ACOUSTIC ANALYSES OF THE ORAL VOWELS OF GBE

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DECLARATION

I, Pascal Kpodo, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my own original work and it has not been submitted, either in part or whole for another degree elsewhere

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We hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis/dissertation/project as laid down by the University of Education, Winneba.

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To the everlasting memory of my mentor,

Prof. J.N. Akpanglo-Nartey

and

the ever-cherished love of my friend,

Dr Christiana Hammond.

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ABSTRACT

The study aims at establishing the phonetic identity of each of the vowels of Gbe by determining the underlying phonetic parameters that characterize the vowel system. It also aims at comparing the vowel spaces of the Ewe and Gen dialects to state their similarities or differences. Finally, the study seeks to investigate the durational properties of the oral vowels of Gbe. The Kay Elemetrics Computerized Speech Lab (CSL-4500) and the SPSS software packages were used to analyse the oral vowels uttered by 120 purposively sampled native speakers. The CSL-4500 was used to generate the formant frequency and durational values of the vowels while the SPSS software was used to conduct tests of Analysis of Variance to determine the within-groups and between-groups differences. The study finds out that the vowel space of Ewe is slightly wider than the vowel space of the Gen dialect and that while there is significant variability between the comparable front vowels of Ewe and Gen, the back vowels of the two dialects are similar. The study further finds out that [a] in Gbe is a low central unrounded vowel and, therefore, there is no back unrounded vowel in Gbe. The study concludes that the rounding feature and the backness feature are redundant in Gbe. Hence, it is not necessary to specify both features in describing the Gbe vowels. In terms of duration, Gbe vowels are longer in the environment of voiceless consonants than the voiced ones and also in high-tone syllables than in low-tone ones.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter introduces the whole study by establishing the background and the theoretical framework within which the study is situated. The chapter goes on to present the problem statement, the purpose and the specific objectives of the study. Subsequent to the research objectives, the chapter also presents the research questions that guide the entire study. Finally, the chapter highlights the significance of the study, as well as indicates the delimitation of the study.

1.1 Background of the Study

This thesis seeks to conduct an instrumental analysis of the oral vowels of Gbe in order to establish the phonetic identity of each of the oral vowels of Gbe. The study further sets out to determine the acoustic features that characterize the vowel system of Gbe in order to resolve the controversies concerning the phonetic identity of some of the vowels as captured in the literature (Capo, 1985). Also the study investigates the acoustic similarities and differences that exist between the vowel spaces of the two major dialects of Gbe - Ewe and Gen. The study further explored how phonetic environments affect vowel duration in the Gbe language.

Gbe is a cluster of very distinct dialects spoken in the Volta Region of Ghana, the southern part of the Republic of Togo, and the southern part of the Republic of Benin through to some parts of Nigeria. This language is often referred to as Ewe in the linguistics literature. However, following Capo

(1985), this study used the label Gbe, since the name Ewe also doubles as the name for one of the five major dialects constituting the Gbe language. Ewe as a label is therefore limited to the dialect spoken in the southern part of the Volta Region of Ghana.

The Gbe language can be divided into five major dialects namely: Ewe, Gen, Fon, Aja and Phla-Phera dialects (Capo, 1980). One of the grounds of commonality among these rather distinct dialects with varying degrees of mutual intelligibility is the fact that they all refer to “language” as "gbe" and therefore suffix their referential names with the morpheme /-gbe/. For example, the individual dialects are usually referred to as Eʋegbe, Fongbe, Gengbe and others by the native speakers.

“Evidence from the linguistics literature available on Gbe suggests that the language has sixteen phonemic vowels from which each dialect selects a slightly different set” (Kpodo, 2017, p.208). The vowels identified in the literature are: [i], [e], [ɛ], [ə], [a], [ɔ], [o], [u], [ĩ], [.], [ɛ̃], [ə̃], [ã], [ɔ̃], [õ], [ũ]. No individual dialect of Gbe has all these sixteen vowels in its inventory.

Individually, the vowel systems of the various dialects constituting the Gbe language have been intensively studied, most especially, Ewe and some of its sub-dialects: (Ansre, 1961; Capo, 1980; Stahlke, 1971; Clement, 1974; Smith, 1968; Stewart, 1983; Gbegble, 2006). All these studies except Gbegble (2006) provided traditional articulatory descriptions of the vowel systems of these individual dialects. Ladefoged and Johnson (2011) argued that the description of vowels based on the traditional articulatory parameters may not be very accurate and that a vowel that is described as a back vowel universally may vary considerably from language to language in the degree of backness

(Ladefoged, 1993). Ladefoged further explains that the use of the backness and vowel height dimensions to contrast vowels should be replaced with the use of acoustic terms.

According to Kpodo (2013, p.179), "it has been established that, there are quality differences among vowels transcribed with similar symbols in different languages". Owing to this, there is, therefore, the need to study the vowels of Gbe through instrumental analysis to give a precise and systematic description of each of the vowels. This, therefore, is the motivation for the current study, although Gbe vowels have been severally investigated in the past.

1.2 Theoretical Framework

The present study is situated within two theoretical frameworks that seek to make predictions on the general distribution and configuration of vowels within the acoustic vowel space across languages. These two theories are the Adaptive Dispersion Theory (Lindblom, 1986) and the Quantal Theory of Speech (Stevens, 1989).

In a survey conducted by Maddieson (1984) to investigate vowel inventory preferences for languages, it was established that languages with the least number of vowels have three vowels in their inventory while languages with the largest inventories have twenty-four vowels. In this survey, Maddieson further established the variations among languages concerning their inventory sizes. Out of the three hundred and seventeen (317) languages studied in this survey, 45% of them have between five to seven vowels in their inventory. According to the survey results, the most preferred vowel inventory size is the five vowel inventory followed by six vowels inventory and then seven vowels inventory sizes. It was also established that the same types of vowels tend to make up the inventories of these languages such that if a language has only three vowels, those three vowels will most likely be [i], [a] and [u]. Five-vowels systems usually have [i, e, a, o, u] and the seven-vowel systems have [ɛ] and [ɔ] in addition to the five vowels already stated. The study also showed that six-vowel systems usually have [i, e, æ, ɑ, o, u] making up their inventory. Maddieson further found out that a larger majority of languages in the world have [i], [a], and [u] constituting their vowel inventory. These three vowels generally define the extreme points of the general acoustic space and, therefore are referred to differently in the literature as “point vowels” (Bradlow, 1995; Maddieson, 2009) or "corner vowels" (Jackson & McGowan, 2012).

Other cross-linguistic studies have shown that the organization of vowel inventories is principally controlled by articulatory, as well as auditory, constraints (Al-Tamimi & Ferragne, 2005). These revelations triggered some theoretical studies which attempted to make predictions about how the configuration of vowel systems are influenced by the size of the vowel inventory of the language. Stevens (1989) is one of such studies which attempted to predict the configurations of vowel systems universally.

The variation in the configuration of the articulatory apparatus is continuous across the articulatory space. Anytime the configuration of the articulatory apparatus is manipulated, there is a resultant change in the acoustic/auditory effect. It was observed that the variations in the configuration of the articulatory apparatus and their resultant variations in the acoustic correlates are not the same throughout the articulatory space.

It was further observed that within certain regions of the articulatory space, changes in the configuration of articulatory apparatus result in minimal corresponding acoustic effects whereas, in other regions of the articulatory space, the smallest change in the configuration of the articulatory apparatus produces significant corresponding acoustic effects. The relations between the articulatory versus acoustic parameters which see acoustic patterns changing from one state to another in direct reaction to changes in the articulatory parameters through a range of values has been described as quantal in nature. The quantal theory proposed that the discontinuous relationship between articulatory movements and their corresponding acoustic effects is responsible for the organization of vowel inventories cross-linguistically.

The regions within the articulatory space where there is minimal change in acoustic/auditory effects as a result of changes in the configuration of articulatory apparatus correspond to the areas where the three most extreme vowels [i], [u] and [a] are produced. The Quantal Theory, therefore, claims that these three point-vowels must be in approximately the same location across all languages no matter what the vowel inventory sizes of the languages are. The theory also states that since the three quantal vowels are produced within phonetically stable regions, there should be less intra-category variation for them than for all the intermediate vowels.

The Adaptive Dispersion Theory (Lindblom, 1986), on the other hand, proposed that an Adaptive Dispersion of the sounds in order to maintain sufficient perceptual contrast principle governs the organization of speech sounds. This means that in every language, vowels are organized within the acoustic vowel space in such a way that each of the vowels will be distinct on the auditory scale (Al-Tamimi & Ferragne, 2005; Marusso, 2016). Lindblom further intimates that there should be clearer variations among vowels in smaller inventory systems than in larger inventory systems.

Several studies have been conducted to find out how true the claims made by the Quantal Theory (QT) and the Adaptive Dispersion Theory (ADT) are. In most of these studies, phonetic differences of similar segments were observed.

In the bid to put the generalization of the Adaptive Dispersion Theory that irrespective of the vowel inventory size, vowels will be clearly distinct within the acoustic vowel space to test, Jongman, Fourakis and Sereno (1989) conducted a study in which English vowel space with eleven monophthong vowels and German vowel space with fourteen monophthong vowels were compared with the Greek vowel space which has only five monophthong vowels. After plotting the vowels within the auditory-perceptual space, the results show that the location of [i] and [u] of English and German are more peripheral than their counterparts in Greek making the vowel spaces of the two relatively larger inventory size languages: English and German more expanded than the vowel space of Greek which has a much smaller inventory size. The finding of this study supports the generalization that the configuration of vowels within the acoustic vowel space dependents upon the number of vowels constituting the vowel inventory of the language. As a result of this finding, they agreed that the general configuration of vowels within the vowel space is largely controlled by the number of vowels in the system.

In a study conducted by Bradlow (1995), the English vowel space with eleven monophthong vowels was compared with the Spanish vowel space with only five monophthong vowels. The researcher found out that the distributions of the vowels within the acoustic vowel space across languages are partly a function of a language-specific base of articulation, and that the English vowels occupy more space than the Spanish vowels, evidently as a result of the fact that English has more vowels in its inventory than Spanish. She, however, did not report any significant variation in the within-category clusters for languages with large vowel inventory systems vis-à-vis those with small inventory systems.

Kpodo (2008) conducted a comparative acoustic study involving four Ghana Togo Mountain languages: Siwu and Sele both seven vowel languages and Siya and Ikpana both nine vowel languages. This study, among other things sought to analyse how vowel inventory size of each of these languages affect how the vowels are organized within the acoustic vowel space.

Comparing each vowel space to the others, Kpodo found out that Siwu and Sele vowel spaces which are both seven-vowel languages are quite similar, with Siwu occupying a slightly wider area. Siya and Ikpana, the two nine vowel systems, on the other hand, are quite different from each other. Siya vowels occupy a relatively wider space than the vowels of Ikpana. This is because the low vowel [a] of Ikpana is located far above its Siya counterpart making the Ikpana vowel space smaller than that of Siya. The conclusion reached by this researcher is that the distribution of the vowels in the four languages does not convincingly support either the Quantal or the Adaptive Dispersion theories and that it is difficult to tell if inventory size does affect the organization of vowels in the vowel space and how.

1.3 Statement of the Problem

Many researchers have attempted to provide detailed phonetic descriptions for the Gbe vowels (Smith, 1968; Stahlke, 1971; Clement, 1974; Ford, 1973; Capo, 1985). However, these attempts have generated several disagreements amongst these scholars relating to which of the vowel features are relevant and which are not as well as what the phonetic identities of the individual vowels are.

While Berry (1951); Ansre (1961) and Capo (1985) specified [a] as [-Back, -Round], implying that the feature [Back] and [Round] are redundant in Ewe, Smith (1968) and Clement (1974) specified [a] as [+Back, -Round]. To Clement and Smith, the features [back] and [round] are not redundant and are therefore both necessary in describing the vowel system of Ewe.

The tongue-height feature for [ɛ] and [ɔ] is the source of yet another disagreement concerning the feature specification for the Ewe vowels. While Stahlke and Ford specified [ɛ] and [ɔ] as [-Low] Capo and Smith considered them [+Low].

In the light of these disagreements, Capo (1985) concluded that it is needful to conduct a thorough instrumental analysis of all the Gbe vowels so that the phonetic identity of each of them can be properly assessed.

These disagreements can be traced to two factors:

1) The fact that all these studies (Ansre, 1961; Capo, 1980; Stahlke, 1971; Clement, 1974; Smith, 1968; Stewart, 1983) based their conclusions on approaches which are impressionistic and therefore highly subjective.
2) By specifying the vowels as [±High] and [±Back], the earlier researchers (Smith, 1968; Stahlke, 1971; Ford, 1973; Clement, 1974; Capo, 1980; Stewart, 1983) treated the features [Back] and [High] as binary features.

Meanwhile, it had been stated in the literature that "both of the features [High] and [Back] must be multivalued, because vowel systems may contrast more than two values along each dimension and there is, therefore, no justification for regarding any single phonetic parameter as a composite of binary feature" (Lindau, 1978, p.545). In the words of Lindau (1978, p.245) citing Ladefoged (1971), "in describing phonological processes, the use of binary features to express movements along a single parameter amounts to wrong claims about relationships between vowels".

Gbegble (2006) sought to resolve the disagreement by conducting a spectrographic analysis of the vowels of Ewe (one of the major dialects of Gbe). She found out that, [a] in Ewe is shifted towards the back. Gbegble's finding as far as [a] is concerned agrees with Smith's (1968) feature specifications for [a]. Smith specified [a] as [+Back] while Clement (1974) and Capo (1985) specified [a] as [-Back, -Front]. Considering these two specifications for [a], in the literature, we are proposing one of three possibilities as far as the low unrounded vowel is concerned. Ewe either has a central low unrounded [a] or a back low unrounded vowel [ɑ] or both. It is therefore imperative to conduct more investigations into the low unrounded vowel in order to find out which of the three possibilities is really the case.

Gbegble also found out that [ɛ], as produced by Anlo and Avenor speakers, is significantly higher than [e]. However, one major problem in Gbegble's methodology which is possibly responsible for this finding is her over-reliance on the orthography of Ewe. Even though Ewe has a single orthography, to a large extent, every native speaker reads in their respective native dialects. Typically, to the educated Anlo and Avenor speakers, there is no one-to-one correlation between the IPA symbols and the Ewe graphemes, at least, as far as [e] and [ɛ] are concerned. To these speakers, the grapheme <e> reads as [ɛ] whereas the grapheme <ɛ> reads as [e]. This is not so among the educated Ʋedome or the Inland Ewe speakers. While the educated Ʋedome speaker will pronounce the (orthographic) word “akpe” as [àkpé], the educated Anlo and Avenor speakers will pronounce the same word as [àkpɛ́] or rather [àkpə́].

In addition to this oversight, Gbegble (2006) like Clement (1974) and others analysed the vowels of Ewe - one of the five main dialects of Gbe. Therefore, there is no instrumental study of the vowel system of the language taking care of more than just one dialect which created a gap in the literature on the vowels of Gbe.

Another problem yet to be tackled in the study of Gbe vowels is in the area of the inherent duration of the individual vowels of Gbe. The duration of the vowels of each language is known to have been pre-specified in its grammar. It has been established in the linguistic literature that inherently, some vowels are longer than others and that the mean duration of vowels vary from vowel to vowel on the order of 30ms (House & Fairbanks, 1953; Peterson & Lehiste, 1960). To discuss vowel lengthening phenomenon in the Gbe language, it is pertinent to establish the inherent duration of each of the vowels. As far as the available literature can show, this is yet to be done.

Finally, another grey area within the literature on the vowels of Gbe is the fact that the knowledge about how various phonetic environments affect vowel duration in the Gbe language is almost non-existent. There is, therefore, the need to investigate the effect of phonetic environments on the duration of vowels in Gbe.

In any attempt to resolve the disagreement that characterizes the feature specifications of the vowels of Gbe and to fill the gaps in the literature on the Gbe vowels, it is imperative to conduct an instrumental analysis into the vowels of Gbe - at least Gen and Ewe, two most similar of the five major dialects of the language.

1.4 Purpose of the Study

The main purpose of this thesis was to conduct an instrumental analysis of the Gbe vowels in order to establish the phonetic identity of each of the oral vowels. The study provides a systematic phonetic description for each of the vowels of Gbe by determining formant frequency (F0, F1, F2, F3) and duration values from broadband spectrograms based on which the precise descriptions of the vowels of Gbe were given. The study further stated the acoustic similarities and differences between the vowel spaces of Gen and Ewe thereby stating the acoustic similarities and differences between comparable vowels.

Invariably, this study sought to contribute to the discussion on what the true phonetic identity of the vowels of Gbe are by using an instrumental analysis approach to determine the acoustic properties of the vowels. In addition to the formant frequency measures, the study also sought to ascertain the inherent durations of the individual vowels of Gbe and investigate the effect of phonetic environments on vowel duration in the language.

1.5 Research Objectives

By the time this study is completed, the following objectives would have been achieved. It is the aim of the study to:

1. determine the phonetic identity of the individual vowels of Gbe.
2. establish the similarities and differences between the vowel spaces of the two dialects of Gbe - Gen and Ewe.
3. ascertain the durational properties of the vowels of Gbe.
4. explore the effect of phonetic environments on vowel duration in Gbe.
5. find out some systematic patterns in the durational variations of the vowels across the various dialects.
6. determine whether the configuration of the vowels of Gbe within the acoustic vowel space supports the theoretical assumptions made by both the Quantal theory and the Adaptive Dispersion Theory.

1.6 Research Questions

To achieve the objectives of this study and solve the identified problems stated earlier, there was the need to find answers for the following questions:

1. What are the phonetic identities of the individual vowel sounds of Gbe?
2. How different are the vowel spaces of the two dialects of Gbe (Gen and Ewe) from each other?
3. What are the durational properties of the individual vowels of Gbe?
4. How do the various phonetic environments affect vowel duration in Gbe?
5. What systematic patterns exist in the durational variations of the vowels across the dialects?
6. To what extent does the configuration of the Gbe vowel space confirm the claims made by the QT or the ADT?

1.7 Significance of the Study

This study will not only be answering the call for the need to conduct an instrumental analysis into the vowels of Gbe thereby resolving the subtle controversy surrounding what the true phonetic features of the Gbe vowels are, but also provide a description and documentation on the vowel space configuration of Gbe.

In the first place, this study will be significant to language teachers, especially those who teach the Gbe language as a second language to non-native students and those who teach foreign languages to the native speakers of the Gbe language. This study is crucial to these categories of people since it has been established that the "traditional articulatory description of vowels is not entirely satisfactory" (Ladefoged & Johnson, 2011, p. 197). Citing Ladefoged (1993), Kpodo (2013, p.179) explains that “vowels described as 'high' across languages do not have the same height, and that the so-called 'back' vowels vary considerably in their degree of backness". He maintains that the use of vowel backness and height as labels to contrast vowels is not necessarily accurate and that the description of vowels should be done using acoustic labels instead. In relation to the use of tongue height and backness in the description of vowels, Ladefoged and Johnson (2011, p.198) states that "there is no doubt these terms are appropriate for describing the relationships between different vowel qualities, but to some extent, phoneticians have been using these terms and labels to specify acoustic dimensions rather than as descriptions of actual tongue positions". It is always necessary to conduct an instrumental investigation into the vowels of every language in order to provide precise and systematic descriptions for the vowels since the literature has succinctly shown that vowels represented by similar symbols usually vary from one another in terms of vowel quality.

The findings of this study will facilitate the learning and teaching of English and French as second languages to pupils from the Gbe language speaking communities. This is because teachers of these foreign languages working within the Gbe language communities will gain the linguistic resources needed for the comparison of the vowel spaces of Gbe and the foreign languages they teach and then predict correctly which vowel sounds are more likely to pose problems or otherwise to the learners due to the degree of variation between the vowels system of Gbe which is their native language and that of the respective foreign languages they are learning.

According to the tenets of the practice of contrastive analysis, the comparison of the vowel systems of two different languages must involve a thorough analysis of the two separate systems (L_1 and L_2) to be able to predict, detect and correct the pronunciation errors for second language learners (Lado, 1957). Lado reiterated the fact that the conduct of such an analysis must involve all factors concerning the sound system: factors "such as phonetics, phonemic sequences of phonemes and intonation patterns" (cited in Kpodo, 2013, p.178). He concluded that the objective of such an analysis is to ensure that the teaching and learning of foreign languages sees the needed improvement.

Additionally, this study seeks to help teachers of the Gbe language at every level. This is important because, as Akpanglo-Nartey (2006, p.6) puts it, "a major concern of all language teachers is that they present the structure of the language(s) they teach as truthfully as possible. This means that an accurate description of the language must be made available to the language teacher at all levels of grammar including, the phonetic, phonology, morphology, syntactic and semantic levels".

Also, this study will be significant to software developers and programmers who are interested in developing speech recognition software for the Gbe language.

In a broad sense, this study sought to contribute to the ongoing research aimed at giving a scientific description of the sounds of African languages.

1.8 Delimitation

Even though five dialects have been identified for the Gbe language, the current study only focused on the vowels of only Gen and Ewe dialects of

Gbe. The Gbe language has five major dialects namely, Aja, Ewe, Fon, Gen and Phla-Phera. Previous studies of vowels of Gbe were limited to only one of the five dialects. Even though it has been suggested that any study of the vowel system of Gbe must take into consideration all vowels of all the dialects in order to be representative enough, it was not possible to study all the dialects in the current study due to constraints of time and other resources. However, the study selected Ewe and Gen due to their closeness on the mutual intelligibility continuum.

The possible presence of the two high lax vowels [ɪ] and [ʊ] have been mentioned in the literature (Ansre, 1961), however, the current study did not explore this possibility. Also, the current study did not compare the formant frequencies of vowels produced by male speakers with that of female speakers.

Finally, the current study only investigated the phonetic properties of the oral vowels of Gbe. Even though the literature of Gbe adequately demonstrates the presence of both oral and nasal vowels in the vowel inventory of Gbe, this study did not investigate the phonetic properties of the nasal vowels since all vowels are inherently oral. There is enough evidence in the literature to support the fact that the nasal vowels of Gbe are just nasalized vowels which have been phonologized over a period of time (Ruhlen, 1973).

1.9 Summary

In this chapter, the whole study was introduced by stating the problem that the research sought to investigate and resolve. The chapter stated the purpose and the specific objectives of the study. The main aim of the study as stated in the chapter was to conduct an instrumental analysis of the oral vowels of Gbe in order to establish the phonetic identity for each of the vowels. This chapter further listed the six research questions that guided the entire study. After the research questions, the significance of the study was stated. This study is significant because it sought to resolve the controversy concerning the phonetic descriptions of some of the vowels of Gbe. The chapter ended on delimiting the study but not without discussing the theoretical frameworks within which the study was situated.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviewed relevant existing literature in order to properly situate the study within the desired context. The literature review touched on previous acoustic studies of vowels from a global perspective before narrowing it down to the development of acoustic study of vowels in Ghana. Additionally, the review traced the practice of acoustic analysis of speech sounds from 1877 through 1988 to the present days paying particular attention to the changing trends in the methodology employed by scholars in the field. The literature review has been very crucial because the methodologies discussed in the literature shaped the approach used in the current study.

This chapter also reviewed the works of some pioneering scholars who studied the vowels of Gbe. The review of these works were very necessary for setting the stage for the current work. The review of studies such as Berry (1951), Ansre (1961), Smith (1968), Stahlke (1970, 1971), Clement (1974) and Capo (1981, 1985) and others clearly revealed the contradictory evidence and knowledge gaps in the literature on the vowels of Gbe.

The final issues discussed in this review of literature were the effect of phonetic environment and syllable weight on the duration of vowel segments.

2.1 Development of the Acoustic Studies of Vowels

Phonetics as a branch of linguistics that deals with the study of speech sounds is such an indispensable foundation for the study of every language (Sweet, 1877 cited in Catford, 1988). This is so because, it is often very necessary for linguists to provide phonetic evidence for all the claims they make about the sound systems of the languages they study. Typically, phonetics deals with how speech sounds are produced by speakers of a language, how they are perceived by listeners, what constitute the nature of speech sounds and ultimately, to what practical use can the knowledge acquired from the study of speech sounds be put (Kpodo, 2015). The study of what constitutes the nature of speech sounds falls under acoustic phonetics. "Acoustic phonetics is the study of the characteristics of speech sounds, which includes the analysis, and description of speech sounds in terms of their physical properties, such as frequency, intensity, and duration" (Mattingly, nd, p.1).

The literature on acoustic phonetics indicates that the experimental investigation of speech sounds through analysis, manipulation and synthesis of speech signals dates as far back as Willis (1830), Wheatstone (1837) and Helmholtz (1863). The works of these men have contributed to the understanding of the physics of speech. The very early experiments were to find out how many resonances are there and how these resonances are related to the cavities within the vocal tract.

In spite of the long history of experimental study of speech, Peterson and Barney (1952) laid the foundation for the study of the properties of vowel by measuring the sound waves of the vowel sounds. Not long after the sound spectrograph was introduced, Peterson and Barney (1952) presented some of the controlled methods used at the Bell Telephone Laboratory. The study involved 76 speakers (33 men, 28 females and 15 children) and 70 listeners. A list of ten monosyllabic words exemplifying the target vowels in between [h] and [d] were given to the participants to read. The utterances were recorded by a magnetic tape recorder. Two different lists of the ten randomized words were given to each of the 76 speakers. Each speaker therefore read each word twice. Acoustic measurements were obtained from narrow-band spectra consisting of fundamental frequency (F0), formant amplitudes and formant frequencies (F1 - F3). The measurements were taken at a single time slice that was considered to be the steady state of the target vowels. The study showed that there is a strong correlation between intended vowels and their formant frequency patterns.

In establishing the set of formant frequencies for American English vowels, Peterson and Barney's (1952) database was used as benchmark. For example, the Peterson and Barney study is frequently used as benchmark in studies of speech synthesis. Their measurements have been relied upon heavily in the validation of vowel normalization algorithms and are frequently used in cross-language comparisons and comparisons between normal and disordered speech (Hillenbrand et al. 1995).

This study became the standard that had been followed by many studies involving acoustic vowel analysis to date. The methodology adopted in the study of PB and the procedure for data analysis still reflect in many studies to date. By placing the Gbe vowels in monosyllabic words and then inserting the words into carrier frames such that the target vowels occur in between two consonant sounds, the current study modelled its data collection approach after the methodology of works (some of which have been discussed in this review) which took their cues from Peterson and Barney (1952).

Wells (1962) was one of the studies that employed the PB study procedures. Wells analysed the vowels in "*heed, hid, head, had, hard, hod, haw'd, hood, who'd, hud and heard"* uttered by adult male speakers of British English (Received Pronunciation). The utterances were recorded and later played into a spectrograph. A Narrow-band frequency/amplitude sections were made at the midpoint of each vowel so as to avoid consonant transition effect on the target vowels. Wells noted that vowels are characterized by formants which are high energy concentrations corresponding to the passbands of the throat and the oral cavity. By means of acoustic spectrographs, Wells (1962) calculated the average frequencies and amplitudes of the lowest three formants of each of the vowels investigated. He also measured the duration of each of the vowels.

Some of the major contributions of this study to instrumental study of vowels are in the area of methodology. According to Wells (1962), in trying to describe vowels through the use of acoustic parameters, there is the need to state, at least, the first few formant frequencies of the vowels.

The study also made it clear that in order to ensure that there is no or little consonant transition effect on the vowels, the frequency and its corresponding amplitude section should be made at the mid-point of the vowel concerned. Wells requested the subjects to produce the test sentences with the same intonation as much as possible for all the sentences in order to keep the pitch almost uniform throughout the recordings. Wells' study prompted several other acoustic studies one of which is Zee (1978).

Zee (1978) sought to analyse how tones affect vowel qualities. He looked at the changes in formant frequency values as direct results of changes in the tone on the vowels. He analysed five Taiwanese Chinese vowels [i], [e], [a], [ɔ], and [u] in the environments of the high tone and the low tone uttered by three male native speakers of Taiwanese. The data was analysed by obtaining the formant frequencies as well as the fundamental frequencies from the LPC spectra. Zee reported that tones indeed affect vowel qualities in some ways.

Another issue which also needed attention following the study of Peterson and Barney (1952) was whether or not there is enough information contained in the acoustic signals of a vowel for its identification and description. Kahn's (1978) study sought to provide answers to this issue about the amount of information contained in the signals of vowels. The researcher selected 20 speakers of American English to produce the vowels, [i], [e], [ɛ], [æ], [a], [ʌ], [ɑ], [o] in carrier frames. The speakers read each carrier frame twice for the researcher to record. The recorded utterances were randomized and presented to the listeners who had some amount of training in phonetics to identify. The correct identification and errors made by the listeners were recorded and graded. The researcher concluded that all the necessary information for the unambiguous identification of an isolated vowel is contained in the acoustic signals of the vowel.

Hillenbrand, Getty, Clark, and Wheeler (1995) replicated and extended Peterson and Barney's (1952) study in which they recorded 45 males, 48 females and 46 children between the ages of ten to twelve years old producing [i], [ɪ], [e], [ɛ], [æ], [a], [ɔ], [o], [ʊ], [u], [ʌ], [ɝ] in /hVd/ context. This study was designed to take care of some issues the researchers identified in Peterson and Barney's work. They therefore investigated, duration, variations along dialectal lines, pitch and formant contours. Unlike Peterson and Barney (1952), these researchers reported the result of their analysis separately for the three groups of participants: male, female and children. The analysis of the data collected by these researchers showed many differences between their data and that of PB regarding the mean F1 and F2 values, and the degree of conflation among comparable vowels. These researchers also found out that vowels may be accurately distinguished through the use of duration and information about spectral change rather than the use of steady-state measures.

To test the validity or otherwise of the findings of Hillenbrand et al. (1995) that vowels are more accurately distinguished through the use of information about spectral change rather than the use of steady-state measures, Huffman and Tamberino (1997) conducted a study using monolingual English speakers from Long Island who produced the vowels in /hVd/ and /bVd/ target words. These researchers observed that many speakers from Long Island have 6 front vowels rather than the 5 front vowels usually treated in studies on American English. By using the discriminant analysis technique, the researchers measured the first and second frequency (F1 and F2) values of the vowels at three time points in each vowel: 20%, 50% and 80% into the duration of the vowels. They evaluated the comparisons of the vowel formant values of different words taken at these time points.

They reported that there are two kinds of the front low unrounded vowel [æ] for these speakers. Besides the low front [æ], there was a higher or a rather tensed [æ] which they use in the word “bad”. This made the set of front vowels more crowded for Long Island speakers. The researchers found out that when the formant values taken at only the midpoint (50% point) were used in describing the vowels, there was no distinction between the vowels in "bed" and "bad" but when the formant values taken at two time points (the 20% and 80% points) of each vowel were used in the description, the two vowels were clearly distinct. This confirmed the hypothesis that the use of dynamic rather than static spectral produced greater discrimination among the vowels within the vowel space.

By the end of the twentieth century, there was enough evidence available in the literature suggesting that the description of vowels is more effective through instrumental analysis rather than impressionistic analysis, most especially when it comes to distinguishing between comparable/similar vowels. Much more insight was gained into which procedures are more likely to provide accurate information about the acoustic characteristics of vowels. Investigation into how external factors such as age and sex influence speech became the focus of researchers (Hanson & Chuang, 1999; Lee, Potamianos & Narayanan, 1999; Yu, De Nil, & Pang, 2015).

Amongst other things, Lee et al. (1999) drawing from the database of Miller, Lee, Uchanski, Heidbreder, Richman and Tadlock (1996) with about four hundred and ninety participants who were between the ages of five to fifty years analyzed the fundamental frequency and the formant frequency values of ten monophthong vowels. They found out that children tend to have higher fundamental frequency and formant frequency values than adults. They also found out that children tend to have greater temporal and spectral variabilities than adults. They attributed their findings to differences in the anatomy of children and adults, as well as the ability to control the articulators. Whiteside, Dobbin, and Henry (2003) explained that children lack mastery over the speech motor skills necessary for the coordination of the vocal-fold vibration and oral release during speech.

Studies that analysed how gender affects the acoustic parameters of vowels also abound in the literature. In one of such studies, Hanson and Chuang (1999) analysed the waveforms and spectra of [æ, ʌ, ɛ] from 21 adult male speakers of American English in order to extract their acoustic parameters relating to their F1 bandwidth, open quotient and spectral tilt. The results of the study were compared to the results of a previous study involving 22 female speakers (Hanson, 1995). The study showed that even though there is some degree of conflation between the values for both genders, the female speakers' mean values are higher than their male counterparts and also, there was more interpersonal variations for the female speakers for all measures. This report is consistent with the explanation offered in the literature that "for female voices, the formant frequency values are about 10% to 15% higher, on account of the fact that the resonance cavities in the female vocal tract are smaller (shorter) by about 10% to 15% than those of male speakers" (Kpodo, 2013, p.179; Goldstein, 1980; Simpson, 2009).

Many other studies confirmed the cross-gender acoustic variations of vowel frequency values such as Chiba and Kajiyama (1941), Fant (1975) and Cox (2002). Although, other researchers such as Akpanglo-Nartey (2006), agreed with these findings that vowel quality is indeed affected by gender, she also explained that the variations between qualities of the vowels produced by male speakers versus the female speakers do not follow any particular pattern. Akpanglo-Nartey, therefore, concluded that besides gender, there may be other factors influencing the variation between the quality of vowels produced by the two groups of speakers.

The effect of gender on vowel quality as established in the literature is very crucial for the design of the current study. Even though, the current study will not examine the phenomenon in the Gbe language, the various findings will guide the population sampling process in order to avoid possible skewing of the mean frequency values for the individual dialects and the Gbe language in general in one way or another.

Watt and Tillotson (2001) analysed fronting of /o/ in Bradford English. Five females and two male speakers between the ages of 17 to 75 years were recorded as they produced a word list of hundred isolated words and eight short phrases which contained the target vowels. The recordings were sampled and formant frequency values of the target vowels taken. In all, acoustic characteristics of 337 tokens of /o/ had been analysed. Plots were made with the F1 values against the difference between the F2 and F1 (F2') values. The researchers found out that there were some indications in the acoustic signals suggesting the fronting of /o/ in GOAT in Bradford English. The study also showed that /o/ is more fronted in the speech of younger Bradford English speakers and also among the female speakers of Bradford English.

Lennes (2003) conducted a research into the variability of the eight Finnish vowel segments /ɑ/, /e/, /i/, /o/, /u/, /y/, /æ/, /ø/. The researcher recorded five dialogues from ten (five males and five females) speakers for the study. The recorded speeches of only four (two males and two females) were segmented and labelled using the Praat software. The vowel tokens were extracted from commonly occurring words and less frequently occurring words. The endpoints of the vowels were identified and marked to prevent the environmental effects from neighbouring consonant phonemes on the target vowels. The formant frequency values were calculated for the first two formants at the midpoints of each vowel segments. The words were categorized in four groups depending on frequency of occurrence from those words that occurred hundreds of times to those that occurred only once. The mean formant frequency values were plotted according to the word-form categories.

Lennes found out that in Finnish, vowel that occurred in frequent word-forms exhibited more variability than vowels in less frequent word-forms. The researcher concluded that the frequency and predictability of vowel segments affect the phonetic quality of the vowel.

Moosmuller and Granser (2003) conducted an acoustic study that sought to compare the vowels of the three dialects of the Albanian Language - Gheg, Tosk and Standard Albanian. Nine male subjects (three speakers each from three regional dialect areas - North Albanian, Middle Albanian and South Albanian) were asked used in the study. The participants read a wordlist, sentences, and a literary text and also spoke spontaneously for a recording. However, only the vowels in stressed syllables were analysed for the study. "All prosodically strong vowels (1170 in total) have been labelled and frame by frame formant frequency contours have been produced. The first three formants were calculated using LPC with 26 coefficients, a pre-emphasis of 0.9, a frame width of 46ms and a 2ms frame shift" (p.659). One-way ANOVA were calculated for every vowel.

Their findings were that all vowels except [e] were significantly different along regional lines. They also found out that /a/ and /ə/ tend to be the weak point in the Standard Albanian vowel system. They added that, besides showing regional variations, the two vowels may have carried some social information too. Following this study, the current study analysed the within category and between category variability of the Gbe vowels across the two major dialect areas.

Ansarin (2004) undertook an acoustic study of Modern Persian vowels. He set out to digitize the vowel chart of Persian. Twelve female speakers were engaged to utter words exemplifying the Persian vowels in hVd environment. The speakers uttered each three time for the recording. The Praat and Speech Analyser were used in the analysis of the sound waves.

This study came out with the first authentic phonetic vowel chart for the Persian language. The researcher also found out that the distribution of the point vowels [i, a, u] in Persian supported the generalization about the role of these vowels in theories of speech. He stated that the "distributional occurrence of these vowels in the vowels space and their relative distance from one another suggest that the pressure to form pattern has made Persian language to develop a vowel system which could be described in a triangular auditory space. He also suggested that the Persian language's three intermediate vowels [e], [æ] and [o] in addition to the three corner vowels [i], [a] and [u] resulted in a vowel system in which the vowels are symmetrically distributed. The current study examined the distribution of the three corner vowels in Gbe in order to establish whether their distribution supports the claims made by the Dispersion Theory of speech.

These earlier acoustic studies of vowels created a new area of interest for phonetic enquiry across the world. Every imaginable process involving vowel sounds had been subjected to acoustic investigation, most especially when those processes involve variabilities that fall beyond human perception. Some of the issues studied across languages were variations between vowels represented by similar symbols across languages (Ladefoged & Johnson, 2011), effect of gender on vowel quality (Hanson & Chuang, 1999; Cox, 2002; Akpanglo-Nartey, 2006; Simpson, 2009), vowel fronting (Watt & Tillotson, 2001) and vowel variability depending on predictability and frequency of occurrence (Lennes, 2003) among others.

2.2 Instrumental Studies in Ghanaian Languages

Acoustic analysis of the vowels of Ghanaian languages has received fair consideration from scholars in the field. Akpanglo-Nartey (2006), conducted a study to systematically describe the vowels of Ga-Dangme using spectrographic analysis. The researcher recorded ten speakers each (comprising five males and five females) from three Ga speaking and three Dangme speaking communities. The respondents were monolinguals who were literate in the Ga-Dangme language.

Twelve vowels (comprising of seven oral vowels and five nasalized vowels) were studied. The vowels were embedded in monosyllabic words preceded by a bilabial consonant. The recorded vowels were later digitized using the Kay Elemetric Computerized Speech Laboratory software at a sampling rate of 11025Hz. The researcher measured the values of F1 and F2 from the middle of each vowel so as to minimize any transitional effects of adjacent consonants on the vowels.

The researcher further performed a one-way ANOVA on the data using the SPSS package. She conducted tests of significance on the individual vowels for each dialect community. Pair wise tests of significance were also carried out for pairs of vowels including [i/e], [e/ɛ], [ɛ/a], [a/ɔ], [o/ɔ] and [u/o]. Additionally, tests of significance were conducted between cognate oral and nasalized pairs, [i/ĩ], [ɛ/ɛ̃], [a/ã], [ɔ/ɔ̃], [u/ũ], and finally all Ga vowels were compared with all Dangme vowels for significance.

She found out that Ga and Dangme basically form a similar vowel space except that Ga vowels were more compact, and that Ga-Dangme has three front vowels [i], [e], [ɛ] and four back vowels [u], [o], [ɔ], [a] with [ɔ] being the most back. The study disproved the traditional view that [a] is a front vowel in Ga and Dangme. The methodology employed in this study was replicated in the current study. The only point of departure between Akpanglo-Nartey (2006) and the current study is in the fact that the current study looked at the durational properties of the Gbe vowels.

Gbegble (2006) conducted a similar study to provide the acoustic parameters that characterize the individual vowels of Ewe as produced by speakers of the three major dialects of Ewe – Ʋedome, Anlo and Tongu.

In all, she recorded forty-four speakers, twenty-four males and twenty females for the study. Both the oral and nasalized vowels of Ewe were embedded in monosyllabic words and put into carrier frames for the speakers to read.

The recordings were then acquired and analysed by the means of the Kay Elemetric Computerized Speech Laboratory (CSL) model 4500. The recordings were digitized and the formant values were measured on broadband spectrograms using the Kay Elemetric Computerized Speech Laboratory software at a sampling rate of 11025Hz. A one-way ANOVA was performed on the data using SPSS package to ascertain the degree of difference that exists among the dialects.

She found out that the choice and the use of [e] [ɛ] [ə] and their nasalized counterparts depend on the individual dialects. She also found out that, [a] in Ewe is shifted towards the back rather than being central as claimed in some Ewe literature.

Adongo (2008) set out to describe the vowels of Gurunɛ and also establish the differences between the vowels produced by female speakers and their male counterparts, as well as, how different the vowels produced by the young adult speakers are from those produced by old adult speakers. Adongo analysed the short oral vowels of Gurunɛ and reported the results separately for the five dialects. ANOVA Test and paired-sampled Test were performed on the nine vowels of Gurunɛ.

Lomotey (2008) conducted a cross-dialect study of the vowels of Akan. She investigated all the fifteen phonemic vowels of Akan - ten oral vowels [i, ɪ, e, ɛ, æ, a, ɔ, o, ʊ, u] and five nasal vowels [ĩ, ẽ, ã, õ, ũ]. Lomotey among other things sort to compare the vowel system of the two main dialects of Akan (Twi and Fante). The utterances of thirty Fante speakers and seventy Twi speakers were recorded for the study. The vowels were embedded into monosyllabic words for the speakers to utter. The recordings were acquired and digitized using the Kay Elemetrics Speech Laboratory software (CSL Model 4500) at a sampling rate of 11025Hz for all three hundred tokens for each vowel. F1 and F2 values were obtained from the broadband spectrograms of each of the vowels. The SPSS software was used to calculate the mean F1 and F2 values, as well as their standard deviations for every vowel. The mean values were used as single points to plot the vowels onto the bark scale. One-way ANOVA and test of significant difference were conducted on the vowels of the various dialect areas. Finally, paired-sampled Test was conducted on pairs of vowels in order to determine their similarity or difference. Lomotey reported some startling findings.

Lomotey (2008) found out that on the perceptual scale, the front vowels [ɪ], [e] and [æ] did not show any variation for the Twi speakers and also, the back vowels [o] and [ʊ] are not significantly different from each other. The same degree of conflation was reported for the vowel pairs [ɪ] and [e] on one hand and the pair [o] and [ʊ] produced by the Fante speakers. She concluded that while Fante has eight oral phonetic vowels [i, {ɪ, e} ɛ, æ, a, ɔ, {o, ʊ} u], Twi seems to have only seven oral phonetic vowels [i, {ɪ, e, æ} ɛ, a, ɔ, {o, ʊ} u] (the vowels within the curly bracket are considered as one and the same on the perceptual scale). She also specified [a] as a central-front vowel in Fante but as a central-back vowel in Twi. Additionally, Lomotey's findings confirmed that there are five nasalized vowels in Akan. Her finding further revealed that the five nasalized vowels of Akan are [ĩ, ɪ̃, ã, ɔ̃, ũ] but not [ĩ, ɛ̃, ã, ɔ̃, ũ] as suggested by earlier researchers such as Dolphyne (1988).

Kpodo (2008) compared the acoustic vowel spaces of four Ghana-Togo Mountain languages; Sele and Siwu, (seven vowel languages) on one hand and Ikpana and Siya (nine vowel languages) on another hand. The only departure of this study from Akpanglo-Nartey (2006) and Gbegble (2006) is the fact that in comparing the four vowel spaces, Kpodo sought to scrutinize the claim that the larger the inventory size of a language, the wider its vowel space. He found out that the distribution of the vowels within vowel spaces of the four languages does not convincingly support either the Quantal or the Adaptive Dispersion theories. He further concluded that it is difficult to tell if indeed vowel inventory size does affect the organization of vowels within the vowel space and how.

Kpodo's (2008) finding corroborates the findings of other studies conducted into the cross-linguistic comparisons of acoustic vowel spaces such as Disner (1983), which reported that similar vowels across two languages will be systematically different from each other. The finding further indicates an interaction between a language-specific effect which causes similar vowels across two languages to differ in a systematic way due to a consistent language-specific adjustment of the articulators and the general expansion effect (Bradlow, 1995).

According to Honikman (1964), the articulatory setting of the most frequently occurring sounds and sound combinations to a large extent determines the base-of-articulation of every language. She illustrated this by saying that "among the consonants of English, cardinal alveolar articulation occurs, in general, considerably more frequently than any other; for this reason, the anchorage required for the cardinal alveolar sounds [t, d, n, ɾ, s, z], should be regarded as the basis of the internal articulatory setting of English utterance" (p.77).

Therefore, the cross-language difference between similar vowels "has been accounted for by the notion of a language-specific base-of-articulation property, which is an important aspect of the description of the sound" (Bradlow, 1995, p.2) systems of languages, and which to some extent systematically distinguishes the phonetic qualities of one language from another even though they might share some phonemic features. In other words, vowel segments that have similar feature specifications and even occupy the same spots within the acoustic vowel space across two different languages may have different phonetic realizations due to the differences in the base-of-articulation settings of each language.

2.3 Description of Gbe Vowels

There have been several impressionistic studies on the vowel system of Gbe. These studies have established the vowel inventory size of the language. Generally, Gbe is said to have sixteen phonemic vowels comprising of eight oral vowels [i], [e], [ɛ], [ə], [a], [ɔ], [o], [u] and eight nasal vowels [ĩ], [ẽ], [ɛ̃], [ə̃], [ã], [ɔ̃], [õ], [ũ] (Clement, 1974 and Capo, 1981). It was however explained that individual dialects of Gbe select unique sets of vowels from these sixteen vowels and that no single dialect of Gbe uses all the sixteen vowels (Capo, 1985).

Capo (1985) posits that the dialect with the richest inventory is Proto-Gbe with a fourteen vowels system comprising [i], [e], [ɛ], [a], [ɔ], [o], [u], [ĩ], [ẽ], [ɛ̃], [ã], [ɔ̃], [õ], [ũ]. All the other dialects of Gbe have twelve vowel systems. While Kpando, Gen and Aja each have [i], [e], [a], [ɔ], [o], [u], [ĩ], [ẽ], [ã], [ɔ̃], [õ], [ũ], Peki has [i], [ɛ], [a], [ɔ], [o], [u], [ĩ], [ɛ̃], [ã], [ɔ̃], [õ], [ũ] and Anlo has [i], [ə], [a], [ɔ], [o], [u], [ĩ], [ə̃], [ã], [ɔ̃], [õ], [ũ]. It is clear that the difference among the vowel systems of the individual dialects of Gbe is in the presence or absence of one or two mid non-back vowels [e], [ɛ] and [ə] as well as their nasal counterparts [ẽ, ɛ̃, ə̃]. Kpando, Gen and Aja have [e] but not [ɛ] and [ə]. Peki has [ɛ] but does not have [e] and [ə] in its inventory. Anlo on the other hand has [ə] but does not have [e] and [ɛ].

Capo further explains that these differences are accounted for by a rule that merges [e] and [ɛ] into /e/ as well as [ẽ] and [ɛ̃] into /ẽ/. In his explanation, at the level of phonetic representation, [ɛ] is synchronically derived from [a] followed by [i]. Even though there is general agreement on the claim that no single dialect of Gbe uses all the sixteen vowels, the specific statements regarding the three vowels [e], [ɛ], and [ə] need further investigation.

Capo's finding that [ɛ] is synchronically derived from [a] and [i] sequence may have been influenced by the orthography. Among the southern speakers of Gbe, the grapheme <ɛ> does not represent the front mid-low unrounded vowel [ɛ] but rather, it represents the mid-high front unrounded vowel, [e]. Kpodo (2017) indicates that the [a] and [i] sequence rather manifest synchronically into [e] but not [ɛ].

Smith (1968) described the vowels of Gbe using the following features: [±High, ±Low, ±Back, ±Round]. As Smith specified [a] as [+Back, -Round], he invariably claimed that the features [Back] and [Round] are not redundant. Hence, in describing any Gbe vowel, both features must be specified. This claim runs contrary to many other descriptions of the Gbe vowel system (Berry, 1951; Ansre, 1961; Clement, 1974).

Working on the Kpando dialect of Gbe, Stahlke (1971) described the vowels using [±High, ±Low, ±Back, ±Round, ±Covered]. In his analysis, [a] is [+Low, -Round], indicating that the features [Back] and [Round] are redundant. Stahlke's specification of [ɛ], [a], [ɔ] as [+Covered] was met with very strong criticism (Capo, 1985). It is however assumed that Stahlke's claim emanated from an earlier generalization that if a language has a five or a seven vowel system, the high vowels will be [-Covered] [i, u] and the low vowels will be [+Covered] [a] (Stahlke, 1970). The generalization further claims that in seven vowel systems, only the mid vowels contrast in coveredness with [e] and [o] being [-Covered] and [ɛ] and [ɔ] being [+Covered]. This generalization is clearly responsible for Stahlke's specification of the low vowel [a] as well as the mid-low vowels [ɛ, ɔ] as [+Covered]. Stahlke further explained that the feature [±Covered] is just another name for [±ATR] as put forward by Chomsky and Halle (1968). Thus, [+Covered] vowels are produced with a retracted tongue root and therefore a constricted pharynx and [-Covered] are produced with an advance tongue root. In the analysis of Stahlke, the feature [±Covered] and for that matter, [±ATR] is very important for the description of the vowels of Ewe.

Clement (1974) agreed with the earlier position that the various dialects of Gbe consistently select the members of their individual vowel systems from a basic eight-vowel set basing his analysis on oral vowels only. He further explained that Anlo does not have [ɛ], while Peki, Kpando and Gen do not have the mid central vowel [ə]. Two things are very striking about Clement's analysis. On one hand is his specification of [ə] and [a] as [+Back] and [-Round] indicating that the feature back and rounded are not redundant in

Gbe. On the other hand, is his use of the feature [ATR]. According to his analysis, [i, e, ə, o, u] are [+ART] while [ɛ, a, ɔ] are [-ATR]. This agrees with Stahlke's (1970) specification using the feature [Coveredness]. The features [Covered] and the [ATR] as well as [Expanded] may just be labels describing the same articulatory phenomenon (Lindau, 1978; Stahlke, 1970). This is owing to the fact that no language contrasts any two of these features.

Recent works on Gbe vowels have not mentioned the feature [ATR] or its other forms in the analysis of the vowels. Capo (1985) concluded on the note that there is no need for the mention of the feature [±ATR] in the specification of the vowels of Gbe. Capo argued that all the Gbe vowels could be adequately specified in terms of tongue position and height as well as the shape of the lips.

Kpodo (2014); Amegashie (2011) and Gbegble (2006) moved away from treating the features [Back] and [High] as binary features since the language clearly contrasts more than two values along the high-low and the front-back dimensions. Along the high-low dimension, four heights have been identified such as high [i, u], mid-high [e, o], mid-low [ɛ, ɔ] and low [a]. Along the front-back dimension, three positions have been identified as follows: front [i, e, ɛ], central [ə, a] and back [u, o, ɔ].

2.4 Vowel Duration

One major focus of the current study is to investigate the inherent durations of the vowels of the Gbe language. Thus, it is very crucial to look at earlier studies of vowel duration. The review of works on duration will inform the approach and the depth of the current study in the analysis of vowel duration in Gbe. In other words, our understanding of not only what has been done in the area of vowel duration, but also how the various studies of vowel duration have been designed and executed, well as what concerns are raised in the study of vowel duration will guide the current study.

Every speech sound has its inherent length (Akpanglo-Nartey, 2002; Kpodo, 2015). The inherent length of any sound is the duration target of that sound which is pre-specified in the grammar of the language (Lisker, 1974). Inherently, some vowel sounds are longer than other vowel sounds. Studies have shown that high vowels are shorter than low vowels, and voiceless consonants are longer than their voiced counterparts and that while voiceless fricatives are longer than all other consonants, [s] and [f] tend to be longer than all other voiceless fricatives (Akpanglo-Nartey, 2002). It has been established that the mean durations of vowels vary from vowel to vowel, on the order of 30ms (House & Fairbanks, 1953; Peterson & Lehiste, 1960), and that there is a high degree of correlation between these means and vowel height such that the lower the vowel, the greater its inherent length (House & Fairbanks, 1953; Peterson & Lehiste, 1960; Akpanglo-Nartey, 2002).

Some explanations have been offered for the correlation between vowel height and vowel length. According to Lehiste (1970), this is purely due to physiological differences in the articulatory gestures for low versus high vowels. Lehiste explained that in the production of low vowels, greater jaw opening is required and that this greater jaw opening takes a longer time to be achieved.

Lisker (1974) contested the physiological claim by stating that each vowel has a duration target specified in the grammar. He stated that low vowels would have been reported as having longer transitions if their duration is an attribute of jaw opening. Instead, low vowels have steady states. He concluded that the correlation between vowel height and vowel duration is synchronically coincidental and that duration targets of vowels may have been grammaticized from earlier physiological patterns. This position received confirmation from Labov and Baranowski (2006). Labov and Baranowski (2006) compared the vowels of two American dialects and found out that there are systematically significant variations between the comparable vowels despite the overlaps in their formant spaces. They attributed the durational contrast between these two dialects to a phonological nature of intrinsic duration of vowels rather than the physiological nature. This finding was later corroborated by Tauberer and Evanini (2009) who found out that vowel duration does not increase as vowels are lowered in language change and hence concluded that intrinsic vowel durations are targets stored in the grammar but not attributes of physiological constraints.

Probably, the most intriguing hypothesis regarding the explanation for the reported correlation between vowel duration and vowel height is the suggestion that the correlation may be due to physiological constraints in some languages or dialects while it may be grammatical in another. Solé and Ohala (2010) investigated vowel duration across three languages: Japanese, Catalan and English. They investigated how speech rate affects vowel duration and found out that for Catalan and English, the sizes of the differences in vowel duration vary depending on speech rates while the results for Japanese showed a constant change in duration as the speech rate changed. Solé and Ohala (2010) conclude that the positive correlation between vowel duration and vowel height is grammatical in English and Catalan, but physiological in Japanese.

2.5 Effect of phonetic environment on vowel duration

It has been established in the literature that phonetic environments do affect the durational properties of vowel segments. One of such effect has been the widely reported obstruent voicing effect on vowel duration in English in which vowels occur longer before voiced obstruents than before voiceless ones (Peterson & Lehiste, 1960; Chen, 1970; Crystal & House, 1988; Laefur, 1992; van Santen, 1992). It was suggested that the size of the effect in English is of a ratio ranging from 1.2 to 1.6 (House, 1961; House & Fairbanks, 1953; Tauberer & Evanini, 2009). Chen (1970) further suggested that the obstruent voicing effect is substantially larger in English than it is in other languages. In support of this, Mitleb (1984) presented a result of a spectrographic test of Arabic minimal pairs by eight Arabs, in which it was revealed that Arabic did not exhibit a difference in vowel duration as a function of a consonant voicing effect. Other studies which did not find any significant consonant voicing effect on vowel duration are Flege and Port (1981) for Arabic and Keating (1979) for Polish and Czech.

Further research into postvocalic consonant voicing effect on vowel duration took a look at the postvocalic consonant cluster effect on vowel duration. The effects of clusters involving two consonants on vowel duration have shown that the voicing of nasals and liquids does not affect vowel duration (Chen, 1970; Crystal & House, 1988d, van Santen, 1992 cited in de Lacy, 1998). It was reported that it is the voicing of the obstruent element in the Liquid+Obstruent or Nasal+Obstruent clusters that affects the duration of the preceding vowel and that the voicing of neither the liquid nor the nasal usually affects the duration of the vowel.

De Lacy (1998) investigated the effect of sonorant+Obstruent coda clusters on the duration of syllable nucleus. In this study, de Lacy analysed how factors such as the continuancy of consonant segments, their voicing feature, as well as the number of segments constituting the coda-cluster affect the duration of preceding vowels. The researcher set out to precisely describe which segment types affect the duration of vowels and which do not and also to determine whether or not the number of segments in coda-clusters affects vowel duration. Unlike the Gbe language which has only nasal consonants constituting its coda, English can have as many as four consonant segments making up its coda (Kpodo, 2015).

De Lacy found out that, for sonorant+obstruent clusters, only the obstruent's voicing type affects the duration of the vowel and that all other consonants tend to block the voicing effect. He reported that "the number of consonants was found to have a small but systematic effect on vowel duration, with sequences of two and three consonants causing vowel shortening of 10-20ms except in sequences beginning with voiceless stops" (p.1).

Several other studies have reported that properties of prosodic environment such as lexical and phrasal stress tend to affect vowel duration systematically (Umeda, 1975; Crystal & House, 1990; Rietveld, Kerkhoff, & Gussenhoven, 2004). Rietveld et al. (2004) investigated how word prosodic structure determines vowel duration in Dutch words, independent of the effects of pitch, accent and phrase-final lengthening. They found out that main stress, secondary stress, and right/left-edge position determine vowel duration in Dutch. They further explained that the durational differences between long and short vowels only surface in syllables with main or secondary stress. These researchers explained that vowels in main stressed syllables are longer than vowels in secondary stressed syllables, and the latter are longer than vowels in unstressed syllables.

There is growing research into the correlation between the information content and predictability of syllables and words vis-à-vis the duration of segments in them (Aylett & Turk, 2004; Bell, Brenier, Gregory, Girand, & Jurafsky, 2009; Cohen Priva, 2015). Citing Aylett and Turk (2004) and also Jurafsky et al. (2001), Shaw and Kawahara (2017, p.1) explains that "in English, more predictable vowels, that is, those that carry less information, are shorter and more centralized than those that carry more information and are therefore less predictable". Drawing from the concept of efficient communication, Shaw and Kawahara (2017) hypothesized that speakers are more likely to utter words and syllables that carry more information much robustly than the words that carry less information because words that carry more information must be uttered as clearly as possible so listeners will not misperceive them.

The interaction between tones and tone-bearing units has been investigated cross-linguistically. According to Yu (2010, p.151), "the relationship between tone and its tone-bearing unit can be described as symbiotic". He further stated that apart from the fact that the primary determinant of tonal contrasts are differences in the level and contour of the fundamental frequency (F0), tonal contrasts are also determined by differences in vowel length too. Yuan (2012) argued that just like the segmental units such as vowels and consonants, tones as articulatory events also have their inherent durational properties. Citing Ohala and Ewan (1973) to emphasize the claim that tones have their inherent duration, Yuan (2012) stated that over the same pitch range, it takes longer time to make a rising tone than a falling tone because maximum speed for pitch change is slower for pitch rises than pitch falls.

Enough evidence exists in the literature supporting the claim that vowels are realized longer whenever they are bearing low-tones than when they are bearing high-tones (Lehiste, 1970; Gandour, 1977). However, there are other research findings which, run counter to the much-reported claim that low-tone bearing vowels are longer than high-tone bearing ones (Connell, 2002; Myers, 2005).

Duanmu (1994) explored the correlation between tonal structure and vowel duration and concluded that in Chinese languages, the distributional restrictions of contour tones are often conditioned by the vowel duration such that long vowels and diphthongs are preferred conditions for contour tones and that short vowels do not take contour tones. The contour tone bearing long vowels were assigned double mora in Duanmu's work suggesting that the duration of these vowels are expected to be twice their intrinsic durations. Gordon (2001) supported Duanmu's (1994) claim that long vowels are most likely to carry contour tones. However, Gordon also found out that besides long vowels, contour tones are carried by even short vowels but in certain environments. Judging from the findings of Gordon (2001) and Yuan (2012), it is expected that short vowels may be lengthened whenever they bear contour tones since the contour tone duration cannot outlast the vocalic segment bearing it.

2.6 Summary

This chapter reviewed the available literature relevant to the current study. The literature review treated topics such as the development of the acoustic study of vowels, the instrumental study of vowels in Ghanaian languages, some studies on the Gbe vowels, vowel duration and effect of phonetic environment on vowel duration.

The section on the development of the acoustic study of vowels reviewed how the field of acoustic analysis of vowels evolved over the years. The review essentially looked at the works of earlier scholars in the field focusing on their approaches in the area of data collection and analysis. These works and their methodologies greatly informed the approach adopted in the current study.

The section on the instrumental study of vowels in Ghanaian languages reviewed works mainly by Ghanaian researchers on the various Ghanaian languages such as Ga, Dangme, Twi, Fante, Gurunɛ and Ewe. These works generally provided descriptions for the vowel systems of the respective languages using spectrographic analysis.

The review further examined earlier studies on the vowels of Gbe. How the Gbe vowels were described by earlier researchers through impressionistic approaches as well as the points of convergence and divergence of these researchers have been highlighted in this review. A further probe into the identified disagreement among scholars on the phonetic descriptions of some vowels became the focus of the objectives of the current study.

Finally, the review touched on vowel duration and factors that affect the duration of vowel segments across languages. Among other things, the review reckoned the fact that vowels have intrinsic durations and that the inherent duration of vowels is both grammatically and physiologically controlled. Factors such as phonetic environment, as well as the prosodic structure of words, have been identified to have effect on the duration of vowels in the literature.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

It is already clear that the primary purpose of this study is to describe the physical properties of the oral vowels of Gbe. As such, the current chapter primarily provides a detailed description of the methodological approach employed in collecting and analysing the data for the study. The first two sections talked about the research design and the research approach used in the study. Other details presented in this chapter are the selection of the dialect communities and the subjects, as well as the data collection strategy. Finally, the chapter presented the procedure for both instrumental and statistical analysis of the data collected.

3.1 Research Design

"Every type of empirical research has an implicit, if not explicit, research design" (Yin, 1994. p.19). The current study employed the qualitative research design. As such, the study is interpretive and descriptive in nature. This notwithstanding, it is not possible to classify this study as belonging to any particular typological category within the field of qualitative research. As Maxwell (2013) pointed out, "it is sometimes difficult to put some studies into such classificatory pigeonholes". Even though Maxwell was quick to add that the standard arrangements of research conditions and methods ensure coherence and logic, he also states that it is not uncommon to come across research designs that just lack the qualities to conform to any typological classification. This however does not mean that such studies do not have any design. It is pertinent to note that qualitative research is more or less a historical artifact which is changing as the field continue to evolve (Taylor, Bogdan, & DeVault, 2016). Thus, the qualitative researchers are flexible in terms of their data collection and data analysis.

The qualitative research design is suited for the current study due to the fact that qualitative research is not as refined and standardized as other research approaches and also because qualitative research does not have rules but only guidelines to follow (Taylor, et al. 2016). In this study, the qualitative research design is construed as a reflexive process operating through every stage of the study whereby each stage influences all others (Maxwell, 2013).

Creswell (2009) cautioned that qualitative and quantitative approaches should not be viewed as polar opposites but rather, they should be treated as different ends on a continuum. Creswell further elaborates that a particular study may tend to be either more qualitative than quantitative or vice versa. This means that it is possible to have some characteristics of quantitative research in a qualitative research design as is the case in the present study. The current study used qualitative data collection procedures such as the judgmental sampling and recording of speech but used quantitative data analysis tools such as One-Way ANOVA and Tukey HSD Post Hoc Test to establish significance of variation between and among variables.

The focus of this study is to investigate the acoustic properties of vowel sounds of the Gbe language through instrumental analysis. To investigate the acoustic correlates (formant frequency and durational values) of the oral vowels, the Kay Elemetrics Computerized Speech Lab (CSL-4500) and the IBM-SPSS software packages were used in the study. The Kay Elemetrics Computerized Speech Lab was used to generate the formant frequency and durational values of the vowels while the IBM-SPSS software was used to conduct Analysis of Variance to determine the within and between groups difference for the vowels produced by the sampled native speakers of the individual dialects of the Gbe language.

3.2 Dialect Classifications

The study was carried out in the Southern part of the Volta Region of Ghana and the Southern part of Togo where Ewe and Gen dialects are predominantly spoken.

Even though there are no known empirical studies on the classification of the subdialects of Ewe, there are several references to identifiable subdialects in the literature on the language. According to Ameka (1991) Ewe can be classified into the following subdialects: Anlo, Avenor, Tongu, Waci, Kpele, Dzodze, Kpedze, Dodome, Ho, Awudome, Pekí, Anfoe, Sovie, Botoku, Kpando, Gbi and Fodome. He further indicated that these subdialects are often classified into three geographical dialects namely: (i) southern dialects (Anlo, Avenor, Tongu, etc.), (ii) central dialects (Ho, Kpedze, Dodome, etc.) and (iii) northern dialects (Gbi, Kpando, Fodome, etc.). He concluded that while the central and northern dialects are sometimes lumped together and referred to as Inland dialects, the southern dialects are also referred to as coastal dialects.

Kpodo (2017) states that the Ewe group in the Volta Region of Ghana is made up of many distinct sub-dialects including Anlo, Avenor, Tongu, Dzodze, Somè, Aflao, Kpedze, Ho, Awudome, Peki, Aŋfoe, Kpando and

Hohoe. He further explains that all these dialects are often grouped into two major (geographical) dialect blocks namely: Inland Dialects comprising of Ho, Awudome, Peki, Aŋfoe, Kpando, Hohoe, Kpedze and the Coastal Dialects made up of Anlo, Avenor, Dzodze, Somè, Tongu, Aflao.

"The Inland Dialects are commonly referred to as Uedome by the speakers of the Coastal Dialects whereas the coastal dialects are generally referred to as Anlo by the speakers of the Inland Dialects. This blanket labelling of the two geographical dialect blocks goes beyond the fact that the speakers of the various coastal dialects hardly perceive the various dialectal nuances that mark one Inland dialect variety off from the others just as the various Inland dialect speakers do not easily perceive the various dialectal nuances that set one coastal dialect variety apart from all the others" (Kpodo, 2017, p.206-207).

Kpodo (2017) found out that some phonological features and operations seem to accentuate this Inland-Coastal dichotomy. The data for the current study was collected along the lines of these dialect blocks. We did this to investigate if there are significant variations among these sub-dialects to justify their classification, at least at the phonetic level.

3.2.1 Selection of dialect communities

In selecting the dialect communities for data collection, only towns with high concentration of the indigenous speakers of the respective subdialects were selected. This was to ensure that the subdialect spoken by the subjects are free from any dialectal influences from other dialects of Ewe.

The data for the Coastal Dialects was collected from Avenɔpedo, Tsiame and Mepe representing Avenɔ, Anlo and Tɔŋu sub-dialects respectively. Data for the Inland Dialects was collected from Ho-Dome in the Ho Municipality and Fesi in the Kpando District representing the Ho and Kpando sub-dialects, respectively. On the part of the Gen dialect, data was collected from Be, Anexɔ and Agoe. It was the judgment of the researcher that the selected communities are representative enough for the language area.

3.3 The Subjects

In the selection of the subjects for the study, the researcher mainly used the judgmental sampling technique.

Anderson (2003) cited in Gbegble (2006) describes the judgmental sampling as a sampling procedure in which the researcher identifies types of subjects based on certain predetermined factors while planning the study and then attempts to locate them during the fieldwork stage of the study. For the kind of data needed in this study, it was necessary to select native speakers who spent the past twenty years within the respective dialect communities and therefore speak the native language consistently in their daily activities. To ensure that the selected participants do not speak a second language on regular basis, people with very low educational background (not exceeding senior high school) were preferred. Therefore, all the selected participants for the study are not educated beyond the senior high school level since people with college education, even if they lived all their lives within the respective dialect communities, they may also be speaking English or French (the respective official languages in Ghana and Togo spoken by all educated people) from time to time. This is to eliminate the influence that the phonological system of a second language is likely to have on the first language. The judgmental sampling technique was used to ensure that only people who possessed the required characteristics were selected for the recording.

In each community, people were randomly selected for the initial interview. The random selection was used because the researcher did not know any of the participants, as well as their backgrounds, prior to the study. The purpose of the initial interview was to establish the suitability or otherwise of the prospective participants. After the interview, those who qualified for the study were selected for the recording. Within each dialect community, the researcher combined the judgmental sampling and the Snowball methods in the selection of the participants for the study.

The snowball technique is a process whereby the researcher asks some of the randomly selected participants to recommend others who might be willing to participate in the study (Milroy & Gordon, 2003). In each community, after recording the first randomly selected subjects, the researcher asked them to lead him to friends and families who may be suitable for the study and who may be willing to participate.

In all, 128 speakers, 64 male speakers and 64 female speakers between the ages of twenty and sixty years who had lived the past twenty years within the respective dialect communities and whose levels of education did not exceed senior high school were selected for the recording.

Eight males and eight females were recorded from each of the eight communities. The same number of males and females was to eliminate the cross-gender acoustic variations in the frequency values for the vowels. It has been established in the literature that "for female voices, the formant frequency values are about 10% to 15% higher, on account of the fact that the resonance cavities in the female vocal tract are smaller (shorter) by about 10% to 15% than those of male speakers" (Kpodo, 2013, p.179; Goldstein, 1980; Simpson, 2009). This researcher, therefore, sampled an equal number of men and women for the study in order to ensure a balanced representation of the population of the various dialect communities and also avoid instances of skewed mean formant frequency values.

Another factor that has been found to affect vowel quality is age. The age of the subjects is also limited to between 20-60yrs because it has been established in the literature that age affects vowel quality (Hawkins & Midgley, 2005).

Ideally, the researcher would have recorded monolingual speakers but that had not been possible. All the selected native speakers were functionally monolingual in the sense that even though some of them studied and can speak a second language, their major medium of communication is Ewe and Gen for the two respective dialect areas. All the subjects demonstrated normal speech and hearing abilities.

3.4 Data Collection

In this study, the data collected for analysis is sound. The sounds recorded were not translated into text but treated and analysed as sounds. The data for this study was collected mainly from primary sources: recordings of speeches of native speakers of the two dialects of Gbe. The study analysed the seven oral vowel phonemes of Gbe, traditionally mentioned in the literature.

Additionally, the study analysed the schwa [ə] which is often mentioned but treated as though it is not there. Due to the inconsistencies in the literature regarding the phonetic description of the low unrounded vowel [a] especially along the front-back dimension, this study analysed [a] in the environment of [b] which is a front consonant and [k] which is a back consonant in order to investigate the degree of the effect of the place of articulation on the quality of the vowel.

Since the Gbe language is predominantly an open syllable language, the target vowels were placed in CV contexts for production by the subjects. For each dialect, words exemplifying the respective vowel contrasts were selected such that the target vowels occurred after the voiced bilabial plosive [b]. This rendered a list of monosyllabic words such as, *bi, be, bɛ, bə, ba, bɔ, bo, bu, ka* for the vowel phonemes. The test words containing the target vowels were then embedded in the carrier frame "*Magblɔ* ...... *baa*" meaning "*I will say* ...... *surely*" whereby the test words occupied the blank space in the carrier frame. This ensured that each of the target vowels occurred between two voiced bilabial plosives [b]. The test words are presented in table 3.2.1.

Table 3.2.1: Test words exemplifying target vowels

Target vowels	Test word in isolation	Gloss
[i]	[bì]	burn
[e]	[bè]	Cheat him/her
[ɛ]	[bɛ̀]	hide
[ə]	[əvə̀]	two
[a]	[bà]	cheat
[ɔ]	[bɔ̀]	Bend
[o]	[bò]	Portion of land to clear
[u]	[bù]	count
[ka]	[kà]	rope

When the individual test words containing the target vowels were placed into the carrier frame, the following sentences were generated:

(1) *Magblɔ bi baa. – I will surely say burn.*

Magblɔ be baa. – I will surely say cheat him/her.

Magblɔ bɛ baa. – I will surely say hide.

Magblɔ əvə baa. – I will surely say two.

Magblɔ ba baa. – I will surely say cheat.

Magblɔ bɔ baa. – I will surely say bend.

Magblɔ bo baa. – I will surely say portion of land to clear.

Magblɔ bu baa. – I will surely say count.

Magblɔ ka baa. – I will surely say rope.

The sentences containing the target vowels were boldly written on paper and presented to the participants to read. The participants read each sentence three times yielding twenty-four (24) tokens of target vowels per speaker, that is, eight (8) vowels in three (3) repetitions for each vowel. Three hundred and eighty-four (384) vowel tokens were obtained for the eight (8) vowels for each sub-dialect community of Gbe. In all, three thousand and seventy-two (3,072) vowel tokens were elicited from the one hundred and twenty-eight (128) native speakers who were selected from the eight (8) communities within the Gen and Ewe speaking areas. An extra three hundred and eighty-four (384) vowel tokens for [a] in the environment of a dorsal (ka) were elicited from the one hundred and twenty-eight (128) speakers.

The subjects were made to read the carrier sentences as naturally as possible for the recording. English or French glosses for each word containing the target vowels written in parenthesis beneath each test word were provided to aid the subjects. We did this to eliminate any type of ambiguity that may occur due to tonal variations.

Additionally, the speeches of the subjects within natural conversational contexts were recorded from two communities each from the Gen and Ewe speaking areas. This was used to extract some of the target vowels from naturally occurring utterances in phonetic environments similar to the ones produced by the carrier frames. These naturally occurring vowel tokens were later analysed and their frequency values compared to the frequency values of the tokens generated by the carrier frames. This was used to validate the vowel tokens of the target vowels.

Finally, [i], [e], [a], [ɔ], [o], [u] were placed in various phonetic environments rendering the words in table 3.1 which were then embedded into the same carrier frame for twenty (20) speakers each from the Gen dialect and Ewe dialect communities to produce for the recording.

Table 3.2.2 Gbe vowels in varying phonetic environments

[i]	[e]	[a]	[ɔ]	[o]	[u]
di	de	da	dɔ	do	du
ti	te	ta	tɔ	to	tu
atike	teka	taku	tɔka	tǒ	tukpe
tiŋ	keŋ	taŋtaŋ	kɔtɔɔ	tokpo	tuŋ
litii	betee	tikaa		toŋ	kutuu
		tǎ		lotoo	

These recordings were used to investigate the effect of phonetic environments on the durational properties of the individual vowels. The participants read the target words three times each for the recording. In these recordings, the mid-low front vowel [ɛ] and the schwa [ə] were exempted because preliminary analysis revealed that these two vowels are not used by every dialect community within the Gbe language.

The recordings were made by a Sony IC Recorder (ICD-UX560F) in quiet places within the respective dialect communities in order to avoid background noise, which may affect the quality of the recording. This was to ensure that the effect of extraneous noise was minimized as much as possible as noise can negatively affect the quality of the recording and subsequently affect the vowel qualities.

3.5 Instrumental Analysis

The recordings of each vowel sample were acquired from the digital recorder into a computer interface known as Kay Elemetric Computerized Speech Lab (CSL-4500) at a sampling rate of 11025Hz. The Computerized

Speech Lab produces a graphic display of speech samples that are conventionally called spectrograms.

Formant resonances of the vowels and the effects of changes in pitch and vocal effort were exemplified in spectrograms of natural speech. Spectrograms provide spectral analysis of the energy present at each frequency or band of frequencies within a complex acoustic signal. The spectrograms show visual representations of the sounds with their formants arranged according to the vowel type. In the words of Ladefoged and Johnson (2011),

> *...a vowel sound contains a number of different pitches simultaneously. There is the pitch at which it is actually spoken, and there are the various overtone pitches that give it its distinctive quality. We distinguish one vowel from another by the differences in these overtones. The overtones are called formants, and the lowest three formants distinguish vowels from each other.*

The formant frequency values, as well as the durational values were extracted by the software from the wideband spectrogram for each vowel. Wideband spectrograms are very suitable for tracking vowel formants (Kinnunen, 2003). The Figure 3.3.1 shows a sample of the waveforms and spectrogram for the front high vowel [i] uttered by Anlo male speaker 4. The waveforms show variations in air pressure as the speaker makes the utterances. Vertical pulses normally show periods of vibration of the vocal cords whereas single horizontal lines show periods of silence. The wideband spectrogram also shows vertical striations representing the vibrations of the vocal cords during the utterance. The signals in both boxes were then synchronized, mapping each waveform onto its spectrographic representation in order to ensure that the formant values are taken from the desired point in the waveform.

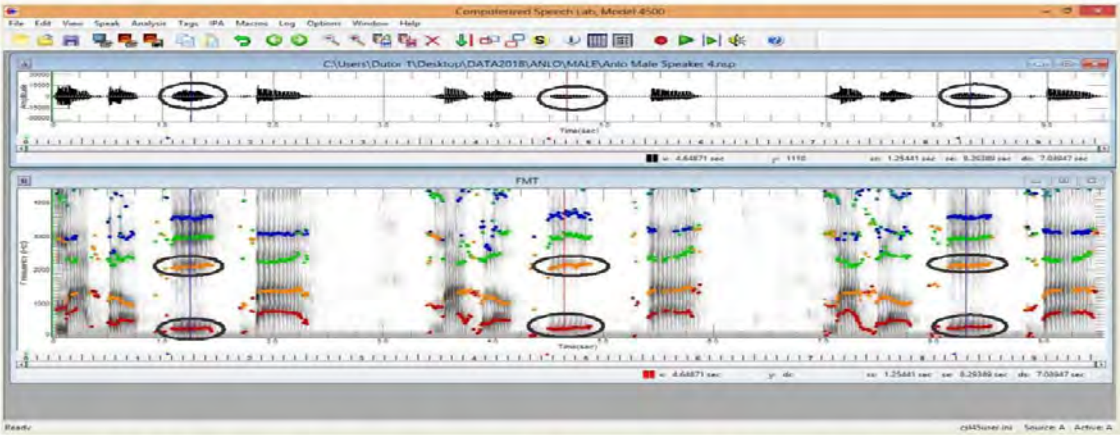


Figure 3.3.1 *Waveform and spectrogram of Anlo male speaker 4 saying 'Magblɔ bi baa.' in three repetitions. The first two formants as well as the wave forms of the target vowel have been circled. The dark horizontal bars indicated by coloured lines, show the formants. The vertical frame goes from 0Hz to 4000Hz with F1, F2, ..., arranged for each sound.*

As can be seen from figure 3.3.1, the first two formants, as well as the waveforms of the target vowel, have been circled. In addition to the dark horizontal bars showing the formants, they are also indicated by coloured lines. The first formant (F1) is indicated by the red line and the second formant (F2) is indicated by the yellow lines. The vertical frame goes from 0Hz to 4000Hz which is sufficient to show the component frequencies for the vowel. The first formant, which is inversely related to the vowel height dimension is very low indicating that the vowel is a high vowel while the second formant, which represents the front-back dimension of the vowel is above 2000Hz indicating that the vowel is a front vowel.

On the spectrogram, a time scale is shown along the bottom of the figure running from left to right, and the vertical scale shows the frequencies in Hertz (Hz). The relative intensity of each component frequency is shown by the darkness of the mark. As a result, the formants show up as dark horizontal bars. From the bottom of the horizontal bar, the first two formants that are said to determine the quality of vowels were taken.

For each vowel token, a steady-state portion was found near the midpoint of the vowel. The midpoints of the target vowels were selected in order to minimize the influence of any adjacent segments as well as minimize any transitional effect on the vowels.

The formant frequency values for the first and second formants (F1 and F2) were extracted from the formant history of the spectrogram since it has been established in the literature that the higher formants indicate a person's voice quality (Ladefoged, 2006; Cox, 2002). The First formant, (F1), inversely corresponds to vowel height (openness) while the second formant, (F2), corresponds to both backness and lip rounding. As Ladefoged and Johnson (2011, p.198) puts it;

> *The so-called front–back dimension has a more complex relationship to the formant frequencies. As we have noted, the second formant is affected by both backness and lip rounding. We can eliminate some of the effects of lip rounding by considering the second formant in relation to the first. The degree of backness is best related to the difference between the first and the second formant frequencies. The closer they are together, the more "back" a vowel sounds.*

Following Ladefoged and Johnson (2011) the effect of lip rounding was eliminated by using the difference between F2 and F1 instead of F2. Thus, the formant frequency values of formant one (F1) and formant two (F2) of the individual vowels per dialect were tabulated and the difference between F1 and F2 calculated. F1 values were plotted on the vertical axis (ordinate) against the difference between formant one and formant two, (F2-F1) F2' on the horizontal axis (abscissa).

3.6 Statistical Analysis

The (SPSS) software package was used to conduct a One-Way analysis of variance (ANOVA) on the individual vowels in order to determine the means and standard deviation values for each vowel and variations within and across the various dialects. The mean of F1 and F2' values were used in plotting the vowel points within the acoustic vowel space. A Tukey Post Hoc tests for significant differences were performed separately on F1 and F2' values for similar vowels across the dialects and also, between adjacent vowels within the same dialects. The Tukey Post Hoc test was conducted to investigate the auditory differences or similarities between adjacent vowels within a particular vowel space in order to establish whether or not the speakers of the dialect adequately distinguish between the vowels on the auditory scale. The Tukey Post Hoc test was again conducted between similar vowel sounds among various dialects to establish the articulatory variations among the various dialects regarding the individual vowel sounds.

3.7 Summary

This chapter presented the methodological procedure for the study from data collection through data analysis. The chapter started with how the current research was designed following the qualitative research paradigm without necessarily fitting the design into any particular typological orientation. The design was described as qualitative due to the fact that the qualitative data collection procedure was used in the data collection. This notwithstanding, some quantitative data analysis tools were used in data analysis. The rest of the chapter presented the overall design of the study starting from the selection of the dialect communities, as well as the sampling procedures used in the study. Finally, the chapter explained the instrumental analysis processes adopted, as well as the statistical analysis process used in the study.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF RESULTS

4.0 Introduction

The current chapter presents and discusses the results of the study. Using tables showing the mean formant frequency values and durational values of the vowels of the respective dialects of the Gbe language, the chapter systematically presented the acoustic correlates of the oral vowels of Gbe. The figures presented in this chapter showed the graphical representations of the locations of the vowels within the acoustic vowel space of the individual dialects as well as that of the Gbe language. The chapter further discussed the variations that showed up among comparable vowels across the various dialect communities. Finally, the results of the investigation into the environmental effects on the duration of the vowels, as well as the syllable weight and syllable duration were also presented in the rest of the chapter.

4.1 Presentation of Results

The results of the spectrographic analysis of all the vowel tokens of the respective dialect communities of Gbe namely Anlo, Ho, Kpando, Avenor, Tongu and Gen were presented. In all, nine (9) vowels in three repetitions for each of the 128 speakers from the six major dialect communities were analysed. A total of 3,456 oral vowel tokens were analysed. The frequency values for the two lowest formants (F1 and F2) were measured. The $F2^{I}$ (F2-F1) values for each of the three repetitions of each vowel per speaker was calculated. The results of these measurements are presented in this chapter in the form of tables and figures. The tables contain the mean values and standard deviations of the F1 and F2[1] (F2-F1), as well as the durational values of all oral vowels in the respective dialects.

The figures present the formant plots of the vowels using the FPlot[1] software program. The FPlot software program plots the mean of the F1 values against the mean F2[1] (F2-F1) values which are on the vertical and the horizontal axes respectively. The spacing of the formant frequency values follows a non-linear Bark scale.

4.2 Presentation and Discussion of Anlo Vowels

The vowel space of Anlo is presented in this section. Table 4.2.1 presents the summary of the means and standard deviations of F1 and F2[1] values of each of the eight oral vowels and [a] in the environment of [k] uttered by the eight male and eight female speakers of the Anlo dialect. These values were used in plotting the vowel points indicated on the Anlo vowel space (Figure 4.2.1) described in this section.

Table 4.2.1: F1 and F2[1] means and standard deviations of the formant frequency values of each oral vowel of Anlo

ANLO SPEAKERS										
Vowels		i	e	ɛ	ə	a	ɔ	o	u	a'
F1	Mean	330	487	584	604	839	593	427	357	832
	Std.Dev	64	133	53	53	77	69	52	46	75
F2[1]	Mean	1988	1524	1083	1002	643	361	370	326	657
	Std.Dev	288	321	356	236	151	63	63	80	144

[1]The FPlot is a software program that produces formant plots of vowels. Two different types of plot are available: a plot of F1 vs. F2, or a plot of F1 vs. F2 - F1 (sometimes referred to as "F2'"). In both cases, the spacing of frequency values follows a non-linear Bark scale. The FPlot software is available at http://casali.canil.ca/.

The high front vowel [i] is located at approximately 330Hz on the vertical axis and 1988Hz on the horizontal axis. It is well removed from the mid-high front vowel [e] which is located at approximately 487Hz on the vertical axis and 1524Hz on the horizontal axis. The mid-low front vowel [ɛ] is located at approximately 584Hz and 1083Hz on the vertical and horizontal axes respectively. The mean frequency values of the front vowels of Anlo indicated clear distinctions among the vowels.

On the part of the back vowels of Anlo, as shown by the mean frequency values in the table, the high back vowel [u] is located at approximately 357Hz and 326Hz on the vertical and horizontal axes respectively. This means that in terms of height, the back high vowel is slightly lower than the front high vowel. The mid-high back vowel [o] is located approximately at 427Hz on the vertical axis and 370Hz on the horizontal axis. The mid-low back vowel [ɔ] is located around 593Hz and 361Hz on the vertical and horizontal axes respectively. The low vowel [a] is located at approximately 839Hz on the vertical axis and 648Hz on the horizontal axis. The low vowel produced in the environment of [k] is located at approximately 832Hz and 657Hz on the vertical and the horizontal axes respectively. Comparatively, the [a] measured in the environment of [b] is slightly lower and slightly more back than the [a] measured in the environment of [k]. The variation among the frequency values of the back vowels is less than that of the front vowels indicating that the front vowels are more dispersed than their back counterparts.

Table 4.2.2: Mean Duration and standard Deviation values for Anlo oral vowels

Vowel	Duration	Std.Dev
i	238	54
e	212	38
ɛ	206	42
ə	204	36
a	226	40
ɔ	227	47
o	224	35
u	209	47

Table 4.2.2 shows the mean and standard deviations of the duration of each vowel produced by the Anlo speakers. The shortest vowel as produced by the Anlo speakers is [ə] produced at an average duration of 204ms while the longest vowel is [i] produced with an average duration of 238ms. There seems to be some correlation between vowel height and vowel duration as far as the back vowels are concerned such that the lower the back vowel, the longer its duration. The high back vowel [u] is shorter than the mid-high back vowel [o] which is, in turn, shorter than its adjacent vowel [ɔ]. However, this correlation between vowel height and duration does not extend to the non-back vowels, [i], [e], [ɛ], [ə] and [a]. From the low region, [a] is longer than [ɛ] and [ɛ] is also longer than [e]. However, the high front vowel [i] is longer than all the other non-back vowels.

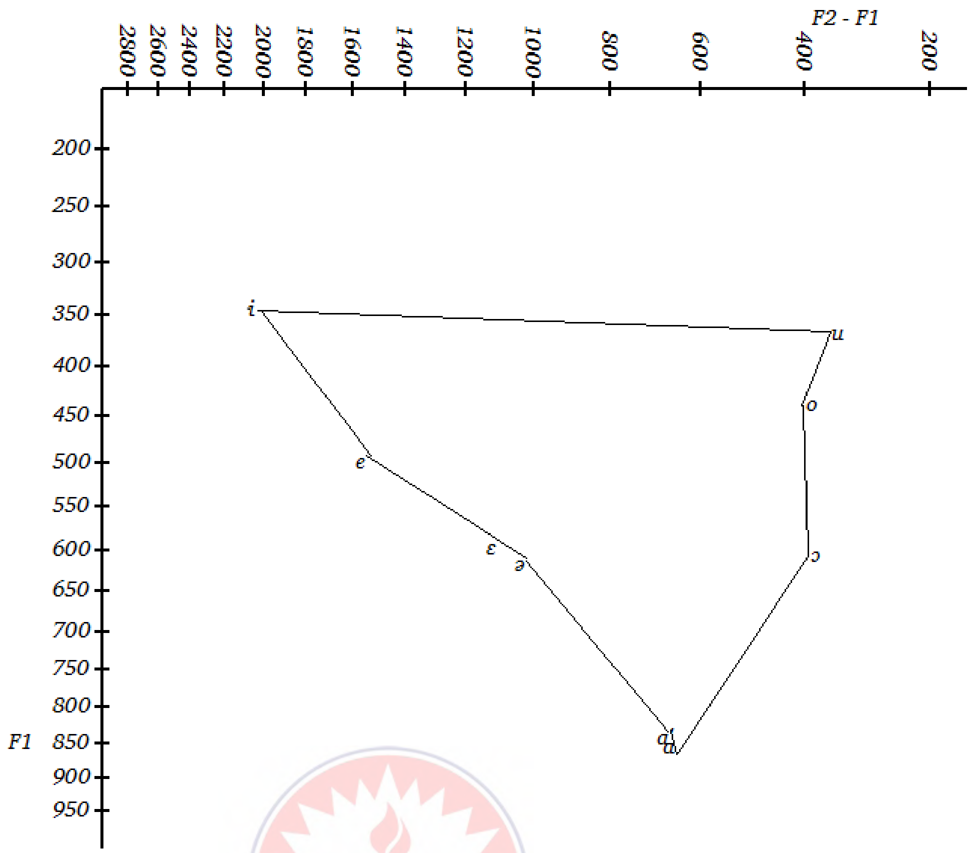


FIGURE 4.2.1: The Vowel Space of Anlo Speakers

Figure 4.2.1 shows the mean locations of the nine oral vowels uttered by the Anlo speakers. [i] and [e] are prominently located within the front zone of the vowel space while [ɛ] and [ə] are clustered close to the central part of the vowel space. On the part of the back vowels, [u], [o] and [ɔ] are all located at the back. Even though [u] is the most back vowel among the three back vowels, there seems to be some conflation among the three back vowels in terms of backness. The location of the [ɛ] and [ə] seems to support the report that Anlo speakers do not use [ɛ] (Mensah, 1977 cited in Gbegble, 2006).

The acoustic vowel space of the Anlo speakers follows the prediction of the Quantal Theory (QT) whereby [i], [a] and [u] are located within the predicted zones (the three corners) of the acoustic vowel space. The configuration of the Anlo vowel space shows that all the vowels are well dispersed within the vowel space except [ɛ] and [ə]. Following the claims of Adaptive Dispersion Theory that adjacent vowels repel one another in other to maintain auditory distinction within the acoustic space, the conflation between [ɛ] and [ə] can be explained as Anlo having only one of the two vowels in its inventory. This is consistent with the suggestion that Anlo does not use the mid-low front vowel [ɛ] but rather Anlo uses [ə] (Capo, 1985).

To determine the significance of the variation between the various vowels within the dialect, a One-Way ANOVA was conducted and the results presented in Table 4.2.3.

Table 4.2.3 Result of One-Way ANOVA comparing F1 and F2' mean values separately for the oral vowel of Anlo

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
F1	Between Groups	7705577.550	8	963197.194	172.129	.001
	Within Groups	1365371.525	244	5595.785		
	Total	9070949.075	252			
F2'	Between Groups	73929585.824	8	9241198.228	191.145	.001
	Within Groups	11796524.160	244	48346.410		
	Total	85726109.984	252			

The results of the One-Way ANOVA showed statistically significant differences among the individual vowels within the Anlo vowel space both in terms of vowel height and backness at the 0.05 probability alpha level. A Tukey HSD Post Hoc multiple comparisons analysis was conducted to ascertain the variations between specific adjacent vowels within the Anlo vowel space and, the result is presented in Table 4.2.4. The Post Hoc test was conducted to establish the degree of conflation between the adjacent vowels. Due to this, even though the Post Hoc test compared each of the vowels to all the other vowels within the vowel space, only the results of the adjacent vowels are presented in Table 4.2.4.

Table 4.2.4 Result of Tukey HSD Post Hoc Test comparing F1 and F2[1] mean values separately for adjacent oral vowels of Anlo

Vowel Comparisons	F1/Height		F2[1]/Backness	
	Mean Diff.	Sig.	Mean Diff.	Sig.
i – e	-157.129*	.001	464.145*	.001
e - ɛ	-97.167*	.001	441.133*	.001
ɛ - ə	-20.467*	.986	80.983	.917
ə - a	-235.133*	.001	358.150*	.001
a - ɔ	246.867*	.001	282.533*	.001
ɔ – o	165.186*	.001	-8.353	.999
o - u	70.414*	.028	43.495	.999
a-k[a]	7.200	.999	-13.200	.999

Table 4.2.4 shows the result of the Post Hoc Test performed on the vowels of Anlo to determine the significance of variation or similarity between adjacent vowels within the vowel space. The results showed that at a confidence level of 95%, there is a high degree of conflation between the front mid-low vowel [ɛ] and the central mid-low vowel [ə]. This showed that the Anlo speakers do not distinguish between these two vowels as separate vowels. As indicated above, Anlo speakers use only one of the two vowels in their day to day interactions rather than both. Judging from the location of the front mid-low vowel [ɛ] supported by the Tukey Post Hoc Test result, it is clear that the Anlo speakers use [ə] rather than [ɛ] as indicated in the literature. The Post Hoc results showed that [u] and [o] are very similar in terms of backness with a p-value of [p<.999]. [o] and [ɔ] are virtually the same in terms of backness with a p-value of [p<.999].

On the part of the front vowels, the Post Hoc results showed that the front vowels are significantly different from one another in terms of both the vowel height and backness indicating that all the front vowels are well dispersed as predicted by the ADT.

4.3 Presentation and Discussion of Avenor Vowels

The mean F1 and $F2^1$ values, and the duration values, as well as the acoustic vowel space of the Avenor vowels are presented in this section. Table 4.3.1 presents the means and standard deviations of the formant frequency values of the nine recorded oral vowels uttered three times each by the speakers of Avenor.

Table 4.3.1: F1 and $F2^1$ means and standard deviations of the formant frequency values of each oral vowel of Avenor

		AVENOR SPEAKERS								
Vowels		i	e	ɛ	ə	a	ɔ	o	u	a'
F	Mean	365	474	589	618	758	605	426	371	794
1	Std.Dev	67	91	85	50	106	68	35	52	73
F	Mean	1983	1659	1342	1163	762	397	396	351	704
2^1	Std.Dev	321	338	276	397	253	91	64	98	168

The front high vowel [i] is located approximately at 365Hz on the vertical axis and 1983Hz on the horizontal axis while the high back vowel [u] which is the most back of all the back vowels is located at approximately 371Hz on the vertical axis and 351Hz on the horizontal axis. The high front vowel is slightly higher than its back counterpart as shown by their F1 values.

The low vowel [a] is located at approximately 758Hz on the vertical axis and 762Hz on the horizontal axis. [a] produced in the environment of [k] is located at approximately 794Hz and 704Hz on the vertical and the horizontal axes respectively. This indicates a marginal difference between the two occurrences of [a] such that [a] in the environment of a front consonant is located slightly higher and less front than its counterpart [a] produced in the environment of [k].

The mid-high front vowel [e] is located at approximately 474Hz and 1659Hz on the vertical and horizontal axes respectively. Judging from the mean frequency figures in the table, the high front vowel and the mid-high front vowel are very distinct. The mid-low front vowel [ɛ] is located at approximately 589Hz on the vertical axis and 1342Hz on the horizontal axis. [ə] is located at 618Hz on the vertical axis and 1163Hz on the horizontal axis. The frequency values of the mid-low front vowel [ɛ] and the schwa [ə] are very close on both axes indicating a high degree of conflation between these two vowels. On the part of the two intermediate back vowels, [o] is located at approximately 426Hz on the vertical axis and 396Hz on the horizontal axis while [ɔ] is located at approximately 605Hz and 397Hz on the vertical and the horizontal axes respectively. In terms of backness, the mid-high back vowel and the mid-low back vowels are conflated.

The Table 4.3.2 presents the mean duration values and the standard deviations of the Avenor vowels.

Table 4.3.2: Mean Duration and standard Deviation values for Avenor oral vowels

Vowel	Duration	Std.Dev
i	209	57
e	211	53
ɛ	217	46
ə	203	51
a	227	47
ɔ	222	45
o	230	62
u	208	48

The longest vowel is [o] produced within 230ms and the shortest vowel is [ə] produced within 203ms. The front vowels seemed to display some correlation between vowel height and duration such that the higher the vowel, the shorter its duration. The front high vowel which is 209ms long is shorter than the mid-high front vowel [e] which is 211ms long. [e] is also shorter than its lower front counterpart [ɛ] which is 217ms. This observable correlation between vowel height and vowel duration was not found among the back vowels. While the high back vowel [u] which is 208ms long is shorter than [o] and [ɔ], the mid-high back vowel [o] is longer than its lower back counter counterpart [ɔ].

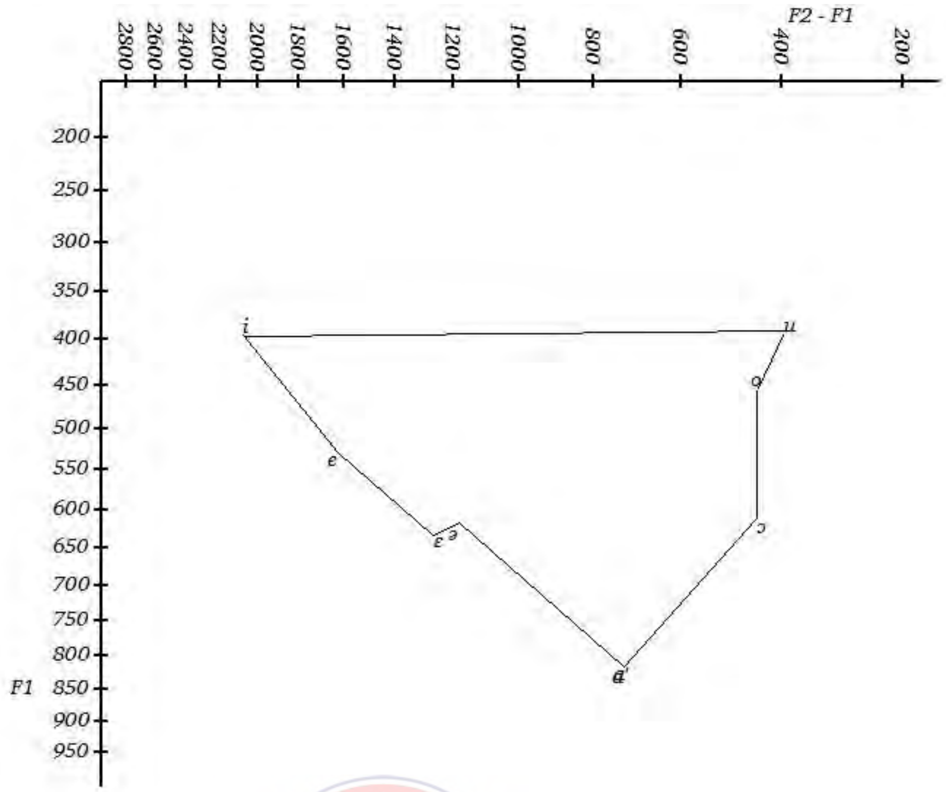


FIGURE 4.3.1: The Vowel Space of Avenor Speakers

Figure 4.3.1 shows the mean locations of the nine oral vowels uttered by the Avenor speakers. [i] and [e] are located within the front zone of the space while [ɛ] and [ə] are clustered around the front part of the vowel space. The front high vowel [i] is the most front of all the front vowels. Just by looking at the plots, it is obvious that [e] is much more shifted towards the centre of the space. On the part of the back vowels, [u], [o] and [ɔ] are all located at the back. Even though [u] seems to be the most back vowel, it is only marginally more back than the others. Therefore, there is no significant difference between the three back vowels in terms of backness. [a] is located prominently in the central low region. [a] in Avenor is therefore, a central low vowel.

In order to determine the significance of variations and similarities between adjacent vowels within the vowel space of Avenor, a One-Way ANOVA was performed as exemplified in Table 4.3.3.

Table 4.3.3 Result of One-Way ANOVA comparing F1 and F2¹ mean values separately for the oral vowels of Avenor

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	8122050.875	8	1015256.359	187.647	.001
F1	Within Groups	2120900.951	392	5410.462		
	Total	10242951.825	400			
	Between Groups	143069942.633	8	17883742.829	304.369	.001
F2'	Within Groups	23032652.808	392	58756.767		
	Total	166102595.441	400			

The results of the One-Way ANOVA showed statistically significant differences among the vowels within the Avenor vowel space both in terms of vowel height and backness at the 0.05 probability alpha level. However, it was not clear from the One-Way ANOVA test which vowels differ from which vowel. Therefore, to ascertain the variations between, especially the adjacent vowels within the vowel space, a Tukey HSD Post Hoc analysis was conducted and the results are presented in Table 4.3.4.

Table 4.3.4 Result of Tukey HSD Post Hoc Test comparing F1 and F2¹ mean values separately for adjacent oral vowels of Avenor

Vowel Comparisons	F1/Height		F2¹/Backness	
	Mean Diff.	**Sig.**	**Mean Diff.**	**Sig.**
i – e	-108.797*	.001	324.086*	.001
e - ɛ	-115.685*	.001	316.841*	.001
ɛ - ə	-28.187	.839	179.500	.078
ə - a	-140.860*	.001	401.235*	.001
a - ɔ	153.822*	.001	364.486*	.001
ɔ – o	178.446*	.001	1.561	.999
o - u	55.280*	.005	44.759	.991
a-k[a]	-36.021	.626	57.211	.992

The Tukey HSD Post Hoc test compared the mean F1 and F2[I] values of each vowel to every other vowel within the vowel inventory of the Avenor dialect. However, only the results of adjacent vowels are presented in Table 4.3.4. [i] and [e] are significantly different from each other both in terms of height at a 'p' values of [p<.001] and backness with a 'p' value of [p<.001] indicating the fact that the two front vowels are completely distinct. On the front/back dimension, [i] is shown in the vowel space (Figure 4.3.1) to be more front than [e], and the [e] is more shifted towards the centre of the vowel space rather than being in the front. The statistical analysis on the front/back dimension of the vowels showed no significant differences between the adjacent back vowels [u] and [o] on one hand and [o] and [ɔ] with "p" values of [p<.991] and [p<.999] respectively in terms of backness.

The Post Hoc showed that Avenor speakers just like the Anlo speakers do not distinguish between [ɛ] and [ə] in their speech. Judging from the location of these two vowels and the variation between them and the front high vowel [i] on one side and [e] which as indicated earlier is shifted towards the centre of the space, it is fair to state that the Avenor speakers use the mid-low central vowel [ə] rather than mid-low front vowel [ɛ].

Unlike the front vowels, all the back vowels are only significantly different statistically in terms of vowel height but very similar in terms of backness. The post Hoc results also showed that the two occurrence of [a] are very similar in terms of both backness (p<.992) and height (p<.626) indicating that the variation in the place of articulation of the preceding consonant did not affect the quality of [a] in the Avenor dialect.

4.4 Presentation and Discussion of Ho Vowels

The means and standard deviations of F1 and F2' and the duration values as well as the acoustic vowel space of Ho vowels are presented in this section. The oral vowels of Ho are presented through tables and figures. Table 4.4.1 presents the means and standard deviations of the formant frequency values of the nine-recorded oral vowels, uttered three times each by the speakers of Ho.

Table 4.4.1: F1 and F2' means and standard deviations of the formant frequency values of each oral vowel of Ho

		HO VOWELS							
Vowels		**i**	**e**	**ɛ**	**a**	**ɔ**	**o**	**u**	**a'**
F1	Mean	280	514	535	760	582	414	333	752
	Std.Dev	25	95	91	84	68	45	44	86
F2'	Mean	2024	1495	1505	628	367	354	348	664
	Std.Dev	279	284	318	104	63	60	112	100

The high front vowel [i] is located at approximately 280Hz on the vertical axis and 2024Hz on the horizontal axis. [u] is located at approximately 333Hz on the vertical axis and 348Hz on the horizontal axis. The F1 values of the two high vowels indicated that [i] is higher than [u] within the vowel space. [a] is located at approximately 760Hz on the vertical axis and 628Hz on the horizontal axis. The second occurrence of [a] measured in the environment of [k] is located at approximately 752Hz on the vertical axis and 664Hz on the horizontal axis. The [a] produced in the environment of the bilabial stop is slightly more shifted towards the back than its counterpart. The mid-high front vowel [e] is located at approximately 514Hz and 1495Hz on the vertical and the horizontal axes respectively. The mid-low front vowel [ɛ] is located at approximately 535Hz on the vertical axis and 1505Hz on the horizontal axis. As far as the Ho dialect is concerned, the F2[1] values of the two intermediate back vowels [o] and [ɔ] are not very close as seen in Anlo and Avenor values. While [ɔ] is located at approximately 582Hz and 367Hz on the vertical and the horizontal axes respectively, the mid-high back vowel [o] is located at approximately 414Hz and 358Hz on the vertical and the horizontal axes respectively. The difference between the mid-high back vowel and the mid-low back vowel in terms of backness is about 47Hz.

Table 4.4.2: Mean Duration and standard Deviation values for Ho oral vowels

Vowel	Duration	Std.Dev
i	190	35
e	191	42
ɛ	214	56
a	213	49
ɔ	204	52
o	201	52
u	203	56

Table 4.4.2 presents the mean and standard deviation of the duration of the Ho vowels. The front high vowel [i] uttered in 190ms is the shortest while the mid-low vowel [ɛ] uttered in 214ms is the longest vowel. Among the three front vowels, there seemed to be a correlation between height and vowel duration such that the higher the vowel, the shorter the duration. While the front high vowel [i] is shorter than [e] which is 191ms, the [e] is also shorter than the mid-low front vowel [ɛ]. This inverse correlation between vowel height and vowel duration did not include the back vowels. The high back vowel [u] produced in approximately 203ms is slightly longer than the mid-

high back vowel [o] which is 201ms long. However, the mid-low back vowel [ɔ] is 204ms long and the central low vowel is 213ms long.

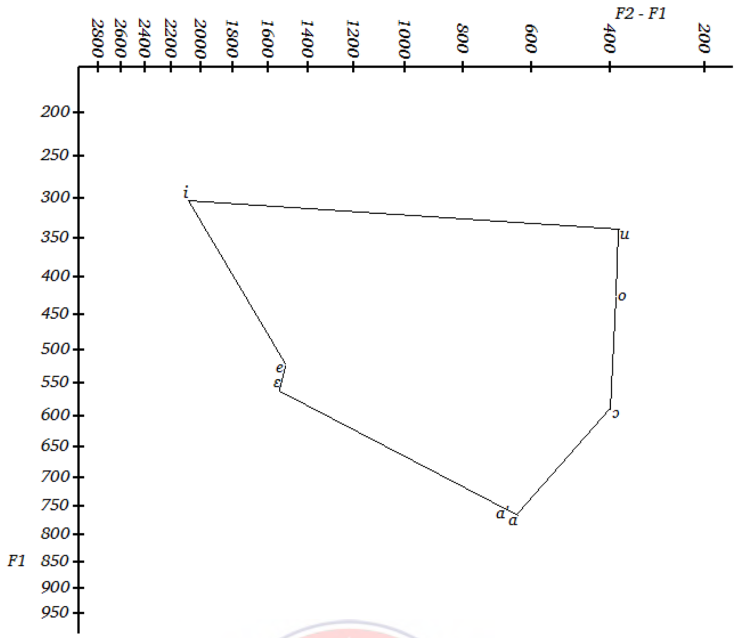


FIGURE 4.4.1 Vowel Space of Ho

The mean formant frequency values of the Ho vowels as presented in Table 4.4.1 were used in plotting the vowel points within the acoustic vowel space for Ho as presented in Figure 4.4.1. The three corner vowels [i], [u] and [a] are located at the front high, back high and the low regions respectively as predicted by the QT. The two front-mid vowels [e] and [ɛ] are conflated in between [i] and [a]. It looks as though the speakers of the Ho dialect use some other cues to distinguish between the mid-high front vowel [e] and the mid-low front vowel [ɛ]. The distribution of these two mid vowels does not follow the adaptive dispersion theory's prediction. According to the prediction of the adaptive dispersion principle, [e] and [ɛ] should have been spaced out at least along the height dimension. [a] is shifted towards the back region rather than being located in the centre of the vowel space. The Ho [a] is therefore a low back unrounded vowel rather than a central low vowel as seen in the case of

Anlo and Avenor. The vowel plots also showed that the [a] in the environment of [b] is more back and slightly lower than the [a] in the environment of [k].

Table 4.4.3 Result of One-Way ANOVA comparing F1 and F2[1] mean values separately for the oral vowels of Ho

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
F1	Between Groups	5879584.167	7	839940.595	160.636	.001
	Within Groups	1124201.528	215	5228.844		
	Total	7003785.695	222			
F2	Between Groups	83987573.040	7	11998224.720	310.202	.001
	Within Groups	8315937.651	215	38678.780		
	Total	92303510.691	222			

Table 4.4.3 shows the result of the One-Way ANOVA test on the vowels of Ho to determine significance of the within-group variation among the individual vowels. The results of the One-Way ANOVA showed statistically significant differences among the vowels within the Ho vowel space both along the vowel height dimension ($p<.001$) and the back/front dimension ($p<.001$). It was, however. not clear from the One-Way ANOVA test how significant are the variations between specific pairs of adjacent vowels. Thus, a Tukey HSD Post Hoc analysis was conducted to ascertain the significance of the differences between adjacent vowels within the vowel space and the results are presented in Table 4.4.4.

Table 4.4.4 Result of Tukey HSD Post Hoc Test comparing F1 and F2[1] mean values separately for adjacent oral vowels of Ho

Vowel Comparisons	F1/Height		F2[1]/Backness	
	Mean Diff.	**Sig.**	**Mean Diff.**	**Sig.**
i – e	-234.195*	.001	529.464*	.001
e - ɛ	-21.147	.951	-10.293	.999
ɛ - a	-224.320*	.001	876.526*	.001
a - ɔ	177.933*	.001	261.400*	.001
ɔ – o	167.800*	.001	12.625	.999
o - u	81.391*	.002	6.328	.999
a-k[a]	7.858	.999	35.525	.998

Table 4.4.4 presents the results of the Tukey HSD Post Hoc multiple comparisons test comparing the mean values of F1 and F2[1] separately for each pair of adjacent vowels within the Ho vowel space. The conflation between the mid-high front vowel [e] and the mid-low front vowel [ɛ] has been confirmed by the Post Hoc test result indicating that the two vowels are significantly similar (p<.951) in terms of height and in terms of backness (p<.999). This level of similarity between the two intermediate front vowels indicated that the Ho speakers do not distinguish between the two vowels. All the back vowels are significantly different from one another in terms of height as expected. However, the back rounded vowels [u], [o] and [ɔ] are very similar in terms of backness as shown in Table 4.4.4.

Even though [a] is within the back region of the vowel space as shown in Figure 4.4.1, it is significantly different from even the least back vowel [ɔ] with a "p" value of [p<.001] in terms of backness. Therefore, [a] in the Ho dialect can be described as a low back unrounded vowel which is rather shifted towards the central region of the vowel space. The location of [a] in the Ho dialect agrees with Smith's (1968) specification of [a] as a [+Back] vowel.

Finally, the results of the one-way Post Hoc test showed that [a] measured in the environment of [b] and [a] measured in the environment of [k] are not significantly different from each other in both the backness (p<.998) and in the height dimensions (p<.999).

4.5 Presentation and Discussion of Tongu Vowels

The results of the oral vowels of Tongu were presented through tables and figures in this section. The mean and standard deviation of the F1 and F2' values, as well as the durational values of the Tongu vowels, are presented. Table 4.5.1 presents the mean and standard deviation of the formant frequency values of the nine recorded oral vowels uttered three times each by the speakers of the Tongu dialect.

Table 4.5.1: F1 and F2' means and standard deviations of the formant frequency values as well as the duration values of each oral vowel of Tongu

TONGU VOWELS										
Vowels		**i**	**e**	**ɛ**	**ə**	**a**	**ɔ**	**o**	**u**	**a'**
F1	Mean	312	501	592	518	761	591	443	334	714
	Std.Dev	70	114	92	41	93	102	83	33	77
F2'	Mean	1977	1608	1289	1044	646	342	375	422	673
	Std.Dev	232	204	144	184	91	41	60	86	111

In the Tongu dialect, while the [a] produced in the environment of bilabial plosive [b] is located at approximately 761Hz on the vertical axis and 646Hz on the horizontal axis, the same [a] produced in the environment of the velar plosive [k] is located at approximately 714Hz on the vertical axis and

673Hz on the horizontal axis. There are, therefore, some marginal variations between the two renditions of [a] in both the height and backness dimensions.

The high front vowel [i] is located in front at approximately 312Hz on the vertical axis and 1977Hz on the horizontal axis while [u] is located at the back at approximately 334Hz on the vertical axis and 422Hz on the horizontal axis. The front high vowel [i] is slightly higher than its back high counterpart [u] judging from the F1 values of the two vowels. However, the mid-high front vowel [e] located at approximately 501Hz on the vertical axis and 1608Hz on the horizontal axis is rather lower than its back counterpart [o] which is located at approximately 443Hz on the vertical axis and 375Hz on the horizontal axis. The mid-low front vowel [ɛ] is located at approximately 592Hz and 1289Hz on the vertical and the horizontal axes respectively. The mid-low back vowel [ɔ] is located at almost the same point as its front counterpart on the vertical axis. [ɔ] is located at approximately 591Hz and 342Hz on the vertical and the horizontal axes respectively.

Table 4.5.2 presents the mean duration and the standard deviation values of the vowels of Tongu. The mid-central vowel [ə] uttered in 182ms is the shortest vowel produced by the Tongu speakers while the central-low vowel [a] uttered in 209ms is the longest vowel.

Table 4.5.2: Mean Duration and standard Deviation values for Tongu oral vowels

Vowel	Duration	Std.Dev
i	188	22
e	191	31
ɛ	193	26
ə	182	29
a	209	28
ɔ	198	26
o	201	37
u	191	32

The front vowels displayed the inverse correlation between vowel height and duration as reported in languages such as English (Lisker, 1974) whereby the lower the vowel, the longer its duration. The high front vowel [i] produced in 188ms is shorter than the mid-high front vowel [e] which is produced within 191ms. [e] is also shorter than [ɛ] which is produced within 193ms. Similar observation would have been made about the back vowels, but for the duration of the mid-high back vowel [o] which is 201ms long. [o] is, therefore, longer than [ɔ] which is 198ms long. The high back vowel [u] produced in 191ms is shorter than the other two back vowels.

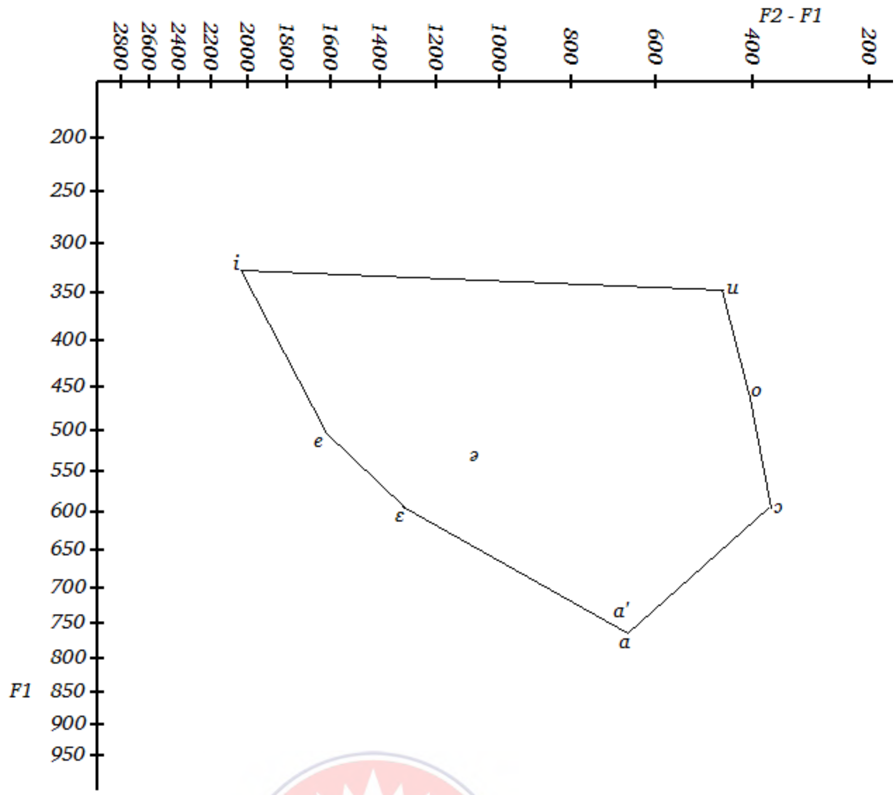


Figure 4.5.1: The Vowel Space of Tongu

The mean F1 and F2[1] values were used in plotting the Tongu vowels within the acoustic vowel space and presented in Figure 4.5.1. It is observable in the figure above that [i], [e] and [ɛ] are located in the front region of the vowel space while [u], [o] and [ɔ] are located at the back. The front high vowel [i] is the most front of the front vowels while the mid-low back [ɔ] is the most back vowel in the back region. The low vowel [a] is shifted prominently into the back region making the space between the high front vowel [i] and [a] much wider than the space between the high back vowel [u] and [a]. Despite this, the vowels are well dispersed for each of them to be auditorily distinct even in the back as predicted by the ADT. The central vowel [ə] is located in the mid-high central region slightly higher than the mid-low front vowel [ɛ]. The distribution of the point vowels [i], [u] and [a] follows the Quantal Theory's prediction as these vowels are located within the hot spot areas of the vowel space.

Finally, the [a] measured in the environment of [b] is located directly below the [a] measured in the environment of [k] within the vowel space. This notwithstanding, the two occurrences of [a] are conflated in term of backness as can be seen in the plot.

Table 4.5.3 Result of One-Way ANOVA comparing F1 and $F2^1$ mean values separately for the oral vowel pairs of Tongu

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
F1	Between Groups	4371504.726	8	546438.091	78.469	.001
	Within Groups	1295254.792	186	6963.735		
	Total	5666759.518	194			
F2'	Between Groups	63480913.478	8	7935114.185	396.530	.001
	Within Groups	3722115.394	186	20011.373		
	Total	67203028.872	194			

Table 4.5.3 shows the result of the One-Way ANOVA test on the vowels of Tongu to determine the significance of the within-group variations among the individual vowels. The results of the One-Way ANOVA test showed that statistically, there are significant differences among the vowels within the Tongu vowel space both in terms of vowel height ($p<.001$) and backness ($p<.001$). It was, however. not clear from the One-Way ANOVA test how significant are the variations between specific pairs of adjacent vowels. Thus, a Tukey HSD Post Hoc analysis was conducted to ascertain the significance of the differences between adjacent vowels within the vowel space and the results are presented in Table 4.5.4.

Table 4.5.4 Result of Tukey HSD Post Hoc Test comparing F1 and F2[1] mean values separately for adjacent oral vowels of Tongu

Vowel Comparisons	F1/Height		F2[1]/Backness	
	Mean Diff.	**Sig.**	**Mean Diff.**	**Sig.**
i – e	-177.125*	.001	374.500*	.001
e - ɛ	-91.054*	.005	319.255*	.001
e - ə	-16.417	.999	564.569*	.001
ɛ - ə	74.638	.323	245.314*	.001
ə - a	-243.571*	.001	397.079*	.001
a - ɔ	169.801*	.001	304.851*	.001
ɔ – o	148.896*	.001	-33.750	.998
o - u	108.917*	.001	-46.208	.968
a-k[a]	47.705	.499	-26.257	.999

Table 4.5.4 presents the results of the Post Hoc test performed on the comparable vowels of Tongu. All the three front vowels are significantly different in terms of both their height and their backness. The central vowel [ə] and the mid-high front vowel [e] are the same in terms of height with a "p" value of [p<.999] but they differ in the front/back dimension with a "p" value of [p<.001] indicating that in Tongu, [ə] is a mid-high central vowel. No variations exist among the back vowels in terms of backness. [u] and [o] are almost the same along the F2[1] dimension with a significance level of [p<.968] while [o] and [ɔ] are also very similar in terms of backness with a significant level of [p<.998].

The Tukey Post Hoc test results showed that the vowels are well dispersed throughout the vowel space. Also, the results showed that the effect of the prevocalic consonants on the formant frequencies of [a] measured from the two environments is not significant either in height (p<.499) and in backness (p<.999).

4.6 Presentation and Discussion of Kpando Vowels

The means and standard deviations of the F1 and F2' values and the durational values of the Kpando vowels are presented in this section. The oral vowels of Kpando analysed in this section are made up of three front vowels, one low vowel and three back vowels. Table 4.6.1 presents mean frequency and duration values, as well as the standard deviations of the vowels uttered by Kpando speakers. Since it has been established in the literature that the Kpando dialect does not have the schwa [ə] in its vowel inventory (Clement, 1974; Capo, 1985; Gbegble, 2006), [ə] is not included in the analysis for Kpando.

Table 4.6.1: F1 and F2' means and standard deviations of the formant frequency values of each oral vowel of Kpando

		KPANDO VOWELS							
Vowels		**i**	**e**	**ɛ**	**a**	**ɔ**	**o**	**u**	**a'**
F1	**Mean**	294	456	616	821	614	460	349	794
	Std.Dev	41	54	86	77	73	68	50	72
F2'	**Mean**	2040	1626	1388	629	311	333	340	634
	Std.Dev	266	134	177	128	84	58	74	94

While the low vowel [a] uttered in the environment of [b] is located at approximately 794Hz on the vertical axis and 634Hz on the horizontal axis, its counterpart uttered in the environment of [k] is located at approximately 794Hz and 634Hz on the vertical and the horizontal axes respectively. There are only marginal variations between the two forms of [a] in height and in backness.

The front high vowel [i] is located at approximately 294Hz and 2040Hz on the vertical and the horizontal axes respectively. The high back vowel [u] is located at approximately 349Hz on the vertical axis and 340Hz on the horizontal axis. The variation between the F1 values of the two high vowels indicated that the front high vowel is higher than its back counterpart. The mid-high front vowel [e] is located at approximately 456Hz and 1626Hz on the vertical and horizontal axes respectively. While [ɛ] is located at approximately 616Hz on the vertical axis and 1388Hz on the horizontal axis, its back counterpart [ɔ] is located at approximately 614Hz on the vertical axis and 311Hz on the horizontal axis. The two mid-low vowels [ɛ] and [ɔ] are very close in terms of their F1 values making them almost equal in height. The mid-high back vowel [o] is located at approximately 460Hz and 333Hz on the vertical and the horizontal axes respectively.

Table 4.6.2: Mean Duration and standard Deviation values for Kpando oral vowels

Vowel	Duration	Std.Dev
i	163	30
e	152	30
ɛ	176	41
a	196	79
ɔ	162	36
o	157	36
u	145	35

Table 4.6.2 displays the mean duration and standard deviation values for the Kpando vowels. The low vowel [a] uttered in 196ms is the longest vowel produced by the Kpando speakers. The front high vowel [i] which is 163ms is slightly longer than its back counterpart [u]. While the mid-high front vowel [e] is 152ms long, the mid-low front vowel [ɛ] is 176ms long. The mid-high back vowel [o] is 157ms and the mid-low back vowel [ɔ] is 162ms.

It is observable from Table 4.6.2 that as far as the back vowels are concerned, the higher the vowel, the shorter it is in duration. Thus, the high back vowel [u] is shorter than the mid-high back vowel [o] and the mid-high back vowel is, in turn, shorter than the mid-low back vowel [ɔ] and finally, [ɔ] is also shorter than the low vowel [a]. This correlation between the height of a vowel and its duration does not occur for the front vowels [i] and [e] but it occurs between [e] and [ɛ], as well as between [ɛ] and [a]. The high front vowel [i] is longer than the other two front vowels within the vowel space.

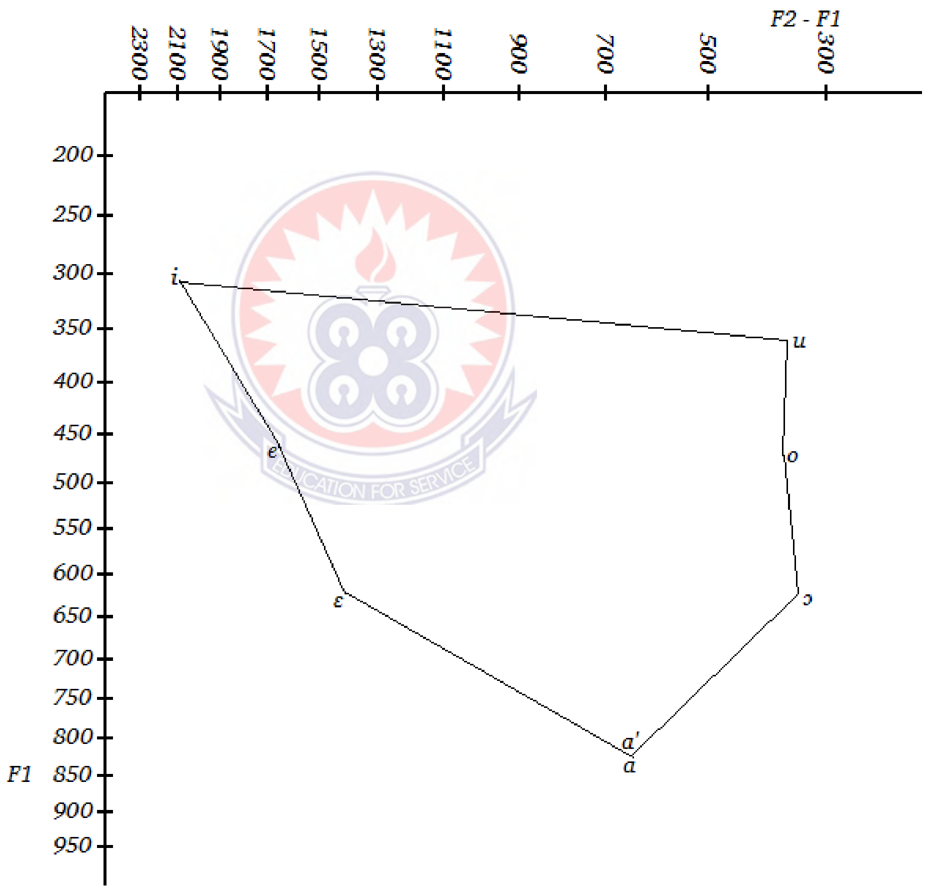


Figure 4.6.1: The Vowel Space of Kpando

Figure 4.6.1 shows the vowel space of the Kpando oral vowels. The difference between the F1 values of the front high vowel [i] and its back counterpart [u] is quite observable in their locations within the vowel space. [i] is located slightly higher than [u] in the vowel space. In the Kpando dialect, all the vowels are well dispersed in conformity with the ADT claim that each vowel repels all the other vowels adjacent to it in order for it to be distinct on the perceptual scale.

[i], [e] and [ɛ] are located within the front region of the vowel space while [u], [o] and [ɔ] are located at the back. The front high vowel [i] is the most front of the front vowels while the mid-low back vowel [ɔ] is the most back vowel. The low vowel [a] is located within the back low region of the space. In terms of frontness, [i] is more front than the mid-high front vowel [e] and [e] is also more front than the mid-low front vowel [ɛ]. The high back vowel [u] conflated with the mid-high back vowel [o] in terms of backness with the former being slightly more back than the later. The most back vowel [ɔ] is only slightly more back than [o]. Considering the fact that the low vowel [a] is located within the back region of the vowel space, it became the least back vowel. [a] in the Kpando dialect is therefore a low back unrounded vowel.

The distribution of the point vowels [i], [u] and [a] follows the Quantal Theory's prediction as these vowels are located within the hot spot areas of the vowel space.

Table 4.6.3 Result of One-Way ANOVA comparing F1 and F2[1] mean values for the oral vowel pairs of Kpando

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
F1	Between Groups	7242836.159	7	1034690.880	228.737	.001
	Within Groups	968026.080	214	4523.486		
	Total	8210862.239	221			
F2'	Between Groups	88166927.088	7	12595275.298	619.192	.001
	Within Groups	4353073.597	214	20341.465		
	Total	92520000.685	221			

Table 4.6.3 displays the result of the One-Way ANOVA test conducted on the vowels of Kpando to determine the significance of the within-group variations among the individual vowels. The results of the One-Way ANOVA test showed that the variations among the individual vowels within the Kpando vowel space are statistically significant both in terms of vowel height (p<.001) and backness (p<.001).

It was, however pertinent to ascertain which exact vowels are different from which vowels. To do this, a Tukey HSD Post Hoc analysis was conducted and the results are presented in Table 4.6.4.

Table 4.6.4 Result of Tukey HSD Post Hoc Test comparing F1 and F2¹ mean values separately for adjacent oral vowels of Kpando

Vowel Comparisons	F1/Height		F2¹/Backness	
	Mean Diff.	**Sig.**	**Mean Diff.**	**Sig.**
i – e	-157.368*	.001	406.264*	.001
e - ɛ	-160.690*	.001	238.379*	.001
ɛ - a	-204.448*	.001	758.862*	.001
a - ɔ	207.212*	.001	318.023*	.001
ɔ – o	153.202*	.001	-22.057	.999
o - u	111.774*	.001	-6.668	.999
a-k[a]	26.902	.809	-5.344	.999

To determine the significance of the variations or similarities between adjacent vowels within the acoustic vowel space of Kpando, a Tukey HSD Post Hoc multiple comparison test was conducted and the results presented in Table 4.6.4. All the three front vowels are significantly different in terms of both their height and backness with 'p' values of [p<.001]. This means that all the front vowels are distinct from one another in terms of height and frontness. However, all the back vowels are similar in terms of backness except [a]. [a] is significantly different from its adjacent counterpart vowel [ɔ] in terms of backness with a 'p' value of [p<.001]. The only variation among the back vowels is in terms of vowel height. The Post Hoc test showed that [u] and [o] are similar in backness with a 'p' value of [p<.999] and [o] is also similar to [ɔ] in terms of backness with a 'p' value of [p<.999]. The two realizations of [a] are very similar. There is therefore no effect of the place of articulation of the preceding consonants on the low vowel [a] as far as the Post Hoc test results are concerned.

4.7 Presentation and Discussion of Gen Vowels

The means and standard deviations of the F1 and F2' values and the durational values of the Gen vowels are presented in this section. The means of the F1 and F2' values were used to plot the vowels within the acoustic vowel space of the Gen dialect. The oral vowels of Gen were presented through tables and figures. Table 4.7.1 presents the means and standard deviations of the formant frequency values for each of the seven vowels uttered three times each by the speakers of Gen. Just as in the case of the Kpando dialect, the schwa has not been analysed for the Gen dialect. This is so because, it has been not in the literature that one of the remarkable differences between the Gen and Ewe is the fact that the Gen dialect does not have [ə] in its vowel inventory (Ameka, 1991).

Table 4.7.1: F1 and F2' means and standard deviations of the formant frequency values of each oral vowel of Gen

GEN VOWELS								
Vowels		**i**	**e**	**ɛ**	**a**	**ɔ**	**o**	**u**
F1	**Mean**	358	428	550	712	601	420	369
	Std.Dev	76	71	92	99	81	36	60
F2'	**Mean**	1978	1712	1478	802	379	370	338
	Std.Dev	254	288	199	287	87	67	106

The front high vowel [i] is located at approximately 358Hz on the vertical axis and 1978Hz on the horizontal axis while [u] is located at approximately 369Hz on the vertical axis and 338Hz on the horizontal axis. The F1 values for the two high vowels indicated that the back high vowel [u] is slightly lower than its front counterpart. The low vowel [a] is located at approximately 712Hz on the vertical axis and 802Hz on the horizontal axis. The F1 value for the [a] is very low. This indicated that [a] is located a little too high within the vowel space thereby shrinking the vowel space for the dialect. The mid-high vowel [e] is located at approximately 428Hz and 1712Hz on the vertical and the horizontal axes respectively. The mid-low front vowel [ɛ] is located at approximately 550Hz on the vertical axis and 1478Hz on the horizontal axis. This indicated that the mid-low front vowel is less front than the mid-high front vowel as can be observed from the F2' values of the two vowels. The mid-high back vowel [o] is located at approximately 420Hz and 370Hz on the vertical and horizontal axes respectively. Finally, the mid-low back vowel [ɔ] is located at approximately 601Hz on the vertical axis and 379Hz on the horizontal axis. There is some degree of conflation among the back vowels in terms of their backness as can be observed from their F2[I] values.

Table 4.7.2: Mean Duration and standard Deviation values for Gen oral vowels

Vowel	Duration	Std.Dev
i	219	58
e	217	52
ɛ	231	37
a	239	42
ɔ	236	45
o	259	55
u	230	43

Table 4.7.2 presents the duration values and standard deviation of the vowels of the Gen dialect. The mid-high vowel [e] is the shortest vowel produced in 217ms followed by the front high vowel [i] which is produced in approximately 219ms. The back counterpart of [e] which is the mid-high back vowel [o] uttered in 259ms is the longest vowel produced by the Gen speakers. The high back vowel [u] is produced in approximately 230ms. Generally, the front vowels of Gen tend to be shorter than their respective back counterparts. The high back vowel [u] is slightly shorter than the mid-high back vowel [o].

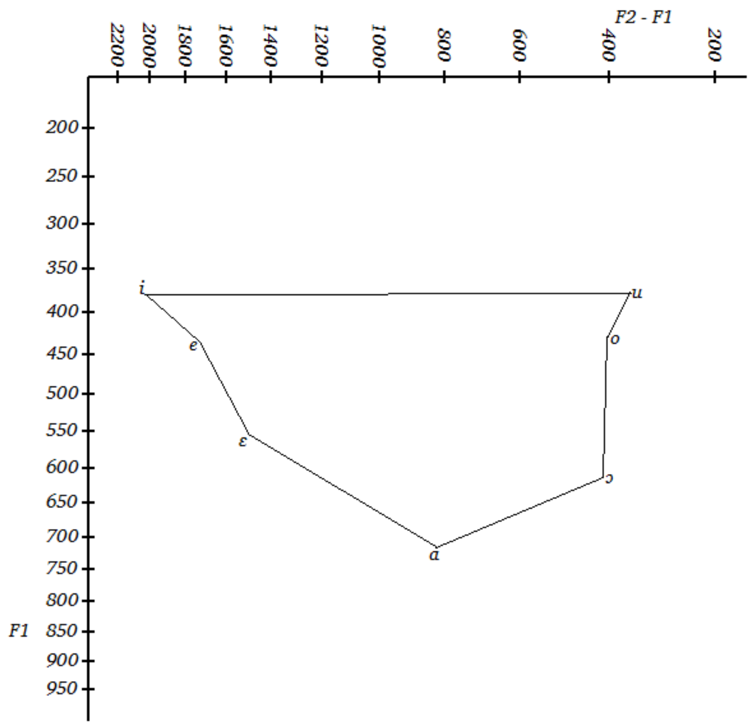


Figure 4.7.1: The Vowel Space of Gen

As shown in Figure 4.7.1, the Gen dialect has three front vowels, [i], [e] and [ɛ] and three back vowels, [u], [o] and [ɔ]. The front high vowel [i] is the most front of the front vowels while the high back vowel [u] is the most back vowel. The mid-high front vowel [e] is more front than the mid-low front vowel [ɛ]. [a] is located at the central low region of the space. The distribution of the Gen vowels is such that the high vowels and their mid-high counterparts are not spaced out. This suggests that there is some degree of conflation between the high vowels and the mid-high vowels in the Gen dialect making the entire vowel space a bit small.

Table 4.7.3 Result of One-Way ANOVA comparing F1 and F2' mean values for the oral vowel of Gen

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
F1	Between Groups	2911414.979	6	485235.830	85.655	.001
	Within Groups	1048022.099	185	5664.984		
	Total	3959437.078	191			
F2'	Between Groups	82530151.495	6	13755025.249	333.404	.001
	Within Groups	7632420.708	185	41256.328		
	Total	90162572.203	191			

Table 4.7.3 displays the result of the One-Way ANOVA test conducted on the vowels of Gen to determine the significance of the variations among the individual vowels within the acoustic vowel space of the dialect. The results of the One-Way ANOVA test showed that the variations among the individual vowels within the Gen vowel space are statistically significant both in terms of vowel height and backness ($p<.001$).

To ascertain which exact vowels are different from which vowels, a Tukey HSD Post Hoc multiple comparisons analysis was conducted and the results are presented in Table 4.7.4. Even though this analysis compared each vowel to all the other vowels within the vowel space of the dialect, only the results of adjacent vowels are presented in Table 4.7.4.

Table 4.7.4 Result of Tukey HSD Post Hoc Test comparing F1 and F2[1] mean values separately for adjacent oral vowels of Gen

Vowel Comparisons	F1/Height		F2[1]/Backness	
	Mean Diff.	Sig.	Mean Diff.	Sig.
i – e	-70.092*	.011	266.167*	.001
e - ɛ	-121.833*	.001	234.241*	.001
ɛ - a	-161.685*	.001	675.722*	.001
a - ɔ	111.173*	.001	422.861*	.001
ɔ – o	181.079*	.001	9.583	.999
o - u	51.081	.145	31.963	.997

The seemingly clustered distribution of the vowels in the high regions of the Gen vowel space was confirmed by the Tukey HSD Post Hoc result as can be seen in Table 4.7.4. In terms of vowel height, there is some degree of conflation between [i] and [e] with a 'p' value of [p<.011]. The similarity between the high back vowel [u] and the mid-high back vowel [o] is even closer with a level of significance of [p<.145] indicating a much higher degree of conflation between the two back vowels than their front counterparts. On the back/front dimension, the high back vowel [u] and mid-high back vowel [o] are very similar, with a 'p' value of [p<.997]. The Post Hoc results indicated that [u] and [o] are very similar in terms of both height and backness and therefore, are less distinct on the auditory scale.

4.8 Multiple Comparisons of all dialects

This section presents how the vowel spaces of the six individual dialects of Gbe compared to one another. Figure 4.8.1 shows the mean frequency values of the six individual dialects plotted separately within the same acoustic space in order to see how the vowel points of one dialect relate to the comparable vowel points of all the other dialects. For the sake of this multiple comparisons, each dialect is assigned special numbers ranging from one (1) to six (6) in the following order: Anlo (1), Avenor (2), Ho (3), Tongu (4), Kpando (5) and Gen (6). The vowels for each dialect are represented by both the symbol for the vowels and the corresponding number for the dialect. Therefore, "a4" on the plot is representing the low vowel [a] for the Tongu dialect while "a2" represents the low vowel [a] for the Avenor dialect. All the vowels of each dialect are connected by a line just as done in the case of the vowel spaces of the individual dialects presented in the earlier sections of this chapter.

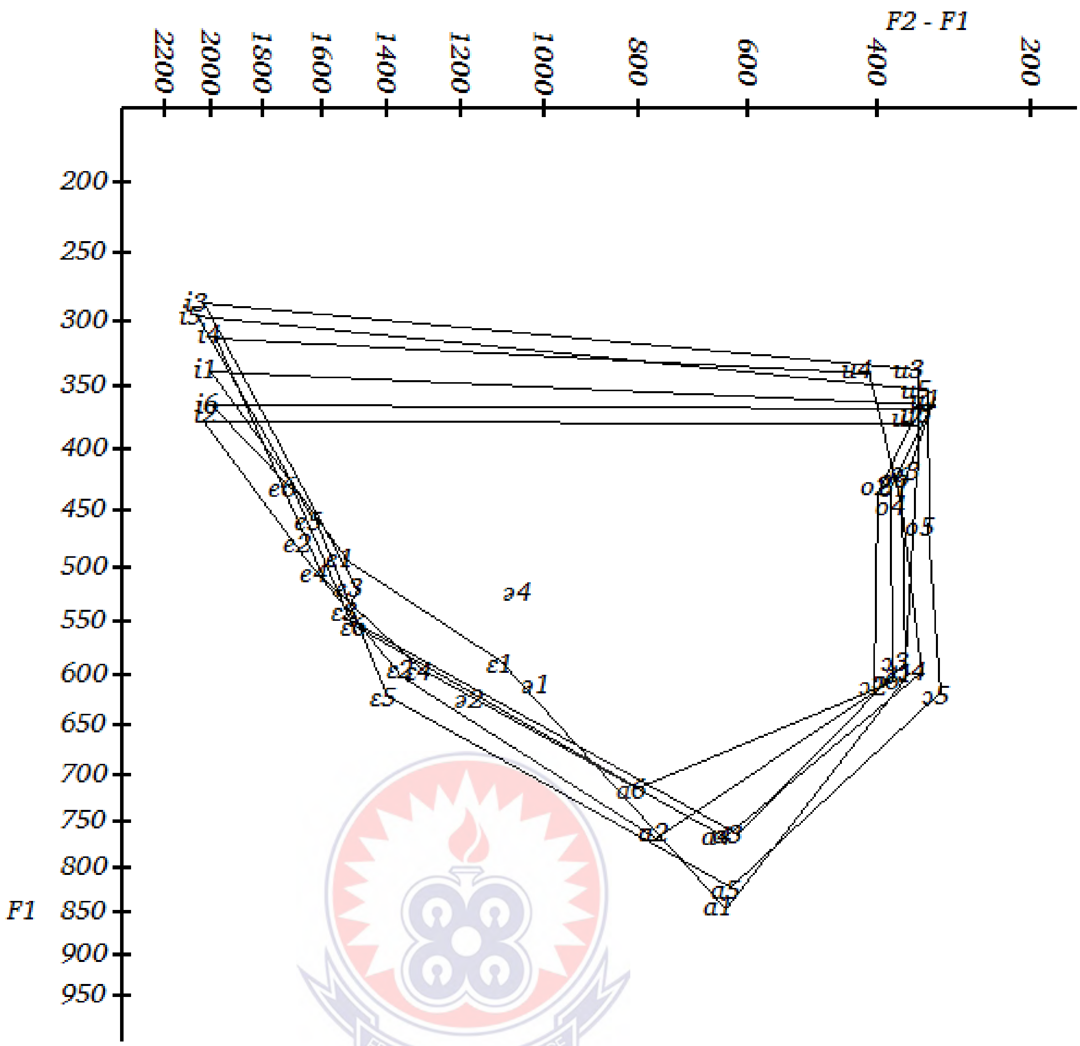


Figure 4.8.1: The Vowel Spaces of all the dialects

It is observable in figure 4.8.1 that Ho has the highest front high vowel [i] while Avenor dialect has the lowest front high vowel [i]. The front high vowels [i] of all the six dialects are located within an exclusive region above the mid-high vowel of all the six dialects such that there is no conflation between the two high front vowels ([i] and [e]) across dialects. However, there is some degree of conflation among the mid-high vowel [e] and the mid-low vowel [ɛ] across all the dialects such that even though all the mid-high vowels can be seen as located slightly above all the mid-low vowels, they seemed clustered within the mid-region of the acoustic vowel space.

In terms of the size of the vowel spaces of the individual dialects, Gen has the smallest vowel space among the six dialects under investigation. The high front vowel of Gen is located almost at the same point as the high front vowel of Avenor which is the lowest among all the six high front vowels. Gen dialect has the highest central low vowel [a] making the distance between the high front vowel [i] and the central low vowel [a] of Gen the shortest among the six dialects. Considering the fact that all the high back vowels are located very close to one another, it is observable that the distance between [a] and [u] of Gen is again the shortest among all the dialects. The vowel space of Kpando is the largest vowel space among the six dialects analysed. This means that the distribution of Kpando vowels is such that the vowels are more dispersed than the vowels of the other five dialects.

Table 4.8.1 Result of One-Way ANOVA comparing mean values of all dialects

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
i	Between Groups	163734.676	5	32746.935	9.686	.001
	Within Groups	524014.715	155	3380.740		
	Total	687749.391	160			
e	Between Groups	181263.165	5	36252.633	3.965	.002
	Within Groups	1444558.707	158	9142.777		
	Total	1625821.872	163			
ɛ	Between Groups	175353.579	5	35070.716	5.494	.001
	Within Groups	976637.490	153	6383.252		
	Total	1151991.069	158			
ə	Between Groups	67983.544	2	33991.772	13.498	.001
	Within Groups	135985.333	54	2518.247		
	Total	203968.877	56			
a	Between Groups	319632.255	5	63926.451	8.644	.001
	Within Groups	1138957.645	154	7395.829		
	Total	1458589.900	159			

ɔ	Between Groups	18903.525	5	3780.705	.704	.621
	Within Groups	795043.157	148	5371.913		
	Total	813946.682	153			
o	Between Groups	40751.517	5	8150.303	2.683	.023
	Within Groups	483043.186	159	3038.007		
	Total	523794.703	164			
u	Between Groups	34884.164	5	6976.833	3.166	.010
	Within Groups	299703.414	136	2203.702		
	Total	334587.577	141			

To determine whether or not there are variations among comparable vowels across the various dialects, a One-Way ANOVA test was performed to compare each dialect to all the other dialects in terms of the individual vowels. In these multiple comparisons, one vowel, (for example the front high vowel [i]) of each dialect is compared to similar vowels in all the other dialects. This investigation is necessary because according to Ladefoged (1993), vowels described as "high" across languages do not necessarily have the same height, and that the so-called "back" vowels vary considerably in their degree of backness. The analysis was carried out to test how significant the variation is among the different dialects relative to the individual vowels.

The results showed a significant difference of [p<.05] probability alpha level among all the dialects in relation to all the vowels except the mid-low back vowel [ɔ]. The results showed that there is no significant difference among all the dialects as far as the mid-low back vowel [ɔ] is concerned with a "p" value of [p<.621].

To ascertain which dialects are significantly different from each other in relation to each of the vowels of Gbe, a Post Hoc analysis was conducted using Tukey HSD test and the result is presented in Tables 4.8.2 - 7. The Post

Hoc test did not include the mid-low back vowel [ɔ] since the One-Way ANOVA test results already showed that there is no significant difference among the dialects in respect of this particular vowel.

Table 4.8.2 Result of Post Hoc test on the comparative difference among dialects relative to [i]

Independent Variables	(I) dialect	(J) dialect	Mean Diff. (I-J)	Sig.
[i]	Anlo	Avenor	-43.220	.087
		Ho	49.500*	.021
		Tongu	-.554	.999
		Kpando	31.250	.341
		Gen	-28.670	.430
	Avenor	Ho	92.720*	.001
		Tongu	42.667	.119
		Kpando	74.470*	.001
		Gen	14.550	.944
	Ho	Tongu	-50.054*	.028
		Kpando	-18.250	.848
		Gen	-78.170*	.001
	Tongu	Kpando	31.804	.366
		Gen	-28.116	.500
	Kpando	Gen	-59.920*	.002

The first vowel considered was the front high vowel [i]. This is one of the three vowels that the Quantal Theory (Stevens, 1989) considers as the hotspot vowels. Following the predictions of the Quantal theory, the location of [i] should not be different irrespective of the language since it is a hotspot vowel. It is argued that, if [i] is expected to be located at the same (hotspot) area irrespective of the inventory size of the vowel system, then across these six dialects, no significant variation was expected as far as the distribution of [i] is concerned.

It is observable from figure 4.8.1 that variations did exist among the various dialects as far as the front high vowel [i] is concerned but only in terms of vowel height. The Ho dialect has the highest front high vowel [i] followed by Kpando. As can be seen in the Figure 4.8.1, the Ho [i] and Kpando [i] are located very close to each other such that it is safe to conclude that the two vowels are very similar. This observable similarity between Ho and Kpando in relation to [i] was confirmed by the result of the multiple comparisons Tukey HSD Post Hoc Test. The level of significance of variance between Ho and Kpando concerning [i] is [$p < .848$] indicating that the [i] in these two dialects are very similar. The dialect with the third-highest front high vowel [i] is Tongu as can be seen in Figure 4.8.1. According to the results of the Tukey HSD Post Hoc Test, the variation between Ho and Tongu in respect of the front high vowel [i] is quite significant with a "p" value of [$p<.028$] indicating that the high front vowel in Tongu is slightly different from that of Ho on the auditory scale. Even though the high front vowel [i] of Tongu and Kpando are slightly different, the variation is not very significant with a 'p' value of [$p<.366$] indicating that while Tongu [i] differs from that of Ho [i], the Tongu [i] is similar to that of Kpando despite the strong similarity between Ho and Kpando in respect of [i]. The front high vowels of these three dialects formed a cluster at the top of the vowel space towering above all the other dialects.

The Ho dialect is, therefore, completely different from Gen, Avenor and Anlo as far as the front high vowel [i] is concerned as shown in Figure 4.8.1 and supported by the results of the multiple comparison Tukey HSD Post Hoc Test shown in Table 4.8.2. According to the results of the multiple comparisons, the level of significance between the [i] of Ho and Avenor is [p<.001], Ho and Gen is [p < .001] and finally, between Ho and Anlo is [p < .021]. The results also showed that the front high vowel [i] of Anlo is very similar to those of Avenor, Tongu, Kpando and Gen at the significant levels of [p<.087], [p<.999], [p<.341] and [p<.430] respectively. The Gen dialect is similar to Anlo, Avenor and Tongu but differs significantly from Ho and Kpando as far as the high front vowel [i] is concerned. The fact that there are statistically significant variations between some dialects of Gbe in relation to this quantal vowel is indicative of the fact that the distribution of the front high vowel across the various dialects is not consistent with the prediction of the Quantal Theory.

The second vowel considered is the low vowel [a]. This vowel is also a quantal vowel and by the predictions of the Quantal Theory, it is expected to be located within the hotspot region and therefore should not be significantly different across the six dialects. However, the One-Way ANOVA results presented in table 4.8.1 showed that differences did exist among the six dialects in relation to this vowel.

During the presentation of the vowels of the individual dialects, it was reported that while the low vowel [a] was located within the central region of the vowel spaces of Anlo, Avenor and Gen, it is located within the back region in the vowel spaces of Ho, Tongu and Kpando. It is, therefore, no wonder that the statistical analysis showed significant variations among the individual dialects in respect of the low vowel.

Table 4.8.3 Result of Tukey HSD Post Hoc test on the comparative difference among dialects relative to [a]

Independent Variables	(I) dialect	(J) dialect	Mean Diff. (I-J)	Sig.
[a]	Anlo	Avenor	26.510	.876
		Ho	79.733*	.006
		Tongu	78.229*	.021
		Kpando	18.639	.961
		Gen	127.615*	.001
	Avenor	Ho	53.223	.229
		Tongu	51.718	.351
		Kpando	-7.871	.999
		Gen	101.105*	.001
	Ho	Tongu	-1.505	.999
		Kpando	-61.094	.076
		Gen	47.881	.293
	Tongu	Kpando	-59.589	.156
		Gen	49.386	.362
	Kpando	Gen	108.976*	.001

Table 4.8.3 presents the results of the Tukey HSD Post Hoc multiple comparison tests to ascertain the degree of variations among the various dialects in respect of the low vowel [a]. The results showed that the following pairs of dialects, Anlo and Avenor, Anlo and Kpando, Avenor and Ho, as well as Avenor and Tongu, are very similar in terms of the low vowel [a]. Avenor and Kpando, Ho and Tongu, Ho and Kpando, Tongu and Kpando, as well as Tongu and Gen, are the other pairs of dialects that have very similar low vowel [a].

Statistically significant variations reported in the Tukey HSD Post Hoc multiple comparison tests result are found in the low central vowels of the following dialects. The Anlo and Ho [a] are significantly different as shown by the Post Hoc result. Anlo [a] is also significantly different from the Tongu, and Gen low central vowels. The result shows that Anlo low central [a] is completely different from the Gen [a] at a significant level of [p < .001]. As already indicated, the Avenor dialect is similar to all the other dialects except the Gen dialect. The Avenor [a] and Gen [a] are significantly different at the "p" value of [p < .001] as indicated by the results. The final two dialects that are significantly different from each other in terms of the low vowel [a] are Kpando and Gen. At the "p" value of [p < .000], the results showed that Kpando [a] had completely different quality from that of the Gen [a].

Table 4.8.4 Result of Tukey HSD Post Hoc test on the comparative difference among dialects relative to [u]

Independent Variables	(I) dialect	(J) dialect	Mean Diff. (I-J)	Sig.
[u]	Anlo	Avenor	-16.762	.850
		Ho	24.391	.506
		Tongu	23.375	.543
		Kpando	8.360	.990
		Gen	-11.519	.956
	Avenor	Ho	41.153*	.048
		Tongu	40.137	.054
		Kpando	25.122	.464
		Gen	5.243	.999
	Ho	Tongu	-1.016	.999
		Kpando	-16.031	.845
		Gen	-35.910	.083
	Tongu	Kpando	-15.015	.873
		Gen	-34.894	.093
	Kpando	Gen	-19.879	.648

The last quantal vowel considered in the Tukey HSD Post Hoc multiple comparison tests is the high back vowel [u]. Being a corner vowel just like the high front unrounded vowel [i] and the low vowel [a], it is predicted to be located in the relatively stable region of the acoustic space

(Stevens 1989). This means that no significant inter-dialect variability is expected for this vowel. According to the results of the Tukey HSD Post Hoc Test, only Ho and the Avenor dialects show some variation regarding the back high vowel with a "p" value of [p<.048]. Besides the variation indicated between Ho and Avenor, no other dialects showed any significant variation as indicated by the test result.

To a large extent, the high back rounded vowel [u] followed the predictions of the Quantal Theory. However, the high front vowel [i] and the low vowel [a] did not follow the prediction of the Quantal Theory since some dialects are significantly different from others in respect of these two vowels.

Table 4.8.5 Result of Tukey HSD Post Hoc test on the comparative difference among dialects relative to [e]

Independent Variables	(I) dialect	(J) dialect	Mean Diff. (I-J)	Sig.
[e]	Anlo	Avenor	-37.883	.698
		Ho	-27.567	.874
		Tongu	-14.550	.994
		Kpando	31.010	.814
		Gen	58.367	.200
	Avenor	Ho	10.317	.999
		Tongu	23.333	.958
		Kpando	68.894	.101
		Gen	96.250^{*}	.006
	Ho	Tongu	13.017	.996
		Kpando	58.577	.180
		Gen	85.933^{*}	.011
	Tongu	Kpando	45.560	.516
		Gen	72.917	.077
	Kpando	Gen	27.356	.893

Considering the mid-high front unrounded vowel [e], there are no significant variations among the individual dialects except between Avenor and Gen as well as between Ho and Gen. The strong similarities among the various dialects in terms of the mid-high front vowel [e] does not agree with the predictions of the Quantal Theory which expects more variability among dialects in terms of the intermediate vowels [e], [ɛ], [o], [ɔ] than the point vowels [i], [a], [u]. Contrary to this prediction, the mid-high front unrounded vowel seems to be similar across all the dialects. The mid-high front vowel of the Gen dialect is significantly different from those of Avenor and Ho. While the level of significant difference between Gen and Avenor is [p<.006], that of Gen and Ho is [p<.011].

The mid-high front vowel [e] is one of the two front intermediate vowels. In order to ascertain whether all the other intermediate vowels will show the same trend in their cross dialect distribution, the multiple comparison tests were conducted on all of the other intermediate vowels.

Table 4.8.6 presents the results of the Tukey HSD Post Hoc multiple comparison tests to ascertain the degree of variations among the various dialects in terms of the mid-low front unrounded vowel [ɛ]. The results show that there is no significant variation between the qualities of the mid-low front unrounded vowels of the following pairs of dialects: Anlo and Avenor, Anlo and Tongu, Anlo and Kpando, Anlo and Ho as well as Anlo and Gen.

Table 4.8.6 Result of Tukey HSD Post Hoc test on the comparative difference among dialects relative to [ɛ]

Independent Variables	(I) dialect	(J) dialect	Mean Diff. (I-J)	Sig.
[ɛ]	Anlo	Avenor	-44.592	.326
		Ho	48.453	.189
		Tongu	-8.438	.999
		Kpando	-32.513	.624
		Gen	33.700	.639
	Avenor	Ho	93.045*	.001
		Tongu	36.154	.632
		Kpando	12.079	.994
		Gen	78.292*	.011
	Ho	Tongu	-56.891	.116
		Kpando	-80.966*	.002
		Gen	-14.753	.985
	Tongu	Kpando	-24.075	.889
		Gen	42.138	.464
	Kpando	Gen	66.213*	.036

There is also no significant difference between the qualities of the mid-low front unrounded vowels of the Avenor and Tongu, Avenor and Kpando, Ho and Tongu, Ho and Gen, Tongu and Kpando as well as Tongu and Gen.

However, the results showed that there are some significant variations between the vowel qualities of the mid-low front unrounded vowel [ɛ] of the following pairs of dialects: Avenor and Ho, Avenor and Gen, Ho and Kpando as well as Kpando and Gen. The mid-low front unrounded vowel [ɛ] of Avenor and Ho are significantly different at the level of significance of [p<.001]. Also, the mid-low front vowel of Avenor is significantly different from that of Gen at the level of significance [p<.011]. The two central Ewe dialects in the study, Ho and Kpando, are significantly different in terms of their mid-low front unrounded vowel [ɛ] at the level of significance of [p<.002]. The final pair of dialects that also showed significant variation as far as the mid-low front unrounded vowel [ɛ] is concerned are Kpando and Gen at the significance level of [p<.036].

The level of variability among the individual dialects of Gbe in relation to the mid-low front vowel seemed to support the claim of the Quantal Theory that there will be more variability for the intermediate vowels than for the point vowels.

Table 4.8.7 Result of Tukey HSD Post Hoc test on the comparative difference among dialects relative to [o]

Independent Variables	(I) dialect	(J) dialect	Mean Diff. (I-J)	Sig.
[o]	Anlo	Avenor	-6.795	.998
		Ho	13.414	.939
		Tongu	-15.128	.919
		Kpando	-33.000	.208
		Gen	7.814	.994
	Avenor	Ho	20.208	.769
		Tongu	-8.333	.995
		Kpando	-26.205	.519
		Gen	14.608	.927
	Ho	Tongu	-28.542	.420
		Kpando	-46.414*	.020
		Gen	-5.600	.999
	Tongu	Kpando	-17.872	.848
		Gen	22.942	.652
	Kpando	Gen	40.814	.056

Table 4.8.7 presents the results of the Tukey HSD Post Hoc multiple comparison tests conducted to ascertain the degree of variations among the various dialects in terms of the mid-high back rounded vowel [o]. The results of the multiple comparisons of the mid-high back rounded vowel across all the six dialects showed that almost all the dialects are similar in terms of this particular vowel. The results indicated that only Ho and Kpando mid-high

back rounded vowels are significantly different from each other at a significant level of [p<.020].

Besides this pair, all other pairs of the six dialects show strong similarities among the dialects in terms of this particular vowel. Anlo and Avenor, Anlo and Ho, Anlo and Tongu, as well as Anlo and Gen, use almost the same mid-high back rounded vowel [o]. The similarities among the six dialects concerning the mid-high back rounded vowel disagreed with the claims made by the Quantal Theory of speech (Stevens, 1989) that there is less intra-category variability for the hotspot vowels than the intermediate vowels suggesting that the intermediate vowels are more likely to be different across dialects than the point vowels. However, the results are indicating the direct opposite of the Quantal Theory claims. It is therefore not surprising that the only vowel which is very similar across all the six dialects is [ɔ], mid-low back rounded vowel which is an intermediate vowel. In all, the back vowels are relatively more stable across the six dialects in that they are very similar across the various dialects than the non-back vowels. The front high vowel [i] is comparatively the most unstable vowel among the Ewe vowels. Almost every dialect produces a slightly different version of [i]. The back vowels are relatively more stable across the dialects of Gbe than their non-back counterparts.

4.9 Presentation and Discussion of Gbe Vowels

The means and standard deviations of the F1 and F2[1] values and the durational values of the vowels recorded from the speakers from the respective dialect communities of Gbe such as Anlo, Ho, Kpando, Avenor, Tongu and Gen are presented in this section.

Table 4.9.1: F1 and F2' means and standard deviations of the formant frequency values of each oral vowel of Gbe

GBE SPEAKERS									
Vowels		**i**	**e**	**ɛ**	**ə**	**a**	**ɔ**	**o**	**u**
F1	**Mean**	327	484	584	596	786	598	433	352
	Std.Dev	66	100	85	60	96	73	57	49
F2'	**Mean**	2000	1591	1324	1076	675	364	370	357
	Std.Dev	284	284	301	313	182	80	65	96

Table 4.9.1 shows the summary of the mean values of F1 and F2' and the standard deviations of the eight (8) oral vowels uttered by the speakers of Gbe. The three corner vowels [i], [u] and [a] are located in the front, at the back and the low region respectively as predicted by the QT. [i] is located in front at approximately 327Hz on the vertical axis and 2000Hz on the horizontal axis while [u] is located at the back at approximately 352Hz on the vertical axis and 357Hz on the horizontal axis. The high front vowel [i] is slightly higher than its back counterpart [u]. The last of the corner vowels, [a] is located at the low region at approximately 786Hz on the vertical axis and 675Hz on the horizontal axis.

The mid-high front vowel [e] is located at approximately 484Hz and 1591Hz on the vertical and the horizontal axes respectively. The high front vowel [i] is much more front than the mid-high front vowel [e]. The mid-low front vowel [ɛ] is located at approximately 584Hz on the vertical axis and 1324Hz on the horizontal axis. This made the mid-low front vowel the least front vowel among the Gbe front vowels. On the part of the back intermediate vowels, [o] is located at approximately 433Hz and 370Hz on the vertical and the horizontal axes respectively while the mid-low back vowel [ɔ] is located at approximately 598Hz on the vertical axis and 364Hz on the horizontal axis. The high back vowel [u] is the most back vowel while the mid-high back vowel [o] is the least back vowel as indicated by the F2[1] values of the back vowels.

Table 4.9.2: Mean Duration and standard Deviation values for Gbe oral vowels

Vowel	Duration	Std.Dev
i	199	50
e	194	47
ɛ	203	46
ə	200	41
a	216	53
ɔ	207	49
o	216	134
u	193	50

Table 4.9.2 presents the means of the vowel duration values and the standard deviations of the individual oral vowels of Gbe. The back high vowel [u] is the shortest vowel produced in approximately 193ms followed by the front mid-high vowel [e] which is produced in approximately 194ms. The central low vowel [a] uttered in approximately 216ms is the longest vowel. The variations in the duration of the Gbe vowels did not support the claim that there is a strong inverse correlation between vowel height and vowel duration as reported in other languages such as English (Lisker, 1974).

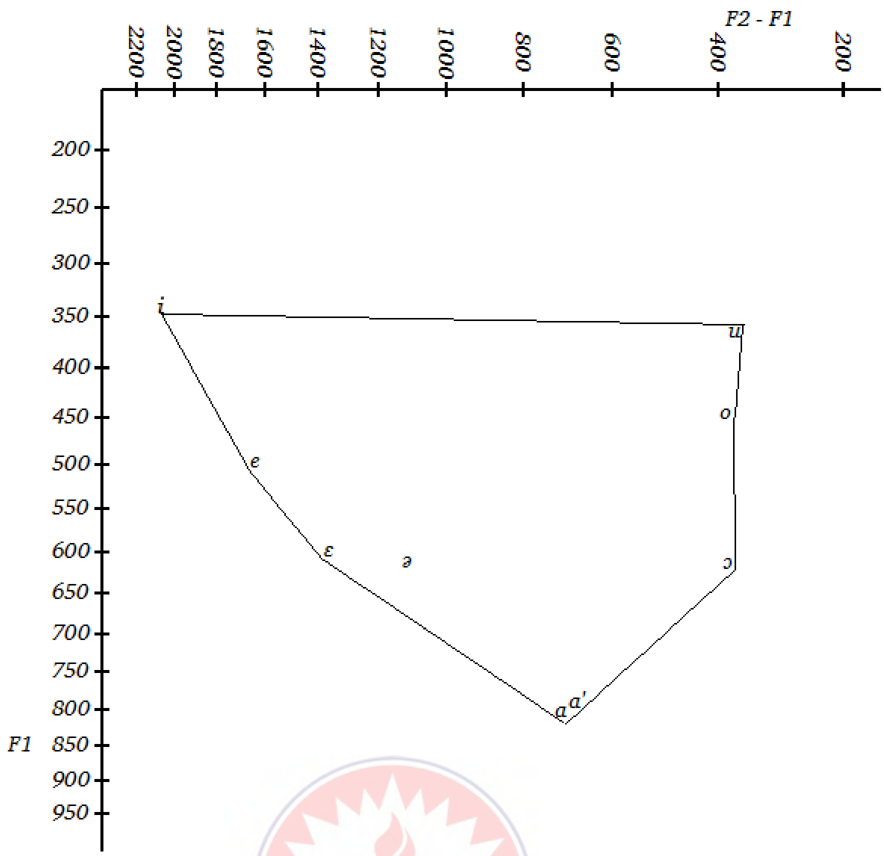


Figure 4.9.1: The Vowel Space of Gbe

Figure 4.9.1 shows the mean locations of the oral vowels uttered by the speakers of the Gbe speaking communities involved in the study. The data shows that there are three front vowels, three back vowels and one central vowel just as was evident in the individual dialects. The vowel [a] is located at the central low zone of the vowel space. The vowel [ə] is a mid-low central vowel located within the central mid-low zone very close to the front mid-low vowel [ɛ] but slightly lower.

The front high vowel [i] is the most front of all the front vowels. The mid-high front vowel [e] is less front and much lower than the front high vowel [i] making the two vowels distinct from each other within the front high zone. The least front vowel is the mid-low front vowel [ɛ] located very close to the central zone of the vowel space. The three back vowels look very similar in terms of backness with the mid-low back vowel [ɔ] being the most back among them.

In terms of vowel spacing between adjacent vowel points, the front vowels are slightly more spaced than the back vowels. This notwithstanding, all the vowels are very much spaced as predicted by the adaptive dispersion theory. The Gbe language being a seven vowel inventory language is expected to have its vowels well-spaced within the acoustic vowel space. The final vowel of interest is [ə]. It is slightly lower and less front than the mid-low front vowel [ɛ]. The location of [ə] confirmed the suggestion by Capo (1985) that the dialects that use this vowel do not use the mid-low front vowel and vice versa.

A One-Way ANOVA test was conducted on the vowels of Gbe in order to ascertain the significance of the similarity or differences between adjacent vowels within the acoustic vowel space of the language. The results of the One-Way ANOVA are presented in Table 4.9.3 below.

Table 4.9.3 Result of One-Way ANOVA comparing F1 and F2[1] mean values separately for the oral vowel pairs of Gbe

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
F1	Between Groups	32749928.785	8	4093741.098	675.034	.001
	Within Groups	7792881.549	1285	6064.499		
	Total	40542810.335	1293			
F2	Between Groups	406546706.121	8	50818338.265	1063.442	.001
	Within Groups	61405870.095	1285	47786.669		
	Total	467952576.216	1293			

The results showed that each vowel is significantly different from all the others around it (p<.001). Thus, to ascertain which exact vowels are different from which vowels, a Tukey HSD Post Hoc multiple comparisons analysis was conducted and the results are presented in Table 4.9.4. Even though in this analysis, each vowel was compared to all the other vowels within the vowel space of the dialect, only the results of adjacent vowels are presented in Table 4.9.4.

Besides the three back vowels [ɔ], [o] and [u] which are similar in terms of backness, no two vowels are similar either in height or in backness. In terms of height, every vowel is distinctly positioned such that all the vowels are significantly different from one another.

Table 4.9.4 Result of Tukey HSD Post Hoc Test comparing F1 and F2¹ mean values separately for adjacent oral vowels of Gbe

Vowel Comparisons	F1/Height		F2¹/Backness	
	Mean Diff.	**Sig.**	**Mean Diff.**	**Sig.**
i – e	-157.106*	.001	251.523*	.001
e - ɛ	-99.501*	.001	167.950*	.001
e - ə	111.870*	.001	-402.940*	.001
ɛ - ə	-12.369	.983	234.990*	001
ə - a	-189.332*	.001	211.531*	.001
ɛ - a	-201.701*	.001	446.522*	.001
a - ɔ	187.570*	.001	499.009*	.001
ɔ – o	165.330*	.001	159.449*	.001
o - u	80.238*	.001	93.622*	.006
a-k[a]	8.730	.990	19.387	.998

The location of the [ə] in the Gbe vowel space, as well as its location in the vowel spaces of the various dialects, makes its existence in the language a very curious case. There was the need to know if the schwa is different or similar to any other vowels within the vowel space.

Table 4.9.4 shows the result of the Post Hoc test comparing [ə] to the two closest vowels around it within the vowel space ([e] and [ɛ]). The results showed that [ə] is significantly different from the front mid-high vowel [e] in both the height [p<.001] and backness [p<.001] dimensions. [ə] is located at approximately the same height as the front mid-low vowel [ɛ] making it clear that in the Gbe language, [ə] is a mid-low vowel. However, in terms of backness, the results show that [ə] is significantly different from [ɛ] even though it is located very close to [ɛ] as can be seen in Figure 4.9.1. The variation between the [ɛ] and [ə] in the backness dimension places [ə] in the central region of the vowel space which appeared to be consistent with the earlier description of [ə] as a central vowel. It, therefore, looks like [a] and [ə] are both central vowels whereas [a] is located at the back end of the central region of the vowel space, [ə] is located at the front end of the central region. This location of the central low vowel [a] agrees with the finding of Gbegble 2006 which described [a] as a central low but more to the back than in the central position.

4.10 Phonetic Environment Effect on the Durational Properties of the Gbe Vowels

This study, among other things, sought to investigate and establish the inherent durations of the individual vowels of Gbe. Table 4.10.1 recaps the durational values of the individual vowels. The claim that there is a strong correlation between vowel height which is indicated here by the first formant frequency value (F1) on one hand and the inherent durations of vowels such that the higher the vowel, the shorter its inherent duration does hold for the front vowels of Gbe to some extent as shown in table 4.10.1. The front high unrounded vowel [i] which is 198ms long is marginally longer than the front mid-high unrounded vowel [e] which is produced around 194ms. However, apart from this unexpected length of the front high unrounded vowel, all other front vowels seem to demonstrate the predicted correlation between vowel height and duration such that [e] is shorter than [ɛ], and the [ɛ] is also shorter than the central low unrounded vowel [a]. Since it has been suggested in the literature that vowel durations are pre-specified in the phonological system of every language, we measured the individual vowels in different phonetic environments in order to identify the duration variations of the vowels (if any) resulting from the variations in the environments in which each of the vowels occurs in the language.

Table 4.10.1: Duration values of each oral vowel of Gbe

Vowel	Duration (ms)	F1 (Hz)
i	198	327
e	193	484
ɛ	202	584
ə	199	596
a	216	786
ɔ	206	598
o	216	433
u	193	352

It is very pertinent to find out how phonetic environments influence the duration of the individual vowels. To investigate the environmental effect on the duration of the vowels, each of the vowels was measured from contrasting phonetic environments.

The Gbe vowels vary from one another in terms of distribution in the language. While the following non-back vowels [e], [ɛ], [ə] and [a] occur at word-initial positions in the various dialects of Gbe, all the back vowels [ɔ], [o], [u] as well as the front high unrounded vowel [i] do not. All these vowels occur in medial and final positions of words in the language.

In addition to these distributional preferences for the vowels, further phonotactic limitations apply to the co-occurrence of certain vowels and certain consonant sounds. For example, while only the rounded vowels [ɔ], [o] and [u] occur after the labial-velar approximant [w], only the unrounded vowels [e], [ɛ], [ə] and [a] occur after the velar approximant [ɰ] (Ansre, 1961; Duthie, 1996; Kpodo, 2014).

The co-occurrence of the round vowels and the labial-velar approximant is because these vowels share the same labial (Rounding) feature with the labial-velar approximant. While [w] is produced with protruded lips, the vowels are produced with rounded lips making it easy to produce both the approximant and the following vowel with a single shape of the lip. To avoid a change in the shape of the lips from the approximant to the vowels, once the needed vowel is unrounded, the preceding approximant [w] changes to a velar approximant [ɰ] that is produced with spread lips. The fact that the labial-velar approximant [w] and the velar approximant [ɰ] are allophones of the same phoneme in Gbe has been stated by Ansre (1961) and Duthie (1996) without necessarily showing which of them is the actual phoneme.

Kpodo (2014) demonstrates that the labial-velar approximant is the phoneme while the velar approximant [ɰ] is the allophone. This is so because the distribution of [w] is wider than the distribution of [ɰ] in the language. These phonotactic constraints ride on the back of the rounding feature of the vowels as indicated earlier. The rounding feature of vowels is captured in the acoustic signal of the vowels represented by the second formant frequency (F2). The fact that it has been established through the acoustic analysis that there is no unrounded vowel at the back region of the vowel space of Gbe, we conclude that at all times one of these two features [±Round] and [±Back] is redundant in the phonological system of the language. This, therefore, means that by specifying one of the two features for any vowel, the other is specified albeit indirectly.

Another feature which is also very functional in the phonological system of Gbe is the height feature. There have been several investigations involving vowel height in the language. While some researchers termed it same height condition, others referred to it as vowel height agreement processes. This process ensures that certain vowels within certain phonetic environments must agree with each other in terms of height. Kpodo (2017) suggests that the underlying form of the 3rd Person Pronominal object enclitic is not the same for the Coastal dialects and the Inland dialects of Ewe. It was explained that the variation between the two dialect blocks is in terms of height. While for the Coastal dialects, the vowel is /i/, in the Inland dialects, it is /e/. What is intriguing about the phenomenon is the "fact that while the agreement process is triggered by the enclitic vowel in the Coastal dialects, it is triggered by the final vowel in the Inland dialects" (Kpodo 2017, p.214). The raising of the low central unrounded vowel /a/ to /e/ in the Coastal dialects can now be explained more clearly since the acoustic analysis shows that Anlo does not have the mid-low unrounded front vowel /ɛ/ in its inventory. Rather, Anlo has the schwa vowel /ə/ which is used in place of the mid-low front unrounded vowel /ɛ/. The earlier analysis by Kpodo (2017) that the final vowel of the verb gets deleted is not entirely correct.

To investigate the effect of the various phonetic environments, we measured the duration of each vowel in the following environments: closed syllable versus open syllables, after voiced versus voiceless obstruents and within high tone versus low tone syllables. Just as we have seen already, it is not possible to have every single vowel occurring in all these environments. However, for this investigation, it was enough to have each vowel in two phonetically contrastive environments to find out if the difference between the two environments will result in a corresponding change in the durational properties of the vowel.

Ewe is principally an open syllable language with the following syllable types:

- V (Vowel only syllable)
- CV (Consonant and vowel)
- CCV (two consonants and vowel)
- V (Nasal consonant only)
- CVC (Consonant, vowel and nasal consonant as a coda)

In these syllable types, the V-element is the nucleus which is usually a vowel and the tone-bearing unit. The "nasal consonant only syllable" is constituted by tone-bearing nasal consonants which are also [+syllabic]. Usually but not exclusively, whenever a nasal consonant occurs before an oral consonant, the two consonants do not belong to the same syllable due to the consonant cluster restriction rule in the Gbe language. In such cases, the nasal consonant constitutes a syllable by itself while the oral consonant constitutes the onset of the following syllable. Gbe is predominantly an open syllable language. This notwithstanding, there are few instances of close syllables in the language. The CVC syllable is a close syllable in which the coda slot is exclusively occupied by a nasal consonant: either the bilabial nasal /m/ or the velar nasal /ŋ/. Kpodo, (2014) states that closed syllables in Ewe usually occur in idiophones or loanwords.

4.10.1 *Effect of syllable type on vowel duration*

As indicated earlier, even though Ewe is mainly an open syllable language, there are few instances of closed syllables in the language. The various vowels were placed in open versus closed syllables in order to investigate the effect of the syllable type on the duration of the vowel. In order to eliminate any influence of tone in the duration of the various vowels, all the vowels were measured from high tone environments. These stimuli were not placed in carrier frames. Rather, the pairs of words were given to the participants to read as single words for the recording. Each participant read each word three times for the recording.

Table 4.10.1.1 The vowels in closed versus open syllables

Closed	Duration	Open	Duration
[táŋ]	114	[tá]	131
[tíŋ]	146	[tí]	194
[tóŋ]	107	[tó]	135
[túŋ]	142	[tú]	233

Table 4.10.1.1 displays the duration values of each vowel in the two contrastive environments. In a closed syllable, [a] is approximately 114ms long but in an open syllable, it is 131ms long. This shows that [a] in a closed syllable is shorter than the [a] in an open syllable by about 17ms. The high front vowel [i] is approximately 146ms long in the closed syllable but about 194ms long in an open syllable. The variation between the [i] in the closed syllable and the [i] in the open syllable is about 48ms. The back high vowel [u] is approximately 142ms in the closed syllable 233ms in the open syllable. Finally, the mid-high back vowel [o] is approximately 107ms in the closed

syllable but 135 in the open syllable. This indicated that [u] and [o] are shorter by about 91ms and about 28ms respectively in closed syllables than in open syllables.

It is observable from the table that in the Gbe language, vowels are consistently shorter when they occur in closed syllables. This finding corroborates the claim made by Ladefoged and Johnson (2011) that vowels are longer in open syllables than in closed syllables in American English. There is, therefore, a systematic variation between the duration of vowels in closed syllable and open environments. This notwithstanding, it is important to note that, the margin of the variations in the duration of vowels in closed syllables vis-à-vis their counterparts in open syllables is not the same for all the vowels. In the case of [a], the variation is about 17ms while in the case of [i] and [u], the variations are about 48ms and 91ms respectively. It is observed that the reduction in duration for high vowels is more pronounced than the reduction in the duration of the low vowel. Therefore, the variations for the two high vowels [i] and [u] are significant enough and are, therefore, perceivable by the native speakers. The perceivable reduction in the duration of these vowels in closed syllables may have been responsible for Ansre's (1961) claim that the high front unrounded vowel [i] and the back high rounded vowel [u] have allophones which occur in closed syllables in the form of the high front unrounded lax vowel [ɪ] and the back high rounded lax vowel [ʊ] respectively. This is due to the fact that the lax vowels are perceptually shorter than their tense vowel counterparts (Halle & Clements, 1983; Kpodo, 2015).

4.10.2 *Effect of syllable onset type on vowel duration*

It has been established in the literature that the voicing type of consonants affects vowel duration in some languages such as English (Peterson & Lehiste, 1960; Chen, 1970; Crystal & House, 1988; Laefur, 1992; van Santen, 1992). Generally, this is described as a consonant voicing effect. In English particularly, it is the voicing type of coda consonants that affects the duration of vowels (de Lacy, 1988). Since the Ewe language is predominantly an open syllable language and has already been established in the previous section that the nasal coda of the few instances of closed syllables in Gbe triggers a reduction in the duration of the vowel in the syllable, there was the need to determine whether or not the onset consonants also influence the duration of vowels in any way.

Table 4.10.2 The vowels preceded by voiced versus voiceless obstruents

Voiced	Duration	Voiceless	Duration
[dì]	124	[tì]	134
[dè]	104	[tè]	121
[dà]	110	[tà]	119
[dò]	131	[tò]	149
[dù]	120	[tù]	127

Table 4.10.2 shows the Gbe vowels [i], [e], [a], [o] and [u] in the environment of voiced versus voiceless consonants. All the words were produced with a low tone in order to eliminate the tonal effect on the vowels. In the environment of the voiced alveolar plosive, the high front vowel [i] was approximately 124ms but in the environment of the voiceless plosive, it was 134ms long. In the environment of the voiceless consonant, the high front vowel is longer by about 10ms. The mid-high front vowel [e] was 104ms in

the environment of the voiced consonant but in the environment of the voiceless consonant, it was 121ms long. While the high back vowel [u] was 120ms in the environment of the voiced consonant, it is 127ms in the environment of the voiceless consonant. Finally, the mid-high back vowel was 131ms in the environment of the voiced consonant and 149ms in the environment of the voiceless consonant. It is clear from the Table that in Gbe, vowels are slightly longer when they are preceded by voiceless consonants than when they are preceded by voiced consonants. This finding is the opposite of what has been reported for consonant voicing effect in English. In English, vowels are longer when they precede voiced consonants than when they precede voiceless consonants (Ladefoged & Johnson, 2011). It is, however, important to note that the environment of the vowel segment in terms of the consonant voicing effect in English is different from the Gbe environment. While it is the postvocalic consonant that affects the vowel duration in English, it is rather the prevocalic consonant that affects the vowel duration in the Gbe language.

4.10.3 *Effect of word type on vowel duration*

Word structure has been identified in the literature as influencing the duration of vowels. In English for example, Ladefoged and Johnson (2011) state that vowels tend to be longer in monosyllabic words than in disyllabic and polysyllabic words. Gbe vowels occur in monosyllabic words as much as they occur in disyllabic and polysyllabic words. It worth noting that one remarkable difference between English and Gbe is the fact that English is a stress language while Gbe is a tone language. Variations in the stress patterns of monosyllabic words versus polysyllabic words in English may be responsible for the variation in the durational properties of vowels in these environments such that while vowels in monosyllabic words are usually stressed and for that matter have longer duration, the same vowels in polysyllabic words may not be stressed and may thus be produced shorter. This major difference between Gbe and English notwithstanding, it is therefore important to find out if the number of syllables in a word also influence the duration of vowels in the language and how. To do this, the vowels were measured from environments of both monosyllabic and disyllabic words with all other environmental conditions held constant. The target vowels were placed in monosyllabic words and disyllabic words preceded by the voiceless alveolar plosive [t]. In each pair, the same tone was used in order to avoid the effect of tone variation on the vowels.

Table 4.10.3: Duration of each vowel in monosyllabic and disyllabic environments

Monosyllabic	Duration	Disyllabic	Duration
t.	197	tāku	178
tō	216	tōkpo	183
tí	194	tíke	127
tú	233	túkpe	211
tɔ̀	228	tɔ̀ka	160
tè	229	tèka	177

Table 4.10.4 shows the comparisons of the duration of each vowel in monosyllabic and disyllabic environments. In disyllabic words, all the vowels were placed before voiceless back plosives. The same tone type was maintained for comparable vowels in the pair of words. This was done to

eliminate the tonal effects on the vowels. The results show that in a monosyllabic environment, [a] was 197ms long while in a disyllabic environment, it was 178ms long. The low vowel [a] was longer in a monosyllabic environment than when it was in the disyllabic environment by 19ms. The mid-high back vowel [o] was approximately 216ms long in the monosyllabic environment but 183ms in the disyllabic environment. The front high vowel [i] was 194ms long in the monosyllabic environment but 127ms in the disyllabic environment. The duration of the high back vowel [u] followed the same pattern. In the monosyllabic environment, [u] was 233ms long but in the disyllabic environment, it was 211ms long. The mid-high front vowel [e] and the mid-low back vowel [ɔ] were also longer in the monosyllabic environment than in the disyllabic environment. These results are consistent with the general claim that all things being equal, vowels are longer in monosyllabic words than in disyllabic words (Ladefoged & Johnson, 2011). This shows that the duration of Gbe vowels is influenced by the number of syllables in the word. This may be due to the variation in the positions of the vowels in the words. In monosyllabic words, the vowels occur as final segments while in polysyllabic words, the vowels occur at medial positions and are thus followed by other segments. This environmental variation may be responsible for the variation in the duration of the vowels in monosyllabic versus polysyllabic words.

4.10.4 *Effect of level tones on vowel duration*

Again, the various vowels were measured from syllables with two contrasting tones: the high tone and the low tones. It is important to find out whether the durational properties of vowels are affected by the tone they bear in Gbe. The interaction between tones and tone bearing units have been the point of interest for many researchers (Manyah, 2006; Zee, 1978). It has been suggested in the literature that just like segmental units such as vowels and consonants, tones as articulatory events also have their inherent durational properties (Yuan, 2012). Yuan further indicated that over the same pitch range, it takes a longer time to make a rising tone than a falling tone because maximum speed for pitch change is slower for pitch rises than pitch falls. This means that rising tones are more likely to be longer than falling tones but there is no indication as to whether or not there is no effect from the tone bearing unit on the duration of the tone. As already seen in this section, contour tone bearing vowels are longer than level tone bearing ones. This is because contour tones are inherently longer than level tones and for that matter, the contour tone bearing vowels are produced longer to last the duration of the tone. It is, therefore, hypothesized here that the durational properties of vowels are affected by the tone on the syllable. To investigate the effect of level tones on the duration of the Gbe vowels, each of the vowels was placed in a high tone syllable and also in a low tone syllable for the participants to read for the recording. The vowels in high tone and low tone syllables rendered the following monosyllabic words:

Gbe	**English gloss**
[tí]	Hardened
[tì]	Fed up
[té]	Press
[tè]	Swell
[tá]	Draw
[tà]	Dress
[tɔ́]	Stop
[tɔ̀]	Respond to a call
[tó]	Ear

[tò]	Simmer
[tú]	Shut
[tù]	Grind

The results of the measurements were presented in table 4.10.4.

Table 4.10.4: Effect of level tones on vowel duration

Test words	HT	LT
ti	158	134
te	141	121
ta	131	119
tɔ	145	128
to	149	135
tu	131	127

The first column shows the test words exemplifying the vowels under investigation while the second and third columns show the duration of each vowel produced in high tone and low tone syllables respectively. The first row in the table shows the duration of the front high vowel bearing a high tone versus a low tone. This shows that while the duration of [i] in the word [tí] is approximately 158ms long, the duration of [i] in [tì] is approximately 134ms long. Thus, the high tone bearing [i] is longer than the low tone bearing [i] by about 24ms. The mid-high front vowel [e] was 141ms and 121ms in the environments of high tone and low tone environments respectively. This shows a variation of about 20ms between the high-tone bearing [e] and the low-tone bearing [e]. In a high-tone environment, the low vowel [a] was 131ms but in the low-tone environment, it was 119ms. The three back vowels [ɔ], [o] and [u] are all longer in their respective high-tone syllables than in the low-tone syllables. These results show that in Gbe, all things being equal, vowels are longer when they are bearing high-tone than when they are bearing low-tone.

4.11 Syllable weight and rhyme duration in Gbe

The Gbe language contrasts vowel duration typically in two instances. The first of these two instances is in the occurrence of level tones versus contour tones. As we have seen in section 4.10, level tone bearing units are produced short while the contour tone bearing units are produced longer. The second instance of durational contrast in Gbe is in the final vowels of some adjectives and their adverb counterparts. The data in (4.11a) exemplifies the durational contrast in the final vowels of adjectives and their adverbs in Gbe.

Data 4.11a	Adjectives	Adverbs
	[liti]	[liti:]
	[legbe]	[legbe:]
	[lakpa]	[lakpa:]
	[lɔtɔ]	[lɔtɔ:]
	[loto]	[loto:]
	[kutu]	[kutu:]

In these pairs of words, the final vowels of the adjectives are all short while their adverb counterparts are all long.

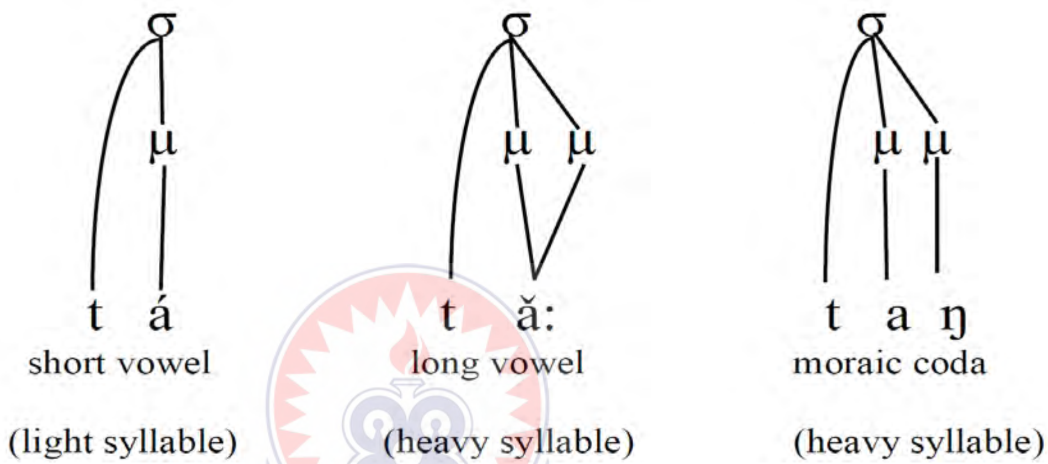
Finally, the third instance of durational contrast in Gbe occurs on verbs, especially in the inland dialects of Ewe. The progressive marker in Gbe is the suffix /-m/. For example: /ko/ meaning “to laugh” versus /kom/ meaning “laughing. Among the inland speakers of the Ewe dialect of Gbe, the progressive marker is normally deleted and when this happens, the final vowel of the verb undergoes a compensatory lengthening. Thus, instead of /kom/, the inland Ewe speaker will say /koo/.

It is important to state that even though these vowels are not phonemically long, they are produced longer in these instances and are, therefore, phonetically long. The occurrence of the phonetically short versus long vowel dichotomy in the Gbe language, therefore, necessitates a different approach to the analysis of Gbe syllable structure. Using the traditional open versus closed syllables classification, the Gbe language is described as predominantly an open syllable language with very few instances of closed syllables.

According to Gussenhoven and Jacobs (2005) and Katamba (1993), contemporary analysis of the syllable focus more on the weight of the syllable rather than the traditional classification of open versus closed syllables. Syllable weight as a phonological concept refers to the contrast between monomoraic and bimoraic syllables. Monomoraic syllables are said to be light syllables while bimoraic syllables are said to be heavy syllables. Ladefoged (1982) says a mora is a unit of timing usually assigned to prosodically active segments in the syllable. Mora as a unit of timing is equivalent to a short vowel. In the mora structure, only segments in the syllable rhymes are assigned mora but onset segments are never assigned mora. Whenever the rhyme of the syllable has a short vowel, it is assigned one mora but when the rhyme has either a long vowel or a diphthong, it is assigned two morae and therefore, said to be bimoraic. Closed syllables, especially with sonorant codas are often assigned two morae. It has been established in the literature that syllable weight tends to influence certain phonological processes in languages across the world.

The focus of this section is to determine the durational contrast between light syllables and heavy syllables in the Gbe language by measuring the rhymes of the syllables. It is hypothesized that the rhyme of a heavy syllable should be two times longer than the rhyme of a light syllable in Gbe drawing from the available literature (Duanmu, 1994). The data in 4.11b presents the three-syllable types in Gbe.

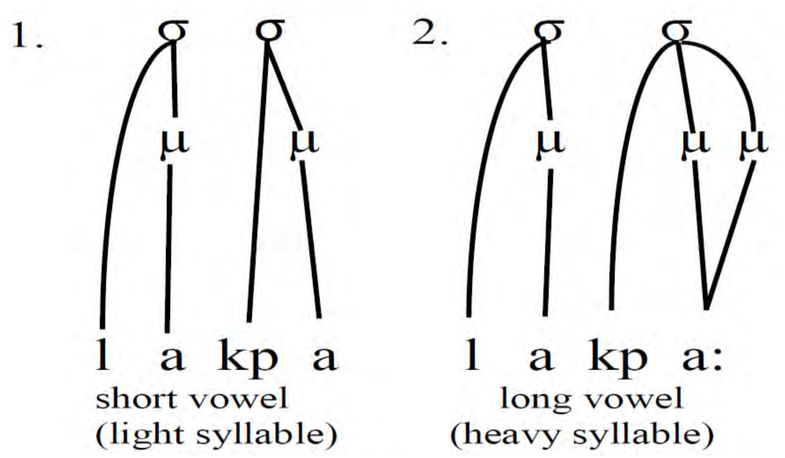
Data 4.11b



The second instance of short versus long vowels mentioned earlier is also supposed to yield light and heavy syllable contrast as shown in data 4.11c.

Data 4.11c-1 has two syllables both of which are light. The focus is on the final syllables of the words in this data. The word in (1) is an adjective that has a short vowel at the final position while the word in (2) is an adverb that has a long vowel at the final position. In this case, the various between these two words is in the duration of the final vowel as shown earlier in data (4.11.a).

Data 4.11c:



In this section, the rhyme duration variation between the light syllables and the heavy syllables in Gbe was investigated by measuring the duration of the rhymes of the light syllables and the heavy syllables to establish the extent of the variation between the rhyme of the heavy syllable and that of the light syllable. Also, the duration of these two types of syllables was be compared to each other to see if the variations between them are significant such that the duration of the rhyme of the heavy syllable will be twice the duration of the rhyme of the light syllable. Table 4.11.1 shows the duration figures of the rhymes of the various syllables.

Table 4.11.1: Duration of syllable rhymes in Gbe

CV	Duration	CVV	Duration	CVN	Duration
tika	103	tika:	227	taŋtaŋ	212
bete	104	bete:	241	keŋ	246
kutu	138	kutu:	216	koŋ	246
loto	142	Loto:	246	tiŋ	252
liti	150	liti:	263	tuŋ	245
kɔtɔ	148	kɔtɔ:	265	kɔŋkɔ	236

Table 4.11.1 shows the duration of the rhymes of the three different syllable types in Gbe. The first syllable type is the CV syllable type, which is designated as a light syllable according to the mora theory. The rhyme duration of the various examples of the light syllables measured fall between 103ms and 150ms long. The shortest of the light syllable rhymes is about 103ms while the longest of the light syllable rhymes is around 150ms. The hypothesis that the rhymes of heavy syllables should be two times longer than that of light syllables has been supported by the result in Table 4.11.1. The duration of the rhymes of heavy syllables are systematically longer than the rhymes of the light syllables measured. The duration of the CVV syllables falls between 216ms and 265ms long while the duration of CVN syllables falls between 212ms and 252ms long. On the average, the rhyme of the heavy syllable is longer than the rhyme of light syllables by approximately 110ms. This result shows that approximately, the the rhyme of the heavy syllable is almost two times longer than the rhyme of the light syllable. This finding is not peculiar to the Gbe language.

What is intriguing about the result is the fact that the duration of all heavy syllables are similar regardless of the rhyme structure: whether the rhyme is constituted by VV or VN. It is hereby proposed that due to the need for the perceptual similarity between the duration of the rhymes of heavy syllables, the nucleus of the CVN syllables tend to be reduced in duration to make room for the sonorant coda within the available prosodic space. This explains the earlier finding that vowels in closed syllables are systematically shorter than the vowels in open syllables, since all closed syllables in the Gbe language have sonorant codas.

4.12 Summary

In this chapter, we have discussed the results of the study. The formant frequency values and the duration values of the vowels of the individual dialects of Gbe have been presented in this chapter. Comparisons were made among the dialects in respect of the various vowels. In comparing the vowel spaces of the six dialects, it was found out that the Gen dialect occupied a smaller space than all the other dialects.

The vowel space of the Gbe language was also presented in this chapter using the mean frequency values of the vowels across all six dialects as vowel points. It was found out that the low vowel [a] is a central vowel rather than a back vowel. This notwithstanding, it was discovered that [a] was located within the back region of the Ho and Kpando dialects of Gbe. This, therefore explained the variation in the description of [a] in the literature by earlier scholars.

Finally, the chapter discussed how various phonetic environments such as syllable type, syllable structure, number of syllables in a word, as well as tones, affect vowel duration in the language. It has been established that all things being equal;

i. vowels will be produced shorter in closed syllables than in open syllables.
ii. vowels will be produced longer in monosyllabic words than in disyllabic words.
iii. a vowel will be longer when it is bearing a high-tone than when it is bearing a low-tone.
iv. rhymes in heavy syllables will be produced longer than rhymes in light syllables.

CHAPTER FIVE

DISCUSSION OF FINDINGS, SUMMARY AND RECOMMENDATION

5.0 Introduction

How the study answered each of the research questions is presented in this chapter by addressing the research questions one after the other. The chapter further presents a summary of the whole report. Finally, the chapter is concluded with recommendations for future studies that will ultimately fill the knowledge gaps exposed in the literature of Gbe due to the delimitations of the current study.

The ultimate focus of the study is to establish the phonetic identity of each of the vowels of Gbe. The study sought to do this by determining the underlying phonetic parameters that characterize the vowel system of the Gbe language in order to resolve the controversy among scholars regarding the phonetic identity of some of the vowels of Gbe. The study specifically used the vowels of two of the five major dialects of the Gbe language. Since this is the first time any single study on the language touched on more than one major dialect, the study also sought to compare the vowel spaces of the two dialects in order to state their similarities and or differences.

The study was guided by the following research questions which have been answered in this section of the report:

1. What are the phonetic identities of the individual vowel sounds of Gbe?
2. How different are the vowel spaces of the two dialects of Gbe (Gen and Ewe) from each other?
3. What are the durational properties of the individual vowels of Gbe?

4. How does phonetic environment affect vowel duration in Gbe?
5. What systematic patterns exist in the durational variations of the vowels across the dialects?
6. To what extent does the configuration of the Gbe vowel space confirm the claims made by the QT or the ADT or both?

In the next six sections of this report, answers to each of the research questions are provided as concisely as possible. These answers have been gleaned from the discussions of the results in chapter four.

5.1 How Different are the Vowel Spaces of the two dialects of Gbe (Ewe and Gen) from each other?

To answer this research question, the vowel spaces of the Ewe and Gen dialects were compared. The mean values of the first formant were plotted against the difference between F1 and F2 for the two dialects. The vowels were coded by placing the figure 1 before all the Ewe vowel symbols and the figure 2 before all the Gen vowel symbols such that the high front vowel of Ewe appeared on the plot as [1i] and that of Gen appeared as [2i] and so on. The vowel spaces of the two dialects of Gbe are presented in the figure 5.1.1.

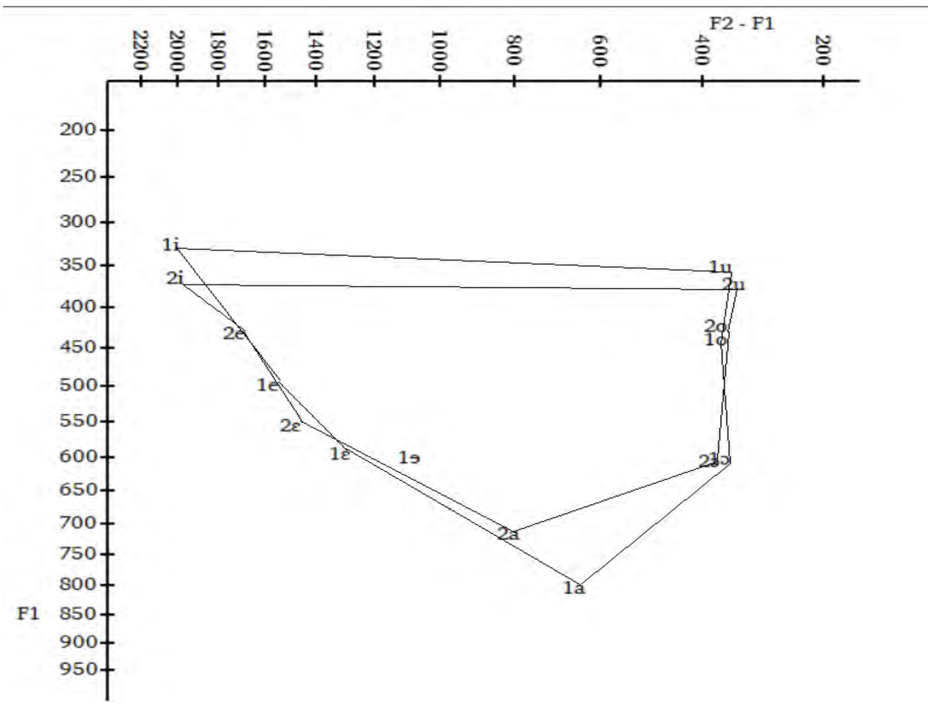


Figure 5.2.1: Vowel spaces of Ewe and Gen

It is observable from the figure that the vowel space of Ewe is wider than the vowel space of Gen. The front and the back high vowels of Ewe are higher than their Gen counterparts. In terms of the central low unrounded vowel, the Ewe [a] is much lower than that of Gen. The locations of these three corner vowels in the two vowel spaces made the Gen vowel space much smaller than the Ewe vowel space.

The distribution of the intermediate vowels in the front region of the vowel space seems to support the predictions of the Quantal Theory of speech that there is more variability between comparable intermediate vowels than for the quantal vowels. The mid-high front vowel [e] and the mid-low front vowel [ɛ] for the Gen dialect are located higher than their Ewe counterparts.

The location of the intermediate vowels in the back region of the two vowel spaces however, does not follow the same pattern. The mid-high back vowel [o] and the mid-low back vowel [ɔ] of the two dialects clustered respectively in the mid-high back and the mid-low back regions. The configuration of the vowels in the two dialects shows that the comparable back vowels of the two dialects are respectively similar to each other than the front vowels and the central vowel. The findings of this study show that it will be more difficult to distinguish between Ewe speakers from Gen speakers in terms of their production of the back vowels than in their production of the non-back vowels.

This notwithstanding, the study concludes that there is a significant difference between the acoustic vowel spaces of the Ewe dialect and the Gen dialect.

5.2 What are the Phonetic Identities of Gbe Vowels?

In all, there are eight oral vowels in the vowel inventory of the Gbe language. The results of the current study confirm the claim in the literature that no single dialect of Gbe uses all the oral vowels. There is no dispute about the location of the front vowels as well as the back vowels. However, the main controversy surrounding the phonetic description of the vowels of Gbe has to do with the low vowel [a]. The findings of the current study established that [a] is a central low unrounded vowel. It is therefore important to state that since there is no unrounded vowel located at the back region of the vowel space, and that all back vowels are rounded and all non-back vowels are unrounded in the Gbe language, it is not necessary to specify both backness and rounding for the Gbe vowels. Thus, once one of the two features is specified, the other is implied.

It is, however, necessary to state that the current study found out that in the Tongu, Ho and Kpando dialects [a] was located within the back region of the vowel space. Therefore, for these three dialects, [a] may be rightly classified as a back vowel. It is believed that the earlier researchers who described [a] as [+Back] (Smith, 1968; Clement, 1974) may have collected their data exclusively from either one or all of these dialects areas for their studies.

As can be seen in figure 4.9.1, the Gbe language has three front vowels. These vowels are the front high vowel [i], the front mid-high vowel [e] and the front mid-low vowel [ɛ]. In terms of the back vowels, Gbe has a high back vowel [u], a mid-high back vowel [o] and mid-low back vowel [ɔ]. The schwa [ə] is found to be a mid-low central vowel.

The Gbe vowel space shows four different levels of vowel height. It is, therefore, necessary to distinguish between the two mid vowels in the front region and the back regions of the vowel space since these vowels are not only phonetically different but are also phonologically contrastive in the language. It is, therefore, crucial to specify these vowels as mid-high vowels ([e], [o]) and mid-low vowels ([ɛ], [ɔ]) respectively and not just mid vowels.

5.3 What are the Durational Properties of the Individual Vowels of Gbe?

All the vowels of Gbe are inherently short ranging from 193ms to 216ms. Each of the vowels of Gbe is different from the others in terms of duration. However, the durational variation pattern of the vowels does not support the claim in the literature that there is a strong correlation between vowel height and duration such that the lower the vowel, the longer its duration and vice versa. While the back vowels seem to follow this prediction, the front vowels do not.

Finally, the so called allophonic variants of the two high vowels, [i] and [u] mentioned in the literature (Ansre, 1961) turned out to be an evidence of reduction of the duration of these two vowels in closed syllables. The following are the durational properties of the individual vowels of Gbe. The front high vowel [i] is approximately 198ms, and the high back vowel [u] is approximately 193ms. The two mid-high vowels [e] and [o] are approximately 193ms and 216ms respectively. While the front mid-low vowel [ɛ] is approximately 202ms, its back counterpart [ɔ] is 206ms approximately. The mid-low central vowel [ə] is approximately 199ms and the central low vowel [a] is approximately 216ms.

5.4 How does Phonetic Environment Affect Vowel Duration in Gbe?

The study found out that the environments in which each of the vowels occurs systematically affect the duration of the vowels. The findings of the investigation show that, all things being equal, the duration of vowel is reduced in closed syllables.

The study also found out that the voicing feature of consonants also systematically affect the durational properties of vowels in Gbe. Vowels tend to be longer whenever they are preceded by voiceless consonants than when they are preceded by voiced consonants.

Additionally, the duration of vowels is affected by tone in Gbe. The study found out that vowels are produced longer in high tone syllables than in low tone syllables. It was, therefore, concluded that tones systematically affect the duration of vowels in the Gbe language.

Also relating to tones, contour tone bearing vowels are significantly longer than level tone bearing vowels. The extent of the variations between the duration of the contour tone bearing vowels and the level tone bearing vowels support the claim in the literature that level tones occur in syllables with short vowels while contour tones occur in syllables with long vowels (Duanmu, 1994). It was concluded that contour tones trigger vowel lengthening process in Gbe.

Vowel duration is also affected by the number of syllables in a word. All things being equal, a vowel in monosyllabic words will be longer than in a disyllabic word in Gbe.

The rhyme duration of light syllables and that of heavy syllables were measured to establish the variations between the rhyme duration of heavy syllables vis-à-vis that of light syllables. The result of the investigation into syllable weight and rhyme duration is presented in figure 5.4.1. There are two basic types of syllables in Gbe: light and heavy syllables. Light syllables are made up of open syllables that have short vowels as nuclei. Short vowels are assigned single mora in the literature. The light syllables are therefore monomoraic in structure.

The heavy syllables are made of either branching rhymes or long vowels. The long vowels are assigned double morae. In the Gbe language, contour tone bearing vowels are long and are therefore assigned two morae. The word-final vowels of certain adverbs are also lengthened and are therefore assigned two morae. Closed syllables are often described as syllables with branching rhymes (Katamba 1993). The only closed syllables in Gbe are the CVN syllables. In the literature, rhymes that are made up of short vowels and sonorant codas are assigned two morae. In terms of syllable weight, every monomoraic syllable is considered light while every bimoraic syllable is considered heavy. In this investigation, we sought to find out if the rhyme duration of heavy syllables will be twice as long as that of light syllables due to the mora count ratio of 2:1.

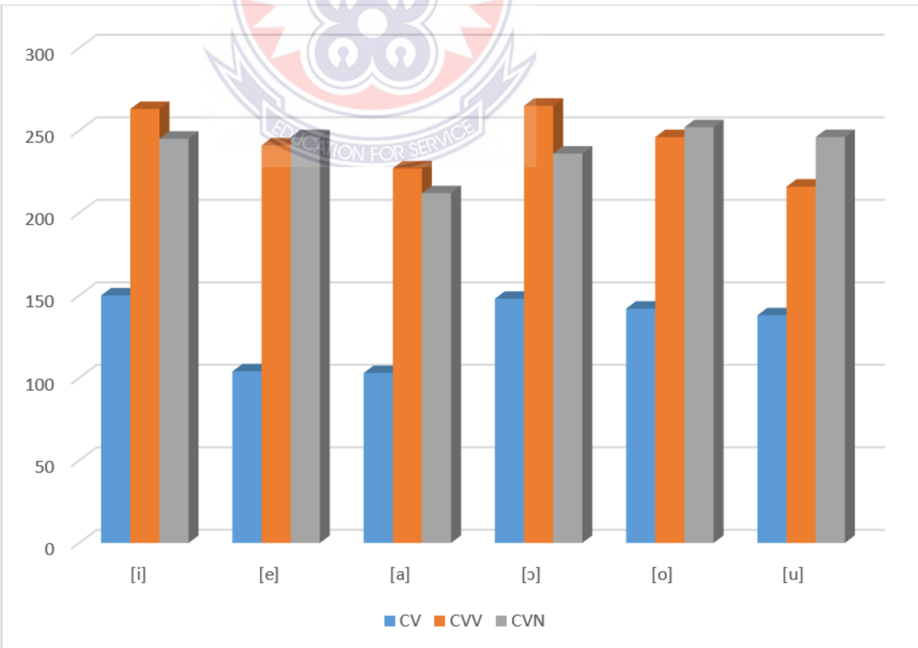


Figure 5.4.1: Duration of light versus heavy syllables

By measuring the rhymes of the three types of syllables in Gbe: CV, CVV and CVC, we found out that the rhymes of heavy (bimoraic) syllables constituted by long vowels or short vowels with sonorant codas are distinctly longer than the rhymes of light (monomoraic) syllables constituted by short vowels only. It is also worthy of note that the rhymes of heavy syllables be it CVV or CVC are similar in length. Even though heavy syllables are assigned two morae while light syllables are assigned one, the rhymes of heavy syllables are not twice as long as those of the light syllables.

5.5 What Systematic Patterns exist in the Durational Variations of the Vowels Across the Dialects?

The investigation into the difference between the two major dialects of Gbe in terms of vowel duration has been carried out by comparing the duration of comparable vowels of the two dialects. The data comparing the duration of the comparable vowels are presented in figure 5.5.1. The duration values of the individual vowels were presented in the form of colored bars for easy observation.

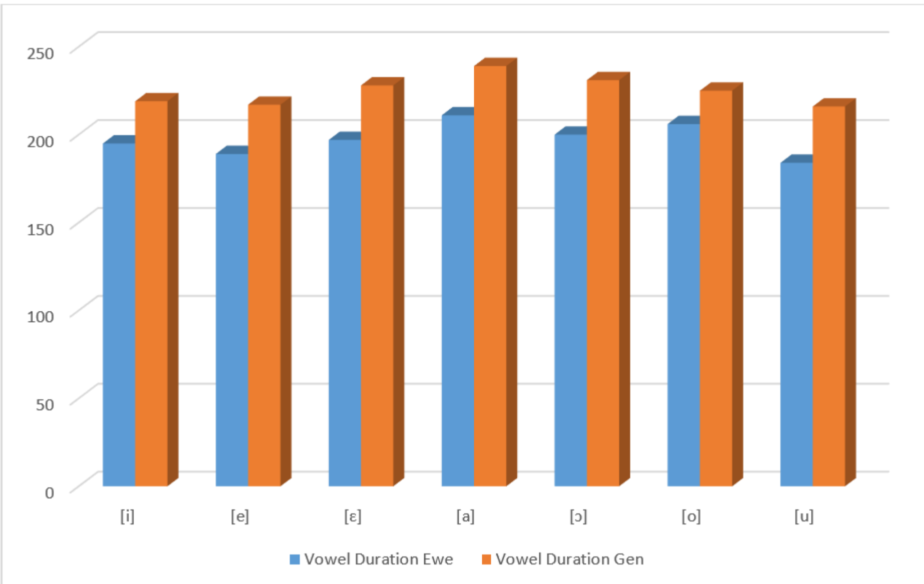


Figure 5.5.1: Comparison of Ewe and Gen vowel duration

The blue bars represent the vowel duration of Ewe and the brown bars represent the vowel duration of Gen. As shown in the figure above, all the vowels of the Gen dialect tend to be longer than their comparable counterparts of the Ewe dialect. The mean durational values of the vowels of the two dialects are presented in table 5.5.1.

Table 5.5.1: Vowel duration of Ewe and Gen

	Vowel Duration	
Vowels	**Ewe**	**Gen**
[i]	195	219
[e]	189	217
[ɛ]	197	228
[a]	211	239
[ɔ]	200	231
[o]	206	225
[u]	184	216

In both dialects, the central low vowel [a] is the longest of all the vowels. Consistent with the duration of the Gbe vowels, the front high vowel [i] is slightly longer than the mid-high front vowel [e] in the two dialects. Again, the back vowels tend to display the predicted correlation between vowel height and duration. The back high vowel [u] is the shortest among the back vowels in both dialects followed by the mid-high back vowel. The mid-low back vowel is the longest back vowel.

5.6 To what extent does the configuration of the Gbe vowel space confirm the claims made by the QT or the ADT?

The configuration of the Gbe vowel space partly confirms both the claims made by the Quantal Theory and the Adaptive Dispersion Theory. The locations of the vowels within the Gbe vowel space systematically follows the prediction of the Quantal Theory whereby the three quantal vowels are located at the three corners of the vowel space. The multiple plots of the vowels of the individual dialects also show that the quantal vowels are all located in their respective hotspot zones as predicted by the QT.

On the part of the distribution of the individual vowels within the Gbe vowel space, the study found out that all the vowels are dispersed following the adaptive perceptual principle put forward by the Adaptive Dispersion Theory. However, the claim that there is greater variability for the intermediate vowels than the point vowels does not hold at least for the back vowels of the various dialects. Contrary to expected likelihood that the intermediate vowels will show more variability than the point vowel, all comparable back intermediate vowels of the various dialects of Gbe show strong similarities. The comparable front intermediate vowels across the various dialects are more variable than the hotspot vowels, just as the QT predicted.

5. 7 Summary of the Study

This study defines the acoustic vowel space of Gbe through spectrographic analysis of the oral vowels of Gbe. The study investigated the acoustic properties of the eight oral vowels of Gbe spoken in Ghana, Togo and Benin. Even though the language has five distinct dialects, the study focused on only two: Ewe spoken in the Volta Region of Ghana and Gen spoken in the south-eastern part of the republic of Togo. Data was collected from Agoe, Be and Anexɔ in Togo for the Gen dialect while the Ewe data was collected from Tsiame, Ho-Dome, Fesi, Avenɔpeme and Adidome for the Anlo, Ho, Kpando, Avenɔ and Tɔŋu subdialects respectively. In all, 128 native speakers who have lived all their lives in their respective dialect communities have been sampled for the study. The data was collected through the recording of target words exemplifying the eight oral vowels of Gbe uttered by the participants. The recordings were acquired into a computer and analysed by a speech analysis software known as Kay Elemetric Computerized Speech Lab (CSL-4500) at a sampling rate of 11025Hz.

The result of the study concludes that the Ewe and Gen dialects of Gbe are observably different from each other in terms of their front vowels. However, there is no significant difference between the two dialects regarding their back vowels.

The between-group analysis of variance conducted to find out how different or similar the comparable vowels are across the various subdialects revealed that there is significant variation between Anlo and Avenor on one hand and Ho, Kpando and Gen on another, regarding the front high vowel [i] and the central low vowel [a]. Besides these two quantal vowels, the rest of the vowels do not show any significant variabilities across the dialects. The configurations of the individual vowel spaces of the various dialects do not consistently follow the predictions of the quantal theory. Even though all the corner vowels are located in the three extreme points of the vowel spaces, there are significant variabilities among the dialects in respect of [i] and [a]. Due to this, these two vowels did not cluster in the hotspot areas as predicted by the Quantal Theory.

The Gbe vowels are adaptively dispersed within the acoustic space following the prediction of the ADT. Gbe has three front vowels namely the high front vowel [i], the mid-high front vowel [e] and the mid-low front vowel [ɛ]. Gbe also has three back vowels namely the high back vowel [u], the mid-high back vowel [o] and the mid-low back vowel [ɔ]. The study established that [a] is a central low vowel. The study further established that all the back vowels of Gbe are round while all the non-back vowels of Gbe are unrounded. The study, therefore, concluded that the feature rounding and backness are redundant in Gbe, hence, unless very crucial, there is no need to specify the two features for any single vowel.

In terms of vowel height, there are four separate levels of height and therefore the height feature, as well as the backness feature, must be multivalued as suggested by Lindau (1978).

All the Gbe vowels are inherently short. However, depending on the environment in which the vowel occurs, it may be produced longer or shorter. Whenever a vowel occurs in a closed syllable, it is produced shorter than its inherent duration. It is these perceivable reduced forms of the vowels in closed syllables that Ansre (1961) described as [-ATR] allophonic variants of the [i] and [u] in Ewe. The study also concludes that factors such as voicing type of preceding consonant, tone, as well as the number of syllables in a word systematically affect the durational properties of the vowels of Gbe. Finally, the study found out that the rhymes of heavy syllables are longer than light syllables. However, even though short vowels are assigned one mora and longer vowels two, the long vowels are not twice as long as the short vowels.

5.8 Recommendations for Further Studies

It is recommended that future studies should focus on the investigation of the nasal vowels of Gbe. The place of nasal vowels in the literature of Gbe was discussed in some detail in the literature. There seemed to be two different positions on the phonetic status of nasal vowels in Gbe. One of these two positions states that vowels are inherently oral and that the presence of a nasal feature in a vowel should be considered as a product of some assimilation process. Stahlke (1971) suggested that the difference between oral vowels and their corresponding nasal vowel counterparts is the presence or absence of nasality and that they are the same in all other features.

Ruhlen (1973) on the other hand suggested that the nasal [ã] is sometimes higher than its oral counterpart in languages such as Portuguese, Yoruba, Nupe and Picuris. He further mentioned the fact that the precise phonetic quality of nasal vowels is often ignored in the available literature and that very often, the oral vowels are listed first and the nasal vowels are then described in terms of the oral vowels whether or not their heights and backness are the same. Consistent with the suggestion of Ruhlen (1973), instrumental analyses which compared the oral vowels to their nasal vowel counterparts in languages such as Gadangme, Akan, Nzema and Sele found out that the nasal [ã] is slightly higher than the oral [a] and that the two sounds are not the same in terms of backness (Akpanglo-Nartey, 2006; Lomotey, 2008; Tomekyin, 2008; Kpodo, 2008).

However, the differences discovered between the sets of [-Low] nasal vowels and their oral counterparts do not follow any systematic pattern in any of the languages studied. It is therefore important for future researchers to investigate the differences and/or similarities that exist between the set of oral vowels and their nasal vowel counterparts in the Gbe language.

Additionally, it is necessary to investigate the effect of syllable weight on the phonological system of Gbe. It has been shown in this study that Gbe has both light and heavy syllables. As such, there are multi-syllable words in Gbe that are made up of only light syllables and others that are made up of both light and heavy syllables. Some languages have been described as weight-sensitive languages while others are not. It is necessary to find out whether the tone patterns and tone processes in Gbe are sensitive to weight or not. There are phonological processes that have been seen as sensitive to syllable weight in many tone languages. Some of these processes such as vowel lengthening in certain positions, vowel deletion and addition as well as tone assimilation were identified to be sensitive to syllable weight in certain language. It is, therefore, important to investigate the effect of syllable weight on these phonological processes in Gbe. It is necessary to know whether there are some systematic relationships between syllable weight and tone in Gbe.

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APPENDIX A:

FORMANT FREQUENCY AND DURATIONAL VALUES

1. Anlo male speakers

SPKS	V	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		298	2179	1881	251	289	2170	1881	255	274	2185	1911	226
2		483	2014	1531									
3		345	1834	1489	253	329	1752	1423	188	326	1847	1521	221
4		281	2120	1839	376	282	2173	1891	339	326	2147	1821	383
5		302	2283	1981	196	274	2252	1978	220	273	2301	2028	210
	e												
1		401	2000	1599	260	371	2067	1696	256	385	2064	1679	217
2		528	1668	1140	175	523	1716	1193	205	527	1703	1176	183
3		468	1666	1198	194	496	1680	1184	241	490	1766	1276	202
4		380	2057	1677	163	366	2006	1640	130	357	2072	1715	140
5		364	2099	1735	204	310	2131	1821	213	371	2076	1705	200
	1												
1		622	1452	830	239	636	1380	744	244	636	1371	735	244
2		651	1356	705	175	622	1350	728	163	619	1342	723	155
3		532	1393	861	205	568	1394	826	249	587	1419	832	215
4		588	1428	840	141	565	1480	915	124	535	1288	753	114
5		546	1541	995	188	585	1467	882	198	559	1401	842	182
	ə												
1		644	1397	753	268	665	1383	718	258	630	1372	742	225
2		644	1370	726	218	643	1398	755	198	639	1353	714	238
3		560	1340	780	222	533	1595	1062	246	546	1500	954	191
4		577	1511	934	141	567	1368	801	141	563	1422	859	135
5		587	1613	1026	209	594	1552	958	196	579	1498	919	179
	a												
1		834	1324	490	257	825	1344	519	232	821	1343	522	272
2		814	1355	541	238	788	1335	547	216	806	1359	553	223
3		790	1393	603	192	766	1438	672	212	655	1091	436	177
4		795	1348	553	171	808	1341	533	190	780	1338	558	187
5		855	1329	474	258	818	1256	438	221	809	1257	448	195
	4												
1		604	888	284	270	591	898	307	280	582	871	289	235
2		584	913	329	250	633	948	315	228	626	998	372	220
3		523	883	360	254	551	893	342	209	510	839	329	218
4		564	865	301	199	541	863	322	165	520	834	314	178
5		522	858	336	240	517	844	327	215	521	819	298	184
	o												
1		395	765	370	264	417	753	336	260	415	767	352	241
2		413	723	310	266	416	784	368	231	413	783	370	236
3		463	822	359	237	488	808	320	233	474	815	341	228
4		373	651	278	200	351	711	360	192	353	721	368	202

5		369	694	325	229				232	355	785	430	225
	u												
1		376	697	321	263	328	694	366	253	373	760	387	253
2		376	760	384	274	390	726	336	274	385	706	321	244
3		415	727	312	177	417	694	277	204	398	713	315	208
4		306	784	478	166	326	690	364	169	316	688	372	132
5		362	713	351	217	315	719	404	158				
	k/a/												
1		838	1337	499	263	849	1359	510	244	844	1358	514	230
2		825	1365	540	270	798	1378	580	246	804	1371	567	254
3		761	1423	662	212	685	1398	713	203	733	1347	614	199
4		787	1330	543	169	768	1337	569	149	773	1318	545	157
5		873	1308	435	227	814	1234	420	230	848	1241	393	

2. Anlo female speakers

ANLO FEMALE SPEAKERS

		TOKEN 1				TOKEN 2				TOKEN 3			
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		431	2310	1879	271	375	2361	1986	271	407	2337	1930	276
2		305	2633	2328	183	292	2518	2226	216	272	2530	2258	233
3		447	2325	1878	200	430	2335	1905	194	404	2307	1903	190
4		302	2665	2363	242	330	2746	2416	196	371	2706	2335	219
5		280	2627	2347	213	254	2613	2359	206	246	2627	2381	202
	e												
1		664	1954	1290	266	647	2094	1447	252	640	2079	1439	269
2		343	2351	2008	252	346	2439	2093	252	345	2411	2066	264
3		611	1868	1257	184	591	1778	1187	196	595	1849	1254	162
4		732	1943	1211	228	732	1995	1263	210	735	1787	1052	258
5		444	2254	1810	200	425	2338	1913	197	414	2411	1997	204
	ɪ												
1		672	1777	1105	270	634	2106	1472	258	655	1898	1243	246
2		492	1784	1292	210	510	1744	1234	193	498	1767	1269	179
3		615	1872	1257	178	610	1811	1201	187	616	1945	1329	194
4		503	2481	1978	273	510	2476	1966	258	501	2311	1810	242
5		641	1646	1005	214	612	1702	1090	221	596	1621	1025	214
	ə												
1		697	1865	1168	214	680	1959	1279	226	659	1993	1334	245
2		546	1708	1162	178	525	1764	1239	171	508	1766	1258	172
5		644	1708	1064	211	627	2030	1403	211	647	2085	1438	194
	a												
1		870	1652	782	257	889	1676	787	336	943	1488	545	315
2		848	1917	1069	204	810	1487	677	197	779	1414	635	197
3		792	1584	792	180	776	1611	835	190	774	1571	797	190
4		1006	1718	712	259	959	1653	694	262	975	1690	715	247
5		963	1734	771	241	914	1730	816	230	922	1721	799	230
	4												

1		679	1005	326	344	633	1182	549	294	677	1172	495	303
2		516	884	368	172	531	908	377	169	507	954	447	197
3		592	957	365	184	590	908	318	177	571	937	366	181
4		740	1119	379	306	730	1131	401	275	715	1130	415	248
5		617	953	336	211	642	1100	458	204	649	1061	412	211
	o												
1		487	851	364	326	492	870	378	225	532	982	450	229
2		411	676	265	210	377	679	302	178	378	669	291	192
3		409	800	391	157	389	787	398	172	385	761	376	184
4		508	991	483	259	500	985	485	255	486	963	477	238
5		468	739	271	214	450	908	458	211	428	870	442	199
	u												
1		427	688	261	270	396	897	501	243				
2		265	539	274	185	318	518	200	181				
3		282	476	194	163	342	615	273	148	242	504	262	154
5		343	602	259		398	622	224					
	k/a/												
1		964	1647	683	334	928	1644	716	274	979	1664	685	247
2		852	1644	792	187	789	1645	856	187	722	1674	952	173
3		782	1623	841	175	810	1614	804	178	763	1565	802	172
4		954	1625	671	267	931	1668	737	235	959	1659	700	217
5		817	1652	835	209	858	1634	776	199	860	1615	755	226

3. Avenor male speakers

AVENOR MALE SPEAKERS

		TOKEN1				TOKEN 2				TOKEN 3			
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		338	1812	1474	163	325	1757	1432	176	290	1778	1488	153
2		335	1965	1630	137	316	1985	1669	150	330	1996	1666	
3		307	1728	1421	120	304	1741	1437	127	323	1753	1430	126
	e												
1		496	1797	1301	156	536	1802	1266	163	554	1748	1194	204
2		426	1965	1539	202	390	1927	1537	175	378	1881	1503	164
3		598	1408	810	111	592	1488	896	124	594	1455	861	114
	1												
1		560	1354	794	159	563	1368	805	141	557	1391	834	169
2		566	1676	1110	181	552	1707	1155	185	535	1781	1246	153
3		676	1502	826	177	615	1518	903	128	592	1477	885	107
	ə												
1		562	1470	908	151	556	1366	810	164	546	1497	951	170
2		548	1709	1161	173	551	1689	1138	162	542	1692	1150	166
3		574	903	329	145	587	967	380	155	589	994	405	136
	a												
1		753	1222	469	167	726	1289	563	184	764	1248	484	167
2		691	1083	392	180	659	1144	485	198	696	1242	546	177
3		715	1194	479	132	698	1186	488	136	744	1201	457	124
	4												
1		580	919	339	180	547	814	267	164	558	884	326	167
2		535	925	390	194	511	913	402	201	523	908	385	175
3		574	903	329	145	587	967	380	155	589	994	405	136
	o												
1		455	789	334	167	411	743	332	1733	420	751	331	153
2		377	774	397	156	368	778	410	159	382	814	432	156
3		405	832	427	134	397	845	448	116	391	800	409	116
	u												
1		330	630	300	135	371	683	312	142	359	717	358	152
2		339	702	363	183	346	741	395	162	324	763	439	168
3		336	806	470	129	323	771	448	116	345	804	459	113
	k/a/												
1		768	1249	481	176	736	1228	492	165	745	1241	496	145
2		726	1332	606	174	691	1138	447	166	727	1239	512	159
3		715	1291	576	120	706	1296	590	117	685	1272	587	120

4. Avenor female speakers

AVENOR FEMALE SPEAKERS											
	TOKEN 1				TOKEN 2				TOKEN 3		
VOWELS	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'
i											
	383	2688	2305	262	415	2780	2365	282	399	2759	2360
	347	2491	2144	269	340	2492	2152	245	396	2439	2043
	395	2648	2253	254	358	2643	2285	213	397	2666	2269
	445	2854	2409	210	419	2882	2463	204	412	2875	2463
	472	2599	2127	252	434	2599	2165	179	467	2763	2296
e											
	432	2397	1965	258	446	2429	1983	305	451	2415	1964
	602	2211	1609	238	605	2231	1626	238	604	2242	1638
	671	2251	1580	215	639	2313	1674	208	631	2214	1583
	562	2346	1784	268	478	2532	2054	285	475	2509	2034
	488	2578	2090	221	466	2479	2013	214	476	2366	1890
1											
	638	1953	1315	273	637	1979	1342	227	635	1995	1360
	616	1608	992	231	621	1610	989	218	605	1596	991
	644	2205	1561	248	775	2188	1413	234	659	2148	1489
	657	2122	1465	280	677	2144	1467	266	675	2189	1514
	681	2076	1395	214	671	2252	1581	214	676	2210	1534
ə											
	665	1985	1320	276	660	1896	1236	224	657	1817	1160
	613	1599	986	233	609	1610	1001	233	604	1606	1002
	644	2265	1621	232	636	2241	1605	214	648	2255	1607
	680	2178	1498	321	671	2159	1488	277	666	2238	1572
	689	2219	1530	213	665	2200	1535	206	658	2174	1516
a											
	895	1758	863	266	866	1746	880	271	863	1734	871
	830	1605	775	249	832	1607	775	256	810	1588	778
	950	1877	927	253	846	1875	1029	225	877	1903	1026
	892	1777	885	245	891	1799	908	249			
	900	1696	796	253	915	1627	712	246	885	1722	837
4											
	657	1021	364	276	638	1041	403	264	650	1041	391
	620	1140	520	221	622	1180	558	222	610	1176	566
	639	1098	459	217	679	1328	649	207	699	1253	554
	603	945	342	231	641	988	347	251	643	979	336
	664	1110	446	224	641	1084	443	227	607	1039	432
o											
	455	899	444	213	443	889	446	228	433	869	436
	439	878	439	201	457	952	495	212	435	901	466
	457	915	458	237	466	892	426	198	457	897	440
	481	964	483	263	468	929	461	246	469	933	464
	466	896	430	207	450	891	441	207	439	862	423

u											
	447	650	203	213	413	699	286	236			
	402	850	448	199	404	866	462	203	386	802	416
	334	724	390	210	373	692	319	206	372	855	483
	346	732	386	248	468	674	206	204			
	414	711	297	181	417	699	282	212			
k/a/											
	841	1585	744	207	843	1692	849	216			
	828	1553	725	204	832	1553	721	240			
	847	1790	943	225	879	1759	880	222			
	909	1722	813	201	899	1758	859	222			

5. Ho male speakers

HO MALE SPEAKERS

		TOKEN 1				TOKEN 2				TOKEN 3		
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'
	i											
1		276	1820	1544	189	276	1736	1460	199	251	1802	1551
2		271	1969	1698	212	260	1953	1693	164	261	1972	1711
3		272	2143	1871	216	273	2165	1892	232	255	2161	1906
4		312	2262	1950	246	280	2172	1892	177	284	2172	1888
5		289	2460	2171	200	295	2501	2206	227	289	2462	2173
	e											
1		530	1870	1340	215	497	1831	1334	221	480	1800	1320
2		365	1799	1434	176	357	1870	1513	223	361	1792	1431
3		535	1892	1357	208	534	1761	1227	218	499	1729	1230
4		553	1798	1245	144	565	1780	1215	160	572	1707	1135
5		340	2453	2113	236	331	2439	2108	247	362	2380	2018
	ɪ											
1		517	1827	1310	266	526	1833	1307	263			
2		499	1695	1196	197	471	1709	1238	182	460	1643	1183
3		556	1760	1204	241	533	1715	1182	222	525	1810	1285
4		408	2089	1681	191	405	2050	1645	168	376	2122	1746
5		600	1969	1369	231	608	1981	1373	223	665	1440	775
	a											
1		761	1304	543	205	770	1339	569	268	763	1346	583
2		573	1172	599	307	711	1148	437	177	671	1230	559
3		765	1418	653	265	770	1346	576	270	776	1372	596
4		694	1298	604	230	669	1273	604	187	682	1347	665
5		713	1412	699	202	721	1463	742	252	728	1451	723
	4											
1		513	938	425	245	501	877	376	248	533	889	356
2		467	820	353	151	472	829	357	155	484	833	349
3		641	959	318	304	615	944	329	298	580	858	278
4		543	921	378	216	544	911	367	224	539	924	385

SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'
5		629	1036	407	223	617	1082	465	212	593	1024	431
	o											
1		363	715	352	244	387	720	333	244	373	703	330
2		344	683	339	158	365	738	373	185	367	750	383
3		395	709	314	246	415	739	324	246	431	728	297
4		373	705	332	204	392	689	297	260	388	681	293
5		405	760	355	237	412	748	336	225			
	u											
1		337	703	366	244	206	870	664	265	342	712	370
2		297	739	442	178	284	663	379	188	318	781	463
3		353	676	323	337	359	639	280	224	338	704	366
4		308	639	331	197	329	630	301	197	366	676	310
5												
	k/a/											
1		717	1318	601	206	755	1363	608	257	732	1321	589
2		701	1283	582	250	646	1266	620	186	614	1246	632
3		778	1399	621	240	741	1388	647	216	747	1388	641
4		691	1347	656	211	692	1350	658	197	685	1311	626
5		676	1466	790	211	648	1437	789	189	662	1425	763

6. Ho female speakers

HO FEMALE SPEAKERS													
		TOKEN 1				TOKEN 2				TOKEN 3			
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		243	2295	2052	135				135				
2		316	2442	2126	138	293	2512	2219	115	218	2204	1986	194
3		247	2600	2353	192	325	2434	2109	223	322	2466	2144	216
4		289	2746	2457	165	289	2746	2457	165	299	2569	2270	146
5		280	2525	2245	228	296	2617	2321	202	281	2607	2326	188
	e												
1		625	2007	1382	141	593	2027	1434	215	523	2006	1483	174
2		683	1816	1133	168	651	1690	1039	130	606	1836	1230	148
3		574	2161	1587	263	544	2158	1614	245	518	2186	1668	256
4		590	2209	1619	144	582	2215	1633	118	567	2222	1655	157
5		500	2298	1798	190	501	2330	1829	190	490	2201	1711	194
	ɪ												
1		590	2057	1467	236	574	2069	1495	181	508	2028	1520	205
2		714	2332	1618	177	644	2156	1512	177	582	2422	1840	185
3		631	2159	1528	323	587	2121	1534	330	546	2142	1596	287
4		412	2566	2154	154	396	2681	2285	110	382	2516	2134	100
5		623	2078	1455	205	618	2098	1480	230	571	2098	1527	256
	a												
1		788	1282	494	147	618	1114	496	186	678	1268	590	136
2		928	1656	728	182	840	1629	789	176	786	1680	894	165
3		842	1442	600	308	830	1536	706	276	779	1345	566	259
4		970	1687	717	180	742	1307	565	180	770	1323	553	163

5		877	1602	725	209	750	1237	487	193	827	1613	786	190
	4												
1		615	999	384	148	530	904	374	132	489	1016	527	160
2		695	921	226	165	656	1079	423	164	601	1012	411	149
3		607	915	308	236	577	839	262	267	553	824	271	270
4		586	965	379	173	621	967	346	144	571	994	423	139
5		720	1086	366	217	693	1109	416	227	669	985	316	236
	o												
1		444	844	400	120	393	793	400	122	362	714	352	106
2		485	814	329	149	443	754	311	146	421	661	240	122
3		451	762	311	256	417	750	333	275	408	692	284	252
4		501	958	457	243	407	802	395	202	393	762	369	148
5		526	1017	491	204	488	967	479	204	457	921	464	223
	u												
1		273	665	392	144	299	645	346	138				
2		377	708	331	136	362	645	283	107				
3		352	518	166	240	321	616	295	250	418	480	62	260
4		314	717	403	226				191	383	659	276	166
5		364	799	435	193	350	768	418	170				199

7. Tongu male speakers

		TONGU MALE SPEAKERS											
		TOKEN 1				TOKEN 2				TOKEN 3			
SPKS	VOWELS	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		305	2241	1936	174	402	2226	1824	155	369	2241	1872	216
2		337	2199	1862	175	302	2212	1910	159	285	2232	1947	216
3		275	2259	1984	173	284	2203	1919	182	272	2234	1962	151
4		293	1994	1701	186	333	1965	1632	186	275	2024	1749	167
5		316	2008	1692	208	263	2049	1786	204	321	2023	1702	207
	e												
1		391	2184	1793	156	423	2211	1788	153	371	2220	1849	156
2		559	1802	1243	190	543	1805	1262	171	557	1821	1264	196
3		353	2160	1807	187	357	2091	1734	178	493	2122	1629	181
4		523	1877	1354		553	1855	1302		596	1921	1325	
5		355	1907	1552	172	330	1961	1631	252	356	2050	1694	209
	l												
1		539	1784	1245	204	546	1889	1343	176	540	1836	1296	162
2		526	1823	1297	176	539	1419	880	192	545	1901	1356	202
3		508	1876	1368	178	528	1843	1315	199	530	1928	1398	199
4		574	1756	1182	173					555	1648	1093	155
5		467	1692	1225	232	464	1767	1303	225	474	1717	1243	233
	ə												
1		560	1517	957	160	557	1507	950	160	543	1649	1106	154
3		542	1367	825	166	540	1435	895	172	524	1388	864	169
5		460	1731	1271	223	470	1746	1276	220	463	1711	1248	216
	a												
1		723	1272	549	199	709	1189	480	192	727	1265	538	

2		764	1331	567	166	789	1406	617	194	761	1396	635	181
3		728	1308	580	198	714	1294	580	207	741	1297	556	216
4		790	1442	652	286	786	1469	683	206	797	1458	661	228
5		609	1358	749	201	544	1314	770	248	622	1333	711	240
	4												
1		519	792	273	173	517	793	276	163	512	789	277	170
2		543	845	302	155	536	867	331	196	547	860	313	225
3		516	861	345	201	534	884	350	229	554	900	346	208
4					192				184				173
5		451	714	263	193	458	825	367	197	462	816	354	197
	o												
1		400	726	326	171	397	714	317	160	393	712	319	174
2		358	627	269	190	400	720	320	203	408	689	281	193
3		359	727	368	199	403	753	350	177	381	738	357	190
4		429	840	411	127	398	806	408	164	411	803	392	180
5		373	867	494	205	362	816	454	268	359	831	472	238
	u												
1		312	707	395		380	713	333	179	371	750	379	120
2		364	588	224	157	343	664	321	189	360	645	285	179
3		330	761	431	216	340	728	388	194	343	748	405	177
4		334	831	497	124	334	845	511	189	326	868	542	163
5		261	718	457	211	298	737	439	240	254	599	345	222
	k/a/												
1		723	1271	548	160	732	1294	562	174	714	1160	446	188
2		794	1407	613	178	770	1464	694	213	747	1408	661	197
3		724	1324	600	223	738	1368	630	184	738	1520	782	181
4		755	1457	702	188	786	1474	688	184	772	1452	680	185
5		594	1430	836	215	568	1435	867	225	548	1330	782	207

8. Tongu female speakers

TONGU FEMALE

		TOKEN 1				TOKEN 2				TOKEN 3			
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		414	2635	2221	184	471	2601	2130	169	560	2576	2016	169
2		286	2450	2164	187	296	2525	2229	191	321	2508	2187	191
3		312	2653	2341	239	305	2752	2447	213	326	2696	2370	198
	e												
1		499	2237	1738	189	510	2382	1872	149	558	2287	1729	145
2		558	2290	1732	211	540	2278	1738	214	501	2223	1722	218
3		712	2241	1529	246	704	2335	1631	215	688	2365	1677	219
	1												
1		701	2164	1463	164	688	2097	1409	144	673	2187	1514	156
2		686	1846	1160	211	699	1864	1165	211	674	1805	1131	188
3		728	2188	1460	223	724	2119	1395	222	715	2118	1403	211
	a												
1		905	1658	753	179	824	1666	842	183	798	1535	737	191
2		884	1527	643	235	881	1482	601	208	890	1562	672	228

	4												
1		741	1105	364	174	727	1129	402	178	719	1059	340	174
2		733	1132	399	232	689	988	299	215	673	1077	404	245
	o												
1		601	961	360	177	631	976	345	162	570	955	385	185
2		458	911	453	245	464	886	422	241	451	829	378	220
3		580	957	377	242	524	841	317	258	511	945	434	248
	u												
1		369	814	445	178	375	780	405	185	366	778	412	159
2		346	719	373	229	335	913	578	233	327	898	571	196
3		311	777	466	224	302	753	451	206	326	791	465	216

9. Kpando male speakers

KPANDO MALE SPEAKERS

		TOKEN 1				TOKEN 2				TOKEN 3			
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
1	i	303	2052	1749	207	347	2023	1676	171	318	2752	2434	155
2		348	2123	1775	173	403	2228	1825	142				
3		237	1951	1714	183	274	2030	1756	154	256	1960	1704	143
4		274	2063	1789	122	279	2135	1856	210	288	2025	1737	172
5		234	2219	1985	141	251	2314	2063	158	227	2219	1992	128
1	e	445	1929	1484	142	459	1827	1368	165	479	1768	1289	165
2		445	1968	1523	146	445	1982	1537	130	440	1961	1521	118
3		393	1934	1541	119	386	1956	1570	107	383	1928	1545	116
4		387	2043	1656	196	372	1994	1622	200	385	1990	1605	183
5		434	1983	1549	110	393	2102	1709	118	414	2050	1636	115
	ε												
1		644	1677	1033	165	679	1671	992	165	605		-605	160
2		626	1890	1264	181	601	1915	1314	184	561	1874	1313	173
3		557	1797	1240	143	553	1773	1220	149	554	1795	1241	155
4		570	1792	1222	164	541	1991	1450	157	560	1814	1254	179
5		529	2024	1495	126	500	2039	1539	123	534	2028	1494	126
	a												
1		908	1449	541	160	826	1425	599	130	849	1440	591	173
2		761	1327	566	128	724	1464	740	112	736	1482	746	112
3		743	1336	593	137	758	1311	553	148	749	1266	517	148
4		701	1163	462	129	710	1239	529	143	714	1197	483	133
5		768	1370	602	106				120	726	1422	696	116
	4												
1		605	1000	395	174	476	1018	542	187	608	986	378	152
2		593	923	330	127	600	990	390	146	574	951	377	153
3		614	952	338	127	620	972	352	124	605	943	338	127
4		572	775	203	132	553	766	213	128	517	784	267	132
5		494	796	302	113					455	748	293	
	o												
1		531	838	307	149	498	872	374	147				

2		467	861	394	208	470	832	362	146	456	826	370	127
3		376	695	319	117	381	742	361	133	398	704	306	156
4		373	673	300	144	363	660	297	167	400	686	286	176
5		389	617	228	142	338	601	263	148	368	686	318	151
	u												
1		388	788	400	244	352	838	486	124	327	819	492	143
2		382	684	302	126	388	601	213	118	378	686	308	110
3		344	660	316	130	349	654	305	142	345	704	359	156
4		357	677	320	146	338	720	382	146	312	756	444	168
5		216	644	428		228	525	297					
	K [a]												
1		816	1471	655	185	762	1380	618	163	768	1319	551	176
3		708	1304	596	127	677	1297	620	127	715	1328	613	135
4		683	1260	577	156	739	1321	582	147	745	1286	541	126
5		741	1389	648	99	717	1363	646	91	671	1306	635	99

10. Kpando female speakers

		KPANDO FEMALE SPEAKERS											
		TOKEN 1				TOKEN 2				TOKEN 3			
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		316	2388	2072	174	327	2532	2205	194				
2		251	2533	2282	136	271	2527	2256	121	270	2493	2223	114
3		280	2435	2155	175	280	2451	2171	147	309	2397	2088	123
4		318	2884	2566	182	311	2781	2470	156	292	2795	2503	156
5		401	2388	1987	238	340	2228	1888	174	348	2341	1993	190
	e												
1		493	2214	1721	197	477	2124	1647	182	479	2169	1690	166
2		558	2266	1708	139	498	2194	1696	135	521	2168	1647	126
3		501	2254	1753	150	446	2223	1777	154	451	2191	1740	137
4		575	2531	1956	193	539	2372	1833	179				
5		488	2042	1554	192	471	2063	1592	140	458	2154	1696	181
	ɛ												
1		677	2197	1520	296	686	2165	1479	225	675	2114	1439	195
2		670	2233	1563	222	637	2100	1463	143	610	2148	1538	136
3		525	2185	1660	170	514	2161	1647	145	496	2154	1658	141
4		771	2296	1525	273	785	2341	1556	210	785	2150	1365	210
5		736	1962	1226	202	665	1938	1273	185	634	1903	1269	169
	a												
1		908	1611	703	235	930	1653	723	213	862	1643	781	226
2		848	1632	784	348	889	1664	775	304	922	1689	767	261
3		770	1165	395	237	853	1508	655	196	847	1417	570	196
4		858	1617	759	425	856	1672	816	310	947	1807	860	245
5		925	1389	464	268	874	1364	490	189	842	1327	485	163
	4												
1		621	927	306	245	710	1052	342	237	699	982	283	210
2		676	884	208	190	672	920	248	139	610	875	265	144

3		708	932	224	193	670	903	233	148	667	922	255	176
5		740	921	181	188	664	1073	409	188	631	1048	417	163
	o												
1		555	1019	464	274	515	900	385	211	521	916	395	179
2		469	750	281	92	467	779	312	101	459	800	341	104
3		541	821	280	147	482	723	241	159	463	798	335	159
4		573	877	304	152	560	856	296	143	546	844	298	160
5		494	866	372	189	463	907	444	174	436	865	429	184
	u												
2		401	683	282	82	382	605	223	89				
3		323	683	360	171	307	577	270	158	315	733	418	124
4		365	681	316	131	370	719	349	149	324	606	282	140
5		385	754	369	155	392	696	304	189	448	719	271	203
	k-a												
1		860	1651	791		822	1632	810		828	1572	744	
2		863	1603	740	106	839	1576	737	97	792	1534	742	97
3		840	1367	527	107	870	1409	539	111	883	1307	424	107
4		872	1583	711	148	908	1624	716	130	883	1589	706	148
5		886	1444	558	144	779	1358	579	139	769	1294	525	139

11. Gen male speakers

GEN MALE SPEAKERS

		TOKEN 1				TOKEN 2				TOKEN 3			
SPKS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		307	2061	1754	166	311	2077	1766	176	301	2099	1798	157
2		278	1939	1661	213	294	1934	1640	176	284	1924	1640	219
3		321	1965	1644	160	299	1995	1696	154				
4		249	2041	1792	300	226	2062	1836	202	273	2033	1760	165
	e												
1		411	1873	1462	182	408	1771	1363	201	301	2099	1798	157
2		415	1739	1324	194	486	1637	1151	178	413	1613	1200	162
3		376	2004	1628	211	382	1933	1551	195				
4		317	1722	1405	164	344	2060	1716	203	365	1996	1631	181
	1												
1		548	1847	1299	222	552	1741	1189	203				
2		499	1741	1242	211	463	1695	1232	196	455	1819	1364	165
3		496	1725	1229	235	470	1703	1233	207				
4		375	1966	1591	197	340	1998	1658	211				
	a												
1		808	1531	723	172	767	1385	618	207				
2		661	1211	550	228	605	1301	696	206				
3		664	1381	717	215	617	1268	651	188				
4		627	1256	629	177	696	1346	650	242	554	1238	684	212
	4												
1		636	934	298	220	598	995	397	205	606	998	392	241
2		546	695	149	234	533	740	207	229	548	862	314	201
3		580	1069	489	279	586	1049	463	296				

4		469	841	372	174	461	788	327	110	420	804	384	152
	o												
1		416	732	316	239	441	774	333	209	406	724	318	204
2		388	665	277	427	378	653	275	165	414	713	299	240
3		394	745	351	307	399	820	421	283	404	830	426	267
4		356	638	282	190	349	620	271	190	352	718	366	178
	u												
1		335	675	340	216	355	689	334	223	370	813	443	223
2		286	582	296	211	286	579	293	192	285	555	270	197
3		360	731	371	266	354	718	364	278	354	718	364	278
4		300	767	467		258	724	466	154	285	515	230	194

12. Gen female speakers

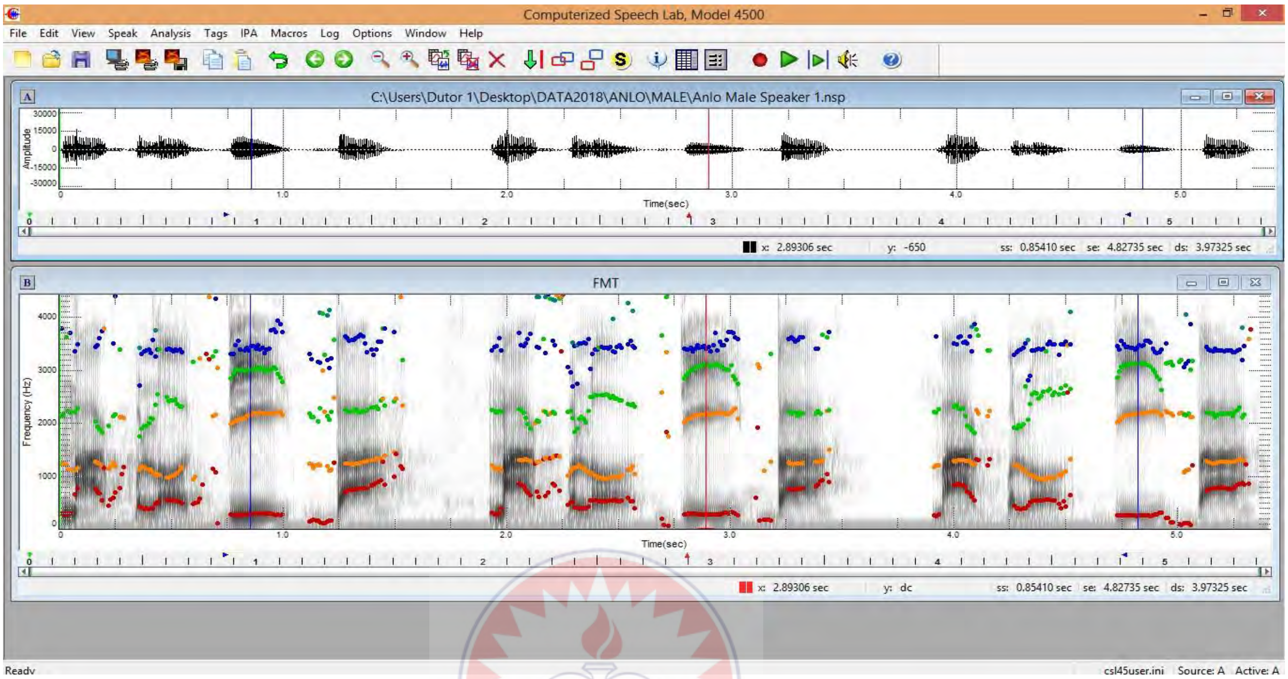
GENGBE FEMALE SPEAKERS													
		TOKEN 1				TOKEN 2				TOKEN 3			
SPKRS	VOWEL	F1	F2	F2'	DUR	F1	F2	F2'	DUR	F1	F2	F2'	DUR
	i												
1		328	2221	1893		320	2160	1840	167	340	2267	1927	187
2		346	2713	2367	329	260	2788	2528	301	383	2719	2336	208
3		460	2358	1898		451	2758	2307		452	2601	2149	
4		435	2412	1977	270	457	2445	1988	260	450	2466	2016	281
5		437	2706	2269	237	457	2713	2256	152	440	2628	2188	152
6		428	2557	2129	318	414	2536	2122	265	388	2580	2192	249
	e												
1		385	2121	1736	227	370	2072	1702	222	400	2082	1682	233
2		477	2508	2031	247	481	2336	1855	275	495	2515	2020	313
3		449	2187	1738	209					439	2318	1879	204
4		585	2133	1548	345	571	2338	1767	293	552	2115	1563	297
5		465	2694	2229	146	449	2366	1917	187	435	2646	2211	187
6		398	2483	2085						396	2430	2034	
	l												
1		649	1955	1306	192	574	1900	1326	184	582	1931	1349	238
2		654	2080	1426	279	625	2298	1673	226	634	2335	1701	230
3		645	2267	1622	250	623	2145	1522	270	494	2185	1691	296
4		653	2250	1597	209	481	2310	1829	277	491	2319	1828	
6		641	2206	1565	264	647	2105	1458	264	613	2151	1538	293
	a												
1		770	1560	790	213	743	1494	751	230	692	1662	970	213
2		580	1439	859	266	508	1337	829	216	513	138	-375	272
3		784	1726	942	237	811	1649	838	265	814	1698	884	192
4		787	1811	1024	319	785	1742	957	279	769	1746	977	319
5		711	1788	1077	236	818	1798	980	236	728	1783	1055	274
6		800	1823	1023	314	764	1854	1090	247	844	1912	1068	287
	4												
1		639	1014	375	244	604	995	391	222	591	974	383	226
2		640	1105	465	221	565	835	270	238	712	1171	459	234
3		599	998	399	322	486	834	348	248	609	951	342	234
4		618	900	282	277	648	1057	409	260	630	1049	419	250

5		693	1182	489	253	647	1167	520	242	642	1152	510	196
6		765	1134	369	293	748	1145	397	297				
	o												
1		385	745	360	225	401	707	306	225	386	688	302	257
2		480	753	273	298	469	929	460	242	466	869	403	253
3		440	869	429	255	427	853	426	260	430	862	432	296
4		454	892	438	266	445	883	438	282	443	884	441	277
5		488	939	451	233	432	892	460	261	449	906	457	224
6		425	802	377	320	437	798	361	348	434	775	341	334
	u												
1		315	585	270	214	350	712	362	271	337	686	349	193
2		440	974	534	212	426	722	296	212				
3		402	623	221	210	430	671	241	240	414	597	183	255
4		429	733	304	233	409	704	295	244				
5		451	915	464	196	438	1071	633	150				
6		414	631	217	329	433	667	234	302	434	711	277	274

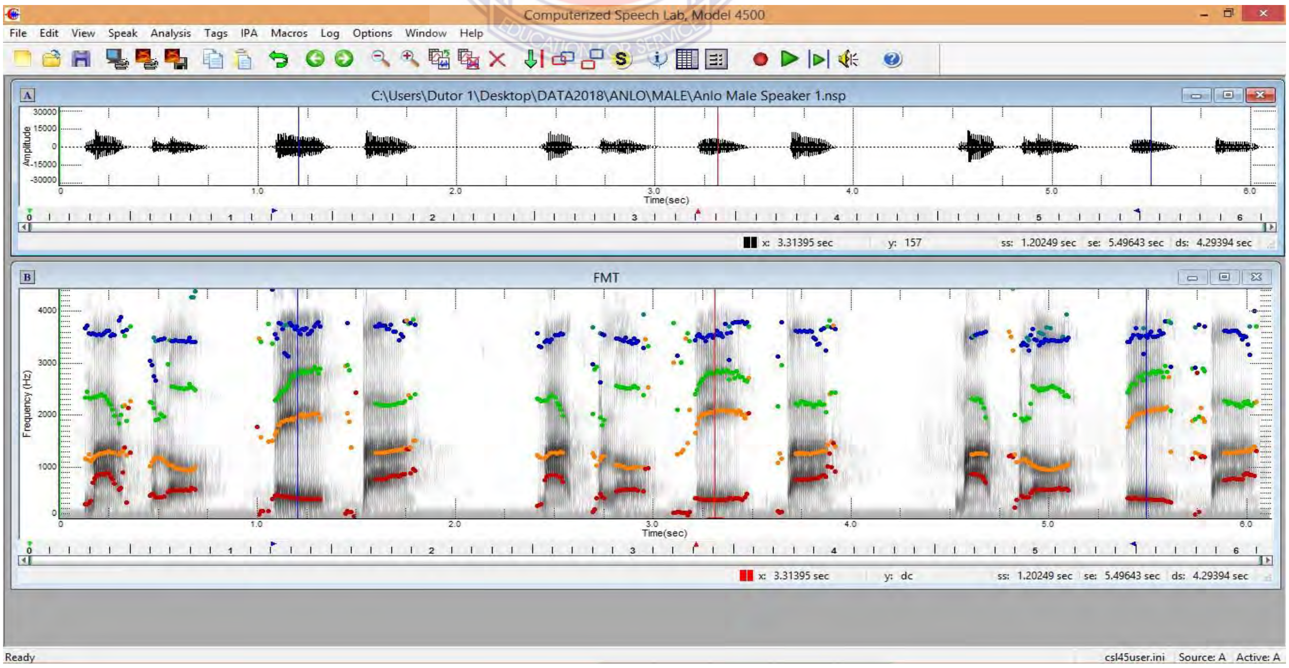
APENDIX B:

SPECTROGRAMS

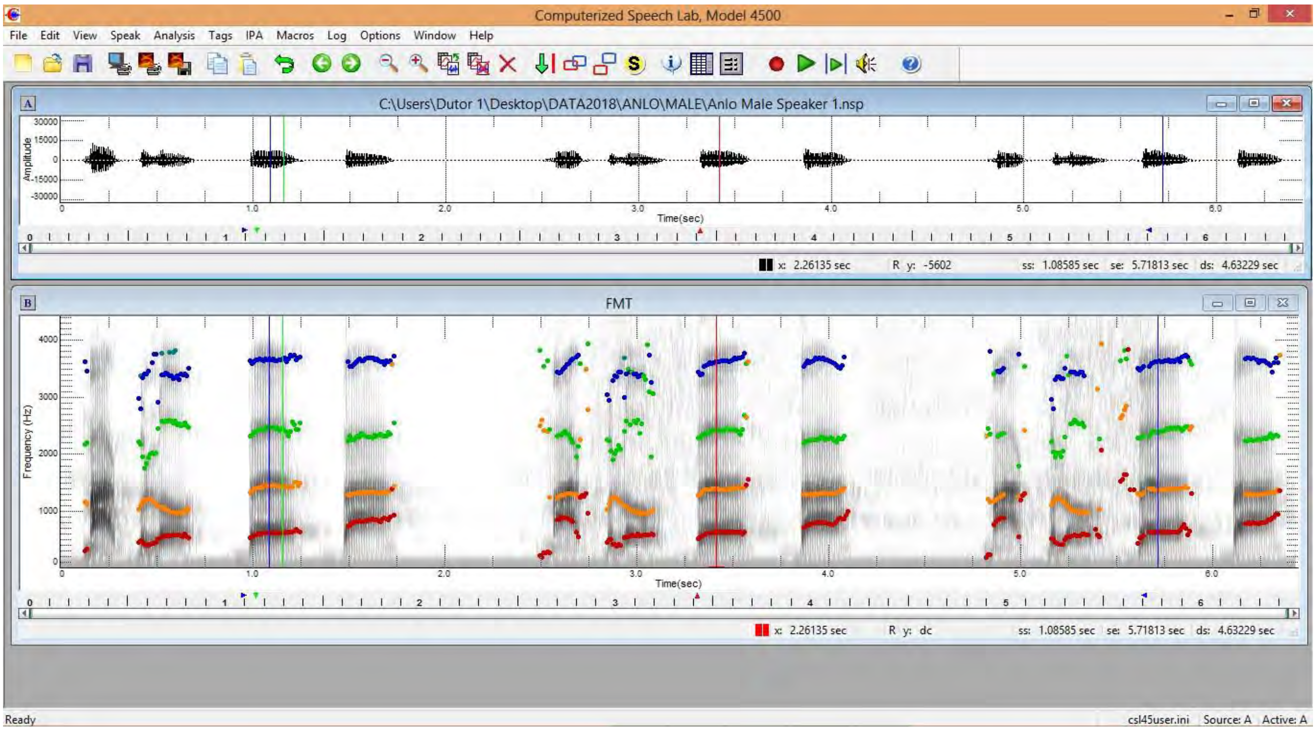
1. Spectrograms of Anlo male speaker one.



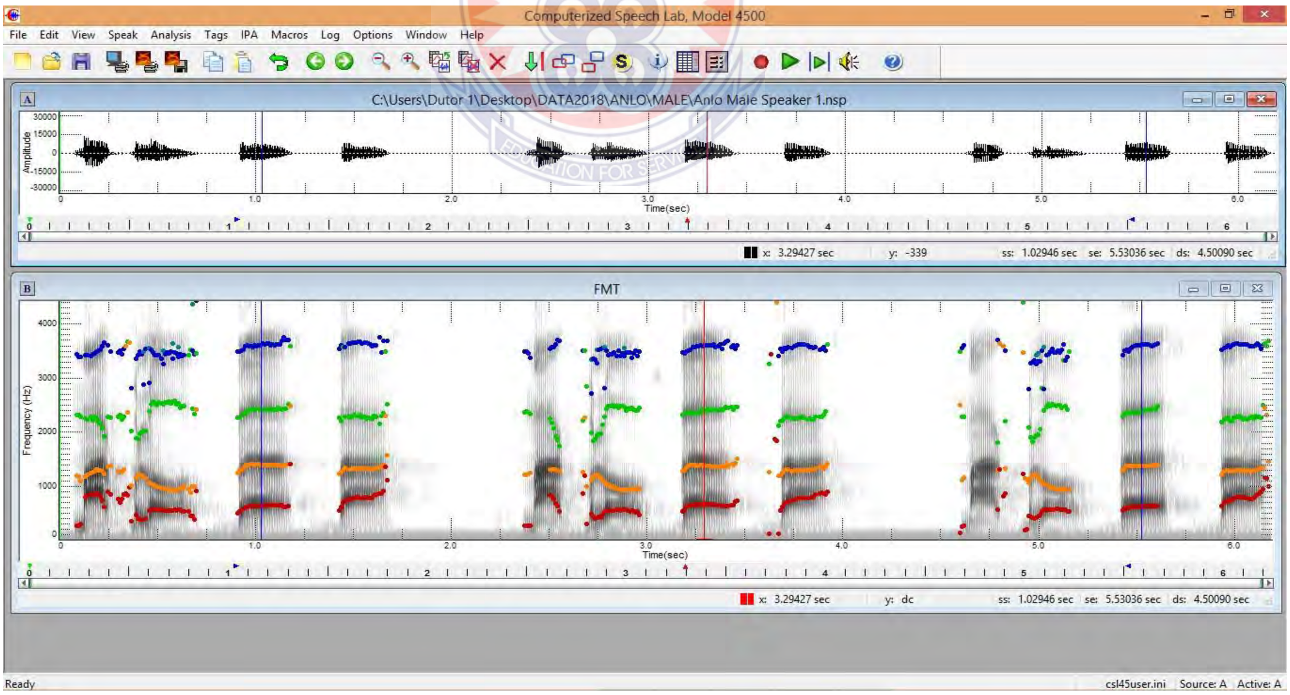
Waveform and spectrogram of Anlo male speaker 1 saying “*Magblɔ bi baa*” in three repetitions.



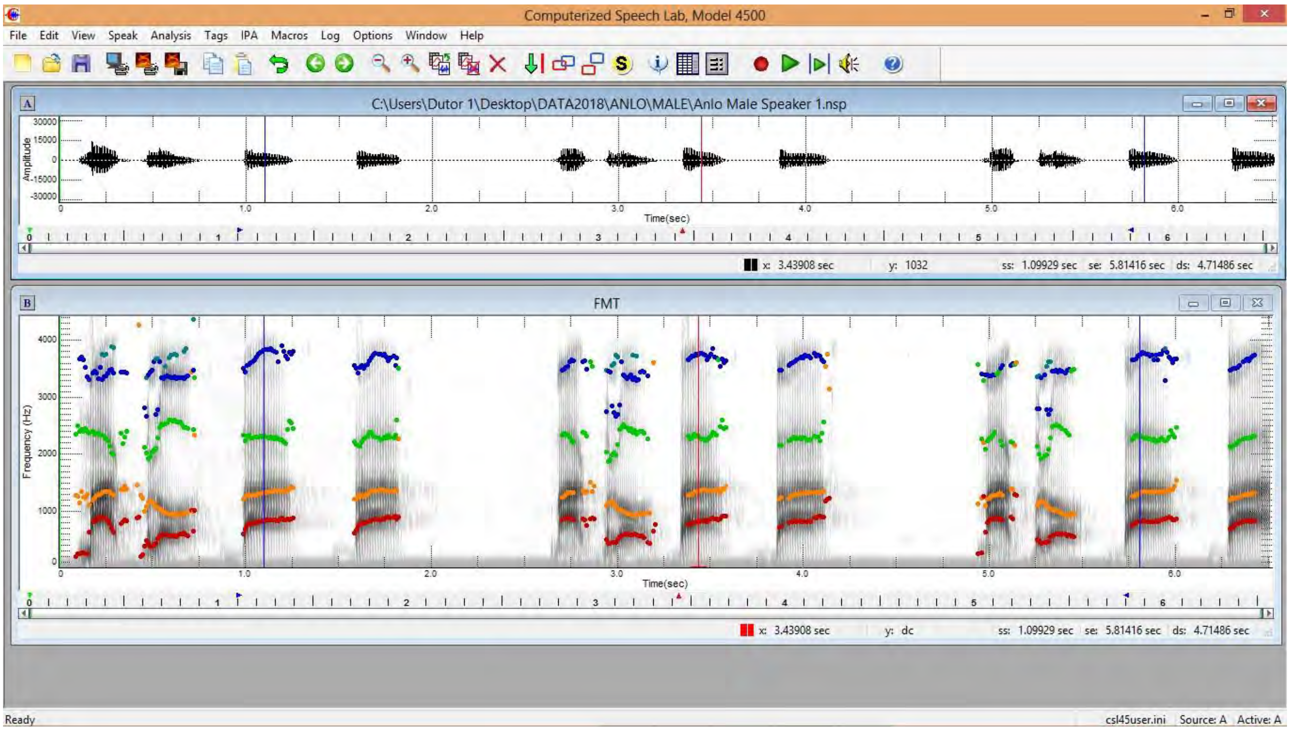
Waveform and spectrogram of Anlo male speaker 1 saying “*Magblɔ be baa*” in three repetitions.



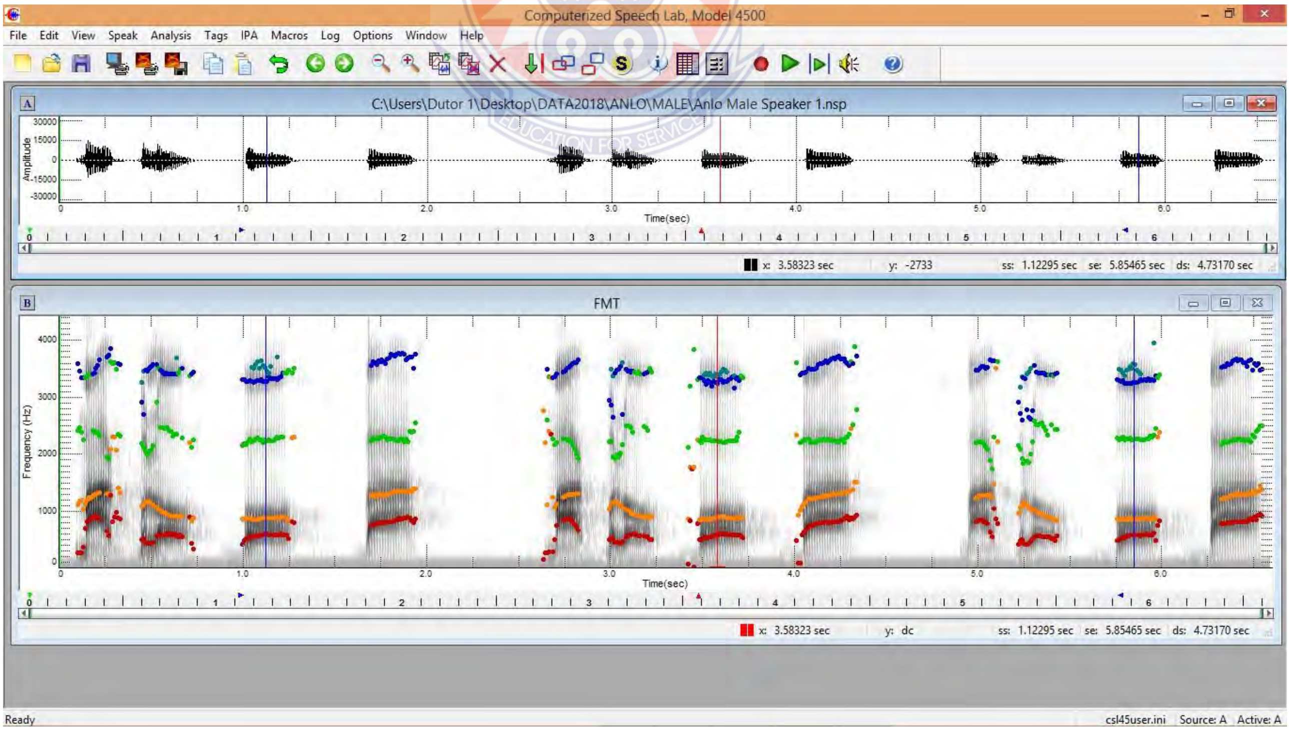
Waveform and spectrogram of Anlo male speaker 1 saying "Magblɔ bɛ baa" in three repetitions.



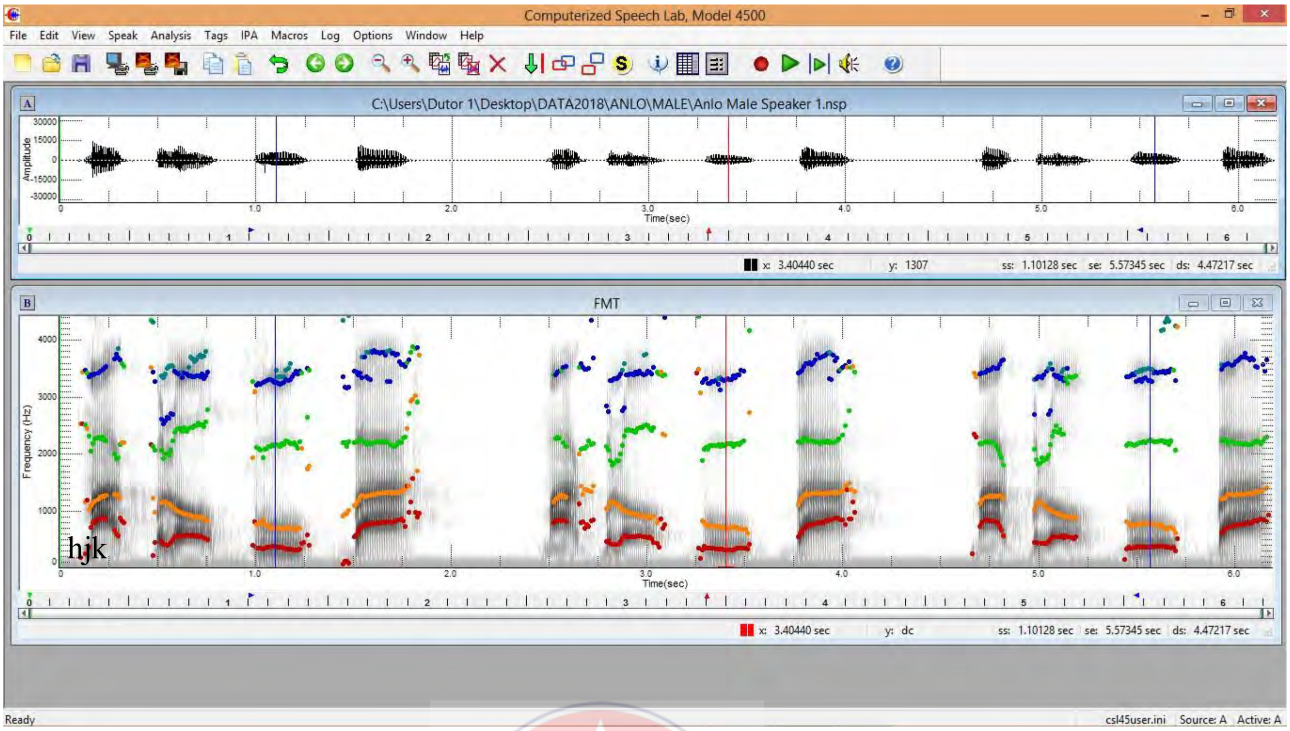
Waveform and spectrogram of Anlo male speaker 1 saying "*Magblɔ bɘ baa*" in three repetitions.



Waveform and spectrogram of Anlo male speaker 1 saying "*Magblɔ ba baa*" in three repetitions.

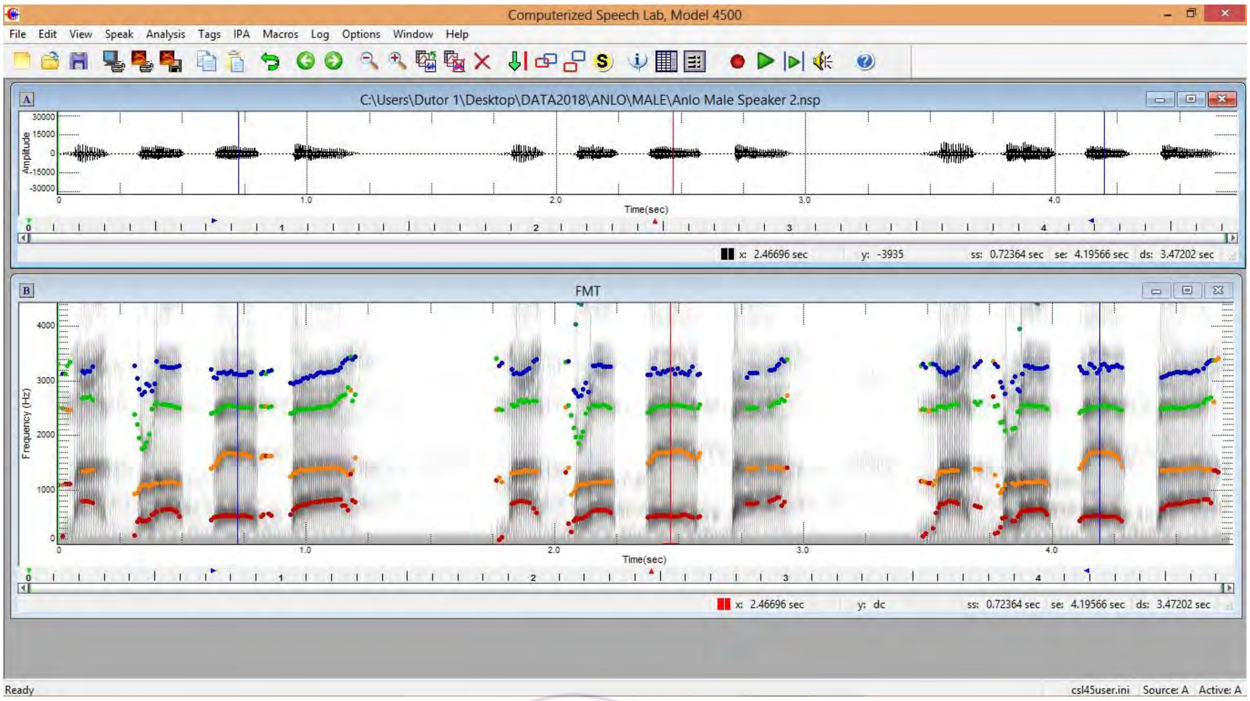


Waveform and spectrogram of Anlo male speaker 1 saying "*Magblɔ bɔ baa*" in three repetitions.

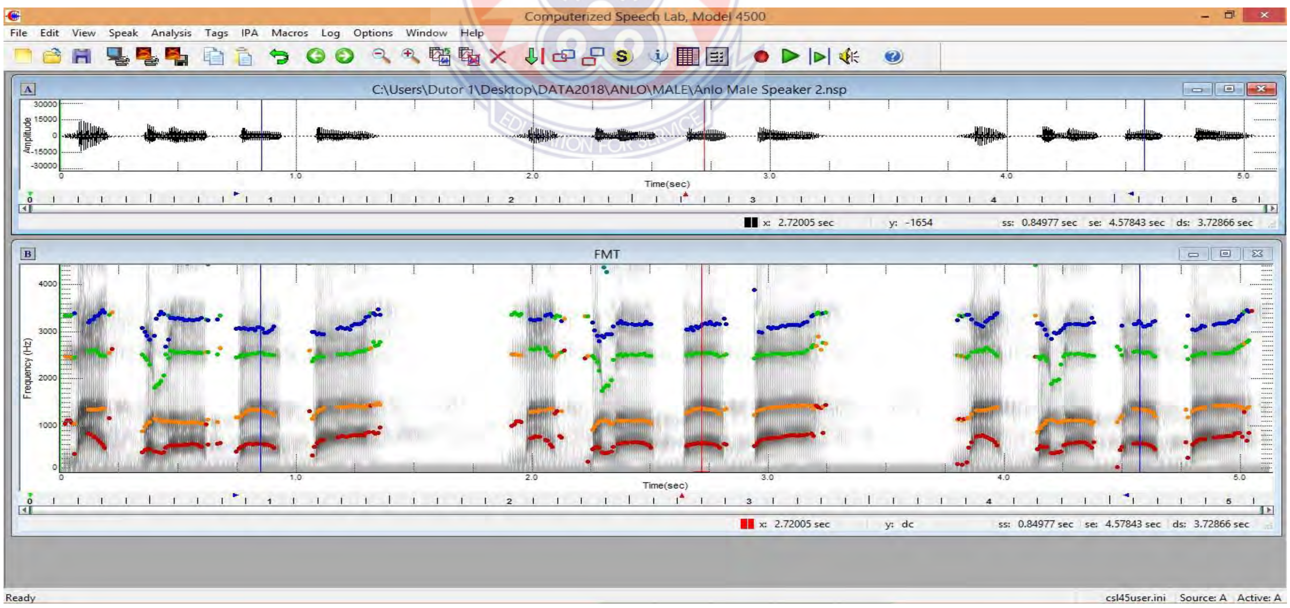


Waveform and spectrogram of Anlo male speaker 1 saying "*Magblɔ bu baa*" in three repetitions.

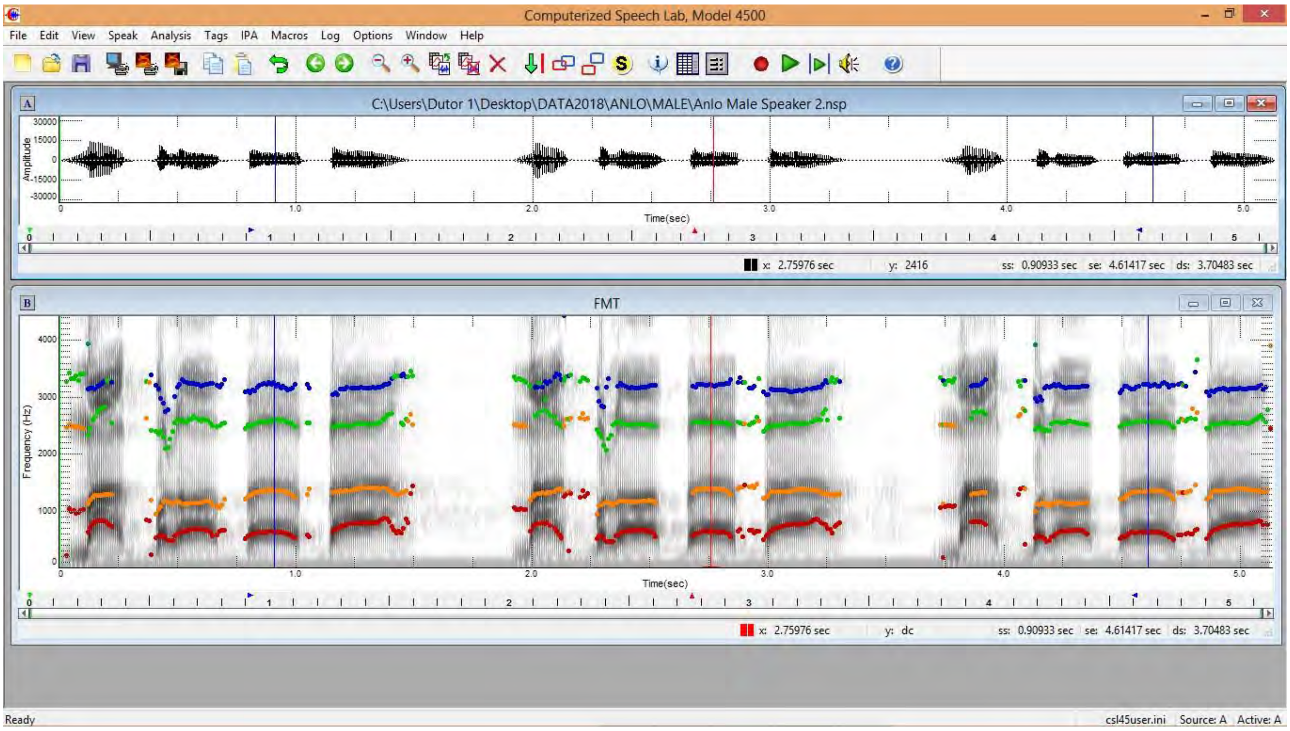
2. Spectrograms of Anlo male speaker 2



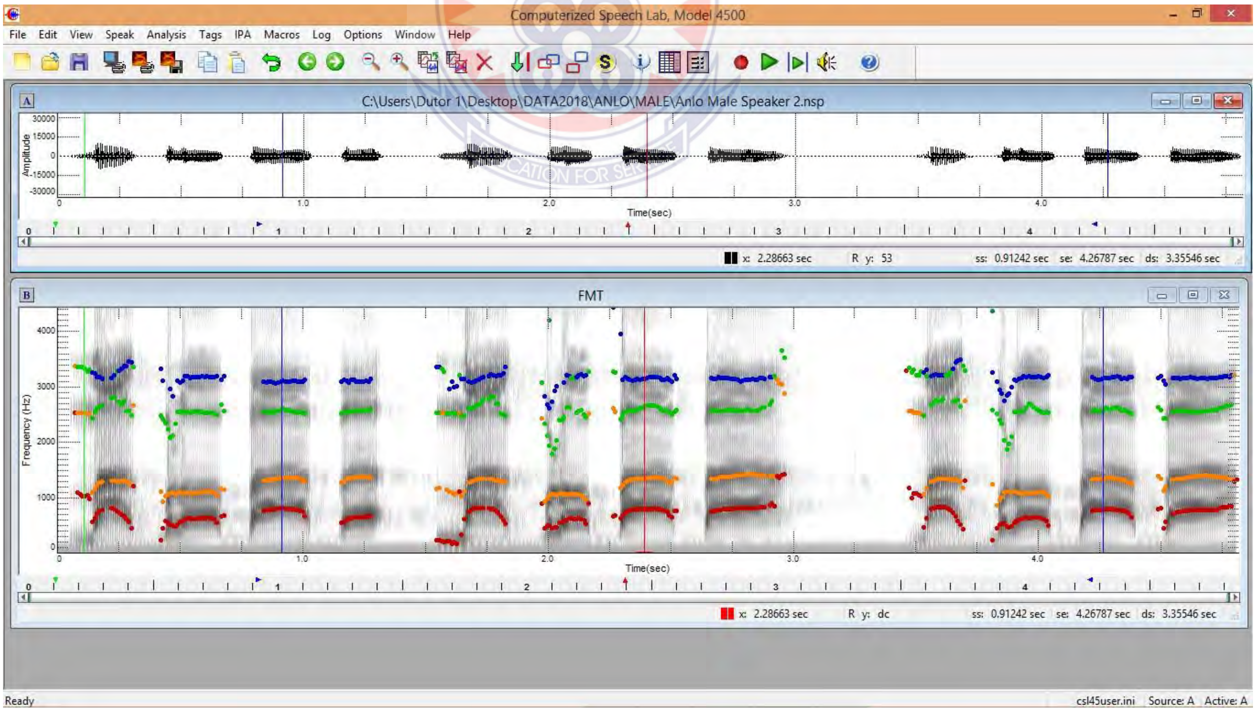
Waveform and spectrogram of Anlo male speaker 2 saying "*Magblɔ be baa*" in three repetitions.



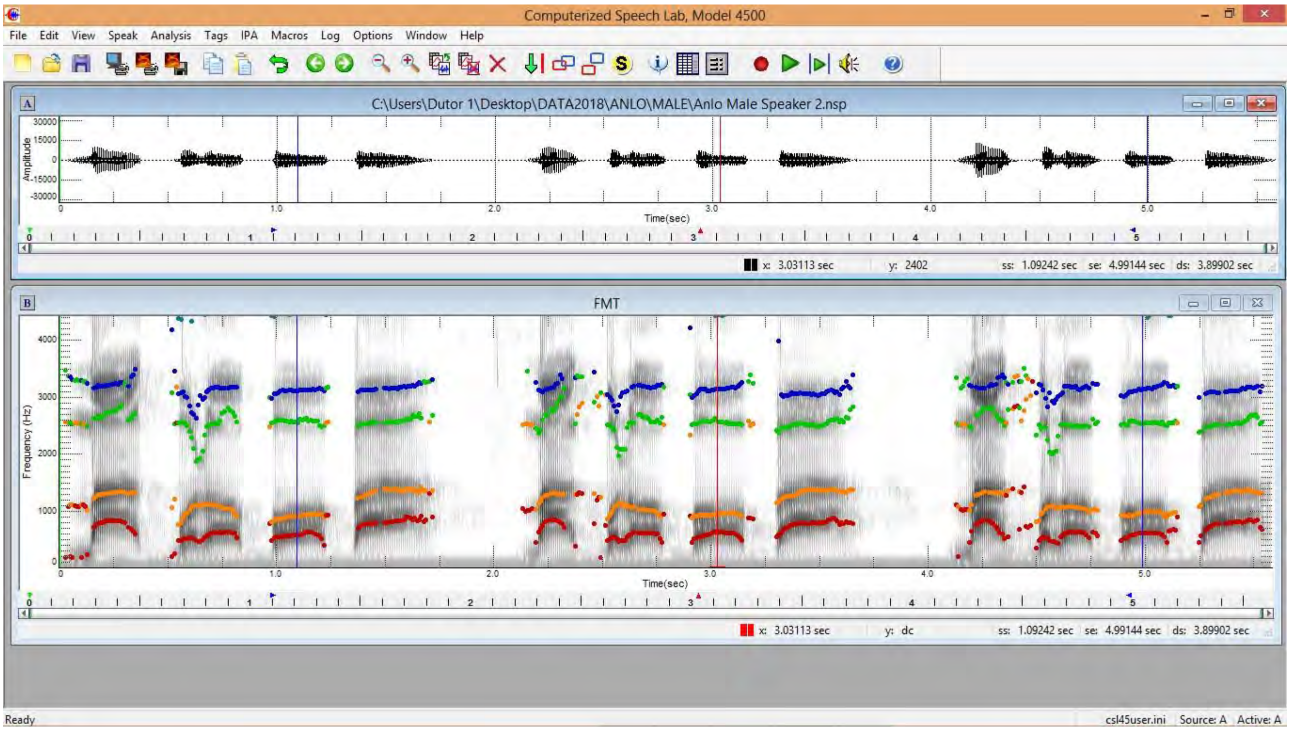
Waveform and spectrogram of Anlo male speaker 2 saying "*Magblɔ bɛ baa*" in three repetitions.



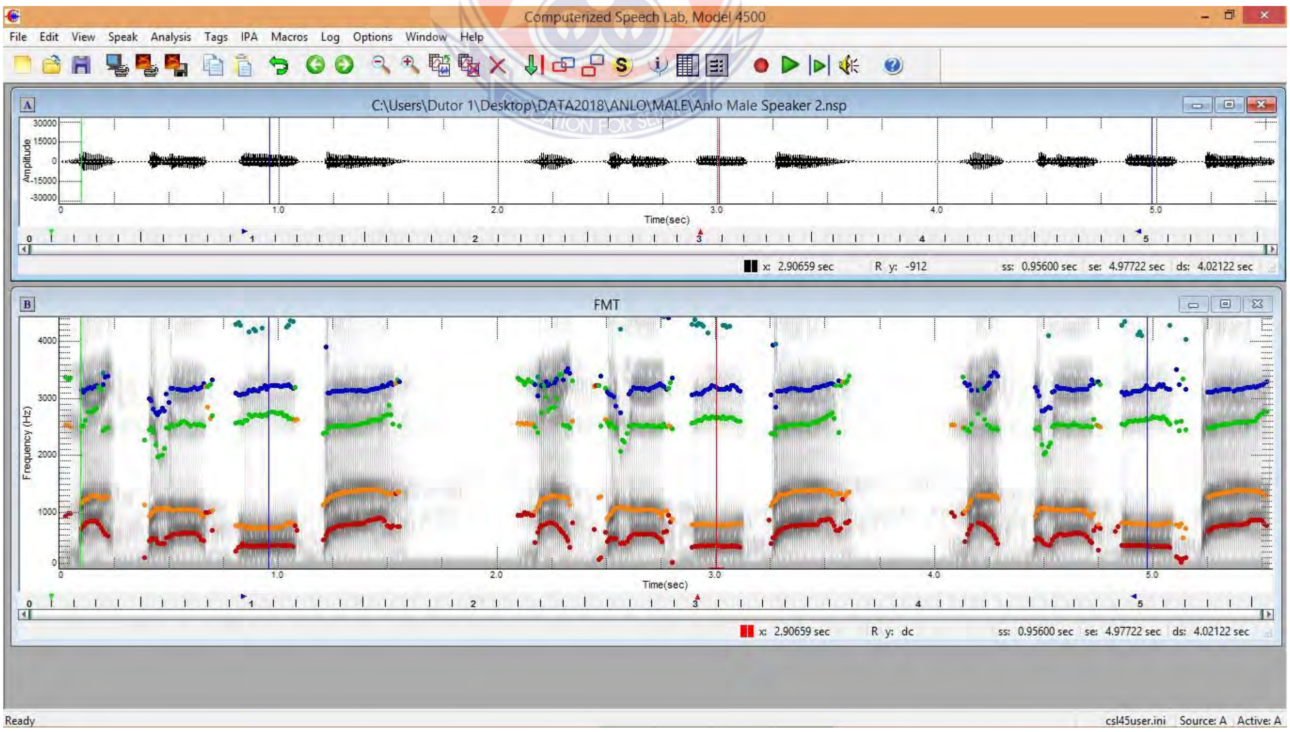
Waveform and spectrogram of Anlo male speaker 2 saying "*Magblɔ bɘ baa*" in three repetitions.



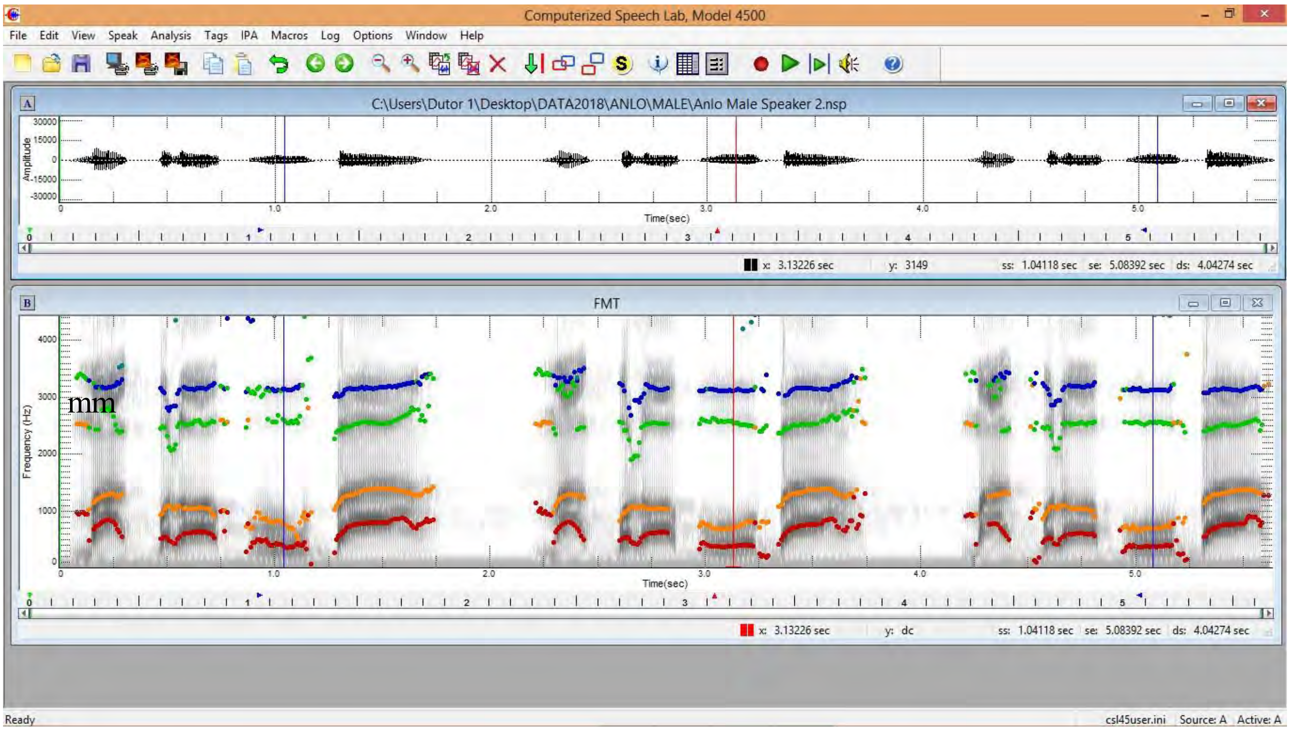
Waveform and spectrogram of Anlo male speaker 2 saying "*Magblɔ ba baa*" in three repetitions.



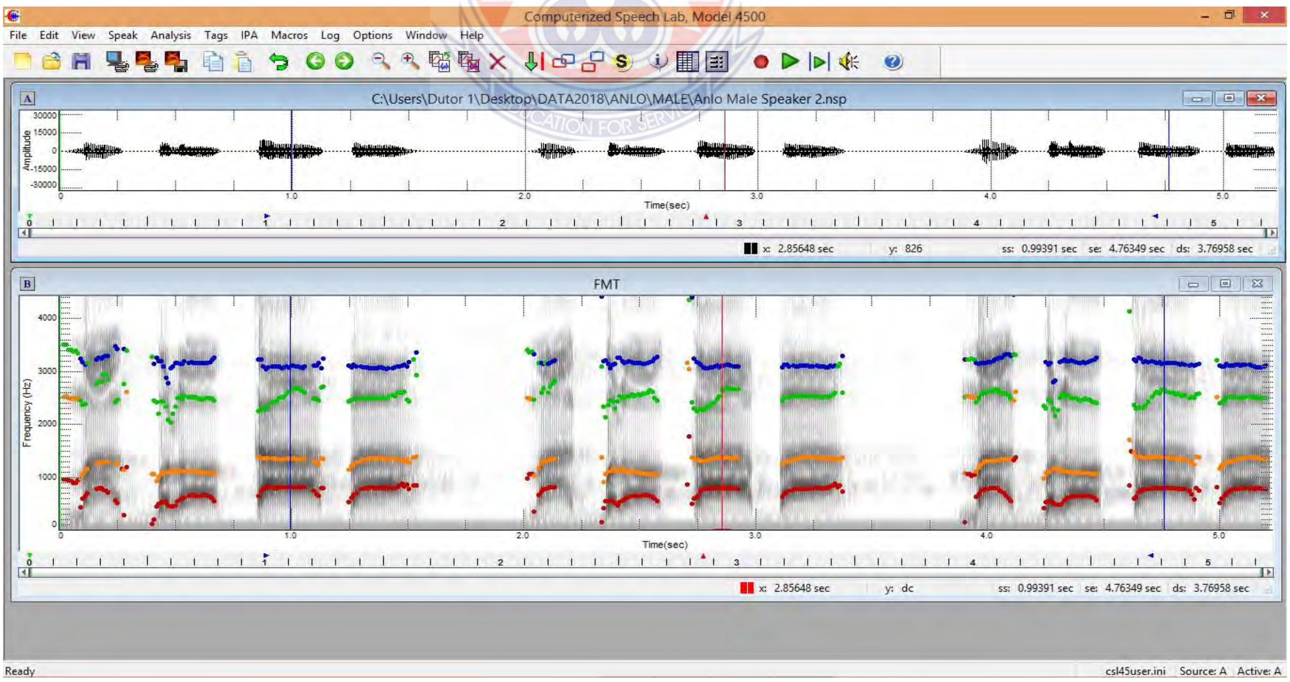
Waveform and spectrogram of Anlo male speaker 2 saying "*Magblɔ bɔ baa*" in three repetitions.



Waveform and spectrogram of Anlo male speaker 2 saying "*Magblɔ bo baa*" in three repetitions.

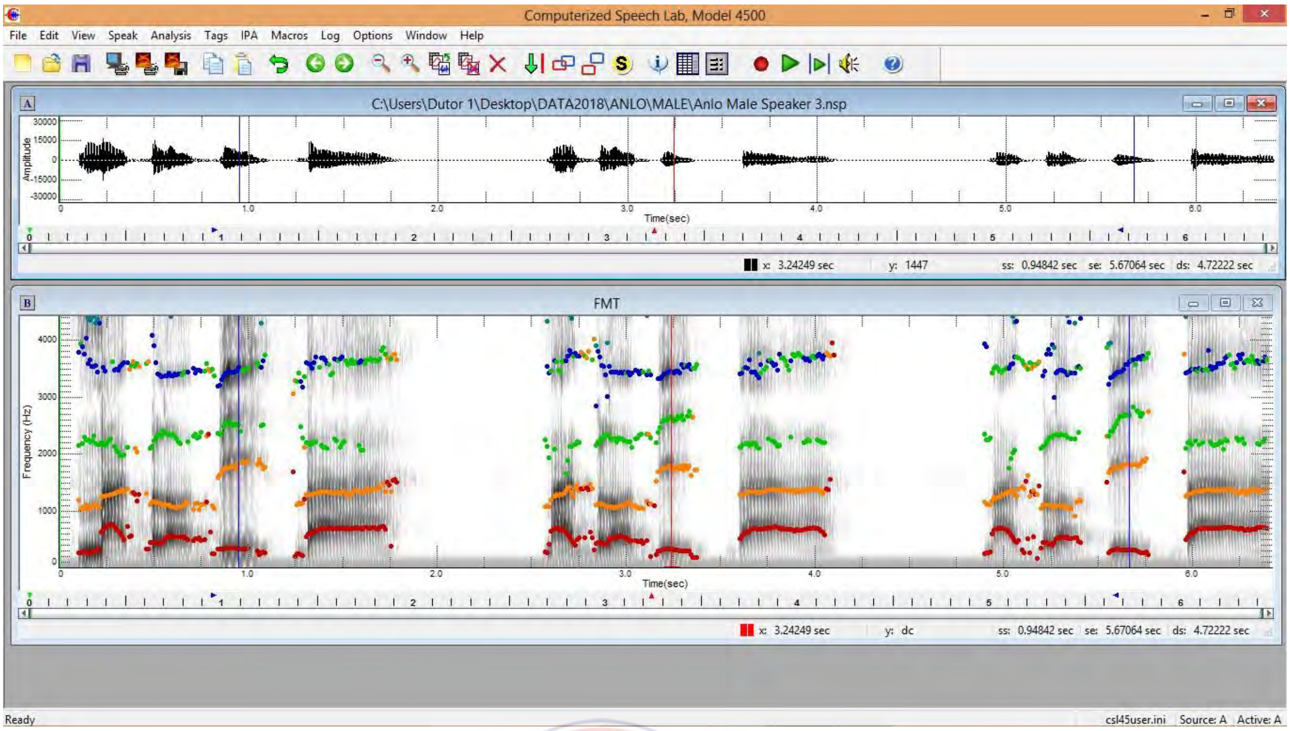


Waveform and spectrogram of Anlo male speaker 2 saying “*Magblɔ bu baa*” in three repetitions.

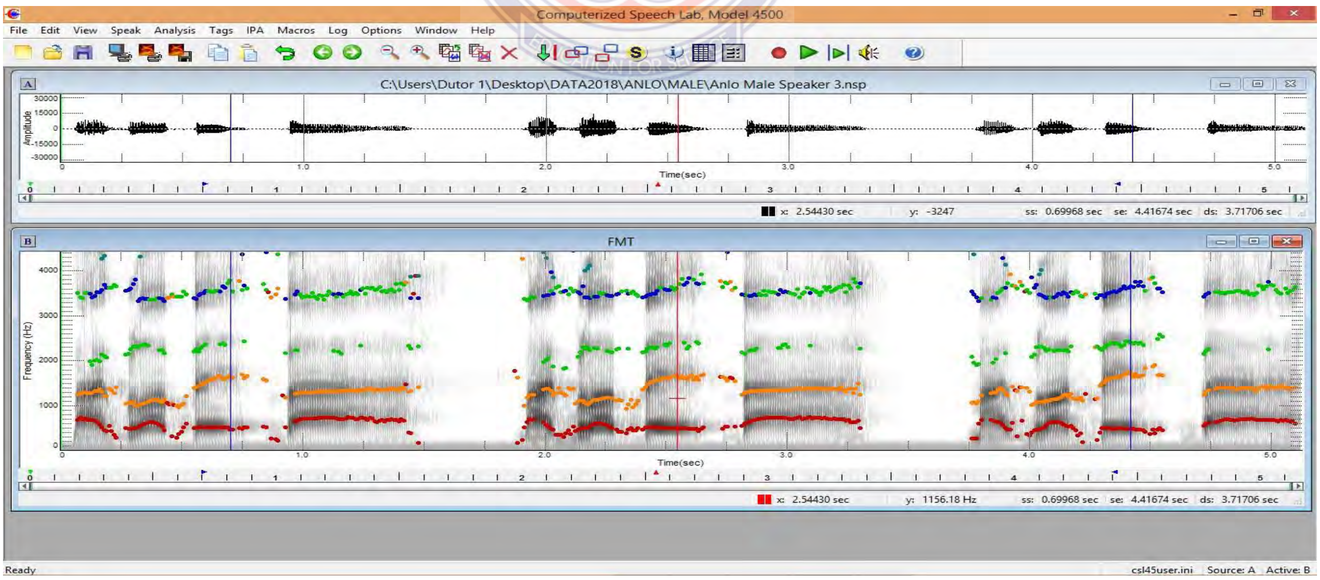


Waveform and spectrogram of Anlo male speaker 2 saying “*Magblɔ ka baa*” in three repetitions.

3. Spectrograms of Anlo male speaker 3

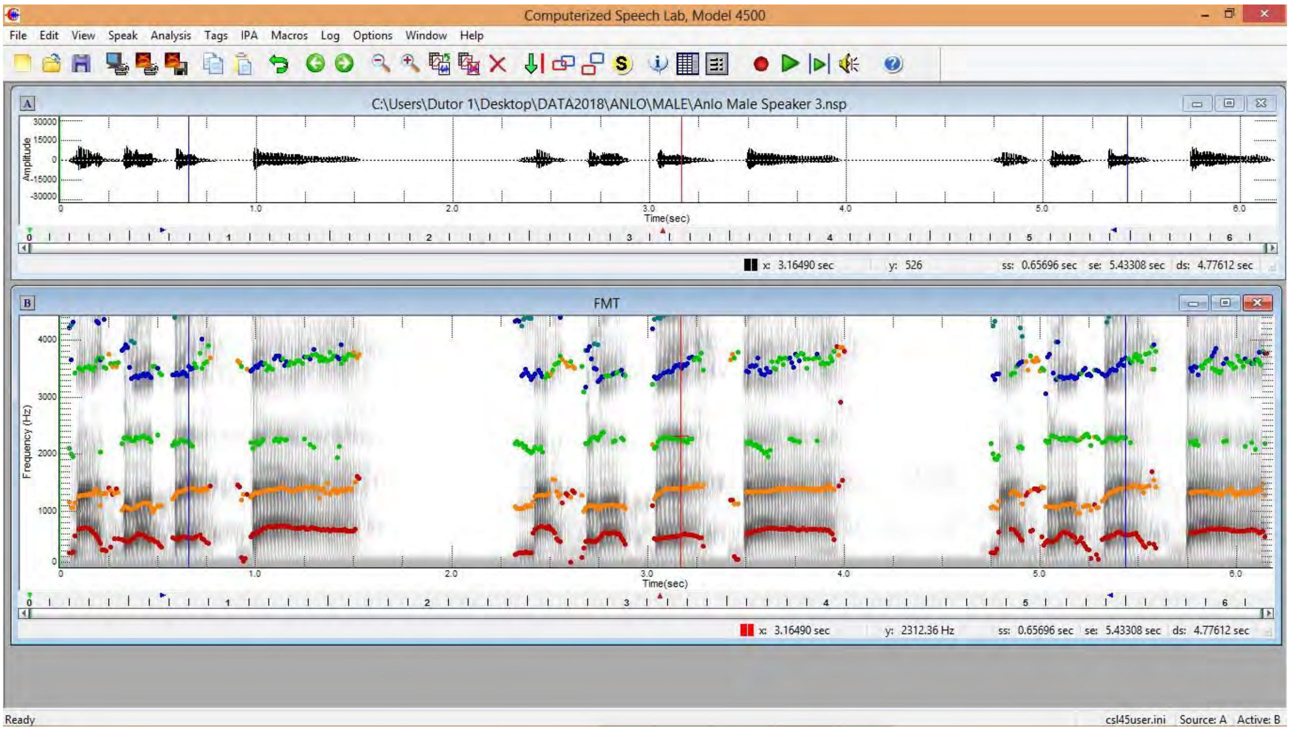


Waveform and spectrogram of Anlo male speaker 3 saying “*Magblɔ bi baa*” in three repetitions.

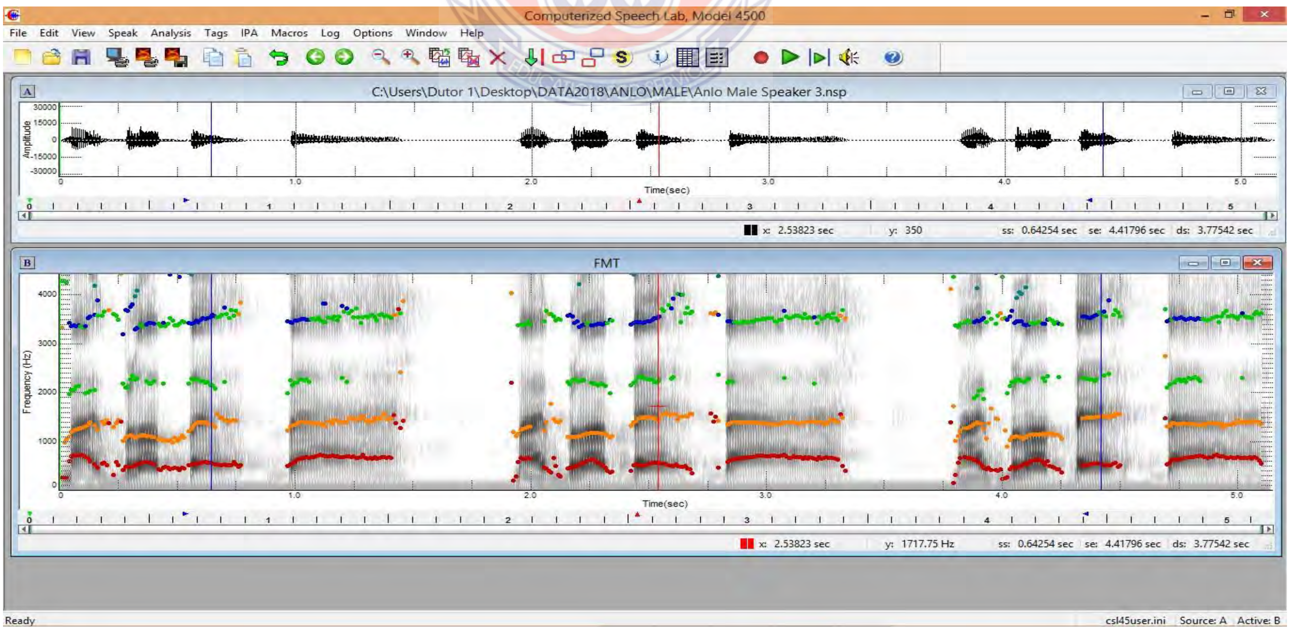


Waveform and spectrogram of Anlo male speaker 3 saying “*Magblɔ be baa*” in three

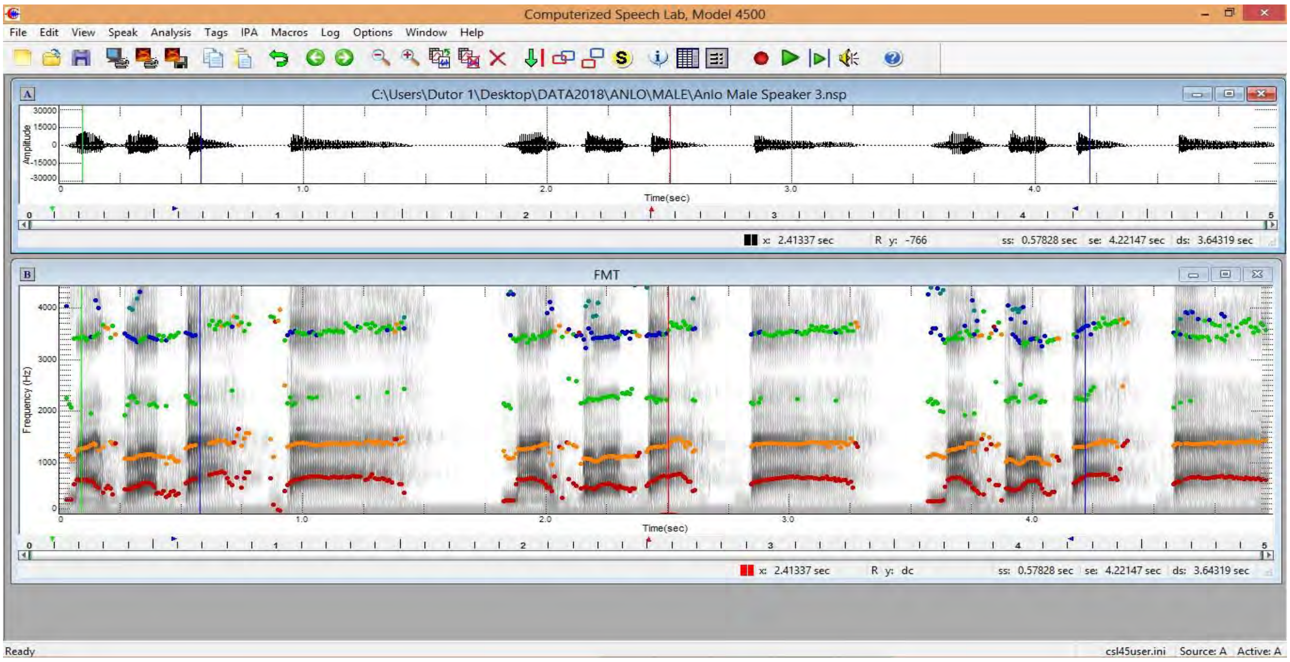
repetitions.



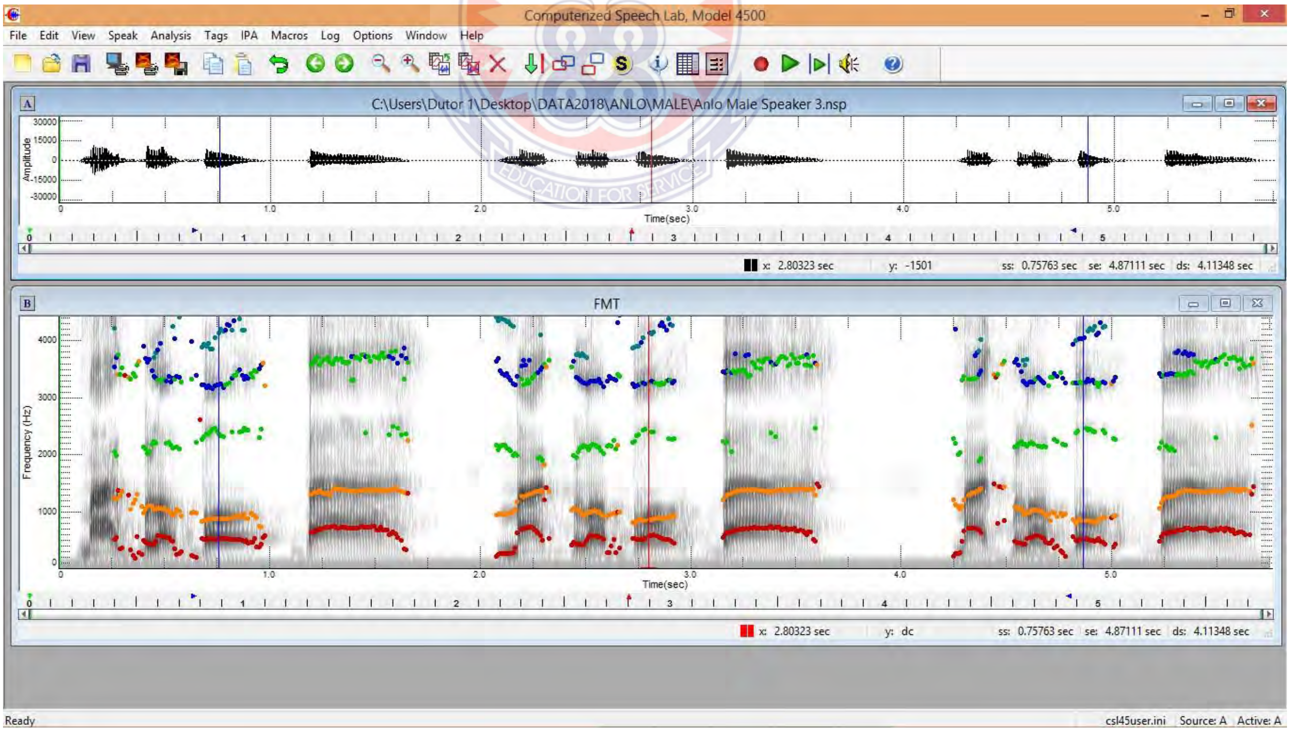
Waveform and spectrogram of Anlo male speaker 3 saying "*Magblɔ bɛ baa*" in three repetitions.



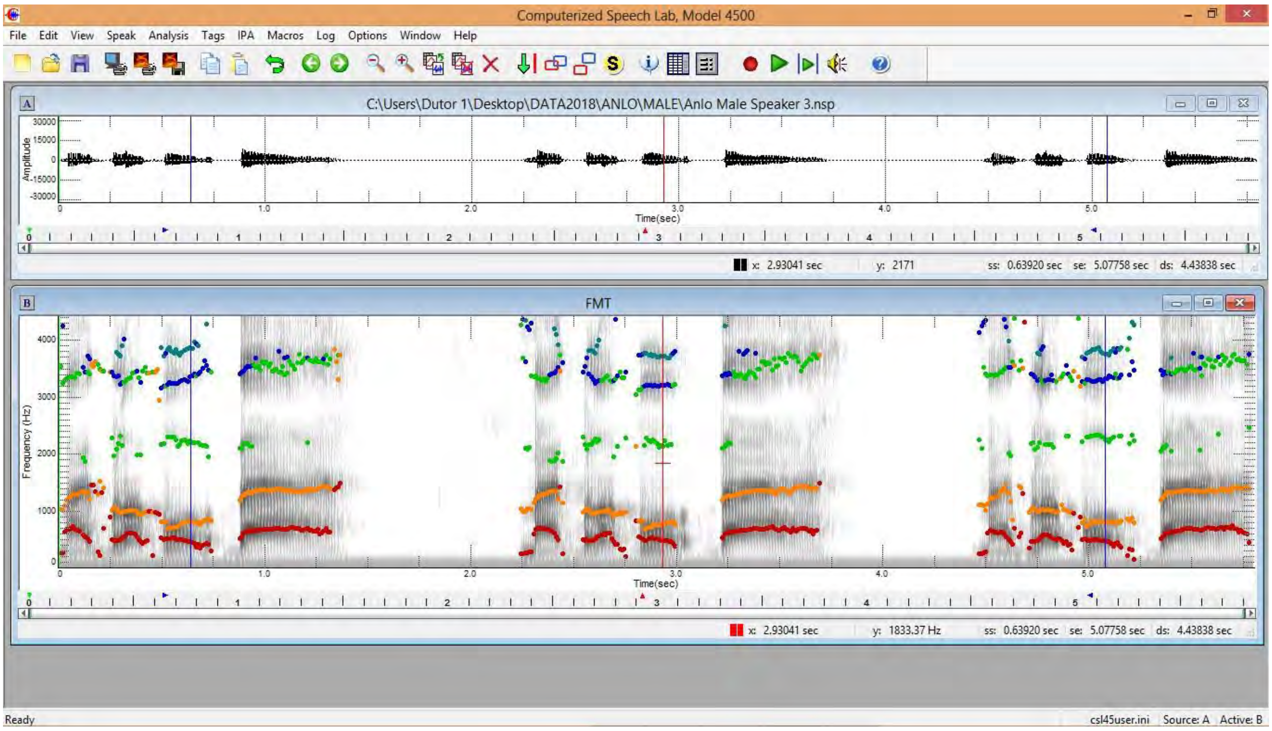
Waveform and spectrogram of Anlo male speaker 3 saying "*Magblɔ bɘ baa*" in three repetitions.



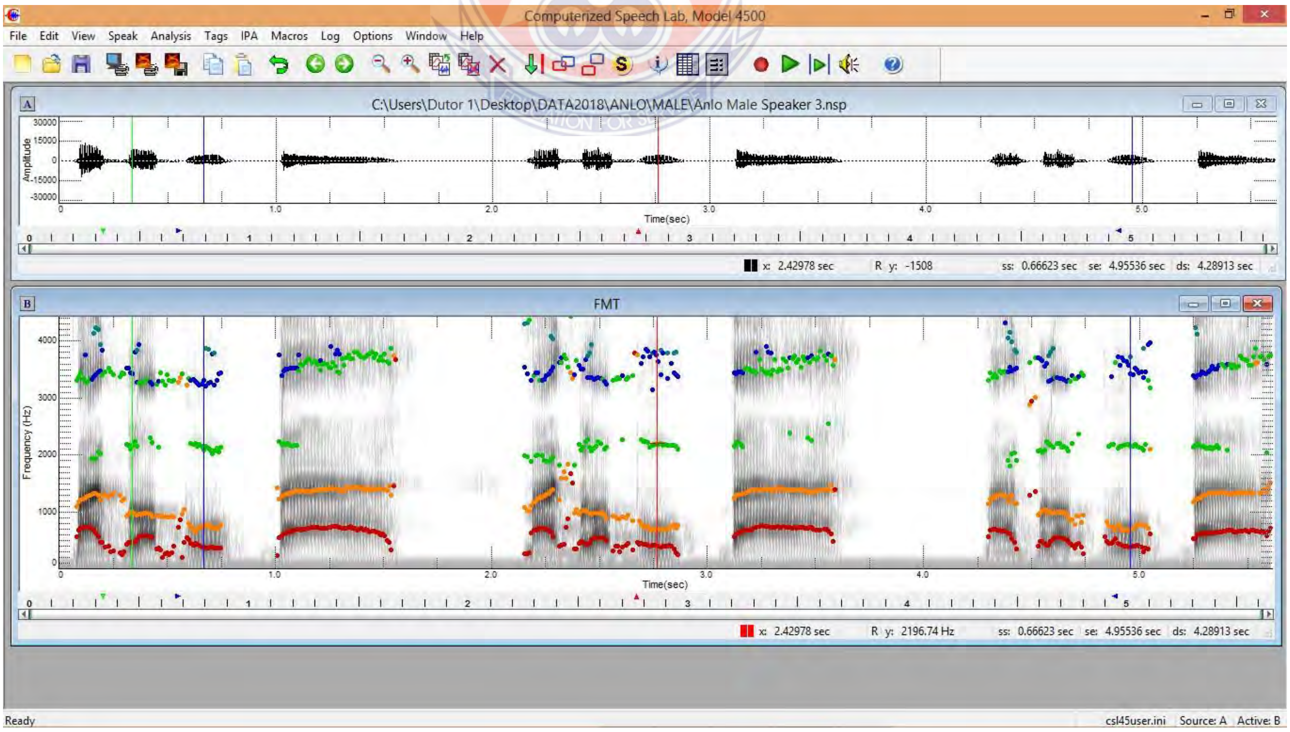
Waveform and spectrogram of Anlo male speaker 3 saying "*Magblɔ ba baa*" in three repetitions.



Waveform and spectrogram of Anlo male speaker 3 saying "*Magblɔ bɔ baa*" in three repetitions.

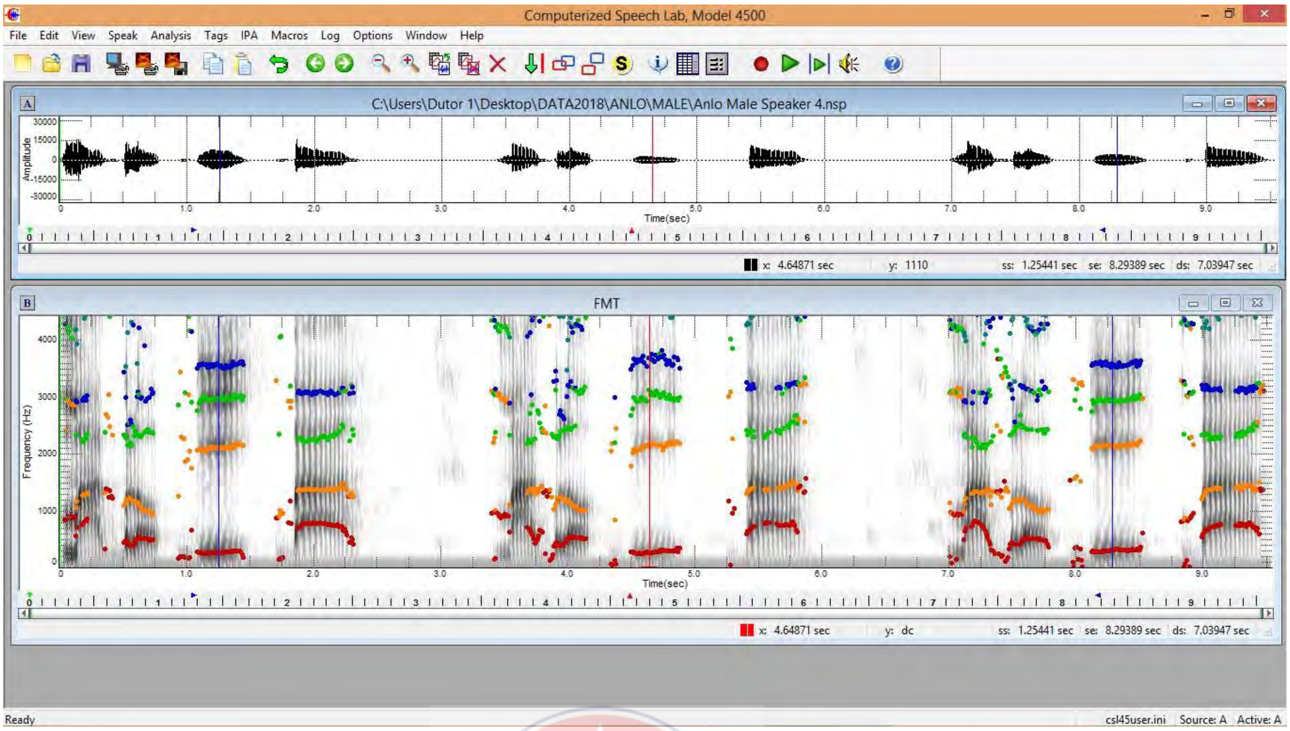


Waveform and spectrogram of Anlo male speaker 3 saying "*Magblɔ bo baa*" in three repetitions.

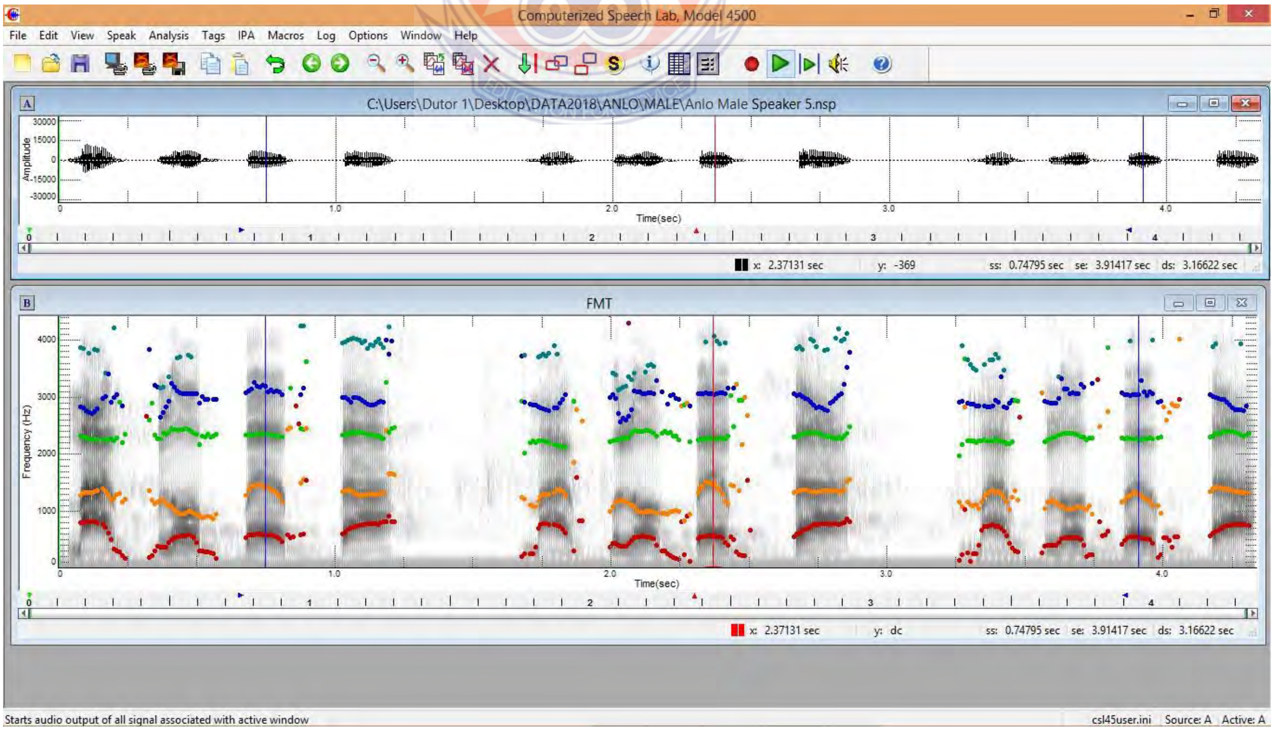


Waveform and spectrogram of Anlo male speaker 3 saying "*Magblɔ bu baa*" in three repetitions.

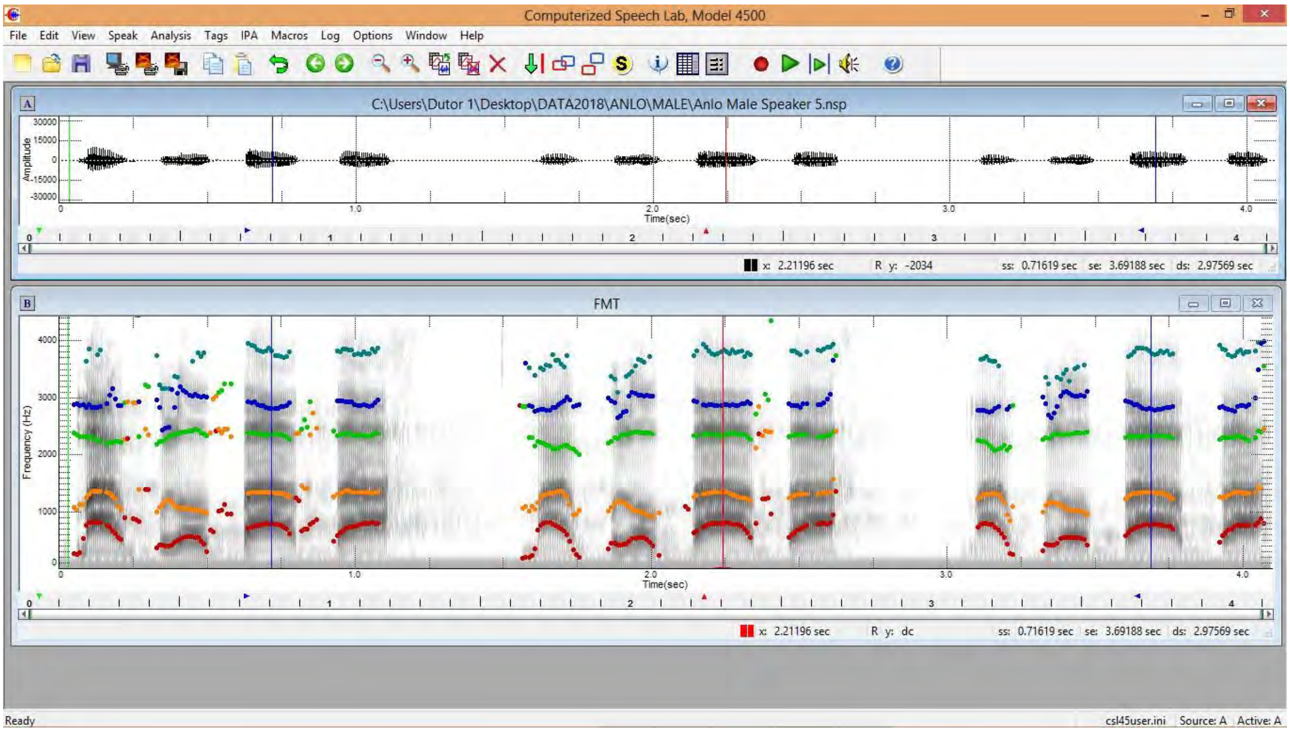
4. Spectrograms of Anlo male speaker 4



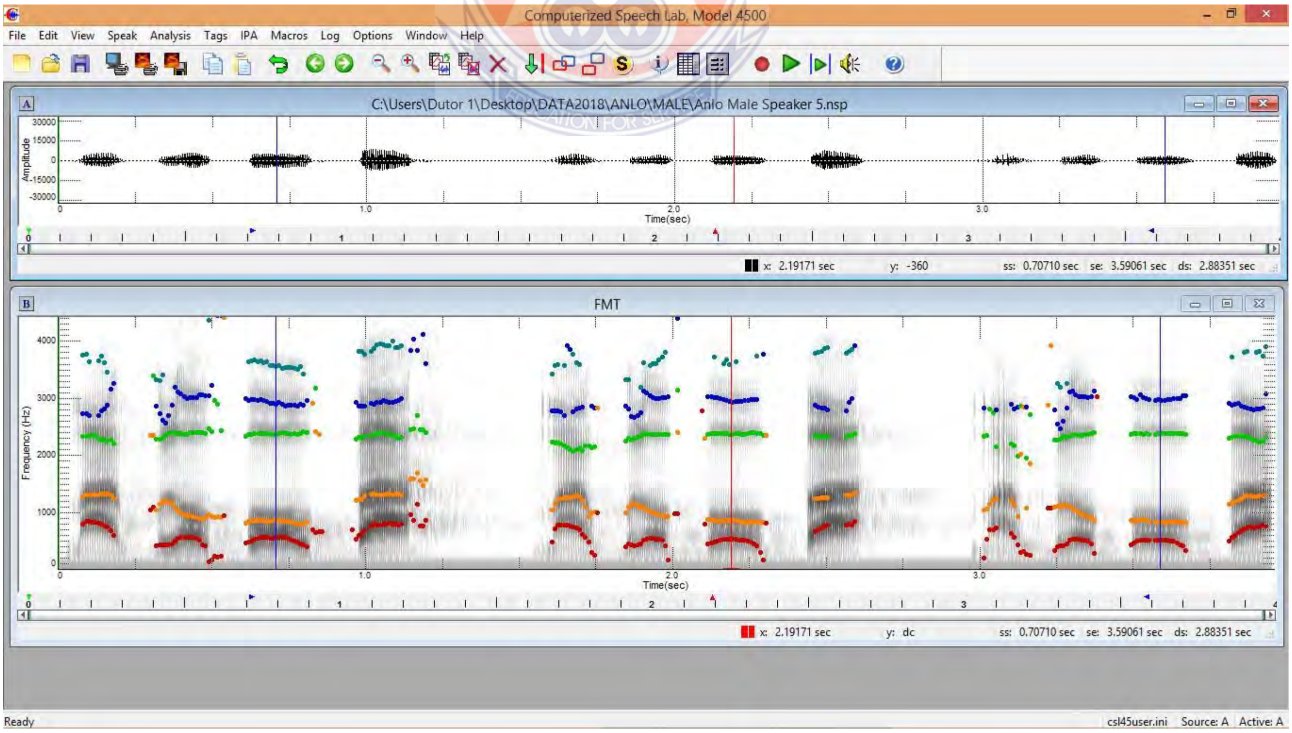
Waveform and spectrogram of Anlo male speaker 4 saying "*Magblɔ bi baa*" in three repetitions.



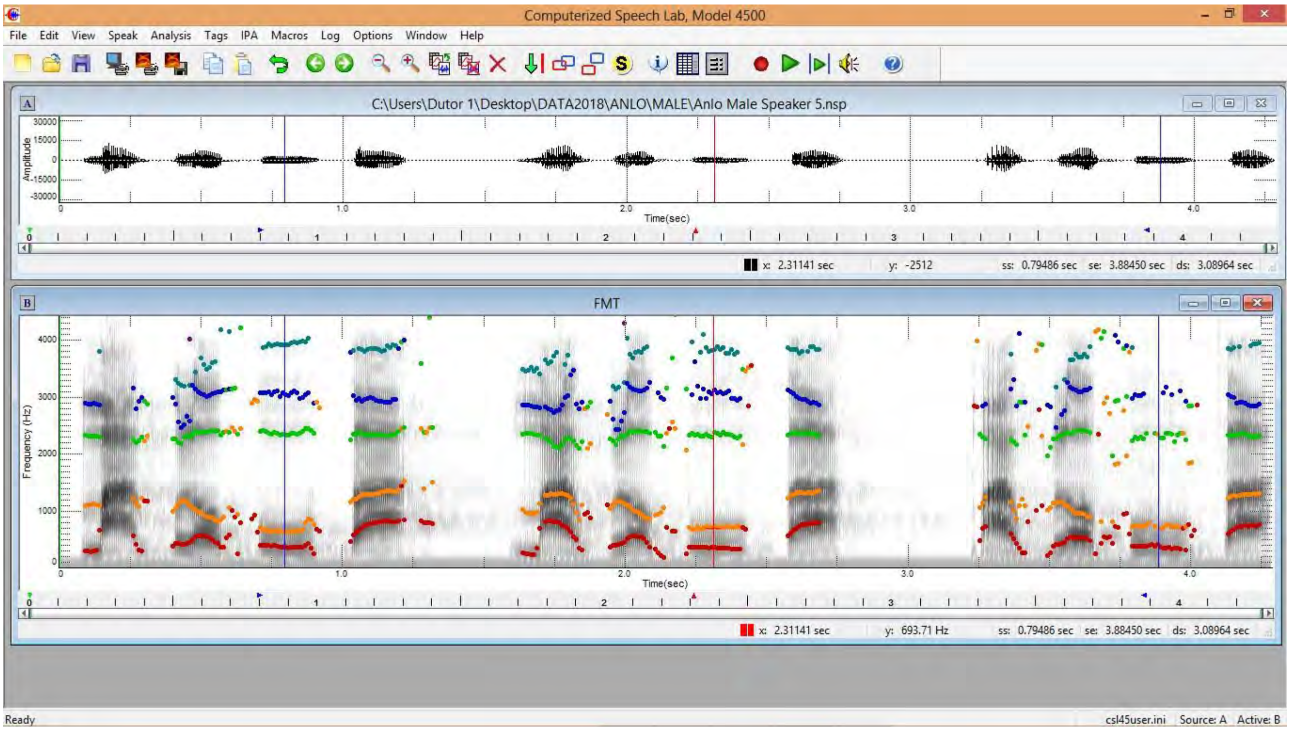
Waveform and spectrogram of Anlo male speaker 4 saying "*Magblɔ bɛ baa*" in three repetitions.



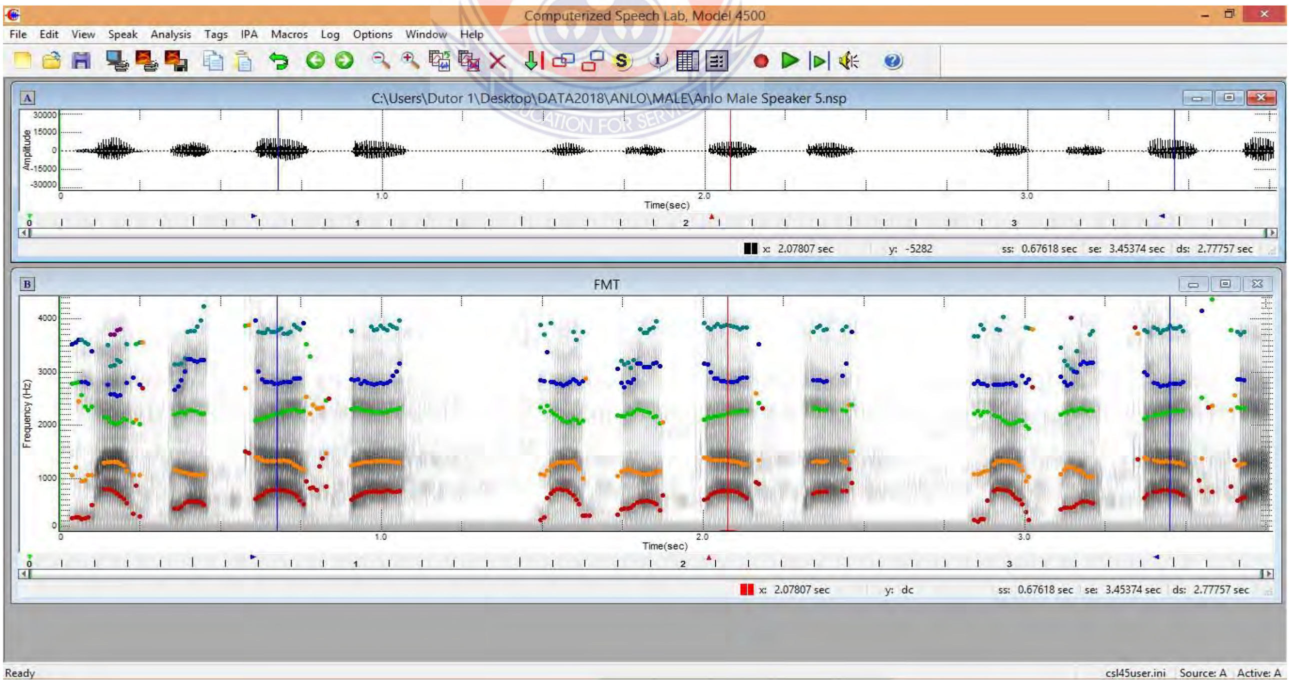
Waveform and spectrogram of Anlo male speaker 4 saying "*Magblɔ ba baa*" in three repetitions.



Waveform and spectrogram of Anlo male speaker 4 saying "*Magblɔ bɔ baa*" in three repetitions.

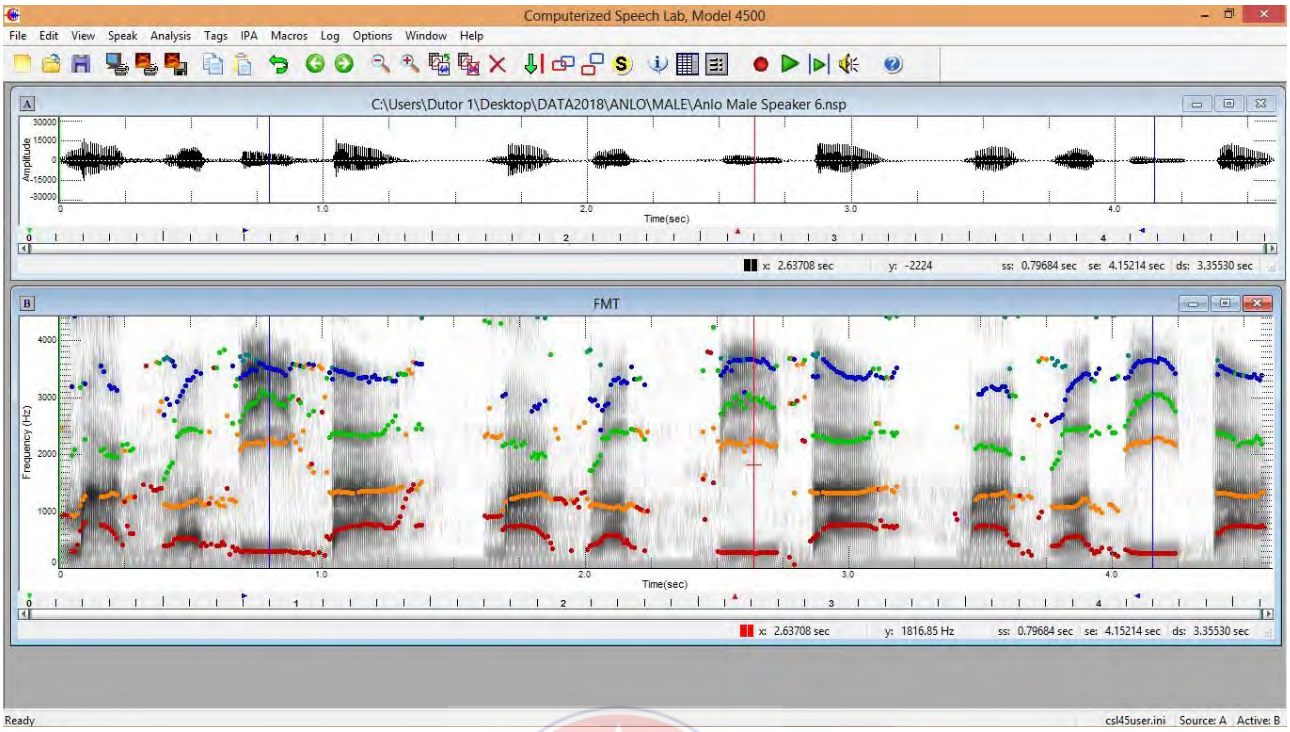


Waveform and spectrogram of Anlo male speaker 4 saying “*Magblɔ bo baa*” in three repetitions.

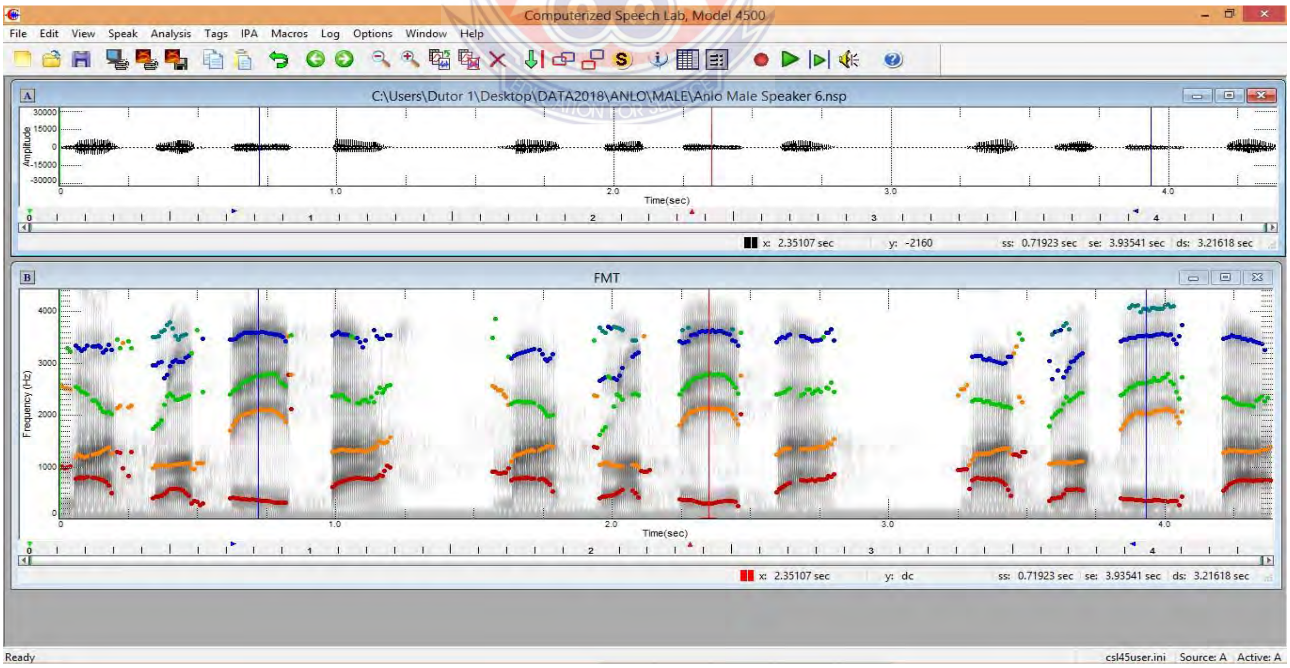


Waveform and spectrogram of Anlo male speaker 4 saying “*Magblɔ ka baa*” in three repetitions.

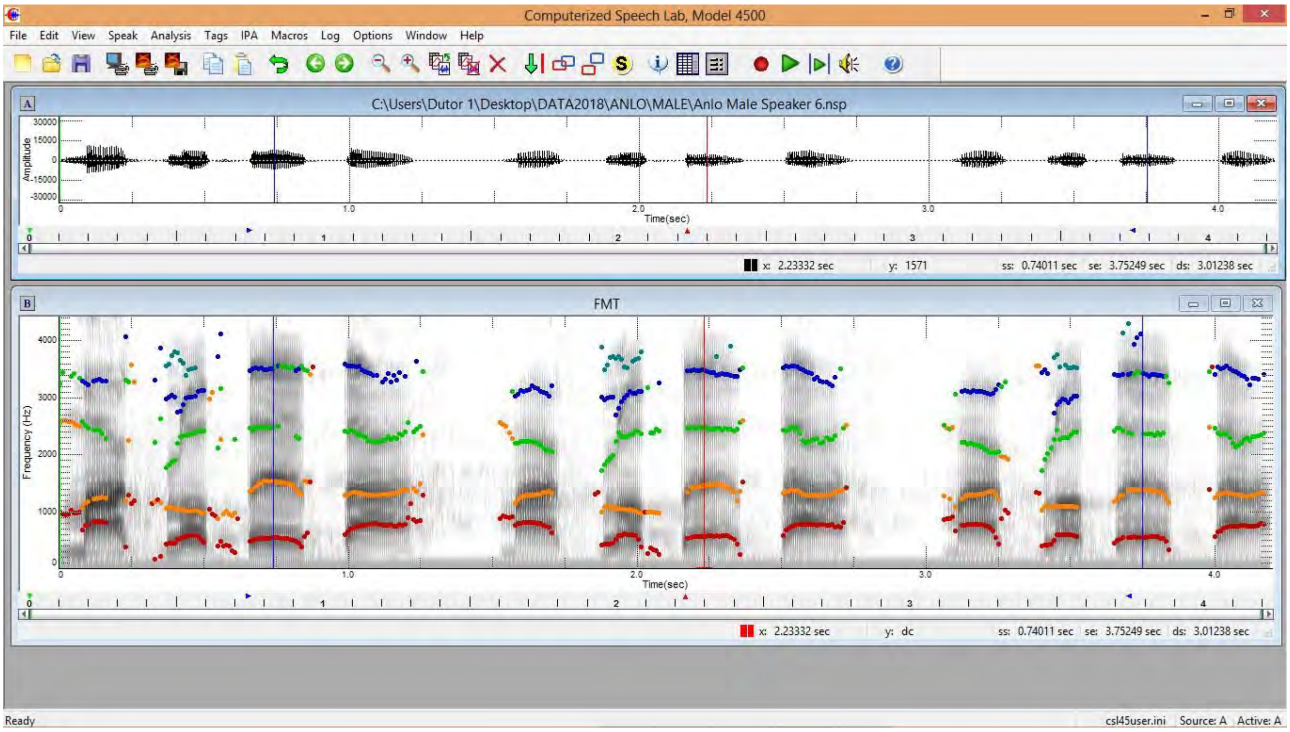
5. Spectrograms of Anlo male speaker 5



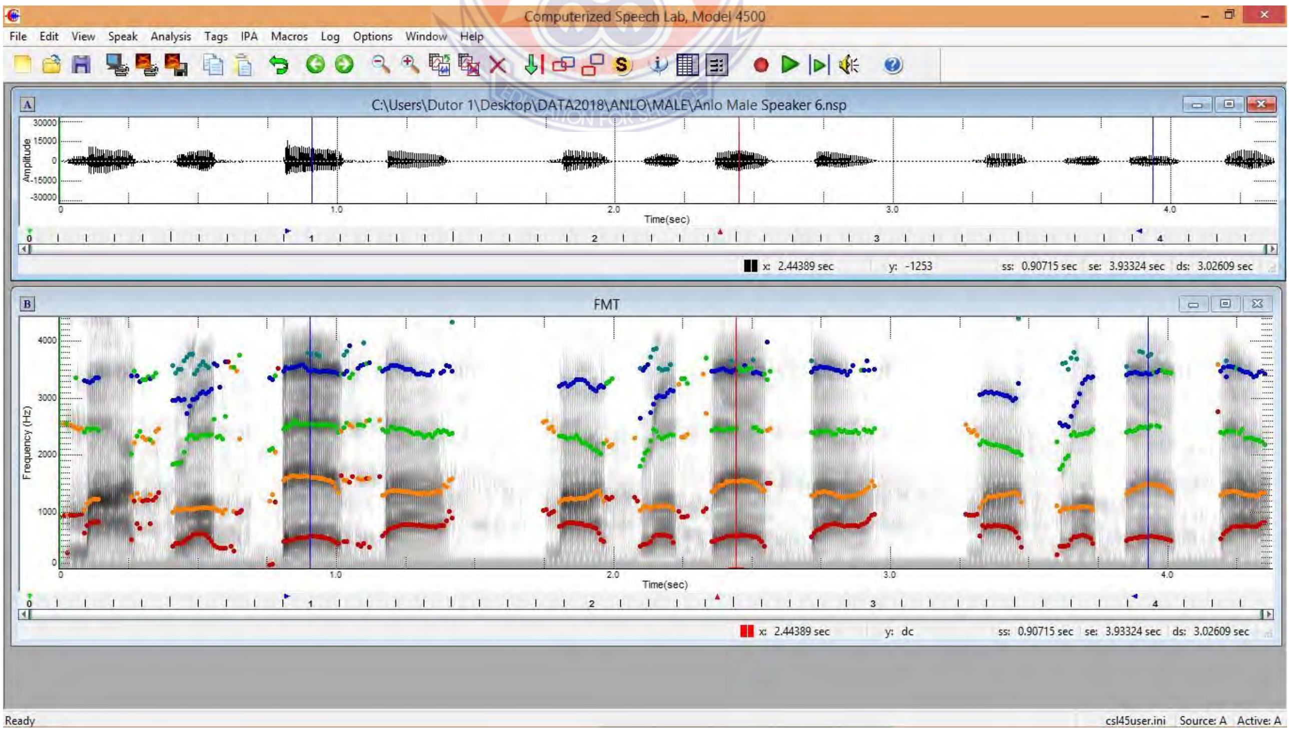
Waveform and spectrogram of Anlo male speaker 5 saying "*Magblɔ bi baa*" in three repetitions.



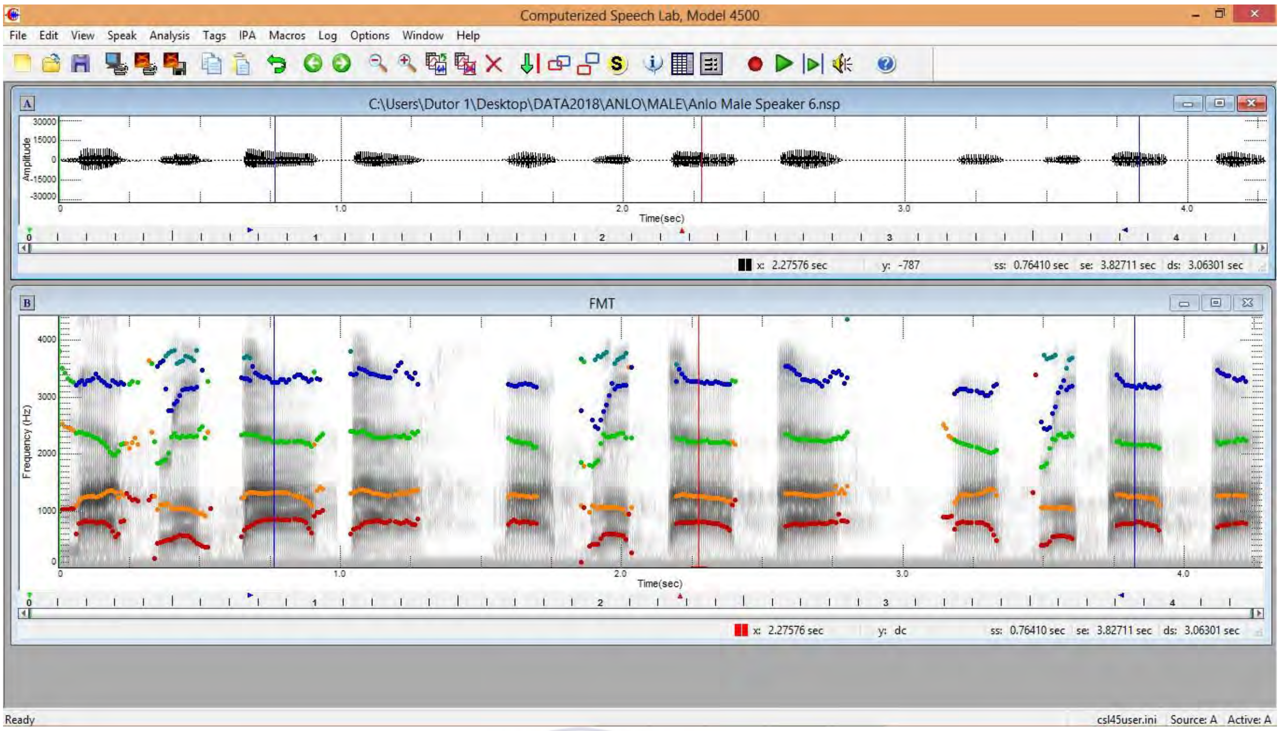
Waveform and spectrogram of Anlo male speaker 5 saying "*Magblɔ be baa*" in three repetitions.



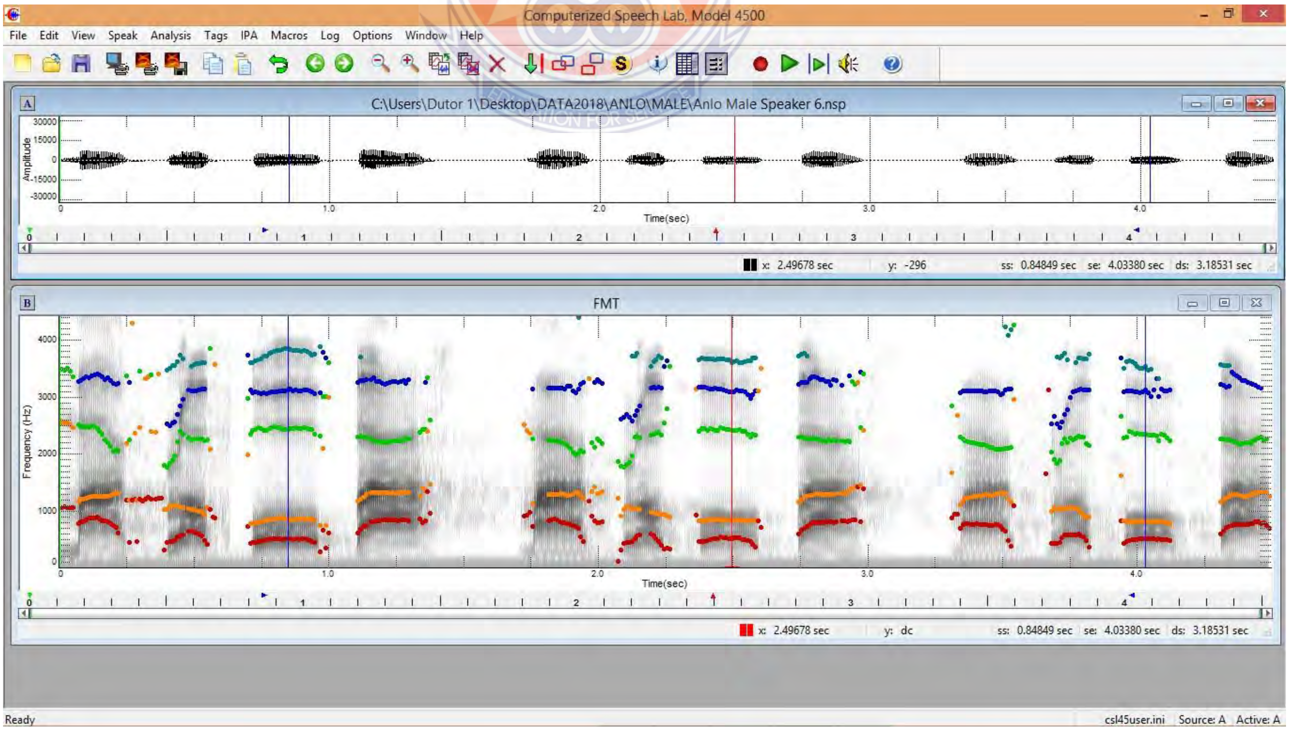
Waveform and spectrogram of Anlo male speaker 5 saying “*Magblɔ bɛ baa*” in three repetitions.



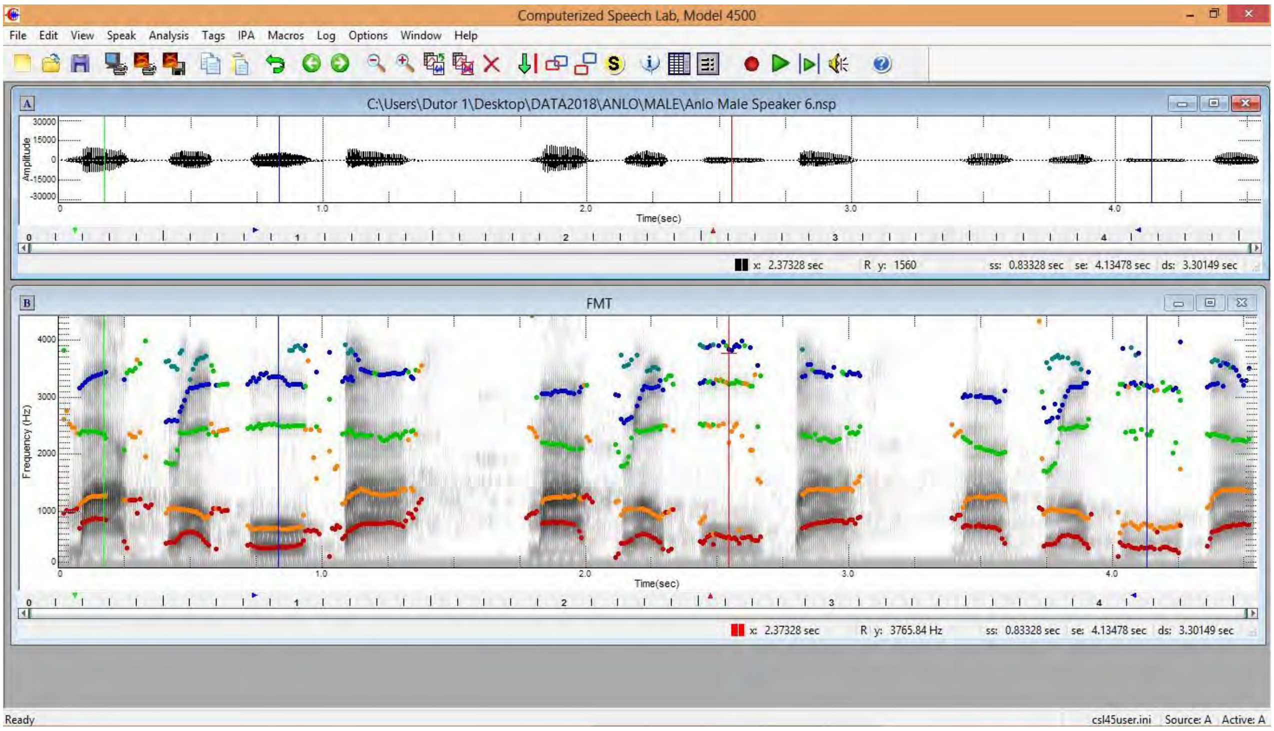
Waveform and spectrogram of Anlo male speaker 5 saying “*Magblɔ bɘ baa*” in three repetitions.



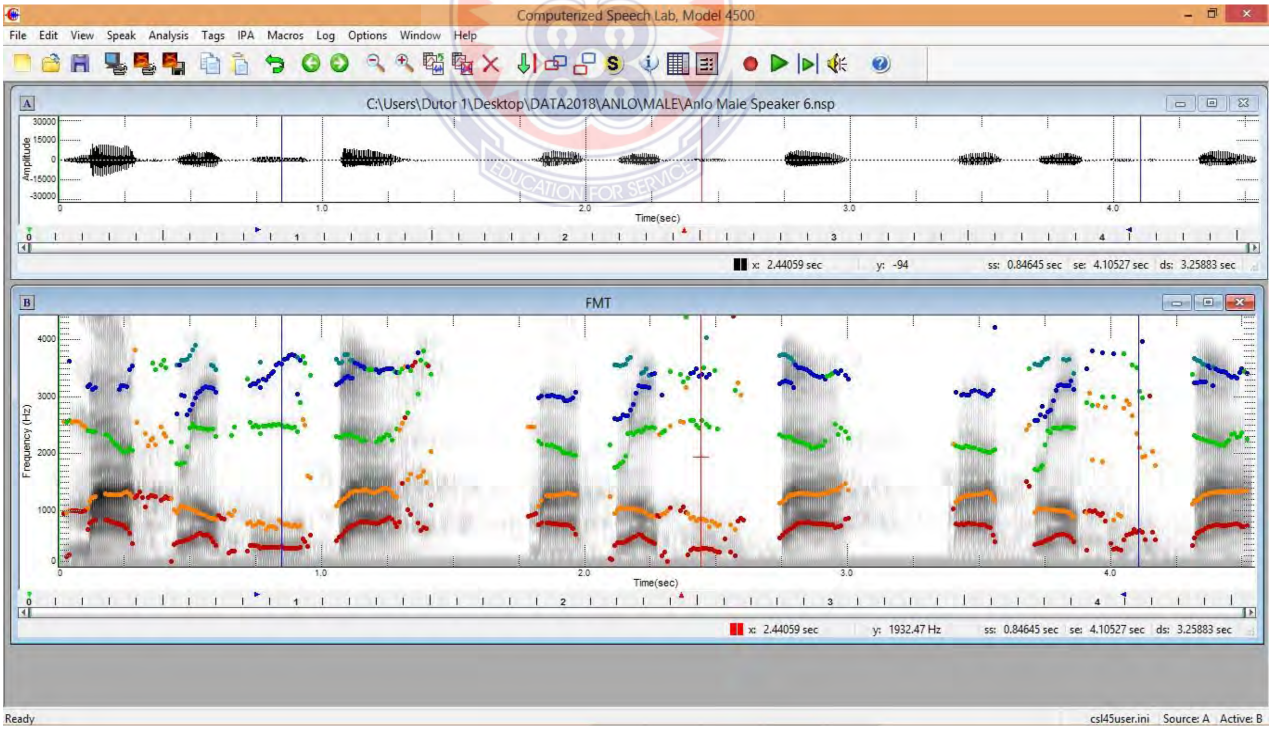
Waveform and spectrogram of Anlo male speaker 5 saying “*Magblɔ ba baa*” in three repetitions.



Waveform and spectrogram of Anlo male speaker 5 saying “*Magblɔ bɔ baa*” in three repetitions.

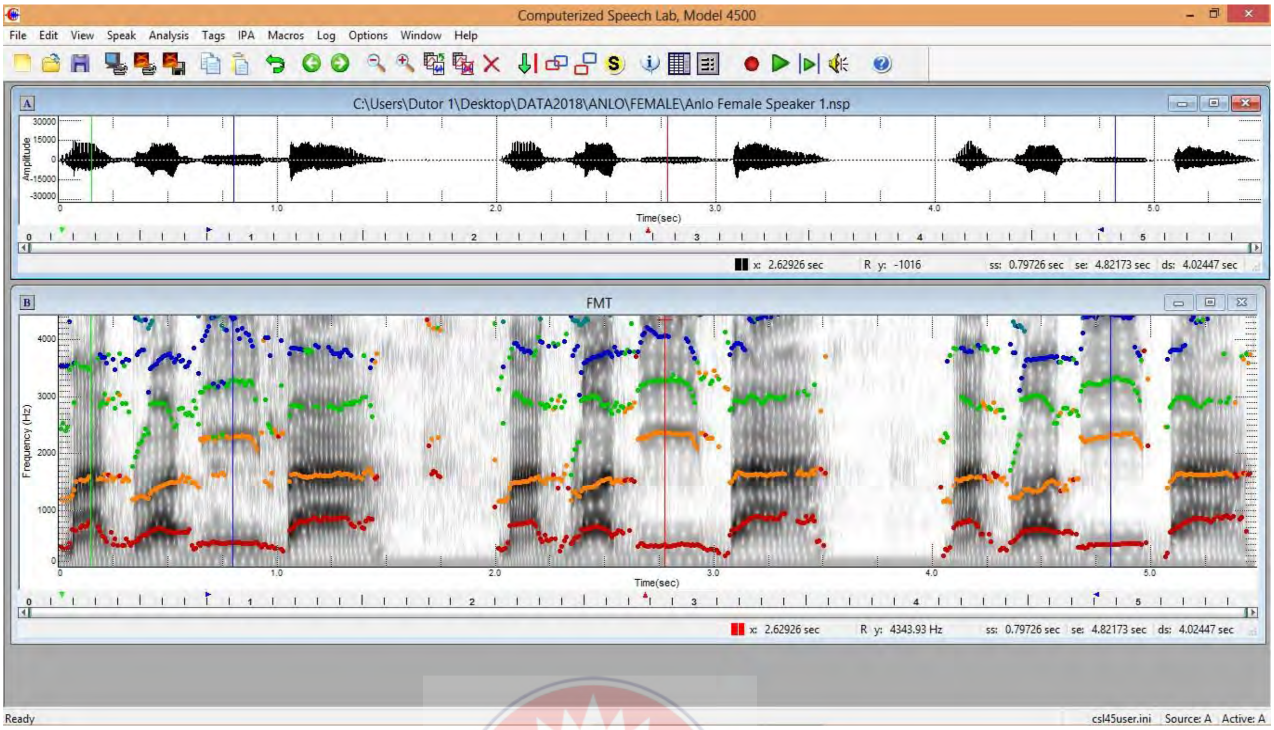


Waveform and spectrogram of Anlo male speaker 5 saying "*Magblɔ bo baa*" in three repetitions.

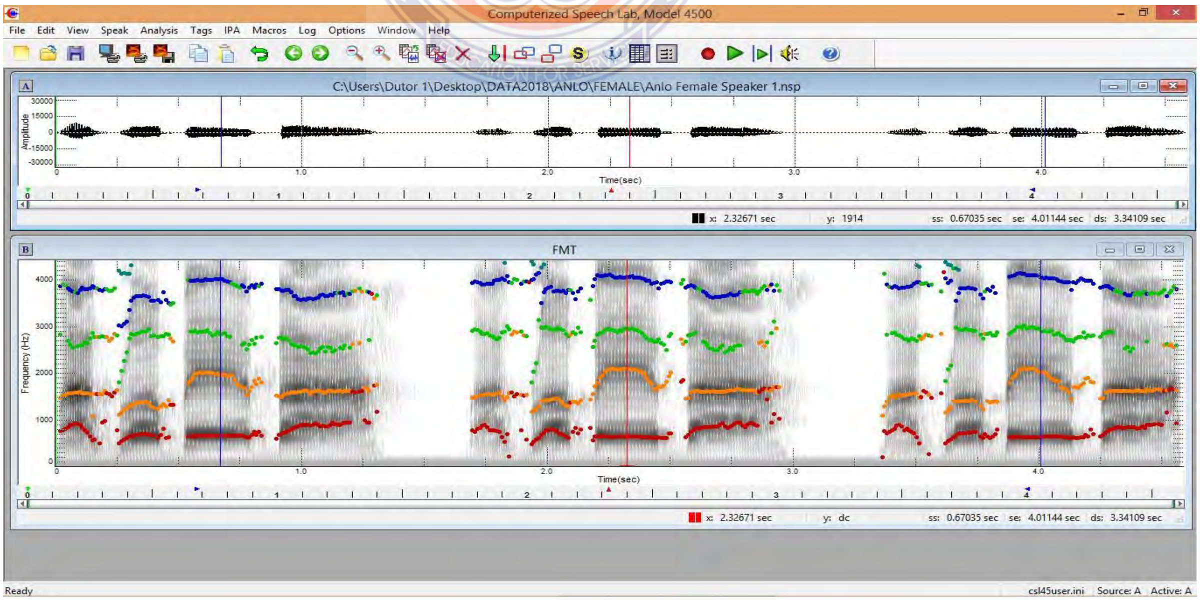


Waveform and spectrogram of Anlo male speaker 5 saying "*Magblɔ bu baa*" in three repetitions.

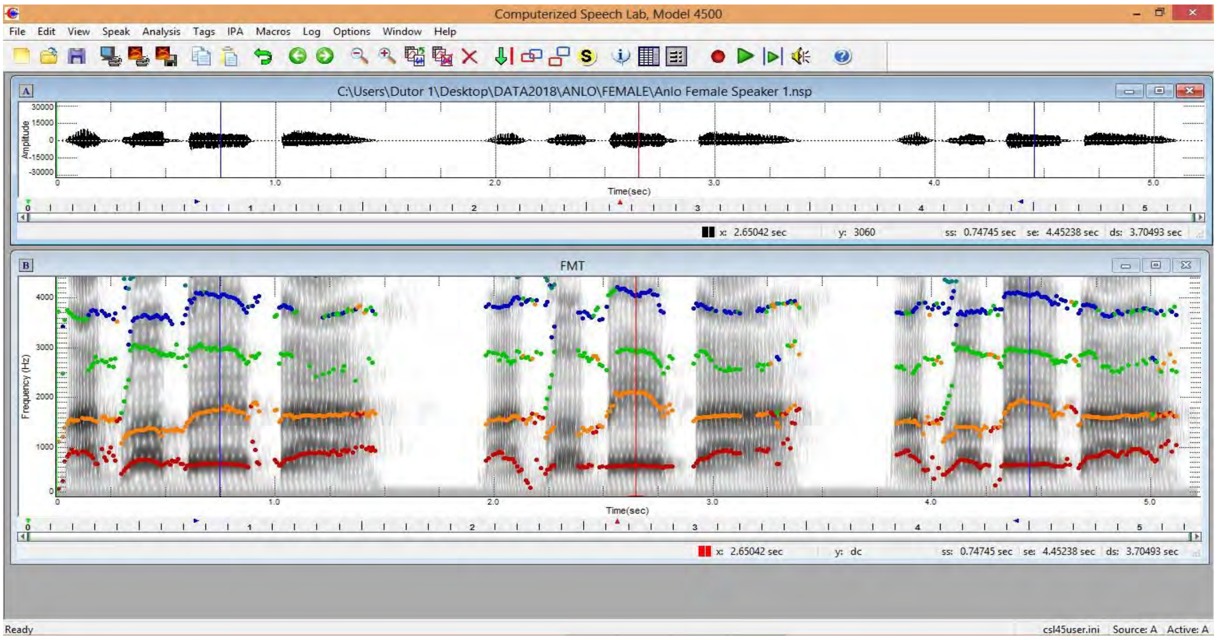
6. Spectrograms of Anlo female speaker 1



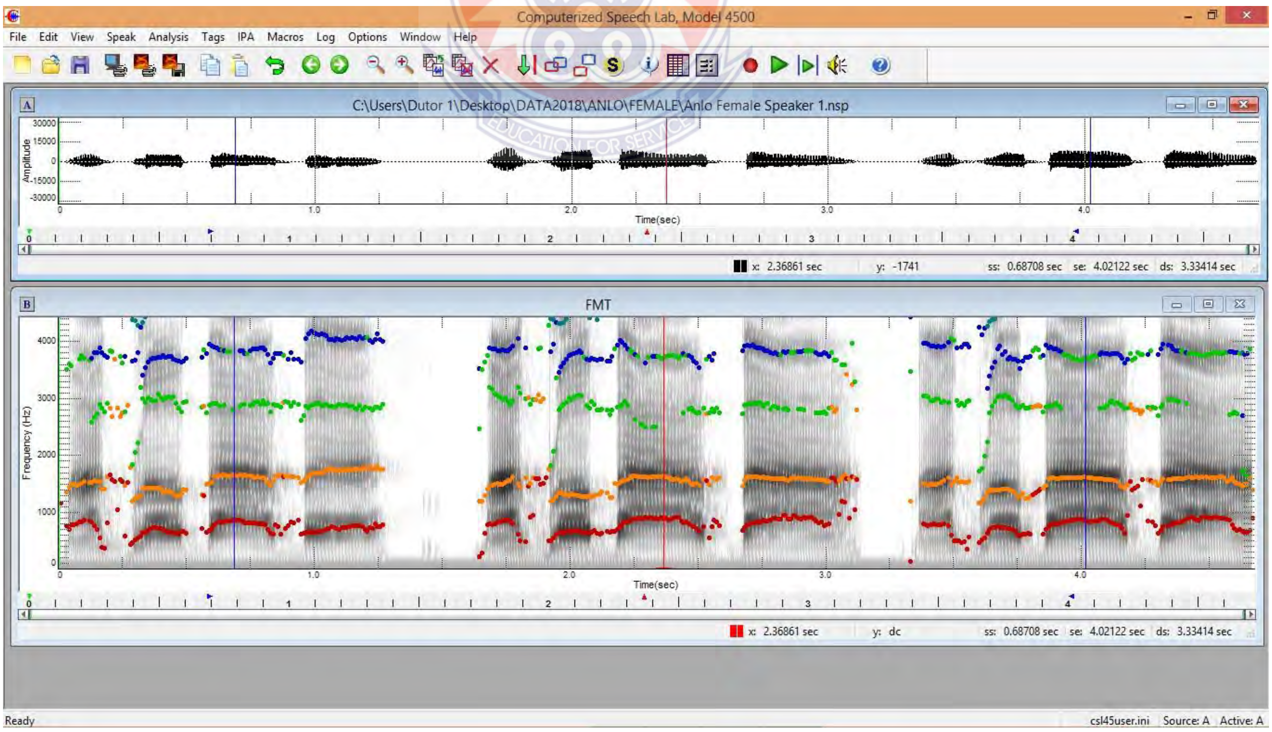
Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ bi baa*" in three repetitions.



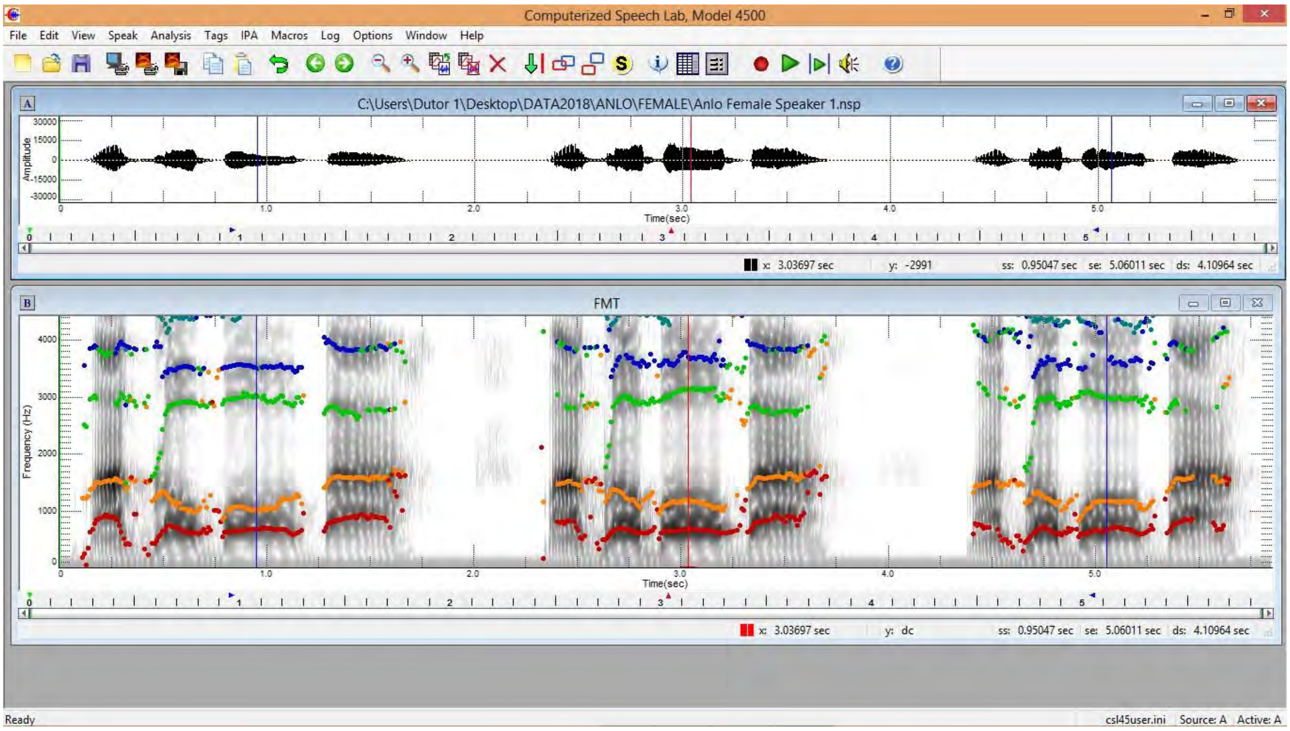
Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ be baa*" in three repetitions.



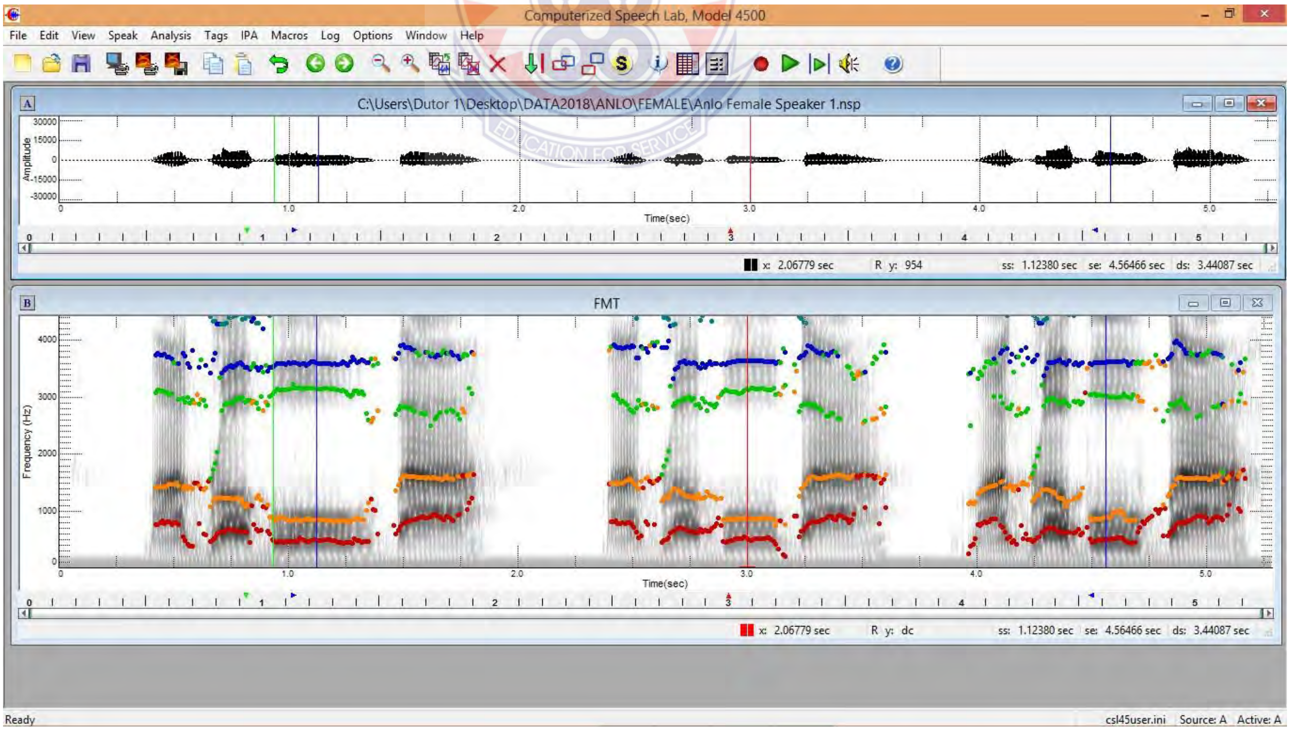
Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ bɛ baa*" in three repetitions.



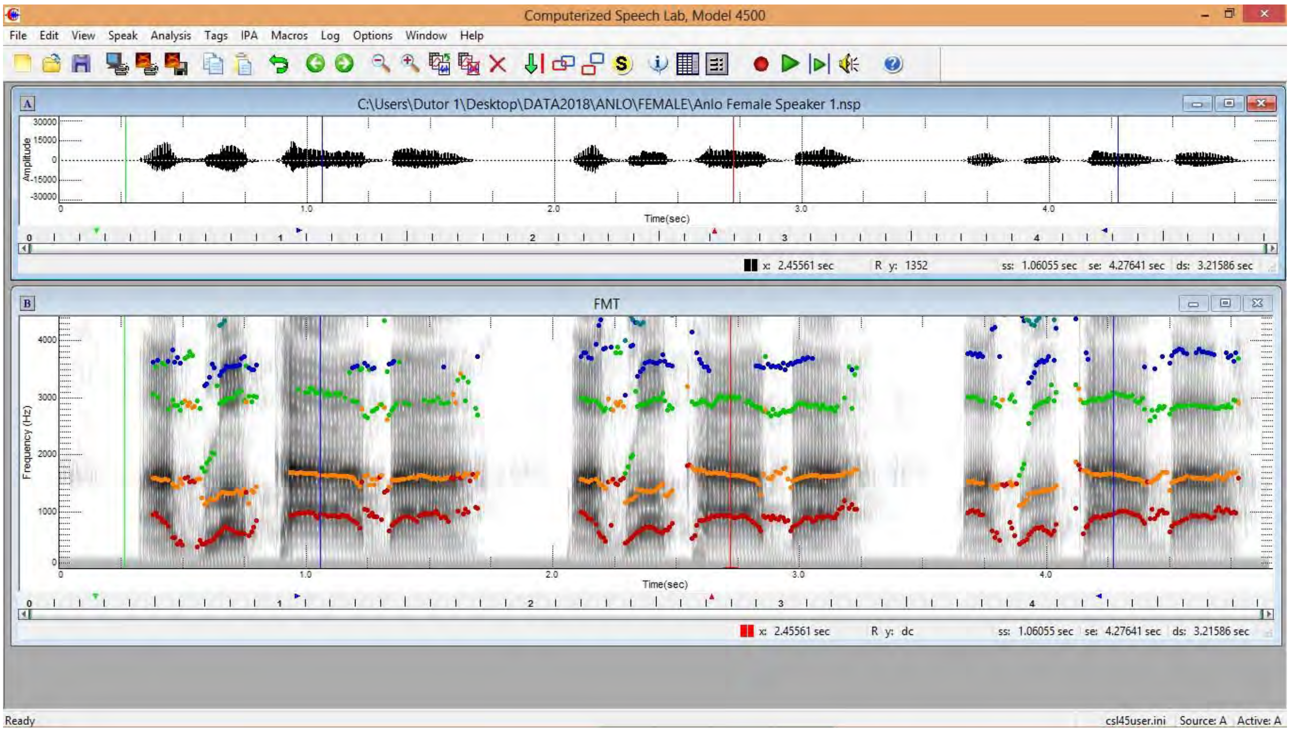
Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ ba baa*" in three repetitions.



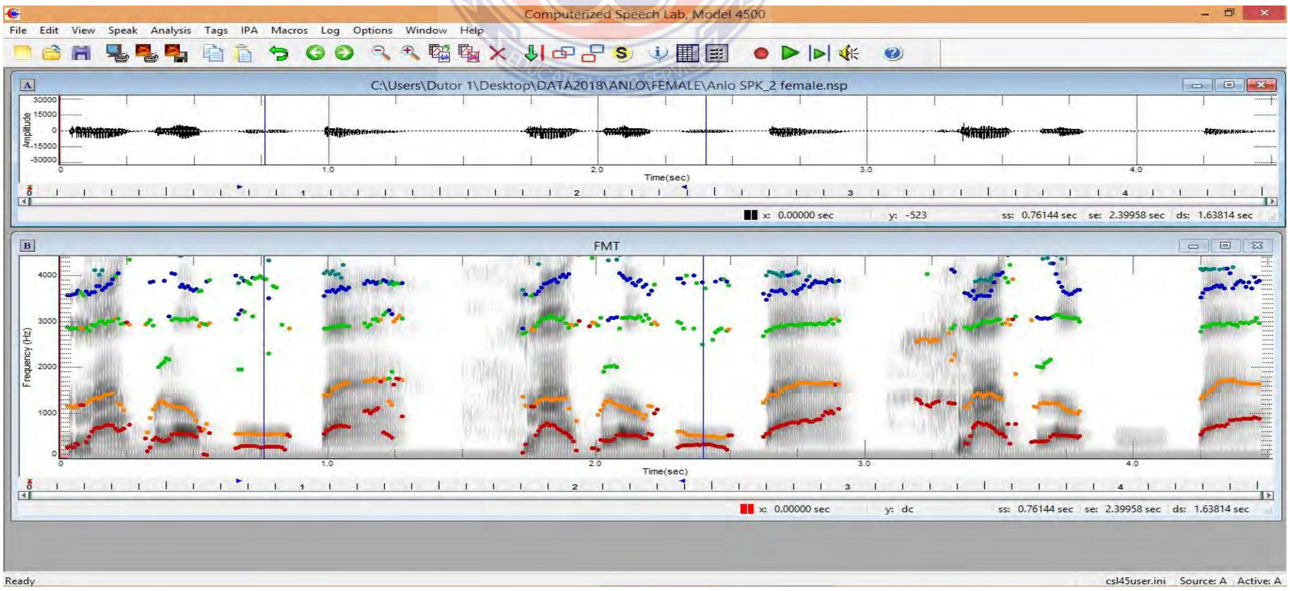
Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ bɔ baa*" in three repetitions.



Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ bo baa*" in three repetitions.

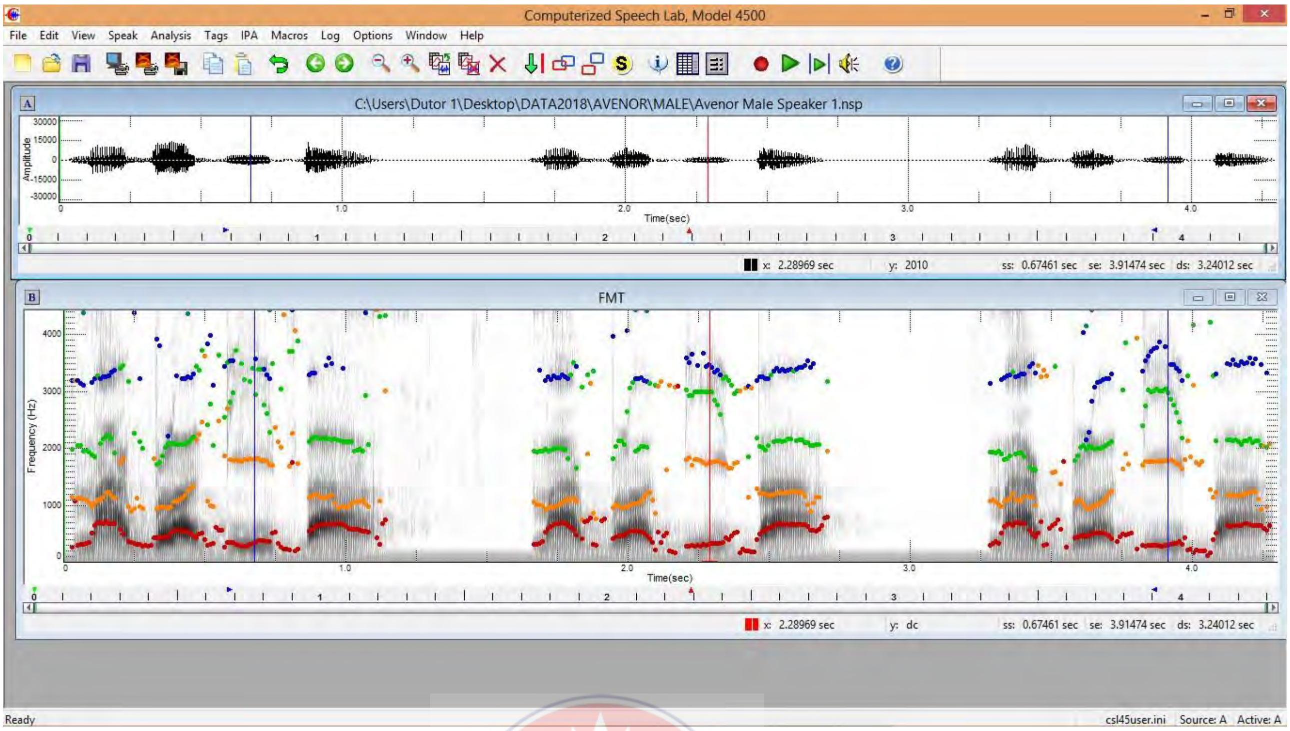


Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ ka baa*" in three repetitions.

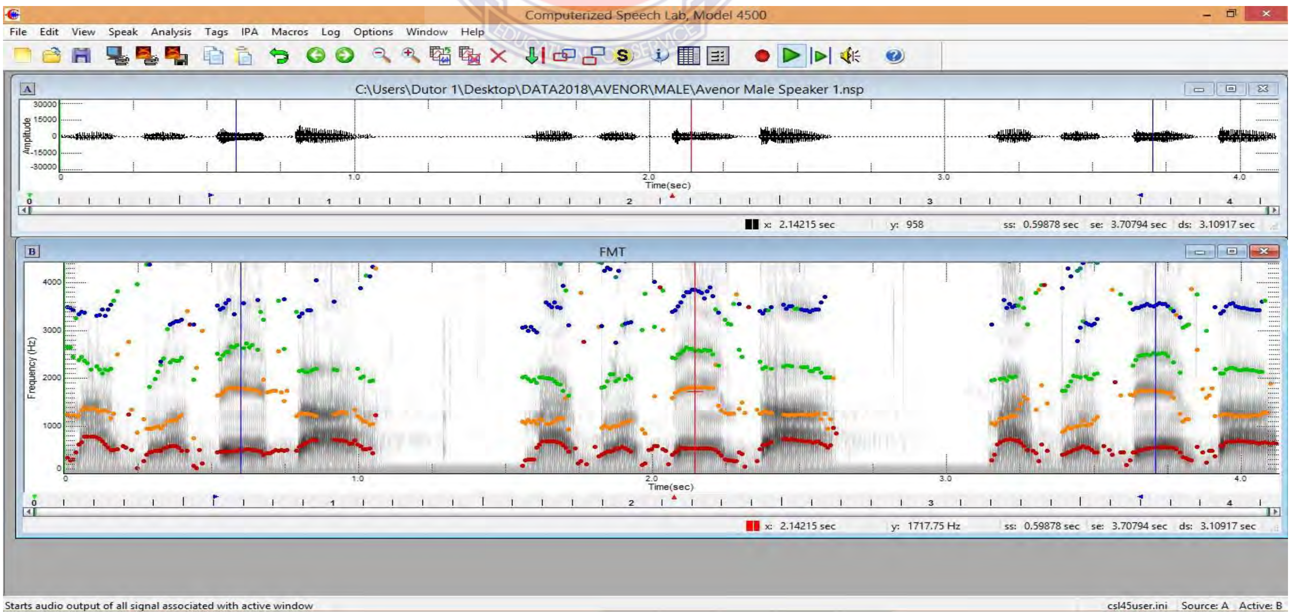


Waveform and spectrogram of Anlo female speaker 1 saying "*Magblɔ bu baa*" in three repetitions.

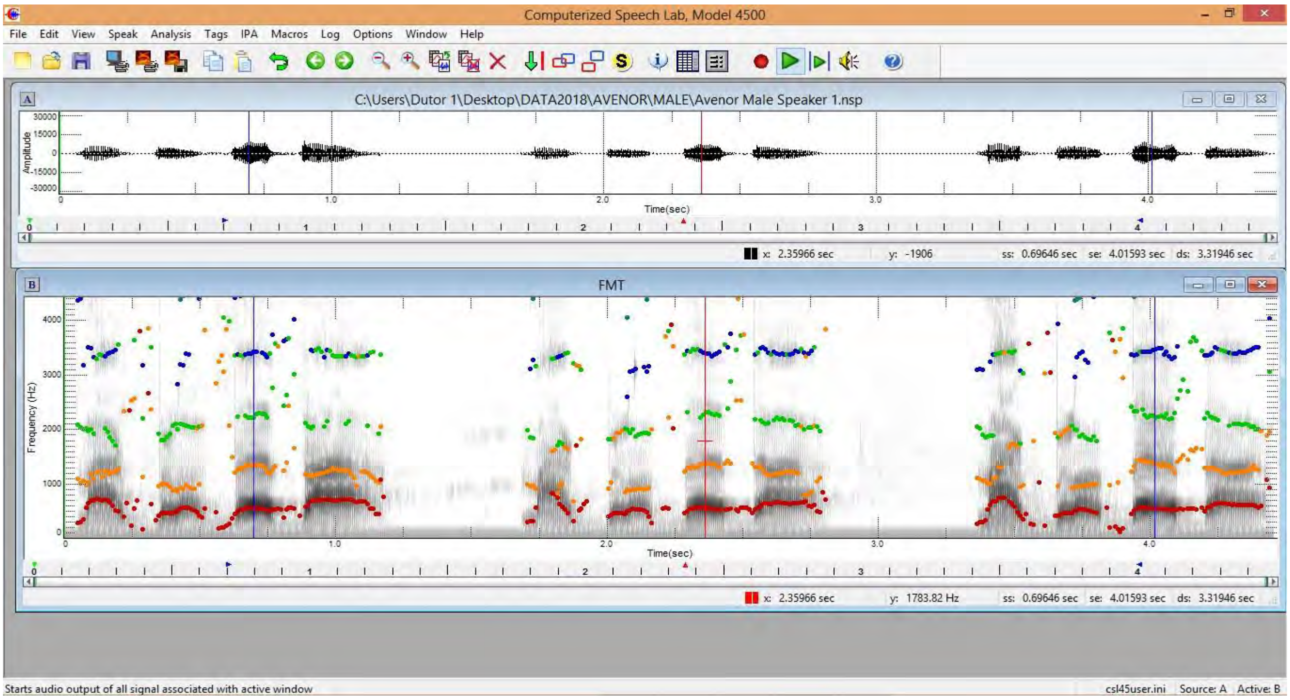
7. Spectrograms of Avenor male speaker 1



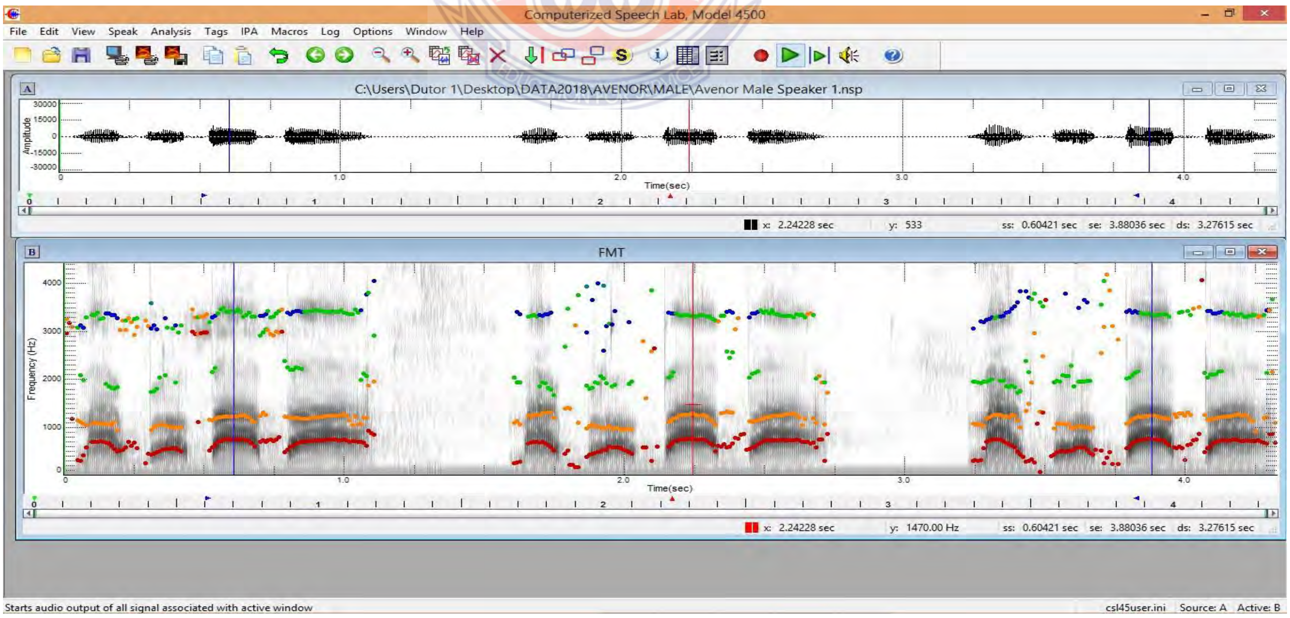
Waveform and spectrogram of Avenor male speaker 1 saying "*Magblɔ bi baa*" in three repetitions.



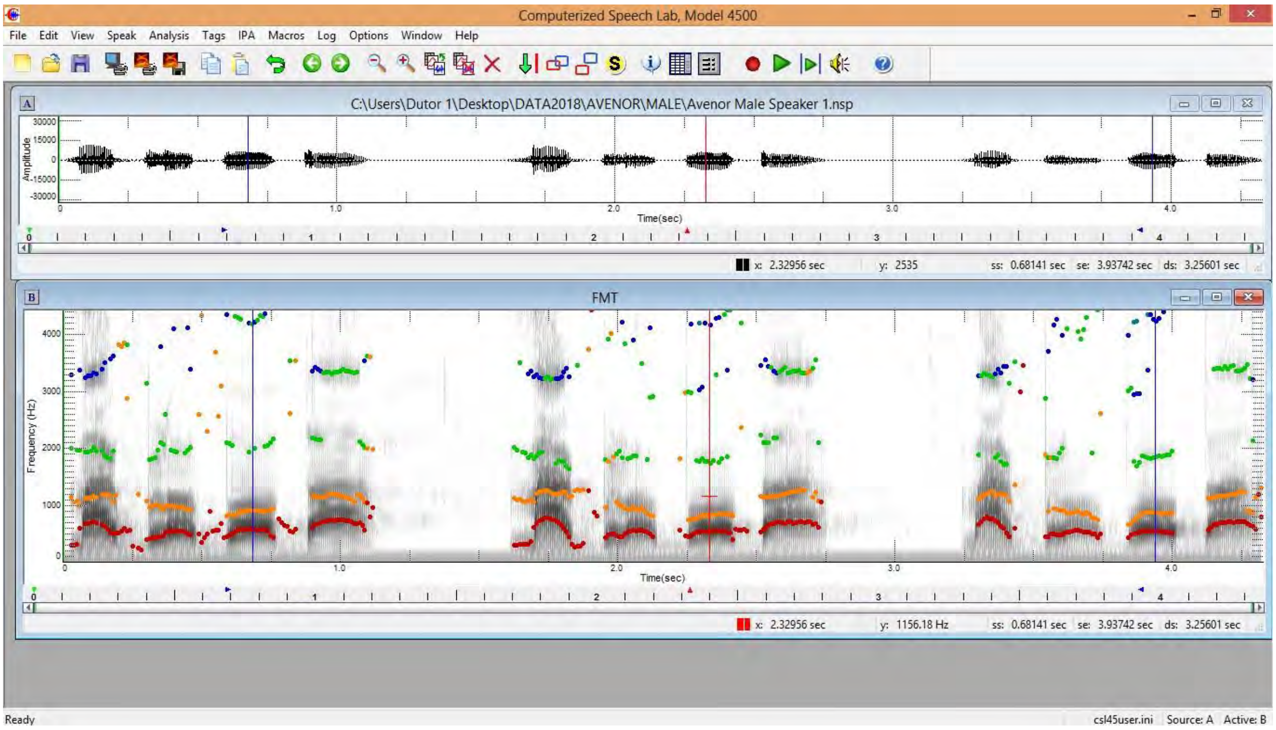
Waveform and spectrogram of Avenor male speaker 1 saying "*Magblɔ be baa*" in three repetitions.



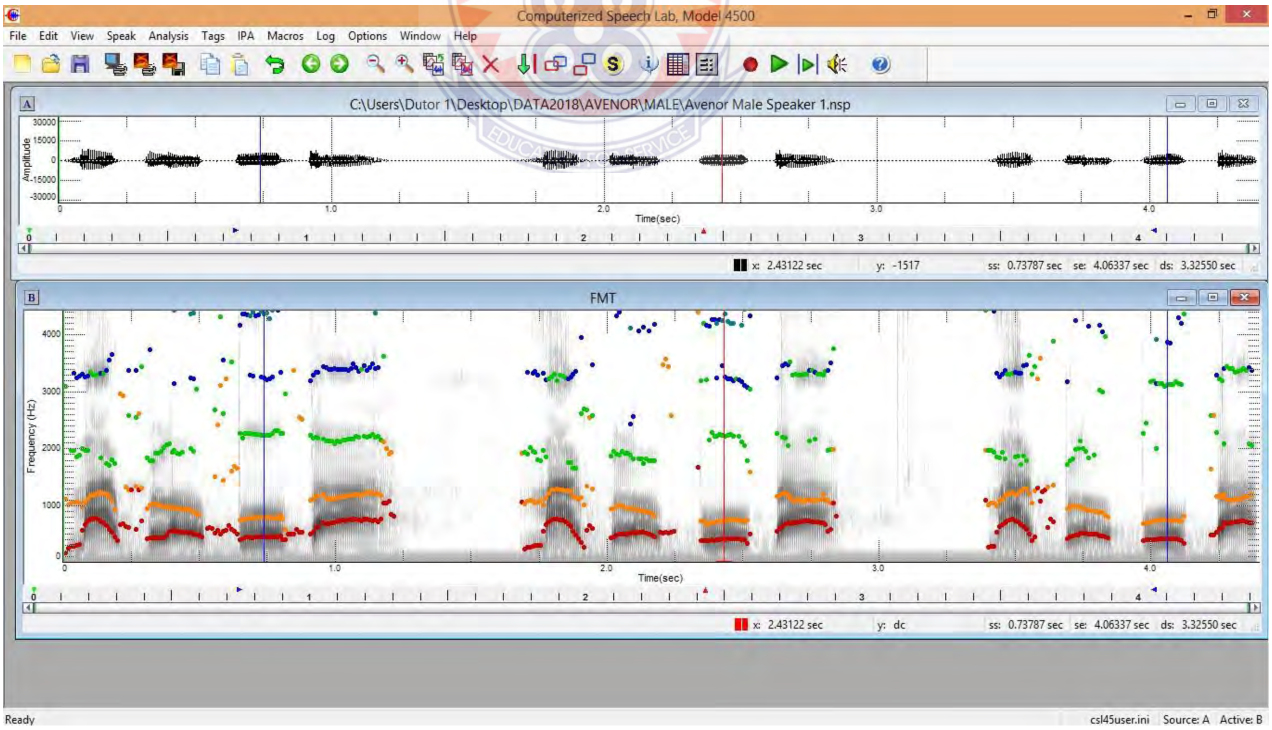
Waveform and spectrogram of Avenor male speaker 1 saying “*Magblɔ bɛ baa*” in three repetitions.



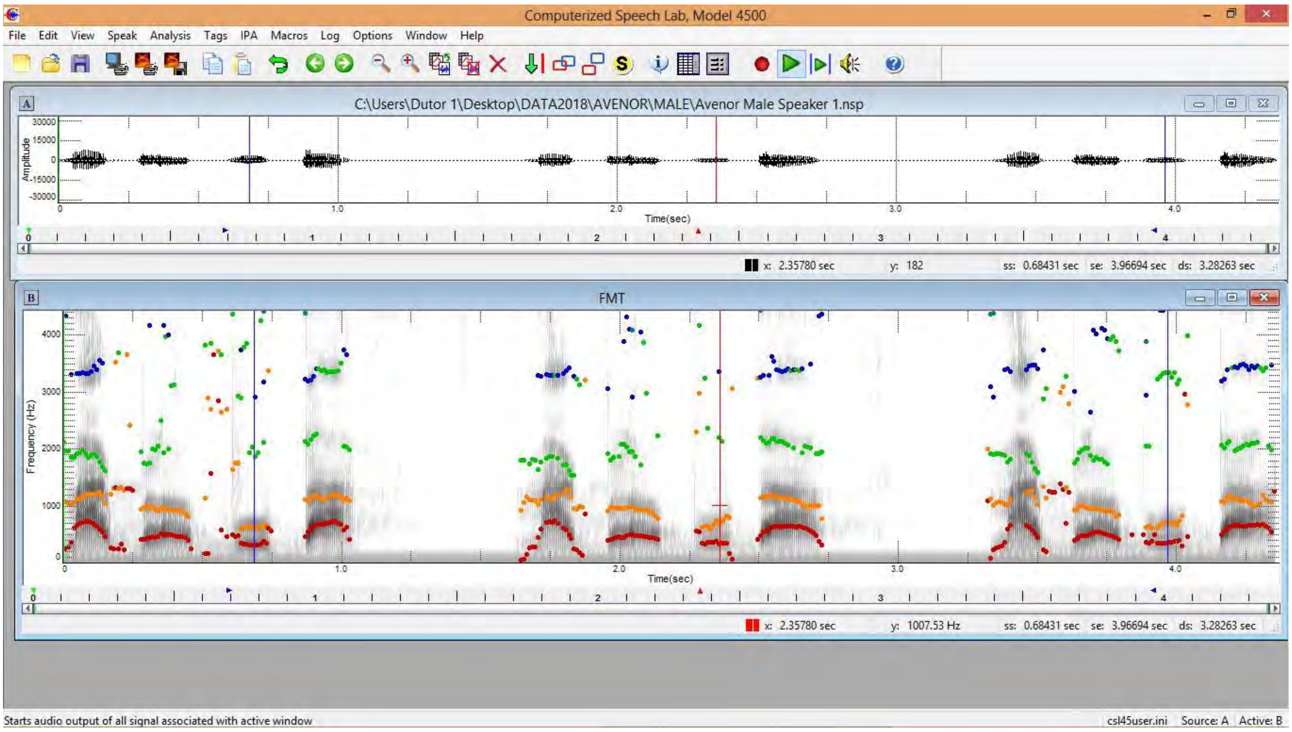
Waveform and spectrogram of Avenor male speaker 1 saying “*Magblɔ ba baa*” in three repetitions.



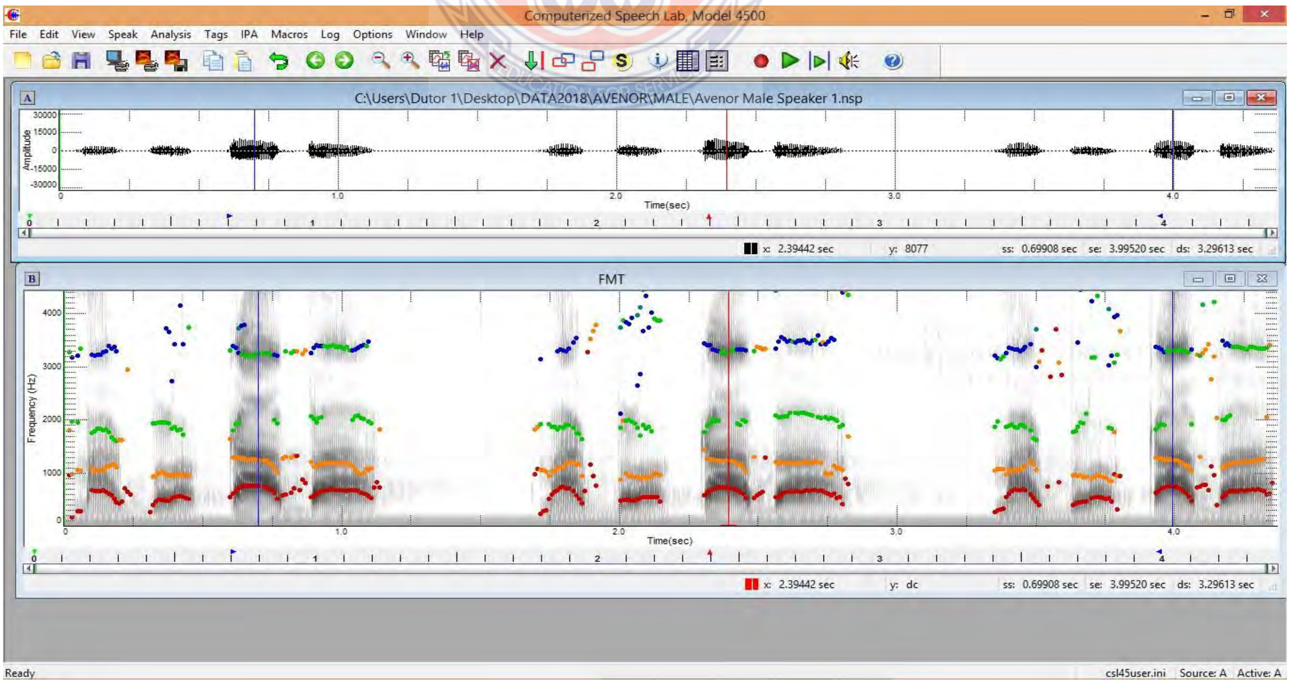
Waveform and spectrogram of Avenor male speaker 1 saying "*Magblɔ bɔ baa*" in three repetitions.



Waveform and spectrogram of Avenor male speaker 1 saying "*Magblɔ bo baa*" in three repetitions.

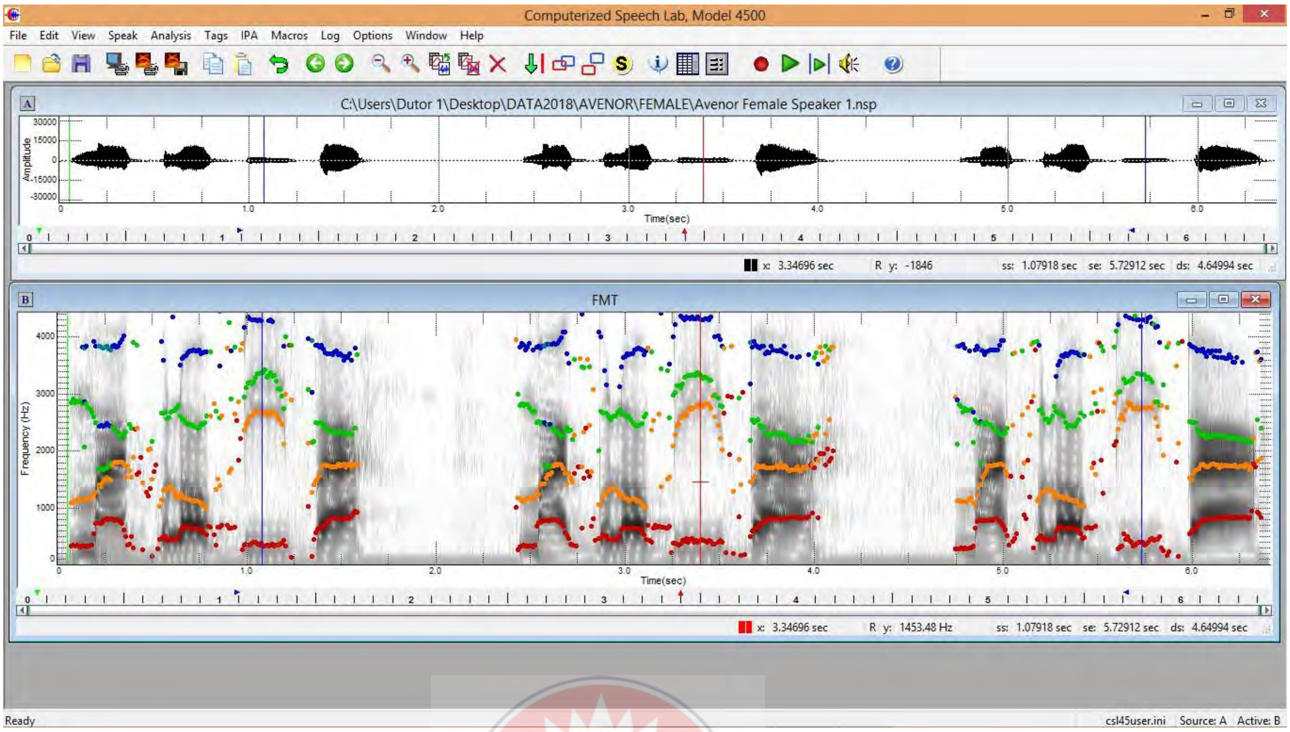


Waveform and spectrogram of Avenor male speaker 1 saying "*Magblɔ bu baa*" in three repetitions.

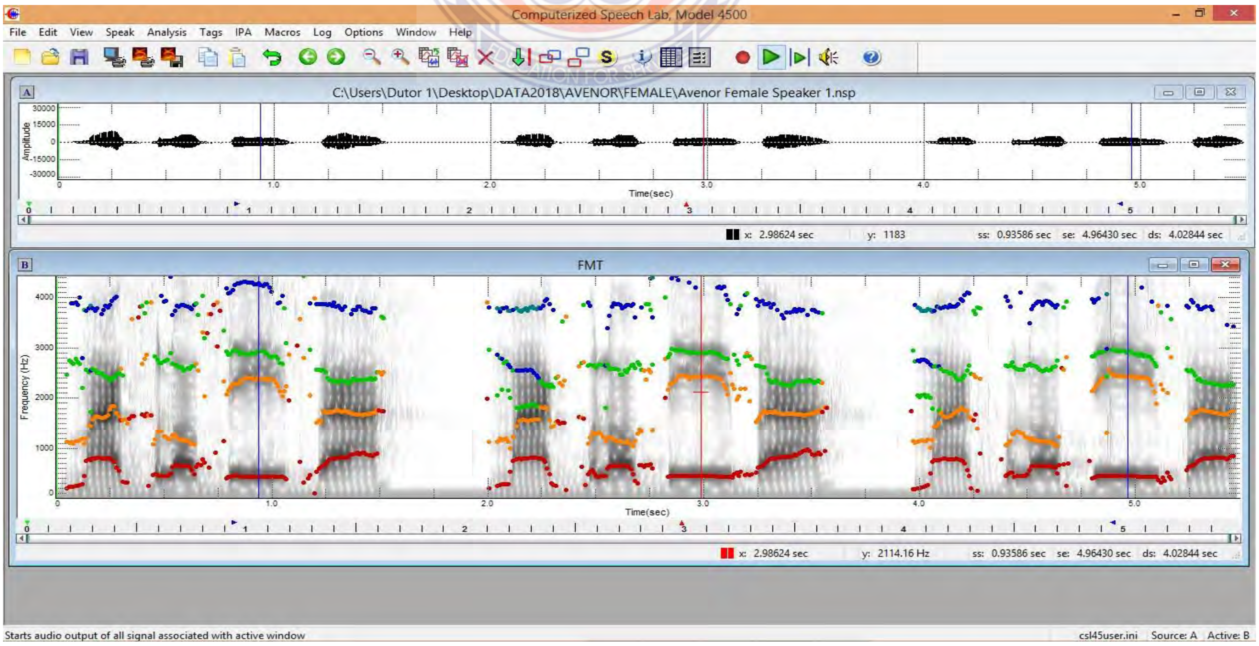


Waveform and spectrogram of Avenor male speaker 1 saying "*Magblɔ ka baa*" in three repetitions.

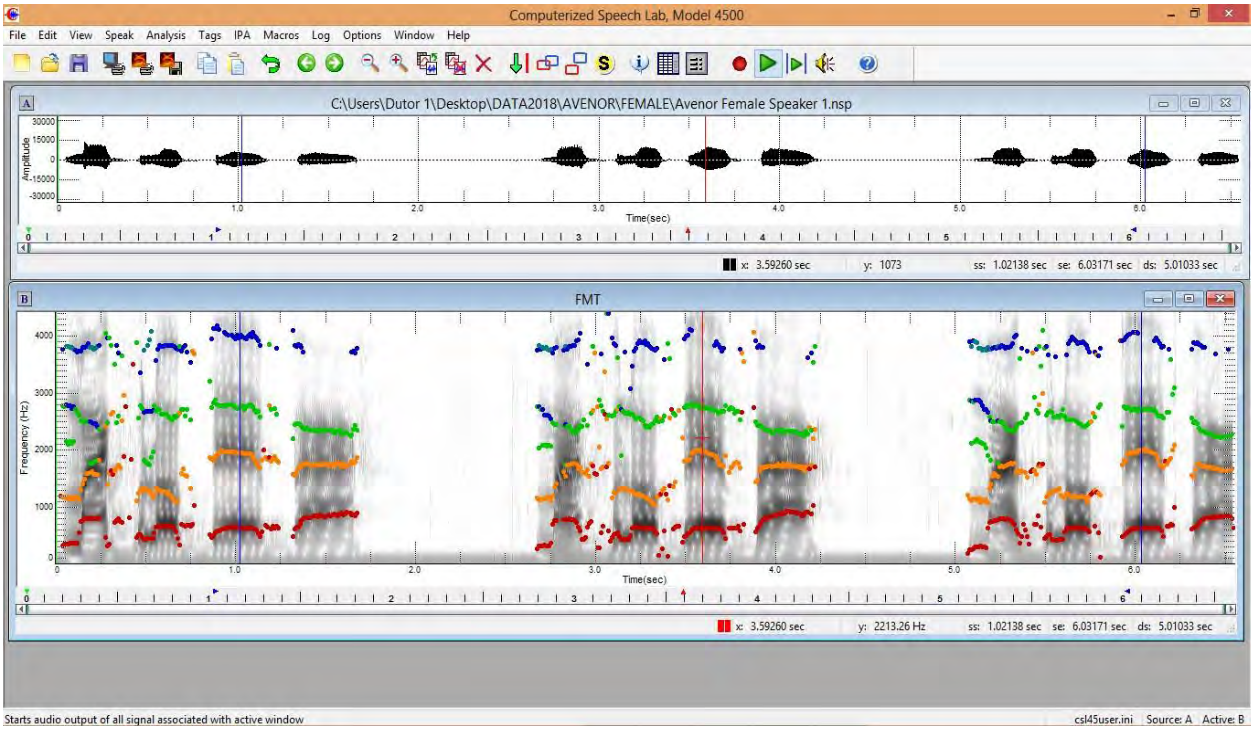
8. Spectrograms of Avenor female speaker 1



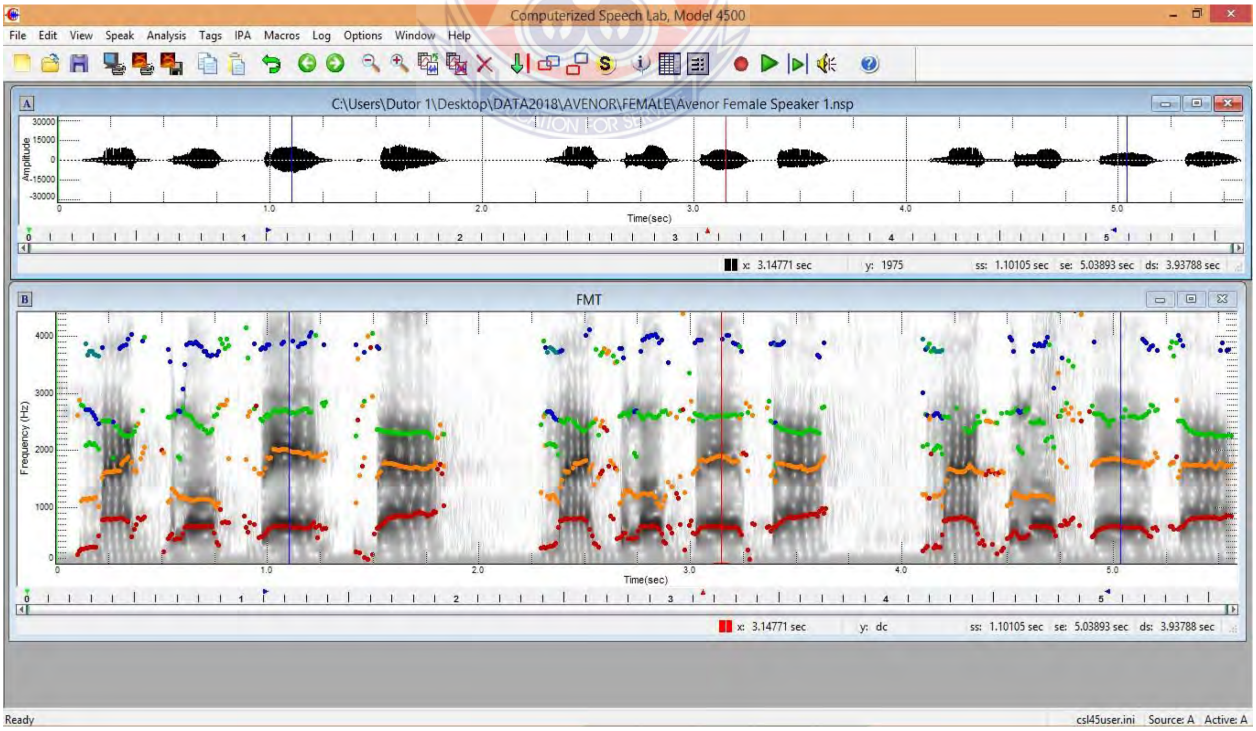
Waveform and spectrogram of Avenor female speaker 1 saying "*Magblɔ bi baa*" in three repetitions.



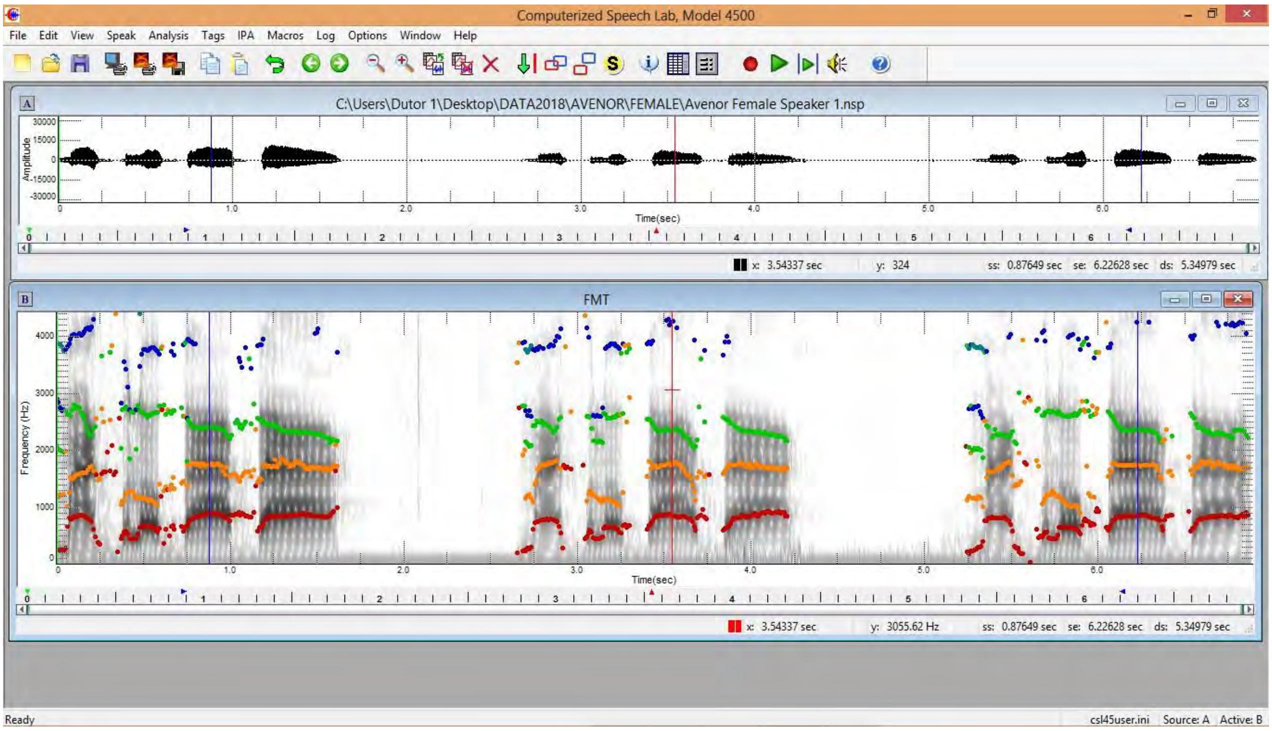
Waveform and spectrogram of Avenor female speaker 1 saying "*Magblɔ be baa*" in three repetitions.



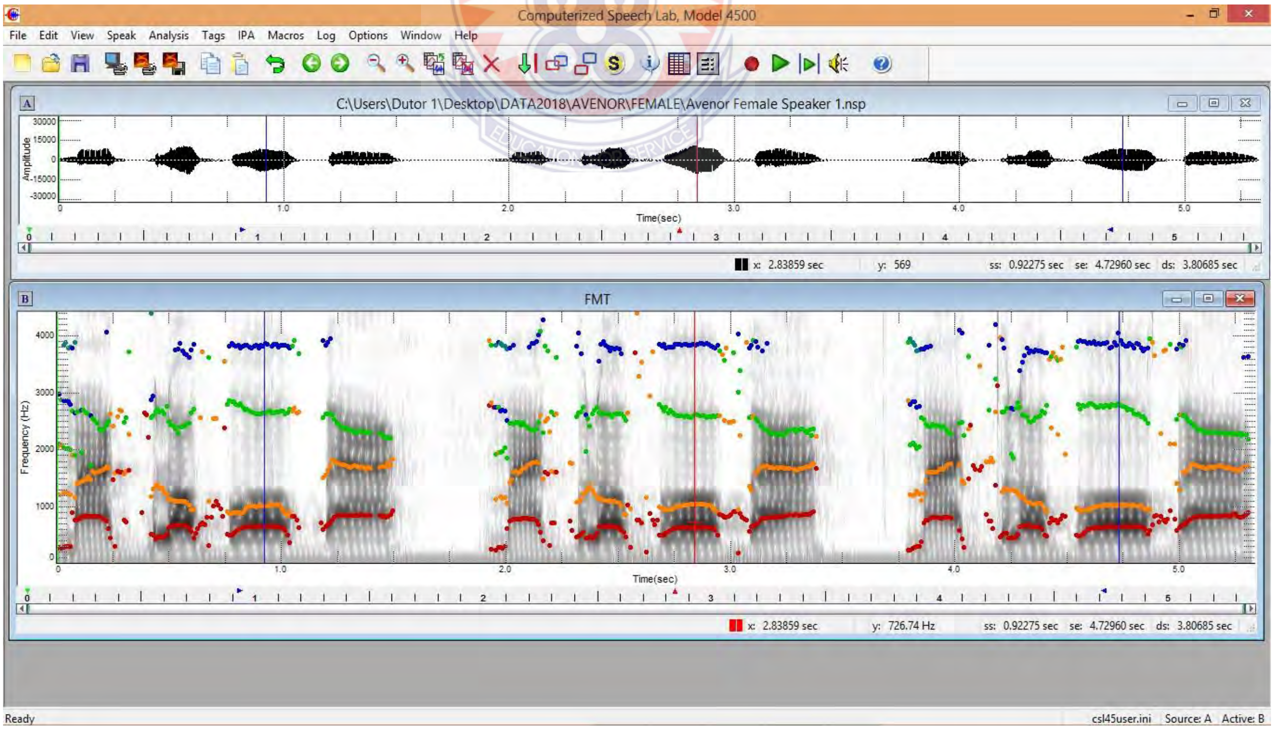
Waveform and spectrogram of Avenor female speaker 1 saying “*Magblɔ bɛ baa*” in three repetitions.



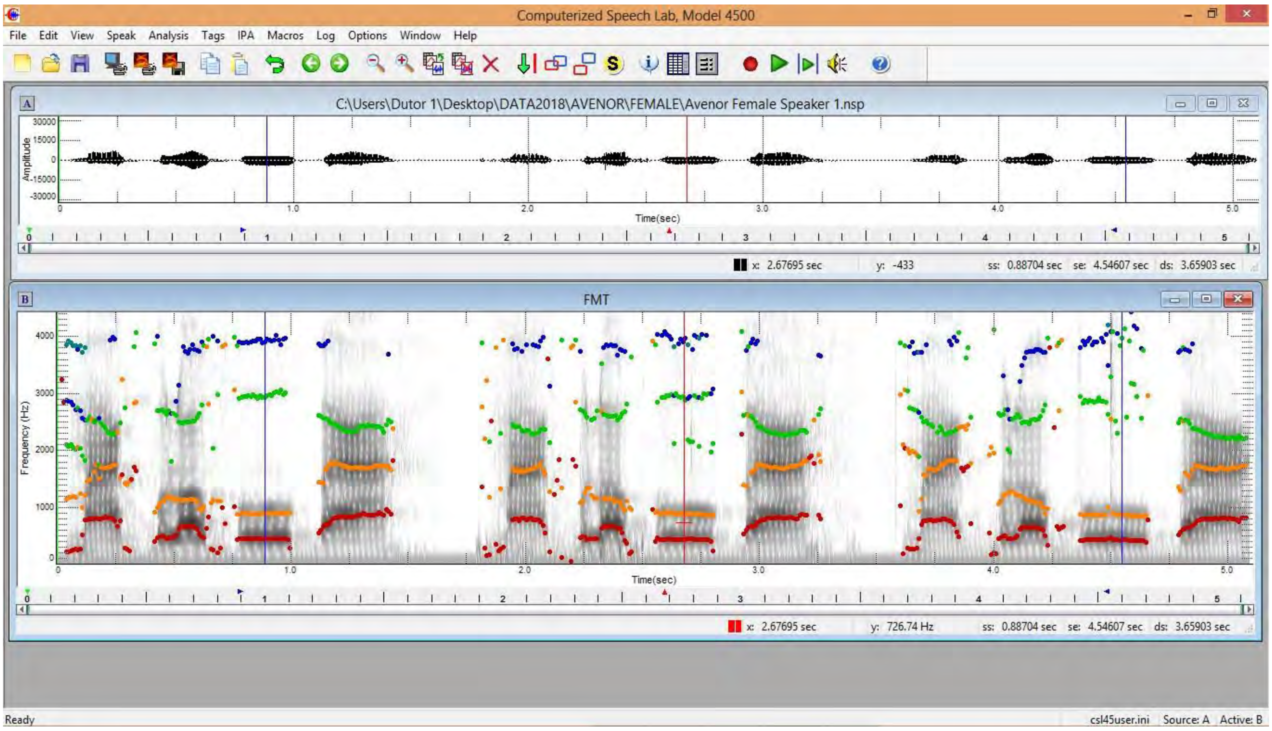
Waveform and spectrogram of Avenor female speaker 1 saying “*Magblɔ bɘ baa*” in three repetitions.



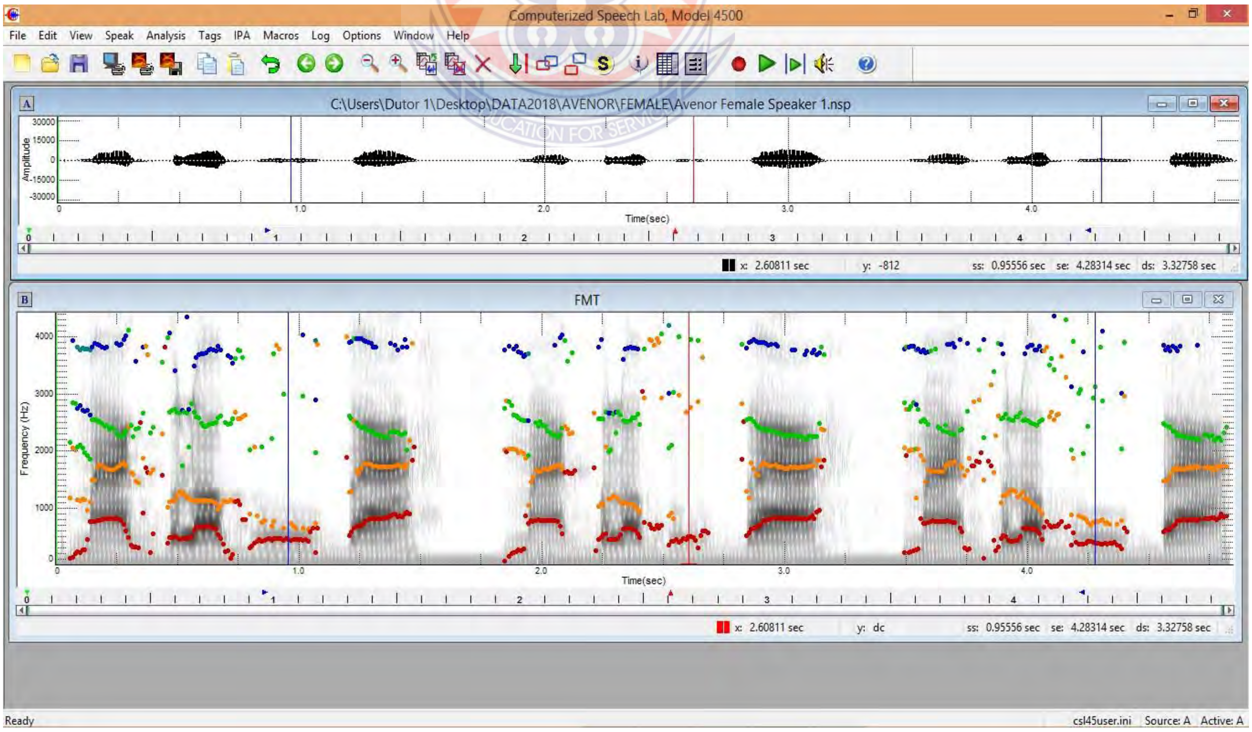
Waveform and spectrogram of Avenor female speaker 1 saying "*Magblɔ ba baa*" in three repetitions.



Waveform and spectrogram of Avenor female speaker 1 saying "*Magblɔ bɔ baa*" in three repetitions.

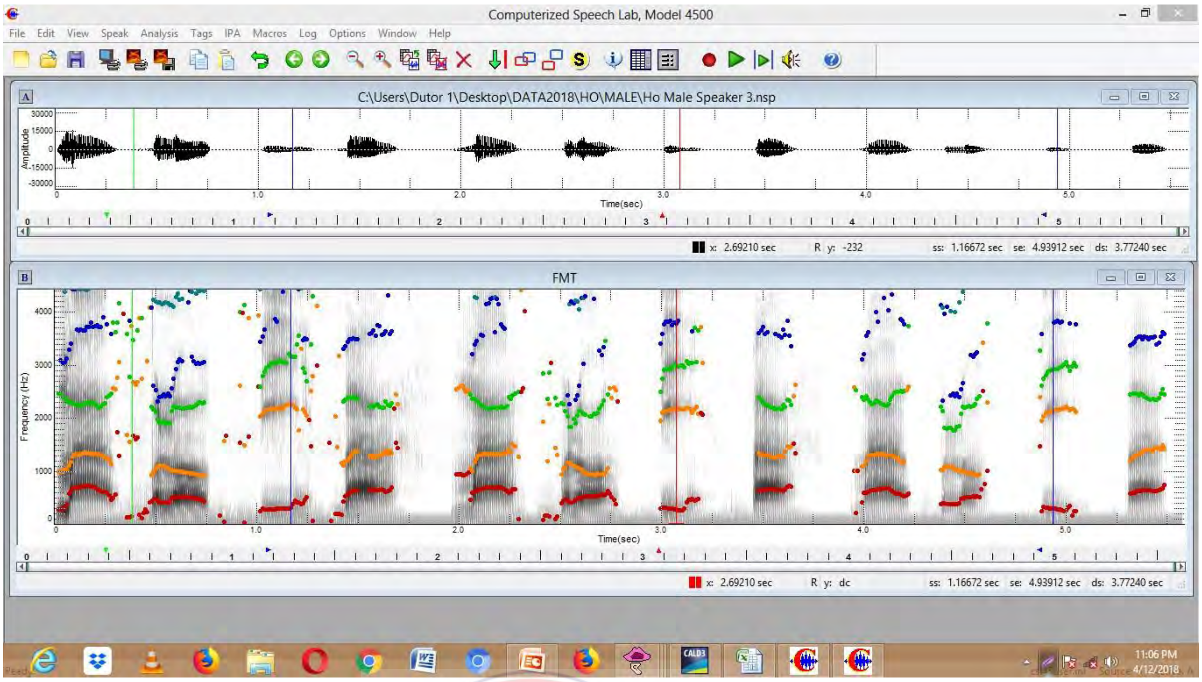


Waveform and spectrogram of Avenor female speaker 1 saying "*Magblɔ bo baa*" in three repetitions.

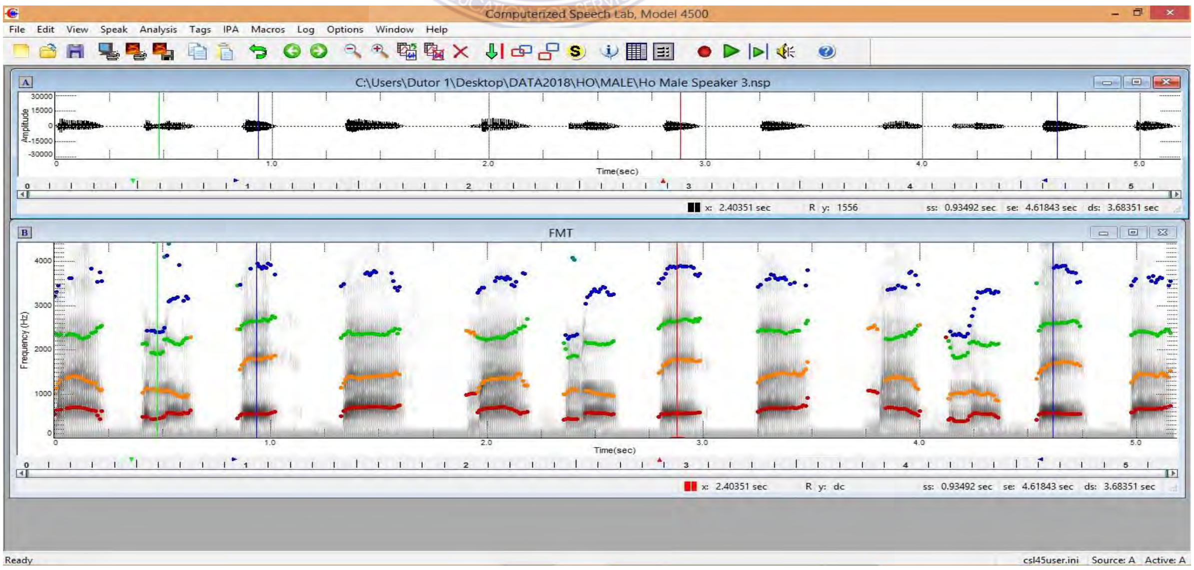


Waveform and spectrogram of Avenor female speaker 1 saying "*Magblɔ bu baa*" in three repetitions.

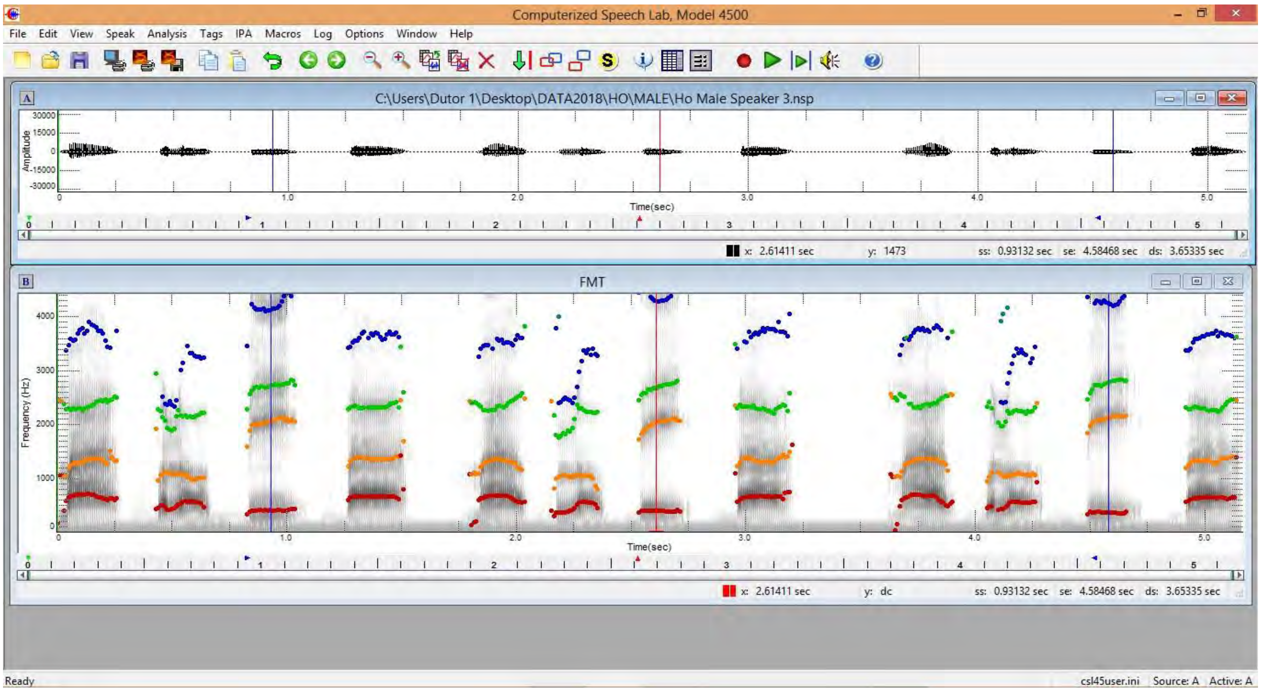
9. Spectrograms of Ho male speaker 3



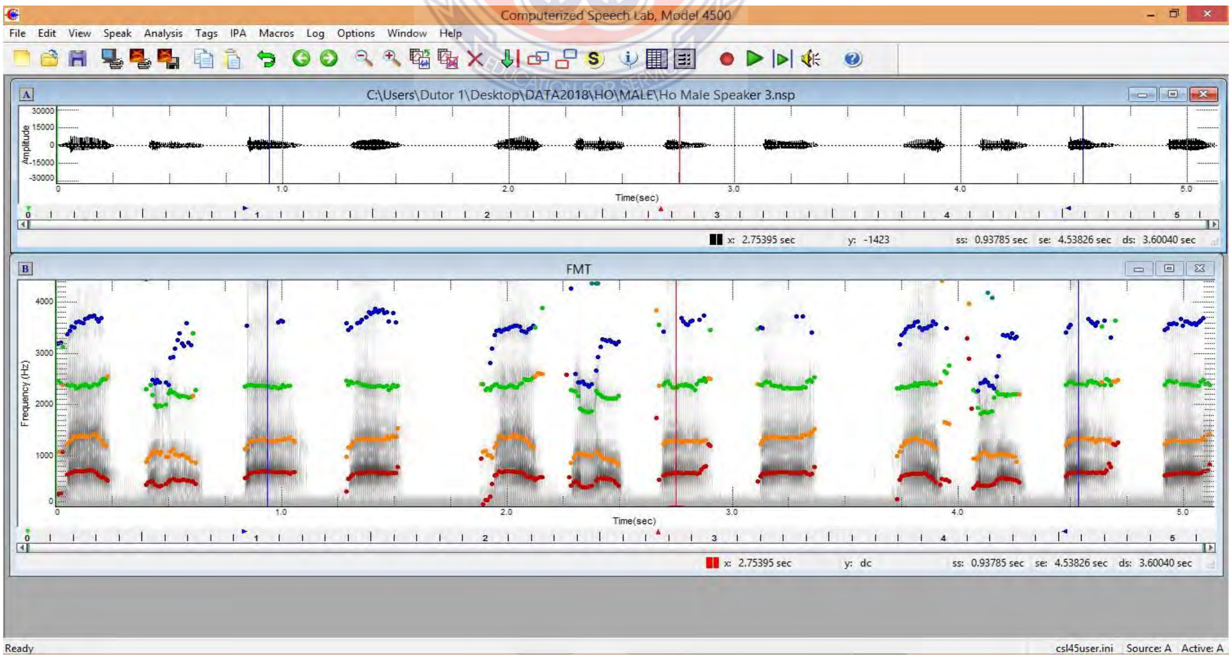
Waveform and spectrogram of Ho male speaker 3 saying "*Magblɔ bi baa*" in three repetitions.



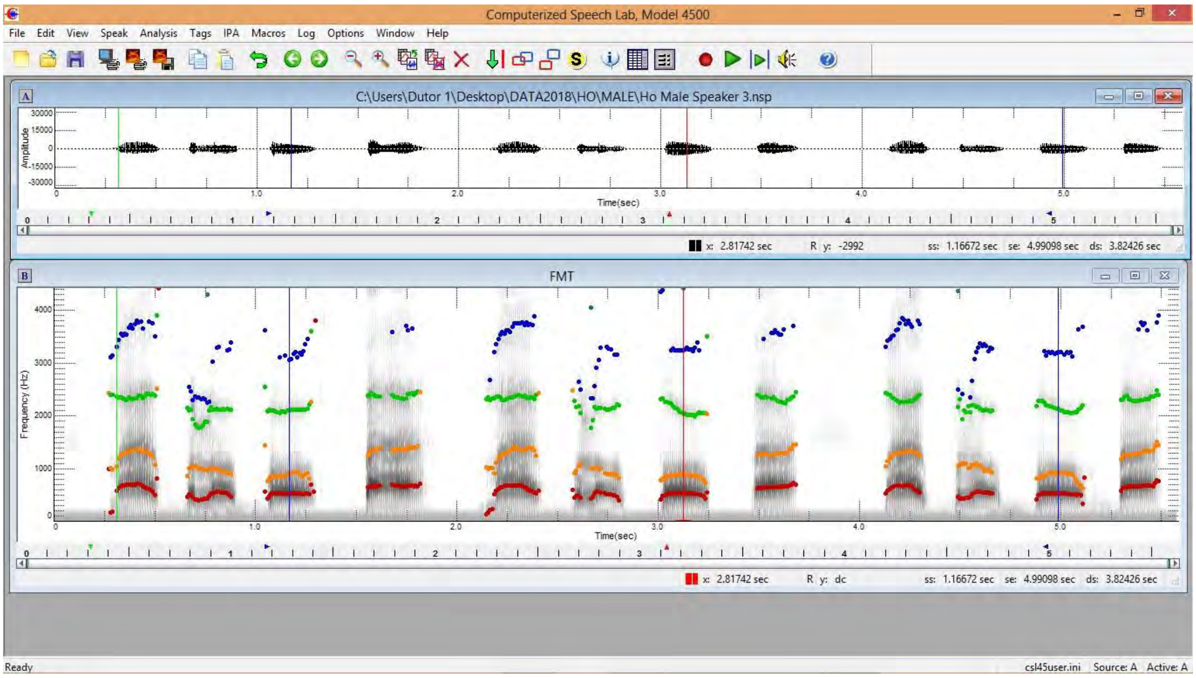
Waveform and spectrogram of Ho male speaker 3 saying "*Magblɔ be baa*" in three repetitions.



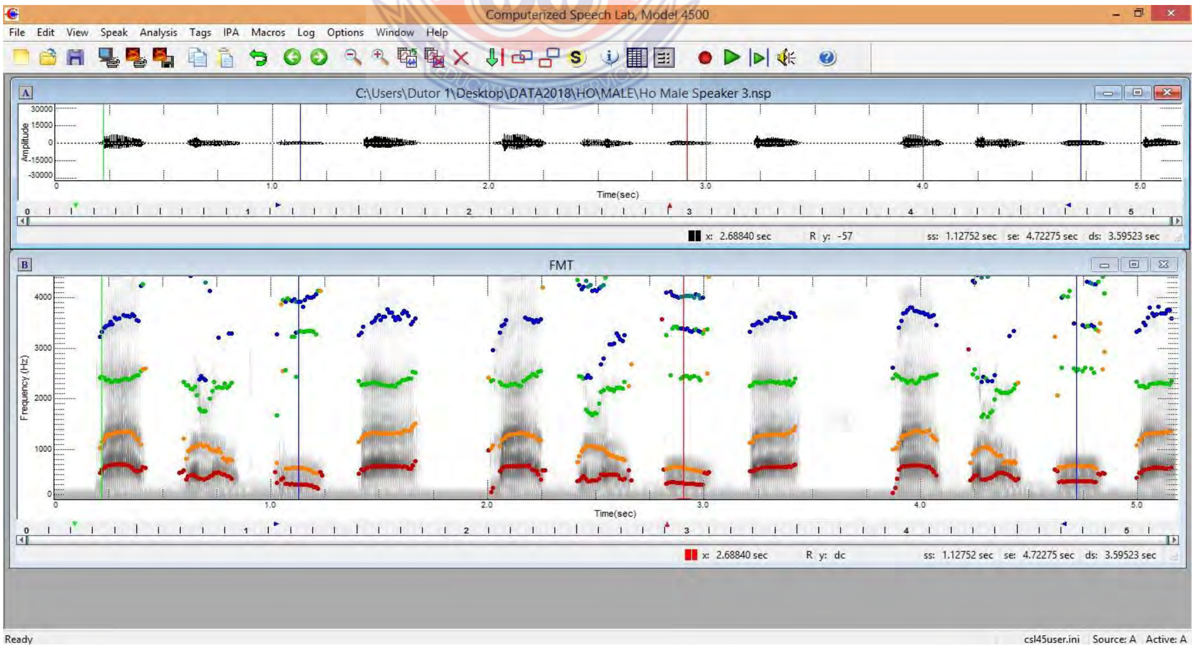
Waveform and spectrogram of Ho male speaker 3 saying "*Magblɔ bɛ baa*" in three repetitions.



Waveform and spectrogram of Ho male speaker 3 saying "*Magblɔ ba baa*" in three repetitions.



Waveform and spectrogram of Ho male speaker 3 saying "*Magblɔ bɔ baa*" in three repetitions.



Waveform and spectrogram of Ho male speaker 3 saying "*Magblɔ bu baa*" in three repetitions.