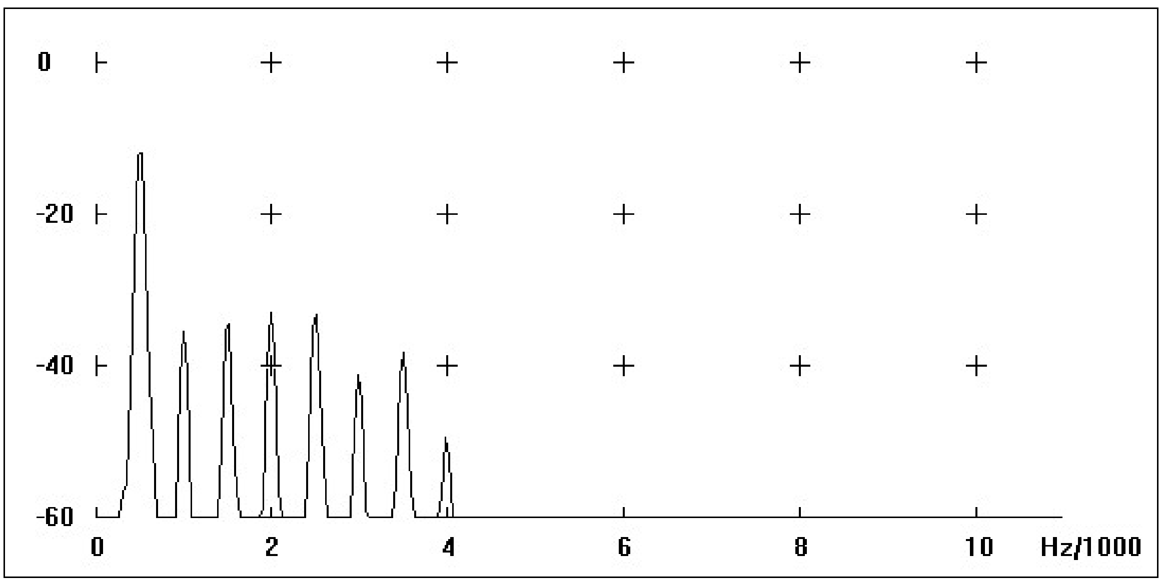


Subject #7 – Analysis of Wave File #8 – October 25, 2000 – F major				
		[si] (sec)	[ɛ] (3.69-4.96 sec)	[a] (5.22-9.38 sec)
Singer's Formant Area	4000+ Hz			Gradual addition of high frequencies at high pitches
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent with additional strength for highest pitches
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Increase from about 30% to about 80%	Increase from about 20% to about 70%	Varying around 30% with increase to 100% at highest pitches
This is a picture of the skillful increase of both the strength of the first formant area and the upper frequencies for the kind of high note that singers strive to achieve. Note the more relaxed vibrato as the singer has found better ways than forcing to enter the top of her voice.				

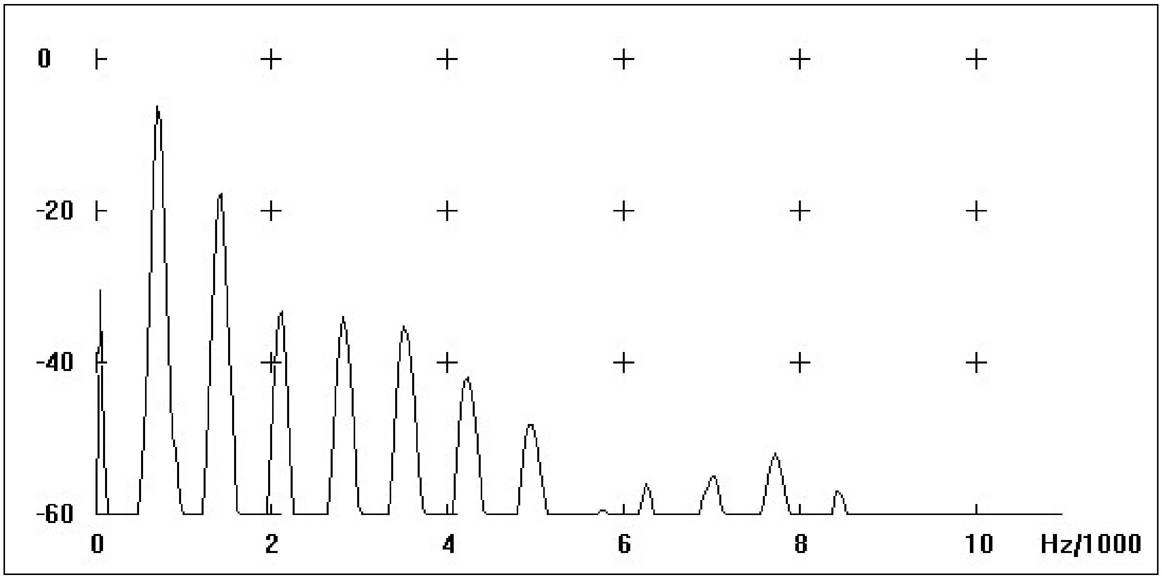
Power Spectrum from Spectrogram #8, Subject #7 at 3.15 seconds [i]



Power Spectrum from Spectrogram #8, Subject #7 at 4.7 seconds [ɛ]

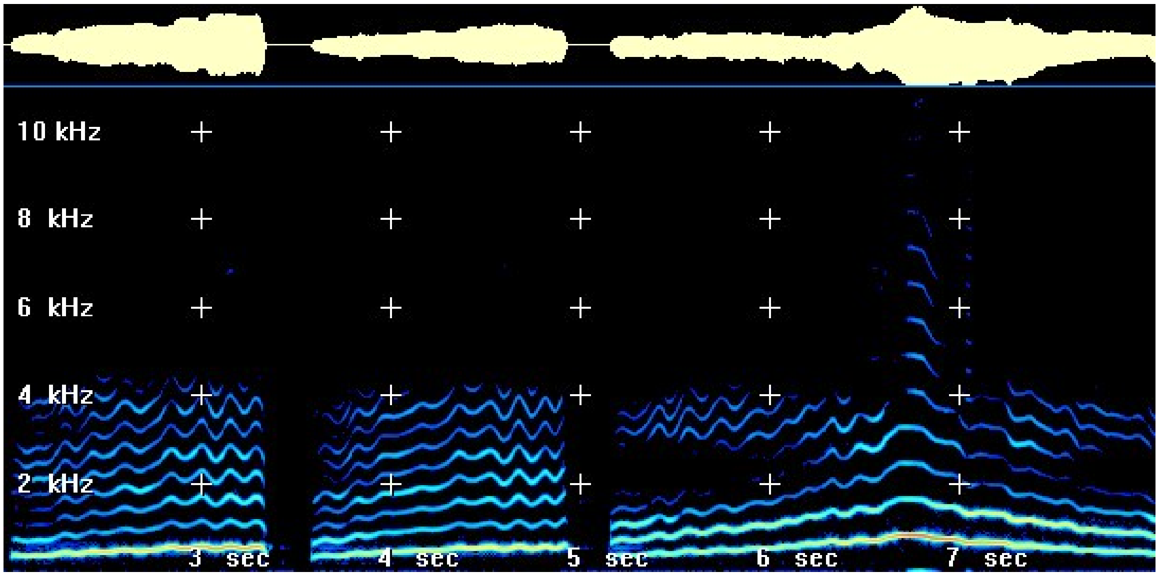


Power Spectrum from Spectrogram #8, Subject #7 at 6.9 seconds [a]



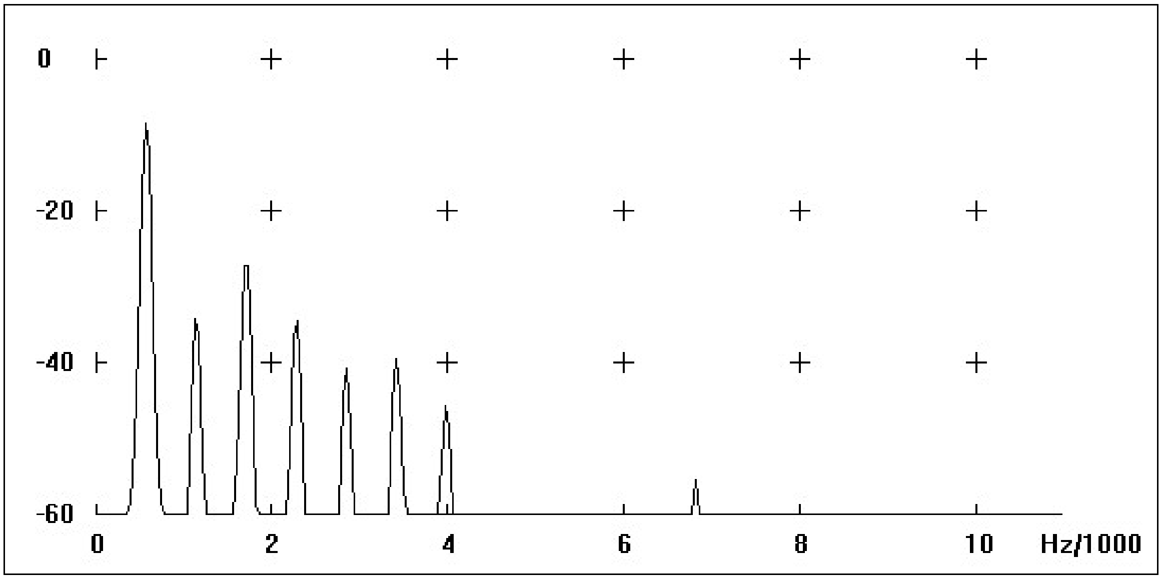
Analysis of Power Spectra from spectrogram #8, Subject #7 – October 25, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.15	3	3	1.0	5	8	.62	.81
4.7	3	3	1.0	5	8	.62	.81
6.9	3	3	1.0	10	13	.76	.88
Average of three chiaroscuro levels							.83

Wave File Number 9 – November 6, 2000 – Subject #7

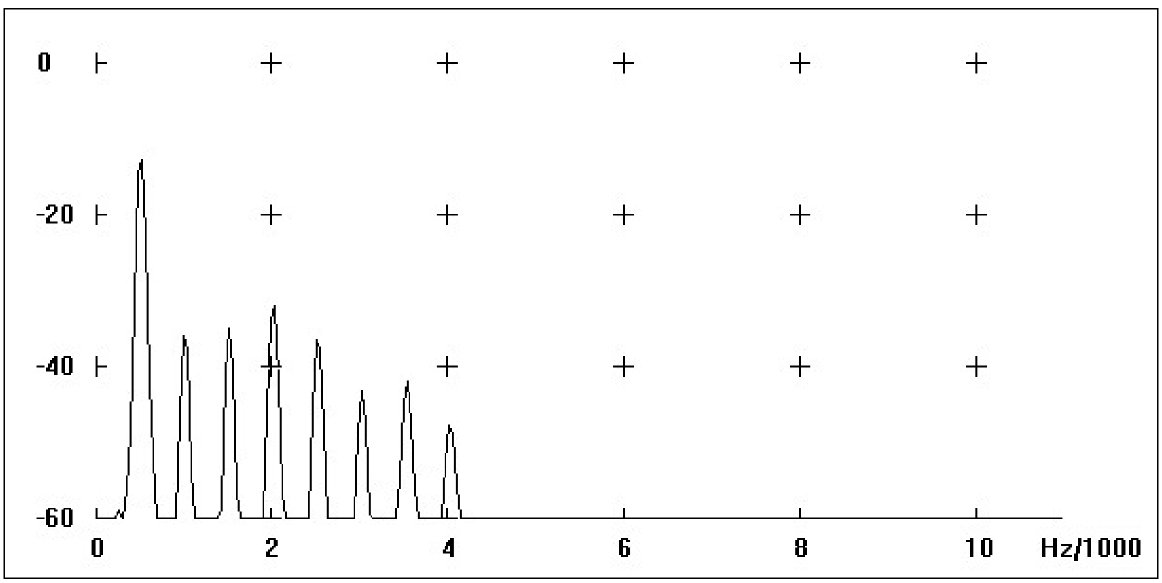


Subject #7 – Analysis of Wave File #9 – November 6, 2000 – F major				
		[si] (2.0-3.33 sec)	[ɛ] (3.6-4.93 sec)	[a] (5.16-9.38 sec)
Singer's Formant Area	4000+ Hz			Conscious addition of high frequencies at high pitches
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Strong and consistent	Strong and consistent
1st Formant Area		Strong	Strong	Strong
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced though not as consistent as in wave file #8
Power Spectrum		Increase from about 20% to about 80%	Increase from about 20% to about 40%	Varying around 30% with increase to 100%
The [a] vowel is not quite as controlled as in wave file #8, but still shows a balanced increase of low and high frequencies.				

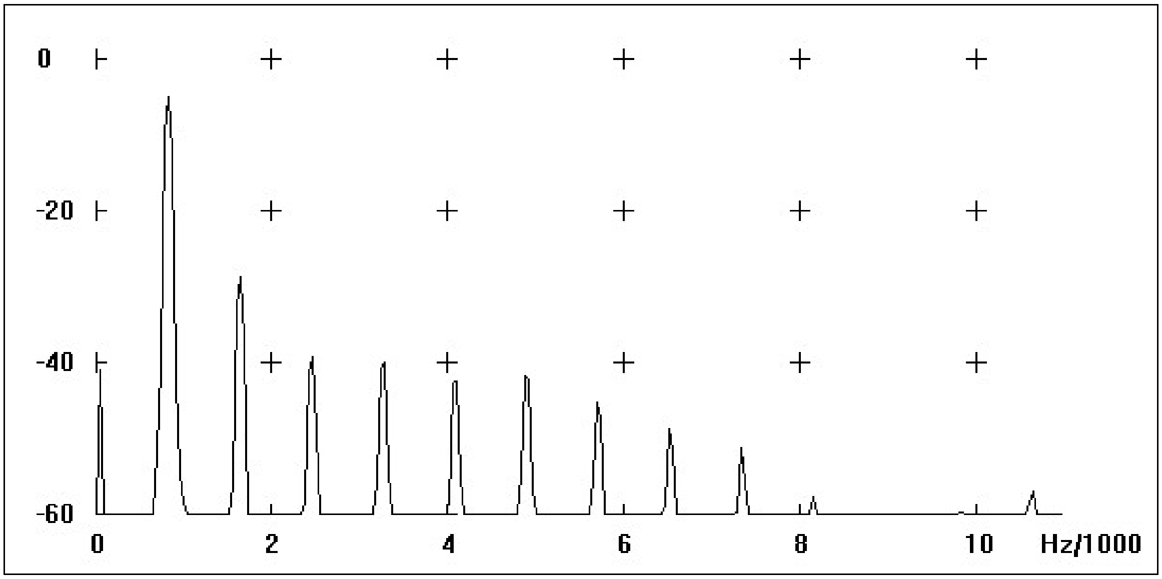
Power Spectrum from Spectrogram #9, Subject #7 at 3.15 seconds [i]



Power Spectrum from Spectrogram #9, Subject #7 at 4.59 seconds [ɛ]

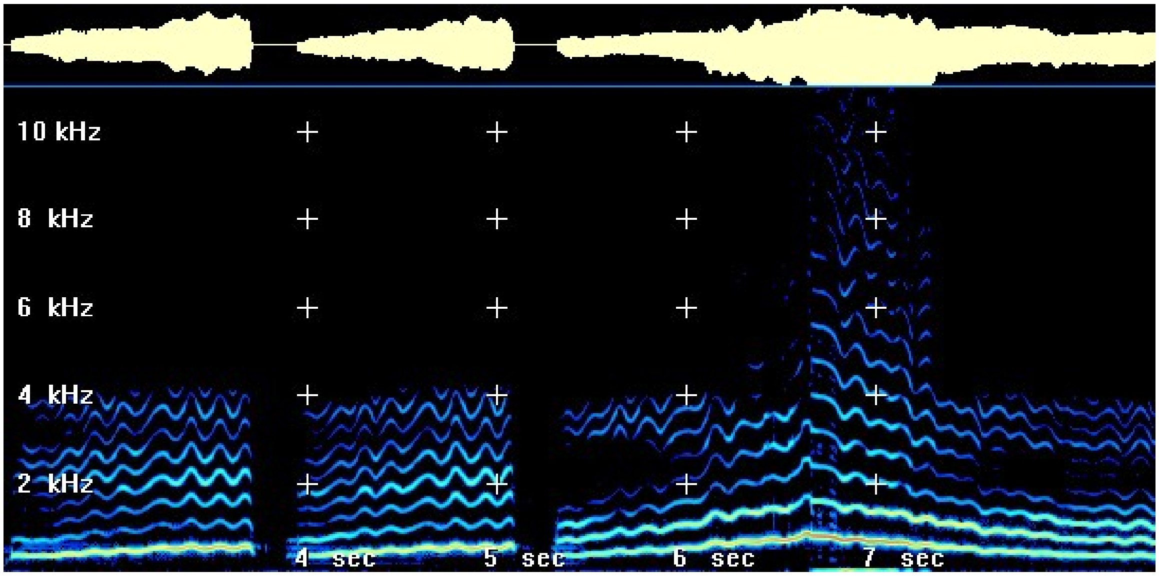


Power Spectrum from Spectrogram #9, Subject #7 at 6.79 seconds [a]



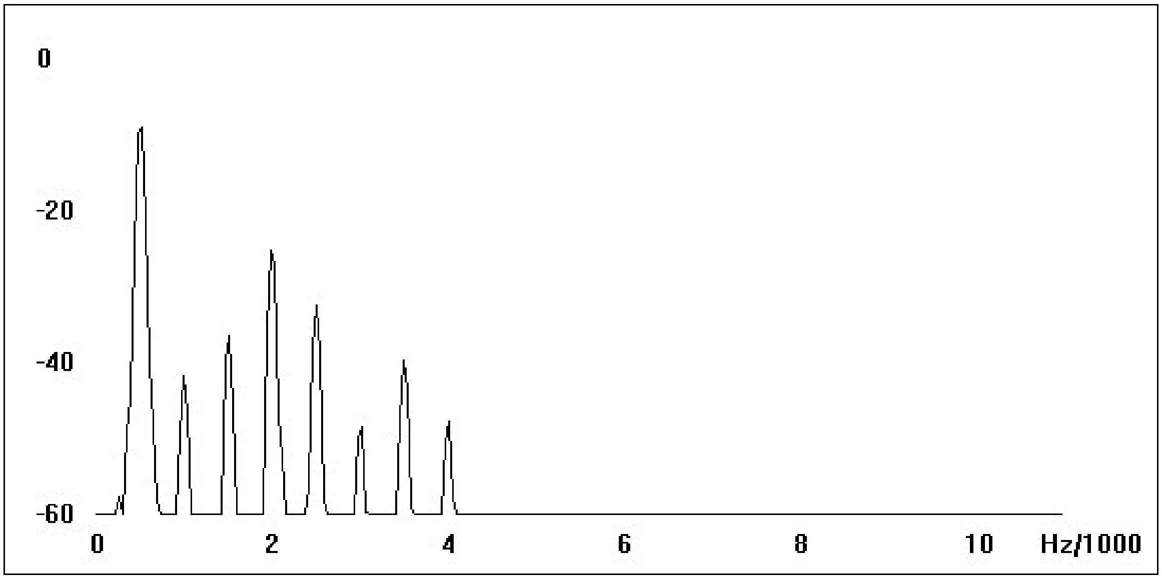
Analysis of Power Spectra from Spectrogram #9, Subject #7 – November 6, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.15	3	3	1.0	5	8	.62	.81
4.59	4	3	.75	5	9	.55	.65
6.79	3	3	1.0	10	13	.76	.88
Average of three chiaroscuro levels							.78

Wave File Number 10 – November 10, 2000 – Subject #7

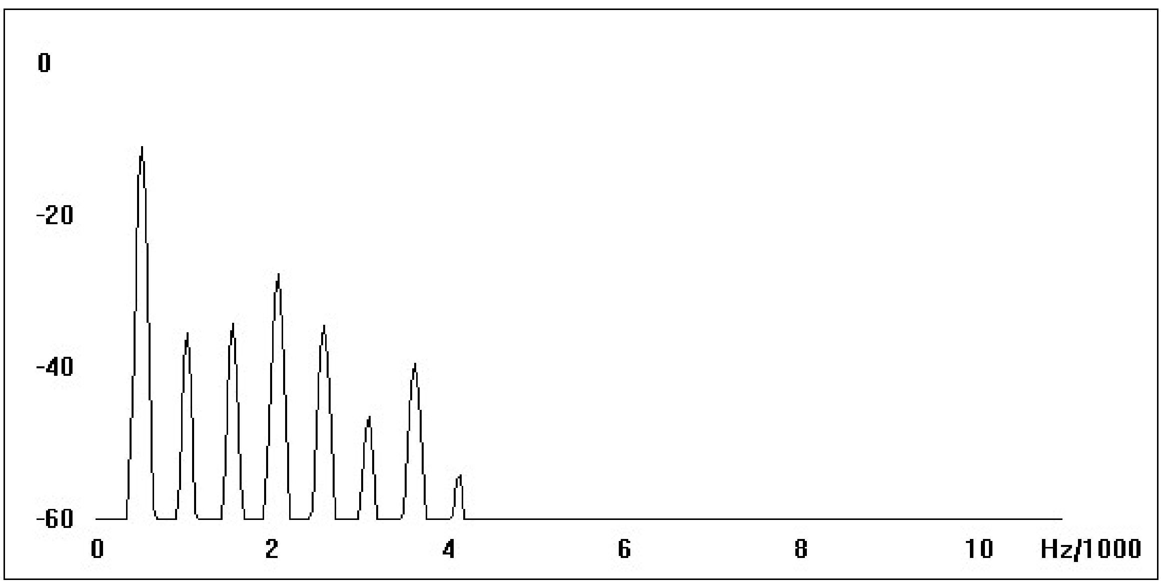


Subject #7 – Analysis of Wave File #10 – November 10, 2000 – F major				
		[si] (2.45-3.7 sec)	[ɛ] (3.98-5.07 sec)	[a] (5.31-8.87 sec)
Singer's Formant Area	4000+ Hz			Addition of high frequencies at high pitches
	2000-4000 Hz	Strong and consistent	Strong and consistent	Strong and consistent
2nd Formant Area (Vowel Definition)		Clear vowel formation	Clear vowel formation	Clear vowel formation
1st Formant Area		Strong and consistent	Strong and consistent	Strong with extra strength at high pitches
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Increase from about 205 to about 80%	Increase from about 20% to about 75%	<> from about 20% to 100%
The [a] vowel in wave file #8 showed a more gradual increase into the high frequencies, but except for that detail, this wave file also shows a skillful increase of both high and low frequencies to achieve a good high note.				

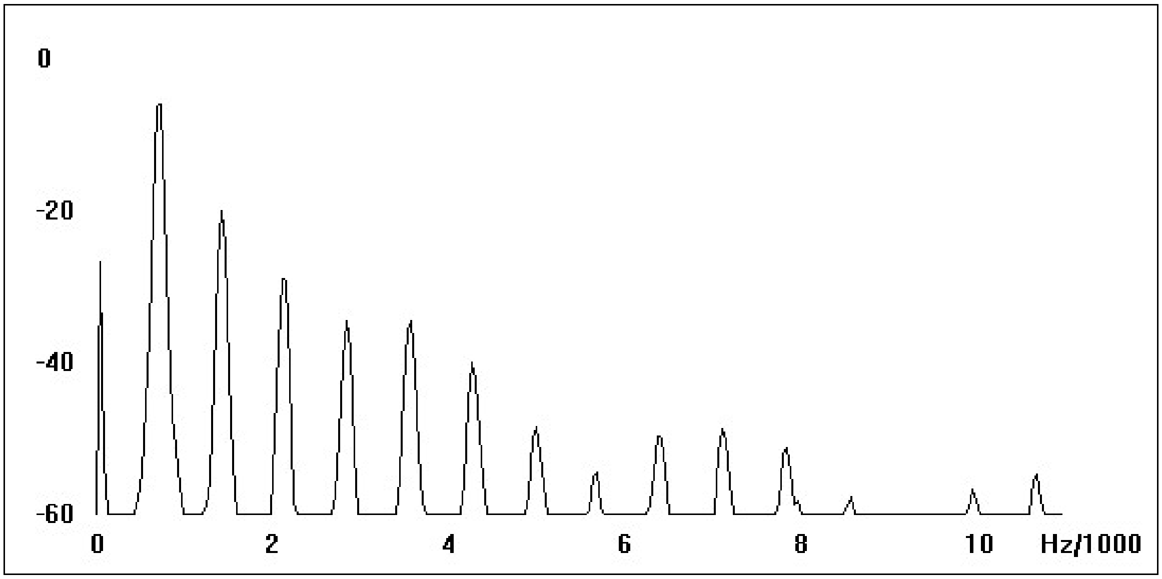
Power Spectrum from Spectrogram #10, Subject #7 at 3.47 seconds [i]



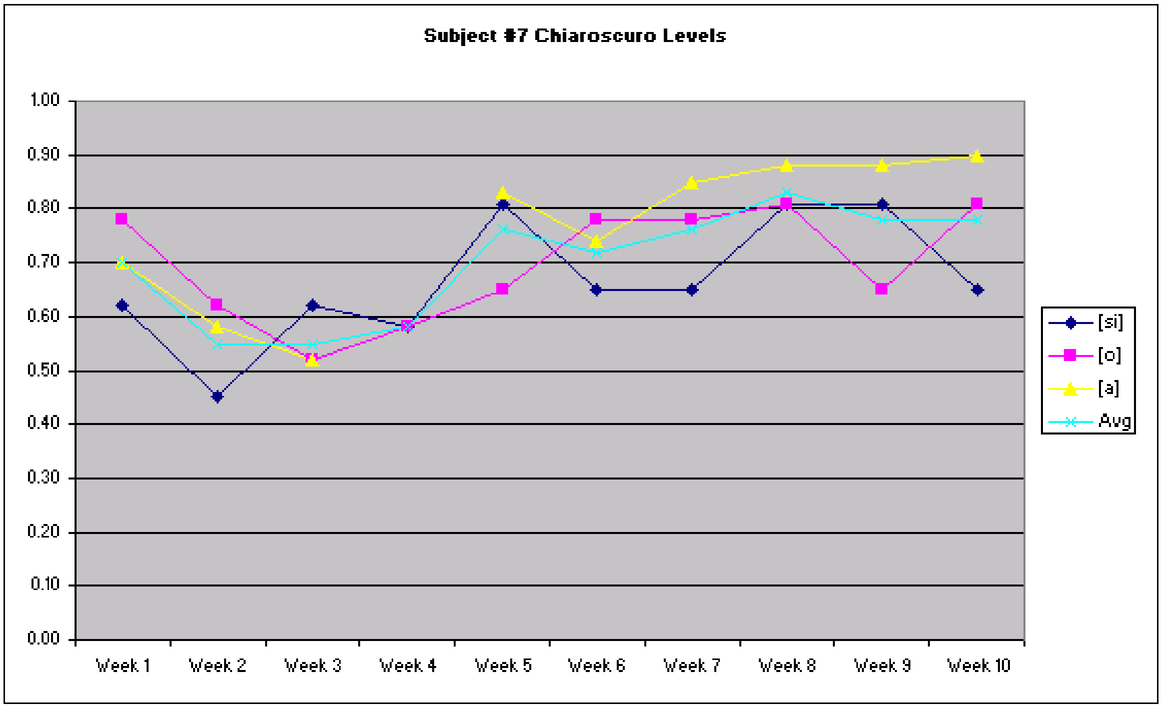
Power Spectrum from Spectrogram #10, Subject #7 at 4.85 seconds [o]

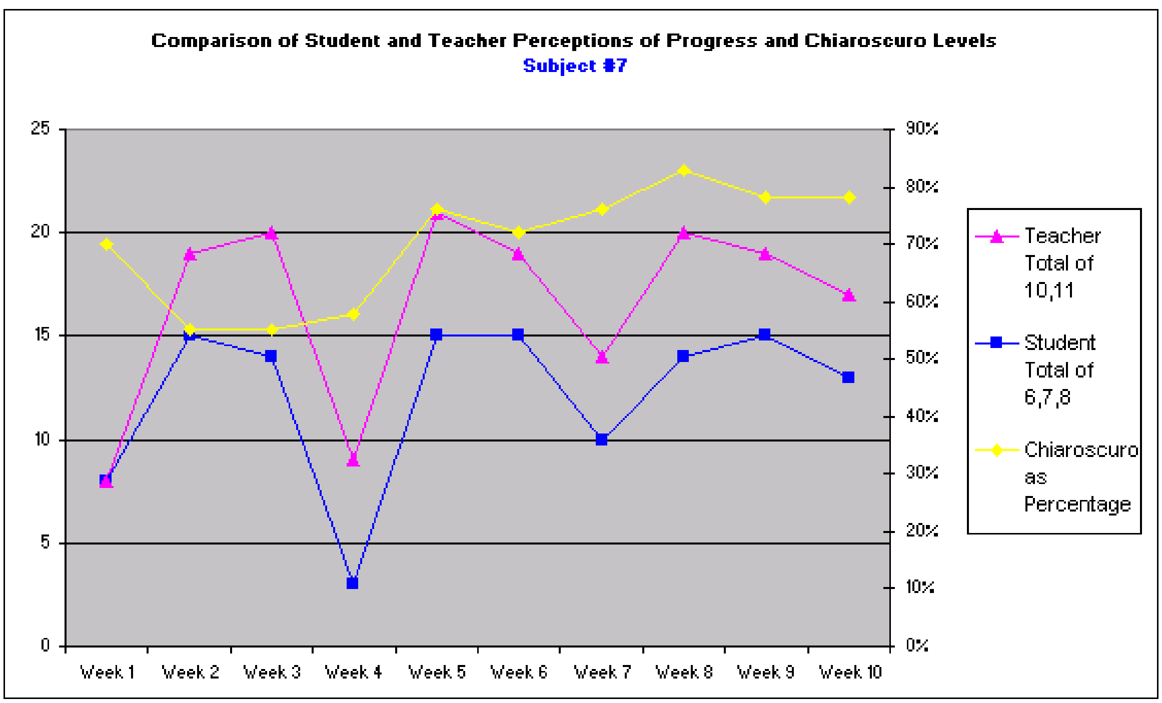


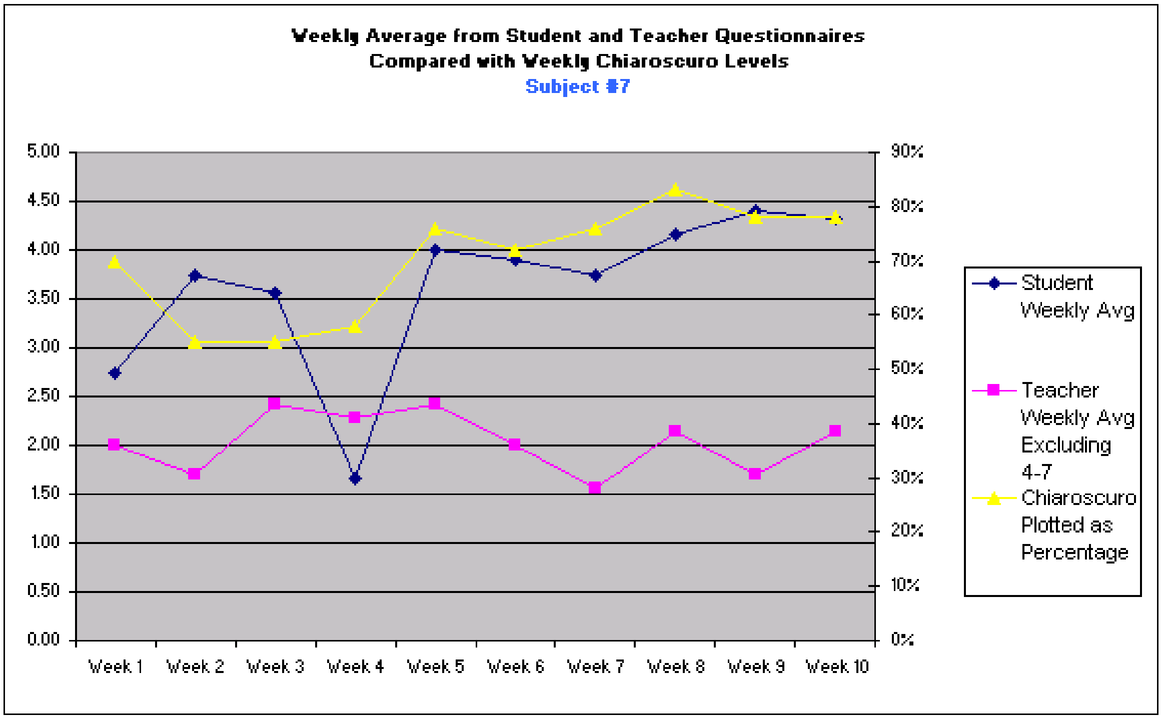
Power Spectrum from Spectrogram #10, Subject #7 at 6.83 seconds [a]



Analysis of Power Spectra from Spectrogram #10, Subject #7 – November 10, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.47	4	3	.75	5	9	.55	.65
4.85	3	3	1.0	5	8	.62	.81
6.83	3	3	1.0	13	16	.81	.9
Average of three chiaroscuro levels							.78


Subject #7 Chiaroscuro Levels
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg


Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #7
25
20
15
10
5
0
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #7
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A8: Subject #8

Subject #8 was a 21-year-old African-American senior majoring in general studies. Her home was in northwestern South Carolina. During the semester in which data were gathered she was preparing for a half-recital, which she performed in January. She had a three-week illness with bronchitis during the semester, but otherwise was healthy.

At the time of the data collection Subject #8 had been a student in the researcher's studio for three years. She first entered the studio as a freshman music performance major with voice as her major instrument. Her vocal production was good from the start, although somewhat over-resonated because of her gospel music background. Even after she changed her major, her innate musicianship and fine ear allowed her to remain in the select choral group and perform on student recitals. She continued to study a music major's repertoire and often performed difficult 20th-century music in student recitals.

Subject #8's voice was a bright lyric mezzo with a long lower range extension. She could "belt" in the gospel style but with healthy voice production. The normal range in which she vocalized was from a to a^2, and her vocal production was even throughout that range.

The spectrograph was not of much interest to Subject #8 at first. It seemed intrusive, as if it were just another technology that stood between her and her singing. Eventually she became acquainted with the machine and found that its feedback was positive.

Fall Semester 2000 Repertoire – Subject #8

Barber	*Hermit Songs*: Sweet Little Bell Crucifixion Praises of God
Brahms	Dein blaues Auge (E-flat) Feldeinsamkeit (F)
Bizet	Seguidilla from *Carmen*
Charles Brown	The Barrier
Mark Fax	Love
Mozart	Susannah and Marcellina duet from *Figaro*, Act I
Jule Styne	"You Gotta Have A Gimmick" from *Gypsy*

Lesson record over the data collection period – Subject #8

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10-11
8/23	B	All repertoire was assigned last spring, but not much learning went on this summer	Late and not well prepared	Spent a large proportion of lesson time copying music for accompanist. I have scheduled two lessons a week since she is preparing a recital.	#1 D	Chiaroscuro - .37 Student n/a, n/a, 2 Teacher n/a, n/a
9/1	B	Brahms, Bizet	Not doing much work outside lesson time	She is starting to get sick. We made a plan of attack for her to memorize her recital music. Coaching.		
9/6	B	Brahms – She wants to work on each group in turn	Changed lesson time for Biology lab	She has waited so late to schedule her lesson time that the accompanist assigned to her has already filled her schedule at the times Subject #8 can have her lesson. Promised to schedule a separate ½ hour per week with the pianist. Blaues auge – memorized Has not yet sung in VMC – asked her to sing next week: Feldeinsamkeit	#2 D	Chiaroscuro - .46 Student 4, 4, 2 Teacher 3, 3
9/11			Sick	Lesson cancelled		
9/13			Sick	Lesson cancelled		
9/18			Sick	Lesson cancelled		
9/20	B	Brahms, Bizet	Good	Checked Brahms, which is holding well, coached Bizet	#3 D	Chiaroscuro - .44 Student 2 3 2 Teacher 3, 3
9/25				Lesson cancelled for TN trip		
9/27			Good	After warm-ups I took lesson time for history coaching – she won't come an extra time	#4 D	Chiaroscuro - .49 Student 2, 3, 2 Teacher 3, 3
10/5	B	Brahms, Bizet	Okay	Checked Brahms, coached Bizet (sounded as if she had not begun)	#5 D	Chiaroscuro - .46 Student 3, 3, 2 Teacher 3, 3
10/11	B	Brahms, Bizet	Okay	Brahms good – retained Bizet from last week except last two phrases – coached that part	#6 D	Chiaroscuro - .41 Student 2, 2, 2 Teacher 2, 2
10/16	0		No show			
10/18	B	Barber, Fax, Brown	Okay	Talked about rescheduling recital because of piano majors' injuries – reworked English groups	#7 D	Chiaroscuro - .49 Student 3, 3, 2 Teacher 3, 3
10/25	B	Brahms, Barber, Fax, Bown	Okay	She is working along, but is not motivated-decided no recital	#8 D	Chiaroscuro - .39 Student 4, 4, 2 Teacher 3, 3
11/1	B	Barber, Bizet, Brown, Fax	Okay	Ruling from Chair: she has to do recital and in January – hope she'll get moving	#9 D	Chiaroscuro - .37 Student 3, 3, 1 Teacher 3, 3
3/1/01	A	Exploring jazz repertoire	Good	Relaxed and singing well after recital and 4 weeks rest – did not do opera scenes	#10	Chiaroscuro - .32 Student – 3, 3, 2 Teacher 2, 1

Responses to student questionnaires – Subject #8

Question	8/23	9/2	9/20	9/27	10/5	10/11	10/18	10/25	11/1	3/13/01	**Total of weekly answers to questions 6, 7, 8**
1	2	4	2	2	3	2	2	3	1	2	
2	2	4	2	2	3	2	3	3	1	2	
3	2	3	2	2	2	2	2	2	1	2	
4	2	2	2	2	2	2	2	2	1	2	
5	1	2	2	2	2	2	2	2	1	2	
6	N/A	4	2	2	3	2	3	4	3	3	2.88
7	N/A	4	3	3	3	2	3	4	3	3	3.11
8	2	2	2	2	2	2	2	2	1	2	1.9
9	2	2	2	2	2	2	2	2	1	2	**Average over ten week period**
10	2	2	2	2	2	2	2	2	1	2	
11	2	3	2	2	3	2	2	2	1	2	
12	2	2	2	2	2	2	2	2	1	2	
Weekly Average	1.9	2.83	2.08	2.08	2.41	2	2.25	2.5	1.33	2.16	**2.63**

Responses to student questionnaires – Subject #8

Responses to teacher questionnaires will be numerically listed. The correspondence of numbers to the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)

2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)

3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)

4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)

5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

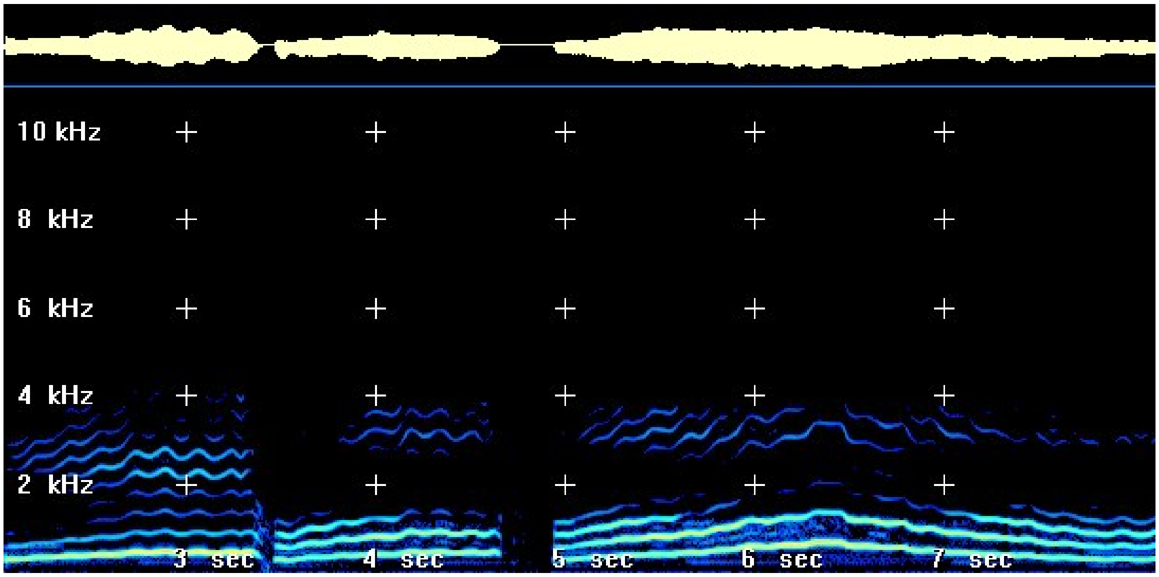
Question	8/23	9/2	9/20	9/27	10/5	10/11	10/18	10/25	11/1	3/13/01	**Total and Average of questions 10 & 11**
1	2	2	2	2	2	2	2	2	2	2	
2	2	3	2	2	2	2	2	3	2	2	
3	2	2	2	2	2	2	2	2	2	2	
4	3	4	4	4	4	3	3	4	4	1	
5	5	5	4	4	5	5	5	4	5	5	
6	3	4	4	4	5	5	4	5	4	1	
7	5	5	5	5	5	5	5	5	5	5	
8	1	2	2	2	3	2	3	3	2	2	
9	2	5	3	3	5	2	2	5	2	2	
10	N/A	3	3	3	3	2	3	3	3	2	**2.77**
11	N/A	3	3	3	3	2	3	3	3	1	**2.66**
Weekly average excluding questions 4-7	1.8	2.85	2.14	2.14	2.85	2	2.14	3	2.28	2.18	**2.72**

Student's Written Reaction to Use of Spectrograph – Subject #8

For me the spectrograph has helped my singing immensely. Before we began using the spectrograph in class, I would know that I had poor breath control, however I did not know why. I am a visual learner and the spectrograph allowed me to visualize where I began to stop using my breath support. I was also able to hear myself, and that enabled me to be able to improve my intonation. The most unique aspect of the spectrograph is that it is so small, yet it accomplishes such a large task. It was very interesting for me to be able to observe myself when I was ill. I could actually see that my voice was not at its best. I feel that I was lucky to have been able to use the spectrograph. I am a senior, but I fell that my voice has improved more over this semester with the use of the spectrograph. In my opinion every voice class should be able to have the use of a spectrograph. As you can tell, I am pleased with my vocal improvements, thanks in part to the spectrograph.

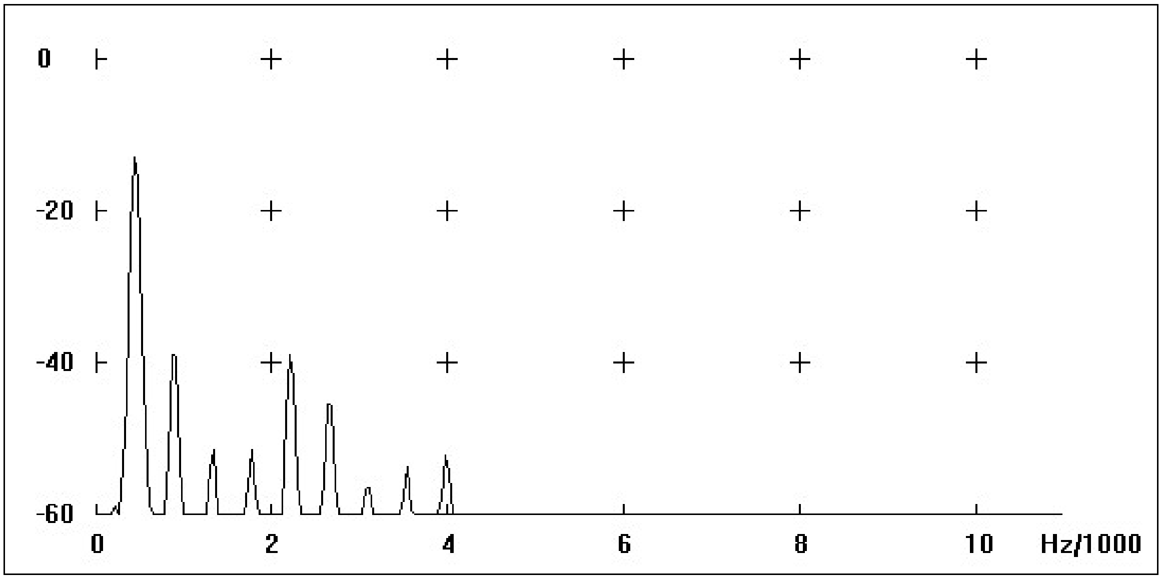
Analysis of Wave Files

Wave File Number 1 – August 23, 2000 – Subject #8

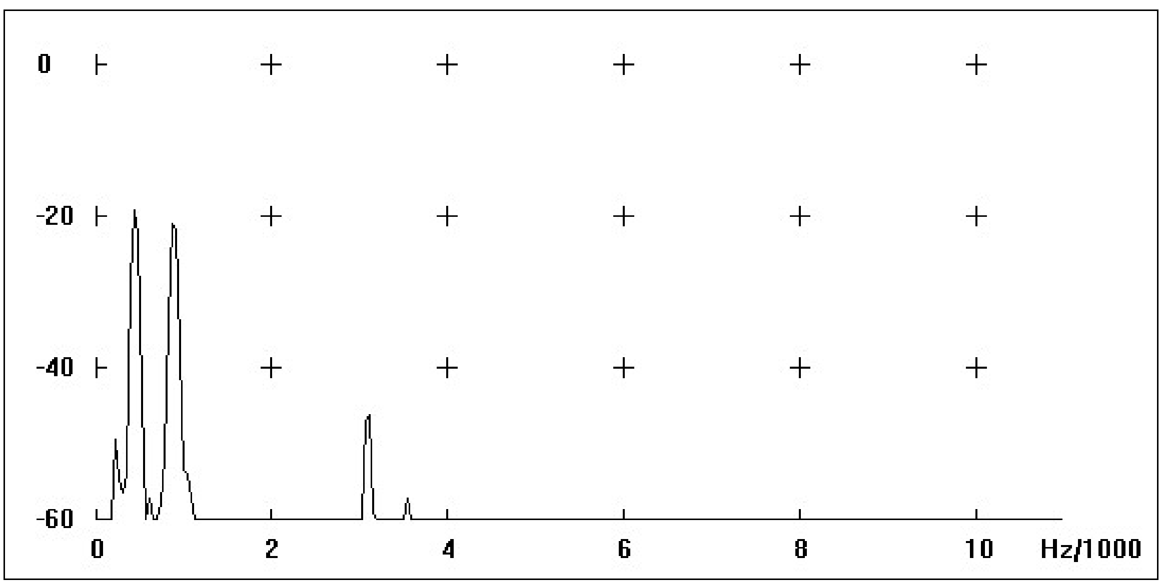


Subject #8 – Analysis of Wave File #1 – August 23, 2000 – D major				
		[si] (2.06-3.34 sec)	[o] (3.47-4.66 sec)	[a] (4.98-8.88 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Two nearly solid bands	Stronger and more consistent
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Nearly balanced	Nearly balanced	Better balanced
Power Spectrum		Increase from about 15% to about 50%	Varying around 25%	<> from about 15% to about 50%
Indicates a voice with sold first formant area and good beginning at producing upper level frequencies.				

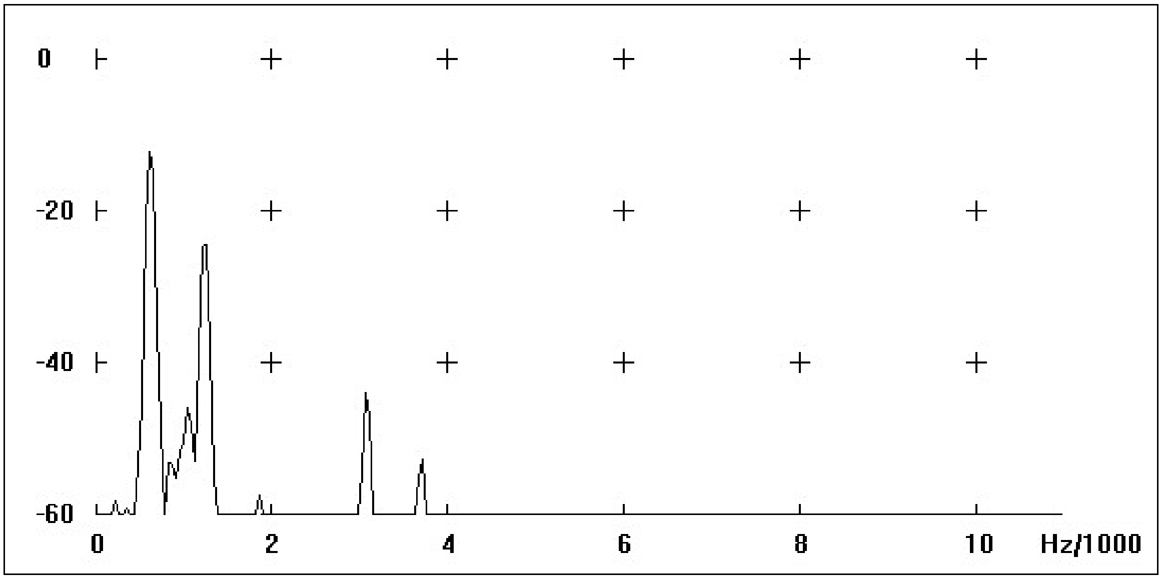
Power spectrum from Spectrogram #1, Subject #8 at 3.28 seconds [i]



Power spectrum from Spectrogram #1, Subject #8 at 4.26 seconds [o]

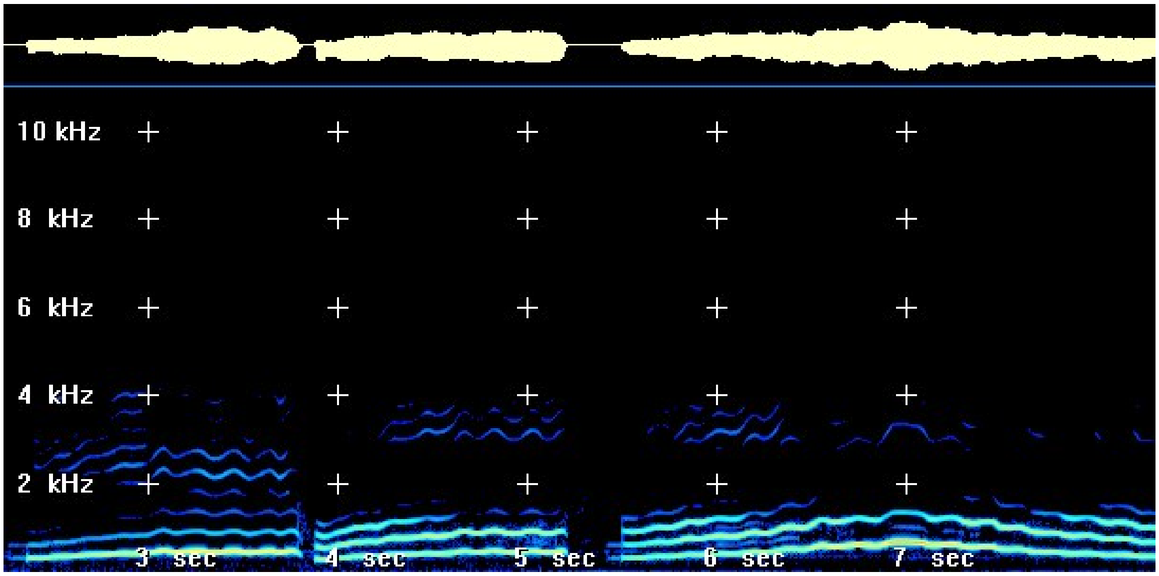


Power spectrum from Spectrogram #1, Subject #8 at 6.2 seconds [a]



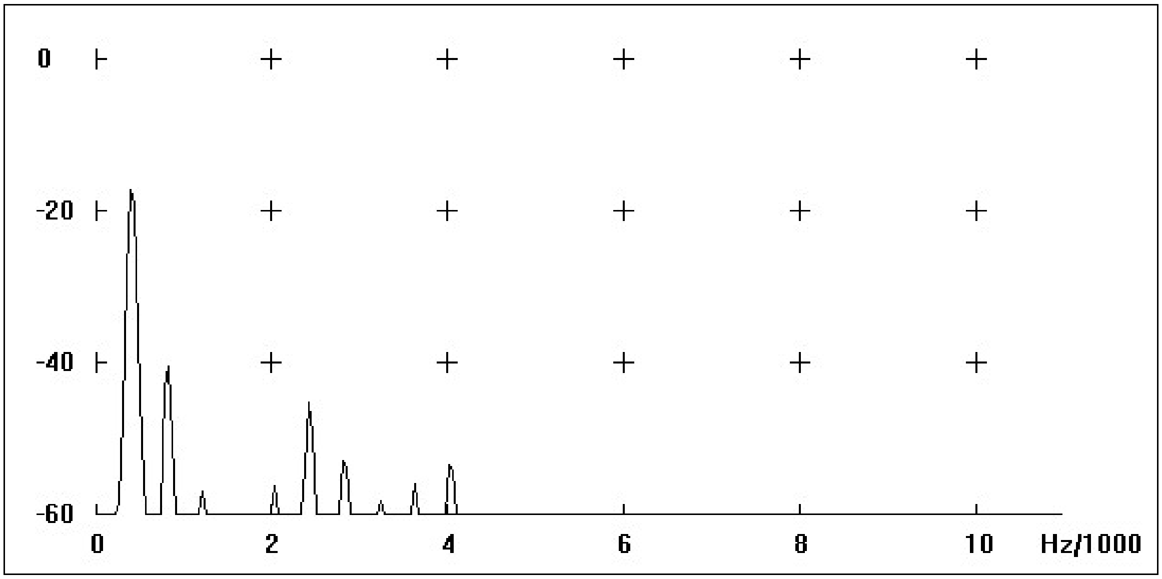
Analysis of Power Spectra from Spectrogram #1, Subject #8 – August 23, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.28	5	2	.4	5	10	.5	.45
4.26	4	2	.5	2	6	.33	.41
6.2	7	2	.28	2	9	.22	.25
Average of three chiaroscuro levels							.37

Wave File Number 2 – September 2, 2000 – Subject #8

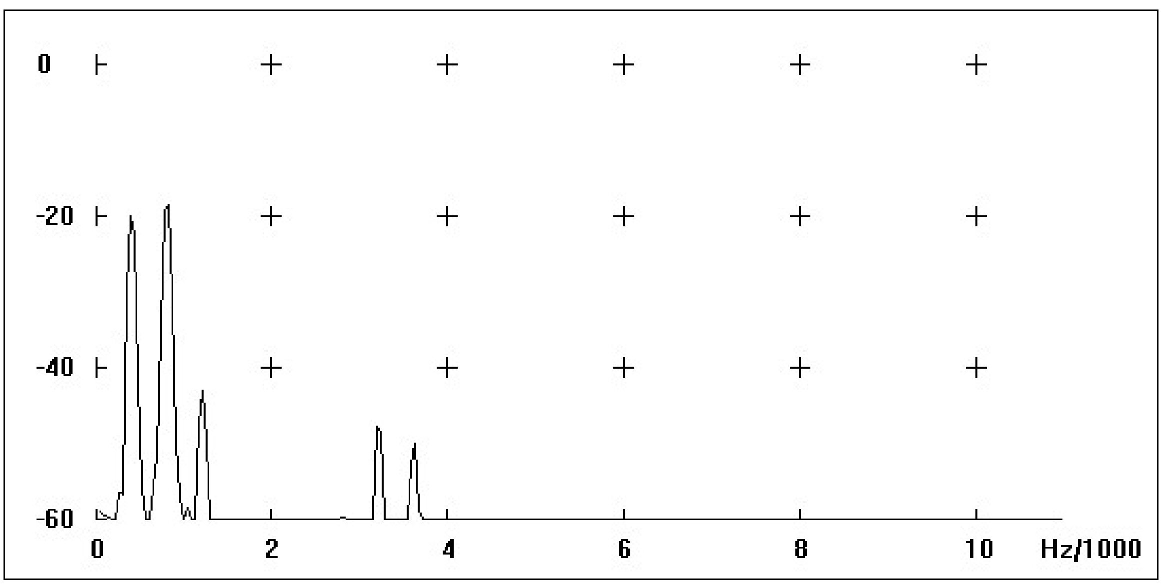


Subject #8 – Analysis of Wave File #2 – September 2, 2000 – D major				
		[si] (2.42-3.8 sec)	[o] (3.87-5.21 sec)	[a] (5.5-9.63 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Scattered indications	Better indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Partially balanced – tendancy to damp upper frequencies
Power Spectrum		Increase from about 10% to about 50%	Varying around 30%	<> from about 10% to about 80%
Voice is strong in lower frequencies with good beginning on upper frequencies.				

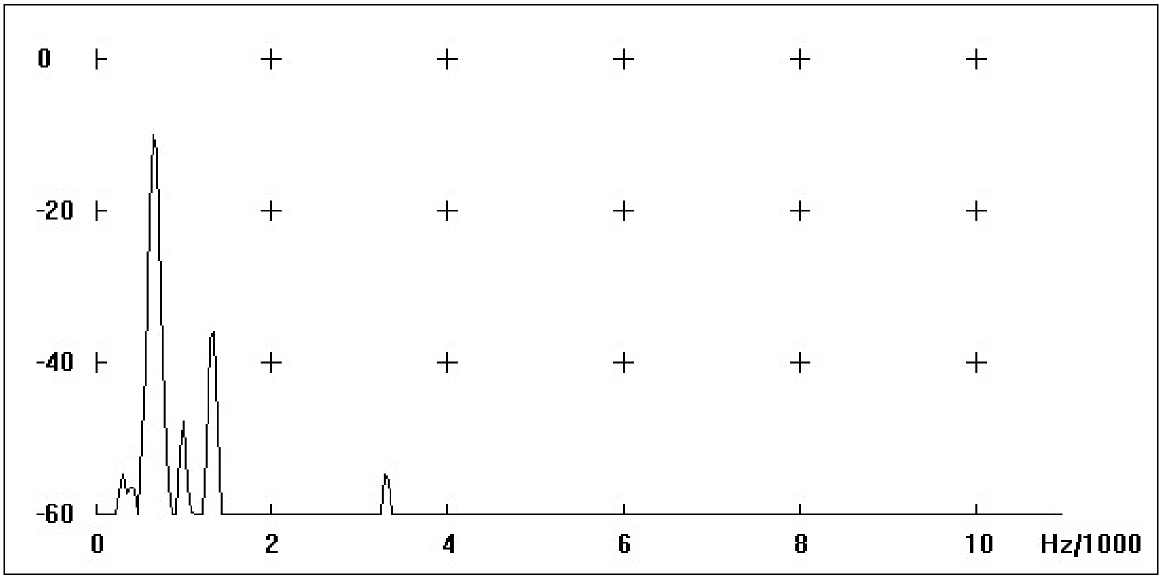
Power spectrum from Spectrogram #2, Subject #8 at 2.87 seconds [i]



Power spectrum from Spectrogram #2, Subject #8 at 4.49 seconds [o]

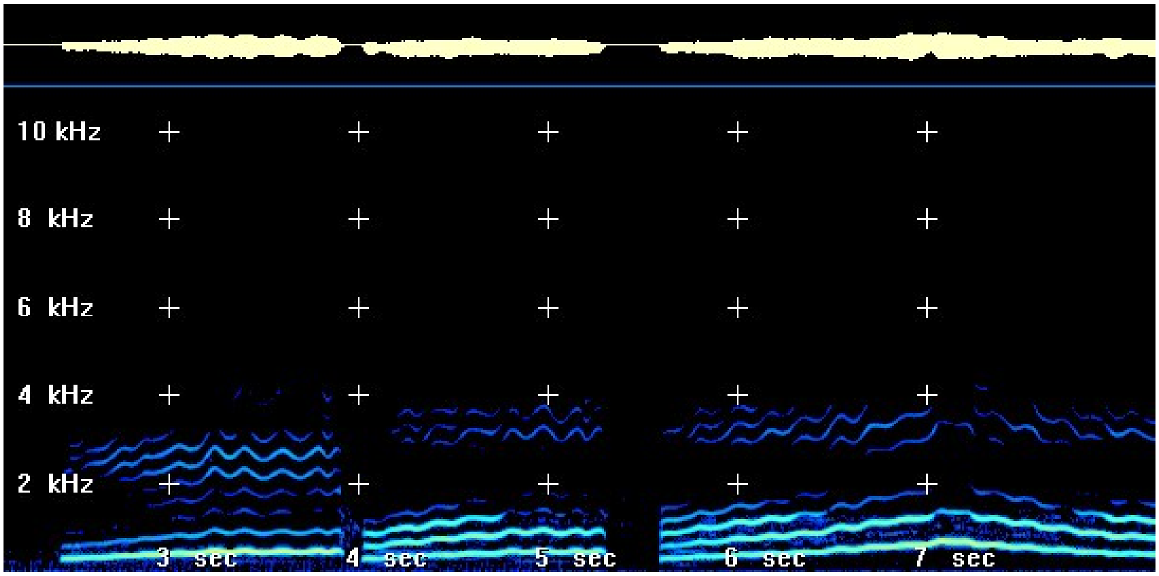


Power spectrum from Spectrogram #2, Subject #8 at 7.07 seconds [a]



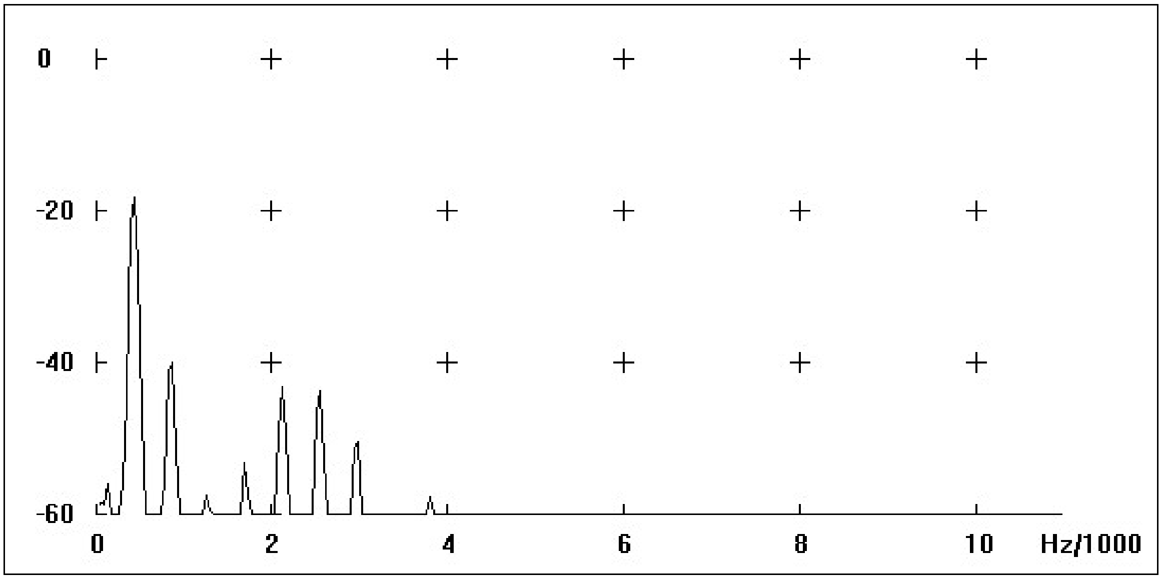
Analysis of Power Spectra from Spectrogram #2, Subject #8 – September 2, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.87	3	2	.66	6	9	.66	.66
4.49	4	2	.5	3	7	.42	.46
7.07	5	2	.4	1	6	.16	.28
Average of three chiaroscuro levels							.46

Wave File Number 3 – September 20, 2000 – Subject #8

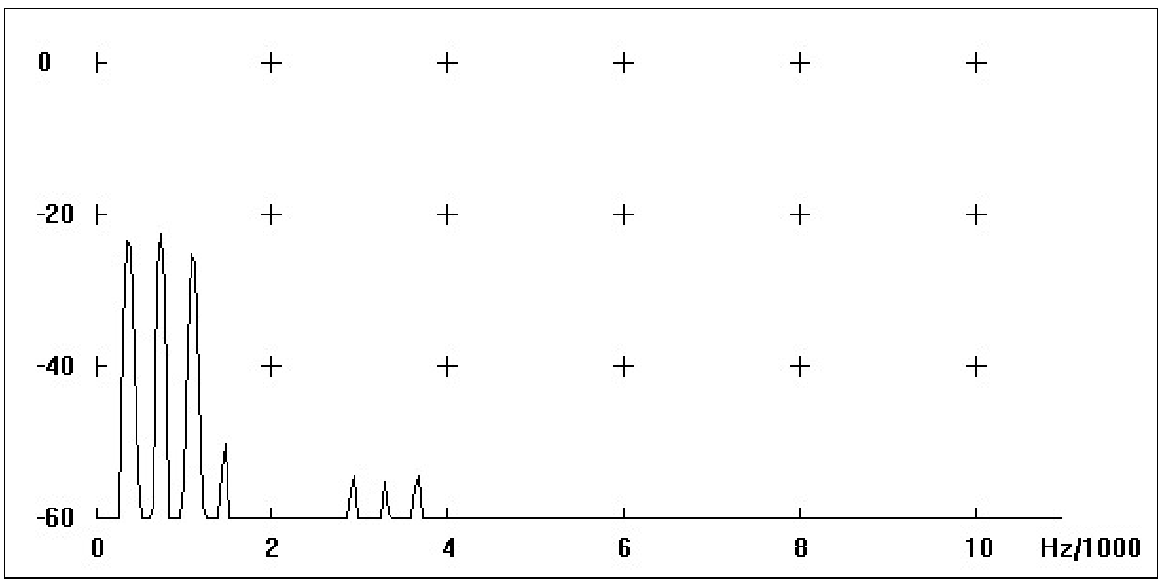


Subject #8 – Analysis of Wave File #3 – September 20, 2000 – D major				
		[si] (2.43-3.89 sec)	[o] (4.04-5.31 sec)	[a] (5.6-9.65 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Stronger indications	Better indications	Better indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Nearly balanced	Nearly balanced	Nearly balanced – tendency to damp upper frequencies
Power Spectrum		Increase from about 10% to about 20%	Varying around 20%	<> from about 10% to about 20%
Better balance than in earlier wave files. More consistency in upper frequencies.				

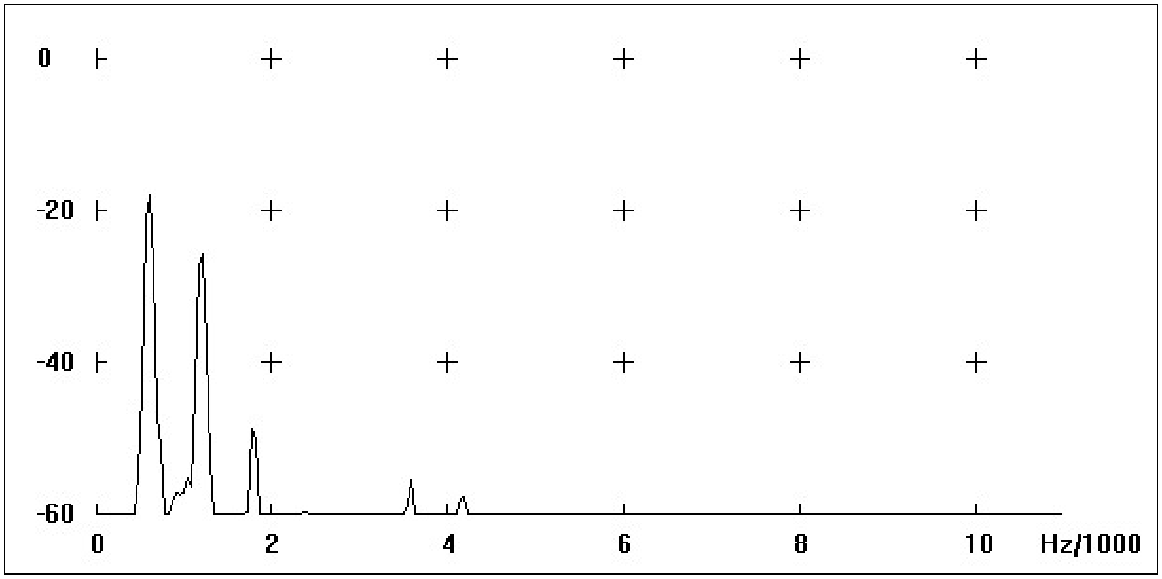
Power spectrum from Spectrogram #3, Subject #8 at 3.49 seconds [i]



Power spectrum from Spectrogram #3, Subject #8 at 4.47 seconds [o]

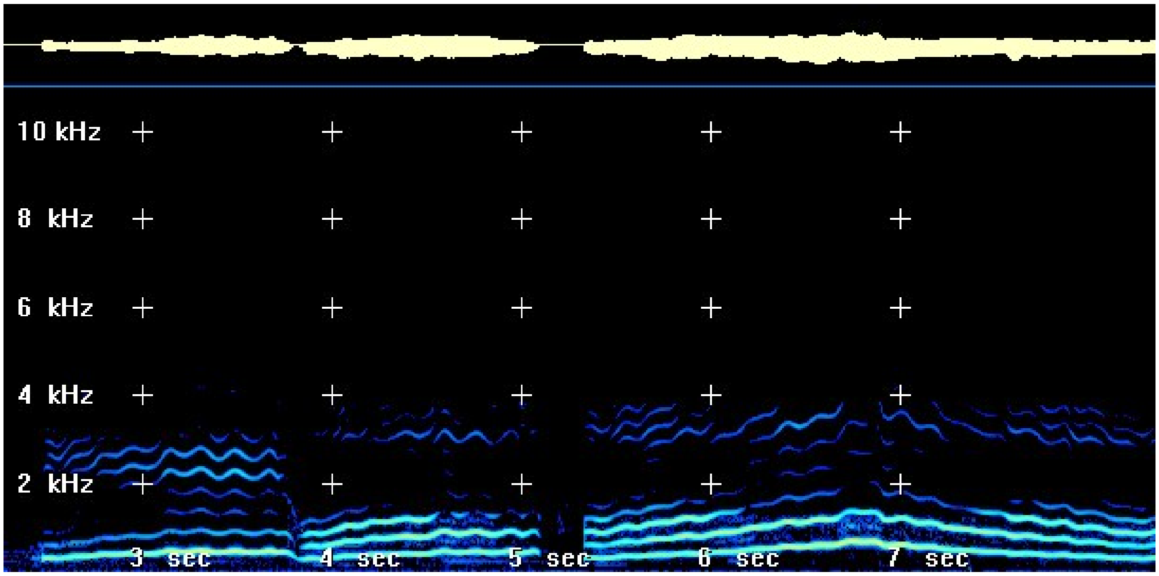


Power spectrum from Spectrogram #3, Subject #8 at 7.29 seconds [a]



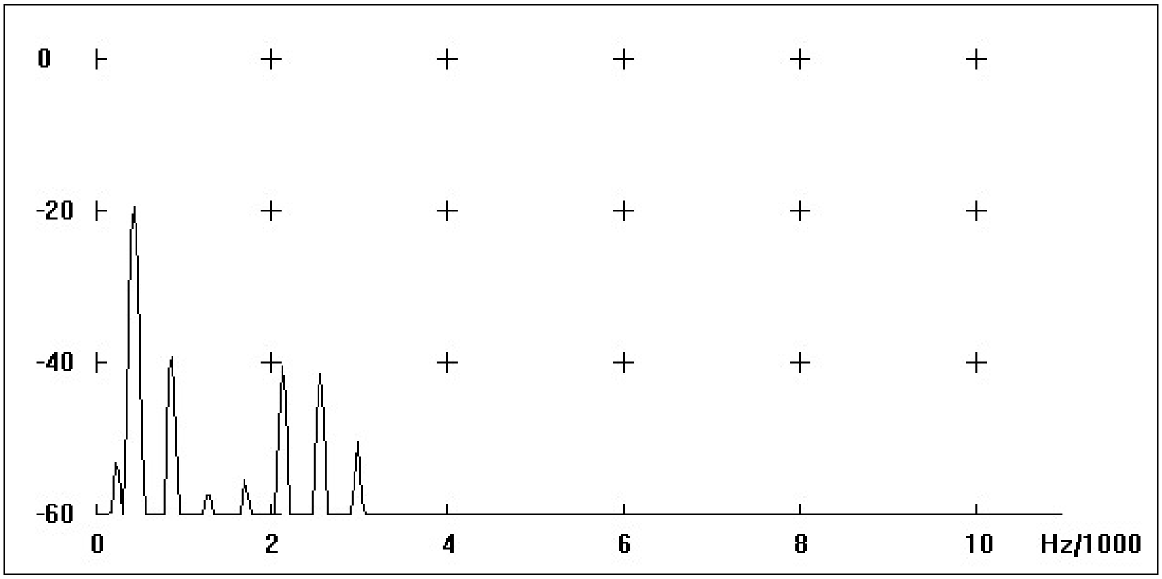
Analysis of Power Spectra from Spectrogram #3, Subject #8 – September 20, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.49	5	2	.4	4	9	.44	.42
4.47	4	3	.75	3	7	.42	.58
7.29	5	2	.4	2	7	.28	.34
Average of three chiaroscuro levels							.44

Wave File Number 4 – September 27, 2000 – Subject #8

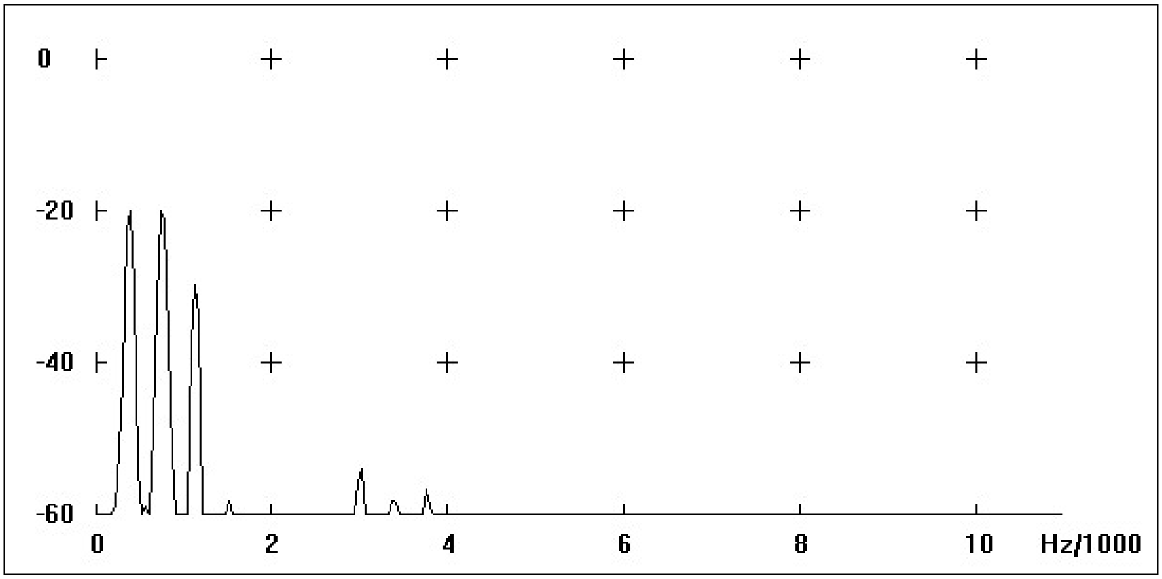


Subject #8 – Analysis of Wave File #4 – September 27, 2000 – D major				
		[si] (2.48-3.73 sec)	[o] (3.85-5.06 sec)	[a] (5.43-9.0 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Better indications	Better indications	Better indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Partially balanced – tendancy to damp upper frequencies
Power Spectrum		Increase from about 10% to about 20%	Varying around 20%	Varying around 25%
Although the upper frequencies are not at strong as in wave file #3, they continue to show better consistency.				

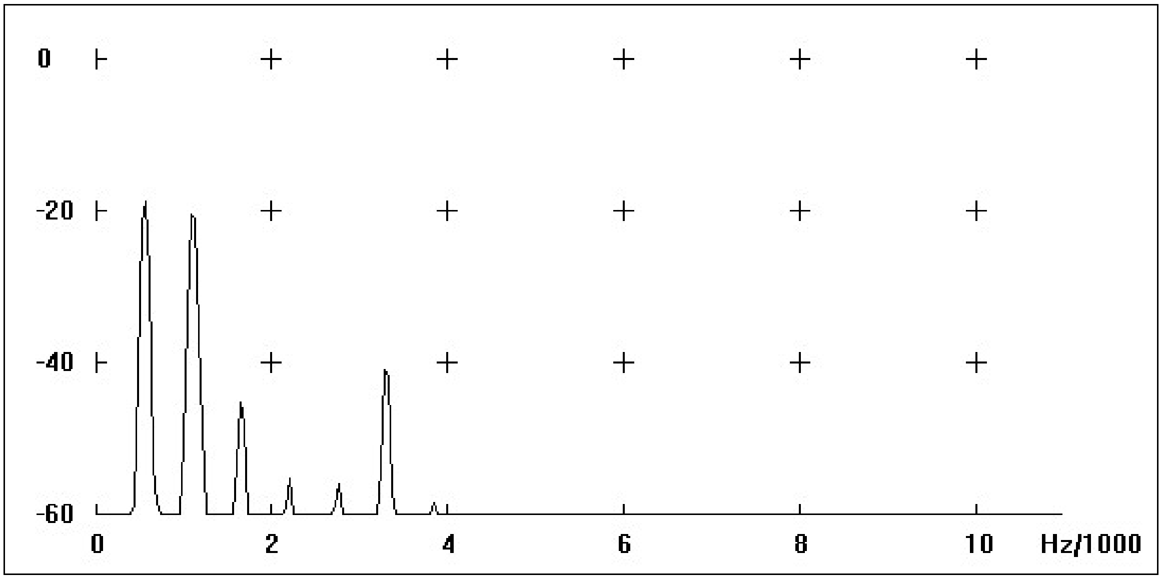
Power spectrum from Spectrogram #4, Subject #8 at 3.41 seconds [i]



Power spectrum from Spectrogram #4, Subject #8 at 4.33 seconds [o]

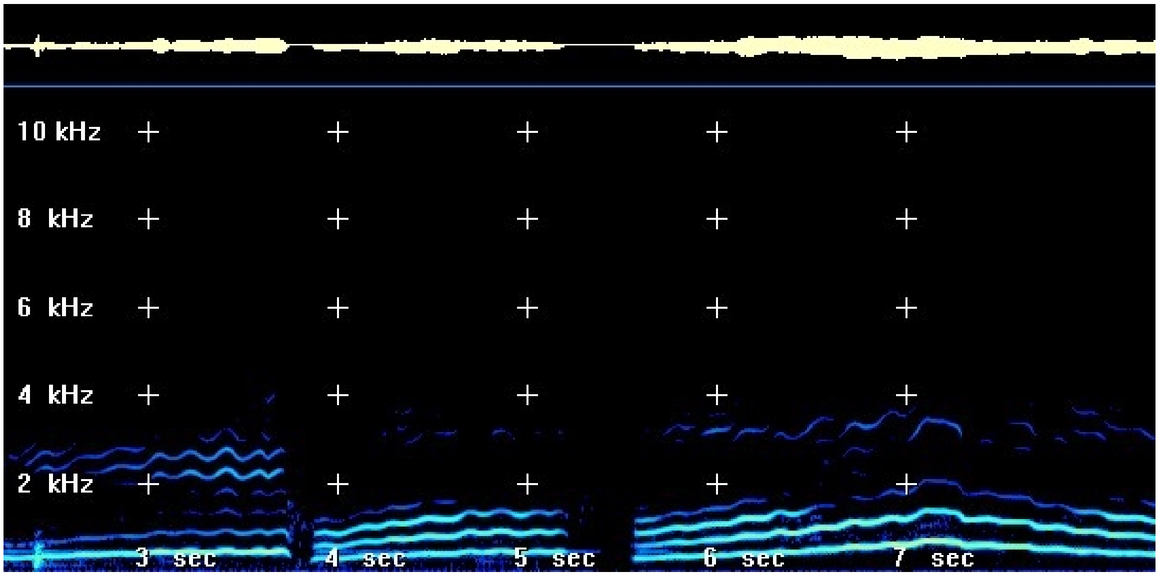


Power spectrum from Spectrogram #4, Subject #8 at 6.47 seconds [a]



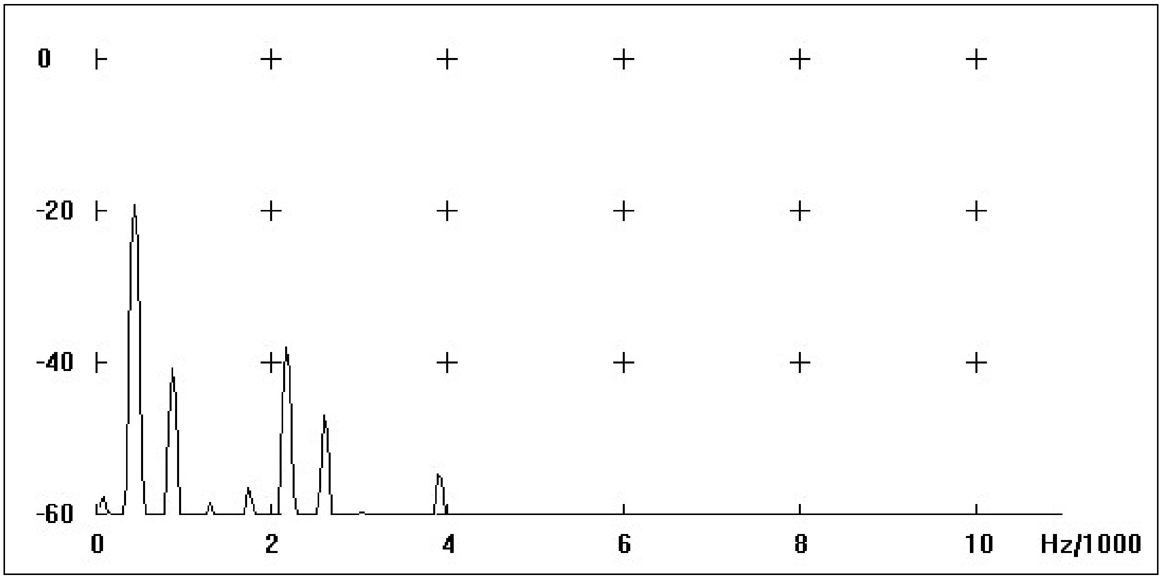
Analysis of Power Spectra from Spectrogram #4, Subject #8 – September 27, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.41	5	2	.4	3	8	.37	.38
4.33	5	3	.6	3	8	.37	.48
6.47	3	2	.66	4	7	.57	.61
Average of three chiaroscuro levels							.49

Wave File Number 5 – October 4, 2000 – Subject #8

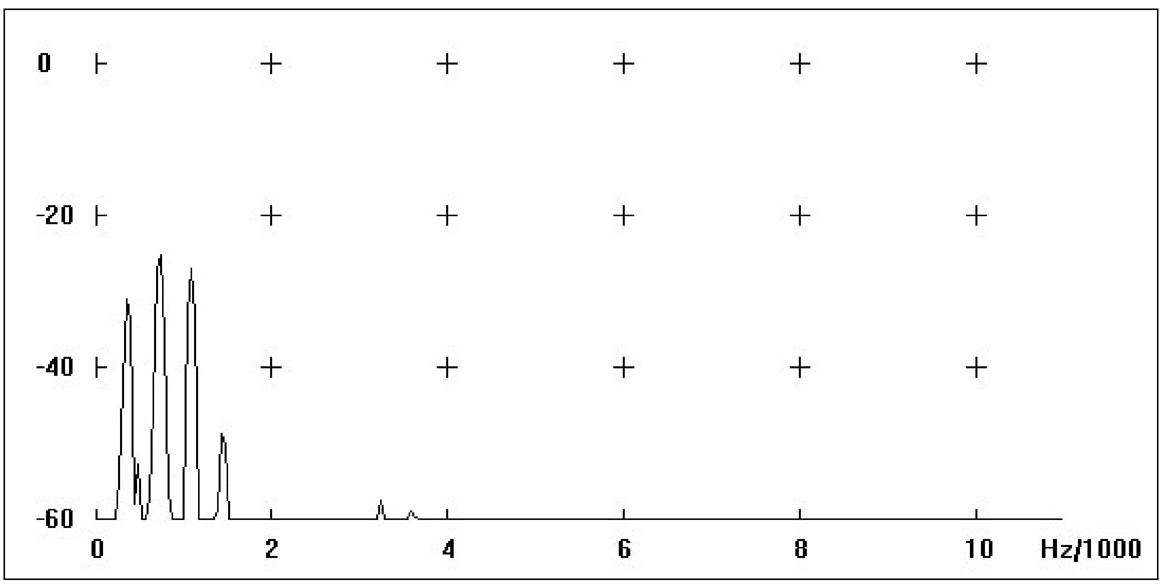


Subject #8 – Analysis of Wave File #5 – October 4, 2000 – D major				
		[si] (2.28-3.71 sec)	[o] (3.86-5.2 sec)	[a] (5.57-9.6 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Scattered indications	Better indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Partially balanced – tendancy to damp upper frequencies
Power Spectrum		Increase from about 5% to about 15%	Varying around 10%	<> from about 10$ to about 20%
The anomaly in the first formant area at about 2.5 is the microphone being bumped.				

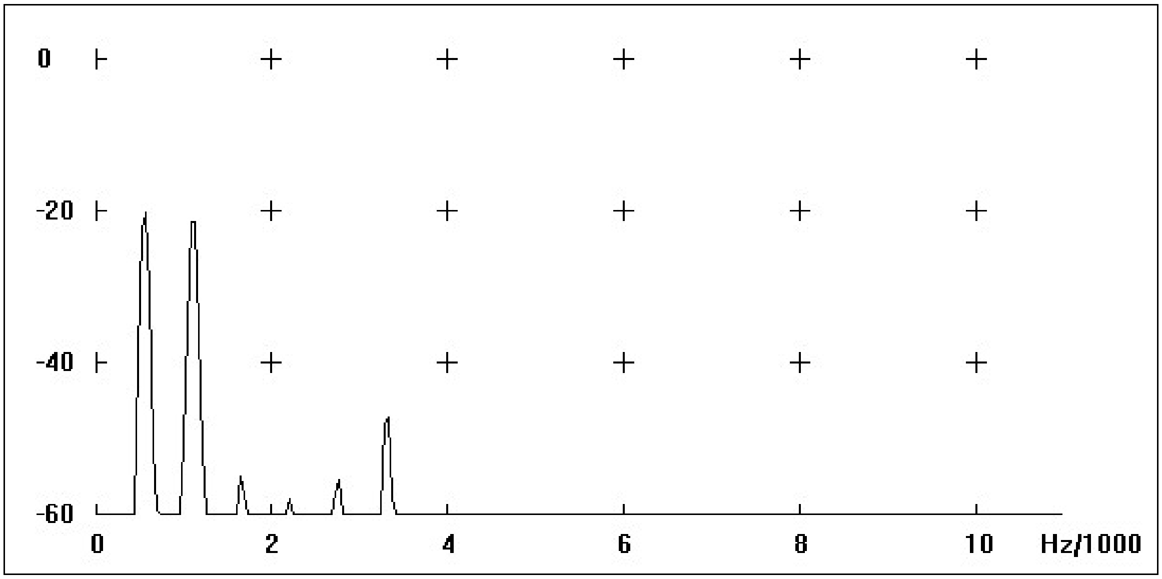
Power spectrum from Spectrogram #5, Subject #8 at 3.65 seconds [i]



Power spectrum from Spectrogram #5, Subject #8 at 4.36 seconds [o]

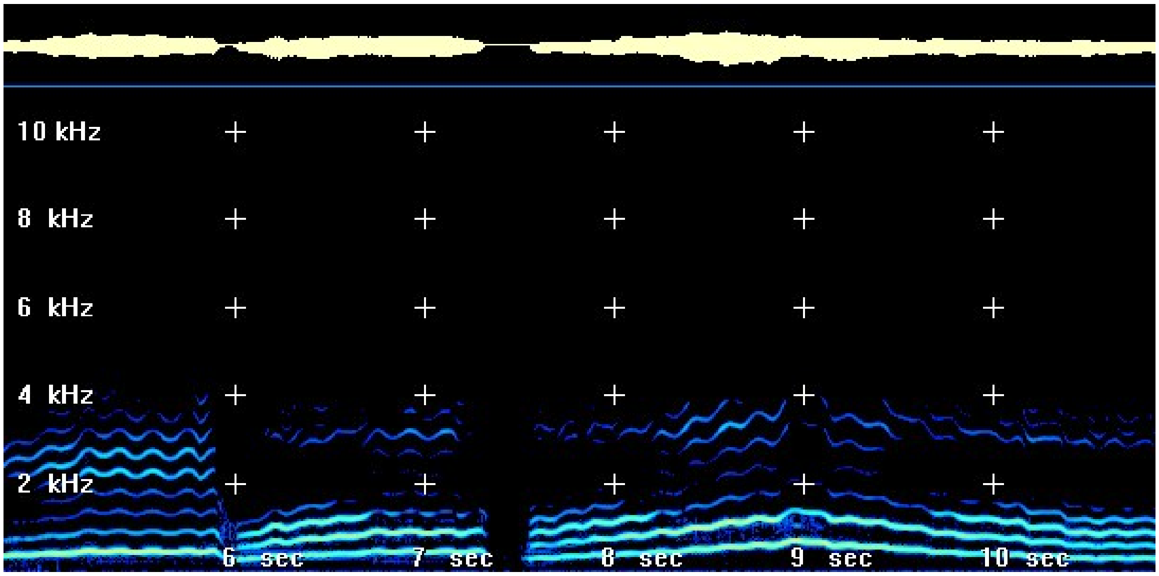


Power spectrum from Spectrogram #5, Subject #8 at 6.78 seconds [a]



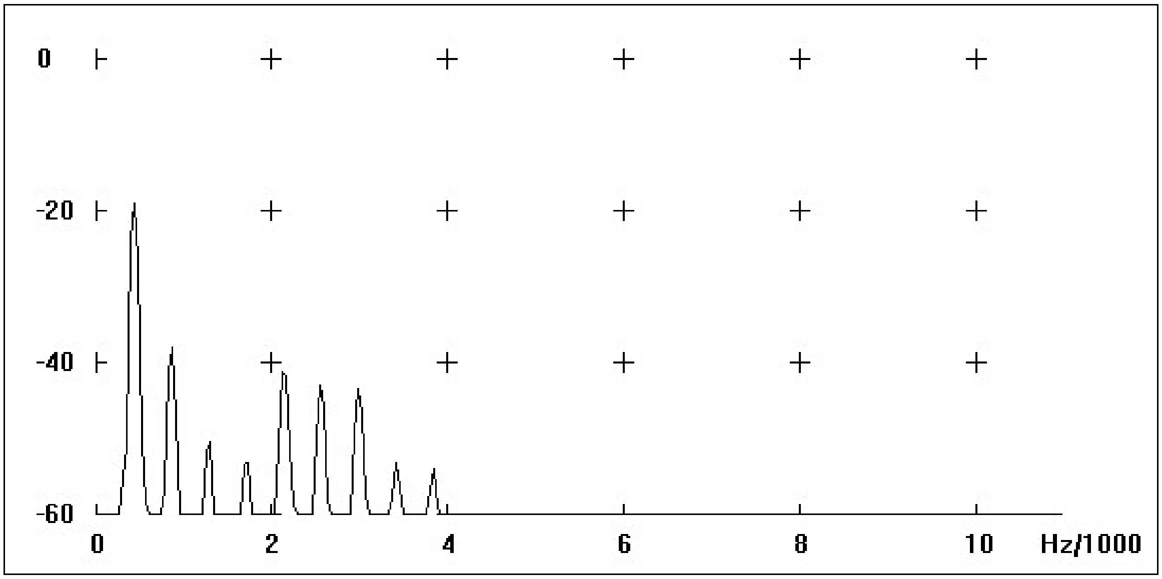
Analysis of Power Spectra from Spectrogram #5, Subject #8 – October 4, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.65	5	2	.4	3	8	.37	.38
4.36	5	3	.6	2	7	.28	.44
6.78	3	2	.66	3	6	.5	.58
Average of three chiaroscuro levels							.46

Wave File Number 6 – October 11, 2000 – Subject #8

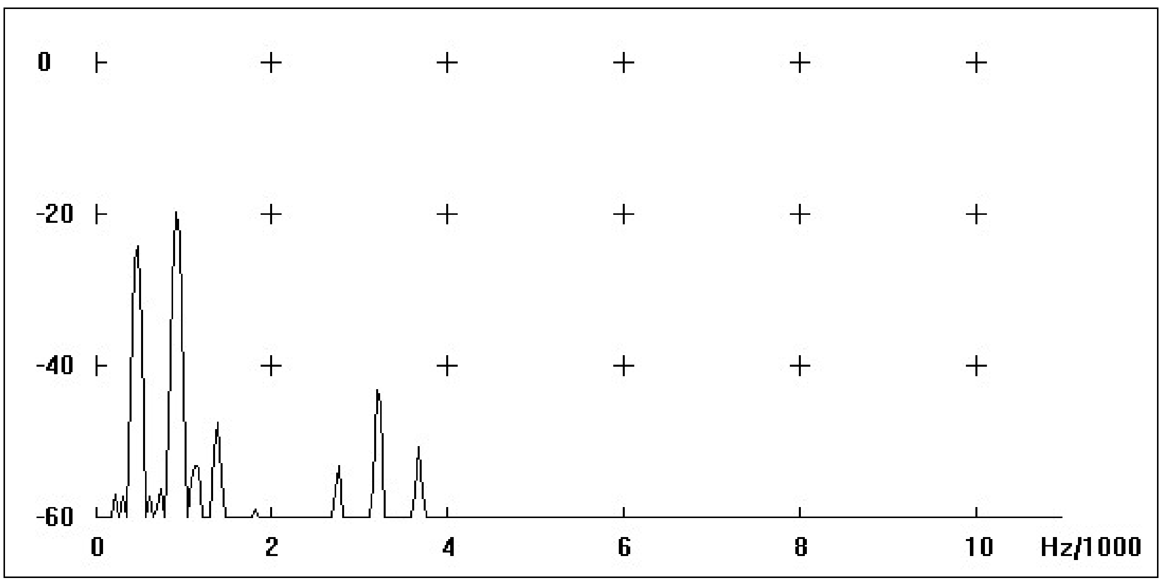


Subject #8 – Analysis of Wave File #6 – October 11, 2000 – D major				
		[si] (4.5-5.88 sec)	[o] (6.02-7.3 sec)	[a] (7.54-8.65 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Better indications	Scattered indications	Better indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Partially balanced – tendancy to damp upper frequencies
Power Spectrum		Increase from about 10% to about 25%	Varying around 25%	<> from about 10% to about 30%
The consistency shown by this student is to be expected from a college student with 3.5 years of voice. The technique is good though not stellar, and the quality of the voice is very good.				

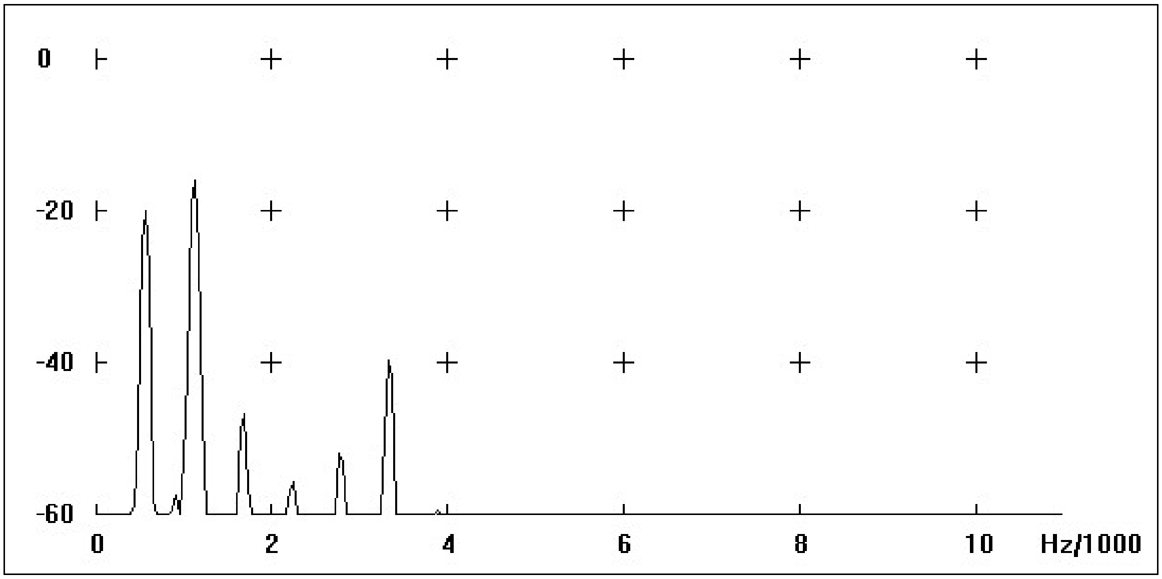
Power spectrum from Spectrogram #6, Subject #8 at 5.82 seconds [i]



Power spectrum from Spectrogram #6, Subject #8 at 6.94 seconds [o]

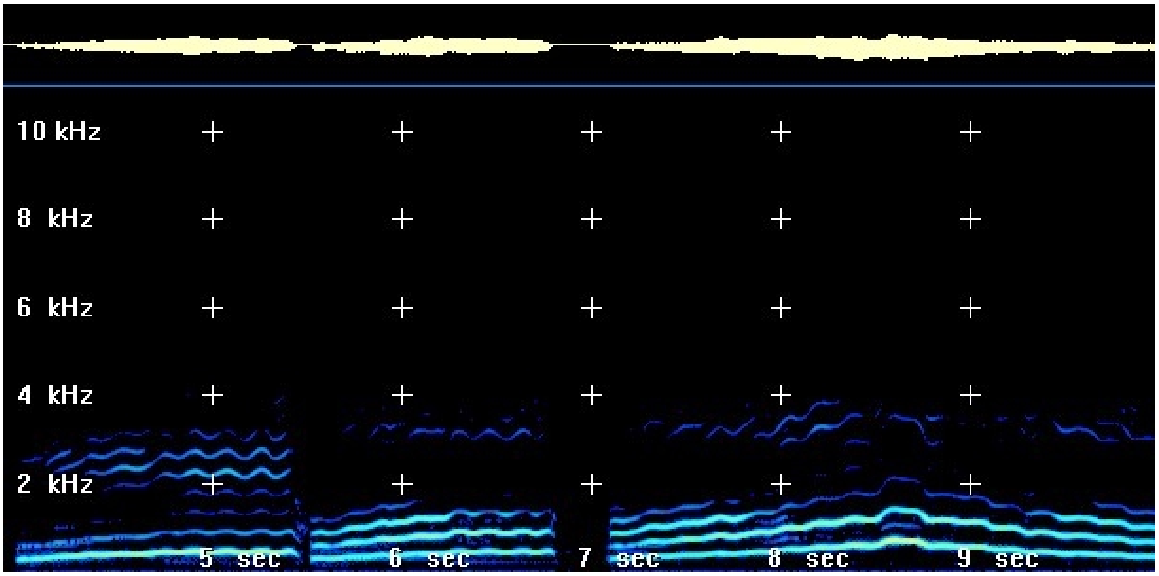


Power spectrum from Spectrogram #6, Subject #8 at 8.65 seconds [a]



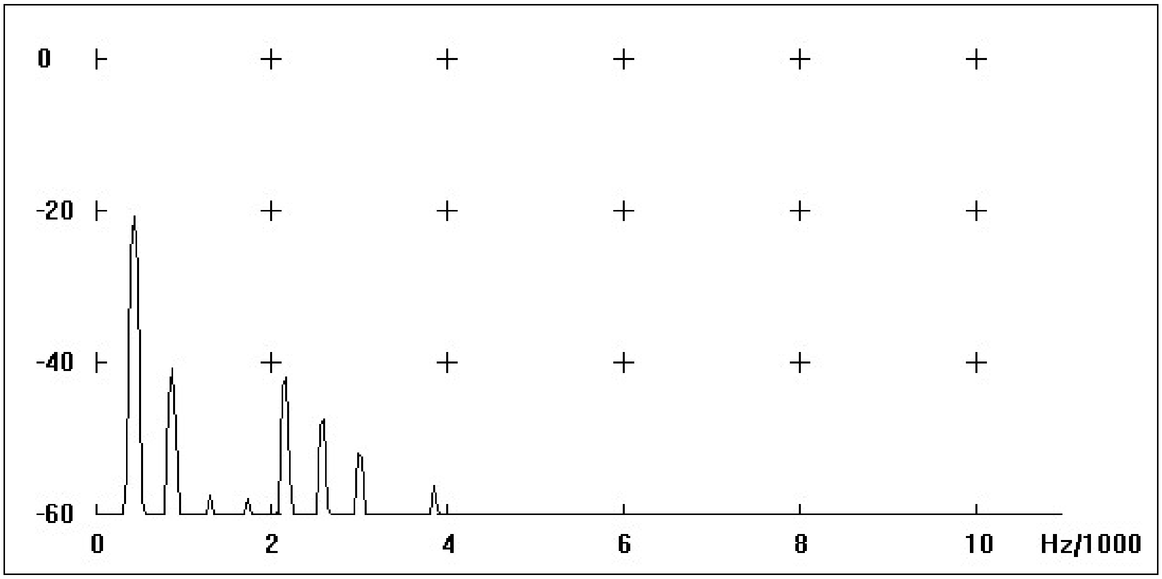
Analysis of Power Spectra from Spectrogram #6, Subject #8 – October 11, 2000							
	First & Second Formant Area $<$ 2000 Hz			Number of Peaks in Singers Formant Area $\geq$ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks $\geq$ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	C	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.82	4	2	.5	5	9	.55	.52
6.94	9	2	.22	3	12	.25	.23
8.65	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.41

Wave File Number 7 – October 18, 2000 – Subject #8

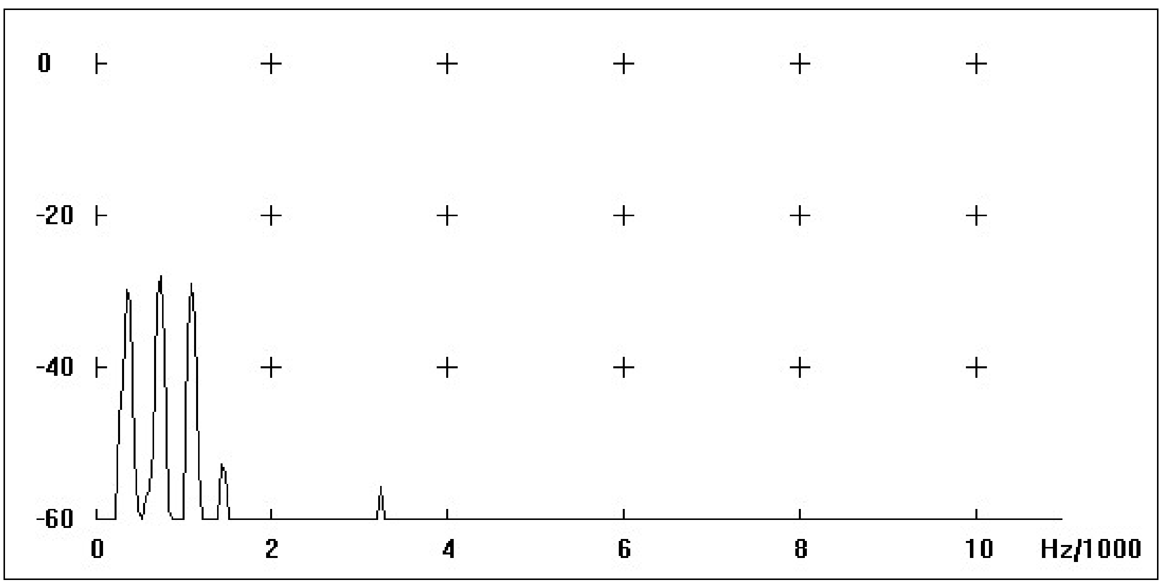


Subject #8 – Analysis of Wave File #7 – October 18, 2000 – D major				
		[si] (3.96-5.4 sec)	[o] (5.52-6.79 sec)	[a] (7.1-11.24 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications	Scattered indications	Better indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Partially balanced – less damping of upper frequencies
Power Spectrum		Increase from about 5% to about 15%	Varying around 15%	<> from about 10% to about 20%
Upper frequencies are slightly more apparent. The tendency to damp them at the highest pitches (around 8.6 seconds) is lessened, but since it is not accompanied by equivalent strengthening of the first formant area, the sound is somewhat over-resonated.				

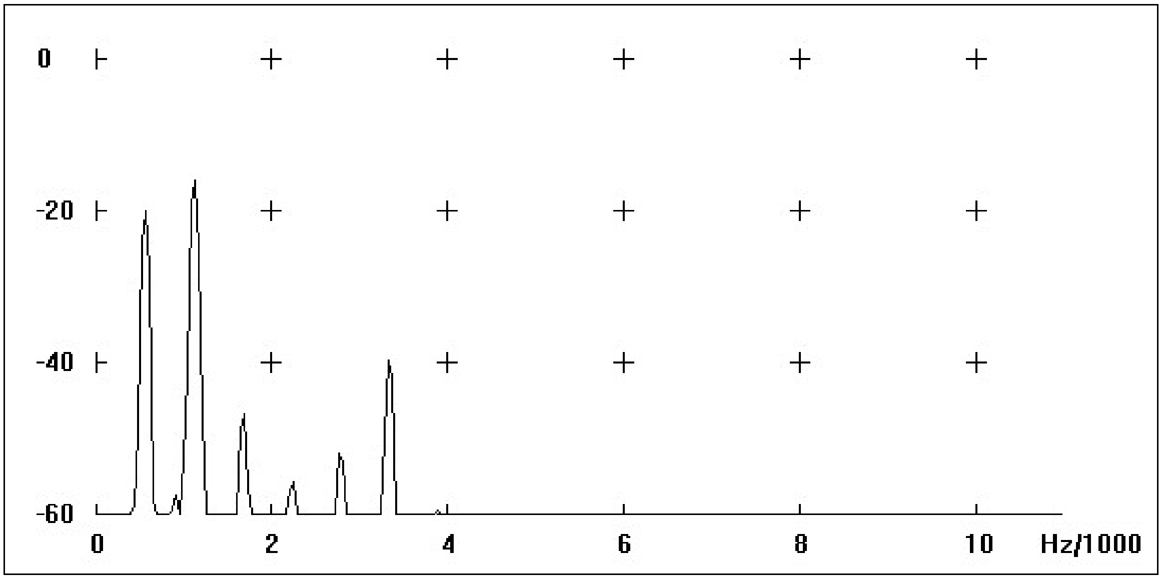
Power spectrum from Spectrogram #7, Subject #8 at 5.35 seconds [i]



Power spectrum from Spectrogram #7, Subject #8 at 5.88 seconds [o]

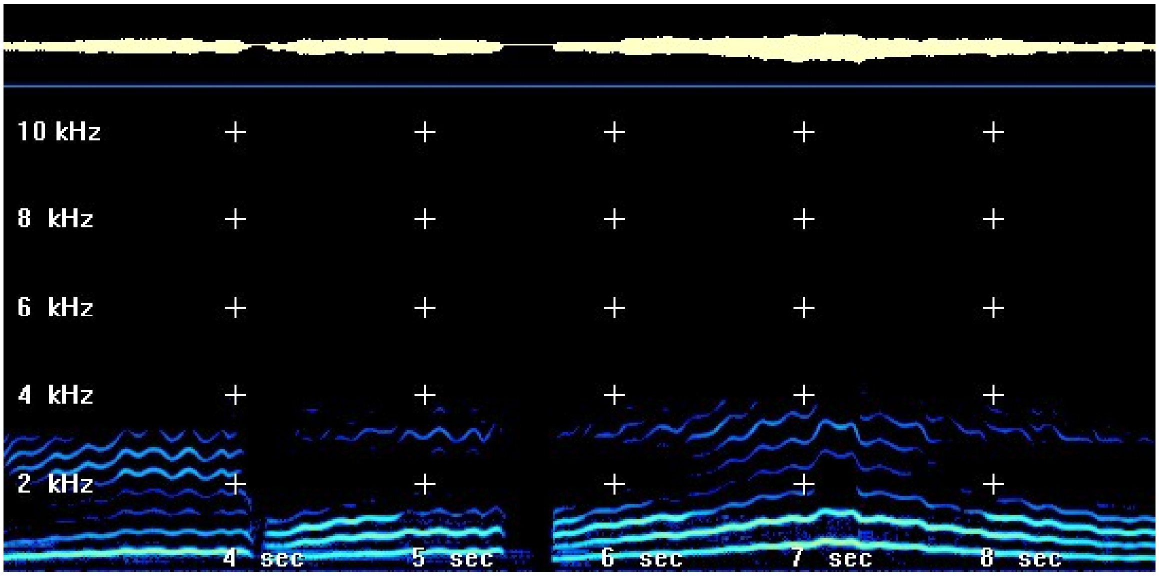


Power spectrum from Spectrogram #7, Subject #8 at 8.25 seconds [a]



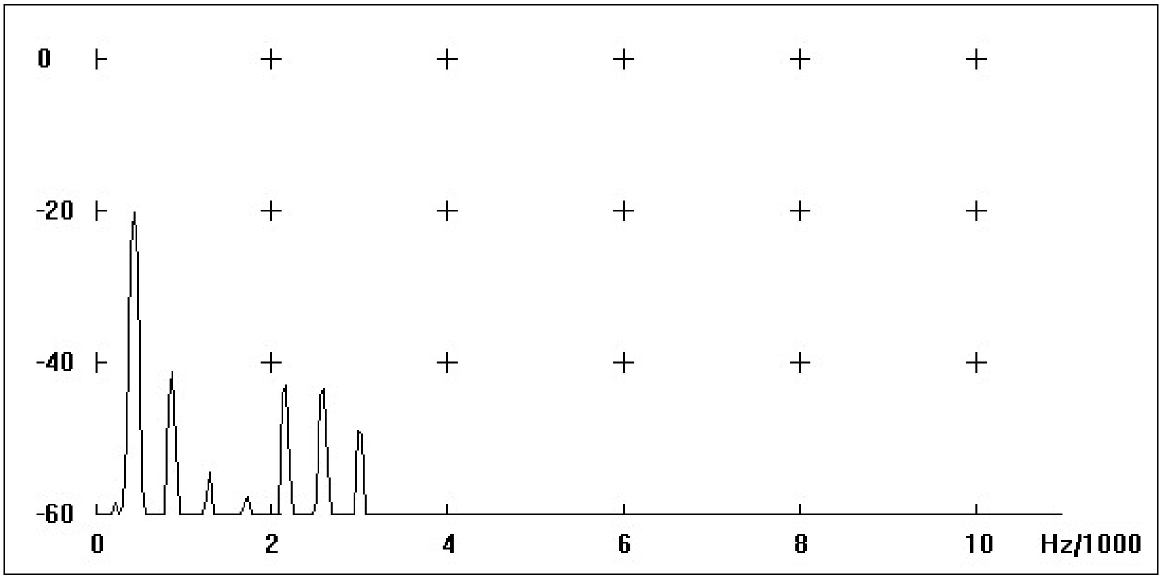
Analysis of Power Spectra from Spectrogram #7, Subject #8 – October 18, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.35	4	2	.5	4	8	.5	.5
5.88	4	3	.75	1	5	.2	.47
8.25	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.49

Wave File Number 8 – October 25, 2000 – Subject #8

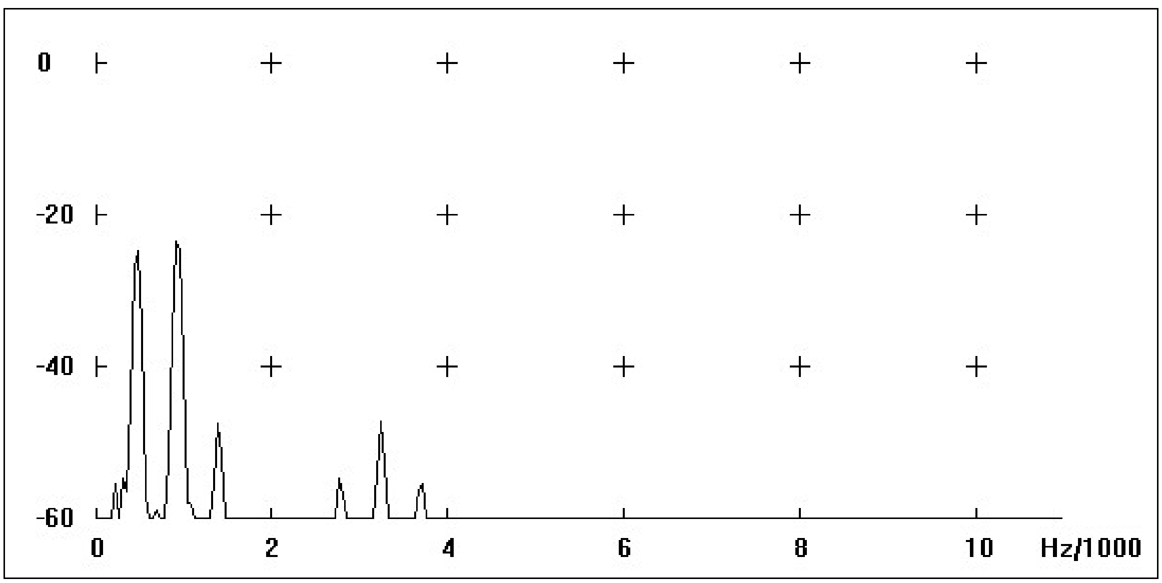


Subject #8 – Analysis of Wave File #8 – October 25, 2000 – D major				
		[si] (2.72-4.02 sec)	[o] (4.15-5.38 sec)	[a] (5.68-9.63 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Stronger indications	Stronger indications	Stronger and more consistent indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Better balanced	Better balanced	Better balanced
Power Spectrum		Increase from about 15% to about 20%	Varying around 20%	<> from about 10% to about 30%
The audible file matches the indications here of a much more balanced sound.				

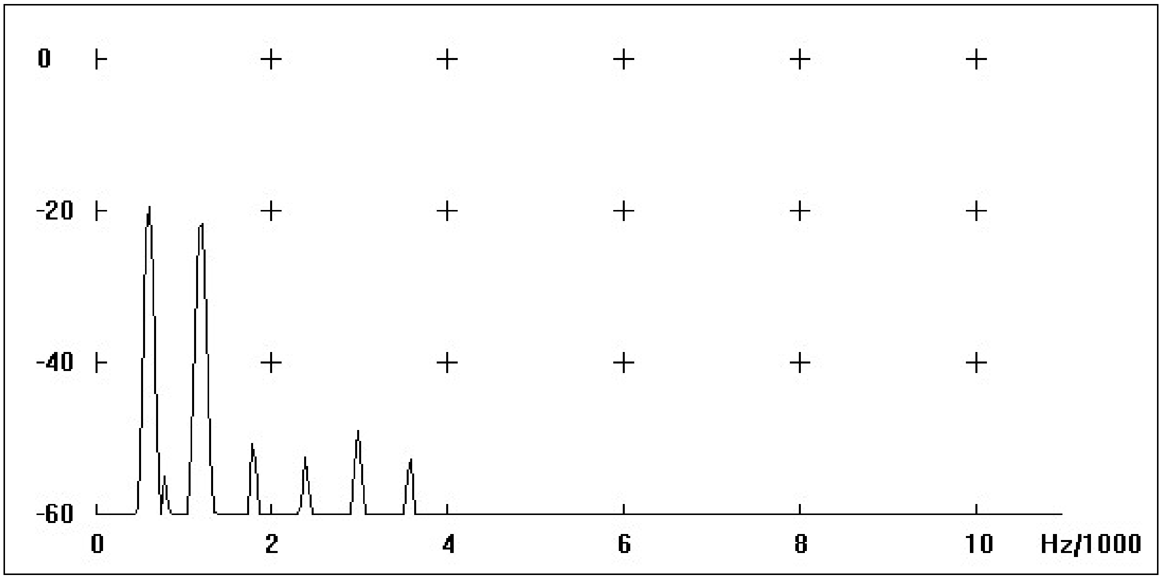
Power spectrum from Spectrogram #8, Subject #8 at 3.66 seconds [i]



Power spectrum from Spectrogram #8, Subject #8 at 5.08 seconds [o]

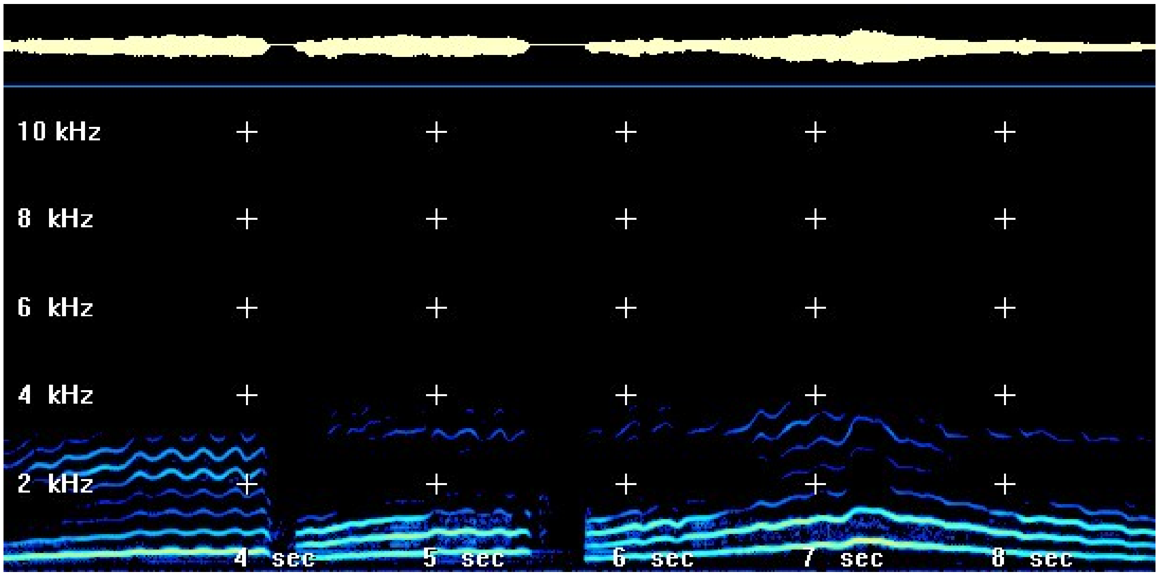


Power spectrum from Spectrogram #8, Subject #8 at 7.05 seconds [a]



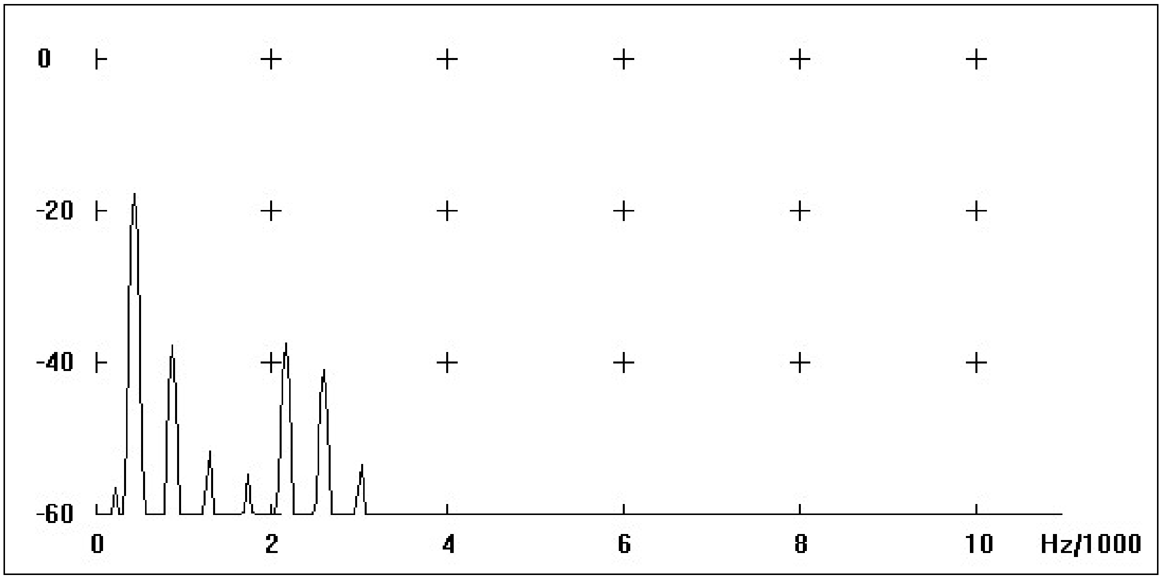
Analysis of Power Spectra from Spectrogram #8, Subject #8 – October 25, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.66	5	2	.4	3	8	.37	.38
5.08	6	2	.33	3	9	.33	.33
7.05	4	2	.5	3	7	.42	.46
Average of three chiaroscuro levels							.39

Wave File Number 9 – November 1, 2000 – Subject #8

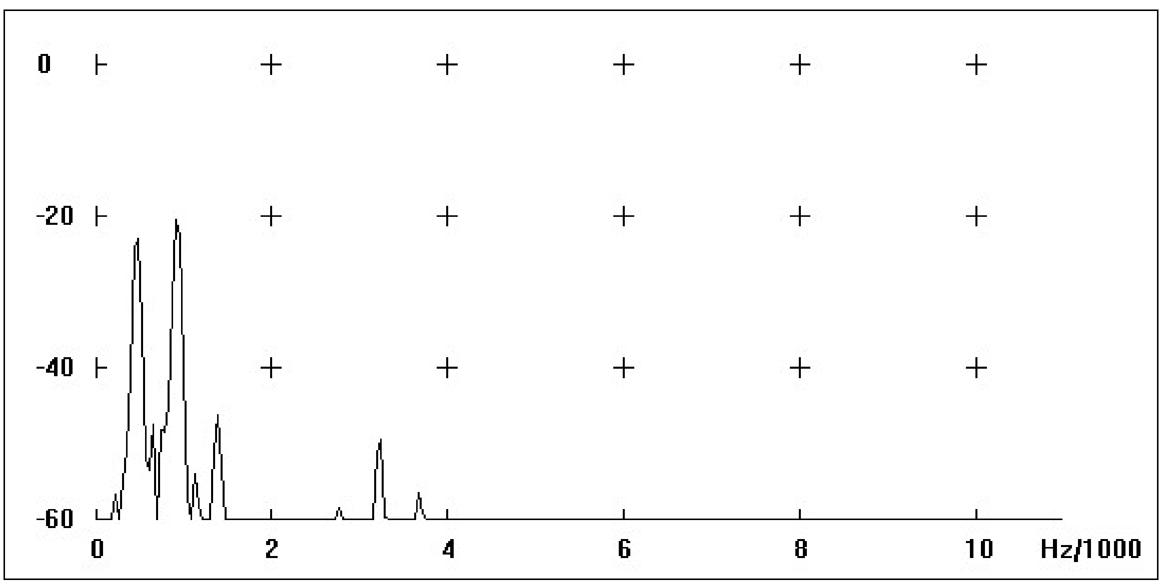


Subject #8 – Analysis of Wave File #9 – November 1, 2000 – D major				
		[si] (2.67-4.09 sec)	[o] (4.25-5.5 sec)	[a] (5.79-9.6 sec)
Singer's Formant Area	4000+ Hz			Beginning to approach this area
	2000-4000 Hz	Stronger and more consistent indications	Scattered indications	Stronger and more consistent indications
2^{nd} Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1^{st} Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Better balanced	Better balanced	Better balanced – more lower frequency equalization at high pitches
Power Spectrum		Increase from about 10% to about 25%	Varying around 25%	<> from about 10% to about 40%
This example shows improved sense of balancing upper and lower frequencies.				

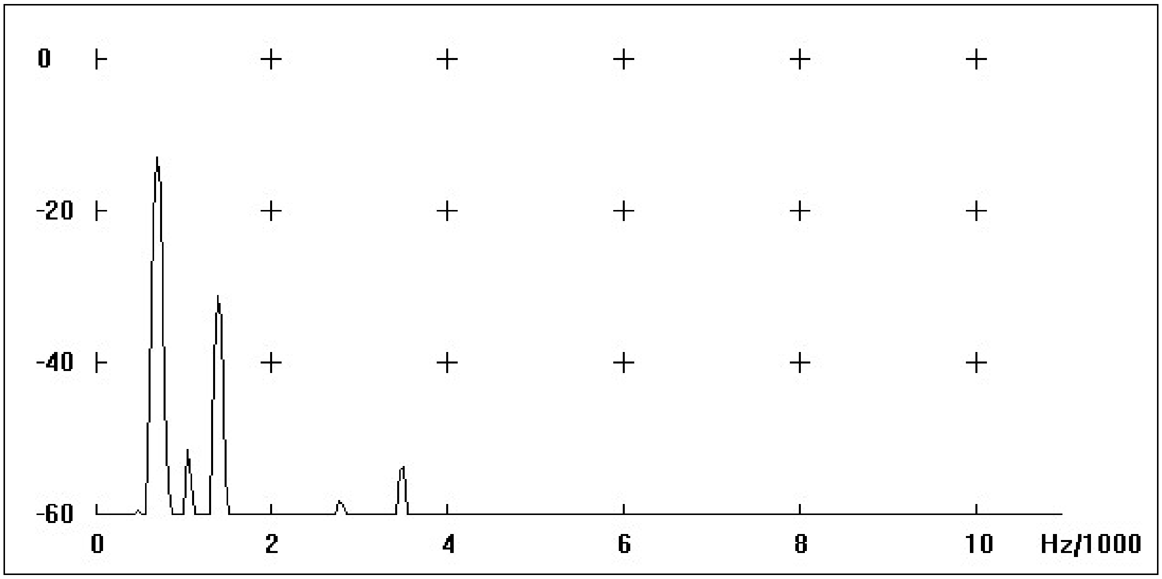
Power spectrum from Spectrogram #9, Subject #8 at 3.67 seconds [i]



Power spectrum from Spectrogram #9, Subject #8 at 5.18 seconds [o]

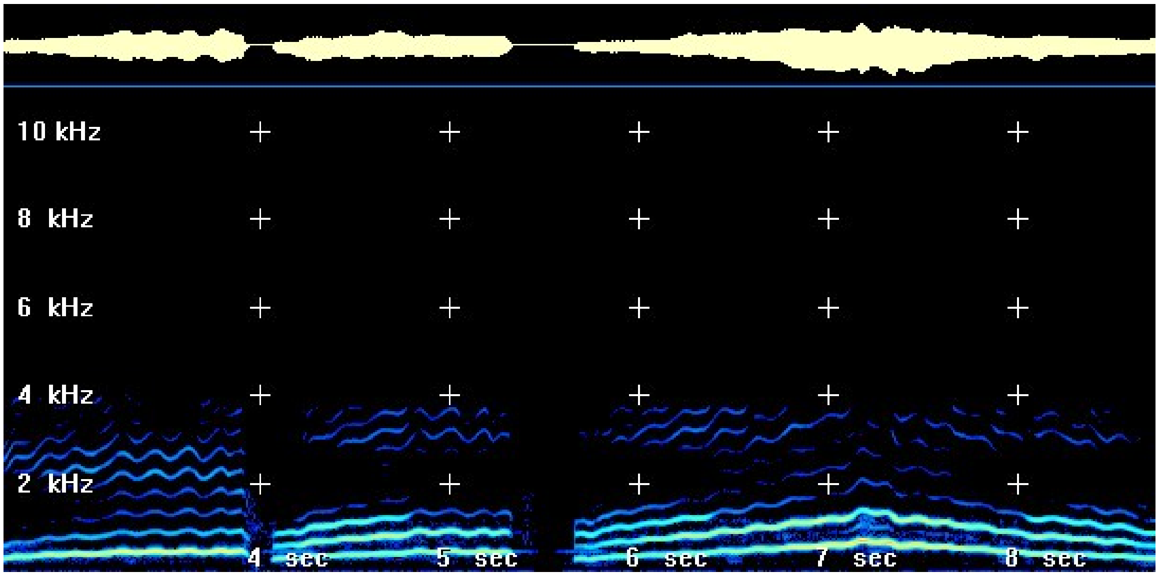


Power spectrum from Spectrogram #9, Subject #8 at 7.28 seconds [a]



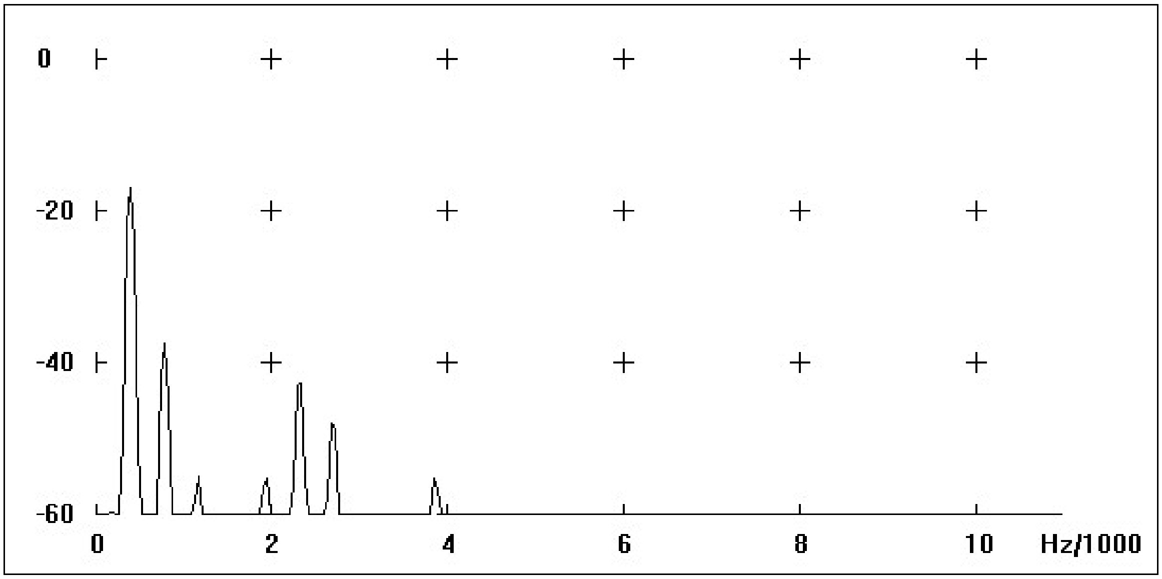
Analysis of Power Spectra from Spectrogram #9, Subject #8 – November 1, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.67	5	2	.4	3	8	.37	.38
5.18	6	2	.33	3	9	.33	.33
7.28	4	2	.5	2	6	.33	.41
Average of three chiaroscuro levels							.37

Wave File Number 10 – March 13, 2001 – Subject #8

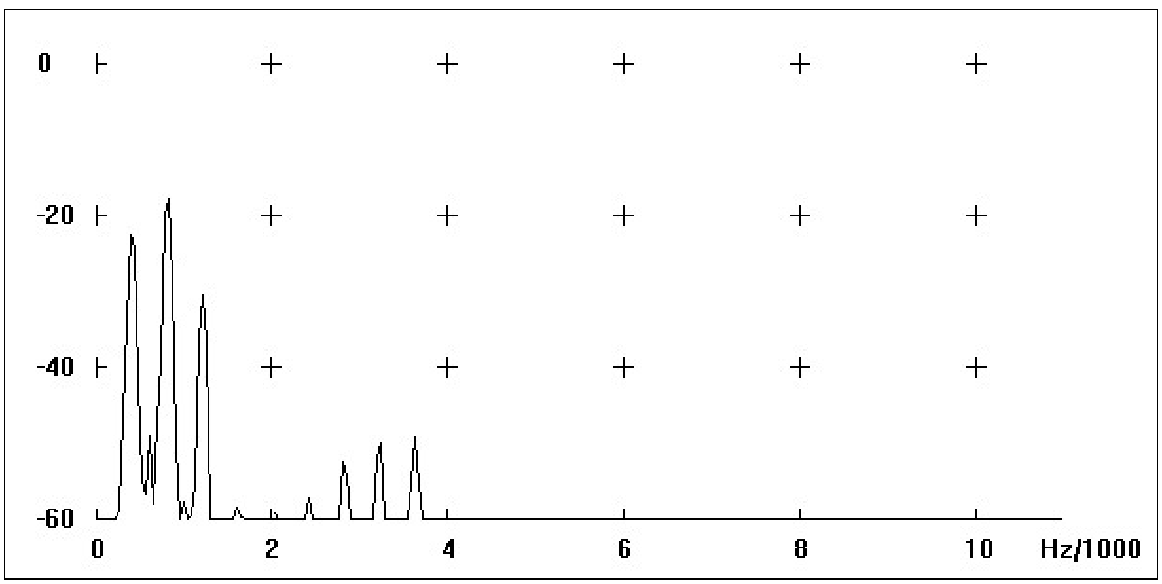


Subject #8 – Analysis of Wave File # 10 – March 13, 2001 – D major				
		[si] (2.6-3.8 sec)	[o] (4.07-5.31 sec)	[a] (5.68-9.5 sec)
Singer's Formant Area	4000+ Hz			Continues to approach this area
	2000-4000 Hz	Strong and consistent	Stronger and more consistent	Stronger and more consistent
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Better balance	Better balanced
Power Spectrum		Increases from about 10% to about 40%	Varying around 30%	<> from about 10% to about 505
The gap from November to March was caused by one of Subject #8's wave files being lost in transit. The March wave file was made after she had quite successfully completed her senior recital and taken about four weeks off from voice lessons. The relaxation in the voice is visible as stronger frequency indications and a more even vibrato.				

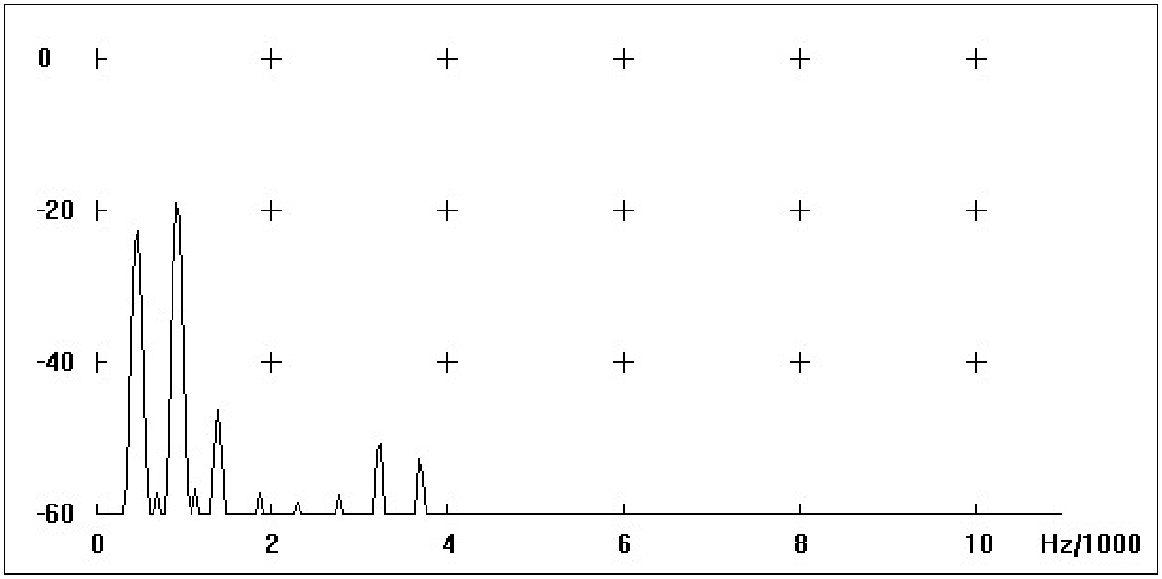
Power spectrum from Spectrogram #10, Subject #8 at 3.08 seconds [i]



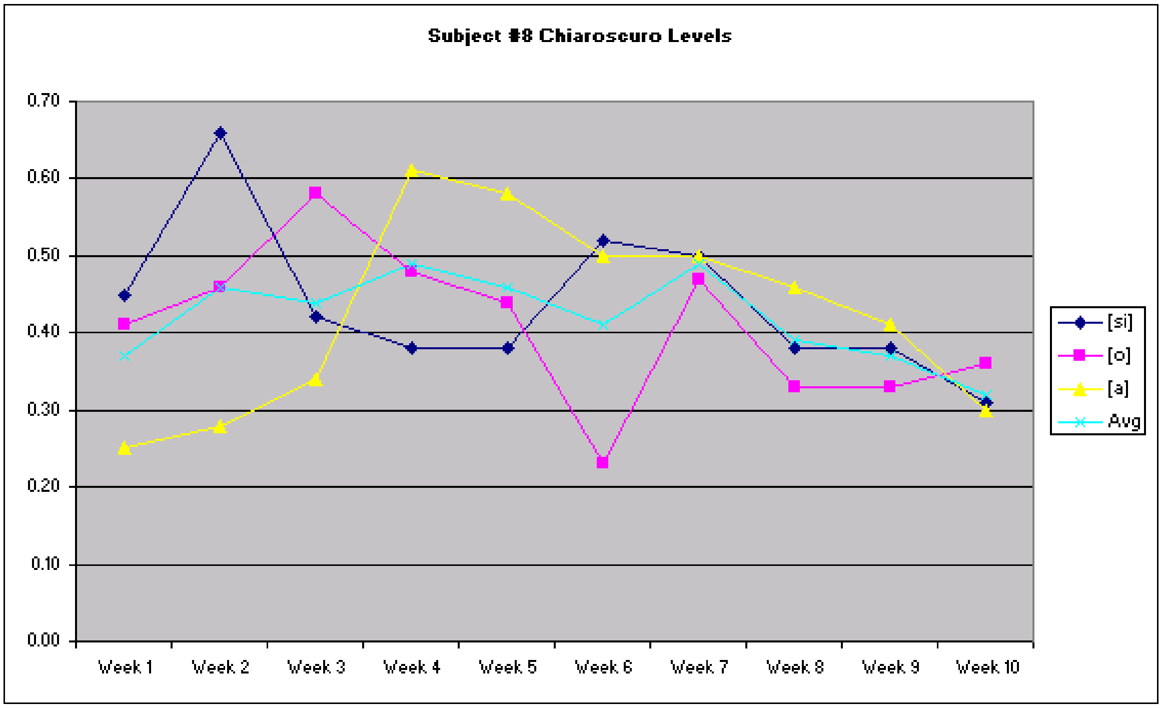
Power spectrum from Spectrogram #10, Subject #8 at 4.67 seconds [o]



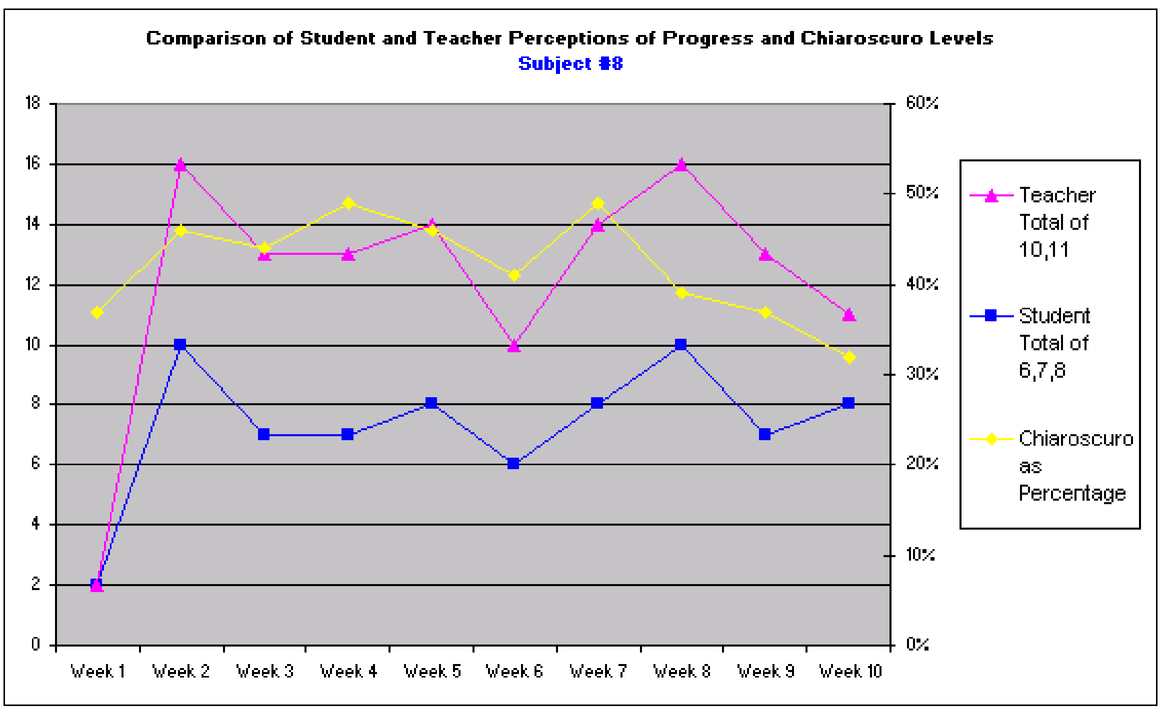
Power spectrum from Spectrogram #10, Subject #8 at 6.47 seconds [a]



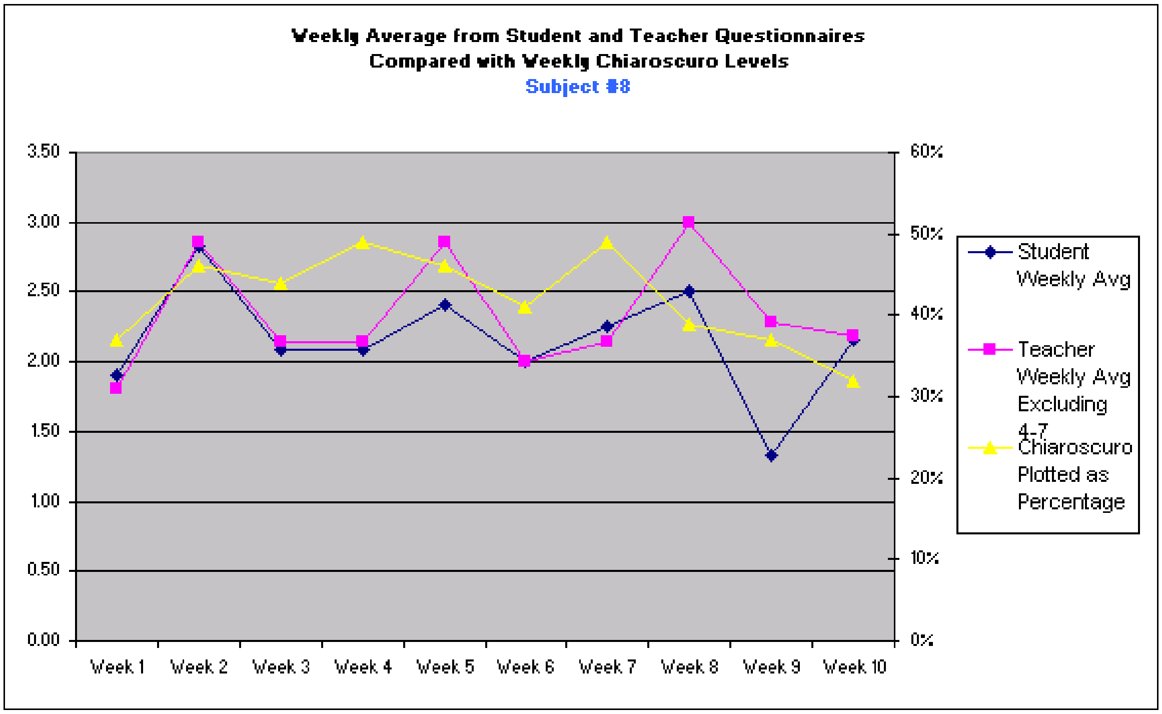
Analysis of Power Spectra from Spectrogram #10, Subject #8, March 13, 2001							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area $\geq$ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks $\geq$ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.08	8	2	.25	3	8	.37	.31
4.67	11	3	.27	5	11	.45	.36
6.47	10	2	.20	4	10	.40	.30
Average of three chiaroscuro levels							.32



Subject #8 Chiaroscuro Levels
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg



Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #8
18
16
14
12
10
8
6
4
2
0
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #8
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

Appendix A9: Subject #9

Subject #9 was a 21-year-old Caucasian senior majoring in musical theatre. She was from Atlanta. During the semester in which data were gathered, she had a leading role in a musical production featuring the music of George Gershwin. She was also was researching her senior thesis project, in which she planned to use music of the 1940's. She had a bout with bronchitis during the semester, but otherwise was healthy.

At the time of the data collection she had been a student in the researcher's studio for two years. When she first entered, her vocal production was very insecure. An excellent actor and dancer, she had almost no musical training and found learning music accurately quite difficult. She attacked the problem of musical training by taking freshman theory and ear training.

Her vocal progress was slow during the first year because she was convinced that the only vocal styles available to her were Broadway-style "belting" and several rock music styles that she had learned from recordings. Fortunately her "belting" style was basically healthy, and her voice was naturally large. Over the next year she moved from her restricted popular vocal styles into a more lyric vocal style, which she gradually accepted as her normal vocal production. She did not lose the ability to "belt" in the style that is currently accepted on Broadway, but she enlarged her abilities along with her range and expressive possibilities. The summer between her junior and senior years she was hired to work in summer stock in a production in Kansas, and she returned much more confident of her vocal abilities.

Subject #9's voice was a warm lyric mezzo-soprano with a two-octave range from a to a^2, and her vocal production was even throughout that range. She was beginning to use her g^2 and a-flat^2 with confidence and to use her a^2 and b-flat^2 without tightening her throat. Her musicianship had improved, and she no longer lost control when she made a pitch error in a melody. She showed every sign of becoming a true musical theatre "triple threat": an actor who can both sing and dance with skill.

The spectrograph was a revelation to Subject #9. Having for so long considered herself to be a second-class singer, she was astounded to see the spectrograph screen displaying a full and resonant sound. Since the spectrograph is neutral as to style, it showed her solid and resonant sound without reference to whether she was singing classical or Broadway vowels. She seemed to have gained self-confidence from having technological evidence that she was making a good sound.

Lesson record over the data collection period – Subject #9

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, 8; Teacher Questions 10-11
8/25	B	Gershwin Audition repertoire	Good	Much angst over upcoming audition – vocally in excellent shape after summer stock success in Kansas	#1 E-flat	Chiaroscuro - .42 Student – n/a, n/a, 1 Teacher n/a, n/a
9/1	B	Gershwin	On time – otherwise in terrible shape, except vocally	Receiving many mixed messages from GTA – confused, frustrated – wishes she had stayed in Kansas – advised asking for chance to read for the part she wants	#2 D	Chiaroscuro - .54 Student – 1, 2, 1 Teacher – 2, 2
9/8	B	Someone Else's Story; How Could I Ever Know	Good	Voice is in good shape – deeply disappointed about GTA show, but determined to behave well – beginning work on a thesis recital	#3 E-flat	Chiaroscuro - .52 Student – 1, 1, 1 Teacher – 2, 3
9/15	B	Gershwin and last week's music	Okay	She is starting to thing about a thesis project – needs to change focus from GTA	#4 E-flat	Chiaroscuro - .48 Student – 1, 1, 1 Teacher – 3, 3
9/22	B	Same music	Okay	Not very rapid progress – working on theme for thesis – maybe big band singers	#5 E-flat	Chiaroscuro - .71 Student – 1, 1, 1 Teacher – 3, 3
9/29	B	Same music	Okay	New idea for thesis: USO – hope she'll have the date or music soon	#6 E-flat	Chiaroscuro - .51 Student – 2, 1, 1 Teacher – 3, 3
10/6	B	Same music	Okay	Voice is in excellent shape – She's involved with the show and not doing much else	#7 E-flat	Chiaroscuro - .54 Student – 1, 1, 1 Teacher – 3, 3
10/13	B	Music lost in family move has turned up – maybe some progress	Very sick, but not stopping for anything	Not much teaching possible – she is coming down with a major cold	#8 C & E-flat	Chiaroscuro - .58 Student – 4, 4, 1 Teacher – 4, 4
10/20			Sick	Lesson cancelled - bronchitis		
10/27			Still sick	Lesson cancelled		
11/10	B	Read through rep	Voice weak but recovering	Working on getting her music together for thesis project – testing out songs	#9 E-flat	Chiaroscuro - .45 Student – 1, 1, 1 Teacher – 3, 3
11/17	B	Read through rep	Voice nearly back	Same thing	#10 E-flat	Chiaroscuro - .70 Student – 2, 1, 1 Teacher – 3, 3

Responses to student questionnaires – Subject #9

Question	8/25	9/1	9/8	9/15	9/22	9/29	10/6	10/13	11/10	11/17	**Total of weekly answers to questions 6. 7. 8**
1	2	2	1	1	1	2	1	3	1	1	
2	2	2	1	1	2	2	2	3	2	2	
3	1	3	1	2	2	2	2	1	2	1	
4	1	1	1	1	1	1	1	2	1	1	
5	1	1	1	1	1	1	1	2	1	1	
6	N/A	1	1	1	1	2	1	4	1	2	1.55
7	N/A	2	1	1	1	1	1	4	1	1	1.44
8	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	**Average over ten week period**
10	1	1	1	1	1	1	1	1	1	1	
11	1	2	2	1	1	1	1	1	1	1	
12	1	1	1	1	1	1	1	1	1	1	
Weekly average	1.2	1.5	1.08	1.08	1.25	1.33	1.16	2	1.07	1.07	**1.44**

Responses to teacher questionnaires – Subject #9

Quantification of the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)

2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)

3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)

4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)

5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

Question	8/25	9/1	9/8	9/15	9/22	9/29	10/6	10/13	11/10	11/17	**Total and Average of questions 10 & 11**
1	2	2	2	2	2	2	2	2	2	2	
2	1	4	2	2	2	2	1	4	2	2	
3	2	3	2	2	2	2	2	3	2	2	
4	2	3	2	3	3	3	4	5	3	5	
5	4	5	5	5	4	5	4	5	5	5	
6	2	5	4	5	5	5	4	5	3	4	
7	5	5	5	5	5	5	5	5	5	5	
8	1	2	2	2	2	2	2	2	2	2	
9	2	5	2	3	2	2	2	2	3	4	
10	N/A	2	2	3	3	3	3	4	3	3	2.88
11	N/A	2	3	3	3	3	3	4	3	3	3
Weekly average excluding questions 4-7	1.6	2.85	2.14	2.42	2.28	2.28	2.14	3	2.42	2.57	**2.94**

Student's Written Response to Use of Spectrograph – Subject #9

The Spectrograph

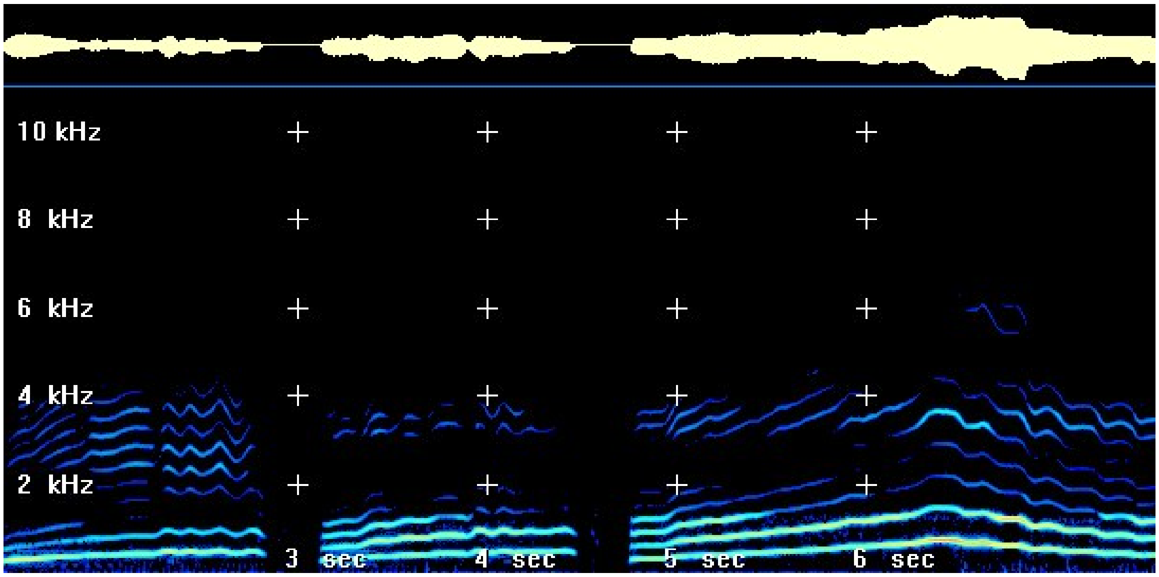
I have found the spectrograph to be very helpful and a learning experience in my weekly voice lessons. I have found my voice and the overall tone have improved during the past ten weeks. The spectrograph helps one to see their voice on the screen, every tone, word, even cough in some instances, show up and you can see exactly what your throat and voice are doing during those different cases.

The part that I found most interesting was the power bar at the top of the screen. It was a yellow line that would travel with the rest of the screen, but this would show how much power your voice was putting out. I personally liked this feature, because sometimes I was told I would sing softly and I could not understand why, but, from watching the power bar, it helped me understand, where I was soft and where I was not.

Another great part about this project was the wave files. It was wonderful to go back and listen to the wave files from the beginning of the project to the ones that were done just a couple of weeks ago. It is always nice to be told that you have made improvement, but to actually have the chance to hear it is wonderful. The best part would have to be the actual viewing of the voice and its progress. It is always wonderful to have documentation of your progress, and the spectrograph was not only a great learning tool, but documentation as well.

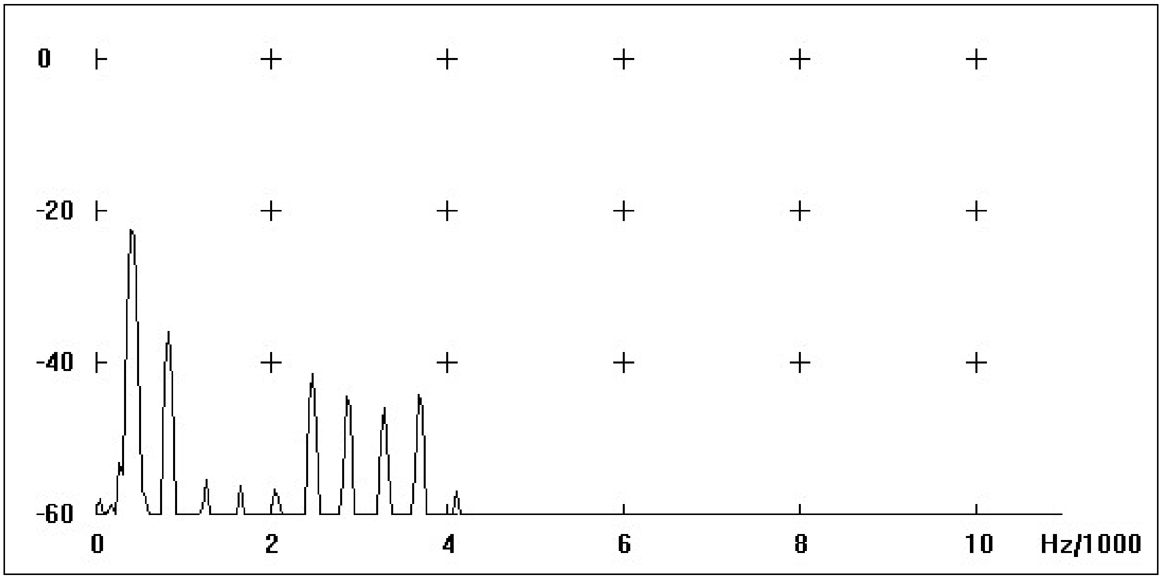
Analysis of Wave Files

Wave File Number 1 – August 25, 2000 – Subject #9

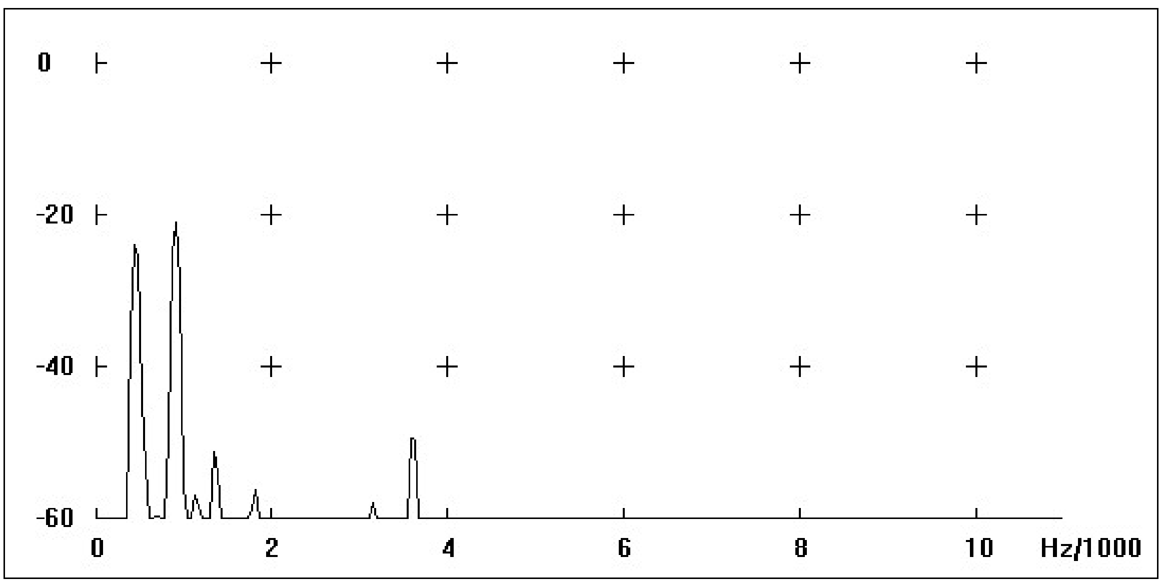


Subject #9 – Analysis of Wave File #1 – August 25, 2000 – E flat major				
		[si] (1.48-2.78 sec)	[o] (3.13-4.45 sec)	[a] (4.77-8.43 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area		Scattered indications
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Well balanced
Power Spectrum		Varying around 25%	Varying around 25%	<> from about 20% to about 90%
This young singer uses a bright vocal production to accomplish the needs of a musical theater performance without destructive belting. Because she adds extra first formant strength when she enters the 4000+ Hz area, her sound continues to be well balanced. She sings with the stylistically correct nearly straight tone, but one notes the quick vibrato on held notes at the ends of phrases, possibly due to release muscular tension required to hold the larynx for a straight tone.				

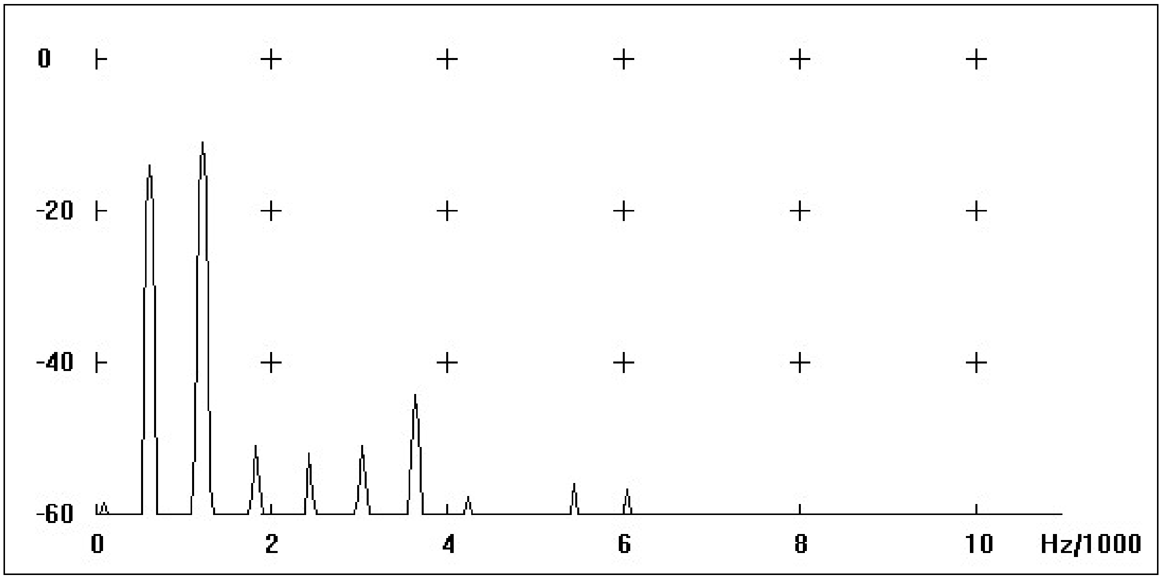
Power Spectrum from Spectrogram #1, Subject #9 at 2.13 seconds [i]



Power Spectrum from Spectrogram #1, Subject #9 at 4.15 seconds [o]

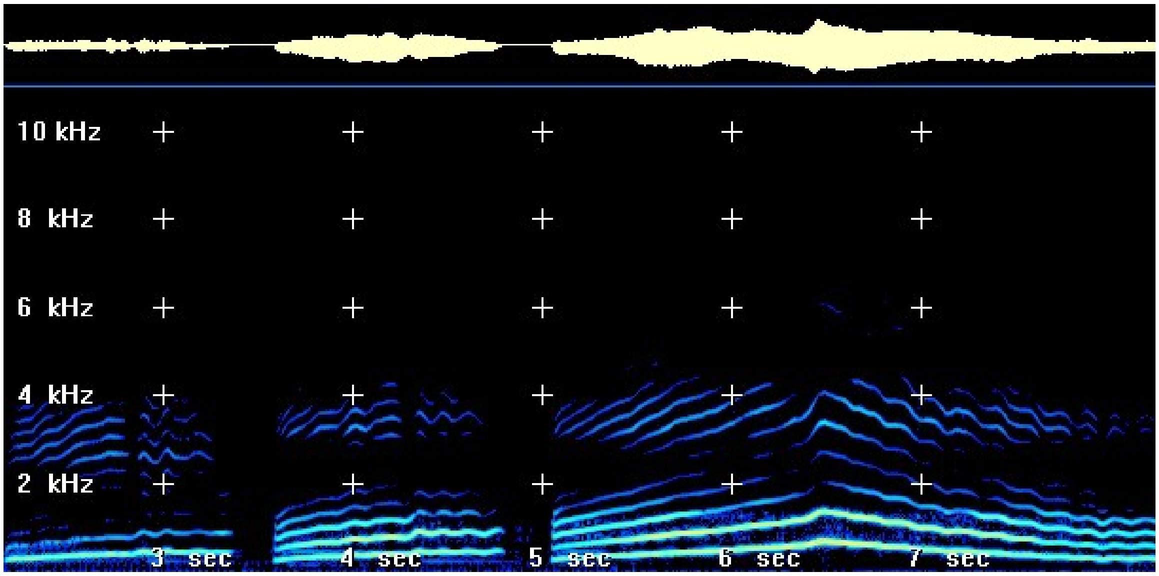


Power Spectrum from Spectrogram #1, Subject #9 at 6.77 seconds [a]



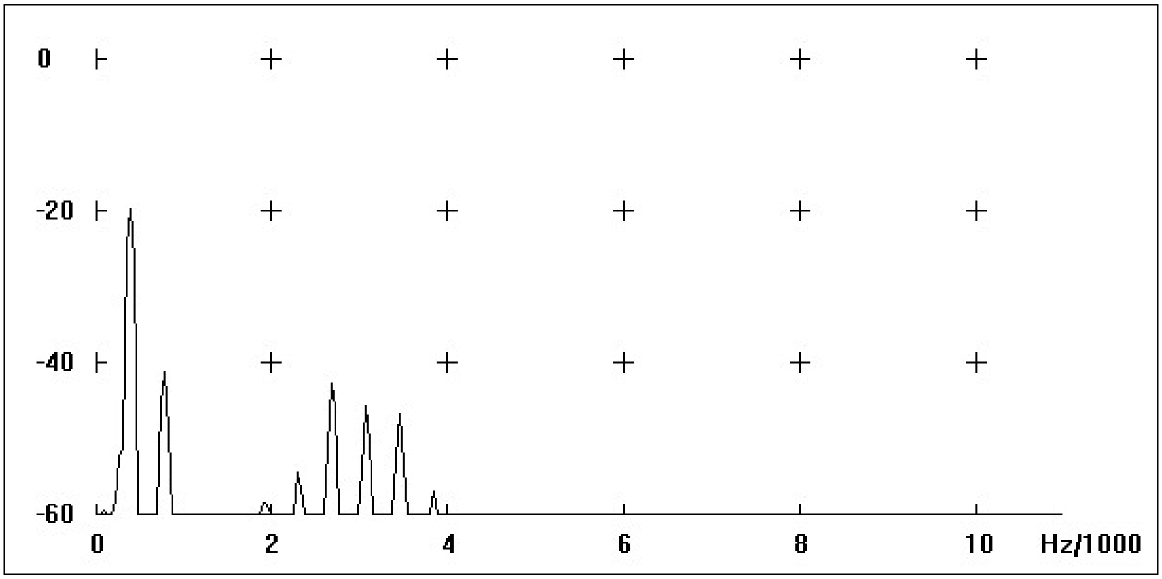
Analysis of Power Spectra from Spectrogram #1, Subject #9 – August 25, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.13	7	2	.28	6	13	.46	.37
4.15	5	2	.4	2	7	.28	.34
6.77	4	2	.5	6	10	.6	.55
Average of three chiaroscuro levels							.42

Wave File Number 2 – September 1, 2000 – Subject #9

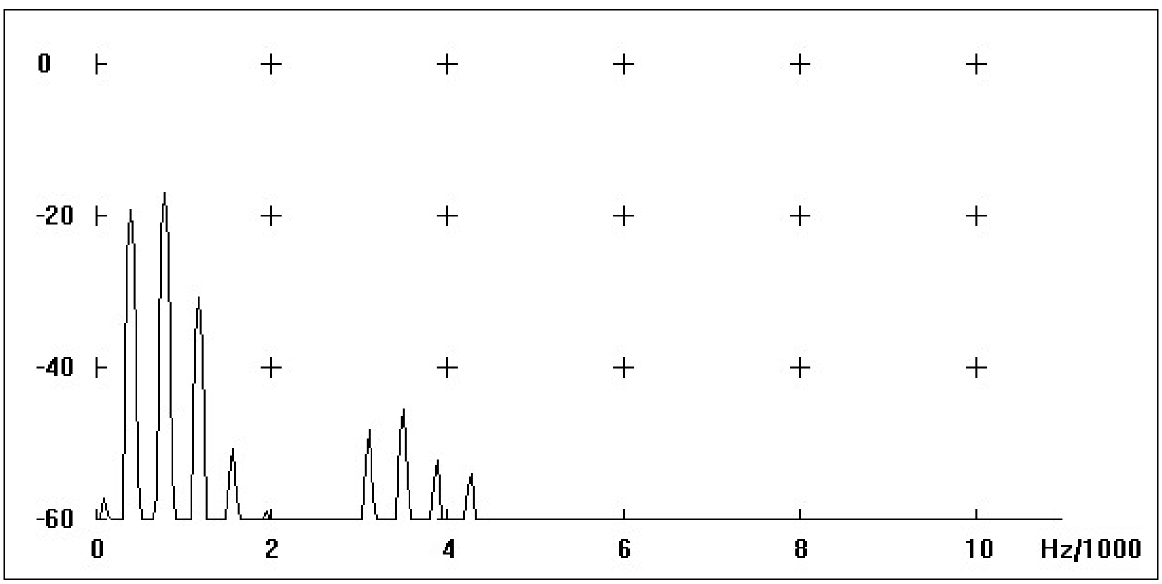


Subject #9 – Analysis of Wave File #2 – September 1, 2000 – D major				
		[si] (2.19-3.34 sec)	[o] (3.59-4.78 sec)	[a] (5.06-8.56 sec)
Singer's Formant Area	4000+ Hz		Entering this area	Entering this area
	2000-4000 Hz	Solid indications	Solid indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 10%	<> from about 10% to about 30%	<> from about 10% to about 70%
Some of the sudden increases in the power spectrum come from audible sudden increases in air pressure.				

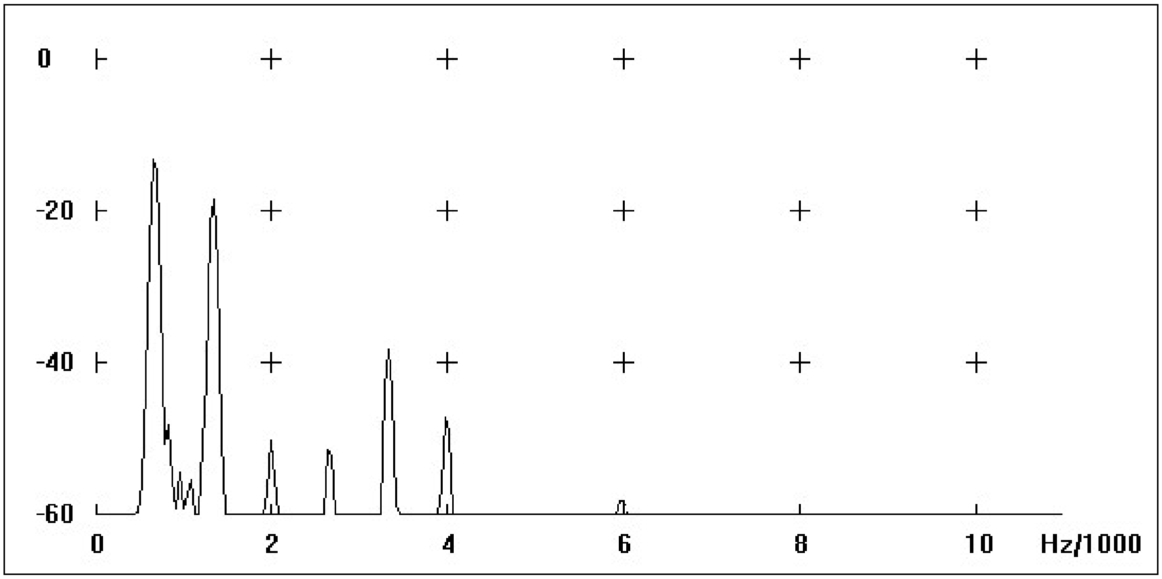
Power Spectrum from Spectrogram #2, Subject #9 at 2.72 seconds [i]



Power Spectrum from Spectrogram #2, Subject #9 at 4.2 seconds [o]

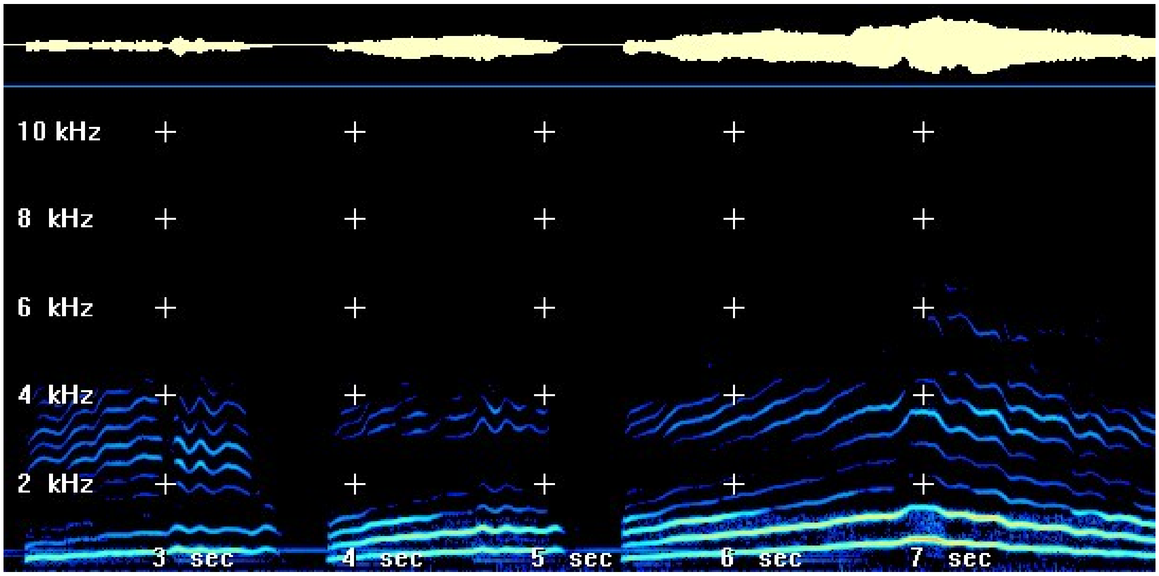


Power Spectrum from Spectrogram #2, Subject #9 at 6.55 seconds [a]



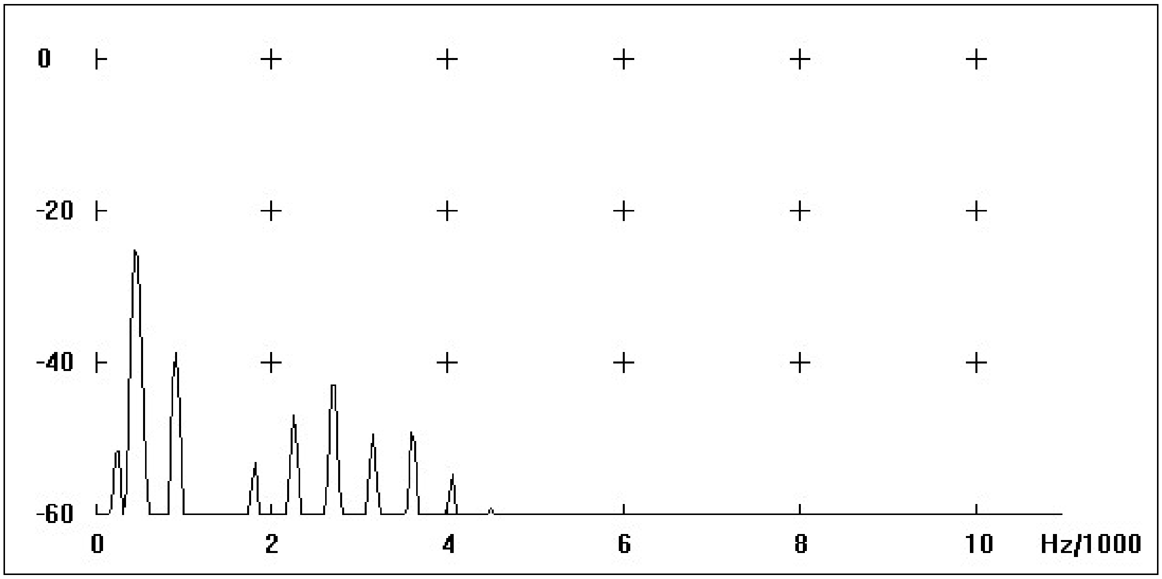
Analysis of Power Spectra from Spectrogram #2, Subject #9 – September 1, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.72	3	2	.66	5	8	.62	.64
4.2	5	3	.6	5	10	.5	.55
6.55	5	2	.4	5	10	.5	.45
Average of three chiaroscuro levels							.54

Wave File Number 3 – September 8, 2000 – Subject #9

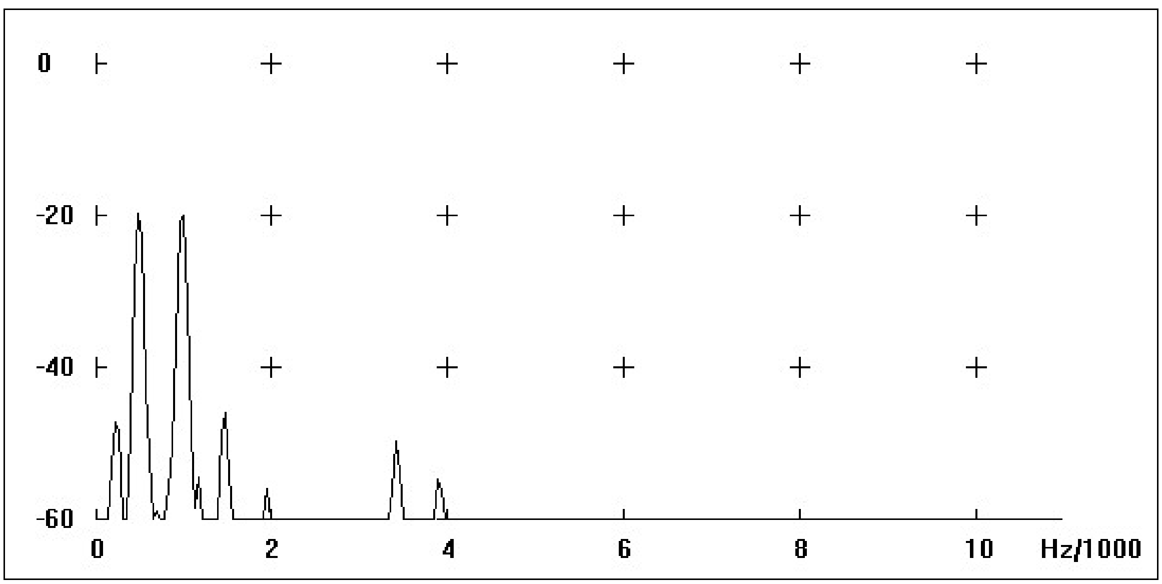


Subject #9 – Analysis of Wave File #3 – September 8, 2000 – E flat major				
		[si] (2.27-3.61 sec)	[o] (3.83-5.09 sec)	[a] (5.42-9.08 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Indications at highest pitches
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		Varying around 15%	<> from about 10% to about 25%	<> from about 20% to about 90%
Well balanced voice with solid beginnings of phrases: all frequencies beginning together				

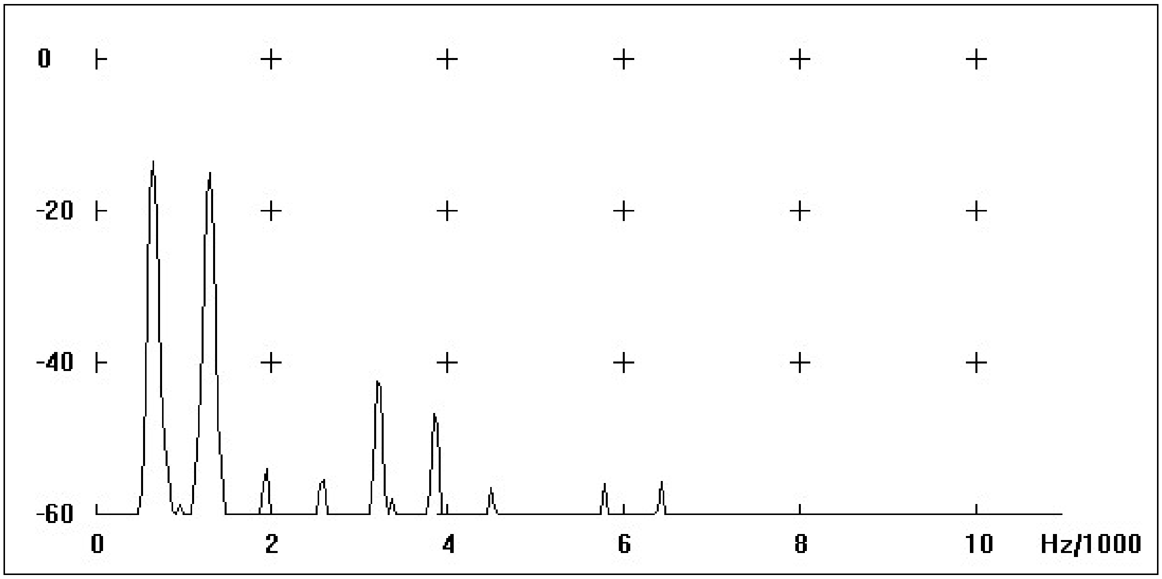
Power Spectrum from Spectrogram #3, Subject #9 at 3.25 seconds [i]



Power Spectrum from Spectrogram #3, Subject #9 at 4.7 seconds [o]

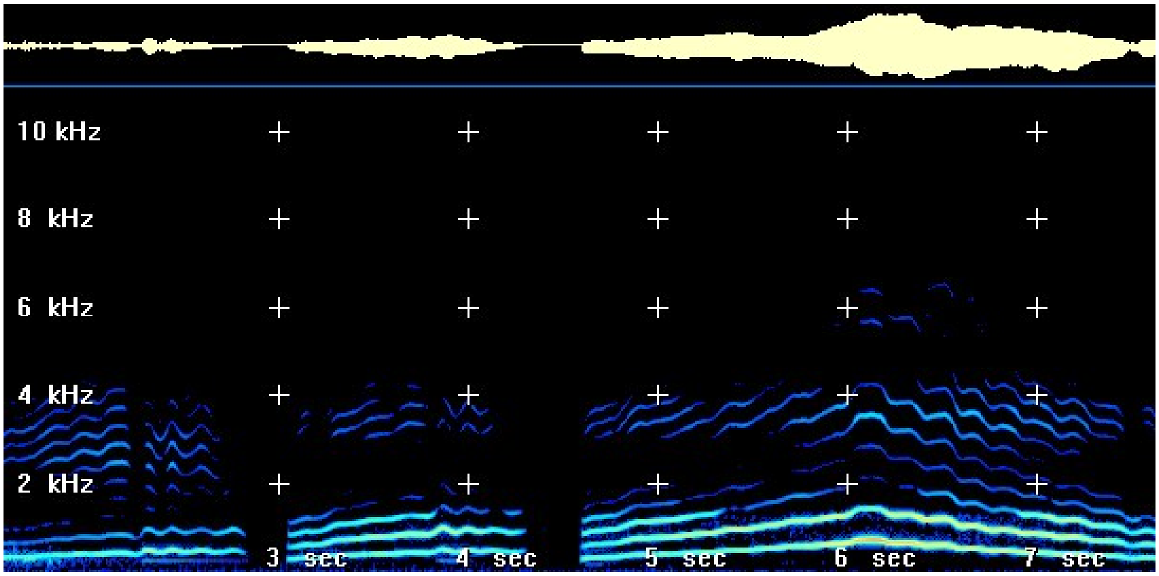


Power Spectrum from Spectrogram #3, Subject #9 at 7.15 seconds [a]



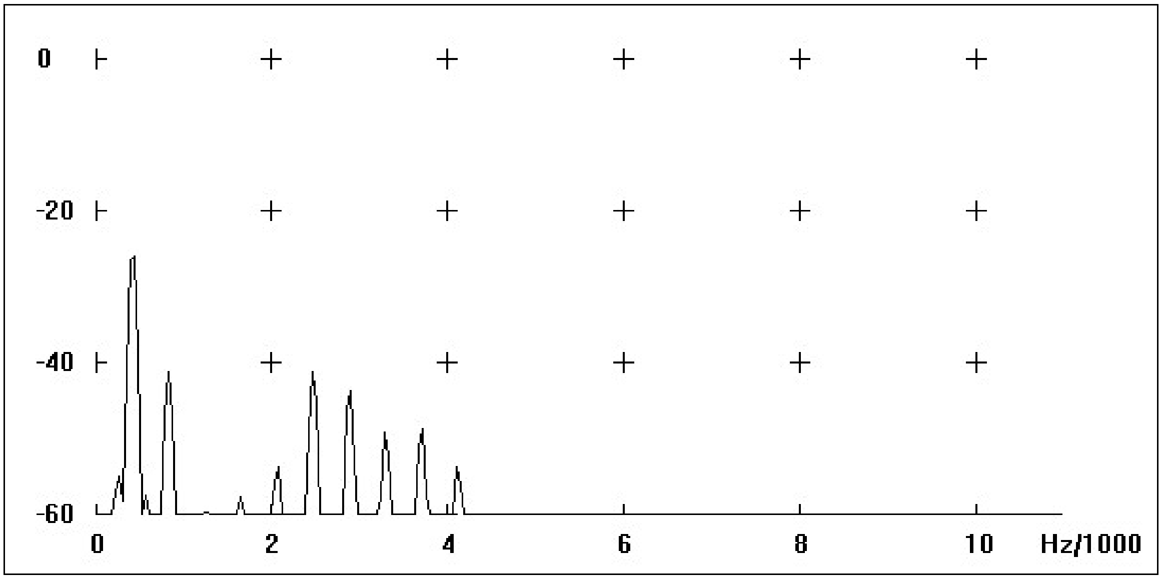
Analysis of Power Spectra from Spectrogram #3, Subject #9 – September 8, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.25	4	2	.5	6	10	.6	.55
4.7	6	2	.33	3	9	.33	.33
7.15	3	2	.66	8	11	.72	.69
Average of three chiaroscuro levels							.52

Wave File Number 4 – September 14, 2000 – Subject #9

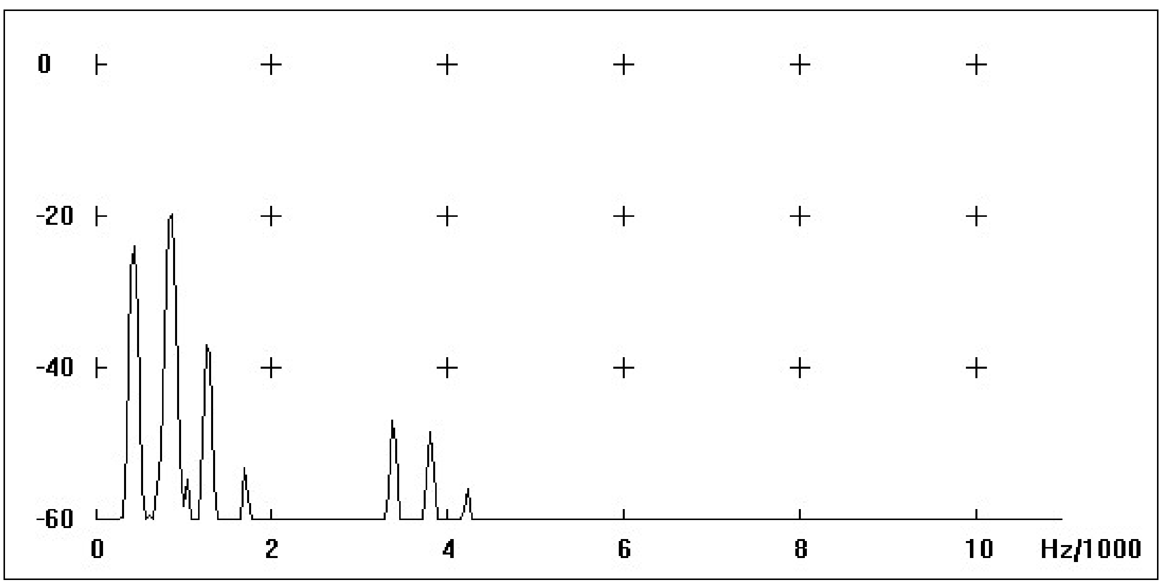


Subject #9 – Analysis of Wave File #4 – September 14, 2000 – E flat major				
		[si] (1.53-2.82 sec)	[o] (3.05-4.29 sec)	[a] (4.58-8.18 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Indications at highest pitches
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Well balanced
Power Spectrum		Varying around 10%	<> from about 10% to about 25%	<> from about 20% to about 90%
The consistency shown by this student is to be expected from a well-trained senior voice student.				

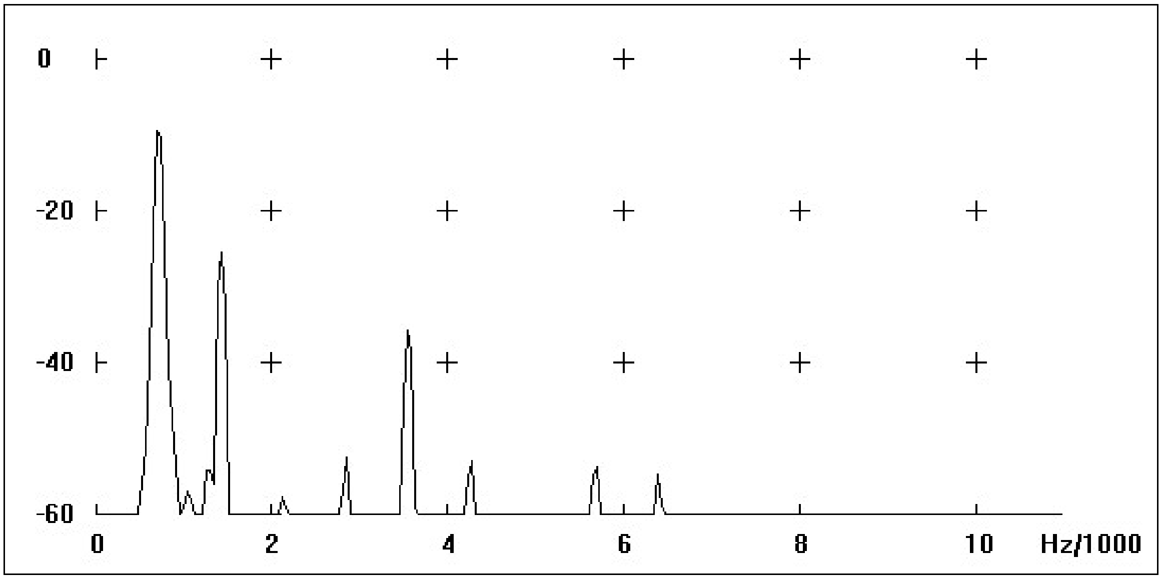
Power Spectrum from Spectrogram #4, Subject #9 at 2.13 seconds [i]



Power Spectrum from Spectrogram #4, Subject #9 at 3.7 seconds [o]

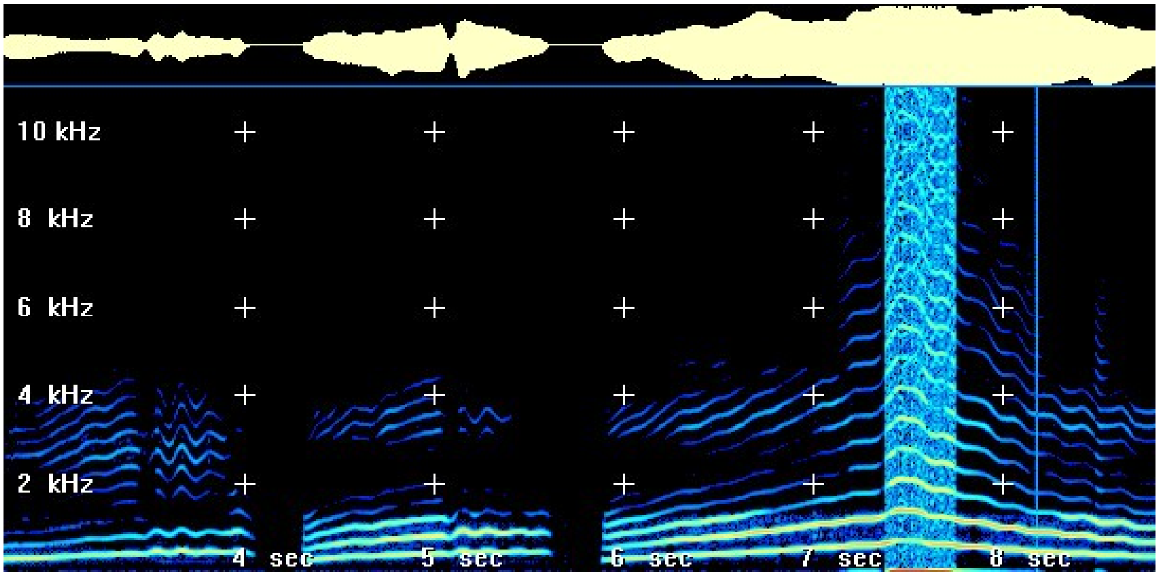


Power Spectrum from Spectrogram #4, Subject #9 at 6.12 seconds [a]



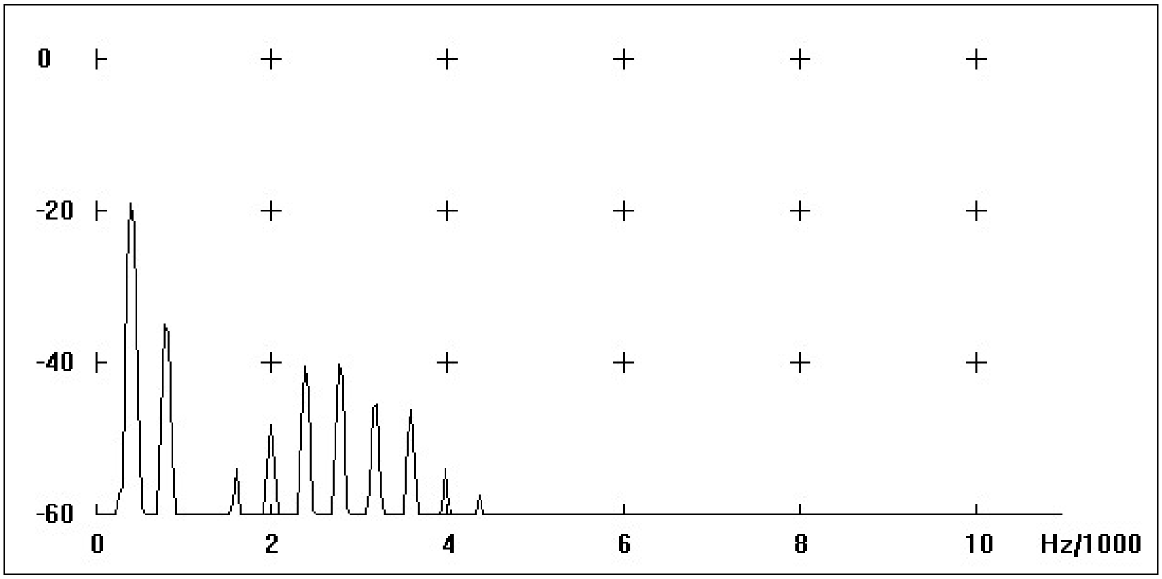
Analysis of Power Spectra from Spectrogram #4, Subject #9 – September 14, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.13	6	2	.33	6	12	.5	.41
3.7	5	3	.6	3	8	.37	.48
6.12	4	2	.5	6	10	.6	.55
Average of three chiaroscuro levels							.48

Wave File Number 5 – September 22, 2000 – Subject #9

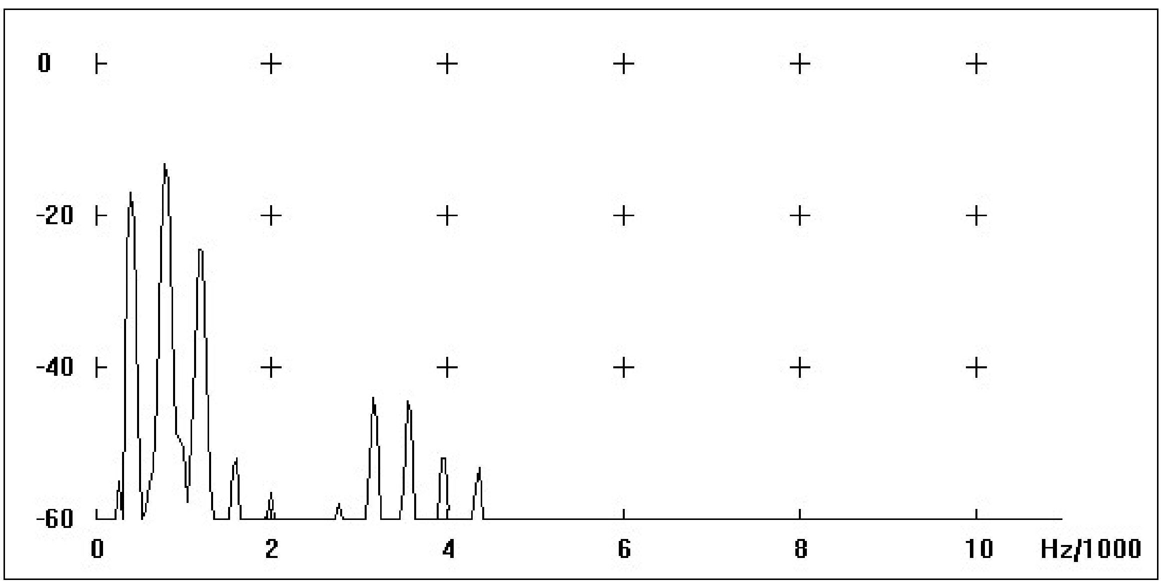


Subject #9 – Analysis of Wave File #5 – September 22, 2000 – D major				
		[si] (2.7-4.04 sec)	[o] (4.29-5.61 sec)	[a] (5.89-9.83 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Indications at highest pitches
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2^{nd} Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1^{st} Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Well balanced
Power Spectrum		Varying around 25% - note loss of power at 3.44 when an aspirated sound interrupted	<> from about 25% to about 75% - note loss of power at 5.08 when an aspirated sound interrupted	<> from about 30% to 100% - note loss of power at 8.9 when an aspirated sound interrupted
The noise between 7.4 and 7.8 seems to have been caused by the singer peaking the microphone. The vertical line at 8.19 is the "play window" cursor which has been inadvertently attached to the file.				

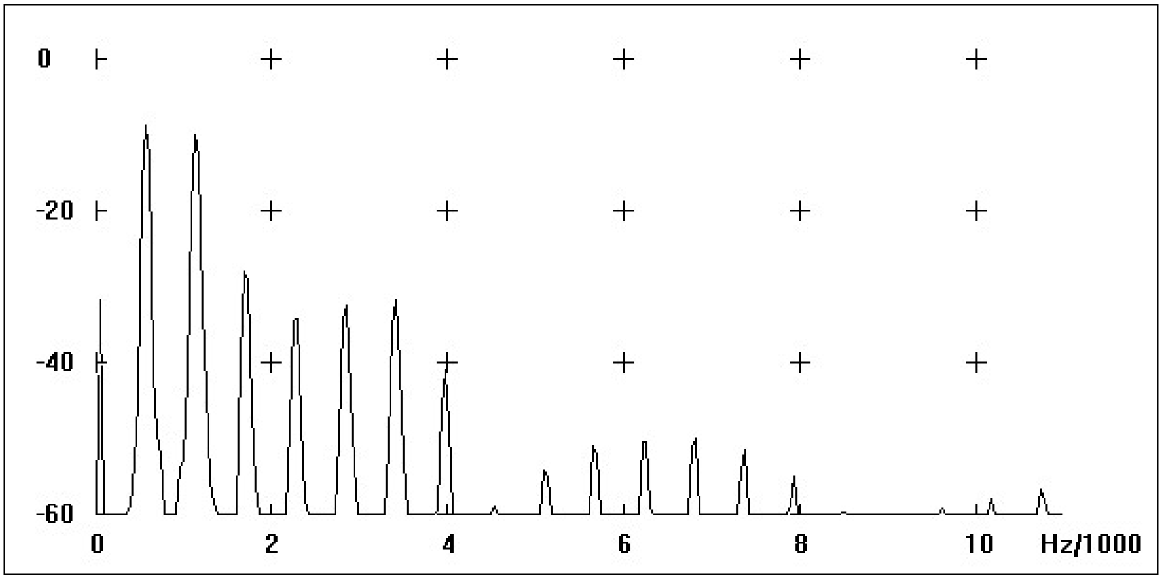
Power Spectrum from Spectrogram #5, Subject #9 at 3.38 seconds [i]



Power Spectrum from Spectrogram #5, Subject #9 at 4.98 seconds [o]

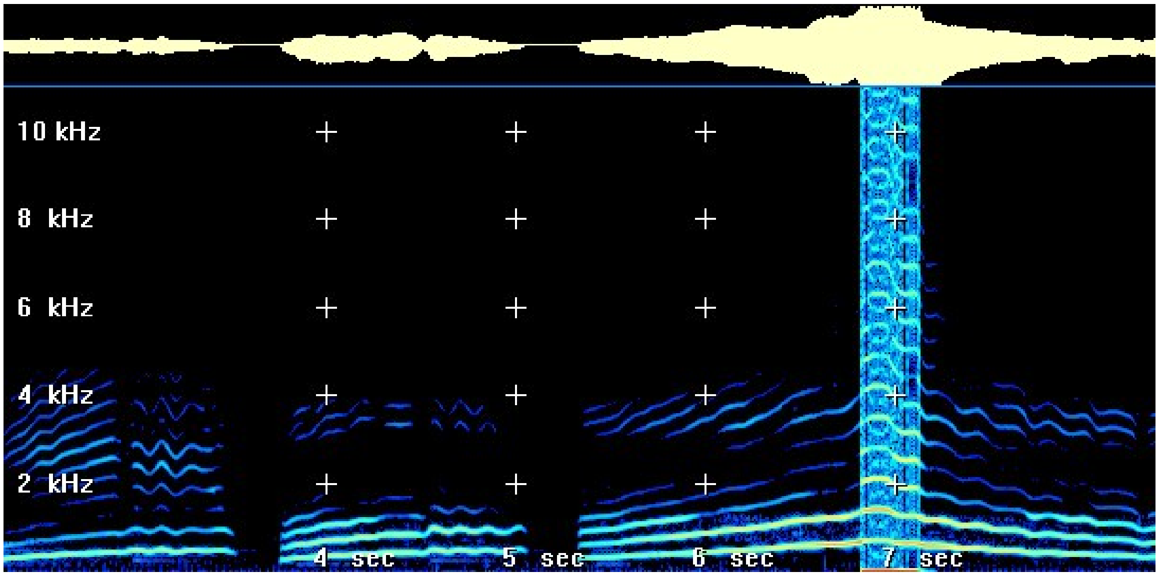


Power Spectrum from Spectrogram #5, Subject #9 at 7.81 seconds [a]



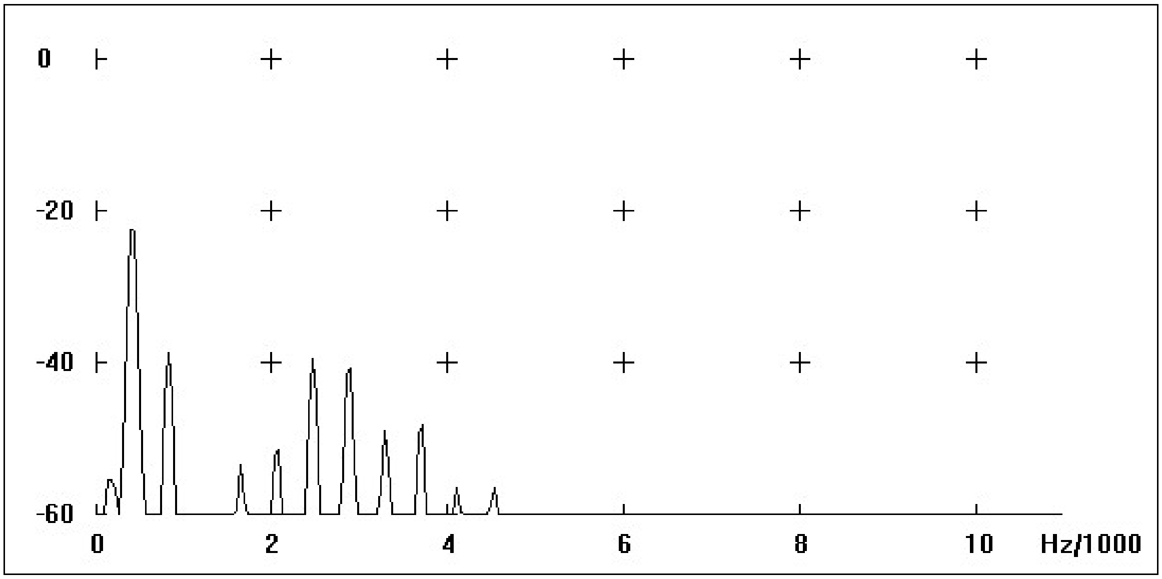
Analysis of Power Spectra from Spectrogram #5, Subject #9 – September 22, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.38	3	2	.66	7	10	.7	.68
4.98	5	3	.6	6	11	.54	.57
7.81	4	4	1.0	15	19	.78	.89
Average of three chiaroscuro levels							.71

Wave File Number 6 – September 29, 2000 – Subject #9

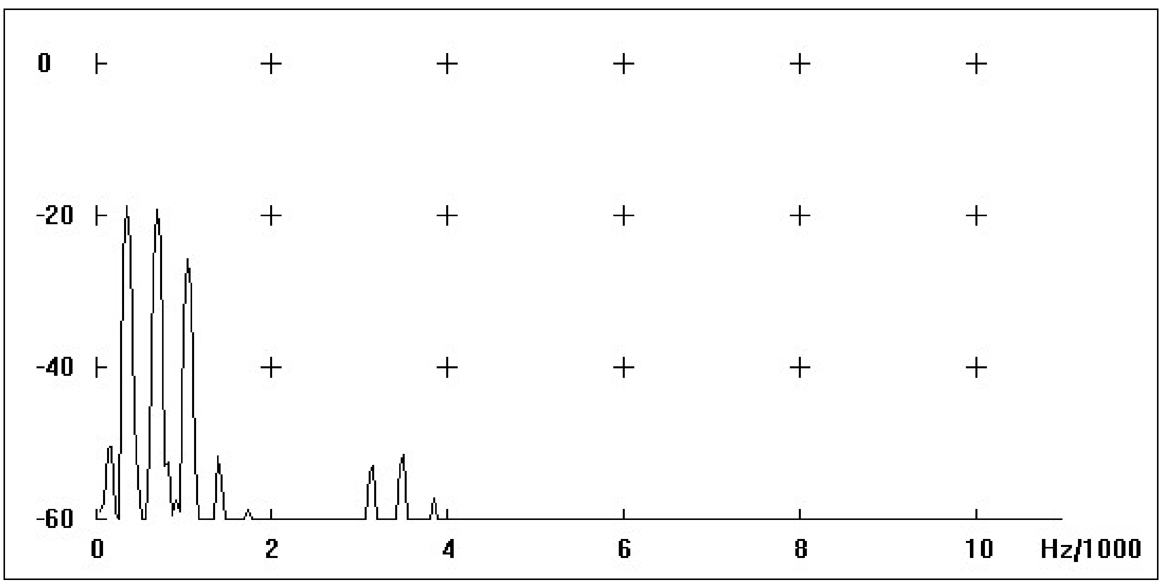


Subject #9 – Analysis of Wave File #6 – September 29, 2000 – E flat major				
		[si] (2.28-3.5 sec)	[o] (3.76-5.05 sec)	[a] (5.32-9.1 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Indications at highest pitches
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Well balanced
Power Spectrum		Varying around 15% - aspirated break at 2.9	Varying around 30% aspirated break at 4.5	<> from about 25% to 100%
Here again the singer has peaked the machine causing noise at 6.8 to 7.1.				

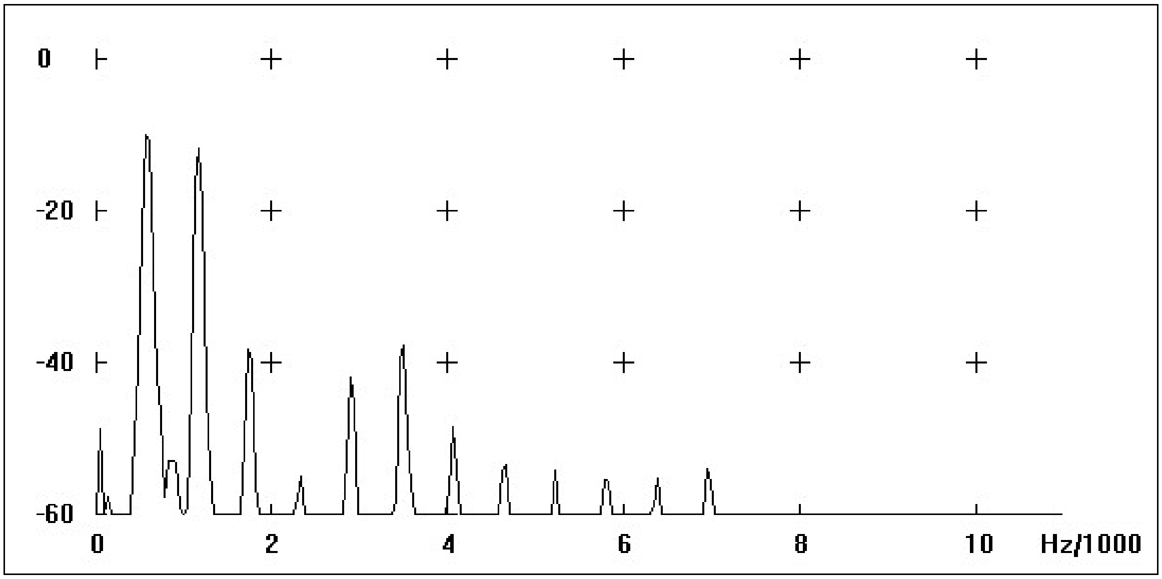
Power Spectrum from Spectrogram #6, Subject #9 at 2.77 seconds [i]



Power Spectrum from Spectrogram #6, Subject #9 at 4.0 seconds [o]

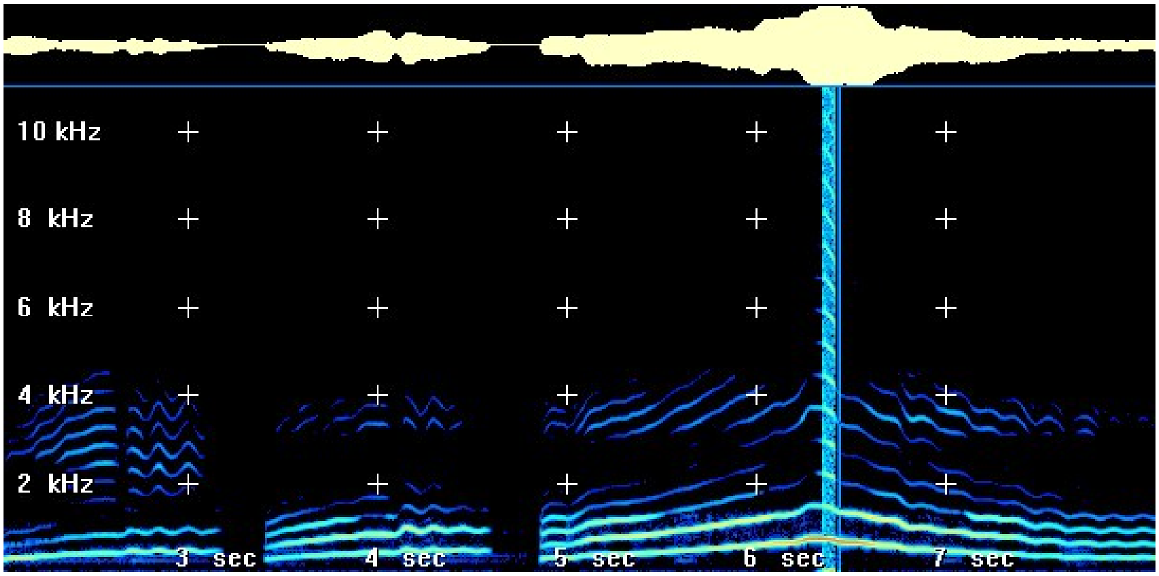


Power Spectrum from Spectrogram #6, Subject #9 at 7.2 seconds [a]



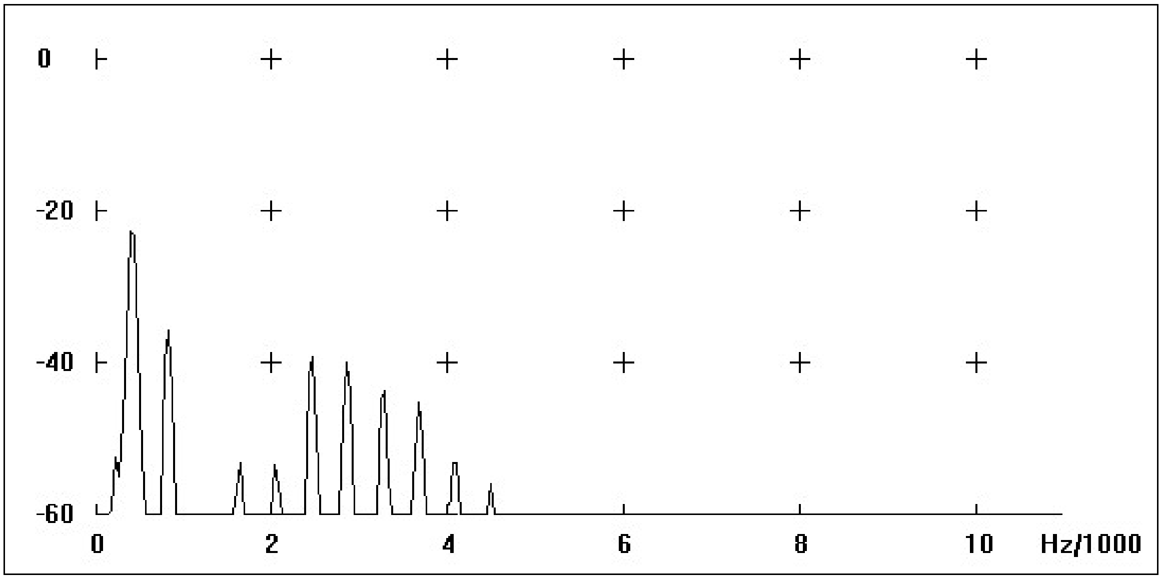
Analysis of Power Spectra from Spectrogram #6, Subject #9 – September 29, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{b/a+c/d}{2}$
2.77	4	2	.5	7	11	.63	.56
4.0	7	3	.42	3	10	.3	.36
7.2	6	3	.5	9	12	.75	.62
Average of three chiaroscuro levels							.51

Wave File Number 7 – October 6, 2000 – Subject #9

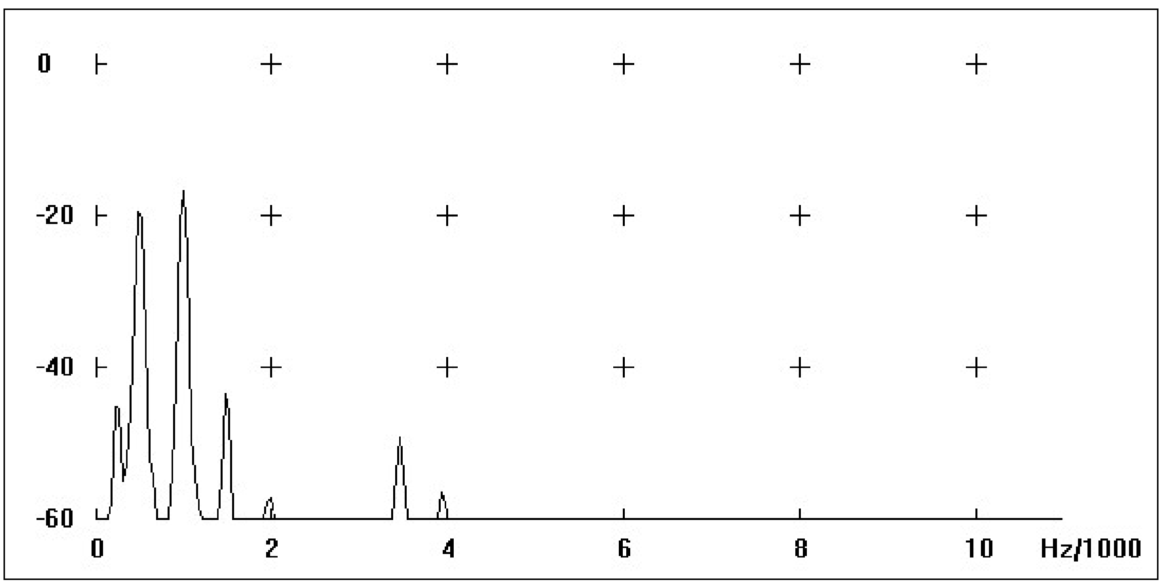


Subject #9 – Analysis of Wave File #7 – October 6, 2000 – E flat major				
		[si] (2.03-3.15 sec)	[o] (3.4-4.6 sec)	[a] (4.85-8.45 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area	Beginning to enter this area	Indications at highest pitches
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 15% - aspirated break at 2.64 seconds	<> from about 15% to about 30% - aspirated break at 4.17 seconds	<> from about 20% to 100%
Student continues to be consistent, although this wave file is a little weaker than wave files 5 and 6.				

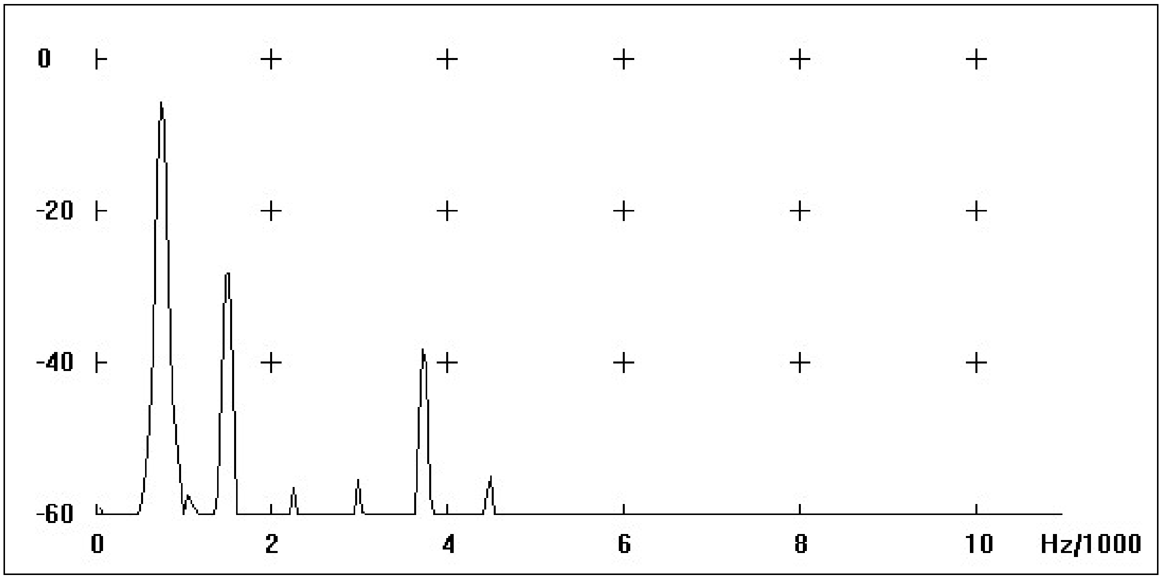
Power Spectrum from Spectrogram #7, Subject #9 at 2.54 seconds [i]



Power Spectrum from Spectrogram #7, Subject #9 at 4.17 seconds [o]

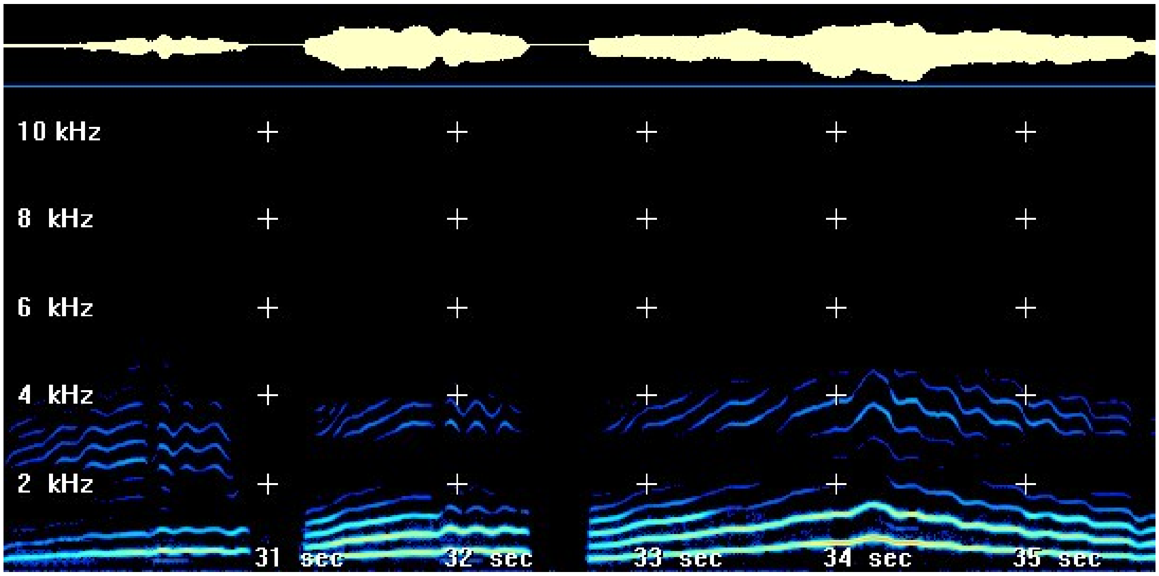


Power Spectrum from Spectrogram #7, Subject #9 at 6.32 seconds [a]



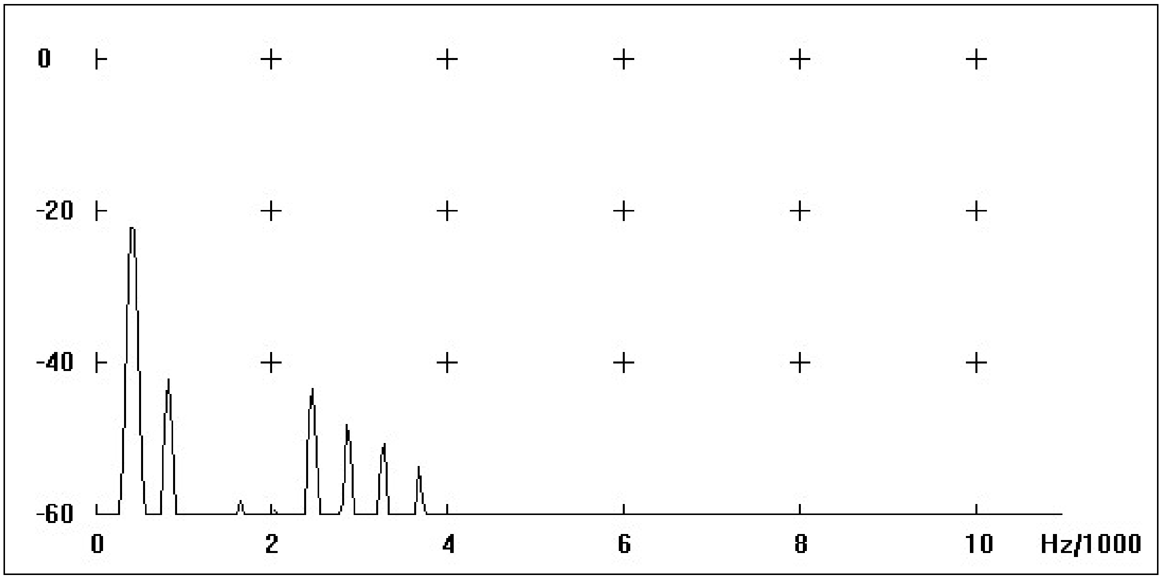
Analysis of Power Spectra from Spectrogram #7, Subject #9 – October 6, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.54	4	2	.5	7	11	.63	.56
4.17	4	2	.5	3	7	.42	.46
6.32	3	2	.66	4	7	.57	.61
Average of three chiaroscuro levels							.54

Wave File Number 8 – October 13, 2000 – Subject #9

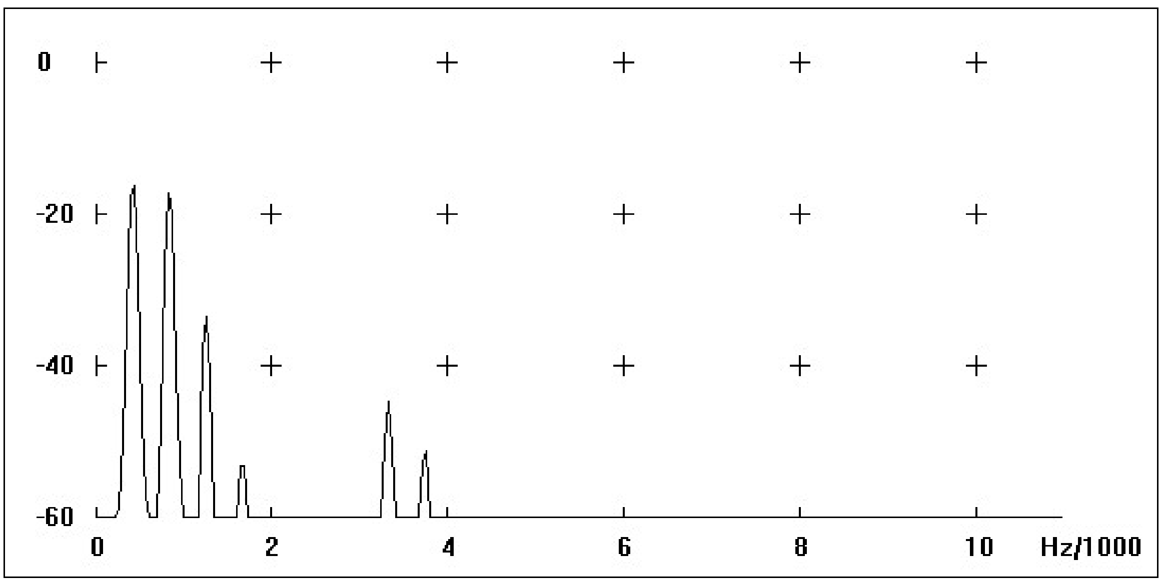


Subject #9 – Analysis of Wave File #8 – September 13, 2000 – E flat major				
		[si] (29.6-30-9 sec)	[o] (31.19-32.3 sec)	[a] (32.7-36.41 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area		Indications at highest pitches
	2000-4000 Hz	Solid indications	Solid indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Well balanced	Well balanced
Power Spectrum		<> from about 5% to about 20% - aspirated break at 30.39	<> from about 20% to about 80% - aspirated break at 31.88	<> from about 20% to about 90% - aspirated break at 35.61
The timings on this wave file are large because all the exercises from C major to E flat major were recorded.				

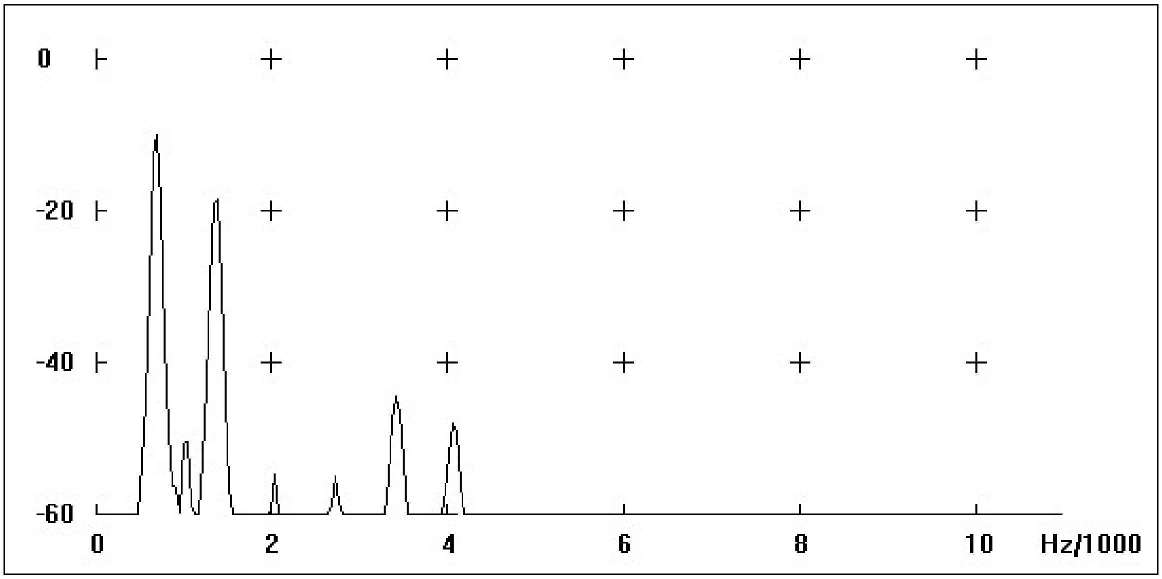
Power Spectrum from Spectrogram 8, Subject #9 at 30.28 seconds [i]



Power Spectrum from Spectrogram 8, Subject #9 at 31.79 seconds [o]

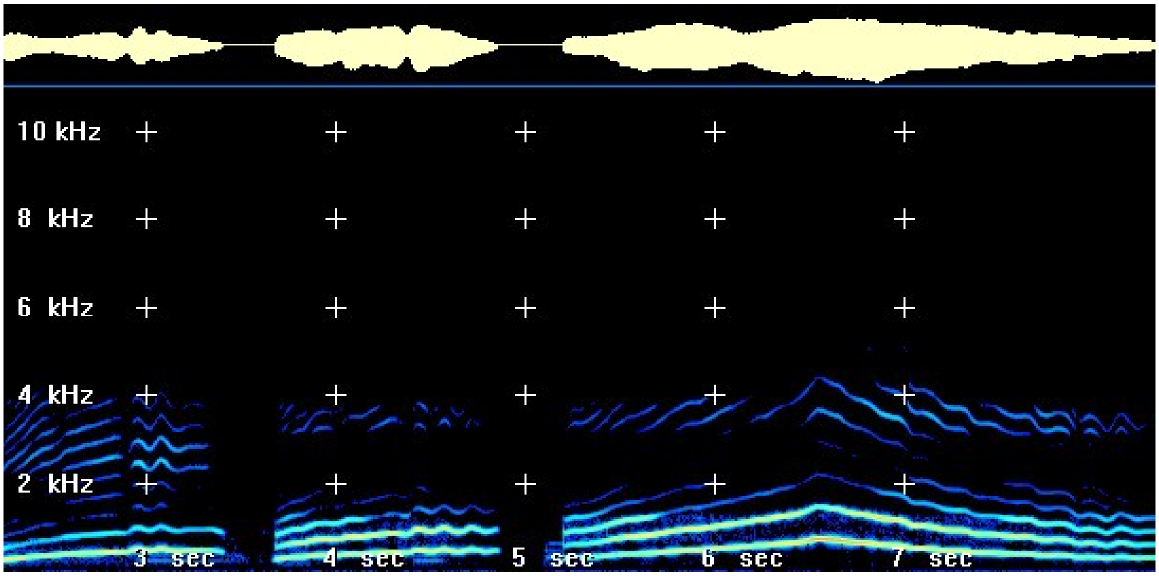


Power Spectrum from Spectrogram 8, Subject #9 at 34.37 seconds [a]



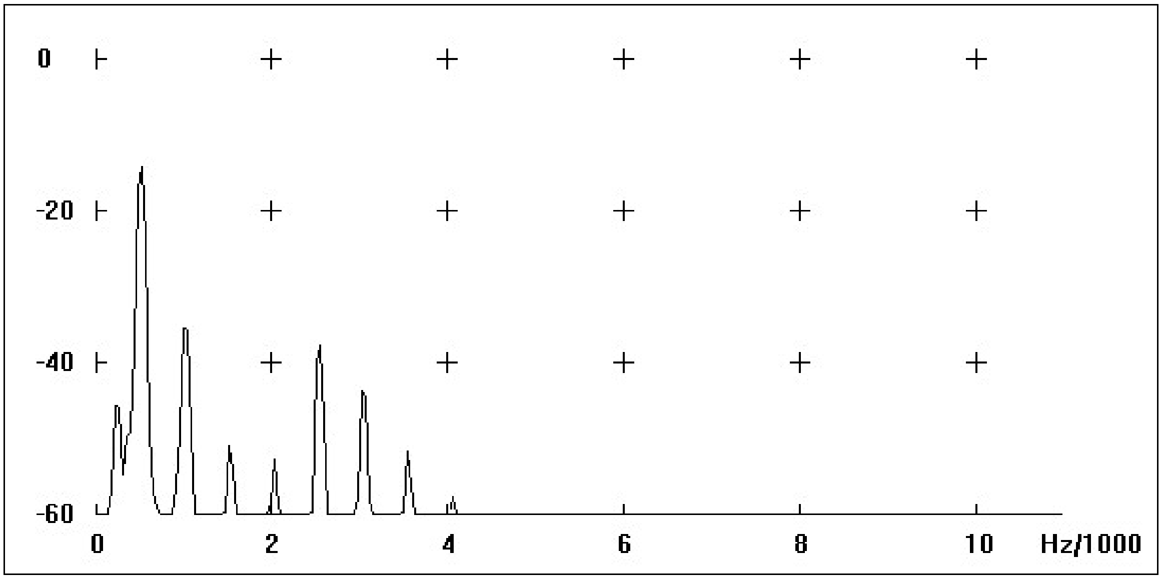
Analysis of Power Spectra from Spectrogram #8, Subject #9 – October 13, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
30.2	3	2	.66	4	7	.57	.61
31.7	4	3	.75	2	6	.33	.54
34.3	3	2	.66	4	7	.57	.61
Average of three chiaroscuro levels							.58

Wave File Number 9 – November 10, 2000 – Subject #9

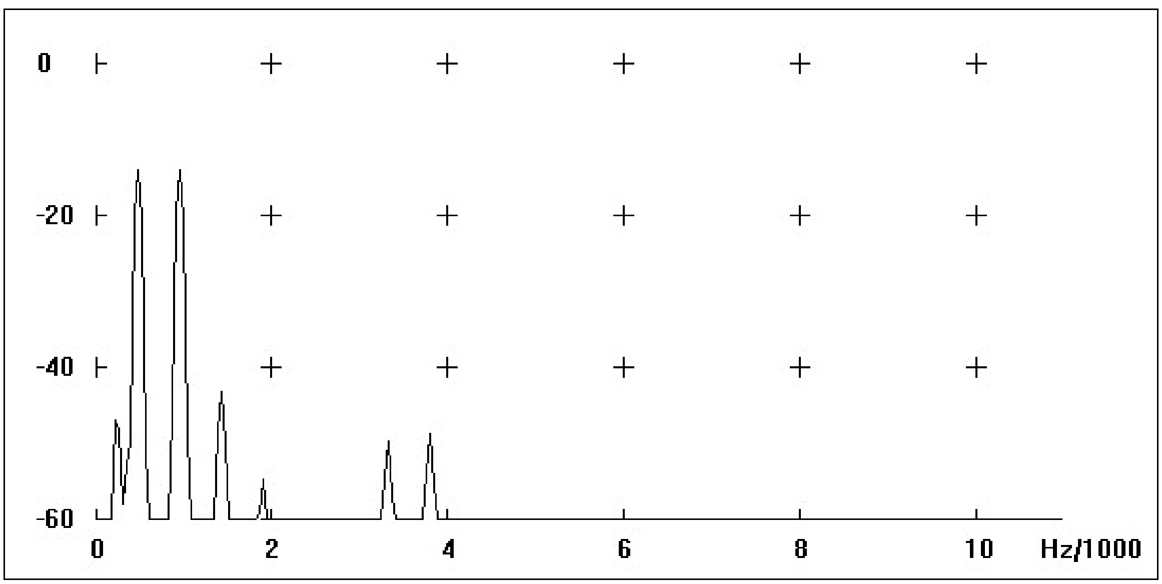


Subject #9 – Analysis of Wave File #9 – November 10, 2000 – E flat major				
		[si] (2.25-3.4 sec)	[o] (3.68-4.85 sec)	[a] (5.2-8.81 sec)
Singer's Formant Area	4000+ Hz			Indications at highest pitches
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Well balanced
Power Spectrum		Varying around 30% - aspirated break at 2.8	Varying around 60% - aspirated break at 4.4	<> from about 20% to about 80%
Consistently good vocal production. Style issues are within the musical theater style.				

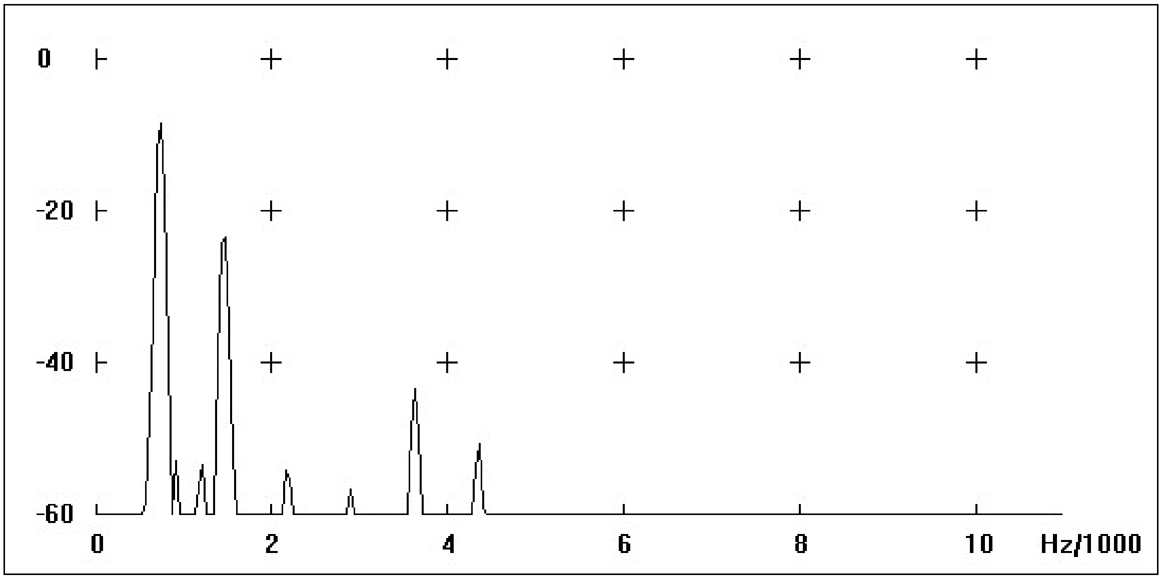
Power Spectrum from Spectrogram 9, Subject #9 at 3.08 seconds [i]



Power Spectrum from Spectrogram 9, Subject #9 at 4.46 seconds [o]

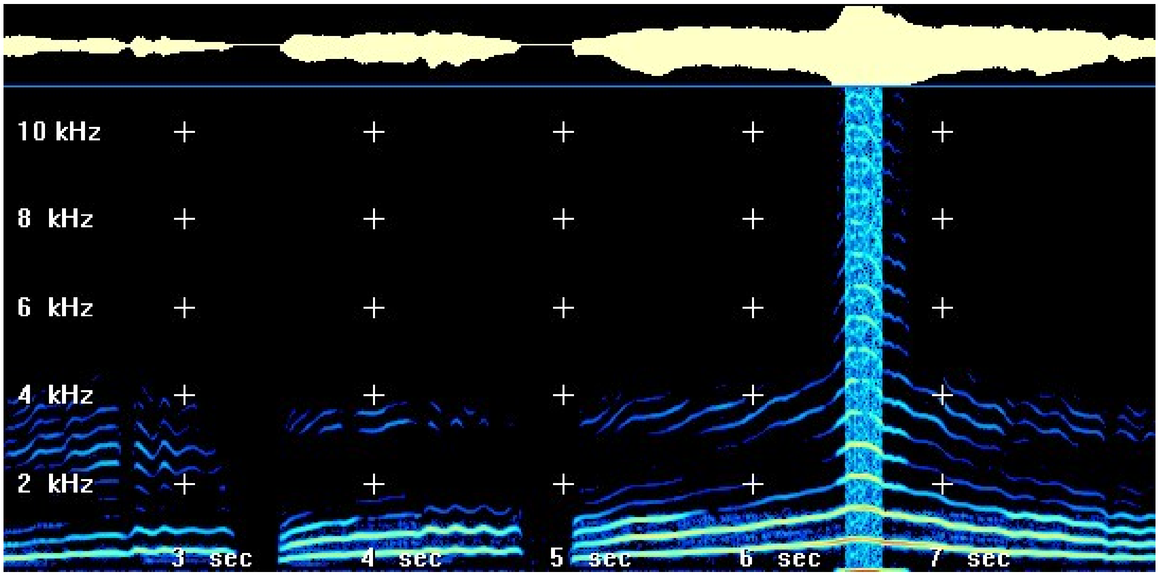


Power Spectrum from Spectrogram 9, Subject #9 at 6.6 seconds [a]



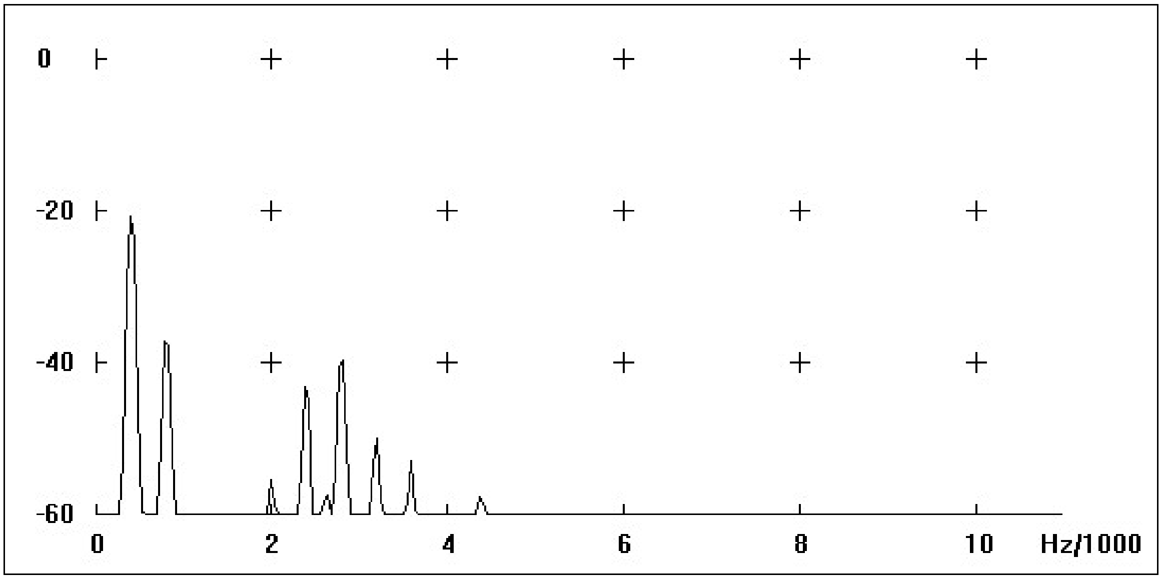
Analysis of Power Spectra from Spectrogram #9, Subject #9 – November 10, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.08	4	2	.5	5	9	.55	.52
4.46	5	2	.4	2	7	.28	.34
6.6	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.45

Wave File #10 – November 17. 2000 – Subject #9

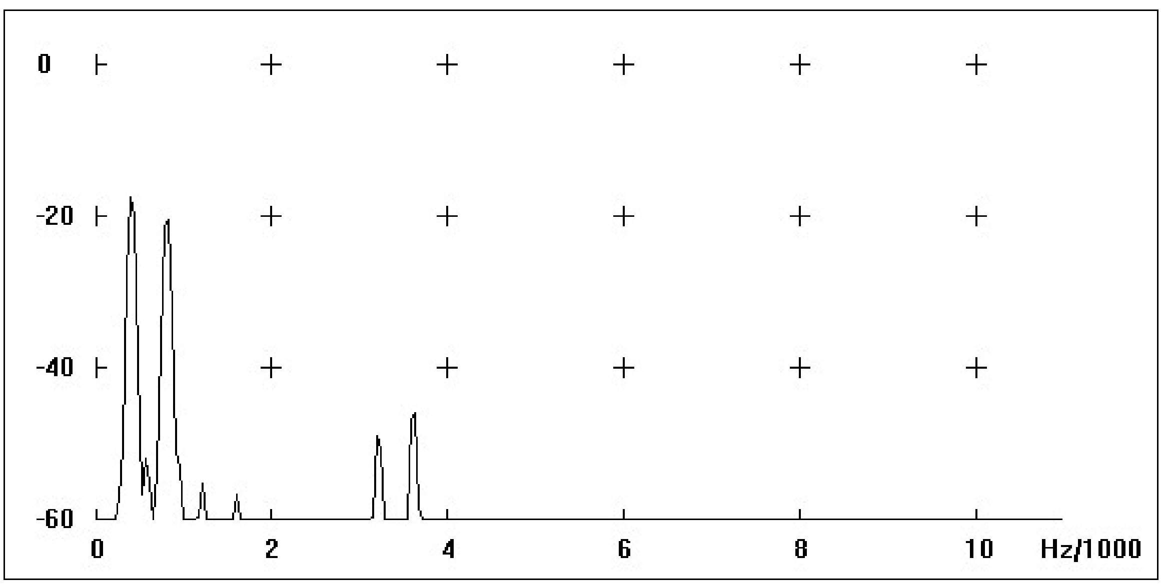


Subject #9 – Analysis of Wave File #10 – November 17, 2000 – E flat major				
		[si] (2.03-3.24 sec)	[o] (3.49-4.78 sec)	[a] (5.05-8.78 sec)
Singer's Formant Area	4000+ Hz			Indications at highest pitches
	2000-4000 Hz	Solid indications	Less solid, but relatively strong indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Strong and consistent	Strong and consistent	Strong and consistent
Chiaroscuro Balance		Well balanced	Weighted toward lower frequencies	Well balanced
Power Spectrum		Varying around 20% - aspirated break at 2.7	Varying around 30% - aspirated break at 4.2	<> from about 205 to 100% - noise at 6.4-6.6 from peaking the microphone
The microphone peaked because of an audible increase in air pressure as the singer made an effort for the high pitches. When she is more gradual in increasing the intensity, she is able to achieve high frequencies without peaking the microphone.				

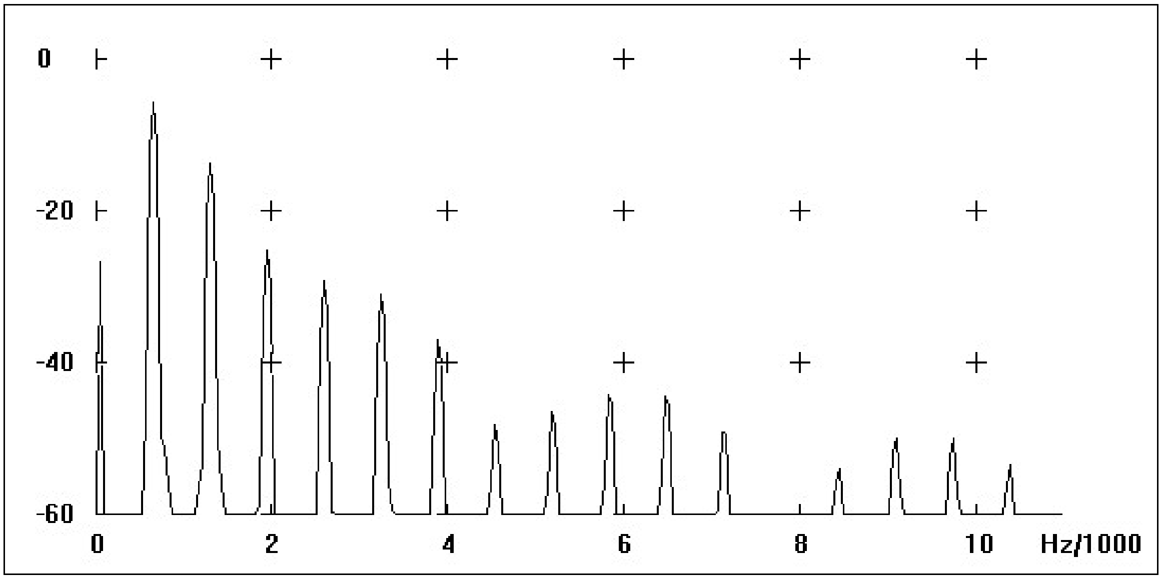
Power Spectrum from Spectrogram #10, Subject #9 at 2.53 seconds [i]



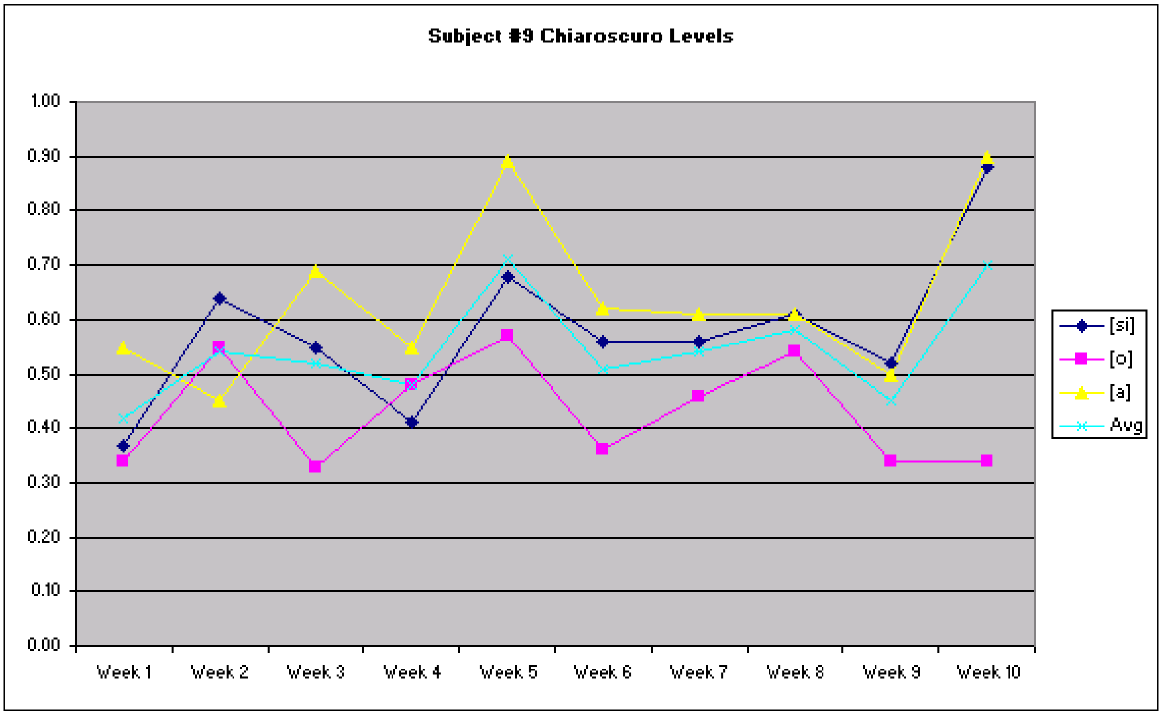
Power Spectrum from Spectrogram #10, Subject #9 at 4.03 seconds [o]

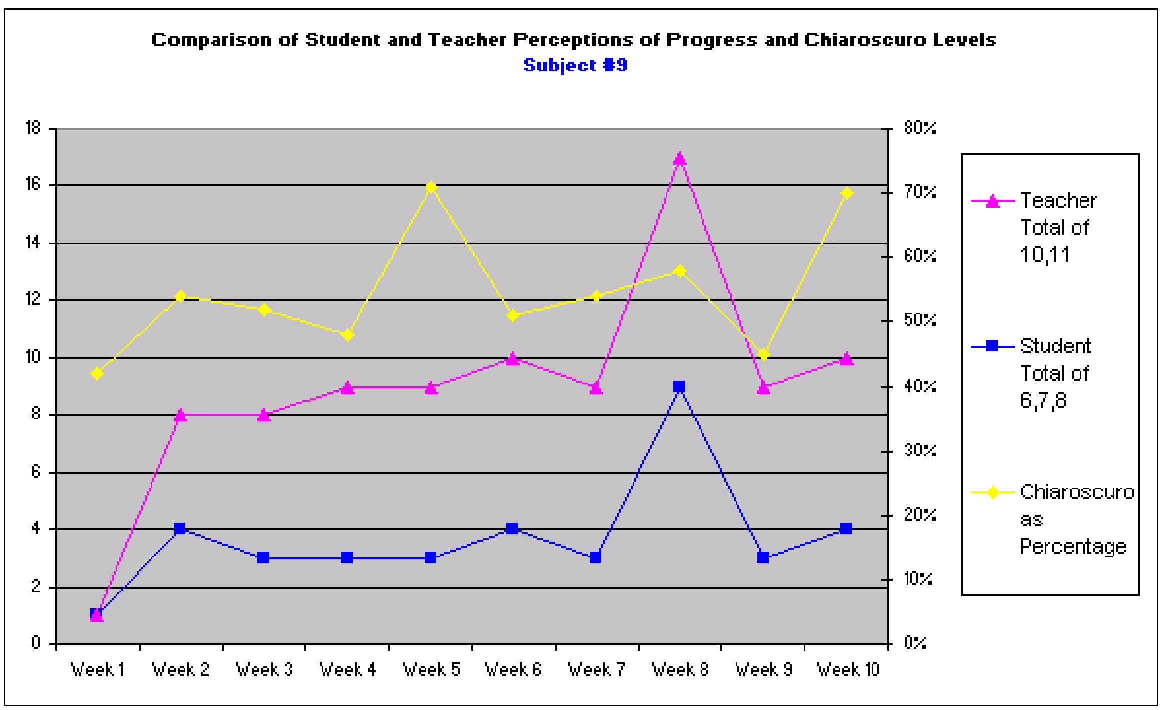


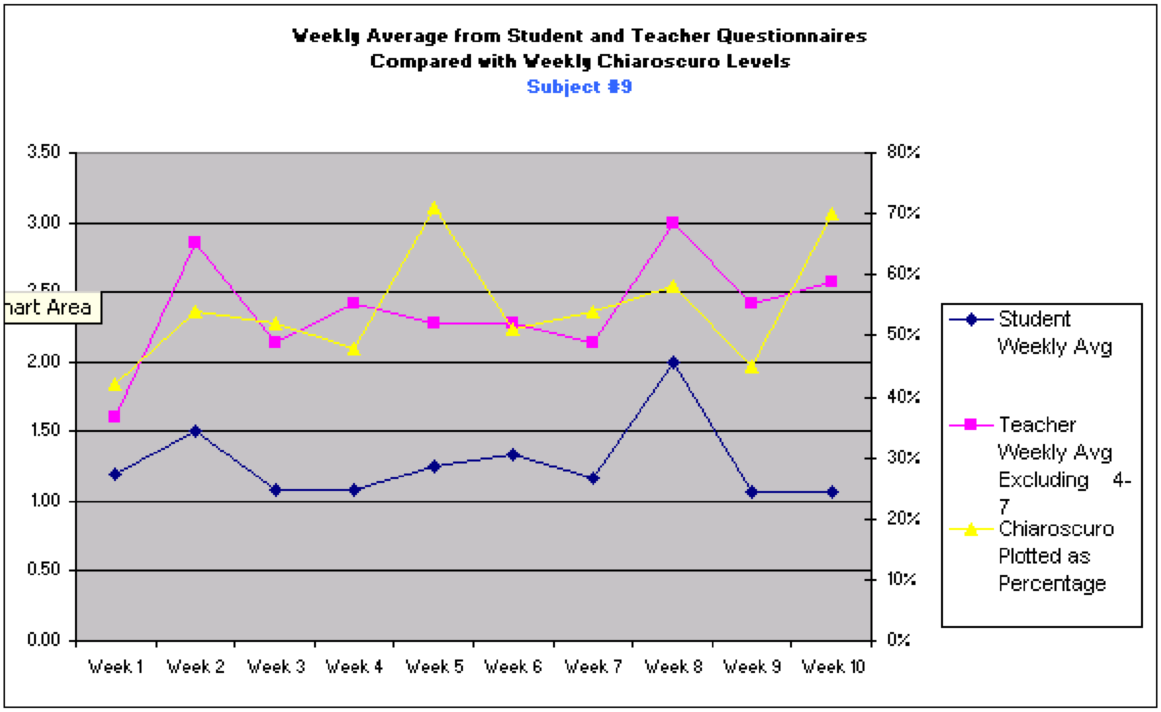
Power Spectrum from Spectrogram #10, Subject #9 at 6.73 seconds [a]



Analysis of Power Spectra from Spectrogram #10, Subject #9 – November 17, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.53	2	2	1.0	7	9	.77	.88
4.03	5	2	.4	2	7	.28	.34
6.73	3	3	1.0	13	16	.81	.9
Average of three chiaroscuro levels							.7


Subject #9 Chiaroscuro Levels
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
[si]
[o]
[a]
Avg


Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #9
18
16
14
12
10
8
6
4
2
0
80%
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #9
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
80%
70%
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage
hart Area

Appendix A10: Subject #10

Subject #10 was a 21-year-old African-American senior majoring in arts management. She was from Columbus, Georgia. At the time of the data collection, she had been a student in the researcher's studio for one year, having first entered as a sophomore transfer music education major with voice as her major instrument. Her lack of background in music and languages hindered her passing all the proficiencies required of a music education major, and she eventually changed her major.

Her vocal production was reasonably good from the beginning of her voice study, suffering only from over-resonation because of her gospel music background. She exhibited a tendency to begin [a] or [o] with glottal attacks, and a tendency to cause throat tension by lifting her chin when singing. The resulting sound was harsh and kept her out of the select choral group until her senior year. She continued to study a music major's repertoire, working particularly hard to gain proficiency with languages even though she was never able to fit the music majors' diction class into her schedule. Her extraordinary work ethic allowed her to make exceptional progress from her starting point.

Subject #10's voice was a bright lyric soprano. She could "belt" in the gospel style, but her voice production was basically healthy if a little tense. The normal range in which she vocalized was from a to b-flat^2, and her vocal production was even up to a^2. Her upper register began to expand as she learned to sing with less tension. Her tone quality and expressiveness improved as she lost some of her debilitating stage fright.

The spectrograph interested Subject #10, who was very intrigued with technology. She seemed to find a connection with the visual aid and to feel more in control of her own sound because she could see the changes as she made them. Her resonant sound showed on the spectrograph, and the tension in her jaw and tongue could be seen as less strong lower frequencies. As she worked for balance, she could see progress.

Fall Semester 2000 Repertoire – Subject #10

Mark Fax	Cassandra's Lullaby from *A Christmas Miracle*
Florence Price	Night
William Grant Still	Grief
Fauré	Après un rêve
Debussy	Nuit d'Etoiles
Brahms	Sonntag
Mozart	Un moto di gioia from *Le Nozze di Figaro*
Gershwin	Summertime from *Porgy and Bess*
Herman	Bosom Buddies from *Mame*

Lesson record over the data collection period – Subject #10

Date	**Grade**	**Repertoire** Studied During Lesson	**Student** Arrival and Preparation	**Teaching Activity** Teaching technique, performance practice, style, or presentation: Coaching music, diction, ensemble, memorization	**Wave File** Number and Key	**Weekly Data** Chiaroscuro Level; Student Questions 6, 7, and 8; Teacher Questions 10-11
8/23	B	Repertoire assigned last spring, but not much progress Debussy, Fauré	On time, but not well prepared	Much time spent copying music for accompanist – the voice has come a long way over the summer and from Chamber Choir – I have high hopes for this year – coaching	#1 E-flat	Chiaroscuro - .45 Student 1, 2, 1 Teacher n/a, n/a
8/31	B	Still, Price, Fax, Brahms	On time, but not well prepared	Disappointed that she's not working too fast - coaching	#2 E-flat	Chiaroscuro - .40 Student 3, 2, 1 Teacher 2, 2
9/5	C	Sonntag	Poor VMC	Embarrassed herself by not having the melody or text ready for VMC		
9/7	B	Sonntag	Sick – Makeup for 9/6 (UGA)	Coached text	#3 E-flat	Chiaroscuro - .39 Student 2, 2, 1 Teacher 4, 4
9/13	B	Still, Price, Faure, Brahms	Good	Has worked on the music, especially Sonntag - doing well – Voice becoming more relaxed - coaching	#4 E flat	Chiaroscuro - .39 Student 1, 1, 1 Teacher 4, 4
9/20	B	Brahms, Mozart	Okay	When she smooths out her sound and is confident of the notes/text, she is making wonderful sounds.	#5 E flat	Chiaroscuro - .43 Student 1, 1, 1 Teacher 2, 2
9/27	B	Brahms, Gershwin	Okay	Struggling to identify her own sound separately from the styles she is used to singing. Still confusing style with vocal production.	#6 E flat	Chiaroscuro - .41 Student 1, 1, 1 Teacher 2, 2
10/4	B	Brahms, Price, Still, Herman	On time – some progress	Working slowly on music – Chair says she didn't pass Tuesday qualifying for student recital – Subject #10 said she did okay – Chair wants her to sing again on Friday. When I heard her on Wednesday, I thought she was okay to sing. She is making good sounds and needs to be consisten.	#7 E flat	Chiaroscuro - .53 Student 1, 1, 1 Teacher 3, 3
10/11	B	Brahms, Gershwin	Good	Doing well – okay for recital	#8 Eflat	Chiaroscuro - .48 Student 1, 1, 1 Teacher 2, 2
10/12	B.	Brahms, Price	Good	Passaggio solidifying – lovely E-F		
10/13	A	Hermann	Excellent	Excellent Broadway Night performance		
10/16	B+	Brahms	Very good	Best yet student recital performance		
10/18	B	Still, Fax	Good	She is discouraged – hope she starts working again	#9 E flat	Chiaroscuro - .36 Student 2, 2, 2 Teacher 3, 3
10/25	B	Still, Price, Gershwin	Good	Her excellent common sense is taking hold – she's determined to tackle these songs	#10 E flat	Chiaroscuro - .41 Student 1, 1, 1 Teacher 3, 3
11/1	A	Still, Price	Excellent	Night is nearly memorized and is beginning to work for her – she's realizing that if she does what is needed in time, the voice will soar		
11/8	A	Still, Price, Gershwin	Excellent	She is starting to transfer ideas from Night to Summertime!		
11/15	A	Still, Price, Gershwin	Excellent	All memorized! Night is sounding so good! Confidence increasing		
11/19	A	Price	Excellent	Student recital: her first success – everything went well – she didn't get scared and her top was lovely		

Responses to student questionnaires – Subject #10

Question	8/23	8/31	9/7	9/13	9/20	9/27	10/4	10/11	10/18	10/25	**Total of weekly answers to questions 6, 7, 8**
1	3	2	4	2	1	1	2	1	2	1	
2	2	2	3	2	1	1	2	1	2	1	
3	1	2	2	1	1	1	2	1	1	1	
4	1	3	1	1	1	2	2	1	1	1	
5	1	5	1	1	1	2	2	1	1	1	
6	1	3	2	1	1	1	1	1	2	1	1.4
7	2	2	2	1	1	1	1	1	2	1	1.4
8	1	1	1	1	1	1	1	1	2	1	1.1
9	1	2	1	1	1	1	1	1	2	1	**Average over ten week period**
10	1	1	1	1	1	1	1	1	2	1	
11	N/A	1	2	1	2	1	1	1	2	1	
12	N/A	1	1	1	1	1	1	1	2	1	
Weekly Average	1.4	2.08	1.75	1.16	1.08	1.16	1.41	1	1.75	1	**1.3**

Responses to teacher questionnaires – Subject #10

Quantification of the verbal categories on the form will be as follows:

1 = Very good (questions 1-3), Most of the attention (Questions 4-7), Often and enthusiastically (Question 8), Frequently pointing out occurrences (Question 9), Much better (Questions 10-11)

2 = Good (questions 1-3), Significant amount (Questions 4-7), Positively (Question 8), Occasionally (Question 9), Better (Questions 10-11)

3 = Acceptable (questions 1-3), Some attention (Questions 4-7). Neutral (Question 8), Only a few overall remarks (Questions 9), Same (Questions 10-11)

4 = Poor (questions 1-3), A little attention (Questions 4-7), Rarely (Question 8), Only responding to student questions (Questions 9), Worse (Questions 10-11)

5 = Unacceptable (questions 1-3), No attention (Questions 4-7), Not at all (Question 8), Only while setting up to make the wave file (Questions 9), Much worse (Questions 10-11)

Question	8/23	8/31	9/7	9/13	9/20	9/27	10/4	10/11	10/12	10/18	**Total and Average of questions 10 & 11**
1	2	2	2	2	2	2	2	2	2	2	
2	1	2	4	4	2	2	3	2	2	3	
3	2	2	2	2	2	2	2	2	2	2	
4	4	3	4	2	3	4	3	3	4	2	
5	5	5	5	5	5	5	5	3	4	5	
6	4	3	4	2	3	4	4	4	5	4	
7	3	2	3	5	5	4	2	5	5	4	
8	1	1	2	2	2	2	2	2	2	2	
9	1	2	2	1	2	2	1	2	2	2	
10	N/A	2	4	4	2	2	3	2	2	3	2.4
11	N/A	2	4	4	2	2	3	2	2	3	2.4
Weekly average excluding questions 4-7	1.4	1.85	2.85	2.71	2	2	2.28	2	2	2.42	**2.4**

Student's Written Reaction to Use of Spectrograph – Subject #10

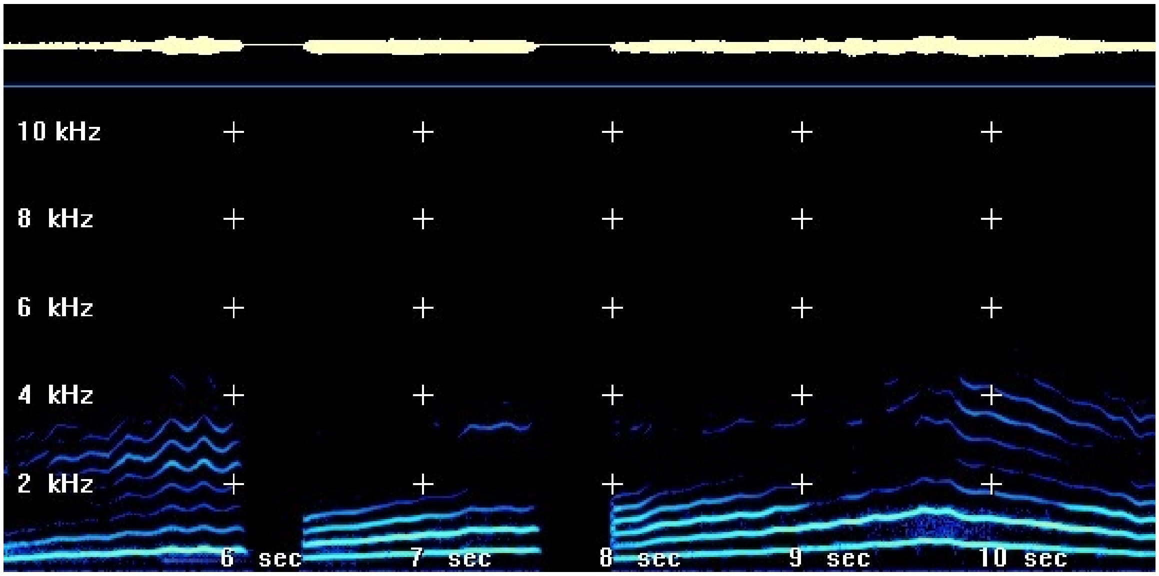
For the last three semesters I have participated with Mrs. Callaway. It has truly been a wonderful experience. I have learned new and exciting things about my voice. The spectrograph tells me what I need to do it I want to make my voice sound different. I can also see my voice looks different when I am sick or even when it's a cloudy day.

Using the spectrograph helps me because I am a visual learner and sometimes when Mrs. Callaway tells me verbally what to do, I don't quite understand. However, when she shows me on the spectrograph, I get a better understanding of what she wants me to do.

The spectrograph is an excellent teaching tool and is very understandable to read. Not only can you see what you are doing wrong, you can hear what you're doing wrong. This program should be used by all voice lesson teachers as a new alternative for students. Not only does the student learn, it helps the teacher learn about their student. Keep using the spectrograph. It works!

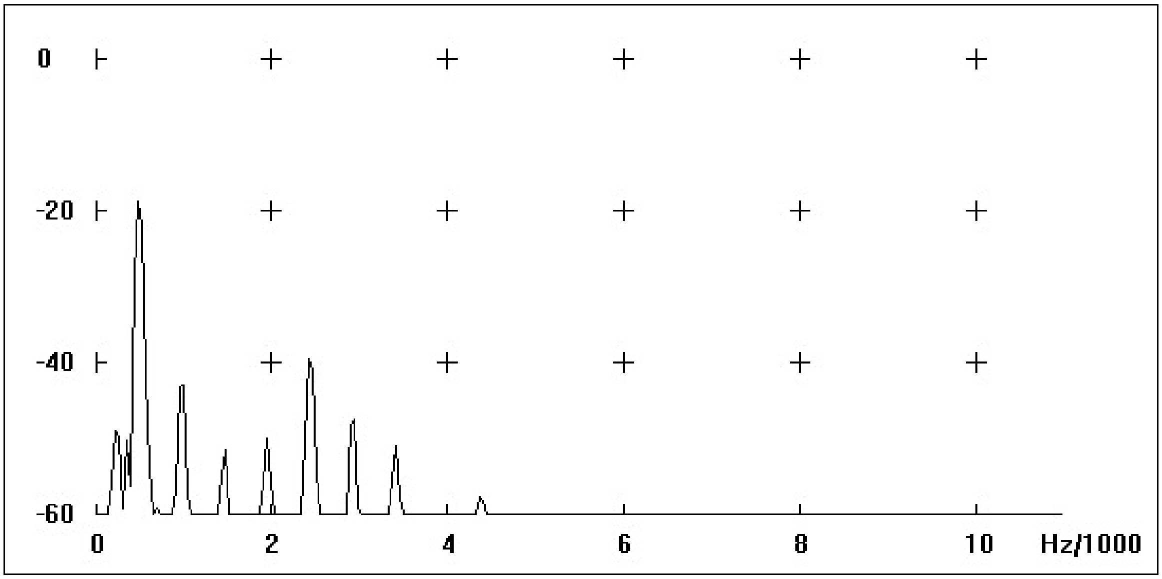
Analysis of Wave Files

Wave File Number 1 – August 23, 2000 – Subject #10

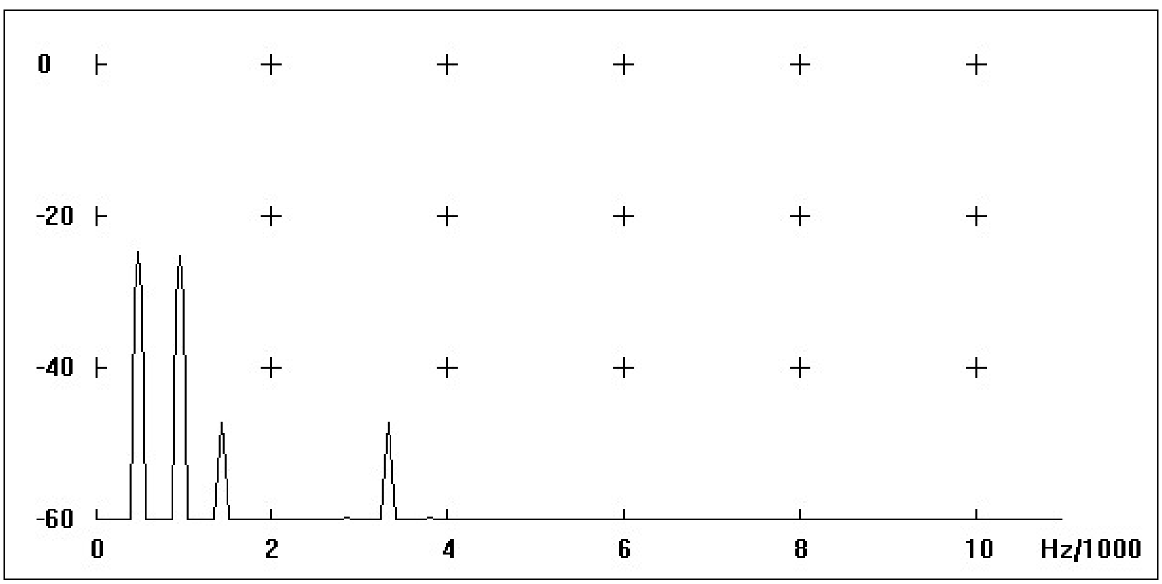


Subject #10 – Analysis of Wave File #1 – August 23, 2000 – E flat major				
		[si] (4.77-6.04 sec)	[o] (6.36-7.6 sec)	[a] (8.0-12.02 sec)
Singer's Formant Area	4000+ Hz	Beginning to enter this area		Beginning to enter this area
	2000-4000 Hz	Scattered indications	Scattered indications	Scattered indications on ascending scale – more solid on descending scale
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Consistent	Consistent	Consistent
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Partially balanced
Power Spectrum		Varying around 20%	Varying around 20%	Varying around 20%
Bright young voice that is struggling with the style change to a healthier production. Tension shows in straight tone singing that is released at the ends of phrases and in the glottal attack at 8.0. Greater strength in the lower frequencies would "warm up" the voice, and freer production would allow the student to make better use of the possibilities in this voice.				

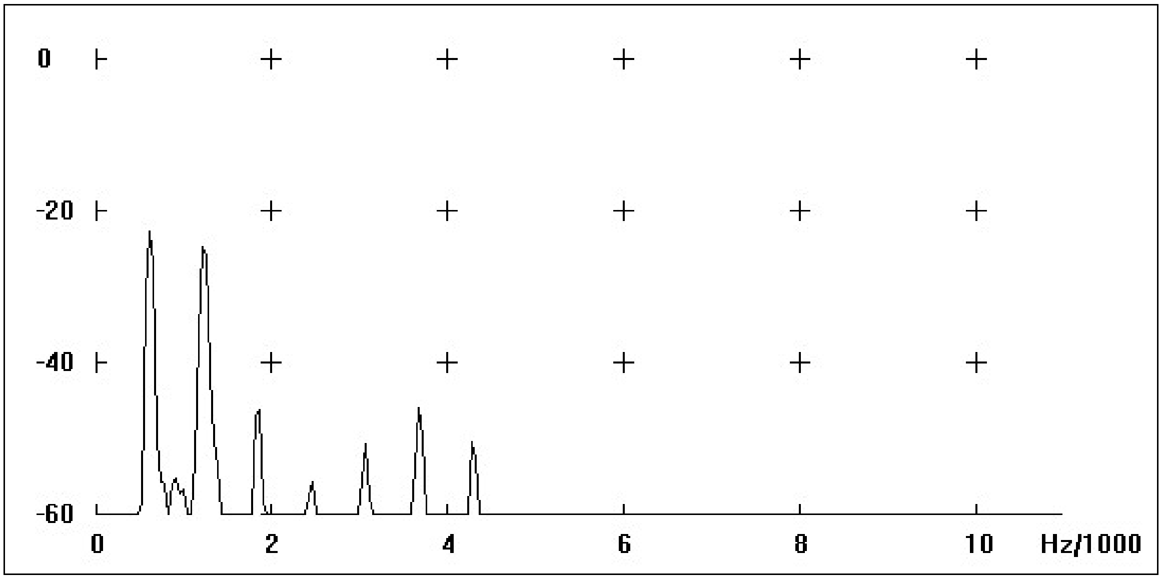
Power spectrum from Spectrogram #1, Subject #10 at 5.71 seconds [i]



Power spectrum from Spectrogram #1, Subject #10 at 7.42 seconds [o]

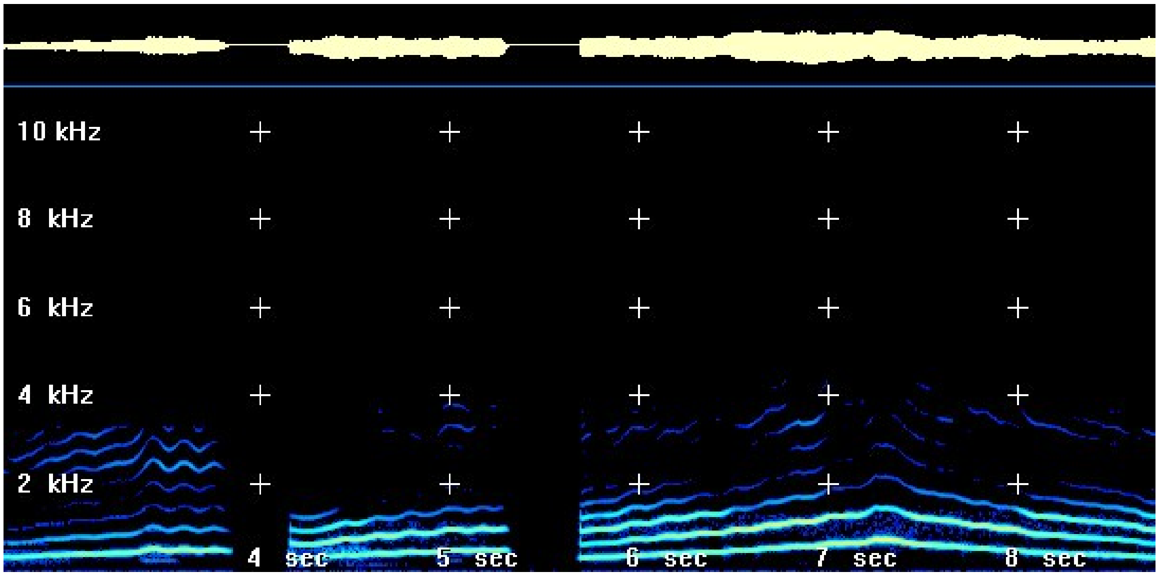


Power spectrum from Spectrogram #1, Subject #10 at 9.88 seconds [a]



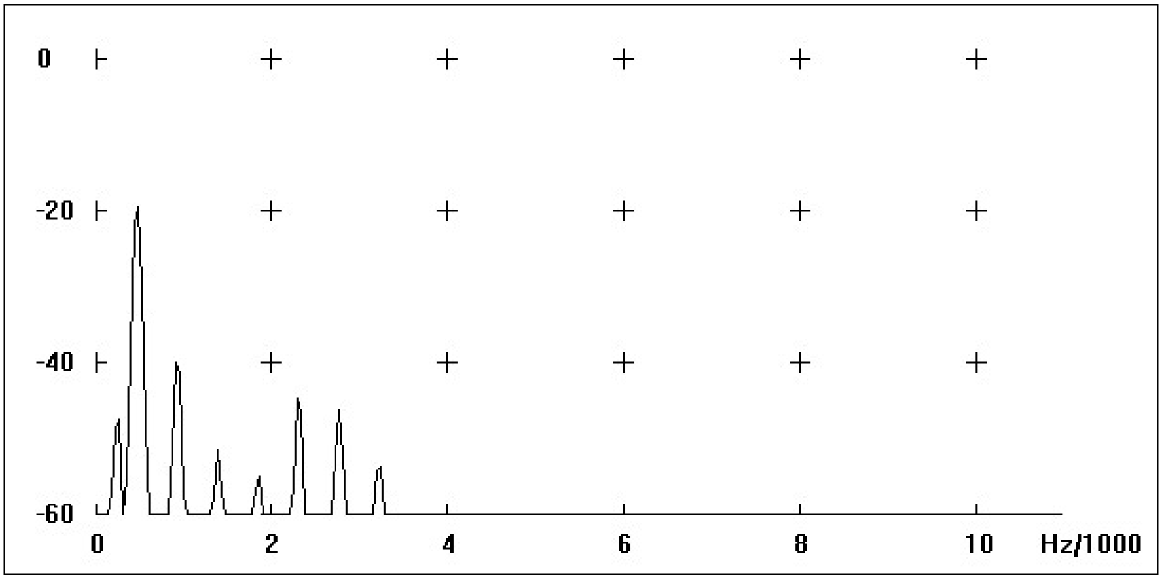
Analysis of Power Spectra from Spectrogram #1, Subject #10 - August 23, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
5.71	4	1	.25	5	9	.55	.37
7.42	3	2	.66	3	6	.5	.58
9.88	5	2	.4	4	9	.44	.42
Average of three chiaroscuro levels							.45

Wave File Number 2 – August 31, 2000 – Subject #10

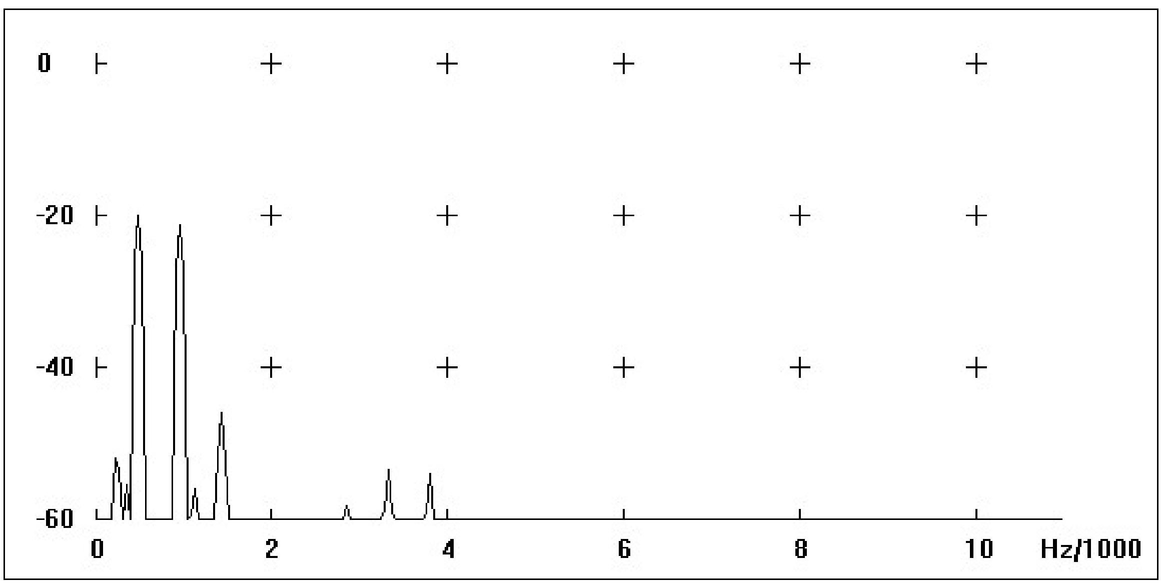


Subject #10 – Analysis of Wave File #2 – August 31, 2000 – E flat major				
		[si] (2.61-3.83 sec)	[o] (4.14-5.31 sec)	[a] (5.67-9.8 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications above vowel	Scattered indications	Scattered indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Consistent	Consistent	Consistent
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 20%	Varying around 30%	<> from about 20% to about 40%
Sound is somewhat less tense as can be seen from somewhat more visible vibrato.				

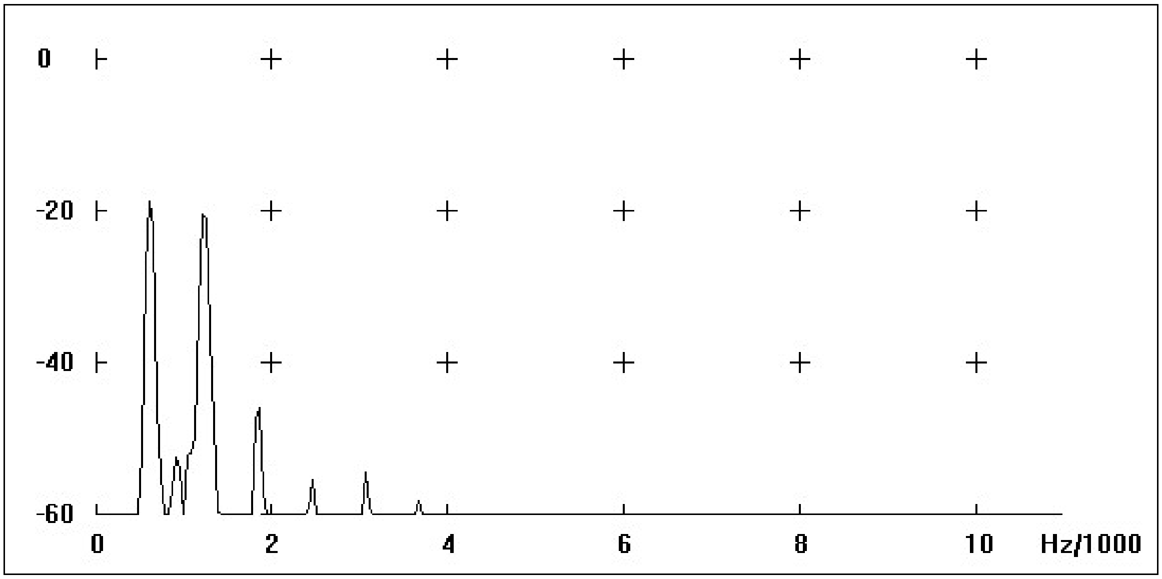
Power spectrum from Spectrogram #2, Subject #10 at 3.53 seconds [i]



Power spectrum from Spectrogram #2, Subject #10 at 5.02 seconds [o]

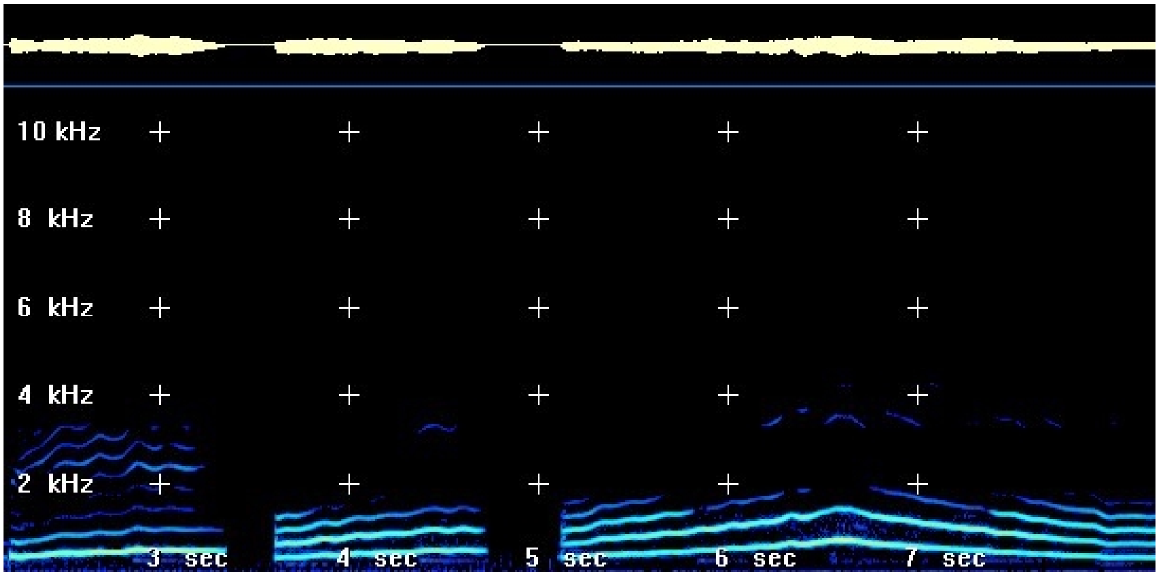


Power spectrum from Spectrogram #2, Subject #10 at 7.48 seconds [a]



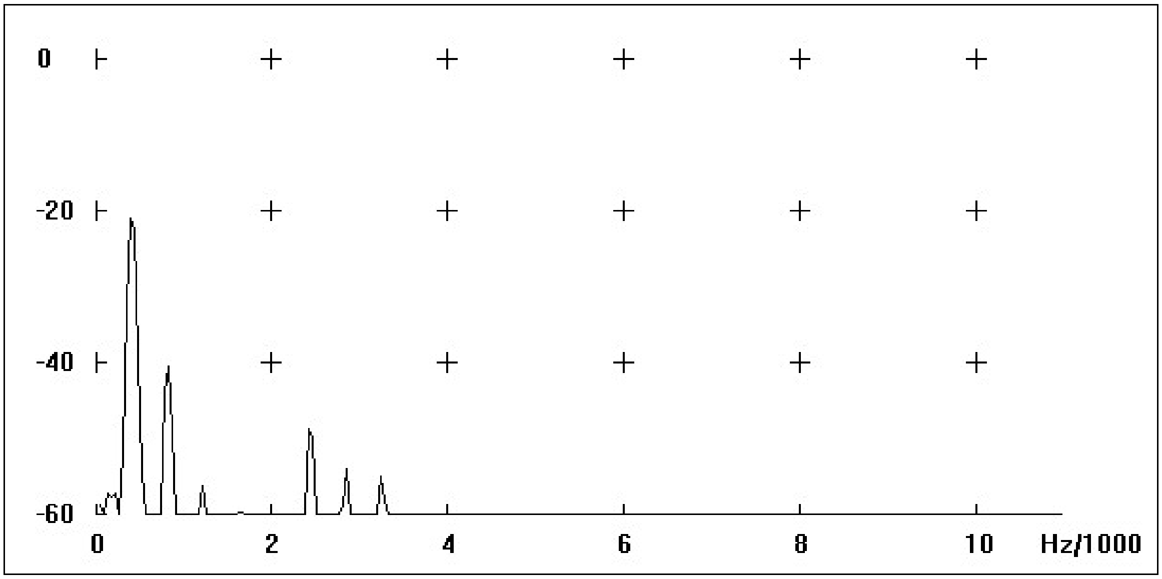
Analysis of Power Spectra from Spectrogram #2, Subject #10 – August 31, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.53	5	2	.4	3	8	.37	.38
5.02	5	2	.4	3	8	.37	.38
7.48	4	2	.5	3	7	.42	.46
Average of three chiaroscuro levels							.4

Wave File Number 3 – September 7, 2000 – Subject #10

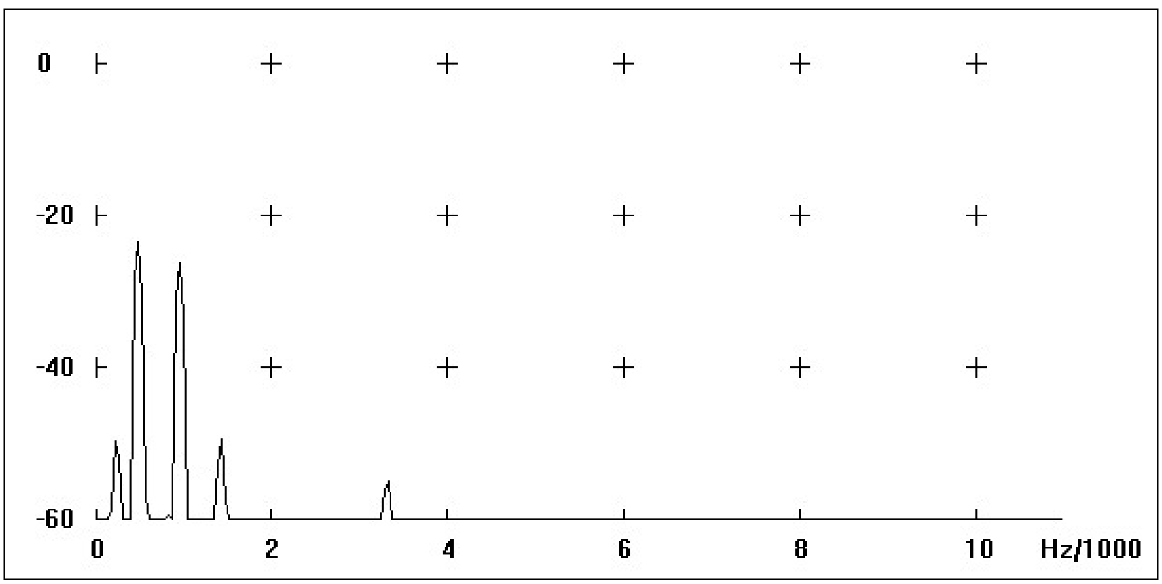


Subject #10 – Analysis of Wave File #3 – September 7, 2000 – E flat major				
		[si] (2.21-3.33 sec)	[o] (3.62-4.68 sec)	[a] (5.13-3.94 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Scattered indications above vowel	Scattered indications	Scattered indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Weak vowel definition	Clear vowel definition
1st Formant Area		Consistent	Consistent	Consistent
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 20%	Varying around 20%	Varying around 20%
Singer's production overall is weak in this wave file.				

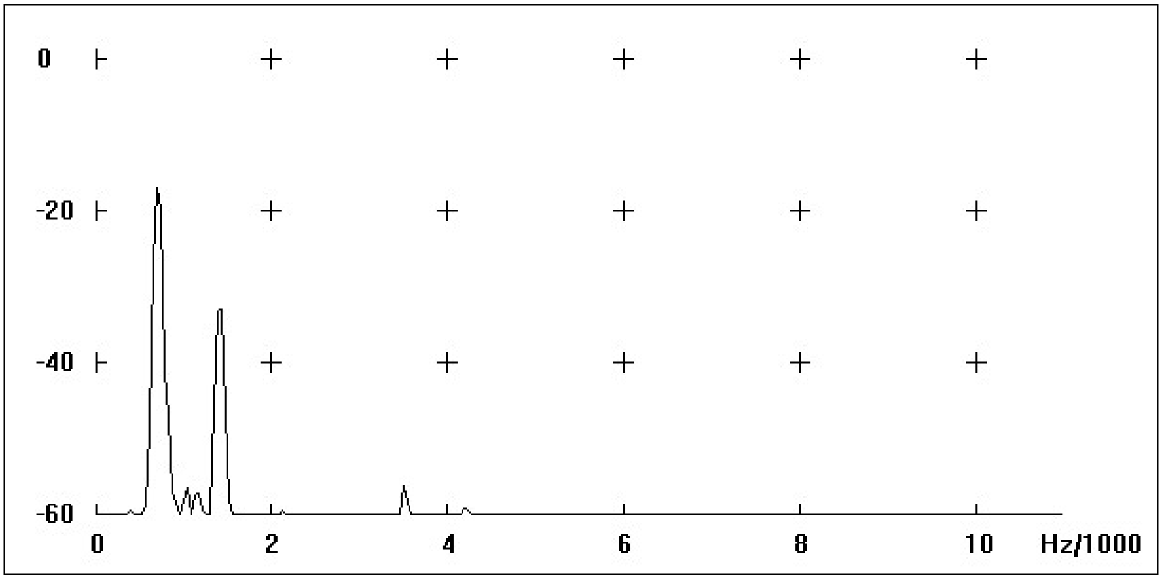
Power spectrum from Spectrogram #3, Subject #10 at 2.57 seconds [i]



Power spectrum from Spectrogram #3, Subject #10 at 4.44 seconds [o]

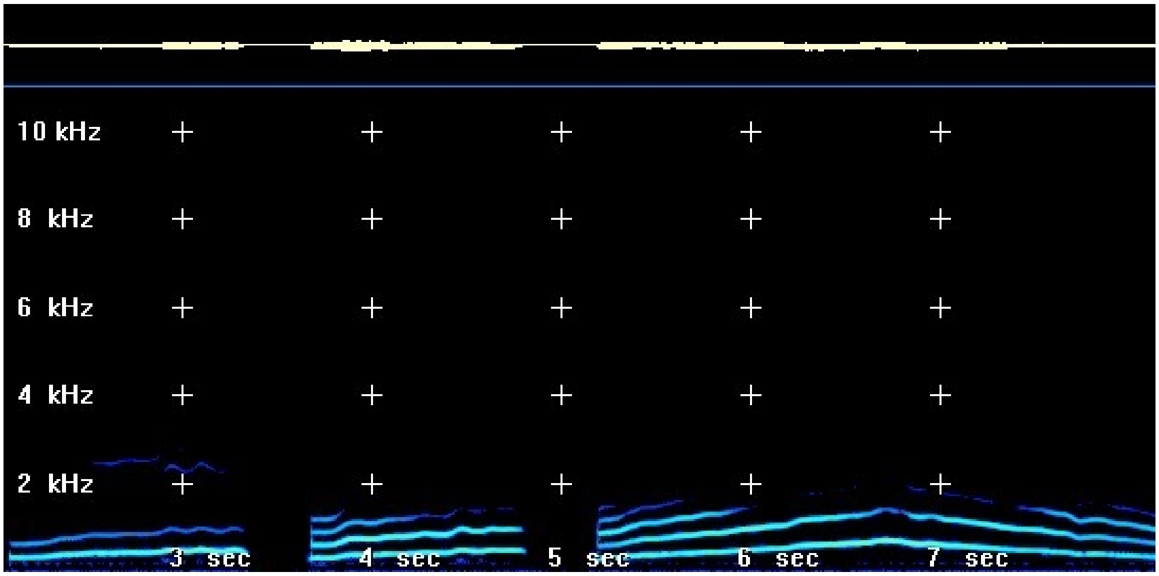


Power spectrum from Spectrogram #3, Subject #10 at 6.63 seconds [a]



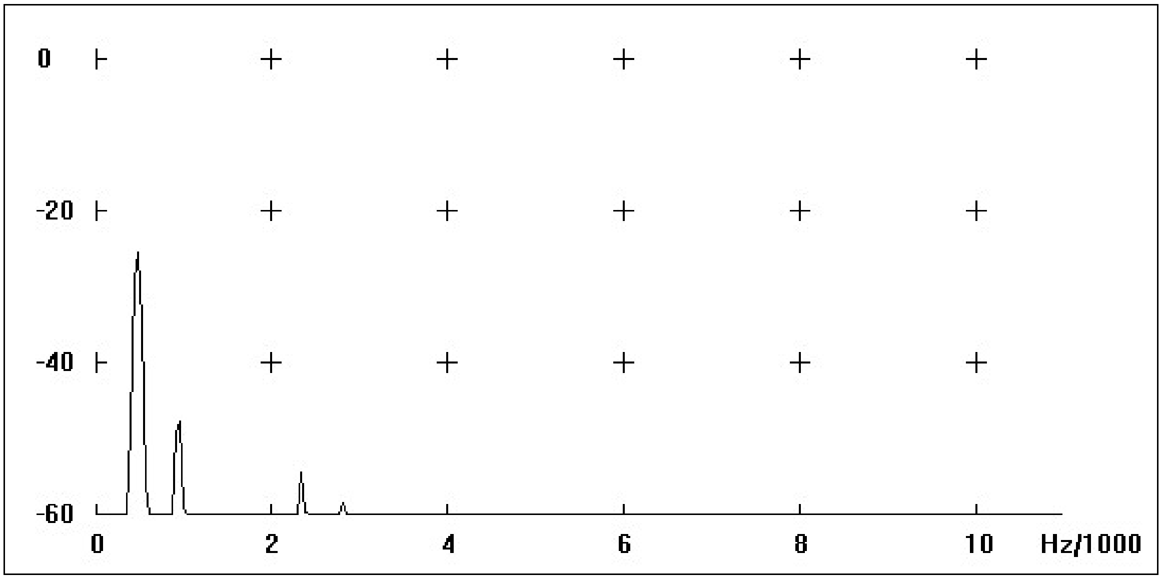
Analysis of Power Spectra from Spectrogram #3, Subject #10 – September 7, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	$F_{1\text{-}2}$ Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.57	4	2	.5	3	7	.42	.46
4.44	4	2	.5	1	5	.2	.35
6.63	5	2	.4	3	8	.37	.38
Average of three chiaroscuro levels							.39

Wave File Number 4 – September 13 – Subject #10

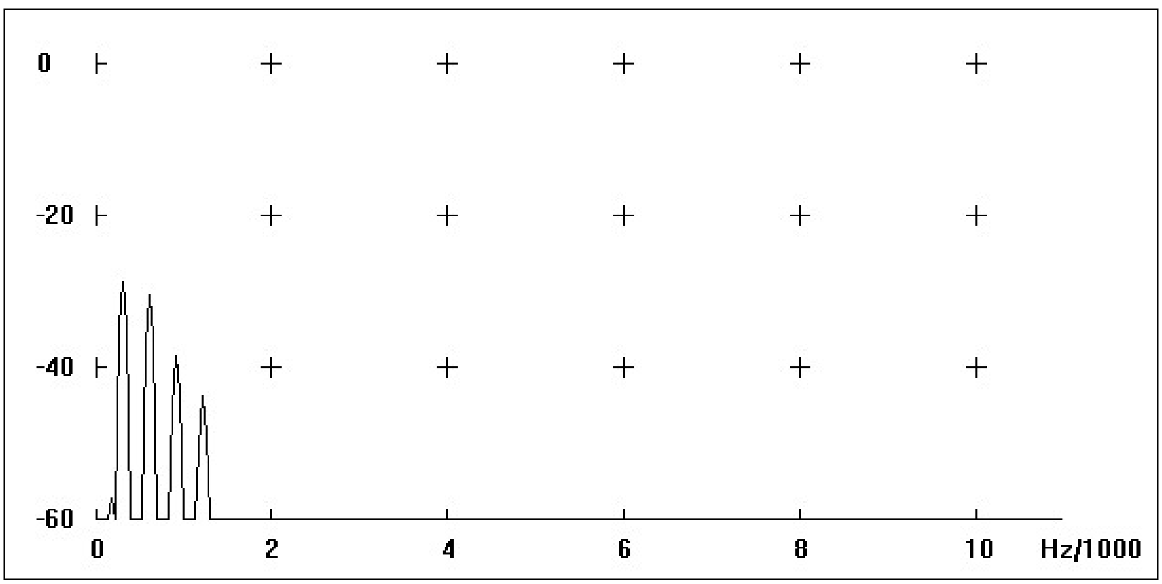


Subject #10 – Analysis of Wave File #4 – September 13, 2000 – E flat major				
		[si] (2.09-3.33 sec)	[o] (3.67-4.81 sec)	[a] (5.2-9.01 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Vowel only		
2nd Formant Area (Vowel Definition)		Weak vowel definition	Weak vowel definition	Weak vowel definition
1st Formant Area		Consistent but weak	Consistent but weak	Consistent but weak
Chiaroscuro Balance		Weighted toward lower frequencies	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Varying around 5%	Varying around 5%	Varying around 5%
Very weak wave file.				

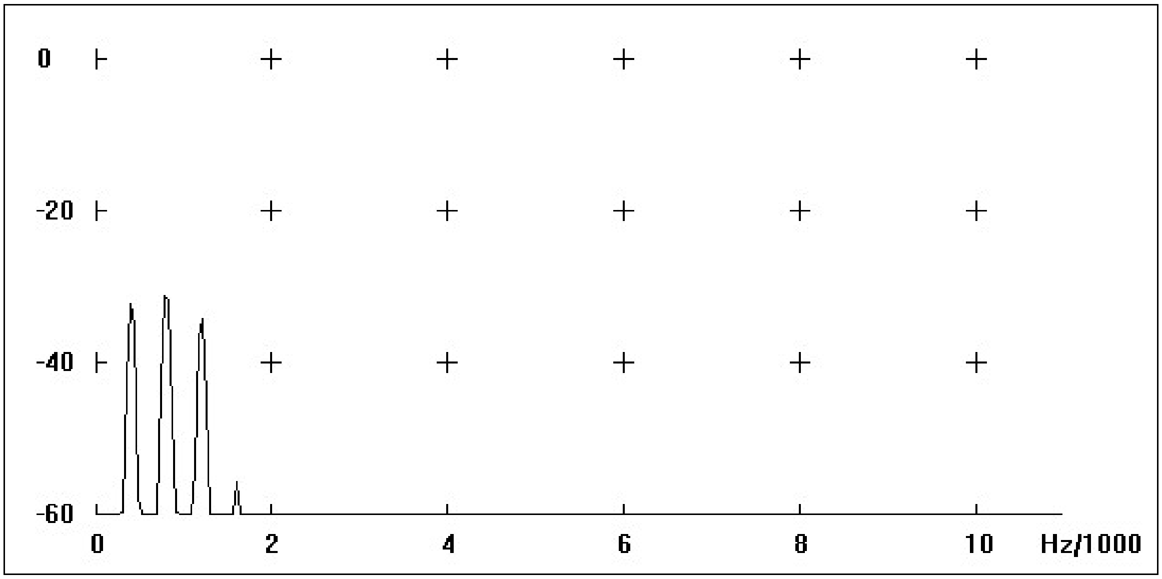
Power spectrum from Spectrogram #4, Subject #10 at 2.99 seconds [i]



Power spectrum from Spectrogram #4, Subject #10 at 3.81 seconds [o]

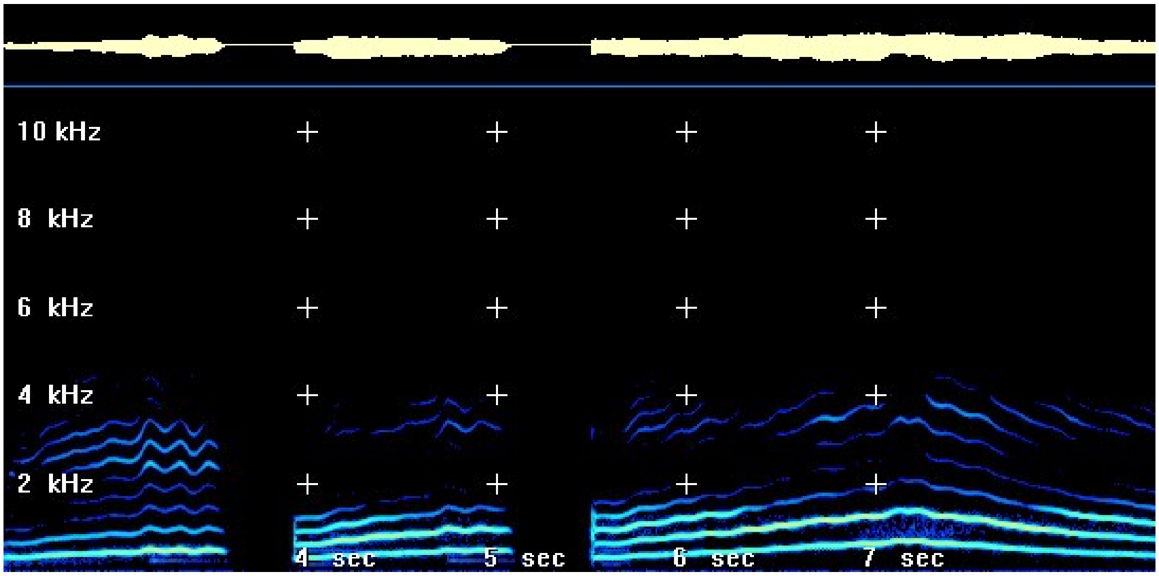


Power spectrum from Spectrogram #4, Subject #10 at 5.63 seconds [a]



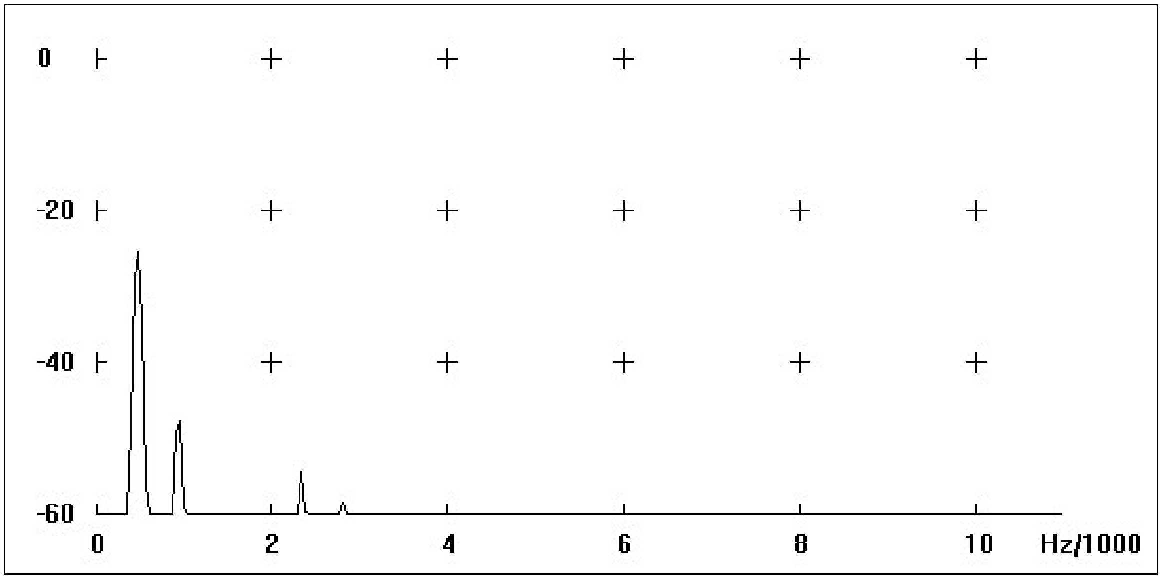
Analysis of Power Spectra from Spectrogram #4, Subject #10 – September 13, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
2.99	2	1	.5	2	4	.5	.5
3.81	5	3	.6	0	5	0	.3
5.63	4	3	.75	0	4	0	.37
Average of three chiaroscuro levels							.39

Wave File Number 5 – September 20, 2000 – Subject #10

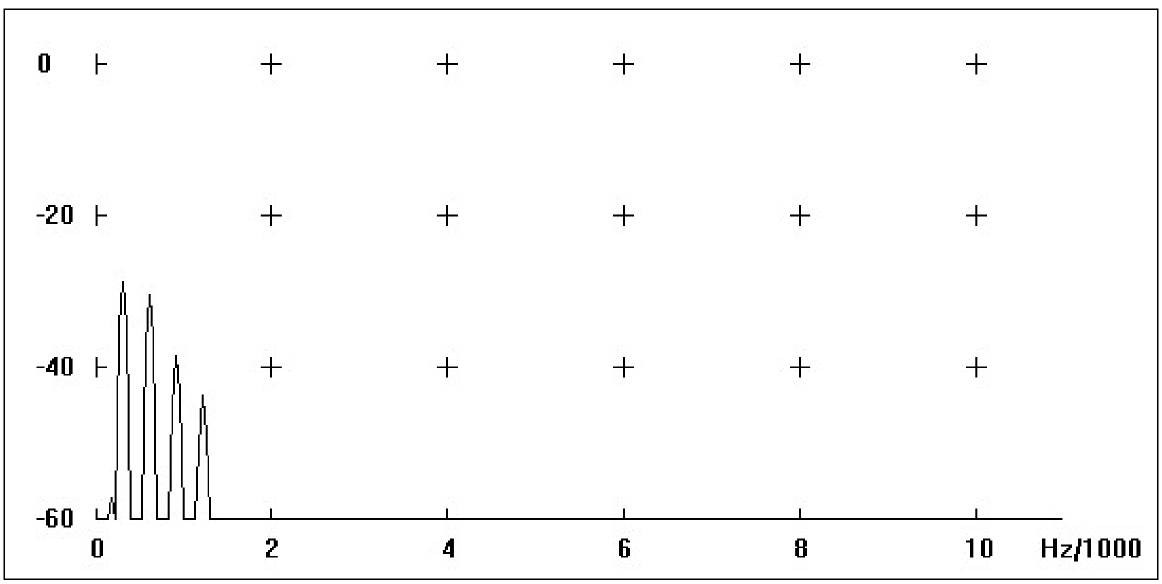


Subject #10 – Analysis of Wave File #5 – September 20, 2000 – E flat major				
		[si] (2.38-3.55 sec)	[o] (3.94-5.07 sec)	[a] (5.51-9.59 sec)
Singer's Formant Area	4000+ Hz		Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Nearly solid indications	Scattered indications	Nearly solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Consistent and stronger	Consistent and stronger	Consistent and stronger
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Partially balanced
Power Spectrum		Increase from about 5% to about 20%	Varying around 20%	Varying around 30%
Voice is functioning more fully than in wave file #4.				

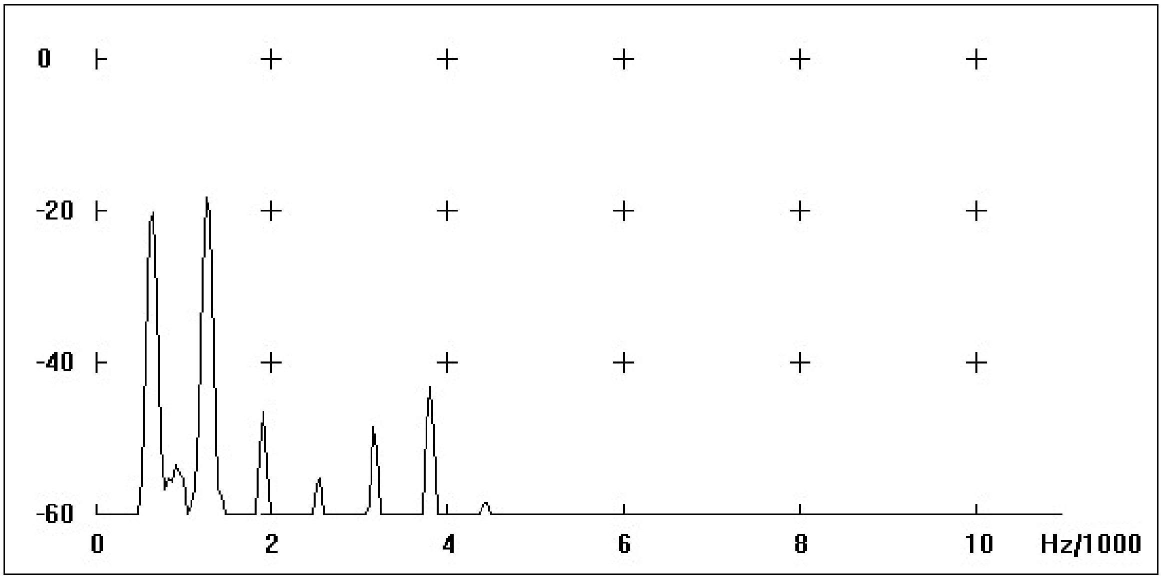
Power spectrum from Spectrogram #5, Subject #10 at 3.16 seconds [i]



Power spectrum from Spectrogram #5, Subject #10 at 4.8 seconds [o]

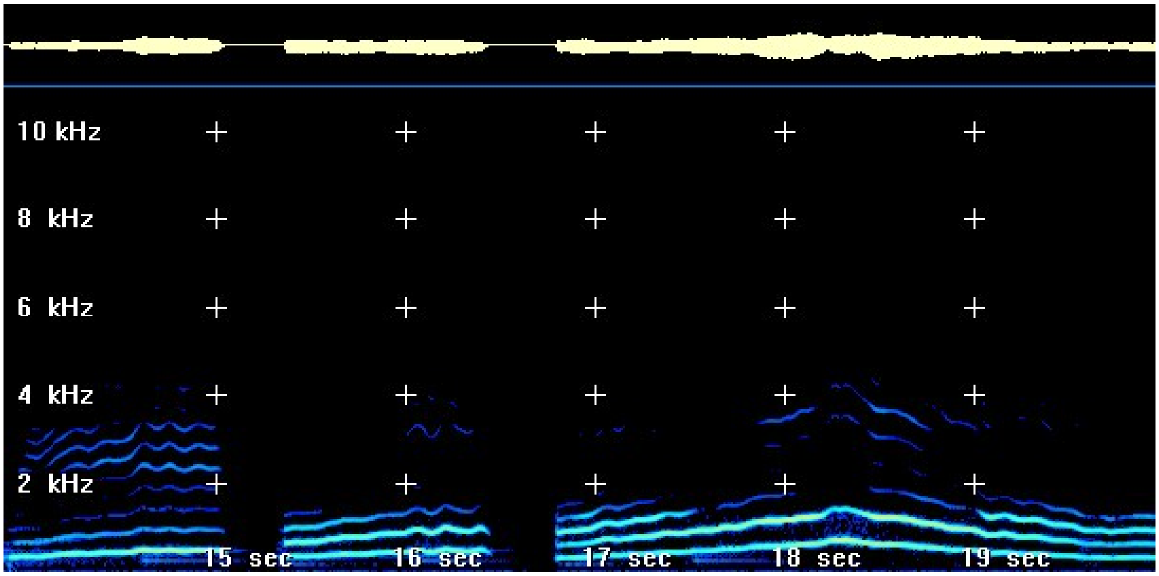


Power spectrum from Spectrogram #5, Subject #10 at 7.33 seconds [a]



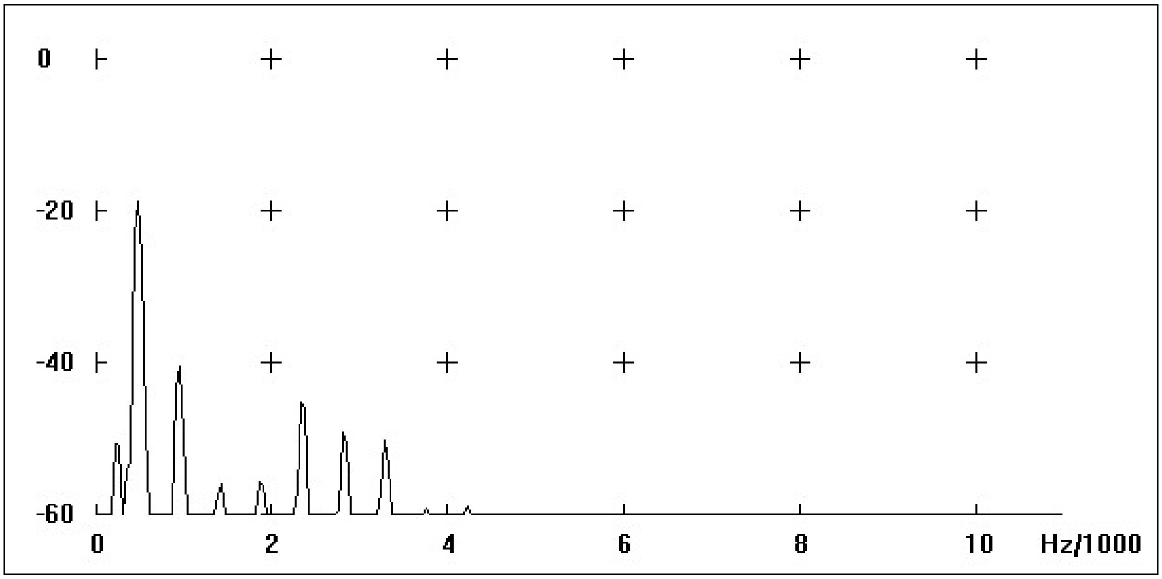
Analysis of Power Spectra from Spectrogram #5, Subject #10 – September 20, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.16	2	1	.5	2	4	.5	.5
4.8	5	3	.6	0	5	0	.3
7.33	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.43

Wave File Number 6 – September 27, 2000 – Subject #10

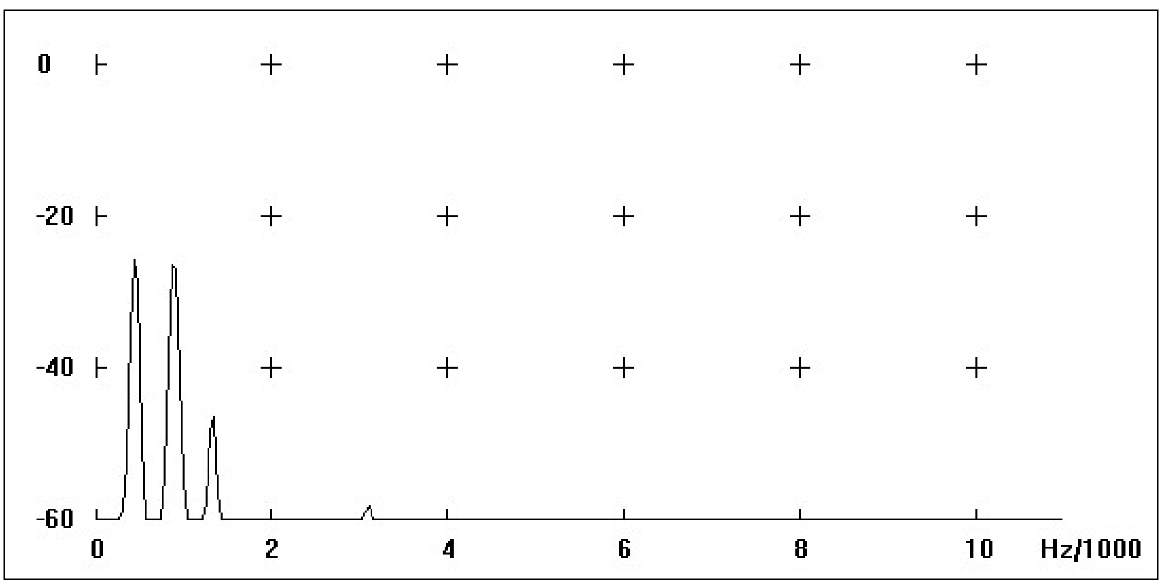


Subject #10 – Analysis of Wave File #6 – September 27, 2000 – E flat major				
		[si] (13.9-15.04 sec)	[o] (15.3-16.42 sec)	[a] (16.8-20.36 sec)
Singer's Formant Area	4000+ Hz			Beginning to enter this area
	2000-4000 Hz	Nearly solid indications	Scattered indications	Scattered indications with damping of upper frequencies at high notes
2nd Formant Area (Vowel Definition)		Clear vowel definition	Weak vowel definition	Clear vowel definition
1st Formant Area		Consistent	Consistent	Consistent
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 10% to about 20%	Varying around 20%	<> from about 20% to about 30% with loss of power when high notes are damped
No indications of progress. High numbers for timings are due to another student's wave file inadvertently being recorded before Subject #10's in this wave file.				

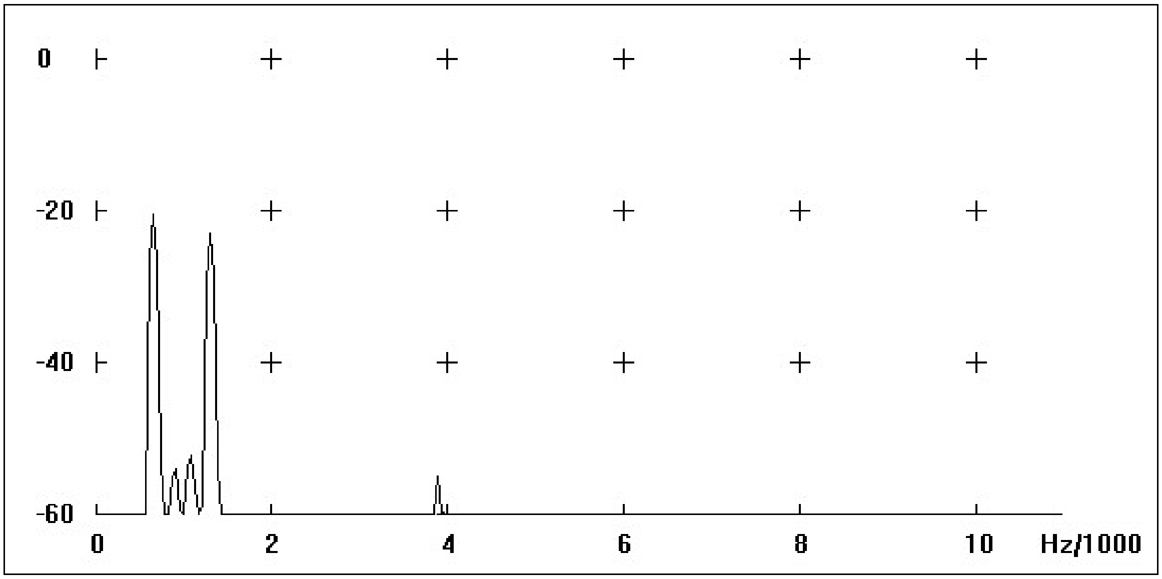
Power spectrum from Spectrogram #6, Subject #10 at 14.82 seconds [i]



Power spectrum from Spectrogram #6, Subject #10 at 16.04 seconds [o]

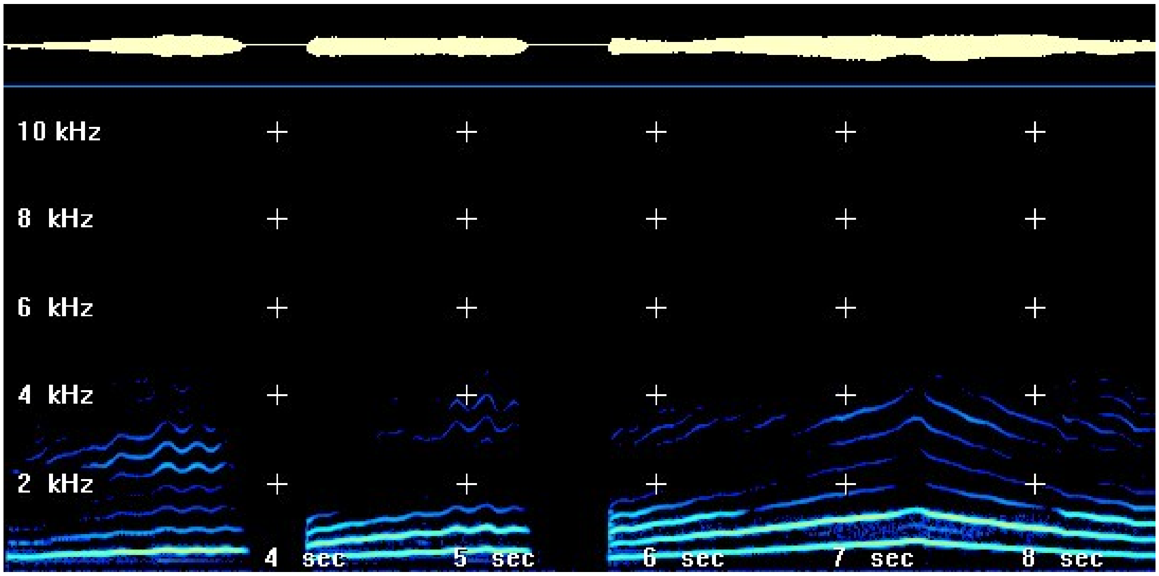


Power spectrum from Spectrogram #6, Subject #10 at 18.47 seconds [a]



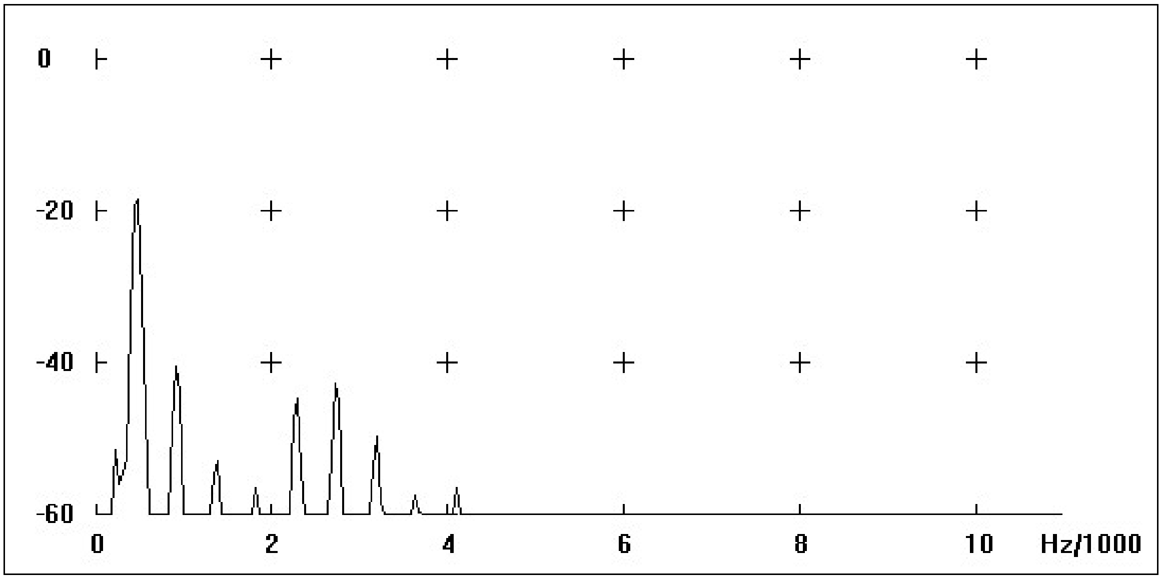
Analysis of Power Spectra from Spectrogram #6, Subject #10 – September 27, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
14.8	5	2	.4	5	10	.5	.45
16.0	3	2	.66	1	4	.25	.45
18.4	4	2	.5	1	5	.2	.35
Average of three chiaroscuro levels							.41

Wave File Number 7 – October 4, 2000 – Subject #10

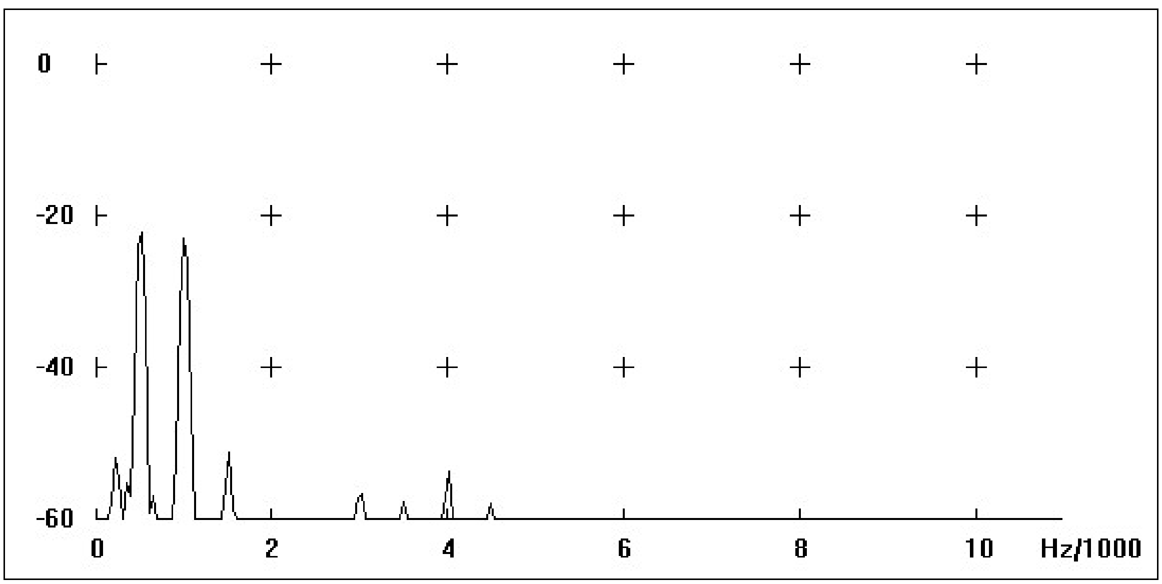


Subject #10 – Analysis of Wave File #7 – October 4, 2000 – E flat major				
		[si] (2.59-3.83 sec)	[o] (4.15-5.34 sec)	[a] (5.76-9.49 sec)
Singer's Formant Area	4000+ Hz		Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Nearly solid indications	Scattered indications	Scattered indications, but damping high notes
2nd Formant Area (Vowel Definition)		Clear vowel definition	Weak vowel definition	Clear vowel definition
1st Formant Area		Consistent	Consistent	Consistent
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Partially balanced
Power Spectrum		Increase from about 55 to about 25%	Varying around 20%	<> from about 15% to about 25% with loss of power at high notes
Tense voice production evidenced by near straight tone singing. Some vibrato allowed at the ends of phrases when tension is released.				

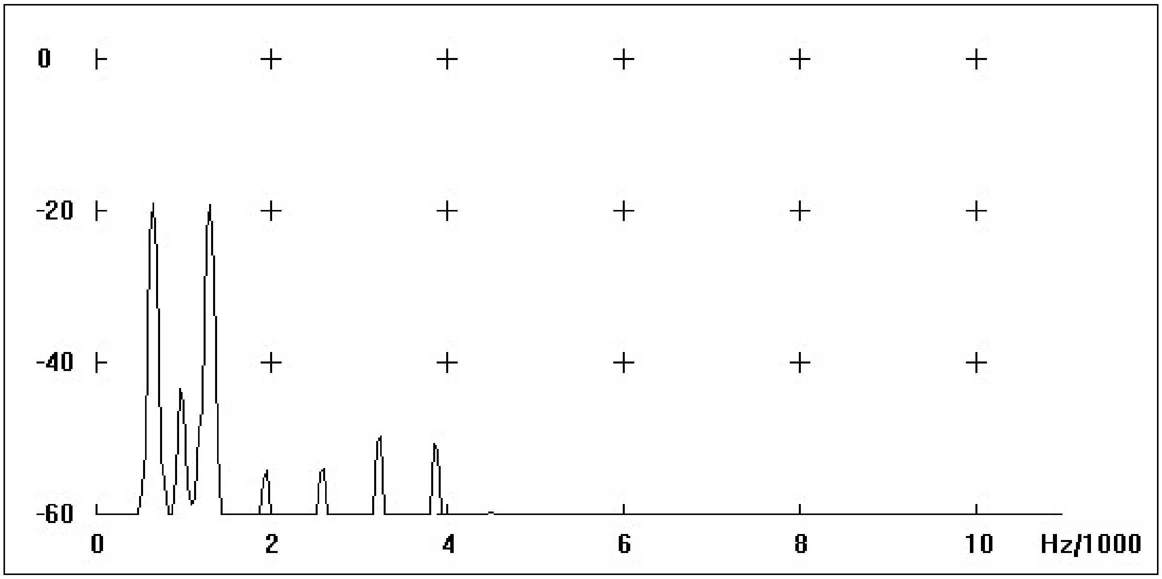
Power Spectrum from Spectrogram #7, Subject #10 at 3.5 seconds [i]



Power Spectrum from Spectrogram #7, Subject #10 at 5.11 seconds [o]

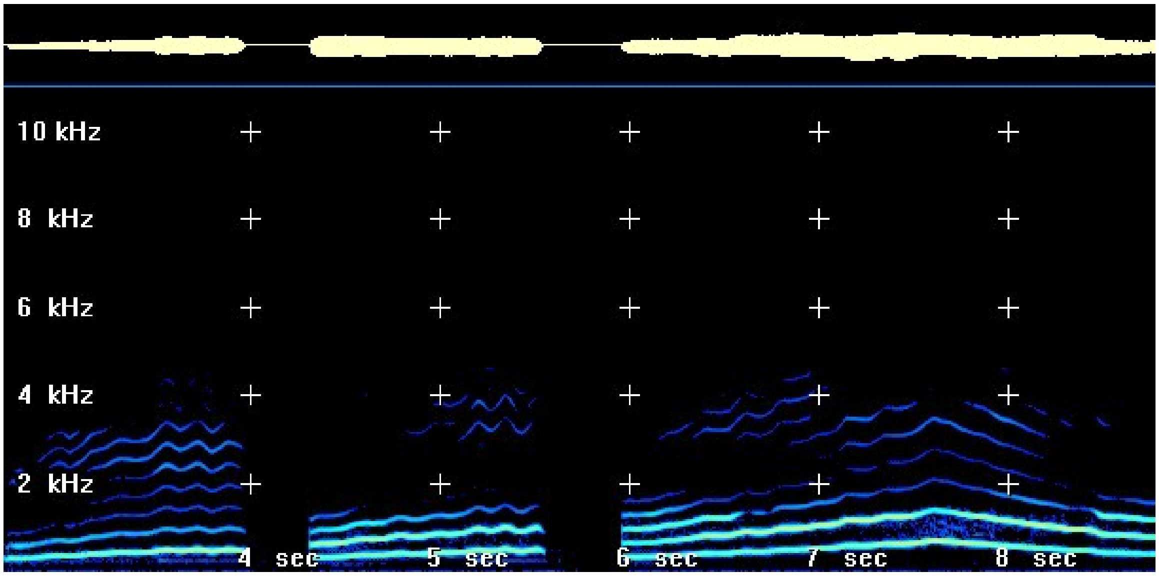


Power Spectrum from Spectrogram #7, Subject #10 at 7.48 seconds [a]



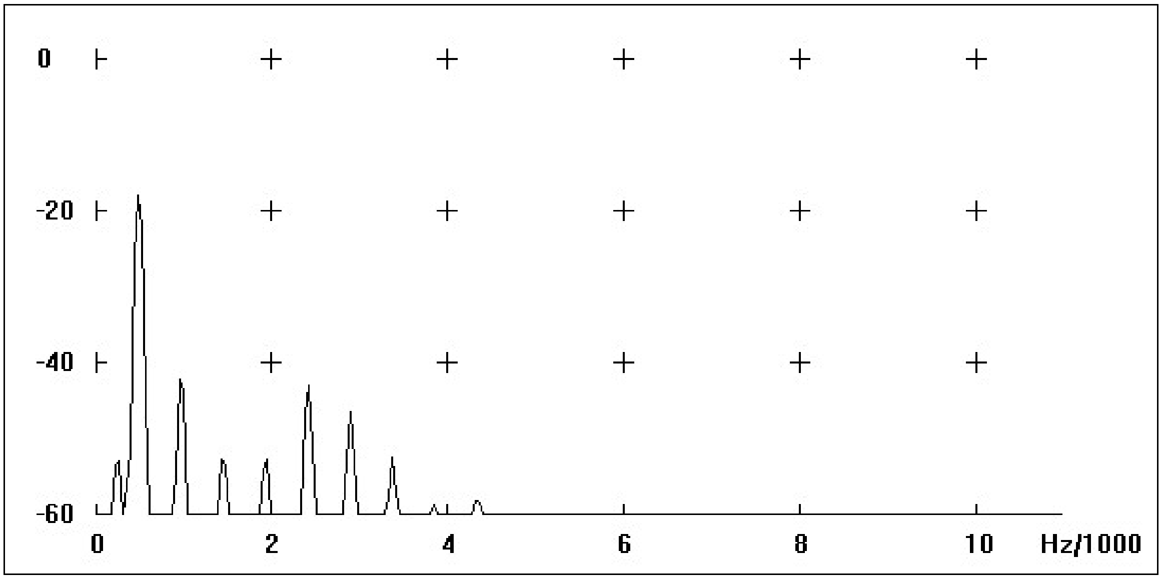
Analysis of Power Spectra from Spectrogram #7, Subject #10 – October 4, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.5	5	2	.4	5	10	.5	.45
5.11	4	2	.5	4	8	.5	.5
7.48	3	2	.66	5	8	.62	.64
Average of three chiaroscuro levels							.53

Wave File Number 8 – October 11, 2000 – Subject #10

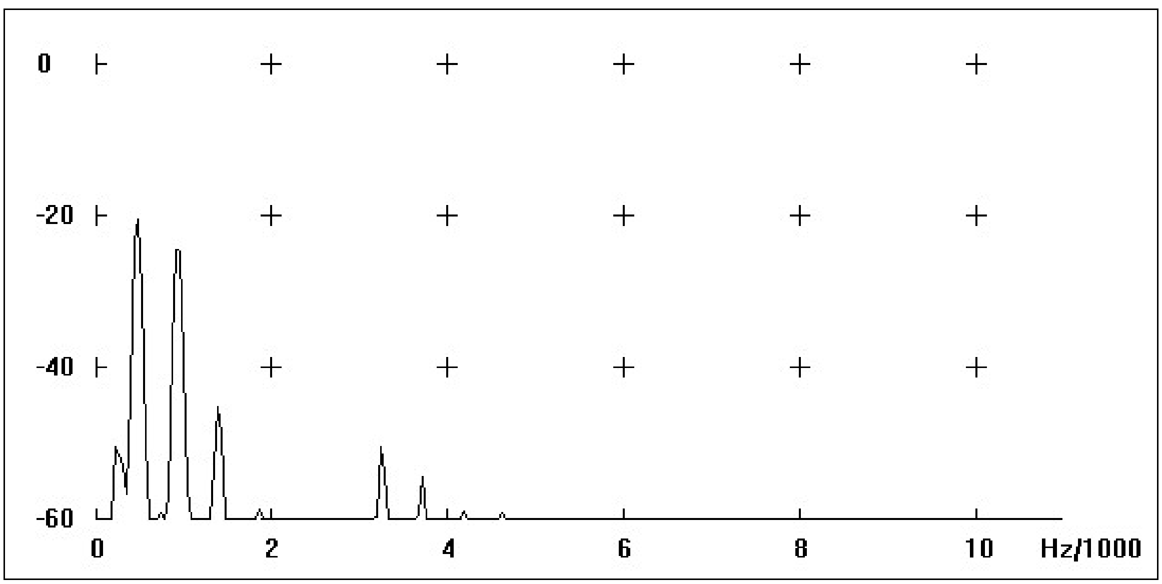


<table>
<tr><td colspan="5">Subject #10 – Analysis of Wave File #8 – October 11, 2000 – E flat major</td></tr>
<tr><td colspan="2"></td><td>[si] (2.7-3.97 sec)</td><td>[o] (4.32-5.54 sec)</td><td>[a] (5.95-9.92 sec)</td></tr>
<tr><td rowspan="2">Singer’s Formant Area</td><td>4000+ Hz</td><td></td><td>Beginning to enter this area</td><td>Beginning to enter this area</td></tr>
<tr><td>2000-4000 Hz</td><td>Nearly solid indications</td><td>Indications occur at the end of the phrase when vibrato appears</td><td>Nearly solid indications</td></tr>
<tr><td colspan="2">2nd Formant Area (Vowel Definition)</td><td>Clear vowel definition</td><td>Clear vowel definition</td><td>Clear vowel definition</td></tr>
<tr><td colspan="2">1st Formant Area</td><td>Consistent</td><td>Consistent</td><td>Consistent</td></tr>
<tr><td colspan="2">Chiaroscuro Balance</td><td>Partially balanced</td><td>Weighted toward lower frequencies</td><td>Partially balanced</td></tr>
<tr><td colspan="2">Power Spectrum</td><td>Increase from about 5% to about 15%</td><td>Varying around 20%</td><td><> from about 10% to about 25%</td></tr>
<tr><td colspan="5">Student is singing with much more energy. Note clean starts and stops of phrases and lessened damping off of high notes.</td></tr>
</table>

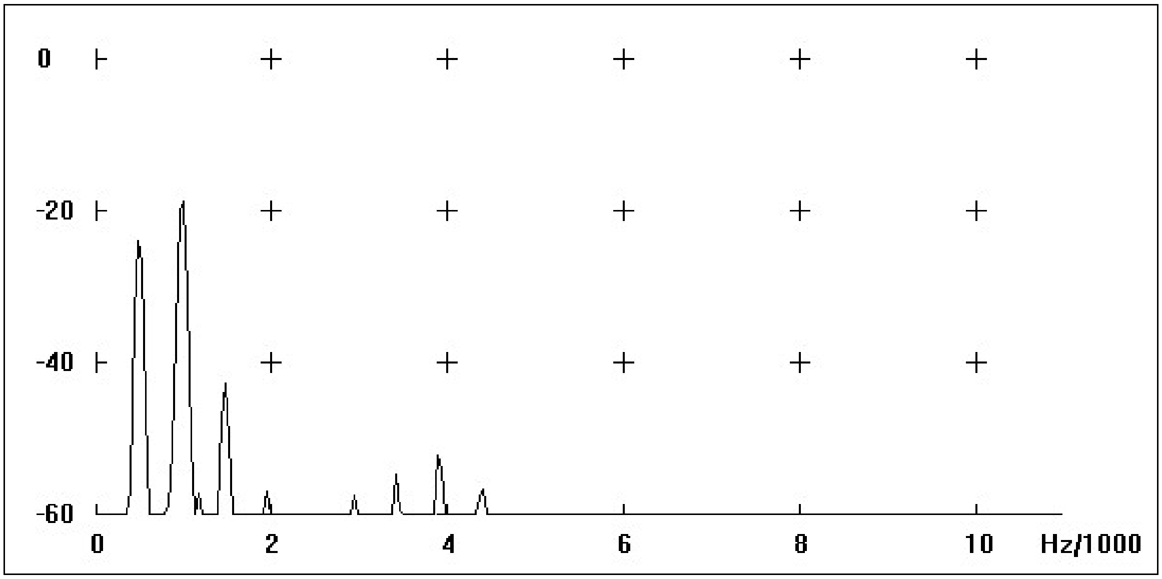
Power spectrum from Spectrogram #8, Subject #10 at 3.58 seconds [i]



Power spectrum from Spectrogram #8, Subject #10 at 5.26 seconds [o]

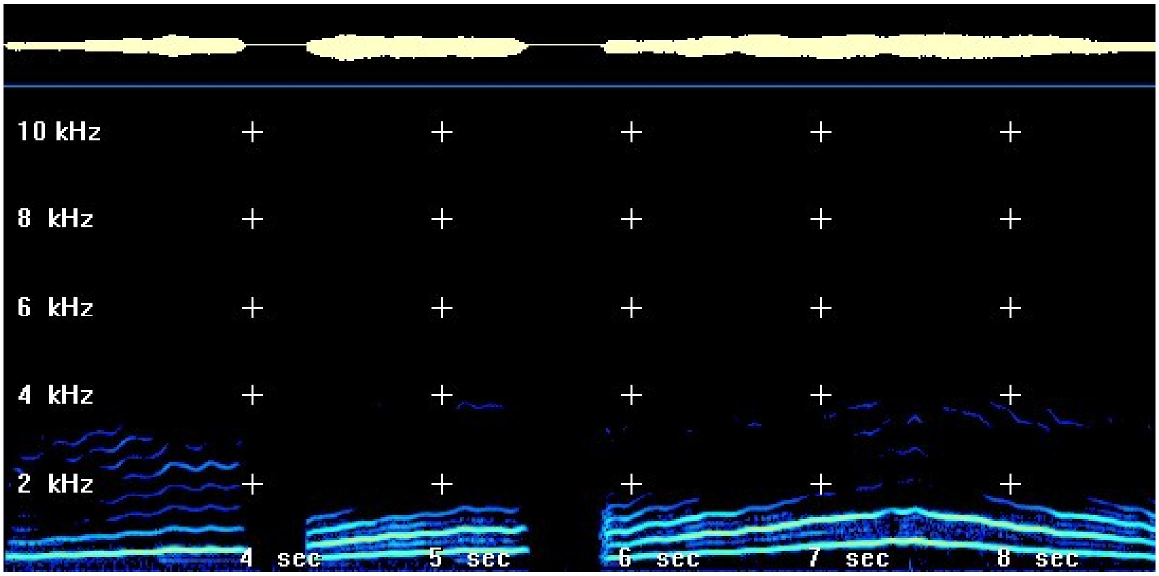


Power spectrum from Spectrogram #8, Subject #10 at 6.9 seconds [a]



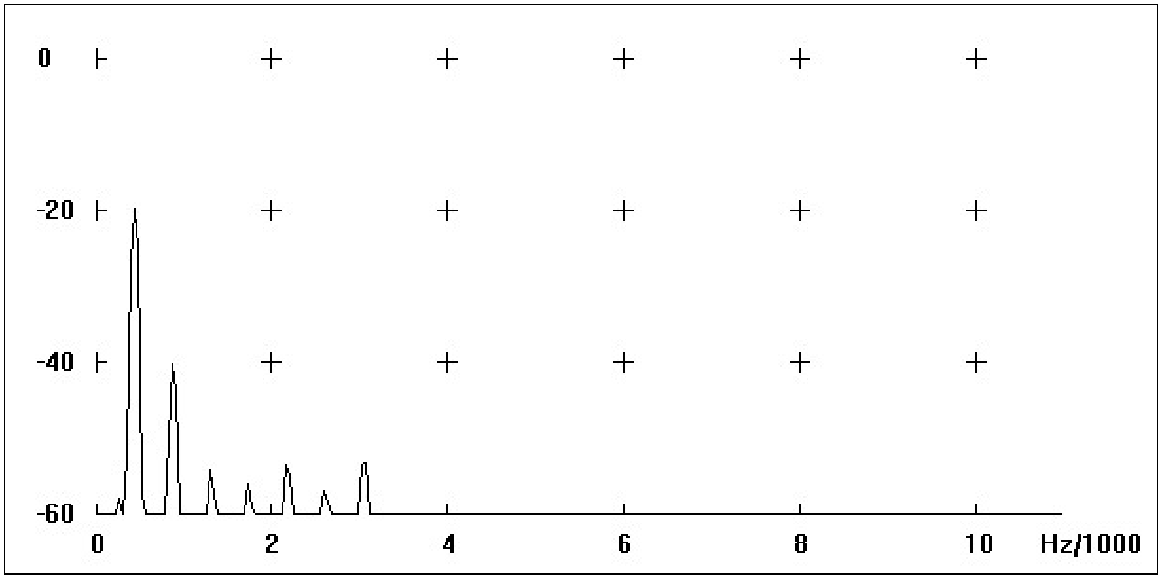
Analysis of Power Spectra from Spectrogram #8, Subject #10 – October 11, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.58	5	2	.4	5	10	.5	.5
5.26	5	2	.4	4	9	.44	.42
6.9	4	2	.5	5	9	.55	.52
Average of three chiaroscuro levels							.48

Wave File Number 9 – October 12, 2000 – Subject #10

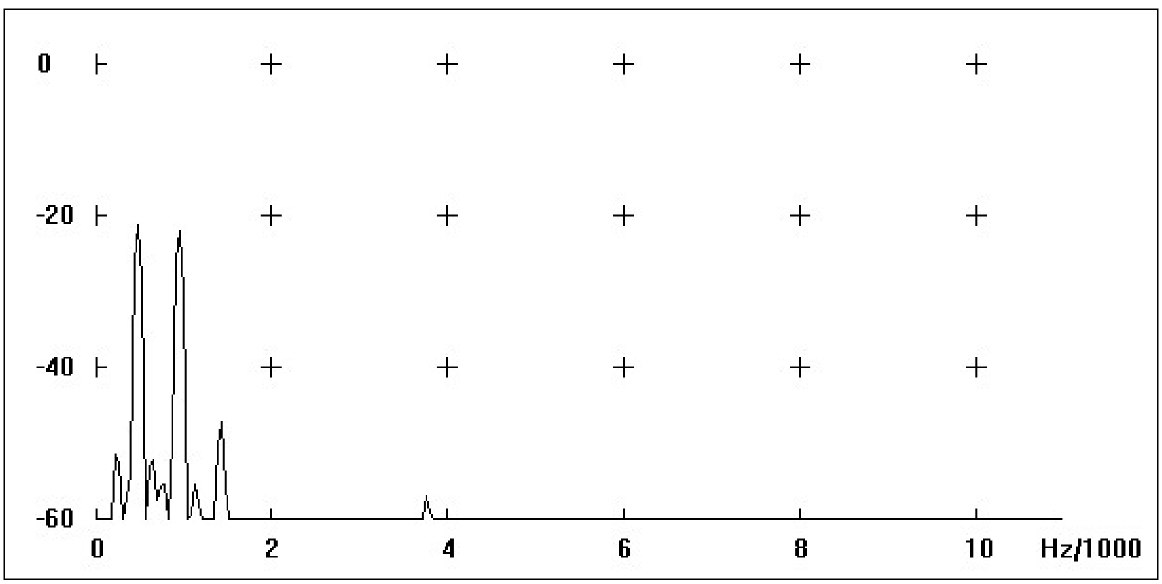


Subject #10 – Analysis of Wave File #9 – October 12, 2000 – E flat major				
		[si] (2.69-3.92 sec)	[o] (4.28-5.44 sec)	[a] (5.87-9.37 sec)
Singer's Formant Area	4000+ Hz			
	2000-4000 Hz	Some indications above vowel	One weak indication	Scattered indications on ascending scale – more on descending scale
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition, but with some noise	Clear vowel definition, but with some noise
1st Formant Area		Consistent	Consistent	Consistent
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Weighted toward lower frequencies
Power Spectrum		Increase from about 10% to about 20%	Varying around 20%	Varying around 20%
Noise in first formant area may be the audible congestion in the throat.				

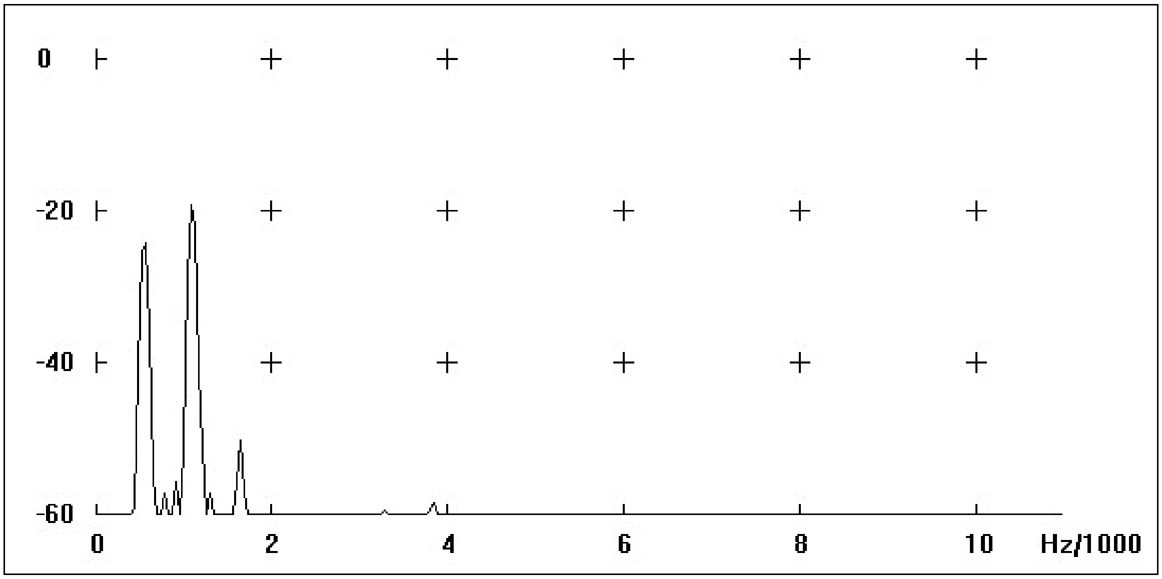
Power Spectrum from Spectrogram #9, Subject #10 at 3.37 seconds [i]



Power Spectrum from Spectrogram #9, Subject #10 at 5.25 seconds [o]

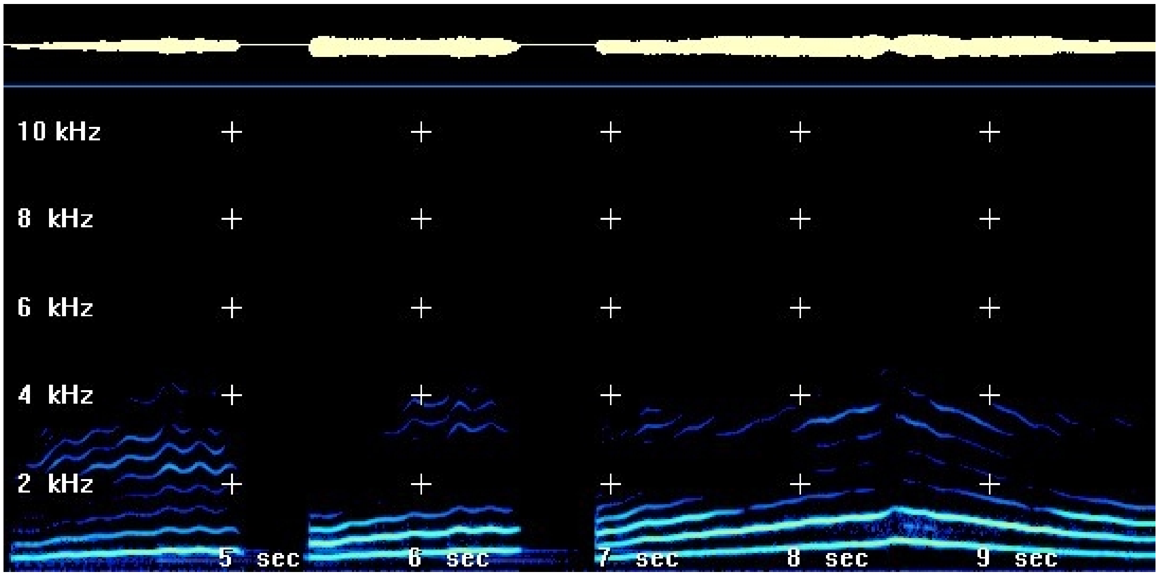


Power Spectrum from Spectrogram #9, Subject #10 at 7.92 seconds [a]



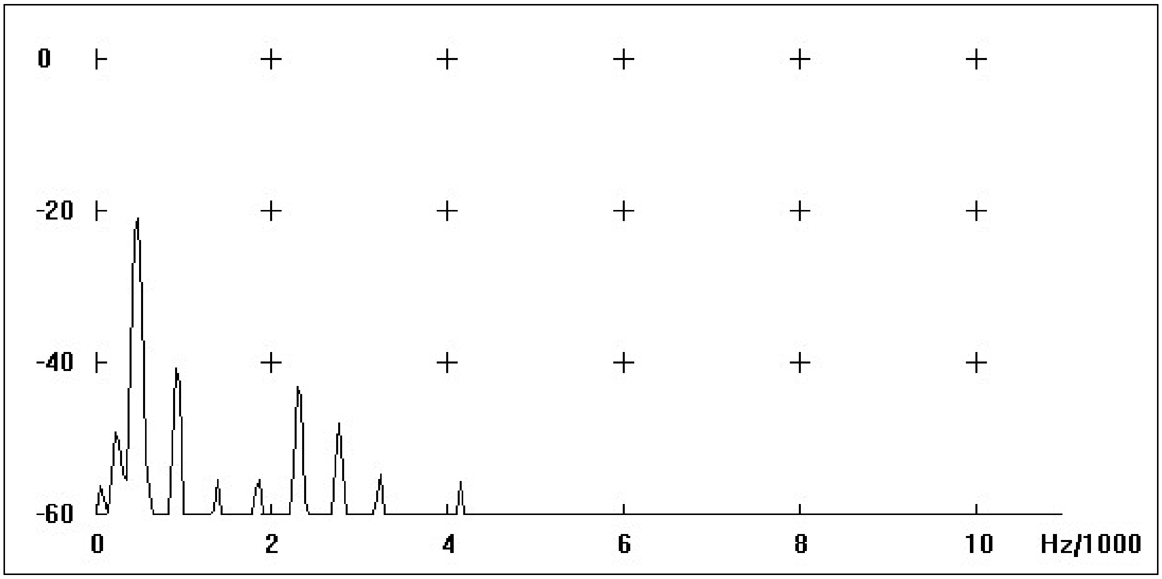
Analysis of Power Spectra from spectrogram #9, Subject #10 – October 12, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.37	5	2	.4	3	8	.37	.38
5.25	7	2	.28	1	8	.12	.2
7.92	6	2	.33	2	8	.25	.29
Average of three chiaroscuro levels							.29

Wave File Number 10 – October 18, 2000 – Subject #10

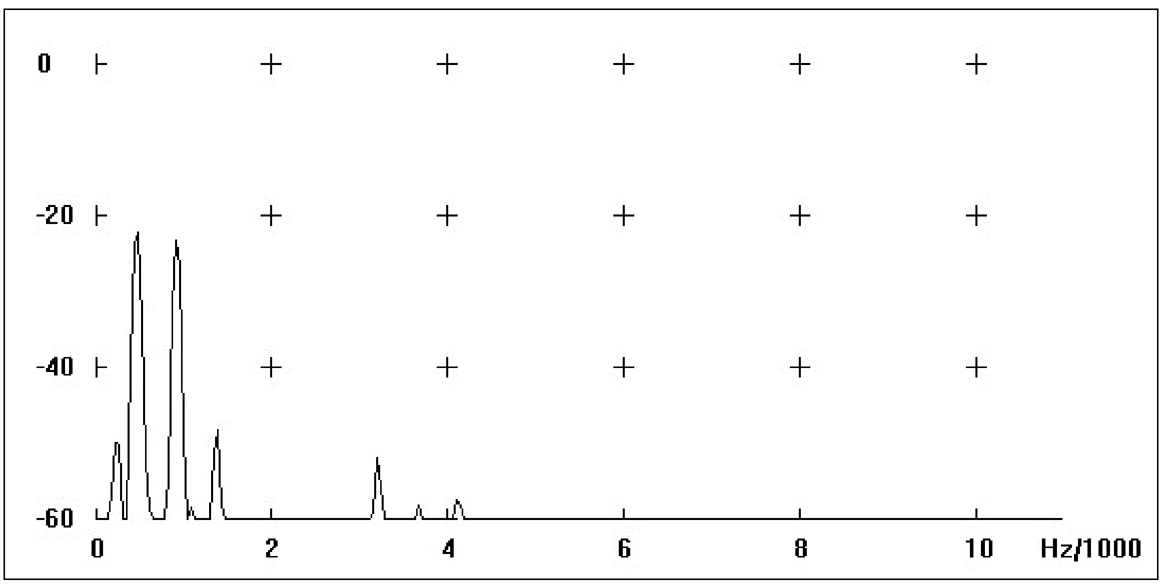


Subject #10 – Analysis of Wave File #10 – October 18, 2000 – E flat major				
		[si] (3.86-5.03 sec)	[o] (5.42-6.53 sec)	[a] (6.93-10.83 sec)
Singer's Formant Area	4000+ Hz		Beginning to enter this area	Beginning to enter this area
	2000-4000 Hz	Solid indications above vowel	Solid indications	Solid indications
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Consistent	Consistent	Consistent and stronger
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Partially balanced
Power Spectrum		Increase from about 5% to about 10%	Varying around 20%	Varying around 20%
The student seems to have made better use of her resonance techniques. More consistency will be the goal.				

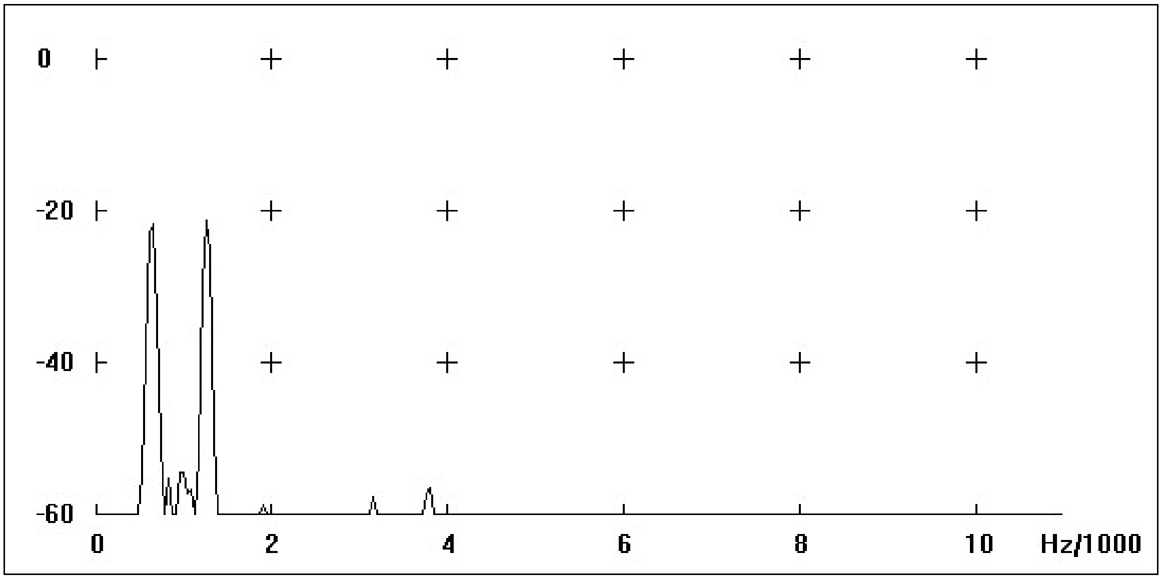
Power Spectrum from Spectrogram #10, Subject #10 at 4.73 seconds [i]



Power spectrum from Spectrogram #10, Subject #10 at 6.29 seconds [o]

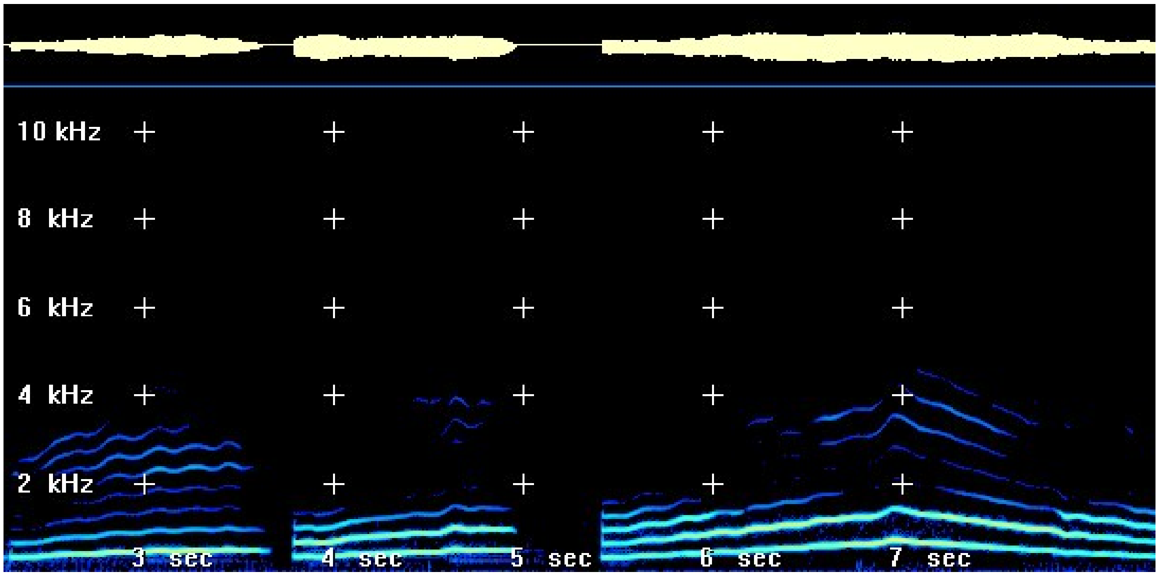


Power spectrum from Spectrogram #10, Subject #10 at 8.43 seconds [a]



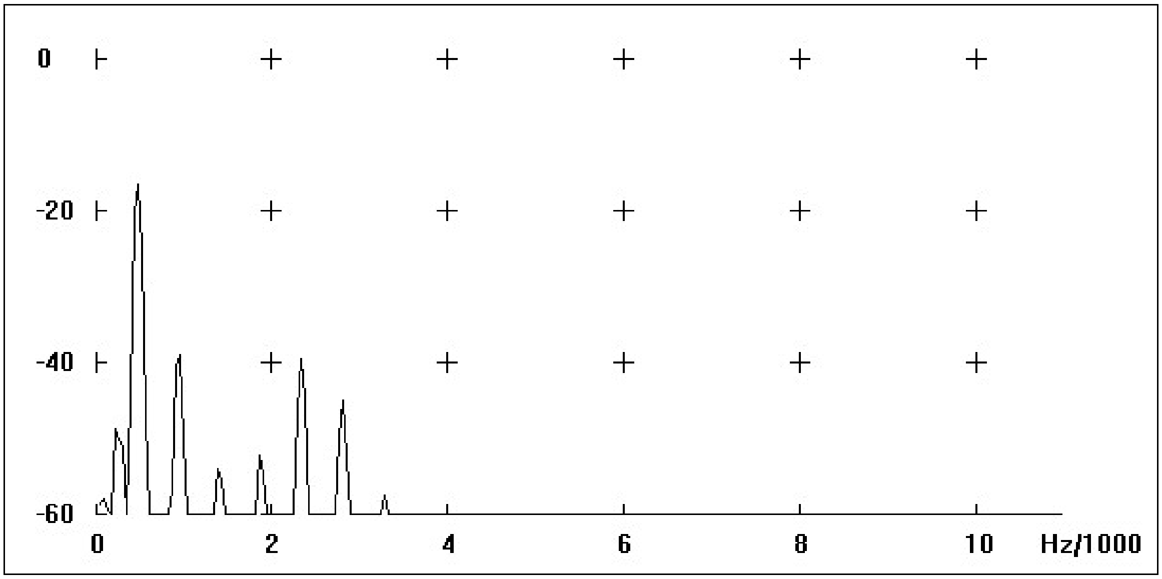
Analysis of Power Spectra from Spectrogram #10, Subject #10 - October 18, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
4.73	6	2	.33	4	10	.4	.36
6.29	5	2	.4	3	8	.37	.38
8.43	5	2	.4	2	7	.28	.34
Average of three chiaroscuro levels							.36

Wave File Number 11 – October 25, 2000 – Subject #10

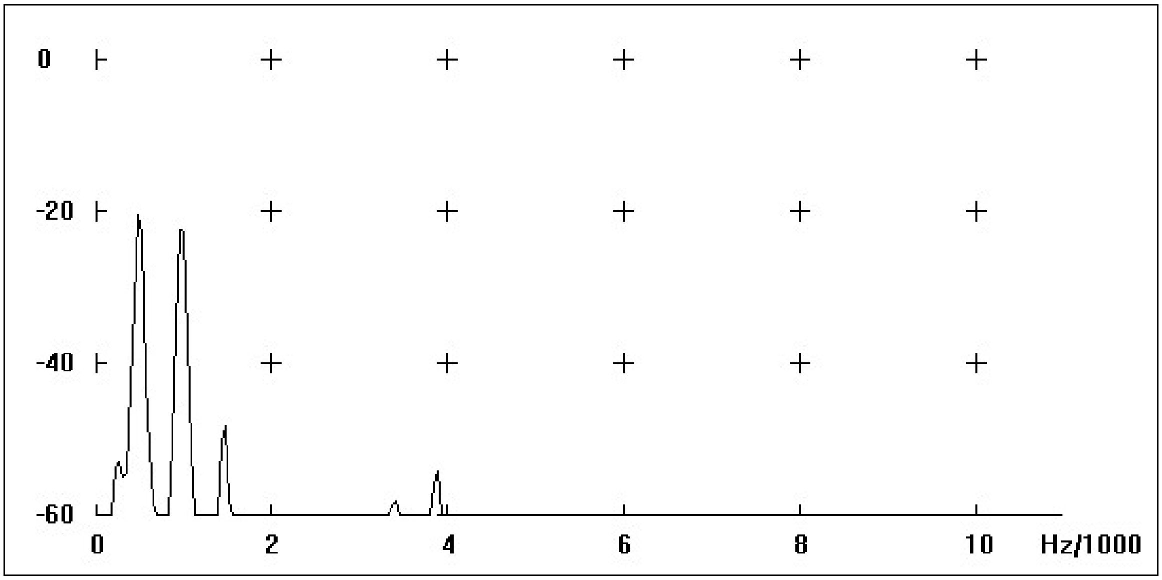


Subject #10 – Analysis of Wave File #11 – October 25, 2000 – E flat major				
		[si] (2.3-3.61 sec)	[o] (3.8-4.97 sec)	[a] (5.43-9.17 sec)
Singer's Formant Area	4000+ Hz			Beginning to enter this area
	2000-4000 Hz	Solid indications above vowel	Scattered indications	Solid indications on highest pitches
2nd Formant Area (Vowel Definition)		Clear vowel definition	Clear vowel definition	Clear vowel definition
1st Formant Area		Consistent	Consistent	Consistent and stronger
Chiaroscuro Balance		Partially balanced	Weighted toward lower frequencies	Partially balanced
Power Spectrum		Increase from about 10% to about 30%	Varying around 30%	<> from about 15% to about 30%
The student is showing more consistency in her use of upper level frequencies and is balancing the added upper level frequencies with increased lower frequencies.				

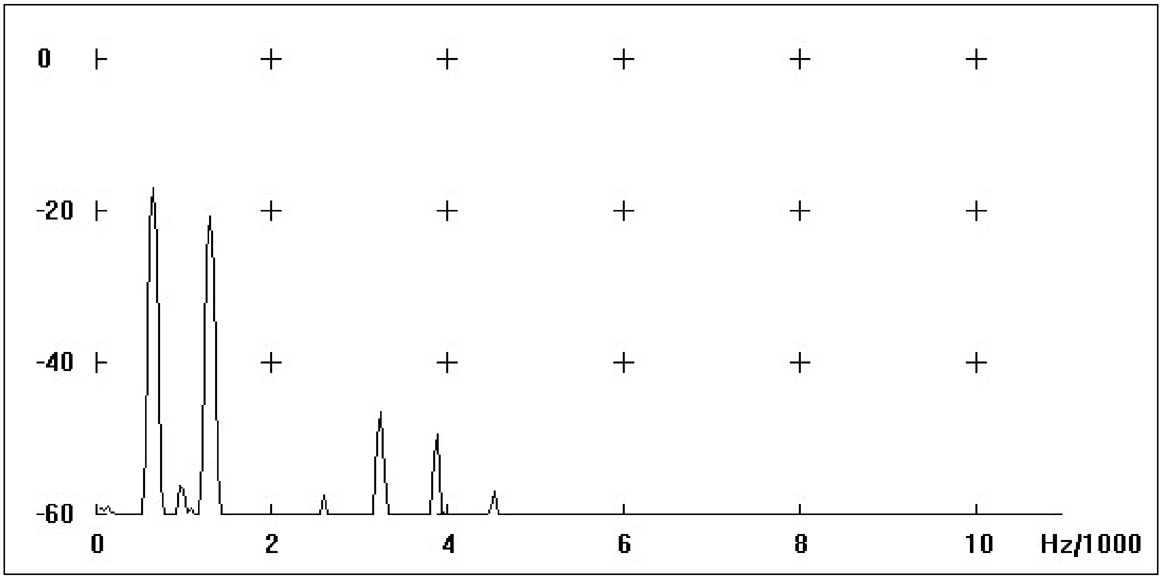
Power Spectrum from Spectrogram #11, Subject #10 at 3.08 seconds [i]



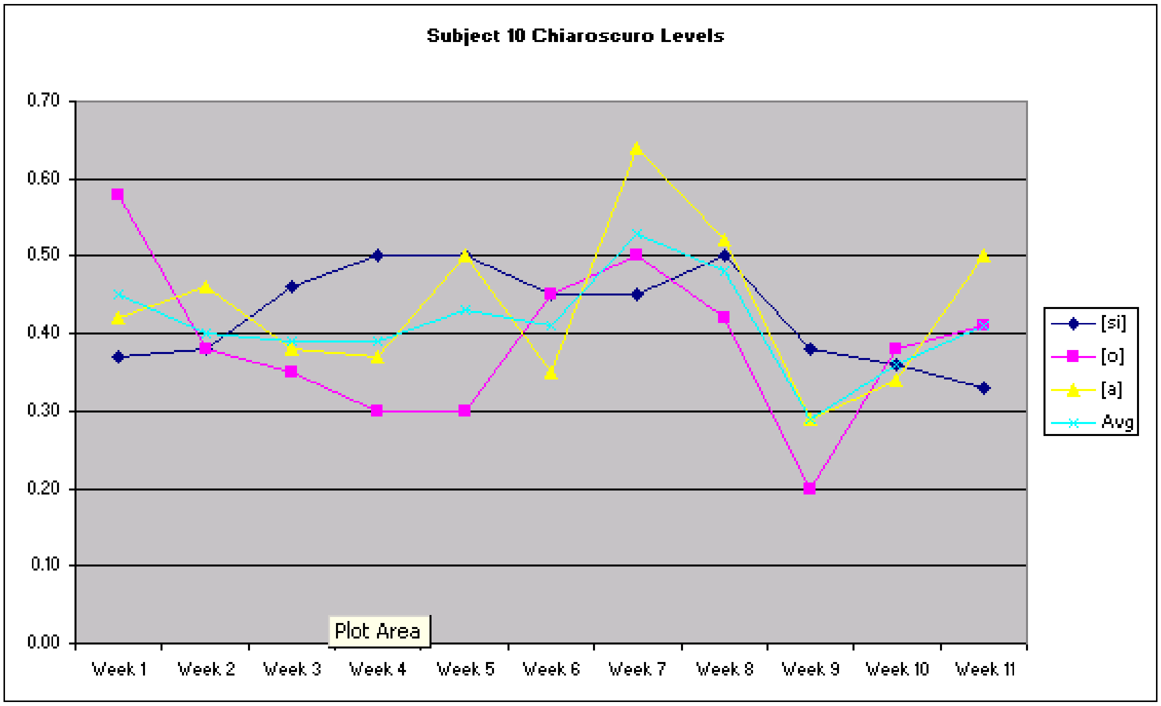
Power spectrum from Spectrogram #1, Subject #101 at 4.63 seconds [o]

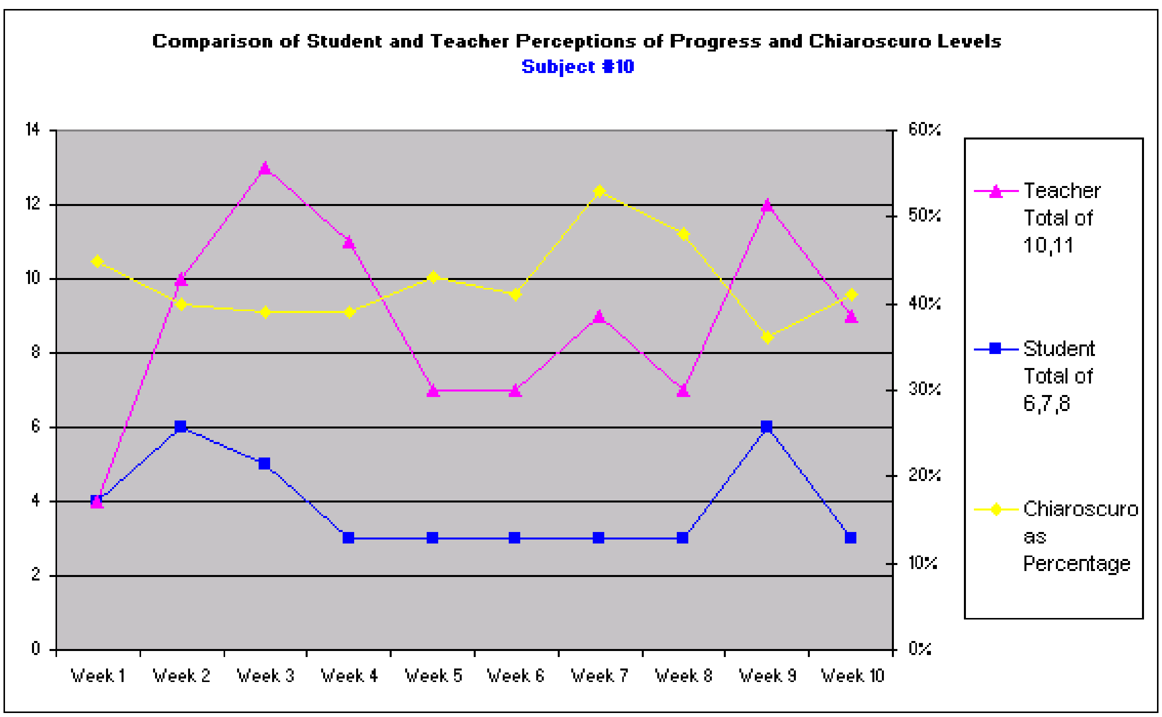


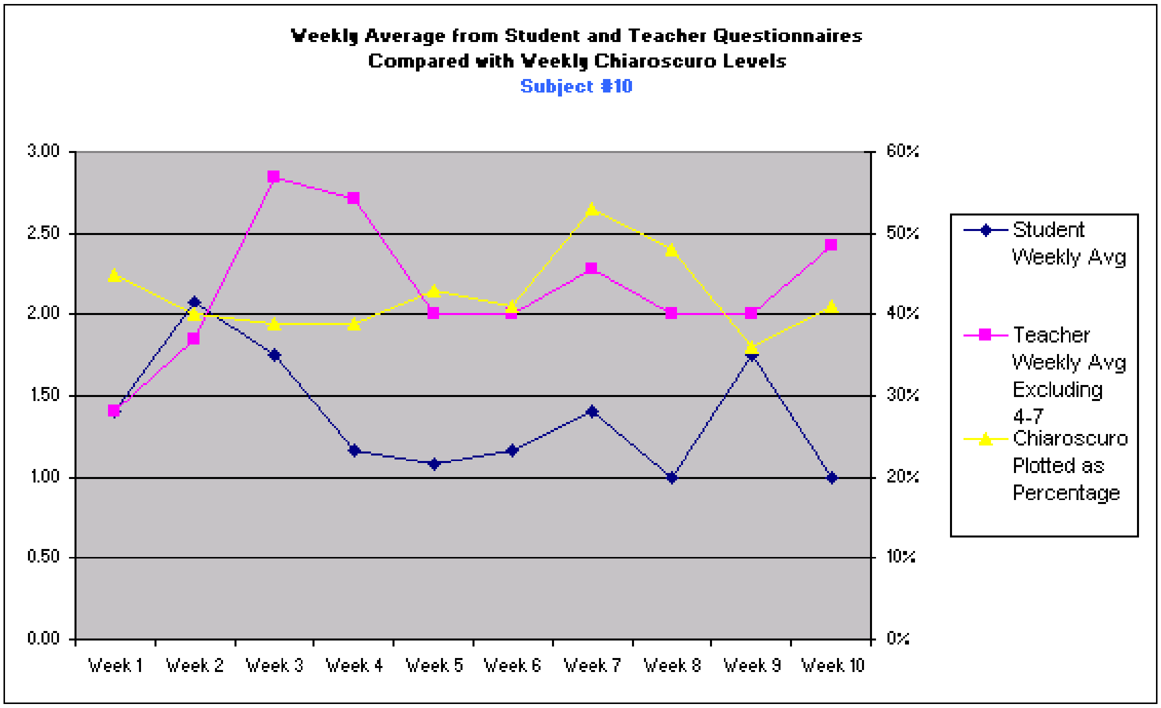
Power spectrum from Spectrogram #1, Subject #101 at 7.13 seconds [a]



Analysis of Power Spectra from Spectrogram #11, Subject #10 – October 25, 2000							
	First & Second Formant Area < 2000 Hz			Number of Peaks in Singers Formant Area ≥ 2000+ Hz	Total number of peaks in entire Power Spectrum	PS Ratio (Ratio of Upper Level Peaks to Total Peaks)	Chiaroscuro Level (average of the two PS Ratios)
	Total number of peaks	Peaks ≥ -40 dB	F_{1-2} Power Spectrum Ratio				
	a	b	$\frac{b}{a}$	c	d	$\frac{c}{d}$	$\frac{(b/a+c/d)}{2}$
3.08	6	2	.33	3	9	.33	.33
4.63	4	2	.5	2	6	.33	.41
7.13	4	2	.5	4	8	.5	.5
Average of three chiaroscuro levels							.41


Subject 10 Chiaroscuro Levels
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Plot Area
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
[si]
[o]
[a]
Avg


Comparison of Student and Teacher Perceptions of Progress and Chiaroscuro Levels
Subject #10
14
12
10
8
6
4
2
0
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Teacher Total of 10,11
Student Total of 6,7,8
Chiaroscuro as Percentage


Weekly Average from Student and Teacher Questionnaires
Compared with Weekly Chiaroscuro Levels
Subject #10
3.00
2.50
2.00
1.50
1.00
0.50
0.00
60%
50%
40%
30%
20%
10%
0%
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Student Weekly Avg
Teacher Weekly Avg Excluding 4-7
Chiaroscuro Plotted as Percentage

APPENDIX B

VOCALISES USED BEFORE AND DURING THE SPECTROGRAPHIC TEST UNIT

WARM-UP EXERCISES
Patricia Callaway
February 1995

Your vocal muscles, like any other muscles, should be gently warmed up before you begin using them. Spend a few minutes (about 10 if you're going to practice for 30 minutes) on these or similar exercises. Sing an exercise in each key moving up by half-steps. A below middle C and the second E above middle C are the boundaries you should stay within when you begin to warm up. Gradually extend the range upward, but do not strain your voice by singing too high or too low or loudly before you've warmed up.

APPENDIX C

STUDENT AND TEACHER QUESTIONNAIRES AND INSTRUCTIONS FOR STUDENTS' WRITTEN REACTIONS TO THE SPECTROGRAPH

University of Georgia
Study of Spectrographic Analysis During Traditional Voice Teaching
by Patricia Callaway

Student Evaluations of Spectrography

Student's Name_________________ Date of lesson______________

Please decide whether or not you agree with the following statements and place a check mark in the box with the number that corresponds to the answer that you feel is most appropriate. Make any additional comments in the space below or on the back of this sheet.

1 – Strongly agree 2 - Agree 3 - Not sure 4 – Disagree 5 – Strongly disagree

	Question	**1**	**2**	**3**	**4**	**5**
1	My voice feels healthy today.					
2	I sang well today.					
3	I was well prepared for my lesson today.					
4	I understood what my teacher wanted me to do in my warm ups.					
5	I understood how the graph on the spectrograph screen reflected what I was doing.					
6	I think that my wave file this week showed improvement from last week.					
7	I think that my wave file this week showed improvement since the beginning of the semester.					
8	I think that studying technique is helping me become a better performer.					
9	I enjoy watching the spectrograph.					
10	It is becoming easier to interpret how the spectrograph reflects what I am singing.					
11	I noticed something today on the spectrograph display that gave me some insight into how I can improve my singing.					
12	I think the spectrograph is helping me improve my tone quality.					

Additional Comments:

University of Georgia
Study of Spectrographic Analysis During Traditional Voice Teaching
by Patricia Callaway

Teacher's Weekly Lesson Evaluations of Spectrography

Student's Name_________________ Date of lesson______________

Questions 1-3: Rate the functioning of each part of the data gathering effort.

	Equipment	Student health, preparation, level of comfort, level of confidence	Degree to which procedure was followed
Very good			
Good			
Acceptable			
Poor			
Unacceptable			

Questions 4-7: During warm-ups, how much was attention to the spectrograph screen focused on each of these issues.

	Resonance	Vibrato	Register Balance	Glottals
Most of the attention				
Significant amount				
Some attention				
A little attention				
No attention				

Question 8: How does the student interact with the spectrograph (i.e., watch the screen, ask questions, experiment)?

Often and enthusiastically	Positively	Neutral	Rarely	Not at all

Question 9: How much did you refer to the spectrograph during warm-ups today?

Frequently pointing out occurrences	Occasionally	Only a few overall remarks	Only responding to student questions	Only while setting up to make the wave file

Questions 10-11: Compare the student's wave file today with these others.

	With last week's	Over the study period so far
Much better		
Better		
Same		
Worse		
Much worse		

University of Georgia
Study of Spectrographic Analysis During Traditional Voice Teaching
by Patricia Callaway

Instructions for Student's Written Reaction to the Spectrograph

You are being asked to write a short description of your reaction to the spectrograph. There are no right or wrong things to say about the technology. What is sought here is your feelings about how it affected your study of voice so far this semester. If you felt that the technology was useful, say so. If you found it intrusive or distracting, you should say that, too. If your opinion changed throughout the period, please describe the changes that it underwent.

The length of this report is up to you, but I would prefer that it stay under two pages. I expect to receive this written report before I turn in your midterm grade. Should you not turn in this report before midterm, your midterm grade will be "Unsatisfactory".

Patricia Callaway
Department of Music
Brenau University
300 Geiger

APPENDIX D

VOICE TEACHERS' EVALUATIONS OF QUESTIONS USED IN STUDENTS' QUESTIONNAIRE

Voice teachers' evaluations of questions used in Student's Likert Scale form

To reduce the usage of technical language in the form used by the students the researcher chose to use language common in college voice studio. To ensure that this language is common throughout the region, several voice teachers from around the state were asked to respond to the questionnaire. They were asked if students in their experience would understand the questions in the manner in which the questions were expressed.

Reply from Andrea Heys, Brenau University, Gainesville, Georgia, September 14, 2000

> Your questions make perfectly good sense!

Reply from Dr. Larry Frazier, State University of West Georgia, Carrollton, Georgia, July 28, 2000

> I believe the singer questions would be crystal clear for any student of voice. The spectrograph questions, also, should be clear for any student fortunate enough to be able to have such a tool at their disposal.

Reply from Rowena Renn, retired professor, Agnes Scott College, Decatur, Georgia and adjunct faculty, State University of West Georgia, Carrollton, Georgia, July 29, 2000

> I see no reason why students can not understand all the questions (1-4 and 8). They are, to me, quite reasonable and seem a unique way to get the student to focus on various aspects of technique.

Reply from Dr. Sandra McClain, Georgia Southern University, and immediate past president of the Georgia Chapter of the National Association of Teachers of Singing, Thursday, July 27, 2000 6:19 PM

> I certainly think that the questions would be understood by my students. The professor probably thinks they are "broad," but student singers know what we mean when we ask those things and they would answer from that perspective (at least I think so).

Reply from Sandy Calloway, Chair of the Department of Music, Truett-McConnell College, Cleveland, Georgia, July 28, 2000

> I have never worked with a spectograph, but I don't think that the questions you posed would prove to be a problem with voice students working with one.

Reply from Dr. Toni Anderson, Chair of the Department of Music, LaGrange College, LaGrange, Georgia, September 01, 2000

> Of course, I think the questions are perfectly clear -- at least to singers. And since singers are the ones answering, what's the problem?

APPENDIX E

CHART OF OVERTONE SERIES FROM WILLIAM VENARD'S

SINGING: THE MECHANISM AND THE TECHNIC

ACOUSTICS

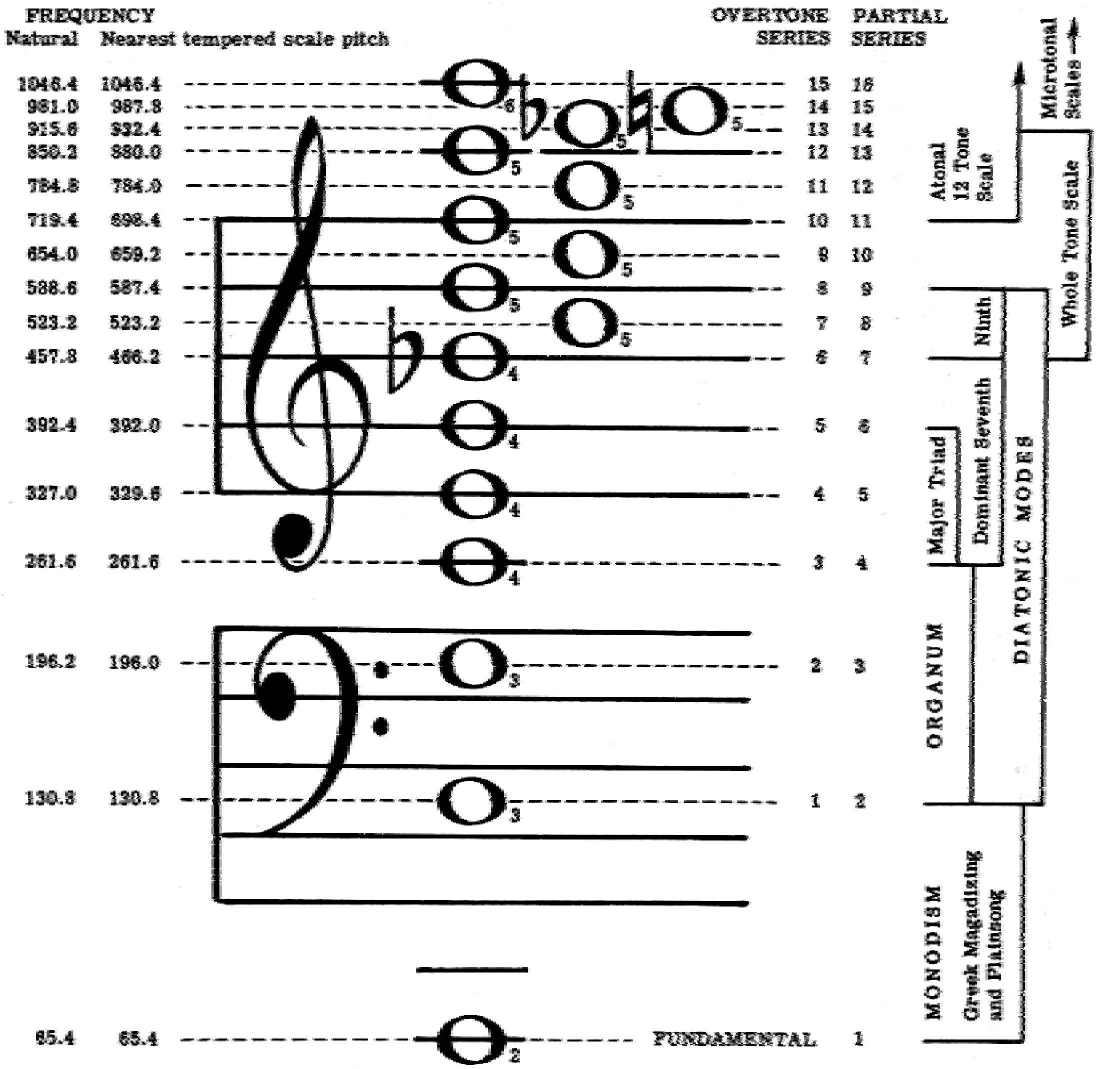


Fig. 8. Chord of Nature

Fundamental assumed to be C below bass staff. Other frequencies are multiples of this, paralleled by their nearest equivalents on tempered keyboard, A–440. In Partial Series, from 1 to 2 is an octave; 2 to 3, a 5th; 3 to 4, a 4th; 4 to 5, a major 3rd; 5 to 6, a minor 3rd; 6 to 7, a minor 3rd, but smaller than 5 to 6; next six intervals are whole steps, progressively smaller, and next three half steps, progressively smaller, going on through quarter and even eighth steps. Partials 2, 4, 8, 16, etc., are octaves above fundamental. Chart at right illustrates how history of music theory parallels harmonic series. Notes in this figure are numbered in accordance with system used for all pitch references in this text. The lowest C on the piano is C_1 and the notes up to the next C are D_1, E_1, etc. Middle C is C_4. Convenient mnemonic device: A_4 is 440 cps.

APPENDIX F

PASSAGGIO OCCURRENCES IN FEMALE VOICE TYPES

Passagio

The passaggio is a challenging part of each voice in which the singer feels less secure control over the pitch and quality of the note she or he is producing. It occurs when the two sets of muscles that tilt the cartilages of the larynx to lengthen the vocal folds change from functioning together to one set functioning by itself, or vice versa. This change in muscular action makes the voice "feel" different at the passaggio point.

The passaggio varies from voice type to voice type, from voice to voice, and even within a voice depending on how the area is approached. A range of pitches, rather than a specific note, is usually referred to as the part of the voice in which passaggio events can occur.

The division of the voice into chest, middle (or mixed), and head registers is based on the location of the passaggii. Richard Miller suggests the following locations of registers and passaggii in female voice. (Miller, *Structure of Singing*, p. 134-135).

Pitch names are given according to the chart from Benjamin, Horvit, and Nelson, *Techniques and Material of Tonal Music*, which is the standard usage at the University of Georgia.

Soprano Voice:

Head voice from g^2 to c^3 ($c\#^3$)

Mixed (middle) register from b-flat to $f\#^2$

Chest register from g to e-flat^1

⇑ Lower or Primo Passaggio

⇑ Upper or Secundo Passaggio

Mezzo-Soprano Voice:

Head voice from f^2 to b-flat^2 (b^2)

Mixed (middle) register from c^1 to e^2 (f^2)

Chest register from e to e^1 (f^1)

⇑ Lower or Primo Passaggio

⇑ Upper or Secundo Passaggio

Contralto Voice:

Head voice from e-flat^2 to a-flat^2

Mixed (middle) register from f^1 to d^2

Chest register from d to g^1 (a-flat^1)

⇑ Lower or Primo Passaggio

⇑ Upper or Secundo Passaggio

APPENDIX G

INTERNATIONAL PHONETIC ALPHABET SYMBOLS

Symbols from the International Phonetic Alphabet Used in this Document

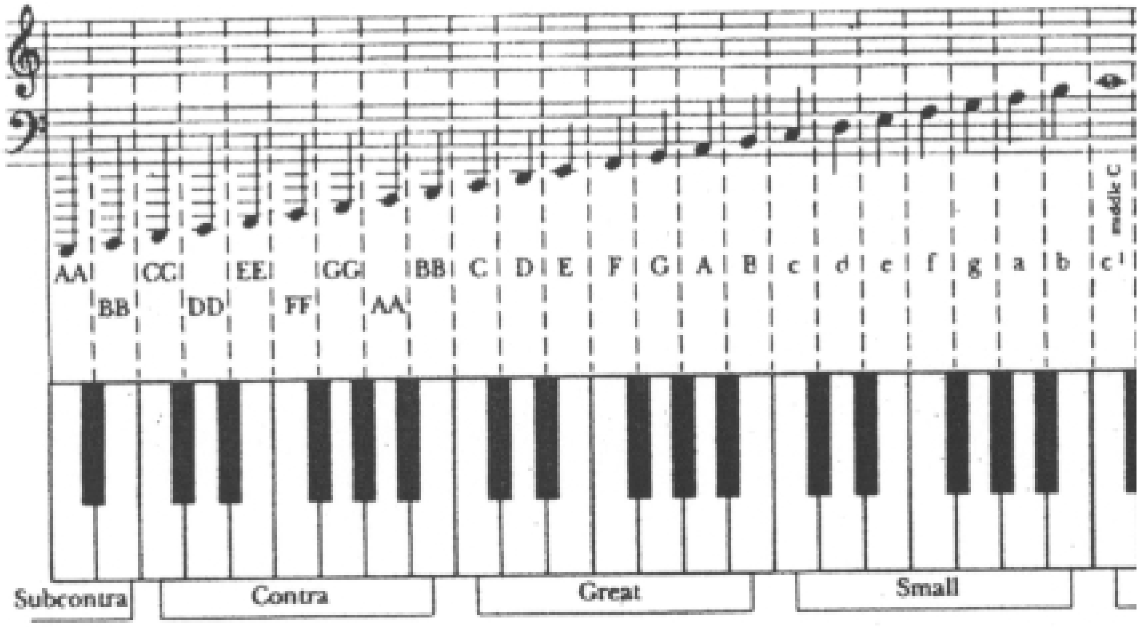
The usage of IPA symbols sometimes varies from author to author. These are the symbols used in both the William Vennard *Singing: The Mechanism and the Technic* and the Richard Miller *Structure of Singing*. The examples are the ones given in the Vennard text on page 136.

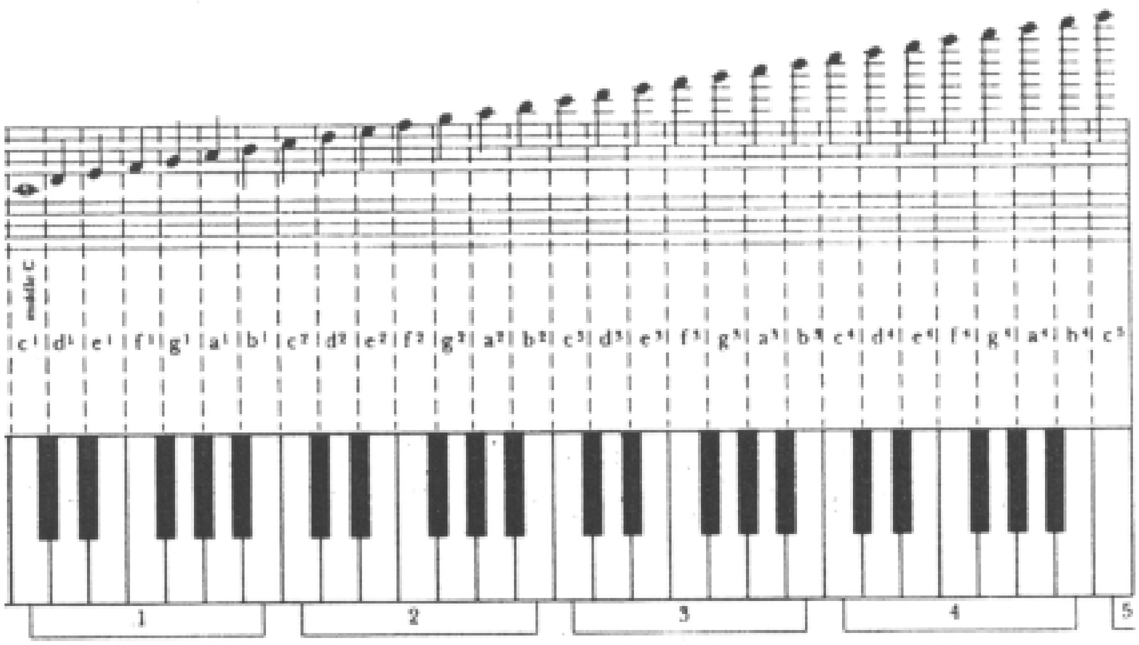
Ee Vowels	[i]	as in beet
	[ɪ]	as in bit
Ay vowels	[e]	as in pay
Eh vowels	[ɛ]	as in pet
	[æ]	as in back
	[a]	as in bask
Ah vowels	[ɑ]	as in calm
	[ɒ]	as in hot
Aw vowels	[ɔ]	as in bawl
	[ə]	as in the (before consonant)
	[ʌ]	as in cut
Oh vowels	[o]	as in tone
	[ʊ]	as in foot
Oo vowels	[u]	as in boot
	[ɜ]	as in word (silent r)
	[y]	French u or German ü (tense)
	[ʏ]	German ü (lax)
	[ø]	French eu or German ö (tense)
	[œ]	French eu or German ö (lax)

APPENDIX H

UNIVERSITY OF GEORGIA SCHOOL OF MUSIC

NOTE NAME DESIGNATIONS





Benjamin, Thomas, Michael M. Horvit and Robert Nelson (1992). *Techniques and Materials of Tonal Music: With an Introduction to Twentieth-Century Techniques.* Fourth Edition. Belmont, California: Wadsworth Publishing Company