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Validating Perceptual Objective Listening Quality Assessment Methods on the tonal Language Igbo.

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Dedication

To Maduabuchi, Chinedu, Chimnaecherem, Somtochukwu and Kenechukwu

Abstract

In recent years a great deal of effort has been expended to develop methods that determine the quality of speech through the use of comparative algorithms. These methods are designed to calculate an index value of quality that correlates to a mean opinion score given by human subjects in evaluation sessions. In this work, we validate PESQ (ITU-T Recommendation P.862) and the TNO proposal (called PSQM2010) on the Perceptual Objective Listening Quality Assessment (POLQA) benchmark, which is the new ITU-T benchmarking for objective measurement of speech quality, on the tonal language Igbo –a language spoken in south eastern- Nigeria . Experiments are done in super wideband mode (48 kHz sampling) and PESQ was applied to down sampled versions of the signals. The result on PESQ P.862.2 shows a good correlation between the subjective and objective measurements on the tonal language Igbo with a correlation coefficient of r = 0.88 on the overall data set. For Dutch, the model shows less correlation between the subjective and the objective measurements (r = 0.84) compared to the tonal language Igbo (r = 0.88). .The results also show that information above 7kHz is less important in Igbo than in Dutch.

For the tonal and non tonal sentences no big differences were found. The correlation between the subjective results for tone and non-tone sentences was 0.96.

The PSQM2010 was optimized for western languages and the correlation for the Dutch super wideband database was 0.91. For Igbo our super wideband result shows a poor correlation of 0.70 between the subjective and objective measurements. Apparently the Igbo language is less sensitive to distortions above 7 kHz leading to good PESQ results and poor PSQM2010 results because PESQ ignores distortions above 7kHz while PSQM2010 takes them into account.

Table of Content

List of Tables

List of Figures

List of Abbreviations

S/n	Abbreviation	Meaning
1	MOS	Mean Opinion Score
2	DAM	Diagnostic Acceptability Measure
3	BSD	Bark Spectral Distortion
4	MBSD	Modified Bark Spectral Distortion
5	MNB	Measuring Normalizing Blocks
6	TOSQA	Telecommunication Objective Speech Quality Assessment
7	PAMS	Perceptual Analysis Measurement System
8	PSQ M	Perceptual Speech Quality Measure
9	PSQM+	Perceptual Speech Quality Measure +
10	PESQ (P.862)	Perceptual Evaluation of Speech Quality(P.862) = PAMS + PSQM (ie ITU recommendation for measurement of speech quality)
11	ITU	International Telecommunication Union
12	ITU-T	Telecommunication Standardization Sector of ITU
13	FFT	Fast Fourier Transform
14	IRS Filter	Intermediate Reference System
15	SNR	Signal –to –Noise Ratio
16	PSTN	Public Switched Telecommunication Network
17	WCDMA	Wideband Code Division Multiple Access
18	CDMA	Code Division Multiple Access
19	sf	sample frequency
20	Sv56	Sample
21	PLC	Programming and Communication Cable
22	PEAQ	Perceptual Evaluation of Audio Quality
23	dBov	dB relative to the overload point of a digital system
24	CELP	Code Excited Linear Prediction

25	MNRU	Modulated Noise Reference Unit
26	ETSI	European Telecommunications Standards Institute
27	EVRC	Enhanced Variable Rate Codec
28	AMBE	Advanced Multi-Band Excitation
29	ACR	Absolute Category Rating
30	PCM	Pulse Code Modulation
31	RMS	Root Mean Square
32	ITU-T STL	ITU-T Software Tools Library
33	AMR	Adaptive Multi Rate a standard speech codec for 3GPP used in GSM and UMTS
34	NB	Narrow Band
35	WB	Wide Band
36	SWB	Super Wide Band
37		
38	DECT	Digital Enhanced Cordless Telecommunications
39	netem	Network Emulator for linux kernel 2.6.7 and higher
40	3GPP	3rd Generation Partnership Project
41	GSM	Global Systems for Mobile communication
42	UMTS	Universal Mobile Telecommunications System
43	ISDN	Integrated Services Digital Network
44	ITU-T P.56	ITU-T Recommendation 56(Objective Measurement of Active Speech Level

Terminologies

S/N	Term	Meaning
1	Telecommunication scenario	Covers all transmission technologies in today's: A) Public switched networks(eg fixed wire PSTN,WCDMA,CDMA) B) Push-over-Cellular, Voice over IP and PSTN- to_ VoIP interconnections, Tetra and C) Commonly used speech processing components (eg codecs, noise reduction systems, adaptive gain control, comfort noise and other types of noise enhancement devices) and their combinations[19].
2	Comfort noise/comfort tone	is artificial background noise used in radio and wireless communications to fill the silence in a transmission resulting from voice activity detection or from the clarity of modern digital lines.
3	Full reference or double ended	Means that the quality prediction is based on the comparison between an undistorted reference signal and the received signal to be scored[19].
4	Listening Speech Quality	The overall speech quality as it is perceived and scored by human subjects in an Absolute Category Rating experiment according to ITU-T P.800/P.830
5	POLQA	Perceptual .Objective Listening Quality Assessment
6	Background noise	An additive noise superimposed with the speech.
7	Reference speech/reference signal/clean speech	The original speech signal without any degradation.
8	Degraded speech/degraded signal	Is the reference signal that has passed through the system under test and was captured either at electrical interface or at the acoustical interface

9	Convolution	Convolution is a mathematical way of combining two signals to form a third signal.
10	SNR	The ratio between the power in the active parts and the A-weighted power of the noise in speech pauses(e.g between the individual sentences)
11	PESQ	An objective method for end-to-end speech quality assessment of narrowband telephone networks and speech codecs
12	dB	Decibel (is a logarithmic unit of measurement that expresses the magnitude of a physical quantity (usually power or intensity) relative to a specified or implied reference level.

CHAPTER ONE

1.1 Introduction

This chapter introduces the research presented in this thesis. It begins by stating the objectives of the research. This is followed by introducing the various methods by which speech quality are measured. After that a short introduction of the case study is given and finally the outline of the thesis.

In the search for the optimization of transmission speed and storage, speech information is often coded, or transmitted with a reduced bandwidth. As a result, quality and/or intelligibility are sometimes degraded. Speech quality is normally defined as the degree of goodness in the perception of speech while speech intelligibility is how well or clearly one can understand what is being said[1]. In order to assess the level of acceptability of degraded speeches, various subjective methods have been developed to test codecs or sound processing systems. Although good results have been demonstrated with these, they are time consuming and expensive due to the necessary involvement of teams of professional or naive subjects.
To reduce cost, computerized objective systems were created with the hope of replacing human subjects. While good results have been reported by several of these systems, they have not reached the accuracy of well constructed subjective tests yet . Therefore, their evaluations and improvements are constantly been researched for further breakthroughs [2].

To date, Objective Speech Quality Measurement systems (OSQMs) have been developed mostly in Europe or the United States, and their effectiveness is only tested for English, several European, and Asian languages but not on African languages such as Igbo, a tonal language spoken in the south -eastern part of Nigeria. A first study towards application to tone languages was carried out in [1] [3].

The objectives of this research are firstly to find out if objective measurement algorithms for measuring speech quality as developed for western languages and that are standardized within the International Telecommunication Unit (ITU) can also be applied to the tonal language Igbo. Secondly to find out if there is a difference between the impact of speech distortions on tonal sentences and non-tonal sentences of the Igbo language. One can imagine that for example the steady state parts in tonal sequences are less affected by impulse distortions. This may then result in a difference in perceived quality for tonal and non-tonal sentences. If such a difference is found we can try to model it in the objective measurement domain.

The best known objective measurement algorithm is Perceptual Evaluation of Speech Quality (PESQ), ITU-T recommendation P.862. PESQ deals with narrow band speech and addresses the effects of filters, jitter and coding distortions.

Currently ITU is benchmarking the follow up proposals of PESQ, known as Perceptual Objective Listening Quality Assessment (POLQA) benchmark. POLQA can

deal with super wideband speech and can be used in a wide variety of distortions. TNO is one of the proponents with its PSQM2010 model. This thesis investigates whether PESQ and PSQM2010 can be applied to the Igbo language under a wide variety of distortions. In addition, if PESQ/PSQM2010 measures quality of Igbo accurately it is a big plus for TNO/PESQ/PSQM2010. But if the PESQ/PSQM2010 result is not good then an improvement should be made in order to be able to make the methods suitable for Igbo.

Igbo is a language spoken in Nigeria by about 40 million people, especially in the south-eastern region once identified as Biafra. The Igbo people are known for their merchants and great travelers and are all over the world. The validation of PESQ/PSQM2010 for the tonal language Igbo is therefore necessary for the benefit of this enormous population.

We are investigating the following issues:

a) Can objective models for measuring speech quality which have been used/trained on western languages predict the quality of the tonal language Igbo?
b) Find out if there is difference between the impact of speech distortions on tonal sentences and non-tonal sentences of the Igbo language.

Speech quality assessment has practical applications in the following areas:

- Constrained optimization of coders and /or channels
- Equipment evaluation for purchase
- Picking “best” designs for standardization (this is what we set out to do in this experiment)
- System monitoring and maintenance alerts.

1.2 Subjective Measurement of Speech Quality

Subjective Measurement of Speech Quality is the assessment of speech quality by human beings who listen to live or recorded speeches and assign a rating to it. This rating can be either a single overall quality or a rating of a particular characteristic (such as clarity or listening effort) or a particular distortion (such as clipping, noise, packet loss, hum).The aim of subjective testing methodology is to measure the degradation contributed by a transmission path (linear and non-linear distortions) , and hence to ensure that the performance of the system is satisfactory.

To perform a subjective test for the evaluations of digital codecs a number of steps are taken .They are depicted in the flowchart below [4]:

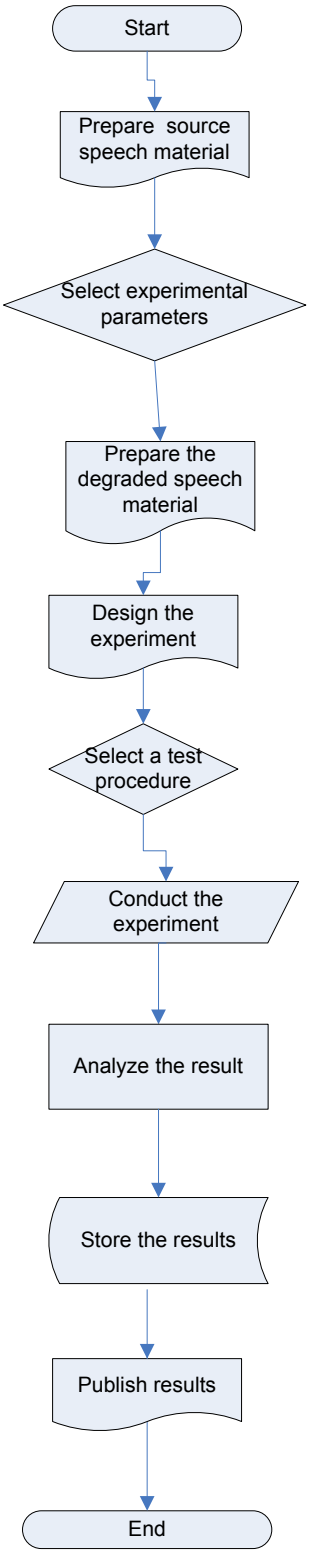


Figure 1: Flowchart on the steps for conducting Subjective Experiment

Usually, subjective tests require a pool of naïve and/or trained listeners, and the test is divided into quality and intelligibility tests. The two classes are not disjoint. Good quality mostly implies good intelligibility. Speech quality encompasses a broader scope that includes intelligibility. There exists a strong correlation between speech quality and intelligibility in that the level of intelligibility relates to the determination of quality. Although speech intelligibility possesses a narrower scope and can even be considered a dimension of speech quality it is by no means inferior since it is the intelligibility of the information content that is often of primary importance in speech [1]. The most popular and widely used intelligibility tests are the Consonant Vowel Consonant Test (CVC, [5]), using three-letter nonsense words in silence, the Speech Reception Threshold test(SRT, [5]), using short everyday sentences in noise adaptive procedure, the Diagnostic Rhyme Test (DRT) and the Modified Rhyme Test (MRT). In the objective domain, the Articulation Index (AI) and the Speech Transmission Index (STI [5]) are standardized and worldwide adopted methods for predicting the speech intelligibility for virtually any electro-acoustic situation. The STI method is a quick and objective method for assessing the speech transmission quality of transmission channels. Using the STI method, the speech transmission index (STI) can both be measured and calculated from the impulse response and noise level of the system under test. The STI, a value between 0 and 1, indicates how well speech is transmitted through the transmission channel with respect to intelligibility. Using the STI-value, the speech intelligibility for different types of speech material (numbers, CVC-words, sentences) can be predicted, using a customized transformation for each type of speech. The focus of this research is on speech quality and not on speech intelligibility.

Well known subjective quality tests include A/B forced comparison test, the Diagnostic Acceptability Measure (DAM) and the Mean Opinion Score (MOS which is an average quality score over a large set of subjects [3]). MOS is one of the widely used and recognized. ITU-T Recommendation P.830 [4] describes in detail how to conduct a subjective test experiment, but the procedure can be summed up as follows: a panel of subjects listens to a set of speech samples, assigning to each sample an overall quality score ranging from 1 (Bad) to 5 (Excellent). The average score of the panel for a given sample is that sample's MOS [6]. To have a reliable assessment of speech quality using MOS it is advisable to consider the standard deviation in addition to the MOS score [3].MOS tests use human subjects to measure the perceived quality but it is time consuming and expensive. Some researchers or organizations may not have the resources to conduct the tests. Moreover it cannot be used in any sort of real-time or online applications. In addition, if the same subject is made to repeat the experiment his opinion may vary. That is, he may give a different MOS score. This is not so in an objective test measure. These shortcomings among other factors have led to the development of objective measures of speech quality.

1.3 Objective Measures of Speech Quality

Objective measures use mathematical expressions to determine the speech quality. The Signal to Noise Ratio (SNR) related measures are better suited for waveform coders,

while spectral distance measures better describe vocoders [3]. It is generally agreed that listening to processed speech gives a better evaluation of the quality than any objective measurement using mathematical expressions. No single objective measure can predict subjective responses well enough to replace subjective testing entirely [3] and modern military and commercial applications still use subjective tests.

Objective speech quality measures can be classified according to the domain in which it operates; these are time domain, spectral domain, or perceptual domain [7]. Time domain measures are usually applicable to analog or waveform coding systems in which the goal is to reproduce the waveform. Signal to Noise Ratio (SNR) and SNRseg (segmental Signal to Noise Ratio) are typical examples of time domain measures. Spectral domain measures are more reliable than time domain measures and less sensitive to the occurrence of time misalignments and phase shifts between the original and the coded signals [3]. However, most spectral domain measures are closely related to speech codec design and are based on speech production models. Their performance is limited both by the constraints of the speech production models used in codecs and by the failure of speech production models in general to adequately describe the listener's auditory response.
Perceptual domain measures, based on human auditory perception appear to have the best chance of predicting subjective quality of speech and other audio signals. These measures transform the signal into a perceptually relevant domain incorporating human auditory models. Examples of perceptual domain measures are BSD, PSQM, MBSD, MNB,PSQM+, TOSQA, PAMS and P.862 . The best known objective perceptual measurement method is PESQ and has been accepted by ITU - T as recommendation P.862 in 2001 [8] for the measurement of speech quality.
Currently ITU is benchmarking the follow up proposals of PESQ, known as the Perceptual Objective Listening Quality Assessment (POLQA) benchmark. POLQA can deal with super wideband speech and can be used in a wide variety of distortions.
All objective measurement methods may fail with certain types of distortions and subjective tests remain necessary. The objective measurement methods described above are also known as black box measurement methods since only the input and output signals are made available to a measurement algorithm [8] and no knowledge of the system under test is required.

The accuracy or effectiveness of an objective measure is determined by its correlation, usually the Pearson (linear) correlation, with MOS scores for a set of data. If an objective measure has a high correlation with MOS, then it is deemed to be an effective measure of perceived speech quality, at least for speech data and transmission systems with the same characteristics as those in the experiment. Indeed, measures that work well under some conditions are not necessarily good predictors of perceived voice quality under other conditions [6].

The differences between subjective and objective speech quality measures are given below.

Subjective Methods

Merits:

- More reliable than objective measures.
- Tests the correct parameters.
- Tests evaluate the subjective quality of voice, or how it is perceived by the end user.
- Takes into account all types of degradation.
- Very accurate.
- Useful for evaluating any audio system with any type of speech or music.

Demerits:

- Consumes time and money.
- It is difficult or even impossible to repeat the exact subject and environment conditions at the time of the test.

Objective Methods

Merits:

- Simple and affordable (cheaper)
- Consumes less time.
- Good at detecting one-dimensional quality changes for example noise level. That is if all the other parameters such as codec, network conditions are kept constant variations in quality due to one parameter can be detected accurately. This consistency does not apply to changes in codec, network scenarios, or any other major changes that will affect several quality dimensions.
- Capable of providing delay estimates between the reference file and the degraded (because it compares them frame by frame).
- Easy to repeat.

Demerits:

- All objective measurement methods may fail with certain types of distortion and subjective tests will remain.
- There is no complete set of objective measurements for the assessment of the overall conversational speech quality of a telephone link.

It should be noted that no evaluation method is one hundred percent accurate. Figure 2 below depicts measurement of speech quality.

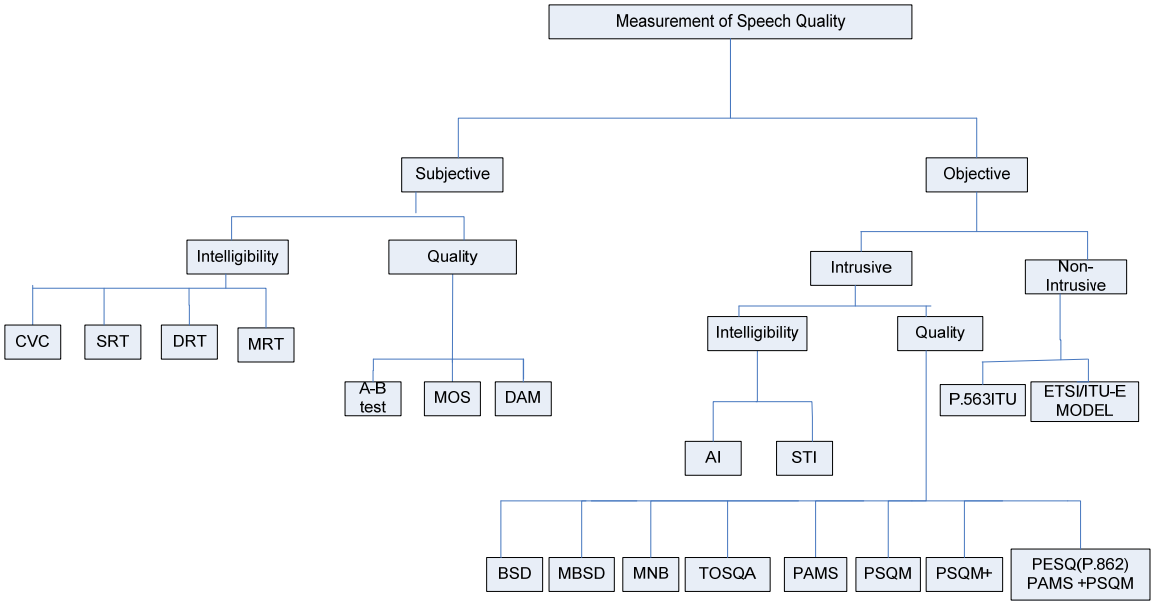


Figure 2: Measurement of Speech Quality

1.4 Case Study-the tonal language of the Igbo People

Igbo people [*eeg•bo*] (sometimes referred to as the **Ibo**, **Eboe**, **Ebo**, **Eboans** or **Heebo**) (Igbo: *Ndi Igbo*) are an ethnic group in Africa numbering in the tens of millions. Most Igbo live in south-eastern Nigeria, where they are one of the larger ethnic groups. Igbo people can be found in significant numbers in Cameroon and Equatorial Guinea. Lesser populations live in other African countries as well as in nations outside of Africa due to migration and to the effects of the Atlantic slave trade. Their exact numbers out of Africa are unknown. They speak the Igbo language, which includes hundreds of different dialects and "Igboid" languages.

The Igbo in Nigeria are found in Abia, Anambra, Ebonyi, Enugu and Imo, as well as in Delta and Rivers States. The Igbo language is predominant throughout these areas, although English (the national language) is also spoken. Prominent towns and cities in the Igboland include Aba, Aguleri, Aboh, Abiriba, Awgu, Oguta, Awka, Igwe Ocha, Abba, Owerri, Orlu, Nnewi, Enugu, Onitsha, Abakaliki, Afikpo, Okigwe, Umuahia, Asaba, Ohafia, Okija, Arochukwu and Igbuzo amongst others.

Igbo is a tonal language, like Yoruba and Chinese. There are hundreds of different dialects and "Igboid" languages that the Igbo language is comprised of such as "Ikwerre" and Ekpeye dialects.

The language was used by John Goldsmith as an example to justify deviating from the classical linear model of phonology as laid out in “The sound Pattern of English”, written in the Roman script [9].

In figures 3 and 4, the geographical location of the Igbo is hierarchical shown.

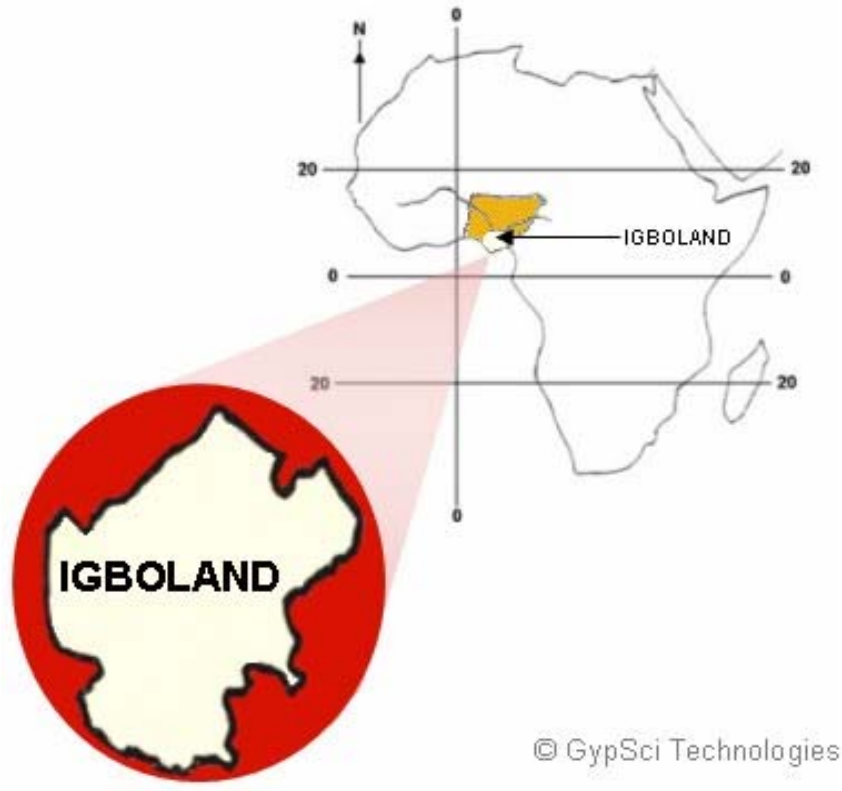


Figure 3:Map of Africa showing the location of Nigeria and Igboland

IGBO LAND IN NIGERIA

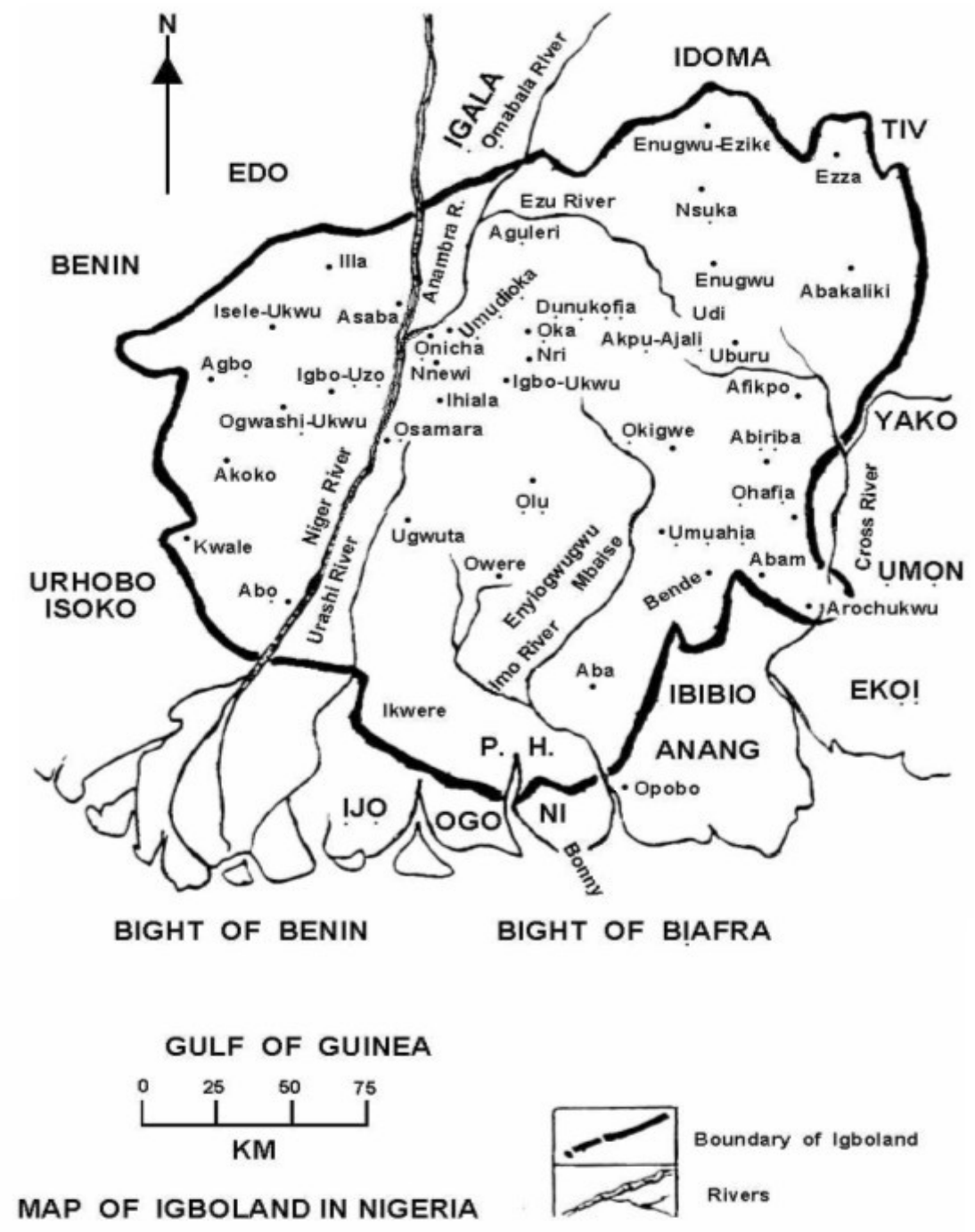


Figure 4:Map of Igboland in Nigeria

1.4.1 Sounds

Table 1: The vowel phonemes of Igbo[10]

S/n	Igbo Vowel Phonemes
1	Ii
2	Ee
3	ɛ
4	Aa
5	Uu,
6	Ɵ
7	Oo
8	ɔ

Igbo is a tonal language with two distinctive tones; high and low. In some cases a third, downstepped high tone is also recognized. The language features vowel harmony with two sets of vowels distinguished by pharyngeal cavity size and can also be described in terms of "Advanced Tongue Root" (ATR).

In some dialects, such as Enu-Onitsha Igbo, the doubly articulated / g͡b / and / k͡p / are realized as a voiced/devoiced bilabial implosive . The approximant /ɹ/ is realized as an alveolar tap[r] between vowels as in *árá*. The Enu-Onitsha Igbo dialect is very much similar to Enuani spoken among the Igbo-Anioma people in Delta State.

Table 2:Consonant phonemes of Standard Igbo

		Bilabial	Labiodental	Dental/ Alveolar	Post-alveolar	palatal	Velar		Labial-velar		Glottal
							plain	labio			
Nasal		m		n		ŋ	ŋ	ŋw			
Plosive		p b		t d			k g	k^w g^w	k͡p	g͡b	
Affricate					tʃ dʒ						
Fricative			f	s z	ʃ		ɣ				ɱ
Approximant	central				ɹ	j			w		
	lateral				l						

Syllables are of the form (C)V (optional consonant, vowel) or N (a syllabic nasal). CV is the most common syllable type. Every syllable bears a tone. Consonant clusters do not occur. The semivowels *j* and *w* can occur between consonant and vowel in some syllables. The semi-vowel in CjV is analyzed as an underlying vowel 'ị', so that *-bịa* is the

phonemic form of *bjá literally meaning* 'come'. On the other hand, 'w' in CwV is analysed as an instance of labialization; so the phonemic form of the verb *-gwá literally meaning* 'tell' is /- g^{w}á/.

1.4.2 Writing system

The most commonly-used orthography for Igbo is currently the *Onwu* (/oŋwu/) Alphabet. It is presented in the table three below, with the International Phonetic Alphabet (IPA) equivalents for the characters [9]. The graphemes <gb> and <kp> are described both as implosives and as co articulated /g/+/b/ and /k/+/p/, thus both values are included in the table.<m> and <n> each represent two phonemes: a nasal consonant and a syllabic nasal.

Tones are sometimes indicated in writing, and sometimes not. When tone is indicated, low tones are shown with a grave accent over the vowel, for example <a> → <à>, and high tones with an acute accent over the vowel, for example <a> → <á>.

For our study we have recorded a total of two hundred (200) sentence pairs in Igbo.Two female native speakers each spoke fifty (50) sentence pairs and the same goes for the two male native speakers. The name of sentence pair indicates who spoke the pair (female1, female2, male1 or male2) and the index number. The or in between the gender and the index number stands for original (ie the original/reference speech). For instance f2or25 denotes 25th original sentence pair spoken by female 2. Of the 200 sentence pairs thirty (30) pairs contain tonal sentences viz: female1 flor01, flor06, flor17, flor36, flor45.For female2 are f2or01, f2or02, f2or13, f2or14, f2or25, f2or26, f2or36 and f2or50. For male1 they are m1or01, m1or08, m1or12, m1or20, m1or26, m1or33, m1or40, m1or45 and m1or50. And for male 2 they are m2or02, m2or06, m2or15, m2or21, m2or30, m2or40, m2or45 and m2or50.
The words with the tones are highlighted with the yellow color in **Appendix A,** which contains all 200 sentence pairs.

Table 3: Igbo Alphabets

S/n	Igbo Alphabet(Onwu)	IPA	S/n	Igbo Alphabet(Onwu)	IPA
1	Aa	/a/	19	Ọọ	/ ɔ /
2	Bb	/b/	20	Pp	/p/
3	GBgb	/ g͡b / ~ gb/	21	KPkp	/ k͡p / ~/ kp/
4	Dd	/d/	22	Rr	/r/
5	Ee	/e/	23	Ss	/s/
6	Ff	/f/	24	SHsh	ʃ
7	Gg	/g/	25	Tt	/t/
8	GHgh	/ ɣ /	26	Uu	/u/
9	Hh	/h/	27	Ụụ	ʊ
10	Ii	/I/	28	Vv	/v/
11	Ịị	/I/	29	Ww	/w/

12	Jj	/dʒ/	30	Yy	/j/
13	Kk	/k/	31	Zz	/z/
14	Ll	/l/	32	CHch	/ tʃ/
15	Mm	/m/ and / m/	33	GWg^{w}	/g^{w}/
16	Nn	/n/ and / n/	34	KWk^{w}	/k^{w}/
17	Ňń	/ ŋ /	35	NW ŋw	/n^{w}/
18	Oo	/o/	36	NYny	nj

1.5 Technical, Economical and Social (TES) Relevance of this Research

Provides the standard for service providers to use in order for them to make high quality services to the end users. Ensures quality of service/experience (QoS/E) for end users. Measuring Quality of User Experience is important not only for users but also for the innovators, investors, venture capitalists (vcs), designers and developers. In addition, if objective measurement systems can predict the impact of distortions in the Igbo language one can use them in quality control in telecommunication services in the Igbo language.

1.6 The Organization of this Thesis

Chapter 1 of this work treats the introduction of the thesis, the objectives, the various methods of measurement of speech quality, an introduction of the case study, the TES of the research and the thesis outline.In chapter 2 a review of the related literature on objective measurement of speech quality is handled. Particular attention is given to PESQ which is the current ITU-T recommendation for objective measurement of speech quality. Chapter 3 discusses the current ITU-T follow up proposals of PESQ which is POLQA. This research validates PESQ and PSQM2010 for the tonal language Igbo. In chapter 4 the speech database used for this research is treated. This includes speech recording , post filtering and various degradation conditions that are applied to samples. Chapter 5 presents the subjective experiment, objective PESQ P.862.2 results and objective PSQM2010 results. In chapter 6 a brief introduction of some tonal words and sentences are treated. In this chapter we present the comparison of the subjective results of the tonal and non tonal sentences. And finally in chapter 7 the thesis is concluded with recommendations for future work.

CHAPTER TWO

2.1 Introduction to the PESQ Measurement Approach

In this chapter we review the various objective measurement methods of speech quality with particular focus on the outgoing ITU-T recommendation P.862 .

In this research we used PESQ and PSQM2010 which are co- developed by TNO to assess the quality of impaired speech samples. The results were compared with the MOS results of the subjective tests. Scatter plots of the results are presented in sections 5.3 and 6.2.

2.2 PESQ

In recent years a great deal of effort has been expended to develop methods that determine the quality of speech through the use of comparative algorithms. These methods are designed to calculate an index value of quality that correlates to a mean opinion score given by human subjects in evaluation sessions. Normally these methods make use of a recorded speech or simulated speech stimulus. This speech stimulus is sent through the system under test and the output signal is compared to the original. Figure 5 below depicts an overview of the basic philosophy used in the development of an objective perception based measurement model.

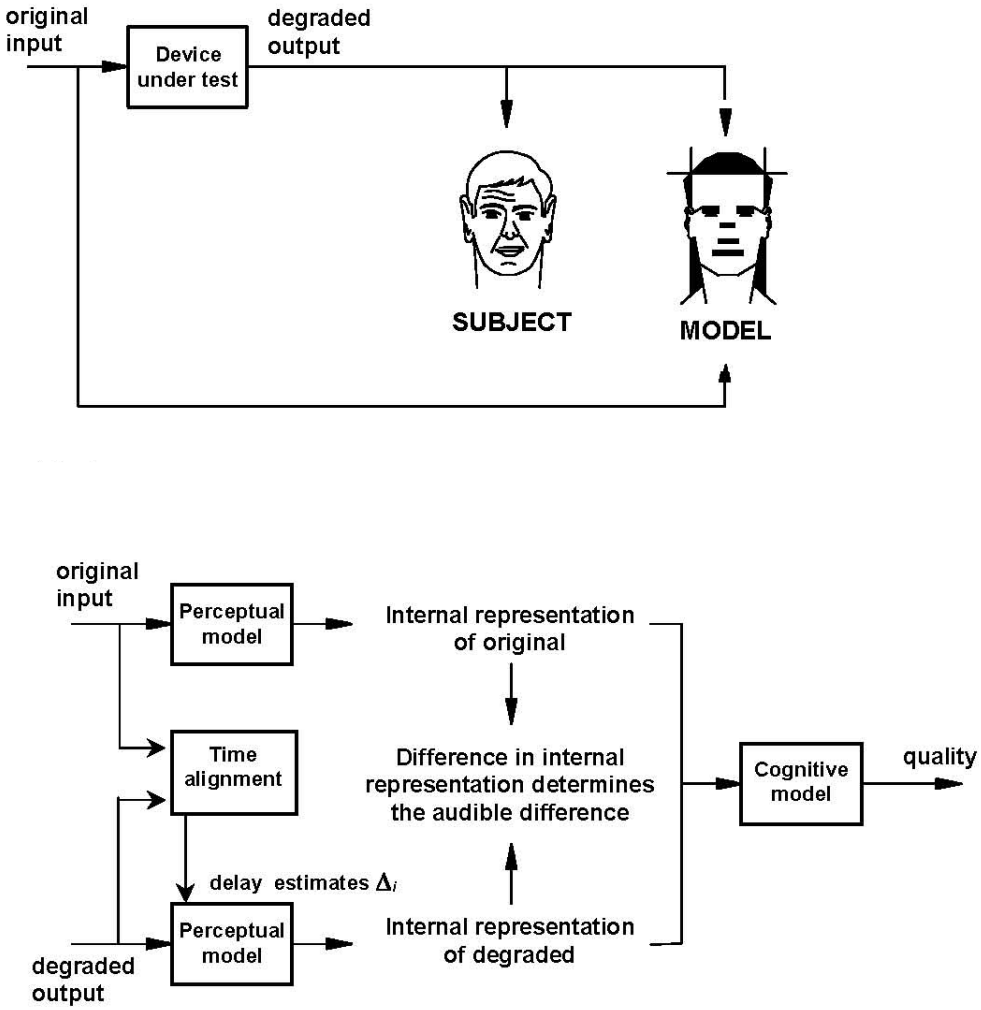


Figure 5: Overview of the basic philosophy used in the development of an objective perception based measurement method.(was taken from [11])

A computer model of the subject, consisting of a perceptual and a cognitive model, is used to compare the output of the device under test (e.g a speech codec or a music codec) with the input, using any audio signal (speech, music or test signal). The input signal is used as a reference signal (the ideal) [8] .

Previous objective speech quality assessment models, such as Bark Spectral Distortion (BSD), the perceptual speech quality measure (PSQM), and measuring normalizing blocks (MNB), have been found to be suitable for assessing only a limited range of distortions. A new model has been developed for use across a wider range of network conditions, including analogue connections,codecs, packet loss and variable delay. Known as perceptual evaluation of speech quality (PESQ), it is the result of integration of the perceptual analysis measurement system (PAMS) and PSQM99, an enhanced version of PSQM [8]. In 2001, PESQ was accepted by ITU-T as recommendation P.862

[12] and represents the best current known objective perceptual measurement method [13, 14]. There is also P.862.2 for wideband extension. PESQ quantifies the speech listening quality for normal telephone band signals (300-3400 Hz bandwidth) under a wide variety of conditions that may include coding distortions, errors, noise, filtering, delay and variable delay. It uses a standard 5-point MOS (Mean Opinion Score) scale with the categories 5 = excellent, 4 = good, 3 = fair, 2 = poor, 1 = bad [15, 16]. PESQ was jointly developed by TNO (KPN) and Psytechnics (British Telecom).Both the perceptual and cognitive model is from TNO [8], which had developed the first ITU-T standard on perceptual measurement of speech quality, Perceptual Speech Quality Measure (PSQM), ITU-T recommendation P.861, [17,18]). In PESQ and PSQM the transformation of the speech signals from the physical (external domain) to the perceptual (internal domain) is performed by four operations viz:

Global time/amplitude alignment, time-frequency mapping, frequency warping and intensity warping (compression). These operations allow limited modeling of the masking behavior of the human auditory system at and above masked threshold and make use of the psychophysical equivalents of frequency (Bark) and intensity (compressed Sone). The cognitive model that operates on the perceptual representation takes into account which type of distortions is most disturbing. Figure 6 depicts the structure of perceptual evaluation of speech quality (PESQ) model.

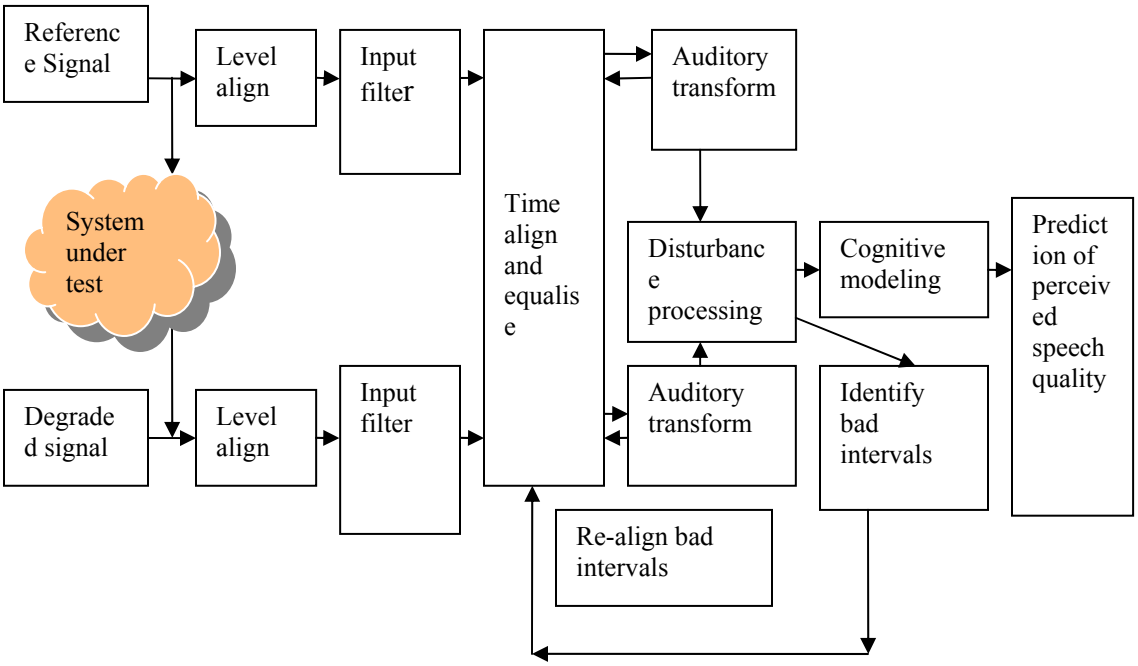


Figure 6:Structure of perceptual evaluation of speech quality(PESQ) model[11]
Note system under test/device under test = (eg a speech codec or a music codec)

2.3 Merits of PESQ

For quality assessment of telephone band speech signals (300-3400 Hz) PESQ performs much better than earlier speech codec assessment models such as P.861 PSQM and MND .The advantages of PESQ over PSQM and MNB are:

- Inclusion of a dynamic, perceptual, time alignment that allows for assessments under a wide variety of time axis distortions.
- Inclusion of an L_p weighting over time that correctly models the higher weight that subjects give on short loud disturbances.
- A better modeling of the asymmetry effect, the difference in disturbance between time-frequency components that are introduced versus time-frequency components that are omitted.
- The ability to correctly deal with linear frequency response distortions
- An improved local power scaling that deals with the perceptual influence of gain variations [11].

2.4 Demerits of PESQ

- The existing ITU-T P.862 is not or not fully approved for wide range of network topologies and their speech processing components.
- It cannot be used for measurement at the acoustical interfaces of a terminal.
- Overly sensitive to delay and time scale manipulations, processing effects and background equipment and impairments.
- Requires that the evaluator sends a reference signal. Though this does not present a problem in a controlled laboratory testing environment, in the real world it would require the testers to set a call.
- Does not take into account the impact of overall playback level.

2.5 Scope of the Objective Model PESQ

The scope of PESQ is limited to 'P.861' + packet switched networks (VoIP),narrow band (200 to 3200 Hz or 50 to 7000 Hz passbands) speech. The specials are time alignment as part of P.862, workarounds for draw backs as defined in P.862.3. Note the scope of P.861 was limited to circuit switched and GSM (2G) networks, narrow band speech. There is no time alignment for P.861.

2.6 Extending PESQ

Currently work is being carried out to extend PESQ towards:

- Acoustic domain measurements, allowing to include microphones and loudspeakers into the measurement.
- Extension towards super wideband speech including quantification of the impact of linear frequency response distortions and noise suppressor distortions, allowing to predict the quality in mixed wideband and narrow band scenarios.
- Inclusion of a degradation analysis where the perceived degradation is decomposed into basic perceptual effects, allowing to find underlying causes for low speech quality. This degradation analysis will also be assessed in the new ITU benchmark for the follow up of PESQ currently known as POLQA [19].

CHAPTER THREE

Perceptual Objective Listening Quality Assessment (POLQA)[1]

Here we present the follow up proposal of P.862 which ITU-T is currently benchmarking.

3.1 Introduction

POLQA is the follow up proposal of PESQ being benchmarked by ITU-T for objective speech quality. This new model is introduced due to the fact that the existing ITU-T P.862 (PESQ) is not or not fully approved for a wide range of network topology complexities and their speech processing components. In addition, PESQ cannot be used for measurements at the acoustical interfaces of a terminal.

3.2 Scope of the Objective Model POLQA

The purpose of the objective model POLQA is to predict overall speech quality in narrowband, wide-band and super-wideband (50 to 14000Hz) telecommunication scenarios as used in P.800 subjective tests. This includes all speech processing components usually considered for telecommunications in clean and noisy conditions. The term 'listening speech quality' means the overall speech quality as perceived and scored by human subjects in an Absolute Category Rating experiment according to ITU-T P.800 / P.830.
The evaluation procedure is based on the proponents models' overall MOS score and separately on each single decomposed degradation score by a statistical evaluation procedure.

A) Narrow-band and super-wideband operational modes
There are two operational modes for POLQA. In one mode the speech samples are scored against a super-wideband (50 to14000Hz) reference signal and predict the MOS-Listening Quality Objective (LQO) on a corresponding scale. The other mode addresses the traditional narrowband telephone conditions. Here the MOS-LQO score is predicted on a common narrow-band (50-3400Hz) MOS when an IRS (telephone band) [20] receive filter is used in the subjective test.

B) Acoustical interfaces
The consideration of the acoustical path to and from (acoustical insertion / acoustical capturing), an actually used terminal is only foreseen for the super-wideband operational mode.
The narrow-band mode remains restricted to the so-called electrical capture of the voice signals. Acoustical insertion can be used for the narrow-band operational mode too.

[1] *Note this part of the report was taken from an internal ITU-T Document intended only for use by the Member States of ITU, by ITU-T Sector Members and Associates, and their respective staff and collaborators in their ITU related work.[19]*

C) Optional results

Besides the predicted MOS-LQO for speech signals provided as the main results, additional outcomes for more detailed quality scores for different distortion classes ("degradation decomposition") are optionally provided for the super-wideband mode of POLQA.

D) Restrictions

POLQA is not intended to score a per-call quality or quality for longer sequences of speech. It is focused on prediction of quality of shorter speech utterances such as 6…12s in length. However, it is intended to prove the POLQA model in a post-evaluating step for its applicability for longer speech utterances by additional subjective tests using longer speech samples as well.

Other dimensions of speech quality such as conversational aspects and talking quality are not within the scope of POLQA. The POLQA candidates consider noises and their influence on overall listening quality in an ITU-T P.800 ACR context only. The prediction of quality as it can be perceived in a noisy listening environment and the related binaural effects are not in the scope of POLQA.

Intended Scenario

The term 'telecommunication scenario' covers all transmission technologies in today's

- Public switched networks (e.g. fixed wire PSTN,GSM,WCDMA,CDMA
- Push-over-Cellular, Voice over IP and PSTN-to-VOIP interconnections, Tetra and
- Commonly used speech processing components (e.g. codecs, noise reduction systems,

Adaptive gain control, comfort noise and other types of voice enhancement devices) and their combinations.

As is the case for P.861 and P.862, the approach of POLQA is called 'full reference' or 'double –ended', which means that the quality prediction is based on the comparison between an undistorted reference signal and the received signal to be scored.

3.3 Test and applications scenarios for POLQA

The so-called 'test scenario' describes a set of individual connections or complete processing chains, which are typical for types of telephony applications (e.g. wireless connections in CDMA, simulated codec transmissions, hands-free terminals).

The 'application scenario' means in this context the anticipated usage of the POLQA model that has already been considered in the design of the databases and the corresponding auditory tests. It covers different types of measuring interfaces or terminal types (handset, headphone, hands-free).

The test scenarios covers commonly used so-called 'simulated' connections from e.g. codec standardizations as well as an equivalent amount of data recorded in real field

scenarios. Both sets of data collections should reflect the actual behavior in today's networks and telephony services. So the latest coding technologies have been taken into account as well as typical telephony services such as video-telephony in 3G networks. The test scenarios are based on clean (noise-free) speech transmissions as well as the transmission of noisy speech (or the insertion of noise into the system under test).

The test scenarios covers the following distortion types:

- Single and tandemmed speech codecs as used in telecommunication scenarios today
- Packet loss and concealment strategies (packet switched connections)
- Frame-and bit-errors(wireless connections)
- Interruptions(such as un-concealed packet loss or handover in GSM)
- Front-End-clipping (temporal clipping)
- Amplitude clipping (overload, saturation)
- Effects of speech processing systems such as noise reduction systems and echo cancellers on clean speech
- Effects of speech processing systems such as noise reduction systems (adaptation phase and converged state) and echo cancellers on pre-noised speech
- Effects of speech-coding systems on pre-noised speech
- Variable delay (VoIP, video-telephony) / Time Warping
- Gain variations
- Influence of linear distortions (spectral shaping), also time variant
- Non-linear distortions produced by the microphone / transducer at acoustical interfaces
- Voice enhancement systems in networks and terminals and their effects on Listening Quality
- Reverberations caused by hands-free test setups in defined acoustical environments.

Compared to the current ITU-T P.862, which is restricted to electrical interfaces only, POLQA covers all four of the following applications given by the different interface types:

a)	Send at electrical interface	-	Receive at electrical interface
b)	Send at acoustical interface	-	Receive at electrical interface
c)	Send at electrical interface	-	Receive at acoustical interface
d)	Send at acoustical interface	-	Receive at acoustical interface

Note that only clauses a) and b) will be applicable for the narrowband operational mode, c) and d) are restricted to the super-wideband operational mode only. Table four below also depicts some differences between PESQ and POLQA.

Table 4: Some differences between PESQ and POLQA

S/n	PESQ	POLQA
1	Narrow band 50-7000Hz	Superwide band 50-14000Hz
2	Deals with a fixed level play out	Deals with the impact of dynamic level play out

CHAPTER FOUR

The Speech Database

In this chapter we present the speech database, the recording of the speeches, the post processing and the various degradation conditions we applied to the speeches.

4.1 Recording of the Speech Database

The speech database was recorded at the acoustical imaging and sound laboratory of TU Delft. There were four native Igbo speakers, two males and two females. Fifty five sentence pairs were recorded for each speaker . From which we selected the best fifty sentence pairs which we used in this research. We used Cool Edit Pro Software for our recording. Fifteen percent (15%) of the sentence pairs were tonal while the rest were general Igbo speeches. The recording was done according to the specification (recommendation) set by ITU-T [19]. The sampling rate of the recorded speeches are 48khz, 16 bit and in mono channel Intel bit order. Distance of talkers mouth from the microphone was 10cm, voice level loud and clear, room condition echo free measurement laboratory.

The duration of the sentence pairs are between 8s - 12seconds. Before recording each sentence pair the talker took a silence of about 1 second, read the first sentence then took another silence for about 2 seconds and then read the second sentence. After a silence of about 5 seconds the talker read the next sentence pair. The speeches were recorded in stereo (double channel) but were saved in mono (single channel).

The file format for the speeches are given below
f1or01.48k.pcm…….. f1or50.48k.pcm
f2or01.48k.pcm…….. f2or50.48k.pcm
m1or01.48k.pcm…….. m1or50.48k.pcm
m2or01.48k.pcm…….. m2or50.48k.pcm

or = original
01 = sentence pair one
48k = 48 000hz
pcm = pulse code modulation
f1,f2,m1,m2 = female1, female2, male1, male2 respectively.

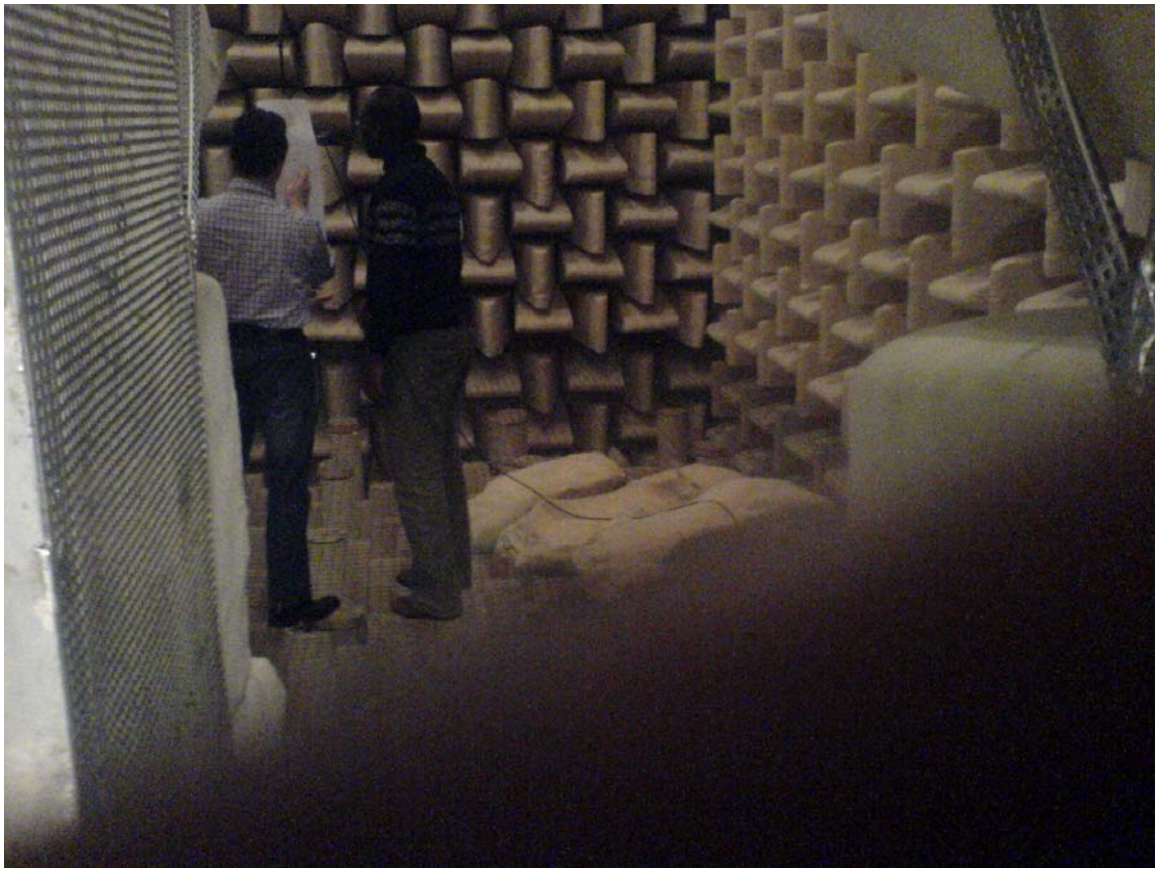


Figure 7: Jeroen van Vugt (Mentor) and Charles Oragui (Male1 Speaker) at TU Delft Acoustic Imaging and Sound Laboratory

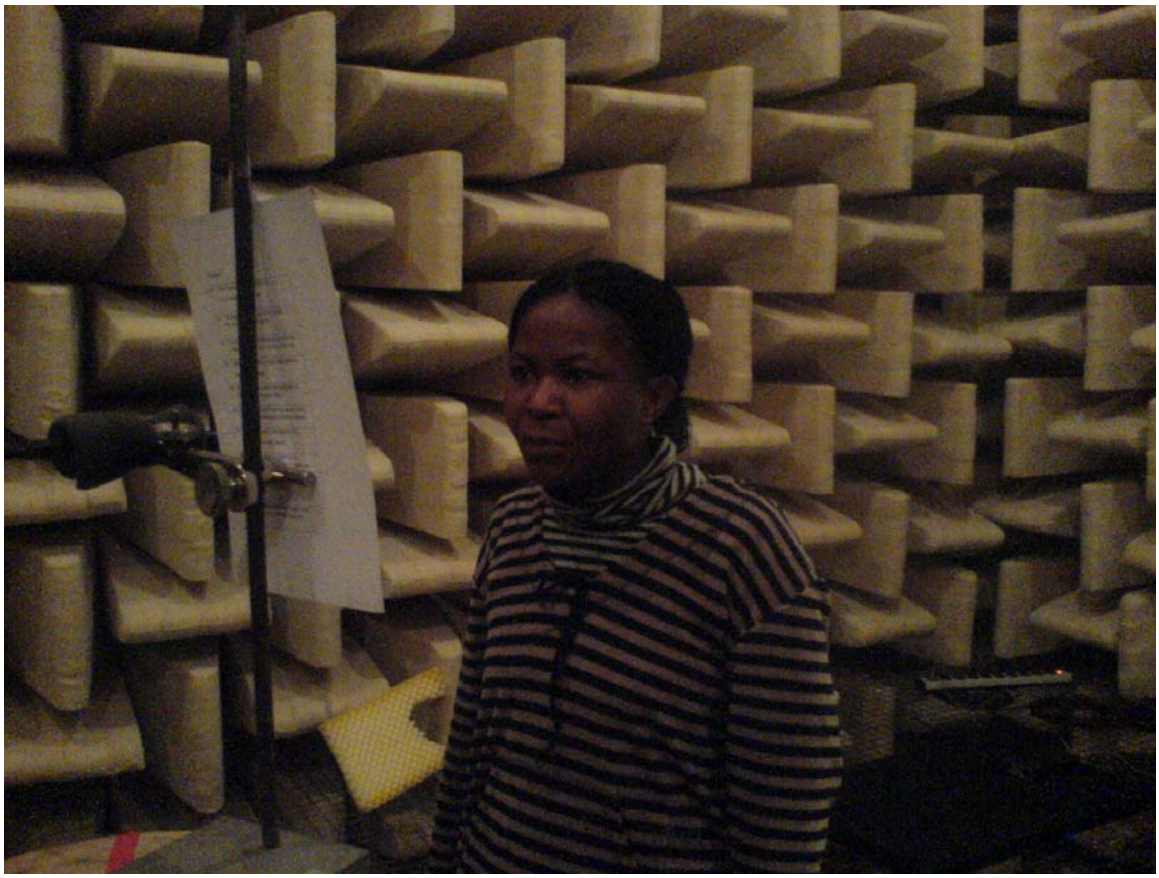


Figure 8: Deborah Ebem(Female 2 Speaker) at TU Delft Acoustic Imaging and Sound Laboratory

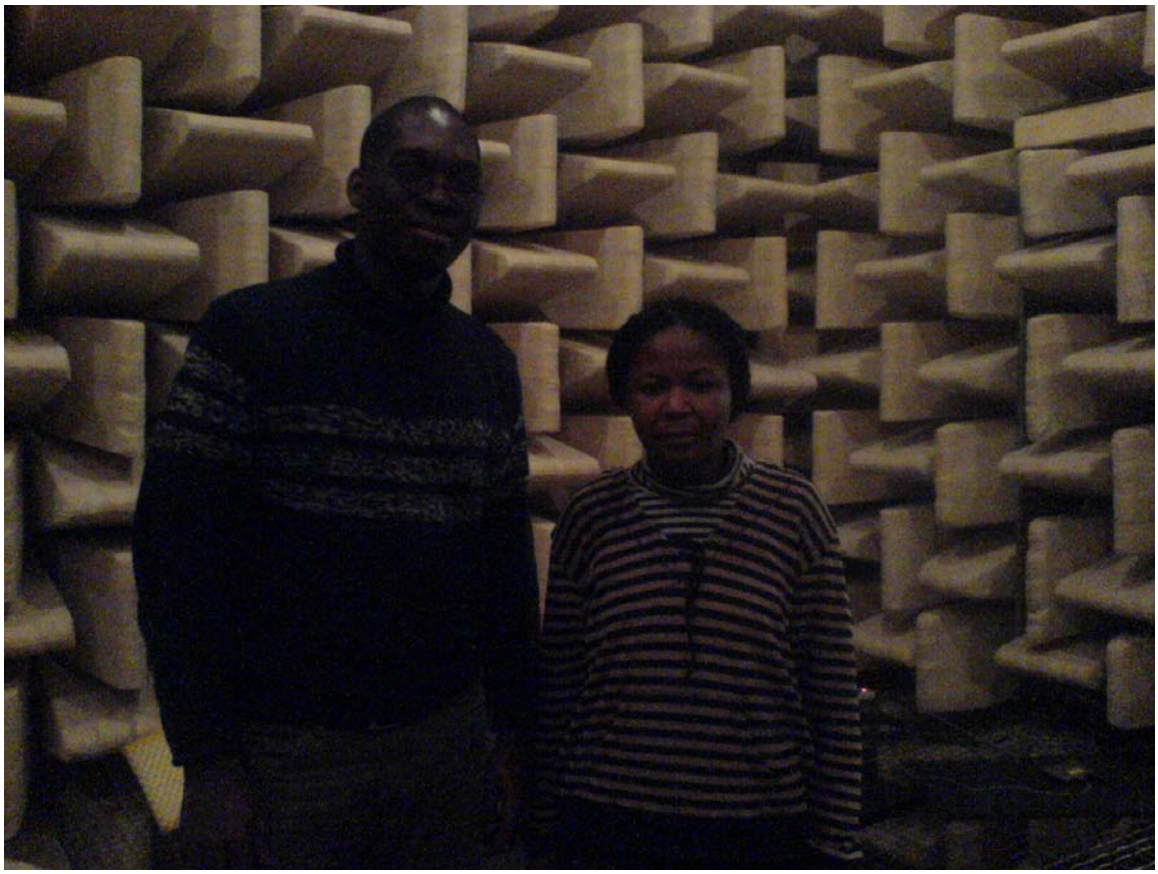


Figure 9: Charles Oragui and Deborah Ebem (Male1 and Female 2 Speakers) at TU Delft Acoustic Imaging and Sound Laboratory

The speech database is presented in **Appendix A.**

4.2 Post processing of the speech samples.

a) Filtering

The speech samples were filtered using super wide band 50-14000khz filter which was created in Cool Edit Pro software. The output format of the filtered speeches are the same as the input format (Raw pcm data,48khz, 16 bit, mono and Intel bit order). By filtering, frequencies below 50 hz and above 14000hz were filtered off respectively. The filters used in this research are presented in **Appendix B.**

b) Scaling/Level alignment

The filtered files were used as input for this stage. The speech samples were level aligned to -26dB according to the specification of ITU-T [20]. By this process all the original clean speeches have the same level of -26dB. The program "Sv56.exe" scales all files to -26dBov, based on ITU-T Recommendation P.56. We used sv56.exe and

sv56female1.bat.txt, sv56female2.bat.txt, sv56male1.bat.txt, sv56male.bat.txt to accomplish this operation.

4.3 Degradation of the speech database

We used 'full-scale database' which covered the entire range of degradation dimensions, background noise and clean conditions as specified by ITU-T for POLQA.They conditions are given below:

- Minimum 44 conditions including the anchor conditions
- Each file must be assessed by at least 8 subjects
- Each condition must include at least four talkers (female1,female2, male1 and male2)
- Each condition must be assessed by at least 96 votes (24 subjects)

The full scale database used for the experiment also contained the following twelve(12) anchor conditions.

Table 5: Anchor Conditions [19]

1	Reference	clean, 0dB attenuation, super-wideband (50 to 14kHz)
2	MNRU	10dB and 25dB (modified MNRU using P.50 shaped noise for modulation)
3	Background noise	12dB Hoth and 20dB babble SNR (relation between P.56 measured at the clean reference and root mean square(r.m.s) noise level)
4	Level according to P.56	-10dB and -20dB
5	Linear filtering	narrowband IRS send and receive filtered, 500-2500Hz and 100-5000Hz
6	Temporal clipping	2% and 20% packet loss, packet size 20ms without packet loss concealment.

The linear filtering IRS (send + receive) was constructed by down sampling the 48kHz reference signal to 16kHz,then the modified IRS send and receive were filtered, and up-sampled to 48 kHz with presentation level 0 dB relative to nominal level.
A total of fifty degradation conditions were defined for the experiment. They are given in **Appendix C(50 degradation conditions)**.

Tables six to eight below show the noises, filters and click pulse noise tones used in the degradation of the speech database.

Table 6: Noise file

S/n	Degradation type	Degradation name	Mix paste level
1	Noise1	12dB Hoth =HothNoise8.1secRMS-38dB.48k.pcm	100
2	Noise2	20dB Babble = Babble8.1secRMS-46dB.48k.pcm	100
3	Noise3	Band noise_heterodyne7kHz8.1sec.48k.pcm	100
4	Noise4	Inside_Train_Noise3_8.1sec.pcm	50
5	Noise5	Work_Noise_Jackhammer_8.1sec.pcm	40
6	Noise6	Inside_Aircraft2_8.1sec.pcm	50
7	Noise7	Pinknoise8.1sec.pcm	20
8	Noise8	Motorway8.1sec.48k.pcm	50
9	Noise9	Whitenoise8.1sec.pcm	3
10	Noise10	Pup_Noise_8.1sec.pcm	80
11	Noise11	Midsize_Car2_100Kmh_8.1sec.pcm	80
12	Noise12	Brownnoise8.1sec.pcm	30
13	Noise13	Car8.1sec.48k.pcm	35
14	Noise14	Nature2_Creek_8.1sec.pcm	50
15	Noise15	Outside_Traffic_Road_8.1sec.pcm	50

Table 7: Filters 50-14k

S/n	Filter name	Frequency range	Mix paste level
1	Filter1	Filter1_500-2500Hz	500-2500 Hz*
2	Filter2	Filter2_100-5000Hz	100-5000 Hz*
3	Filter3	Filter3_SWBrange	Filter, SWB range
4	Filter4	Filter4_SWBrange	Filter, SWB range
5	Filter5	Filter5_WBrange	Filter, WB range,-100dB<50&>7000Hz
6	Filter6	Filter6_WBrange	Filter, WB range,-100dB<50&>7000Hz
7	Filter7	Filter7_NBrange	Filter, NB range,-100dB>4000Hz
8	Filter8	Filter8_NBrange	Filter, NB range,-100dB>4000Hz
9	Filter WB	Filter WB	Filter flat(0 dB) from 0-7kHz, then down with -3 dB at 7.1 kHz to -80 dB at 8 kHz

* For the band limited references we use 500-2500 and 100-5000 as specified , with -3dB at 500/50 and 2500/5000 Hz with a slope>50 dB per octave

Table 8: Clicks_Pulses_Noise_Tones_48k

S/n	Clickspulses & tones	Noise type ,time &saving format	Mix paste level
1	Clickspulses1	Gsmnoise8.1sec.48k.pcm	30
2	Clickspulses1	Kraak8.1sec.48k.pcm	40
3	Tones1	Ratel8.1secWB50_7k.48k.pcm	5

The figures below depict the block diagrams of the live measurements we made for conditions 45,46, 48, 49 and 50. Figure 10: skype connection using netem for condition 45,46 and 48, figure 11**:** DECT-DECT GSM measurement (wireless connection) for

condition 49, figure 12: DECT-DECT GSM measurement (wireless connection) and figure 13: DECT-GSM recording/measurement for condition 50.

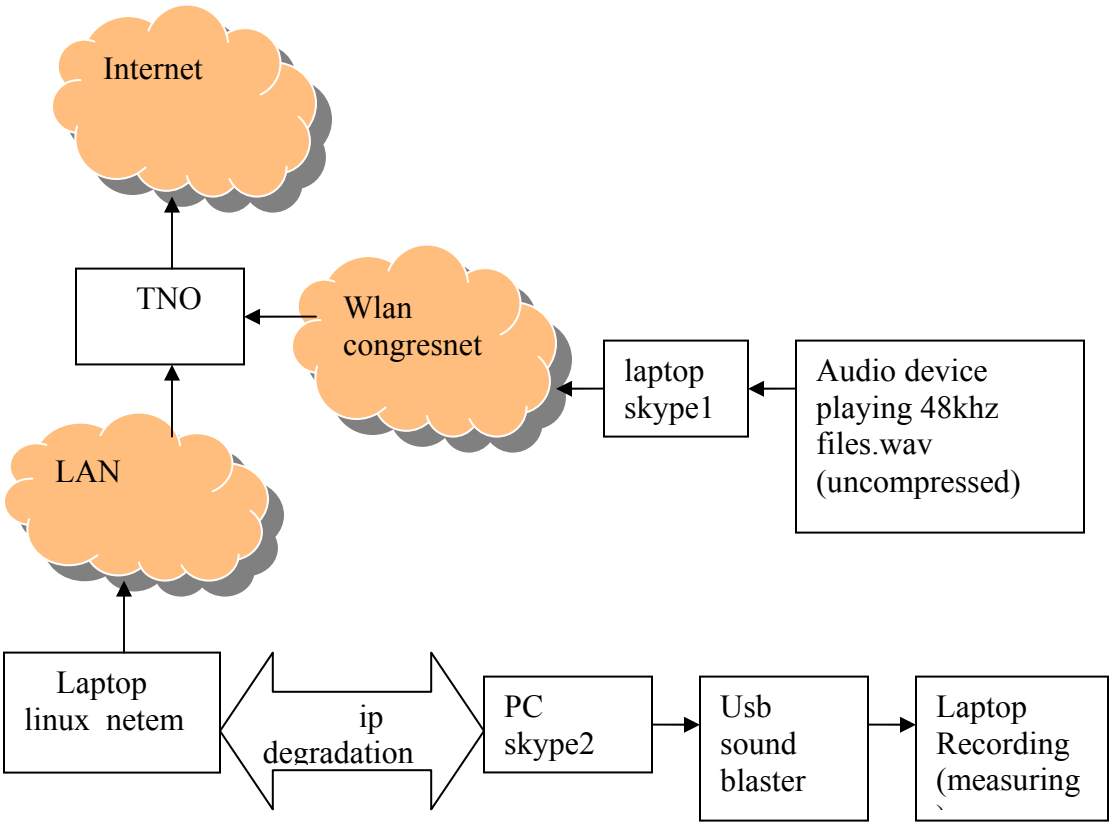


FIGURE 10: SKYPE CONNECTION USING NETEM for condition 45,46 and 48

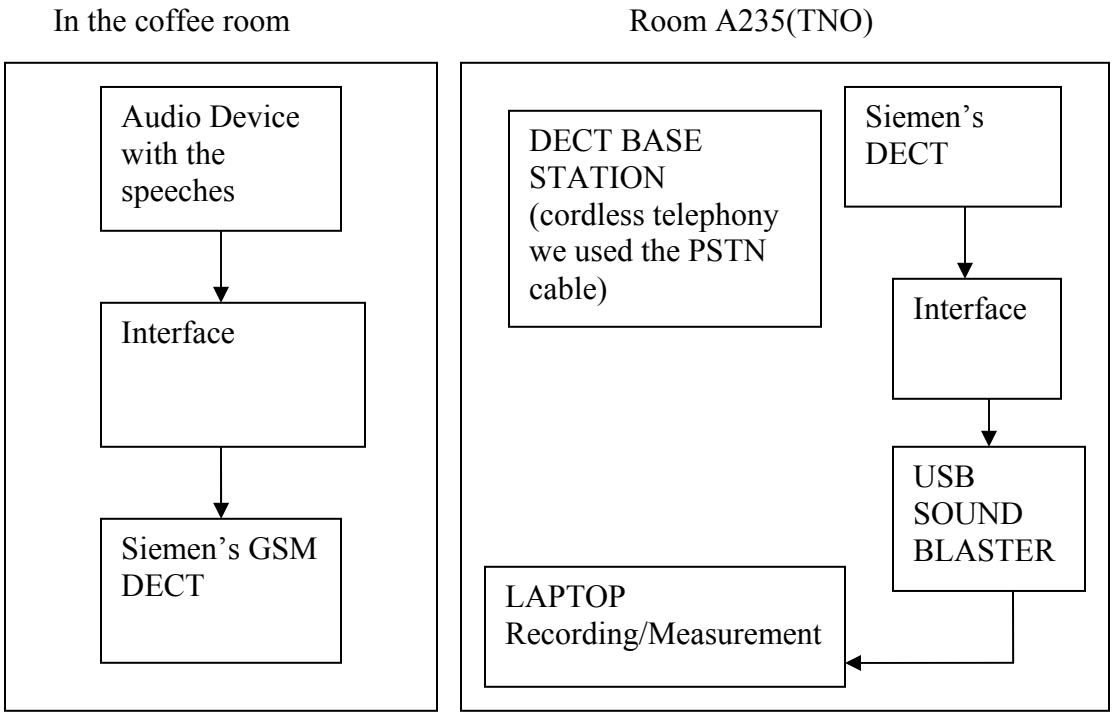


Figure11**:**DECT-DECT GSM MEASUREMENT(wireless connection) for condition 49

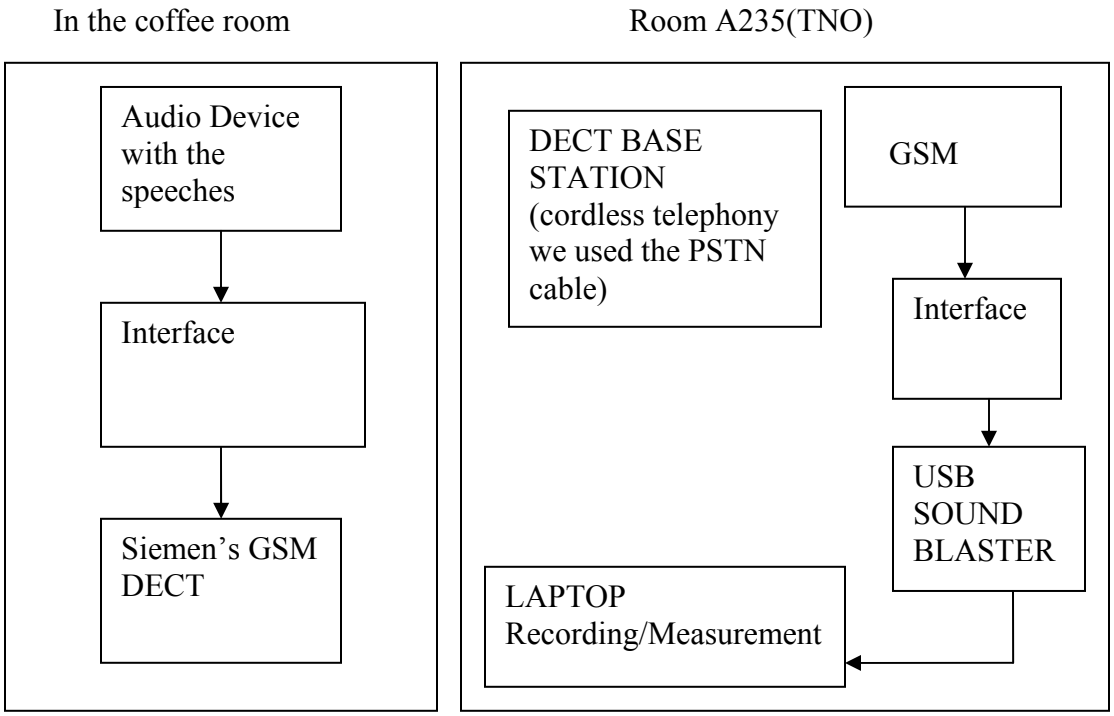


Figure12:DECT-DECT GSM MEASUREMENT(wireless connection)

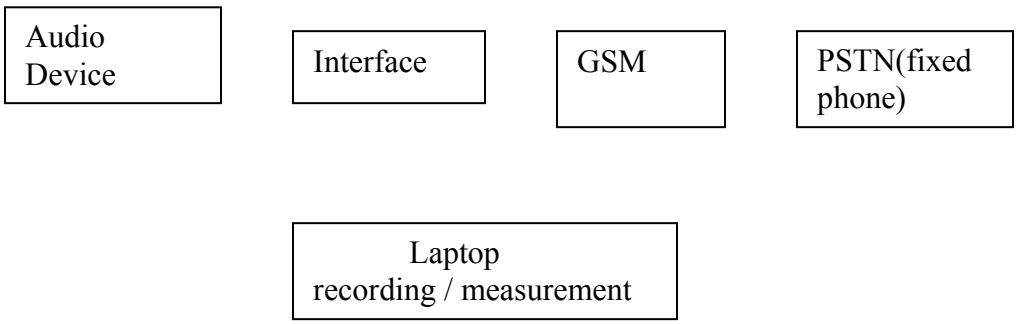


Figure 13: DECT-GSM recording/measurement for condition 50

CHAPTER FIVE

The Subjective Experiment and Objective Analysis

This chapter treats the subjective experiment . Part of this experiment was conducted here in Delft and the other part was conducted in Enugu, Nigeria.

5.1 Subjective Tests

Subjective ratings are gathered in two different listening tests (1) a Mean Opinion Score (MOS) test (also referred to as absolute category rating ([ACR])) and (2) a Degradation Mean Opinion Scores (DMOS) test (also known as degradation category rating ([DCR])). In a DMOS test, listeners hear a reference sample before each test sample, and are presumably providing a rating of relative quality.

The essence of using both methods is to compare the correlation of the objective measures with data from each method. MOS scores are conventionally used both to train and to evaluate objective speech quality measures. However, the objective quality measures estimate subjective scores by comparing the distorted speech to the original speech, which has more in common with a DMOS test. In MOS test, listeners are not provided with a reference sample. In this experiment we used MOS (ACR) method which is the preferred method by ITU-T for assessing speech quality.

5.2 The Experiment

All subjects used were native Igbo speakers with no hearing impairments. They were equally balanced both by gender and age. The total number of subjects was twenty four (24). Twelve (12) males and twelve (12) females and their ages were between eighteen (18) years to seventy (70) years. There were eight (8) subjects in the age group of eighteen (18) to twenty (29), eight (8) subjects in the age group of thirty (30) to forty nine (49) and finally eight (8) subjects in the age group of fifty (50) to seventy (70). The evaluation/experiment was performed using a Pack Bell laptop and a sennheiser HD 201 headphone. In the subjective experiment, the subjects listened to the speech fragment through a sennheiser HD 201 headphone. This is a closed headphone which shields environmental noise. So the subjects only heard the speech signals. It was calibrated using sound level calibration meter (TC Audio).

Before doing the experiment each subject was trained. Each subject used the same practice-igbo.48k.pcm for practice. There were six random orders, four subjects received the same random order. For each random order there were ten runs and each run consists of 20 randomly selected speech samples. That is each subject listened to 200 speech samples and gave his/her scores for each speech sample. The MOS rating of bad = 1, poor =2, fair =3 ,good = 4 and excellent = 5 were used for the test. **Appendix D** shows

the listening test ITU-T POLQA document (ACR random) used, for one run of 20 speech samples.
Sample pictures of subjects doing the experiment are shown in **Appendix E.**

5.3 Objective PESQ Results

In the statistical analysis a simple linear Pearson correlation, r is used. A correlation coefficient close to + or – 1.0 indicates a strong relationship, a correlation coefficient close to 0 indicates a weak relationship. The closer the correlation coefficient is to +1.0 the better the objective measure is at predicting the subjective rating [7].
As a start PESQ P.862.2 (wide band version of PESQ) is validated on the Igbo database as well as on the Dutch database that contains the same distortions. As PESQ is not suited for super wideband a first analysis was made on the down sampled signals. The original files with a bandwidth of 14 kHz (48 kHz sampling) were down sampled to 16kHz (7kHz audio bandwidth). Because speech only contains marginal information above 7 kHz this approximation can provide a first insight as to whether PESQ can be applied to the Igbo language.
Figure 14 gives the result of the evaluation in Igbo while Figure 15 gives the result for Dutch. With a correlation coefficient of 0.88 for Igbo the results are only slightly below the requirement of 0.9. For Dutch the correlation is lower, 0.84 and slightly too low in order to be able to make reliable predictions for super wideband speech.
For Igbo there is one prominent outlier (this is indicated by the number 27 in the figure 14) which corresponds to a condition that used a reverberation degradation as found in medium sized reflective rooms. Igbo subjects find the room reverberation less disturbing than predicted by PESQ. For Dutch there are several outliers predominantly for noisy conditions where a major part of the degrading noise is outside the bandwidth used by PESQ. However one would expect that wideband noisy conditions would be judged too optimistically by the PESQ method. Analysis showed that this is not the case. Apparently subjects could follow the strategy of hearing out the noise separately from the speech because of the natural bandwidth limitation of the speech. This can be interpreted as an auditory streaming effect. The results show that information above 7kHz is less important in Igbo than in Dutch.

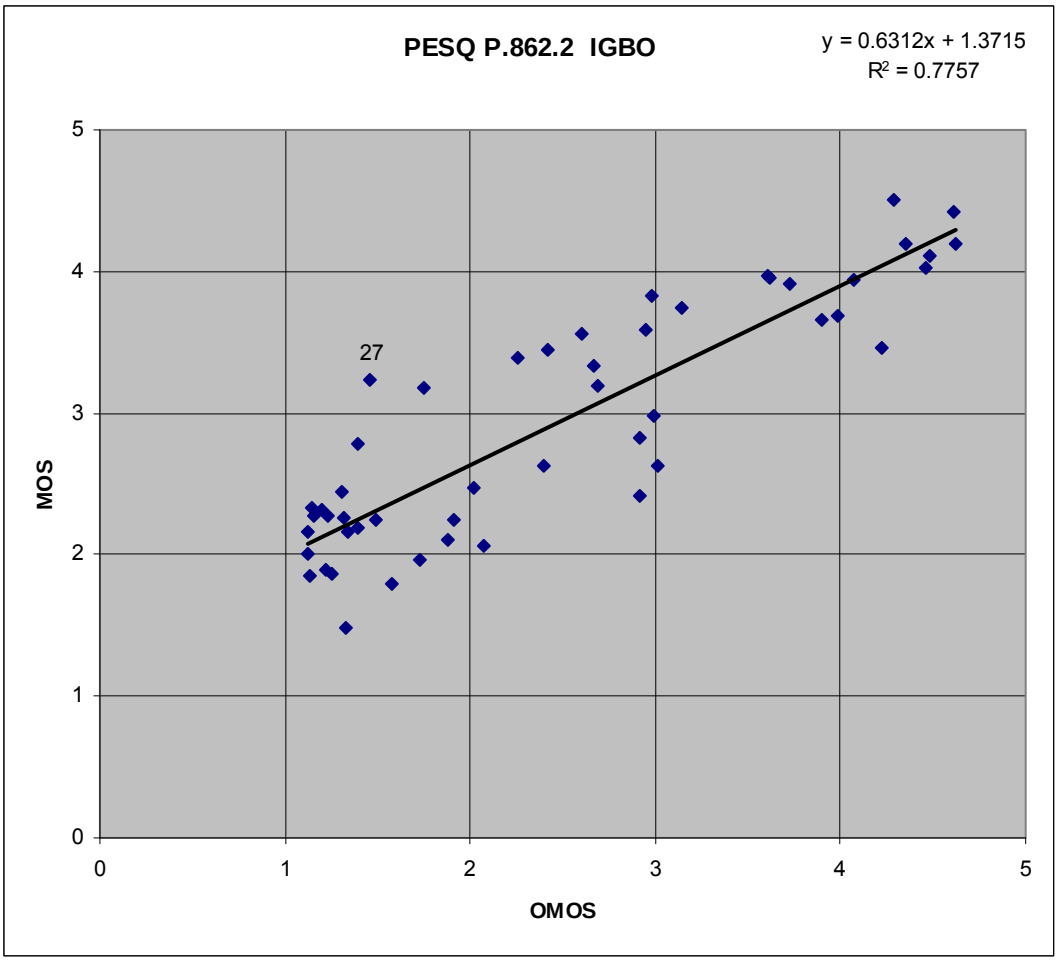


Figure 14: Scatter plot of subjective versus objective results using PESQ P.862.2 scores on the overall Igbo dataset. The correlation between the subjective and the objective measurements is 0.88.

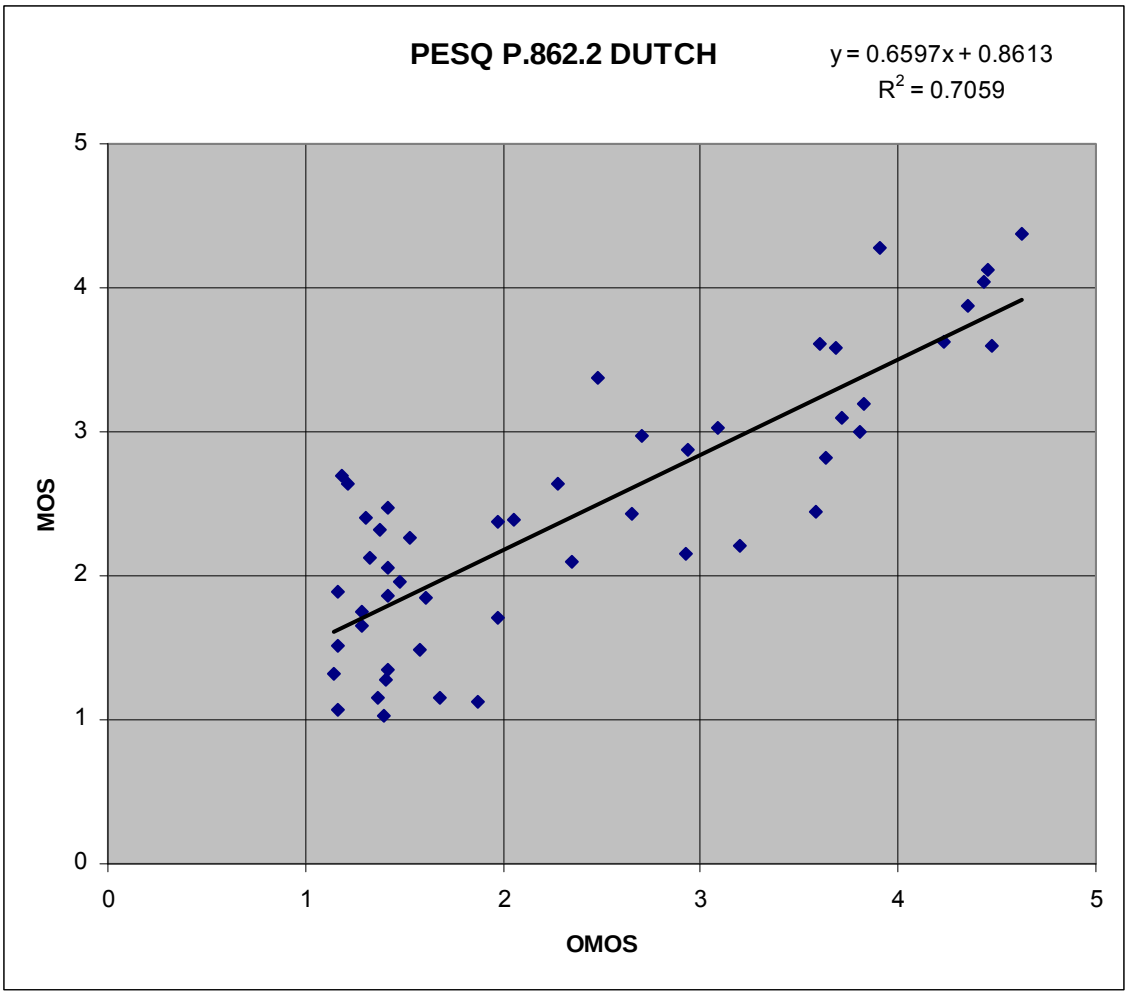


Figure 15: Scatter plot of subjective versus objective results using PESQ P.862.2 scores on the overall Dutch dataset. The correlation between the subjective and the objective measurements is 0.84.

5.4 Objective PSQM2010 Results

The same signals used in the subjective experiment were given to the PSQM2010 measurement algorithm (version886 May 20, 2009). This algorithm was trained on a wide set of distortions in super wideband mode. The results are presented in the figure 16 and figure 17 below.

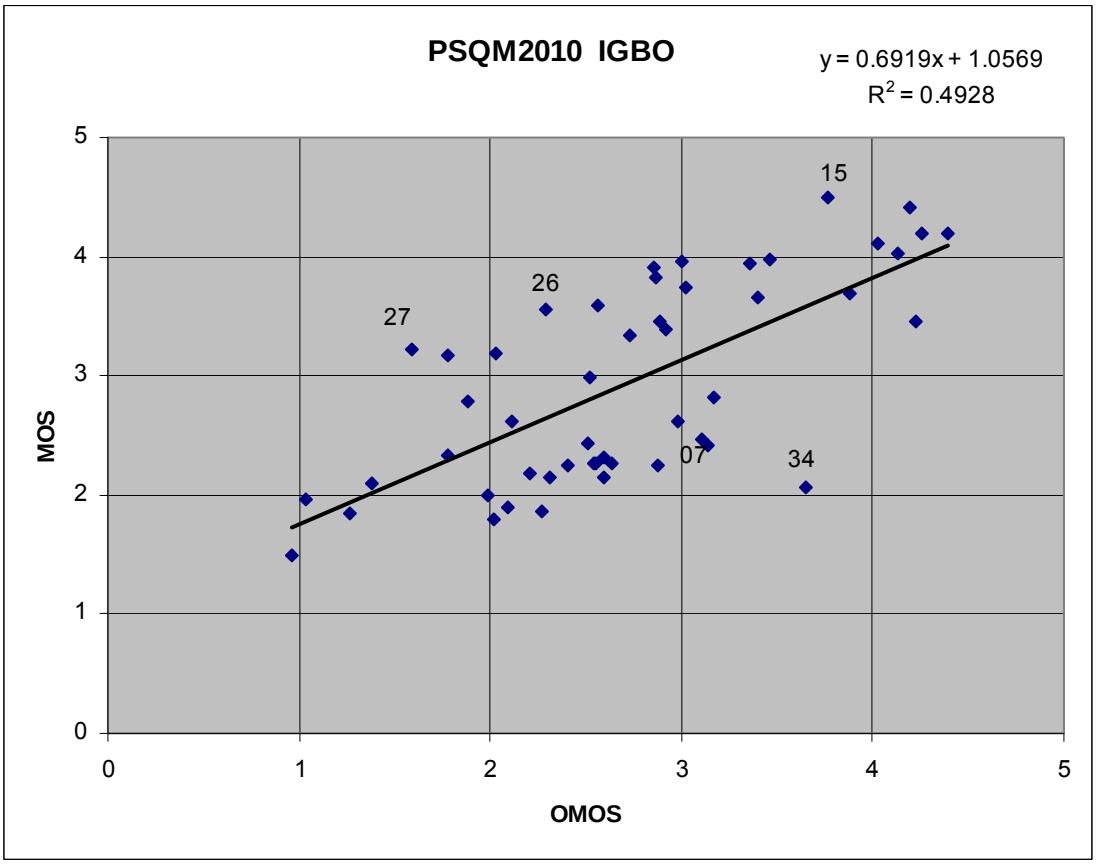


Figure 16: Scatter plot of subjective versus objective results using PSQM2010 scores on the overall IGBO dataset. The correlation between the subjective and the objective measurements is 0.70.

For the Igbo the most prominent outlier is condition 34 where the low presentation level is more disturbing for the Igbo subjects than predicted by the model. Condition 27, the room reverberation condition is again an outlier. Room reverberation is less disturbing for Igbo subjects than predicted by the model.

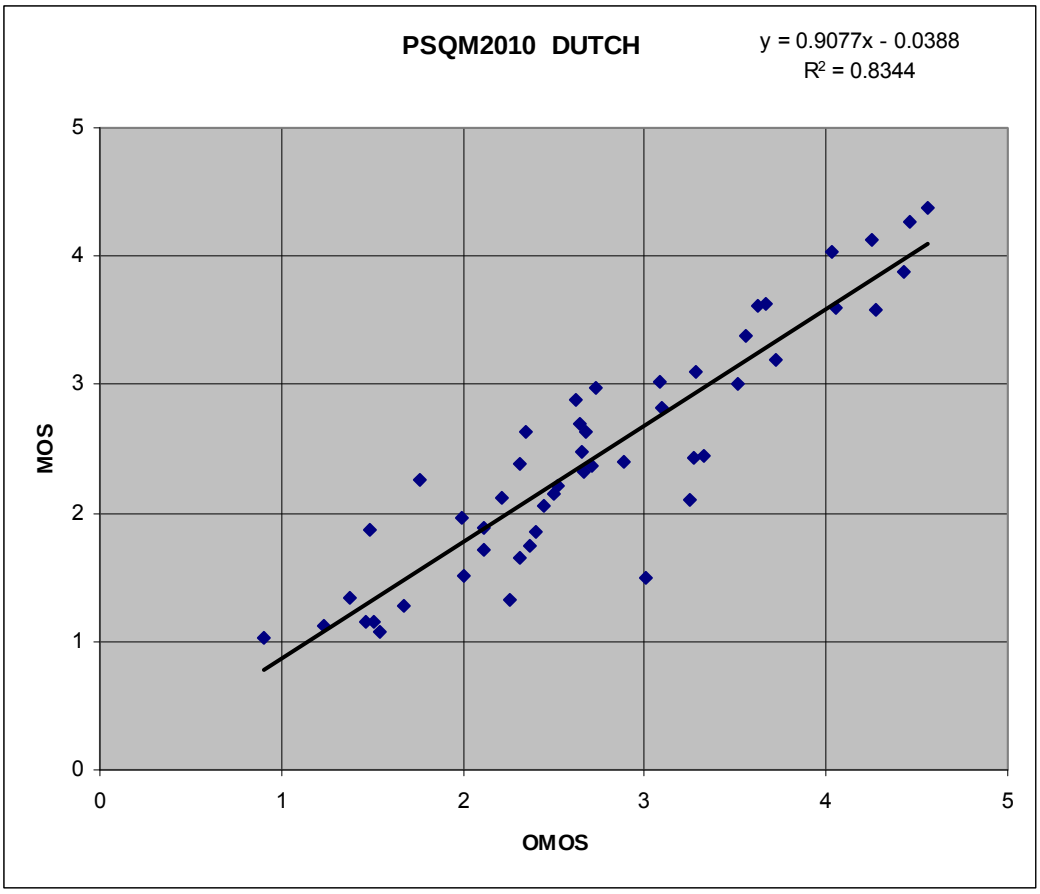


Figure 17: Scatter plot of subjective versus objective results using PSQM2010 scores on the overall Dutch dataset. The correlation between the subjective and the objective measurements is 0.91.

CHAPTER SIX

Tone / Non Tone Sentences

In this chapter we give a brief introduction of some tonal igbo words and we also investigated if there is a discrepancy between the tonal and non tonal sentences used in the experiment with the result of POLQA.

6.1 Classification of nouns in Igbo Language

Nouns in Igbo language can be classified into three criteria. These are traditional, morphological and tonal criteria. In a tonal language the meaning of words depends on the tones (pitch) at which the words are pronounced. The focus of this section is on the tones and the tonal sentences used in this research.

Nouns in Igbo are classified into five tonal criteria. These are Tone Class (TC) I-HH (High High),TCII-LH (Low High),TC III-HL (High Low),TC IV-LL (Low Low) and TC V –HS (High Stepped down tone).

The tone class I nouns are those that have a high high (HH) tone pattern for example

Isi - head
Aka-hand
Akwa- cry

The second class is made up of nouns with a low high (LH) tone pattern. Examples include:

Oke-rat
Aka-aging
Akwa- egg

The tone class three nouns are made up of words with a high low (HL) tone pattern. Such words include :

Akwa-cloth
Oke-boundary
ụlọ-house, home

The tone class four nouns include nouns with an inherent low low (LL) tone pattern , such nouns include:

Ala-land, ground
Akwa-bed
Enyo-mirror

The tone class five nouns are made up of nouns with high tone and another high tone that is a bit lower than the first high tone. This is why it is said to be stepped down tone. Examples include:

Ego-money
Nwoke-man
Anya-eye

Some of these nouns can change their tone patterns either as first or second words of an associative construction. They are therefore classified into two: those that change their tone when they occur as initial words of an associative construction is called Tone Group I while those that change their tone pattern after some words are called Tone Group II nouns [21]. The tonal sentences used in this research demonstrate the above listed criteria/groupings. The meaning of an Igbo noun depends on the tones applied to it. The spelling of the word is the same but based on tone the meaning is different. Take for example the word *akwa* could mean cloth, egg, bed, cry, bridge as shown above. The table below gives examples of igbo nouns/words that have the same spelling but have different meanings based on the class of tone applied to them.

Table 9: Some Igbo words with different meanings

S/n	Igbo word	English
1	Akwa	Cry,cloth,bed,egg,
2	Igwe	Chief,metal,multitude
3	Ude	Fame,pomade,news
4	Eke	Python,market day,town,name of a person
5	Ugbo	Name of a town, farm
6	Ada	Name of a person, fall
7	Oke	Rat,boundary
8	Iro	Enemity,tale
9	Ibu	heavy,load,
10	Nma	Beauty,matchet,knife,farm implement
11	Ugwu	Hill,respect,name of a person
12	Odo	Masquerade,mortar

The tonal sentences used in this research are presented in **APPENDIX A.**The words with the tones are highlighted in yellow.

6.2 Comparison of the subjective results of the tonal and non-tonal sentences

For the experiment nineteen conditions had tonal sentences as well as non tonal sentences. For this set a comparison could be made between the tonal and non-tonal behavior. For the down sampled signals condition 21 showed the most prominent difference with a subjective MOS of 4.8 for the tonal sentence and 4.0 for the non tonal sentence. Statistical analysis shows that this difference is on the edge of statistical significance. Condition 21 is a frequency filter distortion that enhances the lower frequencies, thus changing the timbre of the voice. Apparently this change in timbre has more impact on the non tonal speech. Overall the differences between tonal and non-tonal sentences is too low to draw any final conclusions. Figure 18 shows a scatter plot of the subjective results of non-tonal versus tonal sentences. The correlation between the results of these two sets is 0.96 showing that differences between the two sets are in general small.

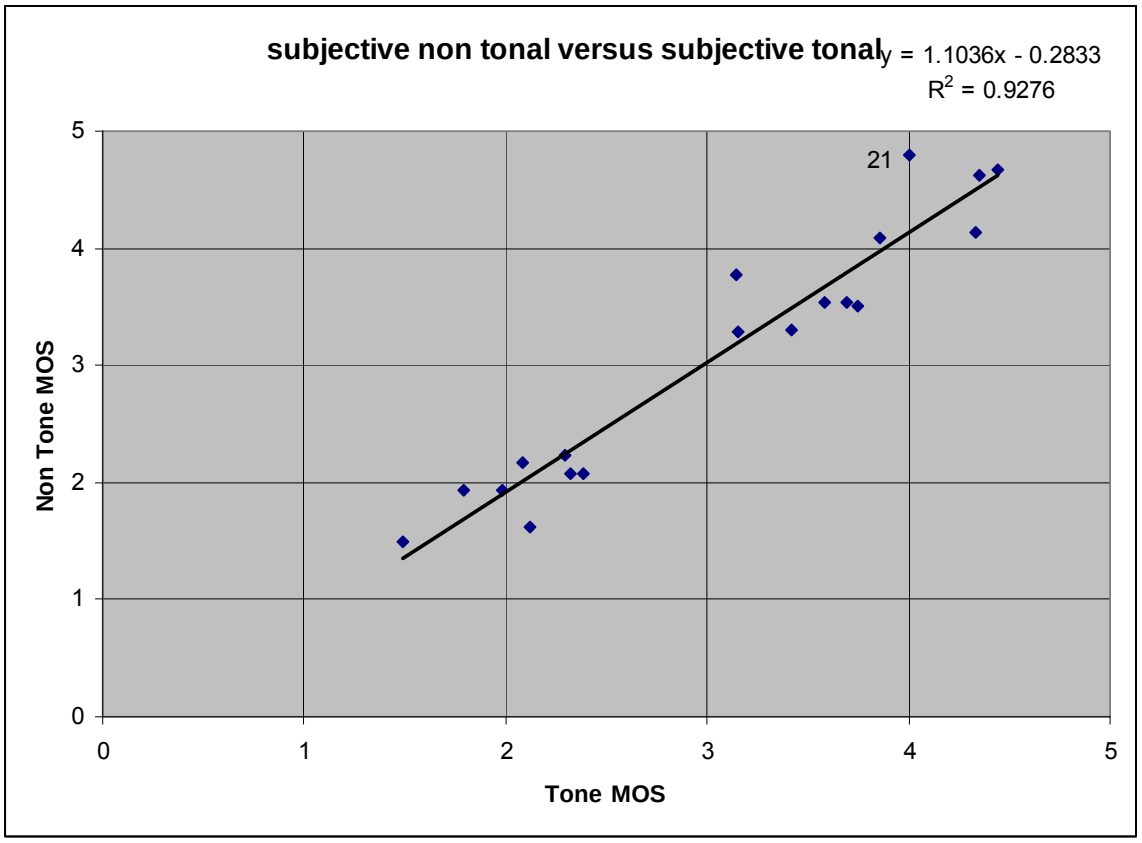


Figure 18: Scatter plot of subjective non tonal versus subjective tonal . There is no significant different behaviour for tone and non-tone sentences, the correlation between the two sets of results is very high, r = 0.96.

CHAPTER SEVEN

Summary, Contributions , Challenges , Recommendation for Future Work and Conclusion
This chapter concludes this thesis work.

7.1 Summary

It is becoming increasingly common to use packet-switched networks, typically based on the Internet Protocol (IP) and/or asynchronous transfer mode (ATM), for carrying real-time speech traffic. This has the potential for significant cost savings over traditional circuit –switched networks, due to the lower cost of switching equipment and the ability to run a single network for both voice and data.

In packet-based transmission, speech is compressed using a coding scheme such as ITU-T Recommendation G.711 or G.723.1, and divided into packets. As a result, quality and /or intelligibility are sometimes degraded. Speech quality is normally defined as the degree of goodness in the perception of speech while speech intelligibility is how well or clearly one can understand what is being said. In terms of speech transmission, speech quality is a characteristic of a speech passed through a speech transmission/processing system. It is a measure of perceived speech degradation compared to the original speech. The quality of a speech is degraded when it is processed with codecs or when it is transmitted and received through data network.

In order to assess the level of acceptability of degraded speeches, various subjective methods have been developed to test codecs or sound processing systems. Although good results have been demonstrated with these, they are time consuming and expensive due to the necessary involvement of teams of professional or naive subjects.
To reduce cost, computerized objective systems were created with the hope of replacing human subjects. While reasonable standards have been reported by several of these systems, they have not reached the accuracy of well constructed subjective tests yet . Therefore, their evaluations and improvements are constantly been researched for further breakthroughs [2].

The user satisfaction of real-time applications is usually expressed in terms of Quality of Experience (QoE).Measuring Quality of User Experience is important not only for users but also for the innovators, investors, venture capitalists (vcs) and developers. QoE can be measured through subjective or objective measurements. One way to quantify QoE is through Mean Opinion Score (MOS). MOS is usually measured by subjective measurement techniques [4] which involves asking the same set of questions to statistically relevant number of people(significantly large number of people).Based on their input, a mean of the opinion score is calculated. This process is always labourous,

time consuming in terms of speech preparation, recording and conducting the experiment. Moreover, it is capital intensive. The upside is that it gives more accurate result than objective techniques.
Objective speech evaluation techniques are mathematical models that approximate results of subjective quality assessment, but are based on criteria and metrics that can be measured objectively and automatically evaluated by a computer program. The objective QoE tests try to simulate/emulate the subjective measurements by comparing the original speech with the degraded speech.

In this work, we validated PESQ and the TNO proposal on the Perceptual Objective Listening Quality Assessment (POLQA) benchmark, which is the new ITU-T benchmarking for objective measurement of speech quality, on the tonal language Igbo –a language spoken in south eastern-Nigeria .We recorded 200 sentence pairs of Igbo speeches at the acoustical and imaging lab of TU Delft. There were four native igbo speakers, two males and two females for the recording .We did our recording with Cool Edit Pro. The speech was recorded, preprocessed and post processed according to ITU-T recommendation for the objective model POLQA [19].We conducted the subjective experiment both in Delft the Netherlands and in Enugu Nigeria. Twenty four (24) native Igbo speakers without hearing impairments participated in our subjective experiment. The gender and ages of the subjects were evenly distributed (12 males and 12 females) . Their ages range from eighteen (18) years to seventy years (70).There were eight subjects in the age group of eighteen (18) to twenty nine (29), eight subjects in the age group of thirty (30) to forty nine (49) and finally eight subjects in the age group of fifty (50) to seventy (70) . Also in each age category the genders were equally evenly distributed that is four (4) males and four (4) females. The experiment was performed using a Packard Bell laptop and a sennheiser HD 201 head phone .

As a start PESQ P.862.2 (wide band version of PESQ) is validated on the Igbo database as well as on the Dutch database that contains the same distortions. As PESQ is not suited for super wideband a first analysis was made on the down sampled signals. The original files with a bandwidth of 14 kHz (48 kHz sampling) were down sampled to 16kHz (7kHz audio bandwidth). Because speech only contains marginal information above 7 kHz this approximation can provide a first insight as to whether PESQ can be applied to the Igbo language. Our result on PESQ P.862.2 shows a good correlation between the subjective and objective measurements on the tonal language Igbo with a correlation coefficient of r = 0.88 on the overall data set. For Dutch, the model shows less correlation between the subjective and the objective measurements (r = 0.84) compared to the tonal language Igbo (r = 0.88). .The results also show that information above 7kHz is less important in Igbo than in Dutch.

The PSQM2010 model does not predict the tonal language Igbo. Our result shows a poor correlation between the subjective and objective measurements with correlation coefficient of r = 0.70. For Dutch, the model shows a strong correlation between the subjective and the objective measurements with correlation coefficient of r = 0.91.

From our stastical analysis on tonal and non tonal sentences of the Igbo language there is no significance difference behaviour between them. The correlation between the two sets is very high, r = 0.96.

7.2 Contributions of this Research.

- Validated PESQ P.862.2 and PSQM2010 on the tonal language Igbo.
- This research has provided scientific evidence that there is only a marginal difference between the tonal and non tonal sentences of the Igbo language.
- To the best knowledge of the author this is the first time such a research is conducted in African language. Thus this research provides a first study towards application to African language.

7.3 Challenges

In the course of doing this research the author encountered a lot of challenges. One of such challenges is that they are very few materials on the tonal language Igbo. Constructing the 200 sentence pairs in Igbo and marking the tones took a lot of time. Secondly conducting the experiment was a big hurdle as some of the subjects were inquisitive, some were skeptical and others especially the youths were enthusiastic. The researcher spent time to explain that it is just an ordinary research for the benefit of the Igbo people and that it is not implicating. It took an enormous amount of time and resources to conduct the experiment.

7.4 Recommendation for future work

- That improvement be made on PSQM2010 to be suitable for the Igbo language.
- That other tone languages, such as Chinese and Yoruba, be investigated to get a more detailed analysis and conclusions.
- Find out if there is a difference in the results of Europeanised and non Europeanised native Igbo speakers.
- Find out if there is a difference between the sentences spoken by male speakers and female speakers.
- Since there are many igboid dialects to find out (why is that even within the communities there is intelligibility difference in the Igbo language for example I can hardly understand anything when an Ikwo or Izzi man from Abakaliki is speaking.

7.5 Conclusions

7.5.1 Empirical conclusions

1. Information above 7 kHz is probably less important in the Igbo language than in Dutch. The PESQ wideband speech quality model does not take into account information above 7khz and provides a better correlation for Igbo than for Dutch, especially in the low quality domain.
2. Igbo language is less sensitive to distortions above 7 kHz.
3. For Igbo room reverberation is less disturbing than for Dutch.
4. For Igbo low presentation levels are more disturbing than for Dutch .
5. There is only a marginal difference between tonal and non tonal sentences of the Igbo language, timbre distortions (frequency response distortions) are probably more disturbing for tone sentences.

7.5.2 General conclusions

We conclude this work by saying that we ventured into this research with enthusiasm, excitement and expectations. It is interesting conducting this research. As research is a puzzle we have been able to solve one in an innovative and dynamic area / way. Going through the stages of this research from conception to completion has been very interesting and exciting to us. With the results of our experiment which is not only beneficial to Igbo people but also to innovators, inventors, service providers, venture capitals , developers, designers and regulatory bodies we look forward to seeing better products provided for the Igbo people. We also look forward to seeing more researches in African languages.

And finally, it is a big plus for TNO and her PESQ P.862.2 model for predicting the tonal language Igbo.

References

[1] Fong Loong Chong, Ian V.McLoughlin, Krzysztof Pawlikowski "A Methodology for Improving PESQ Accuracy for Chinese Speech" , IEEE Publication Volume , Issue , 21-24 Nov. 2005 Page(s):1 – 6

[2] Beerends, J. G., Busz, B. P. Oudshoorn,P. , Van Vugt, J. M., Ahmed, O. K., Niamut, O. A. "Degradation Decomposition of the Perceived Quality of Speech Signals on the Basis of a Perceptual Modeling Approach," J. Audio Eng. Soc., vol. 55, pp. 1059-1076 (2007 Dec.).

[3] Z.LI, Tan, E.C. , McLoughlin, I. and Teo, T.T. "Proposal of standard for intelligibility tests of Chinese speech", in IEEE Proceedings –Vision,Image Signal Processing, vol.147, pp.254-260, 2000.

[4] ITU-T Recommendation P.830 "Subjective Performance Assessment of Telephone-band and wideband digital codecs", Hesinki, 1993 ; revised in 1996.

[5] Beerends, J.G., van Buuren, R. A, van Vugt, J. and Verhave, J. "Objective Speech Intelligibility Measurement on the basis of Natural Speech in Combination with Perceptual Modelling . J.Audio Eng. Soc. , " submitted for publication.

[6] Hall, T.A. "Objective Speech Quality Measures for Internet Telephony" Proc. of SPIE, vol. 4522,pp.128-136, 2001.

[7] Thorpe , L., Yang, W. "Performance of current perceptual objective speech quality measures",in Proc.IEEE Speech Coding Workshop, 1999,pp.144-146

[8] Rix , A. W., Beerends, J.G., Hollier, M.P. and Hekstra, A.P. "Perceptual Evaluation of Speech Quality (PESQ)- a new method for speech quality assessment of telephone networks and codecs",in Proc.IEEE International Conference on Acoustic, Speech and Signal Processing,Salt Lake City,USA,2001,pp.749-752

[9] http://en.wikipedia.org/wiki/Igbo_language

[10] Laver , John "Principles of phonetics" Cambridge University Press, 1994

[11] Beerends,J.G. and Hekstra, A.P., Rix, A.W. and Hollier, M.P. "Perceptual Evaluation of Speech Quality (PESQ), the new ITU standard for end-to-end speech quality assessment. Part II – Psychoacoustic model". J.Audio Eng. Soc., Oct.2002

[12] ITU-T Recommendation P.862, "Perceptual Evaluation of Speech Quality (PESQ), An Objective Method for End-to-end Speech Quality Assessment of Narrowband Telephone Networks and Speech Codecs," Geneva, Switzerland 2001.

[13] Beerends, J.G. and Hekstra, A.P., Rix ,A.W. and Hollier, M.P., "PESQ,the new ITU standard for objective measurement of perceived speech quality, Part II- Perceptual model," J.Audio Eng.Soc.,vol.50,pp.765-778,Oct.2002.

[14] Rix, A. W., Hollier, M. P., Hekstra, A. P. and Beerends, J. G., *"*PESQ, the new ITU standard for objective measurement of perceived speech quality, Part 1 - Time alignment,*"* J. Audio Eng. Soc., vol. 50, pp. 755-764 (2002 Oct.).

[15] ITU-T Recommendation P.800,"Methods for Subjective Determination of Transmission Quality", International Telecommunication Union, Geneva, Switzerland (1996 Aug.).

[16] ITU-T Recommendation P.862.1-Mapping function for transforming P.862 raw result scores to MOS-LQO , Geneva, Switzerland ,2003

[17] Beerends, J.G. and Stemerdink, J.A., "A perceptual speech quality measure based on a psychoacoustic sound representation, " J.Audio Eng.Soc.,42(3): pages 115-123,March 1994

[18] ITU-T Recommendation P.861,"Objective quality measurement of telephone band (300-3400 Hz) speech Geneva, Switzerland Aug. 1996

[19] ITU Study Group 12 Telecommunication Standardization Sector TD 90 rev4(WP 2/12) "Requirement specification for P.Objective Listening Quality Assessment(POLQA)"

[20] ITU-T Recommendation P.48, "Specification for an Intermediate Reference System," International Telecommunication Union, Geneva, Switzerland (1989).

[21] Mbah, B.M.,"GB SYNTAX: Theory and Application to Igbo",Association of Nigerian Authors CRS Chapter,2006.

Appendix A (Speech Database)

Female 1

S/n	Igbo	English
1	Okoro ọbia ahụ buru ibu ọpụrụ ibu ibu di arọ . Ọ gbara arọ ole?	That fat young man that carry heavy load. How old is he?
2	Onye ndu anyi ga eduba anyi n' ụzọ nke ndụ ebighi ebi.	Our leader will lead us on the way to eternal life.
3	Mgbe anyi jere nkụ anyi hụrụ nnukwuu nnụnụ nwere nku mara nma.	When we went to fetch fire wood we saw big bird that has beautiful feathers.
4	nke Ị ji bapụta ụwa site n'Onye-nwe-anyi n'ihi ụzọ di iche iche Ị si enye amara	By which you saved the world through our Lord by the various ways you give grace
5	Ndi mba Isreal dara mba n' ọzara. Iwe Jehova we dakwasi ha.	The Irsealites fainted in the desert the anger of the Lord descended on them.
6	Mgbe nwatakiri a na egwu egwu n' ọhia, ọnya mara ya n' ụkwụ .	When this child was playing in the bush a trap cut him/he was cut by a trap
7	werenu ekele ba n' ọnụ ụzo-ama-Ya Werenu otuto ba n'ogige-Ya nile	Come into his presence with thanksgiving,come into his gate with praise
8	ọkụ na miri bụ ezi ihe. Anyi ji miri asa arụ.	Fire and water are good things. We use water to bath.
9	Ta, ọ bụrụ na unu ege nti olụ -Ya, unu emela ka obi unu sie ike:	Today, if you hear his voice harden not your heart
10	Onye-nwe-anyi nọyere unu. Ka Ọ noyere kwa mọ nke gi.	The Lord be with you and also with you

Female 1

S/n	Igbo	English
11	Aha nnam bụ Mazi Ude. Nnam bu ezigbo madu.	My father's name is Mr Ude. My father is a good man
12	E mesia ọnya di egwu wee pụta n'arụ ya. Ebere nwatakiri afu.	Afterwards sores came out of his body. It is pity for that child.
13	Tikusienu Jehova nkpu ọnwụ ike, ihe nile na eko ume na elu uwa.	Make a joyful noise unto the Lord, Every thing that has breath on earth.
14	Werenu ọnụ fe Jehova ofufe: Werenu iti-nkpụ ọnụ bia n'iru Ya.	Joyfully worship the Lord: Go into his presence with shout of praise
15	Ya onwe-ya bụ Chineke: Ya onwe-ya emewo anyi,	He alone is the Lord He is our maker
16	Anyi bụ atụrụ nke ọzụzụ -anụ Ya. Anyi bụ ọlụ aka ya.	We are the sheep of his pasture. We are his handiwork.
17	Onye iro ahụ ga-akọrọ unu akukọ iro . Miri bụ ndụ azụ.	That enemy will tell you tales. Water is the life boat for fishes.
18	Kelenu Ya, gọzi-kwa-nụ aha-Ya. N'ihi na Jehova di nma	Thank him and adore his name. For God is good
19	rue mbe ebighi-ebi ka ebere-Ya di; Rue ọgbọ nile ka ikwesi ntụkwasi obi Ya di.	His mercies endureth for ever; His faithfulness is from generation to generation.
20	Onye kwesiri ka madụ na-ekele? ọ bụ nani Chineke.	Who should man Greet? It is only God.

Female 1

S/n	Igbo	English
21	Nwa m, I ga ekele osisi?	My child, will you worship trees?
	E-e. I ga- ekele aja? E-e.	No.Will you worship sand? No
22	Olee ebe osimiri nke a si pụta? O si n'ebe di anya pụta.	Where does this sea come from? It came from a far place.
23	Ezi Chineke nke bi n' elu-igwe, Nke pụrụ ime ihe nile	Merciful God that lives in heaven, That is able to do all things
24	Ya kere osimiri na ihe nile di n' ime ya. Ọtụtụ anụ di iche iche bi na osimiri.	He created the sea and all that dwell in it.Numerous animals live in the sea.
25	Gini mere nkwụ adighi n' ala Ndi ọcha? N'ihi na ala ha juru oyi.	Why is it that palm trees are not in the white man's land? Because their land is cold.
26	ọ bụ ala na-ekpo ọkụ ka nkwụ na eto. Nkwụ adighi eto na ala juru oyi.	It is on hot land that palm trees grow. Palm trees do not grow on a cold land.
27	Site na nkwụ, anyi nwere manụ, na akụ na elu-akụ na manya nkwụ na aziza.	Through palm trees we have red oil, kernel,and palm kernel scales and wine and broom.
28	Nwa m cheta na ọbụ Chineke kere nkwụ nye anyi.	My child remember that It is God that created palm tree and gave it to us.
29	N'ihi ya ka anyi kelee ya mgbe nile. Okwesili ma bụrụ kwa ihe ziri ezi.	Becuase of that we should that him all the time.It is good and excellent to do so.
30	Onye nka nka nke a kara nka nka na ezie. Aha onye nkuzi anyi bu mazi Ugwu.	This guru is very old. The name of our teacher is Mr Ugwu.

Female 1

S/n	Igbo	English
31	Umuntakiri atọ a nwere uche. Ehi unu nụrụ unụ nke ukwu.	These three children are wise. Your cow struggled a lot.
32	Ndi ọcha ji ọkụ na miri anya ụgbọ. Obodo ndi ọcha mara nma rinne.	The white man uses fire and water to paddle their cargo/ship/boat.
33	Onye-nwe-anyi meghe ebubere ọnu anyi. Ọnu anyi ga ekwuputa kwa otuto-Gi.	Oh Lord open our libs. Our mouth shall show forth your praise.
34	Chineke, zọputa anyi ọsọsọ. Onye-nwe-anyi, me ngwa nyere anyi aka.	Oh God make speed to help us. Lord make haste to assist us.
35	Tobenu Onye-nwe-anyi. Ka eto Aha Onye-nwe-anyi.	Praise ye the Lord. May the Lord's anme be praised.
36	Ada dara ada , ada ka Ada dara. Anam achọ ọdinma ezinụlọm.	Ada fell down, fell was what Ada did. I am working on the progress of my family.
37	Nwa m, gwa m ihe m b ụ, na ihe aha m bụ. Ana m awa n'iru anyanwụ.	My child, tell me what I am and what my name is. I rise in the presence of the sun.
38	Ọzọ kwa, gi onwe-gi, nwatakiri, agākpọ gi onye-amụma nke	Also, you yourself, child, Will be called a prophet of
39	Onye kachasi ihe nile elu: n'ihi na i ga aga n'iru Onye-nwe-anyi idozi ụzọ Ya nile;	He who is above all:becuase you will go before our Lord to prepare his way.
40	Ime ndi nke Ya ka ha mara nzọpụta: nime nbaghara nmehie nile ha,	To make his people to know salvation: From forgiveness of their sin,

Female 1

S/n	Igbo	English
41	N'ihi obi ebere nke Chineke anyi: nke sitere na elu ga eleta anyi nime ya,	Because the mercy of our God From above will care for us in him,
42	Imụkwasi ndi nọ n'ọchichiri ìhe: iduzi ukwụ -ayí ba n' ụzọ udo.	To lighten the people in darkness with light:to lead our feet to the path of peace.
43	igwa gi mgbe I ga-ebili. lụọ ọlụ gi ,gụọ akwụkwọ, jegharia kwa.	To tell you when you should get up. do your work,read your book and walk about.
44	Adighi m amụ ka I dina n' ihe ndina Gi na-arahụ ụra;	I do not shine when you are lying On yor bed sleeping;
45	Egbe ka eji agbagbụ egbe. Ndi Igbo na azụ ahia ri nne.	Gun is used to kill hawk. The Igbos are merchants.
46	Nna nke ebere nile, anyi ndi-oru-Gi nēkwesigh ekwesi,	Father of all mercy; We your unworthy servants,
47	anyi ekele Gi ekele nke obi di ume-ala, nke si kwa n'obi-anyi pụta,	We give you praise in humulity, That comes out of our heart,
48	bayere ezi ihe nile na obi-ọma nile nke I mere anyi,	With respect to good things and kindness that you have for us,
49	Mgbe m wara, chi abuo. Ana m eleba anya n' ụlọ gi	When I rise, the day breaks. I look into your house
50	nke ndụ nka; ma nke kasi ha nile, n'ihi ihụ -n'anya-Gi nke anapụgh iru ọnụ,	For this life;above all, Because of your uncountable mercy,

Female 2

S/n	Igbo	English
1	Ọgụ madu atọ ndị a jili ọgụ ha luọ ọgụ . Egwu bala ndi obodo anyi na alu.	These sixty persons used their hoe to fight. Fear came over our towns men/peopl.
2	Ndị dibia ga –ewere aja ọma wuo ebe ịchụ aja ha.	The native doctors uses fine sand To build their place of sacrifice.
3	Onwere akụ ri nne, ma ọ gaje ipụnara ogbenye akụ ya.	He has a lot of wealth, But he went and stole a poor mna's wealth.
4	Jehova, Onye-nwe-anyi, Le otu aha-gi di ebube n' ụwa nile!	Oh Lord our God, How wonderful is your name in all the earth!
5	Otu anụ di nke na-arahukari anụ nile n'ụra. Aha ya bụ eji.	There is an animal that sleeps more than other animals. Its name is idiot.
6	karia osisi nile elu, karia igwe-ojii elu. Nwa m, abụ m gini? Gini bụ aha m?	Bigger than all trees, higher than the cloud. My child, what am I?What is my name?
7	Bụ Ihe nke nagabiga n' ụzọ nile nke oke osimiri nile.	Is all that passes on the way Of the sea.
8	Mgbada bụ otu n'ime anụ na-eme otu a. Ndi ụfọdu ji nkita achụ nta.	Grasscutter is one of such animals. Some people uses dog for hunting.
9	ha wee mụta ichụ nta nnụnụ na ichụ nta ọsa, mụtakwa igba ụmụ anụ ndi ọzọ di iche iche.	They learn how to hunt birds and squirrel**,** Learn also how to hunt other animals.
10	ụzọ nta bụ ụzọha ga-esi na-aga n'ọhia. N'ọhia ka ha na eke elu ha ga-anọ.	The route for hunting is the road they will follow in the bush. In the bush they share the hight they will stay.

Female 2

S/n	Igbo	English
11	Ndi uwe oji nwere egbe ha ji alu olu ha.. Udara nka di ụto nke ukwuu.	The police has gun they use for their work. This apple is very sweet.
12	ọ bụ ihe iriba ama ihu umuntakiri. Gosi m oke ehi gi.	It is exciting /interesting seeing children Show me your male cattle.
13	Chineke kere ihe abụọ na enye ihe na ụwa. Aha ha bu anyanwu na onwa.	God created two things that give light in the world. Their names are sun and moon.
14	Dinta agbagbuo egbe dị nta . O ji egbe ya gbagbuo ya.	The hunter has killed a small kite. He used his gun to kill it.
15	Gi Onye tiyeworo ebube-Gi n'elu igwe dum madụ bi.	You that has placed your glory In heaven where people/human live.
16	I siwo n' onụ ụmụ -ntakiri na ụmụ na anwụ ara tọ ntọ -ala ike	Out of the mouth of babes and sucklings have you ordained strength
17	N'ihi ndi-nkpabu-Gi, Ime ka onye-iro na onye nabọ ọbọ kwụsi.	Because of your enemies, That you might still the enemy and the avenger.
18	mbe m' hụrụ elu-igwe-Gi bụ ọlụ nkpisi-aka-Gi ọnwa na kpakpando nile,	When I behold the heavens that is your handy work, The moon and the stars,
19	nke Ị doziworo; Gini ka madụ bụ, na I necheta ya?	That you have prepared,what is man? That you are mindful of him?
20	Na nwa nke madụ, na I neleta ya? I we me ya ka ọ fọdụrụ ya	And the son of man that you take care of him? You made him lower

Female 2

S/n	Igbo	English
21	N'elu ka ha na-anọ agba anụ ha mgbe ụfọdu. Anu ụfọdu na egbu madụ.	They stay on top of trees to do their hunting at times. Some animals kill human beings.
22	n' isi dika okpu-eze. I neme ya ka o nachi ọlụ nile nke aka-Gi abuo.	On head like a crown. You made him to rule all that made with your two hands.
23	Ihe nile ka I doro n'okpuru ụkwụ-ya abua. Ewu na atụrụ na ehi,	You have put all things under his feet. Goat and sheep and cattle,
24	Site n' inọ n'elu ka ndi-nta na-agbanari ajọọ anụ di ka atụ na agụ.	By staying on tree tops that hunters escape from wild animals like antelope and lion.
25	Otu nwanyi nọ n' ọnụ ụzọ ama, na agba ama ụgha.	There is a woman in front of the house of witness, Bearing false witness.
26	ọgwụa di ire; ọ na elu ilu ma i detụ ya ire. ọ bụ ezigbo ọgwụ.	This medicine is powerful, it is bitter if you taste it. It is a good medicine.
27	Jisos bụ ụzọ Eziokwu na ndụ ọ dighi ụzọ ozo esi agakwu Chineke.	Jesus is the way, the truth and life, There is no other way to go God.
28	Aha nwunye m bu Obiọma. ọ bụ Ezigbo nwanyi	The name of my wife is Obioma. She is a good woman.
29	Akwụkwọ na atọ utọ Mana ọna ahia alụ na nmụta	Education/Book is sweet But it is difficult to learn
30	Onye wele ntachi obi ọ ga amụta akwụkwọ Ma ọbụlụ na nne ya na nna ya nwe ego.	Who who is steadfast will learn book If his parents have money.

Female 2

S/n	Igbo	English
31	Ana m ata ya ụta,bu nwoko a ji ụta na akụ .	I blame him,this man that is holding hunting instruments.
	Mana opụrụ pụnara ogbenye akụ ya	But he went and stole a poor man' kernel/wealth.
32	adighi m eguzo, ike adighi agwụ m.	I do n't stop, i do not get tired.
	M na-amụkwasi osisi na ụlọ na miri;	I shine on trees and houses and water;
33	Ihe nile na-ama nma nke ukwu mgbe m mụkwasiri ha.	All things are beautiful Very much when I shine on them.
34	Ana m enye gi ihe, na-enyekwa gi okpom ọkụ.	I give you light, also hot weather.
	Ana m eme ka ọka di iche iche na unere	I make different types of maize and banana
35	na ụdara na mkpụrụ osisi ọzọ chaa. Anọ m na ezi elu-igwe,	And apple and other fruits ripe. I stay in the house/compound of heaven,
36	Oke ahu buru oke nri m gbaba n'oke ọhia di n'oke ala anyi.	That rat carried large portion of my food And ran into a big bush at the boundary of our land.
37	Ọ bụrụ na abiaruo m gi nso, m ga elegbụ gi,	If I get closer to you, I will burn you,
38	m ga-esurekwa ahihia ọkụ. Mgbe m na-awa n' ụtụtụ,	I will set leaves on fire. When I rise in the morning,
39	oke-ọkpa akwasie akwa ike	The rooster crows very loudly
	igwa madụ nile na ama m na abia;	Telling everybody that I am coming;
40	mgbe okwukwuu na ụsụ hụrụ m, ha efelaga gbafue na ọhia.	When owl and bat sees me, They fly away into the bush.

Female 2

S/n	Igbo	English
41	Ana m amụ n' obodo Ndi Ojii nile, na n' obodo Ndi Ọcha nile.	I shine in the black communities, And the white communities.
42	Madụ ụfọdu mara ikpọ anụ ụfọdu ọku n'ọhia, ọ za ha, na-eche na ọ bụ anụ ibe ya.	Some know how to call some animals in the bush, They answer,thinking that it is other animals are calling them.
43	Onye ahia rere nnụ akpa nnu. Chineke huru ụwa na anya.	The saler sold one hundred bags of salt. God loves the world.
44	Ihe ndi okenye ji achụ nta bụ egbe na mma. Nnam ochie bu dinta.	The elders use gun and matchet to hunt. My grand father is a hunter.
45	Ndi mụtara igba ọhia ka a na-akpọ ndi-nta. Mazi Okeke bu onye olu ugbo.	Those that learnth how to shoot in the bush are called hunters. Mr Okeke is a farmer.
46	Onye na-egbu anụ ri nne ka a na-akpọ dinta. ụnyahụ Mazi Udeze gburu nnukwu mgbada.	The that kills animals very regularly is called a hunter. Yesterday Mr Udeze killed a big grass cutter.
47	A na-ezi nkita ichụ nta, ka ọ ga-abụ ha kpọrọ ya baa n'ọhia,	Dogs are taught how to hunt, So that if they take them to the bush,
48	Mgbe e gburu anụ, ya nwe olụ anụ. Ka ndi na-egbu anụ si eme n' ọhia bụ na	When they kill an animal, he owns the neck. The way that hunters do in the bush is that
49	ha na-ebu ụzọ egbu ụzọ nta. Ka onye ọbụla we mara	They first prepare the paths they will follow. For everybody to know.
50	ọtụtụ ihe ọtụtụ di n'ebe a e ji atụ manụ . Bia were otu na ime ha.	There are several measures for measuring oil. Come and take one of them.

Male1

S/n	Igbo	English
1	Mazi Ibe buru ibu, mana ibu obu na isi na anyi gbụ ya.	Mr Ibe is a fat man, But the load he is carrying on his head is weighing him down
2	ọ bughi otu a ka ndi nemebi iwu di; ha di ka ibobo- ọka nke ifufe nefesa.	Not so are the wicked; They are like chaff blown by the wind
3	Uche na eche oke uche. Odighi nma madu ina eche oke uche.	Uche thinks/worries a lot. It si not for somebody to worry a lot.
4	na ezi nnapụta n'ahụhụ nile nke ha. Nka ka anyi nārịọ Gi	And great deliverance from suffering. This we ask you.
5	na n'ọmụma-ikpe ebigh-ebi, *Ezi Onye-nwe-ayi, dọputa ayi.*	And from everlasting judgement, Our good Lord deliver us.
6	Ha si na anụ enwe na-atọ ụtọ nke ukwu, ma iru ya jọrọ njọ.	They say that monkey meat is sweet Very much,but its face is ugly.
7	were ebere uku Gi bopuru anyi ihe-egwu na ihe-ize-ndụ nile nke uchichi ta;	By your bountiful mercy remove dreadful incidents from us And every disaster this night;
8	Mgbe Mazi Ude na aria ọria. O sụrụ ude nke ukwu.	When Mr Ude was sick. He made a lot of sighing.
9	ọchichi na mba nile ama ama, ga ahụ na achụpụghi ndi madụ site na obodo ha.	Government of well know towns Should see that people are not sent away from their towns/communities.
10	Ha si aṅaa alụ ọlụ aṅa? Amaghim otu ha si eme ya.	How do they do different types of job? I do not know how they are doing it.

Male1

S/n	Igbo	English
11	onye were kwa ngọzi nāgha nkpụrụ	He who sows bountifully,
	ga ewere kwa ngozi na ewe ihe ubi.	Will also reap bountifully.
12	Ude ude mazi Ude sụrụ ka na ede rue ta na obodo anyi.	The fame of the sighing Mr Ude made Is still spreading uptill today in our town
13	Onye ihe nagara nke- ọma ka madụ ahụ nke na ejeghi ije	Blessed is the man That does not walk
14	Nke neguzoghi kwa u' ụzọ Ndi nmehie,	Nor stand in the way of sinner,
	Nke nanọghi kwa n' ọnọdu ndi nakwa emo.	Nor seats in the seat of scoffers.
15	kama n' iwu Jehova ka ihe- ụtọ -ya di,	But his delight is in the law of the Lord,
	ọ bu kwa n' iwu-Ya ka ọ natụghari uche	It is his law that he mediates
16	ọ gadi kwa ka osisi akụworo	He is like a tree planted
	n' akụkụ iyi juputara na miri,	By the river side,
17	Nke nami nkpụrụ -ya na mgbe-ya,	That yields its fruits in its season,
	Ọzọ, akwụkwọ -ya adighi-akpọnwụ ;	Also, its leaves does not wither;
18	Ihe na agara ya nke ọma.	He is a blessed man.
	Na ezie ọ bu onye agọzili agọzi.	Indeed he is a blessed man.
19	Onye were aka-ntagide n'agha Nkpụrụ	He who sows sparingly
	Ga ewere kwa aka ntagide na ewe ihe ubi;	Shall also reap sparingly;
20	Oke atụlụ Oke bụ oke nna ya nyere ya.	The male sheep of Oke is his portion from his father.
	Nwa nnem nwanyi hurum na anya.	My sister loves me.

Male1

S/n	Igbo	English
21	Ndi-nmehie agagh-eguzosi kwa ike	Sinners shall not stand
	na nzukọ ndi ezi omume.	In the congregation of the righteous.
22	N' ihi nka ndi nemebi iwu	Becuase of this the wicked
	Agaghi eguzosi ike n'ikpe,	Shall not stand in the judement,
23	N' ihi na Jehova mara ụzọ ndi ezi omume	The Lord knows the way of the righteous
	Ma ụzọ ndi nemebi iwu gala n'iyi.	But the way of the wicked shall perish
24	Madụ na eri ji, na akidi di iche iche.	Humans eat yam, and different kinds of bean.
	Ndi ụfọdu na-eri awọ.	Some others eat toads.
25	Ihe otu ndi na asọ - nsọ,	What some abhors
	ndi ọzọ na-eri ya.	Others eat them.
26	Nwanyi Ugbo, kedu ngbe iga eje ugbo gi? Ugbo gi na Agu Ọwa emebisia	Woman from Ugbo, when are you going to go to your farm? Your farm at Agu Owa is wasted/spoilt
27	ọ bu nani madụ na-esi ite,	It is only man that cook,
	anụ ndi ọzọ na-eri ihe na ndu.	Other animals eat flesh.
28	Madụ ọbula nwere oke ibi ndu nke iwu kwesiri ikwado nke ọma.	Any body has the right to live a life Being supported by the law.
29	Onye nnọchi anya ode akw ụkwọ , n'ihe gbasara ndi achụpụrụ na-obodo ha.	The representative secretary, For those sent out of their towns.
30	Na-kwa ọdi mma ọha na eze, Ha na-enye ntụzi aka nye	And the welfare of the masses That they give advice

Male1

S/n	Igbo	English
31	ụfọdu ndi gbara ọsọ ndu dika umuaka, tumadi ndi na-enweghi onye ntụzi aka,	Some feugees like children, Especially those that do not have advicers,
32	ụmụ nwanyi di ime ndi nwere ụmụaka, ụmụ nwanyi ji isi ezi na ụlọ.	Pregnant women with children, Women who are the leaders of their homes.
33	Nwa m, na-eso m n'azụ igbu azụ. Azụ na atọ ụtọ nke ukwuu.	My child ,follow at the back for fishing. Fish is very sweet/delicious.
34	ọ bụ Chineke kere madụ nile bi na uwa. Madụ bu isi n' ụwa.	It is God that created all human being on earth. Human beings are number 1 in t he world.
35	ọ dikwa nma ka onye nke bụ isi n' ụwa na-ekele aja?	Is it good that he is Who is number 1 in the world worship sand?
36	E-e. Gini mere? N' ihi na aja di n' okpuru ya.	No-no.Why? Because sand is under his foot.
37	Ka amara nke Onye-nwe-anyi Jisus Kraist,na ihụ-n'anya nke Chineke	May the grace of our Lord Jesus Christ and the love of God,
38	,na nnwekọ nke Mọ Nsọ, di nyere anyi nile mgbe nile.	And the fellowship of the holy spirit Be with us all the time.
39	ka nkpa-ha si di iche iche, na enye ha ntachi-obi nime ihe na egbu	As their needs are different, Grant them patience in their suffering
40	Nwanyi na akwa akwa, Ịna akwa akwa na ọkụ kụ yili akwa?	Seamstress, Are you crying because a hen lay an egg ?

Male1

S/n	Igbo	English
41	N'ihi obi ebere gi.	By your grace.
	n'ihi nsọpụrụ nke Ọnu-nēkwuru-anyi,	By the respect of our advocate,
42	Were onyinye elu-igwe nye ya ri-nne;	Give her your heavenly blessings abundantly
	kwe ka ọ di ogologo ndụ na arụ-ike	Grant her long life and strenght
43	na ọdi-nma na ihụnanya	In peace and love
	nye ya ike imerisi ndi-iro-ya nile;	Give the grace to overcome all her enemies;
44	Me ka ọchichiri-anyi ghọ ìhè,	Let our darkness turn into light,
	anyi nāriọ Gi, Onye-nwe-anyi,	We beseech you ,our Lord,
45	Nwanyi na akwa akwa, Ịna akwa akwa na ọkụ kụ yili akwa?	Seamstress, Are you crying because a hen lay an egg ?
46	n'ihi ihụ-n'anya Ọkpara-Gi, I mụrụ nani Ya	By the love of your only begotten son,
	Jisus Kraist, bu Onye-nzọpụta-anyi.	Jesus Kraist , our Lord.
47	echetala ajọ omume-ayi, ma-ọbụ	Do not remember our evil doing,or
	ajọ omume nke nna-ayi	Evil doings of our fathers
48	abọla ọbọ nke nmehie-ayi: rapụ ayi, ezi nna.	Do not take revenge on our sins, leave us good father.
	n'ikpe-azụ, mbe ndụ nka gasiri.	At the end, when this life passes away
49	Ikele-ekele nke Ndinyom	Churching of women
	mgbe ha mụsiri nwa .	after child birth.
50	Adanma mara nma nke ukuu, mana ọbụ nma ka eji gbuo ya.	Adamma is very beautiful , But she was killed with a matchet.

Male 2

S/n	Igbo	English
1	nke ncheghari, na nke inụ-okwu,	By repentance and by hearing/eagerness
	Site na ime ala ala obi anyi .	From the depth/bottom of our heart.
2	Enyi m, nye m ọkụ ; tutu m jee ọkụ azu.	My friend give light, before I go fishing.
	Afa onye nkuzim bu Mazi Okeke	The name of my teacher is Mr Okeke.
3	Otú ayi nwere oge, ka ayi na alụ ezi ihe	As long as we have time let do good
	n'ebe madụ nile nọ	To our fellow human beings.
4	ọla ọcha na ọla edo na-ama nma nke ukwu,	Gold and silver are very beatiful,
	Nwa agbogho obia mara nma.	This lady is beautiful.
5	ụzụ ga-esi anaa kpụọ uzu?	How can a goldsmith do his goldsmit job?
	ụgbọ ndi ọcha bu igwe igwe.	The ship of a white man is metal metal.
6	I hụla igwe madụ ,ndi na eburu ite igwe di aro nke ukwu?	Have you seen these multitude,that are, Carrying metallic pots that very heavy?
7	Osisi nwere akwụkwọ di iche iche.	Tree has different types of leaves.
	Nwata,I ga-eje akwụkwọ.	Child, you have to go to school.
8	Amaghim ebe m ga ebido ebido	I do not know where to start
	Amaghim ebe m ga agwụsi agwụsi	I do not know where to end
9	Ike gwụrụ gi, I dala mba?	Are weary, are you faint hearted?
	Jisi ike na ọlụ gi	Be strengthened in your work.
10	kama ka ayi kwupụta ha	Instead let us confess them
	n'obi di ume-ala, nke nwayọ,	In humility ,quietly,

Male 2

S/n	Igbo	English
11	Ka onye ọ bụla n'etiti unu nye dika	Let every one among you give as
	o buru uzọ rọpụta n'obi-ya:	Has proposed in his heart:
12	ọ bụghi site na nwuta, ma-ọbụ site na nkpa:	Not grudgingly,or out of want:
	Chineke na ahụ onye ji obi ụtọ na enye	
		God loves a cheerful giver
13	Unu ekwela ka eduhie unu;	Do not be deceived
	Chineke abụghi onye anēleli:	God is not mocked:
14	n'ihi na nkpụrụ ọ bụla madụ nāgha,	For whatever seed a man sowerth,
	nke ahụ ka ọ gēweta kwa n'ubi	That shall he reap
15	Madụ nke na –gabiga n'akwa hụrụ ọkụkọ nke na –eyi akwa.	Man that passes through the bride/bed/cloth saw a hen laying egg.
16	ma ka ayi na alụ ezi ihe karisia	Let us do good work more so
	n'ebe ndi èzi na ụnọ okwukwe .	In the house hold of faith.
17	ayi ewetaghi ihe ọ bụla n'ụwa,	We did not bring anything into the world,
	ayi apụghi iwere ihe ọ bụla pụa nime ya.	we will not take anything out of it.
18	Omenala onye ka eji mara ya. Egbe belu ugo belu.	People are known by their culture. Let the kite perch and the eagle perch.
19	Nnem ga ahia o go tele m igba.	My go to the market she buys drum for me.
	Nwam nwoko mara akụ igba.	My son knows how to beat the drum
20	Jehova bu onye nazụm dika atụrụ; ọ dighi ihe kọrọm.	The Lord is my shepherd I shall not want.

Male 2

S/n	Igbo	English
21	Mazi Eke bu ezigbo onye nkuzi.	Mr Eke is a good teacher.
	Aha ahia obodo anyi bụ Eke.	The name of our town's market is Eke.
22	Igbo na atọ ụtọ nke ukwuu.	Igbo is very sweet.
	Onye ọbụla ga asụ asusu Igbo	Every body should speak Igbo
23	Okwu Gi bụ oriọna di na ukwum	Our word is a lamp unto my feet
	na ihe nke di na ụzọm.	And a light unto my path
24	Ha ga amala na Jehova kam ji aba.	They will know that I take my boast in the Lord.
	Ugbo ndi ocha mara nma nke ukwuu.	Ship of the white man is very beautiful.
25	N'ihi na Chineke hụrụ ụwa na anya otua	For God so love the world
	Na onyere ọkpara Ọ mụrụ nani ya	That he gave his only begotten son
26	ka onye ọbụla kwere na ya	That whosoever believer in him
	Ghara ina na iyi	Should not persih
27	Kama ka onwe ndụ ebighi ebi.	But have everlasting life.
	Maka odi nma umu madu.	For the benefit of humanity.
28	N' akụkụ miri nke izu-ike	Besides stream side
	ka ọ nedum nwayọ.	He leads me gently.
29	Jisi ike na ọlụ gi	Be strenghened in your work.
	Olele anya dili onye di ndụ	There is hope for the living.
30	Chineke siri agaghim eke otuto m.	God says I will not share my glory.
	Aha ahia obodo Achi bụ Eke Egbo	The name of Achi town's market is Eke Egbo

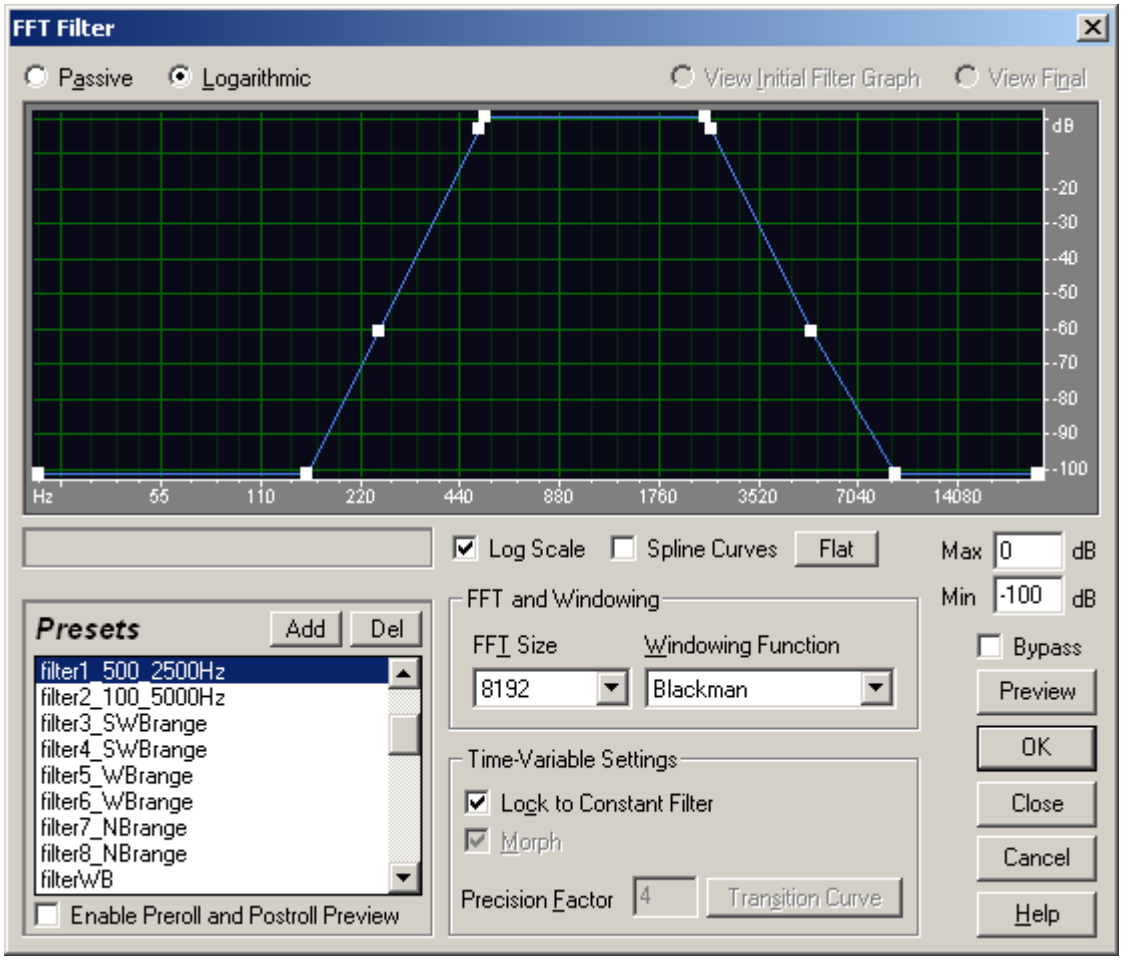
Male 2

S/n	Igbo	English
31	Ndi oru ọgaranya ahu di ole? Ha di oru madu.	How many are the servants/workers of the richman? They are twenty persons.
32	ụmụ agbọghọ ọbia ndia mara nma ọ bụ nnukwuu ngọzi Chineke	These ladies are beautiful It is the work of God
33	Ihe isi ike anaghi adigide Mana ndi siri ike na adigide	Tough time does not last But tough people do
34	Ngana kpuchie ute Agụụ ekpuye ya. Nwam tukwasi Chukwu obi mgbe nile.	A lazy person covers himself with mat hunger uncovers him. My child trust in God always.
35	Agụ bụ anụ ohia di ike nke ukwu, ma agụụ na agụgbụ ya mgbe ụfọdụ.	Lion is wide animal that is very strong, But he can be very hungry at times.
36	Jisi ike asụla ngọngọ Ma ụzọ gi gba ọchichiri	Be strong not weary When there is darkness on your way
37	ihe di iche iche di n'ime ala ọla ọcha na ọla edo na igwe	A lot of things are inside the earth Gold and silver and metal
38	na nnu na nkume na unyi di n'ime ala, ma ha nile adighi n'otu ebe.	And salt and stone and coal are inside the earth but they are not in one place.
39	N' ebe ụfọdu igwe di;n'ebe ọzọ ọla edo di. Ha nile bụ onyinye Chineke.	In some places metal in other places silver. All of them are the gift of God.
40	I riela anụ ezi? O bu ezi anụ . Madu ufodu adighi eri ya.	Have you ever eaten pork? It is a good meat. Some people do not eat it.

Male 2

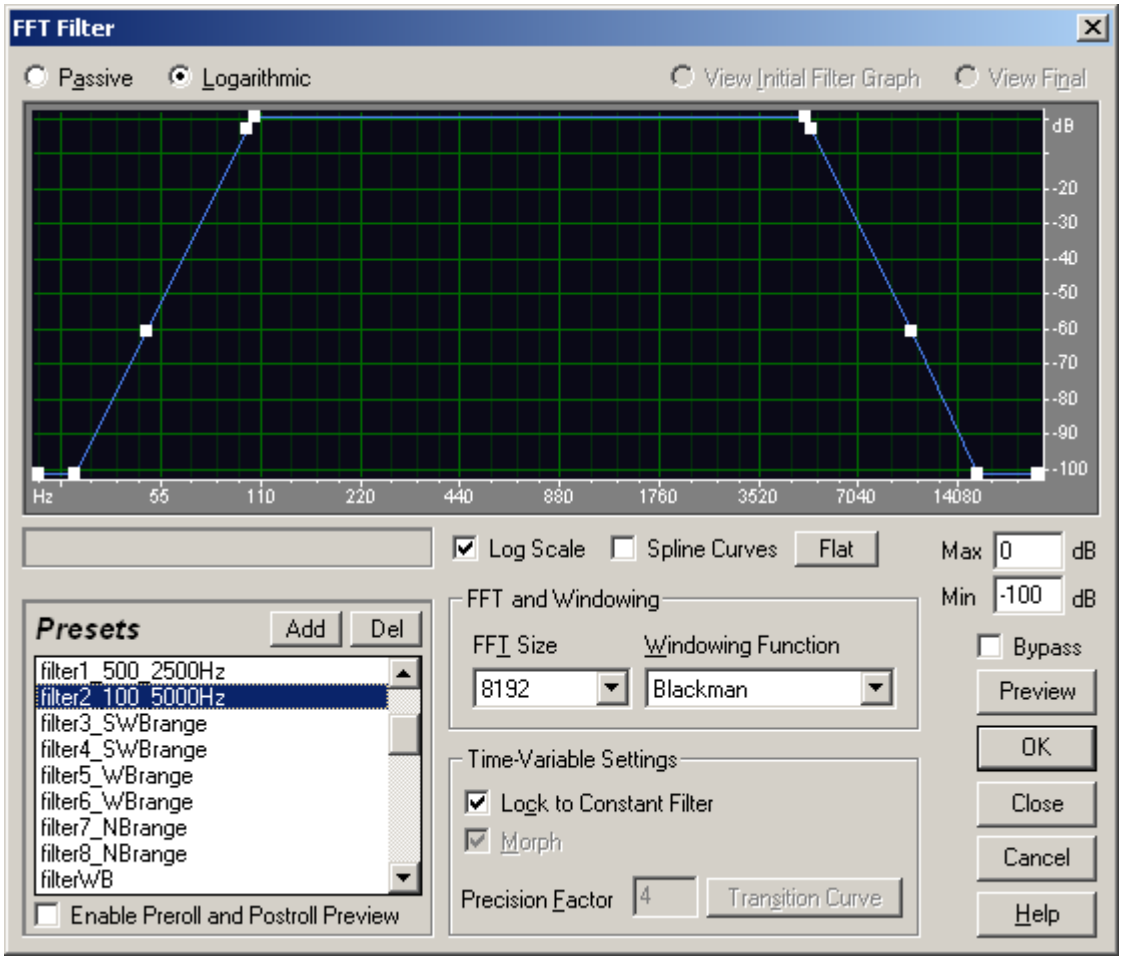
S/n	Igbo	English
41	nma igwe bụ ihe nke madụ ji alụ ọlụ di iche iche.	Metallic knife is what humans Use to do different types of work.
42	Site n'igwe ka anyi ji nwee mma na ọpia na ọgụ	From metal we get/have Knife and rod and hoe
43	na ntu na ite igwe na mma nkwo na ọtụtụ ihe ọzọ.	And nails and iron pots and knife Comb and other things.
44	ọ bụrụ na igwe adighi, anyi ga-esi anaa lụọ ọlụ ubi?	If there is no metal, How can we do farm work?
45	N'ebe ahụ iga ahụ eze, nke na ata ikekere eze.	There you will see a king, That is great anguish.
46	Ebe a na-afụ ọkụ n'ime ya bụ nani igwe. Nnem ji ite igwe esi ofe egwusi.	The place for making fire inside it is only metal. My mother uses metallic pot to cook egwusi soup.
47	ụmụ-nna m'hụrụ n'anya nke-uku,	Dearly beloved brethren,
	Akwụkwọ Nsọ nēzí ayi n'ebe di iche iche	The holy book teaches us in sundry places
48	ka ayi ghara izobe ma-ọbụ	That we should not hide or
	kpuchie ha n'iru Chineke,	Cover them in the presence of God,
49	bụ Nna-ayi nke elu-igwe,	Who is our father in heaven,
	Nke pụrụ ime ihe nile;	That is able to do all things;
50	Ndi isi isii ahu bipuru isi ndi ha dotara n'agha. Manu a na esi isi nke oma.	Those, blind six cut of the head of those they captured. This oil has nice aroma/scent.

Appendix B (Filters used)



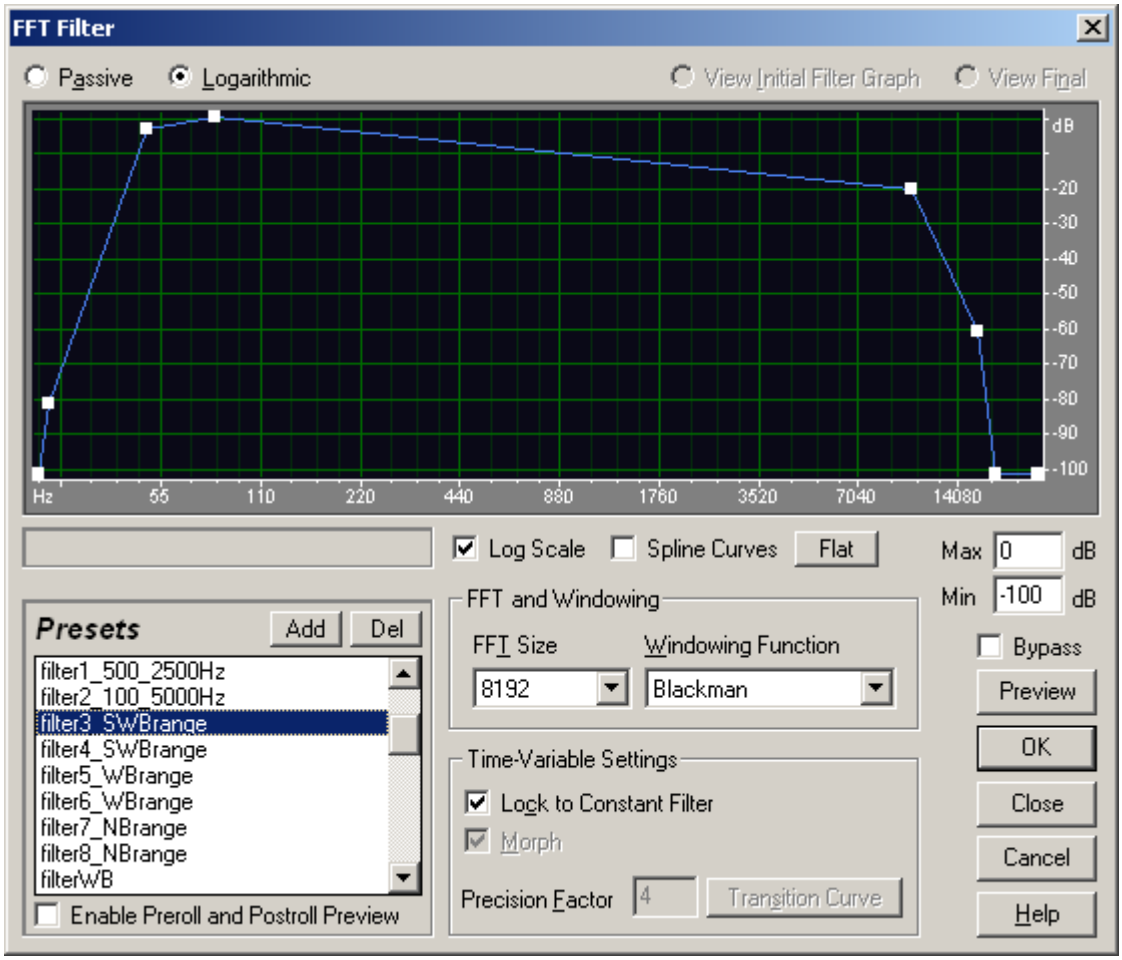
Appendix B1:Filter1_500_2500Hz

Hz	dB
150	-100
250	-60
500	-3
520	0
2400	0
2500	-3
5k	-60
9k	-100

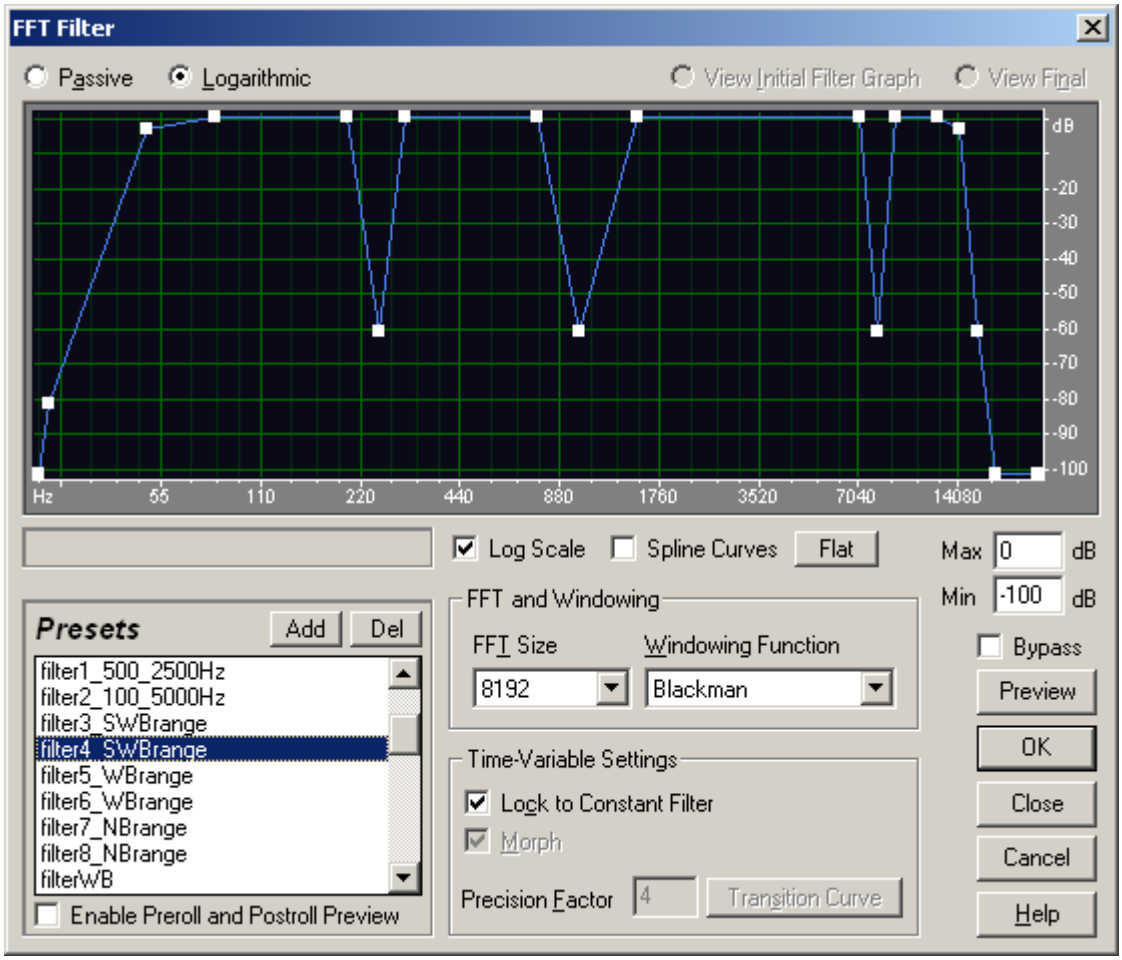


Appendix B1:Filter2_100_5000Hz

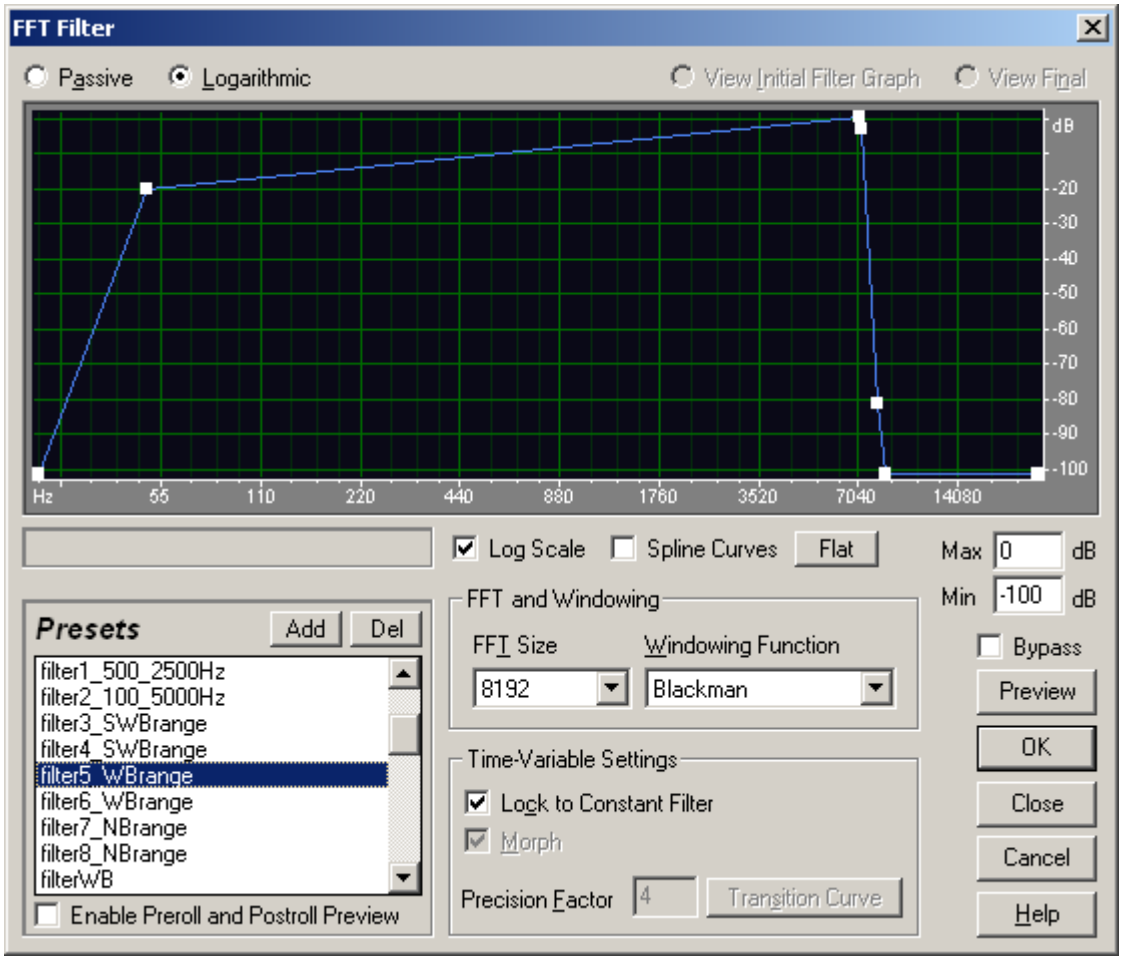
Hz	dB
30	-100
50	-60
100	-3
105	0
4800	0
5k	-3
10k	-60
16k	-100



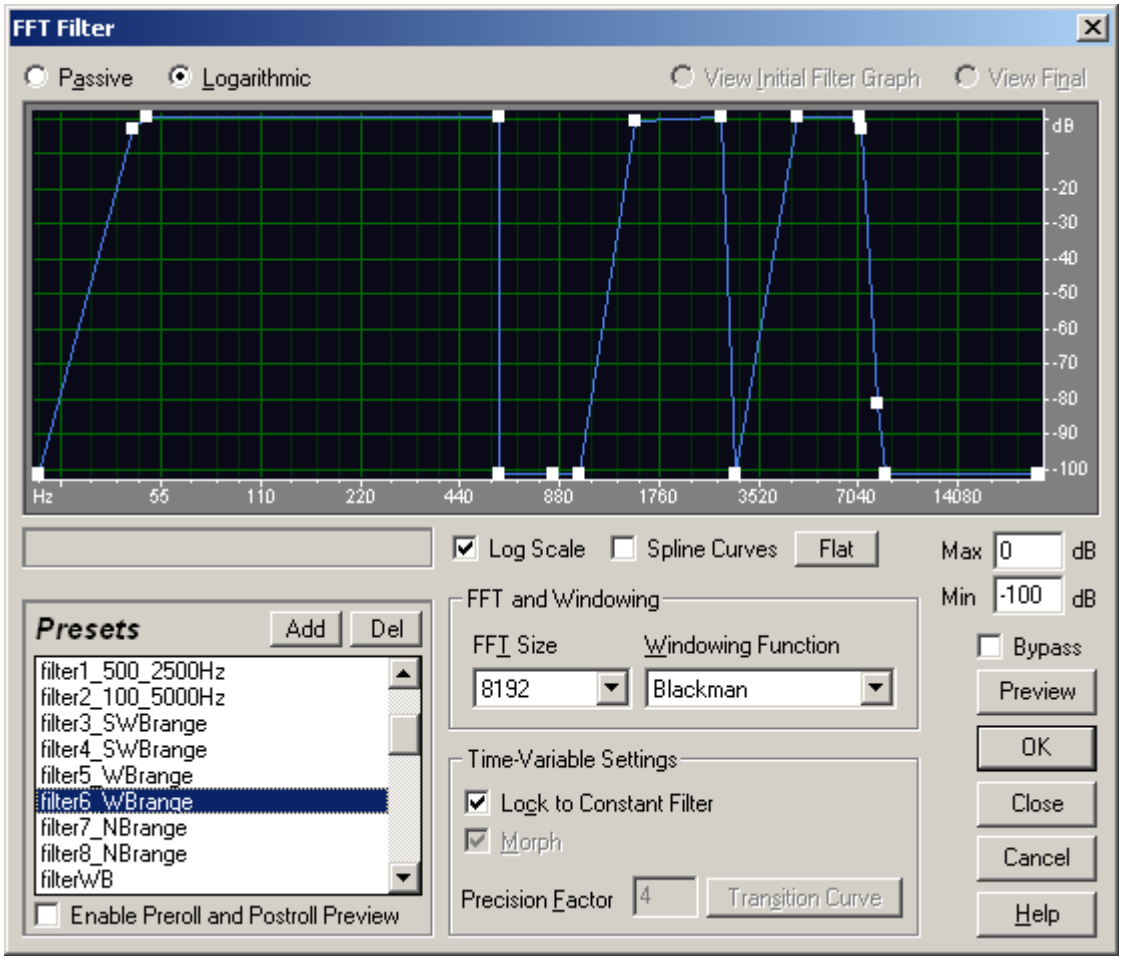
Appendix B1:Filter3_SWBrange



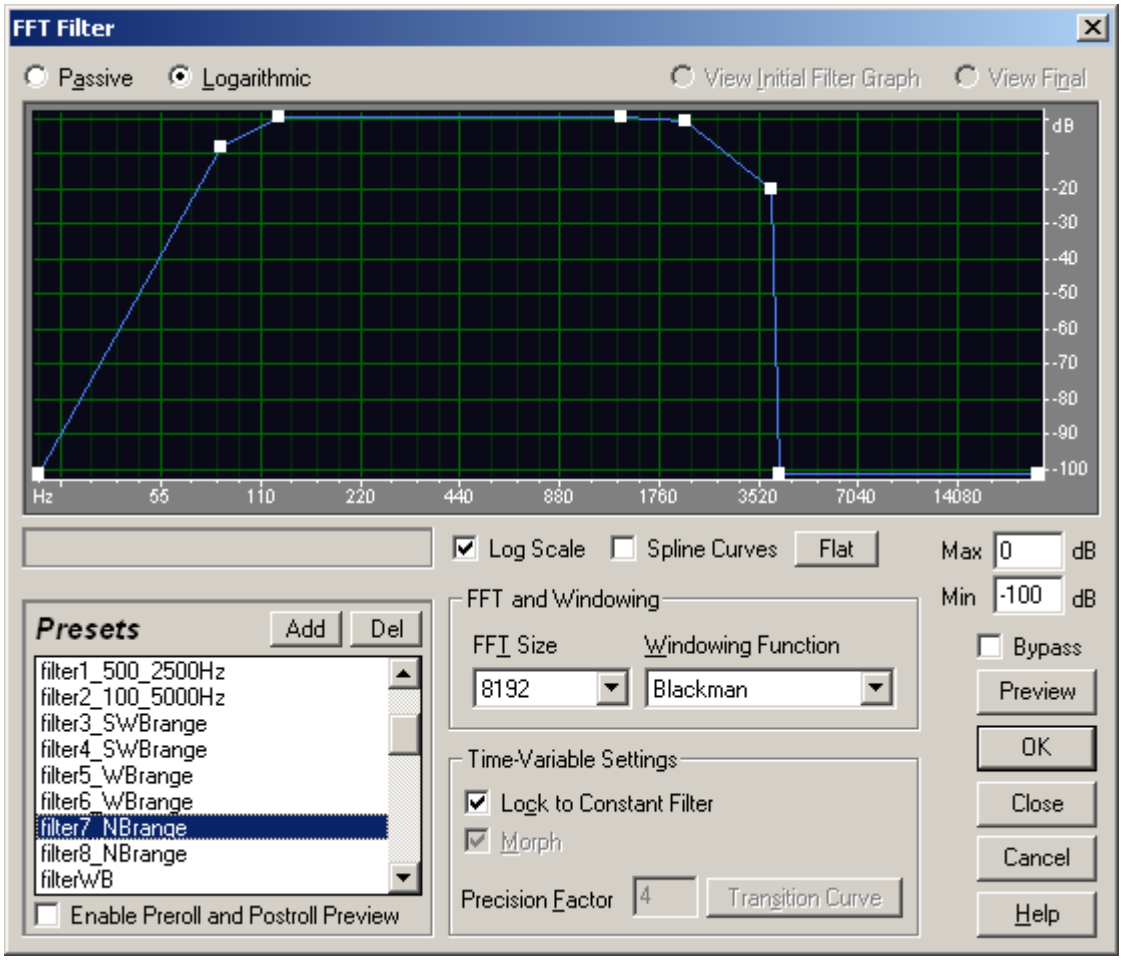
Appendix B1:Filter4_SWBrange



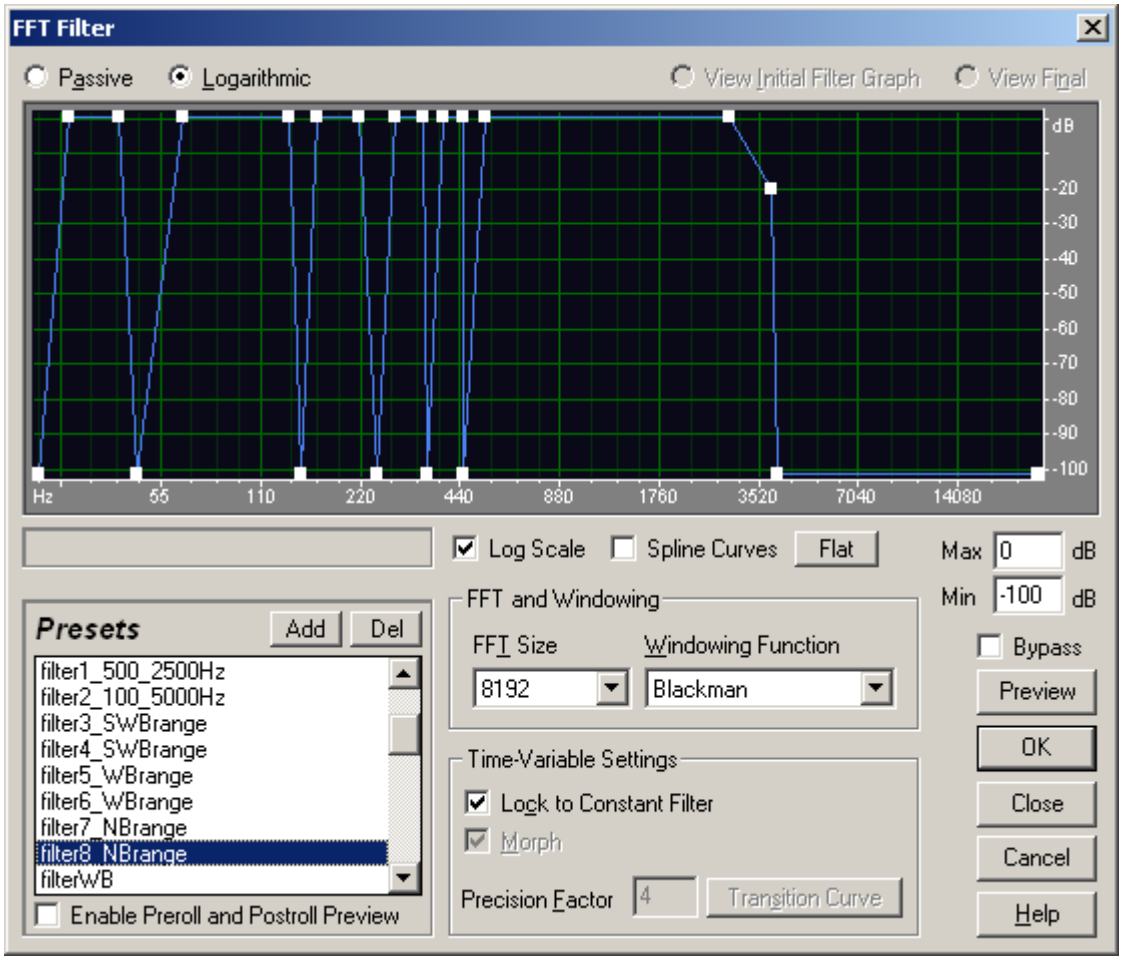
Appendix B1:Filter5_WBrange



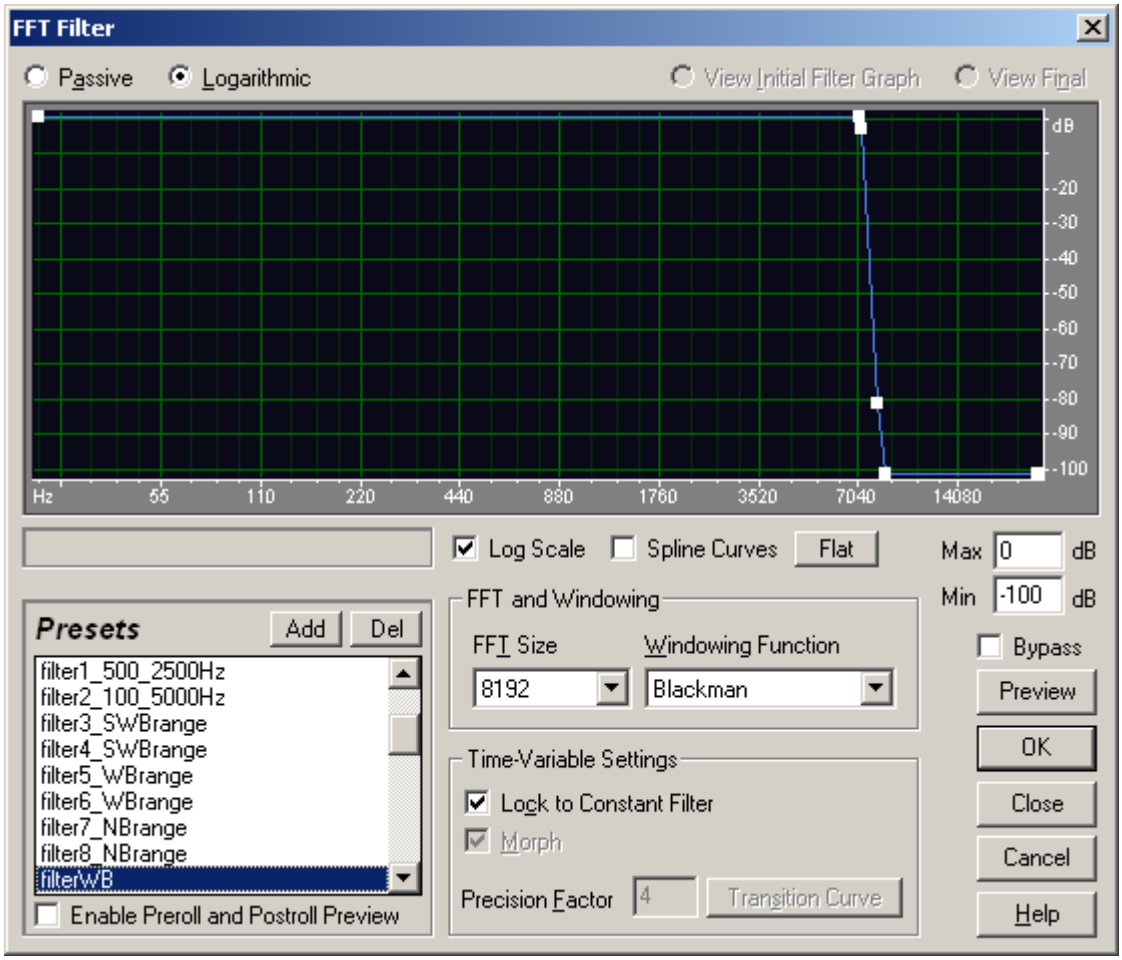
Appendix B1:Filter6_WBrange



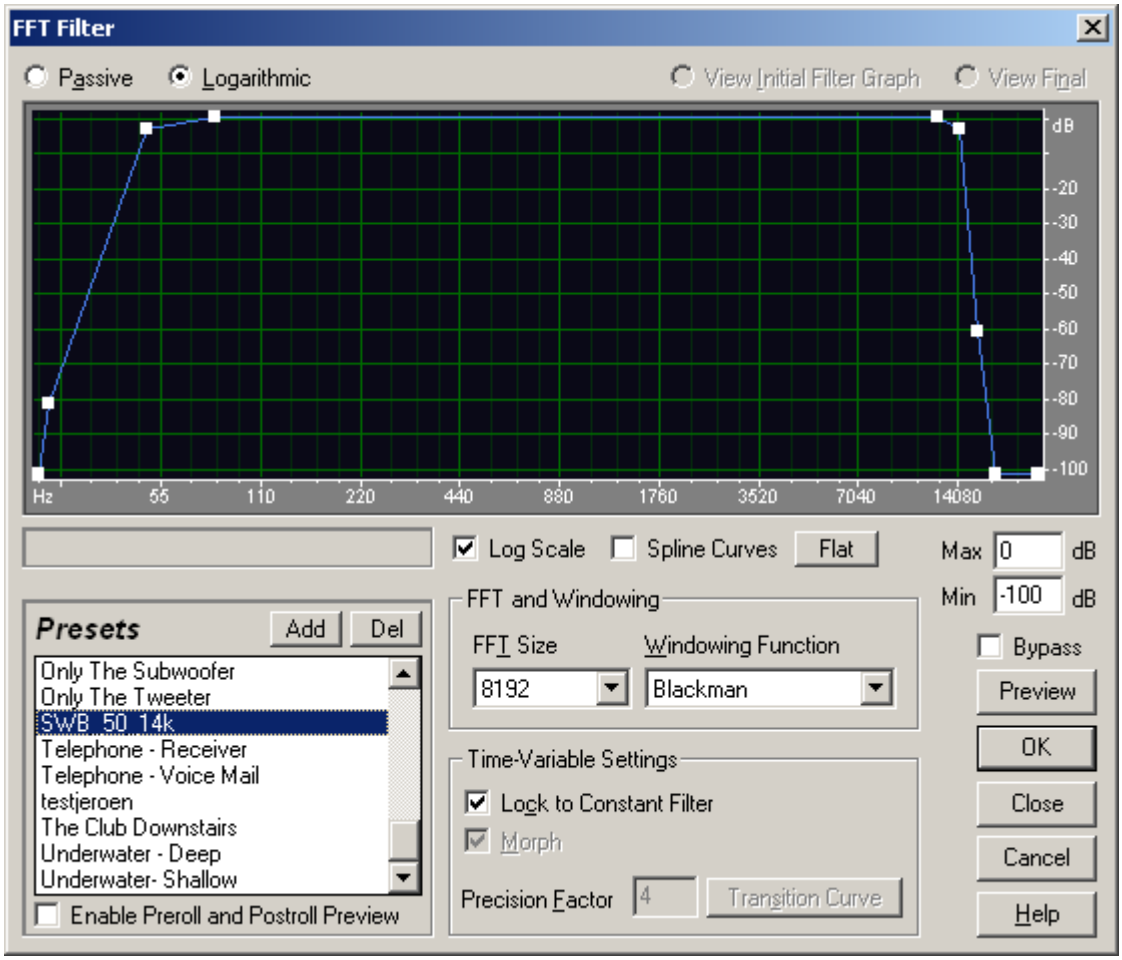
Appendix B1:Filter7_NBrange



Appendix B1:Filter8_NBrange



Hz	dB
7k	0
7.1k	-3
8k	-80
8.4k	-100



Hz	dB
25	-80
50	-3
80	0
12k	0
14k	-3
16k	-60
18k	-100

Appendix C :50 degradation conditions

S/n	Condition	Condition type	SWB/NB/WB
1	1	Clear, loudness	SWB
	2	Noisiness, MNRU 10dB (modified MNRU using P.50 shaped noise)	SWB
	3	Noisiness, MNRU 25dB (modified MNRU using P.50 shaped noise)	SWB
	4	Noise1 (Noisiness), 12dB Hoth,	SWB
	5	Noise2 (Noisiness), 20dB Babble,	SWB
	6	Loudness, Level-10	SWB
	7	Loudness, Level-20	SWB
	8	Down sample to 16kHz,mIRS_send	SWB
	9	Filter 1 (see appendix B)	SWB
	10	Filter 2 (see appendix B)	SWB
	11	Continuity, 2% packet loss 20ms packet size	SWB
	12	Continuity, 20% packet loss 20ms packet size	SWB
	13	Loudness	SWB
	14	Noisiness, MNRU 5dB*[2]	SWB
	15	Noisiness, MNRU 35dB*[2]	SWB
	16	Noise3(Noisiness SNR=4 dB))	SWB
	17	Noise4(Noisiness SNR = 5 dB)	SWB
	18	Noise5(Noisiness SNR = 12 dB)	SWB
	19	Noise6(Noisiness SNR = 4 dB)	SWB
	20	Noise7 (Noisiness SNR = 10 dB)	SWB
	21	Filter 3 (see appendix B)	SWB
	22	Filter 4 (see appendix B)	SWB
	23	Filter 5 (see appendix B)	WB
	24	Filter 6 (see appendix B)	WB
	25	Filter 7 (see appendix B)	NB
	26	Filter 8 (see appendix B)	NB
	27	Filter, ClassRoom.J04.wav	SWB
	28	Filter, Listening or living room.J06.wav	WB
	29	Filter, Grundtvigs Cathedral.J01.wav	NB
	30	Continuity, 5%, frame 20 ms (default20), burst max=2	SWB
	31	Continuity, add clicks/pulses	SWB
	32	Continuity, first 10% loss(frame10msburst1) and add clicks/pulses	SWB
	33	Noise8	WB
	34	Noise9 level -20dB	WB
	35	Add tones, 100Hz,7kHz,heterodyene-like 50 Hz harmonics	WB

36	Noise10	NB
37	Noise11	NB
38	Noise12	NB
39	G.722	WB
40	AMR-WB	WB
41	AMR-WB,Noise13	WB
42	AMR-NB	NB
43	EVRC	NB
44	EVRC	NB
45	Skype (live measurement)	WB
46	Skype (live measurement)	WB
47	Noise14,GSM2POT S (live measurement)	NB
48	Skype (live measurement)	WB
49	Noise15, DECT-DECT (live measurement)	NB
50	DECT-GSM (live measurement)	NB

Appendix D: Listening Test ITU-T POLQA

The listening test ITU-T POLQA documents (ACR random)used.

LISTENING TEST ITU-T POLQA

NAME:

DATE:

AGE Male/Female:

RANDOM ORDER: 1

In this experiment you will be listening to short speech fragments with a headphone. Every fragment contains two short sentences with a short pause between them. When you have listened to both sentences you can write down your opinion. After a short break of about 3 seconds the next sentence pair is played.

To practise you will first get 6 sentence pairs for which you can give your opinion on this sheet. Next 10 test series are played with 20 pairs each.

Example of a sentence pair as played out over the headphone:

Sentence a	silence	Sentence b	Opinion
3 s	2 s	3 s	3 s

PRACTISE SET

Fragment	Bad	Poor	Fair	Good	Excellent
1	1	2	3	4	5
2	1	2	3	4	5
3	1	2	3	4	5
4	1	2	3	4	5
5	1	2	3	4	5
6	1	2	3	4	5

RANDOM 1 run01

Fragment	Bad	Poor	Fair	Good	Excellent
1	1	2	3	4	5
2	1	2	3	4	5
3	1	2	3	4	5
4	1	2	3	4	5
5	1	2	3	4	5
6	1	2	3	4	5
7	1	2	3	4	5
8	1	2	3	4	5
9	1	2	3	4	5
10	1	2	3	4	5
11	1	2	3	4	5
12	1	2	3	4	5
13	1	2	3	4	5
14	1	2	3	4	5
15	1	2	3	4	5
16	1	2	3	4	5
17	1	2	3	4	5
18	1	2	3	4	5

19	1	2	3	4	5
20	1	2	3	4	5

Appendix E: Subjective Experiment

Native Male Igbo Speaker doing the subjective Test

Native Female Igbo Speaker doing the Subjective Test

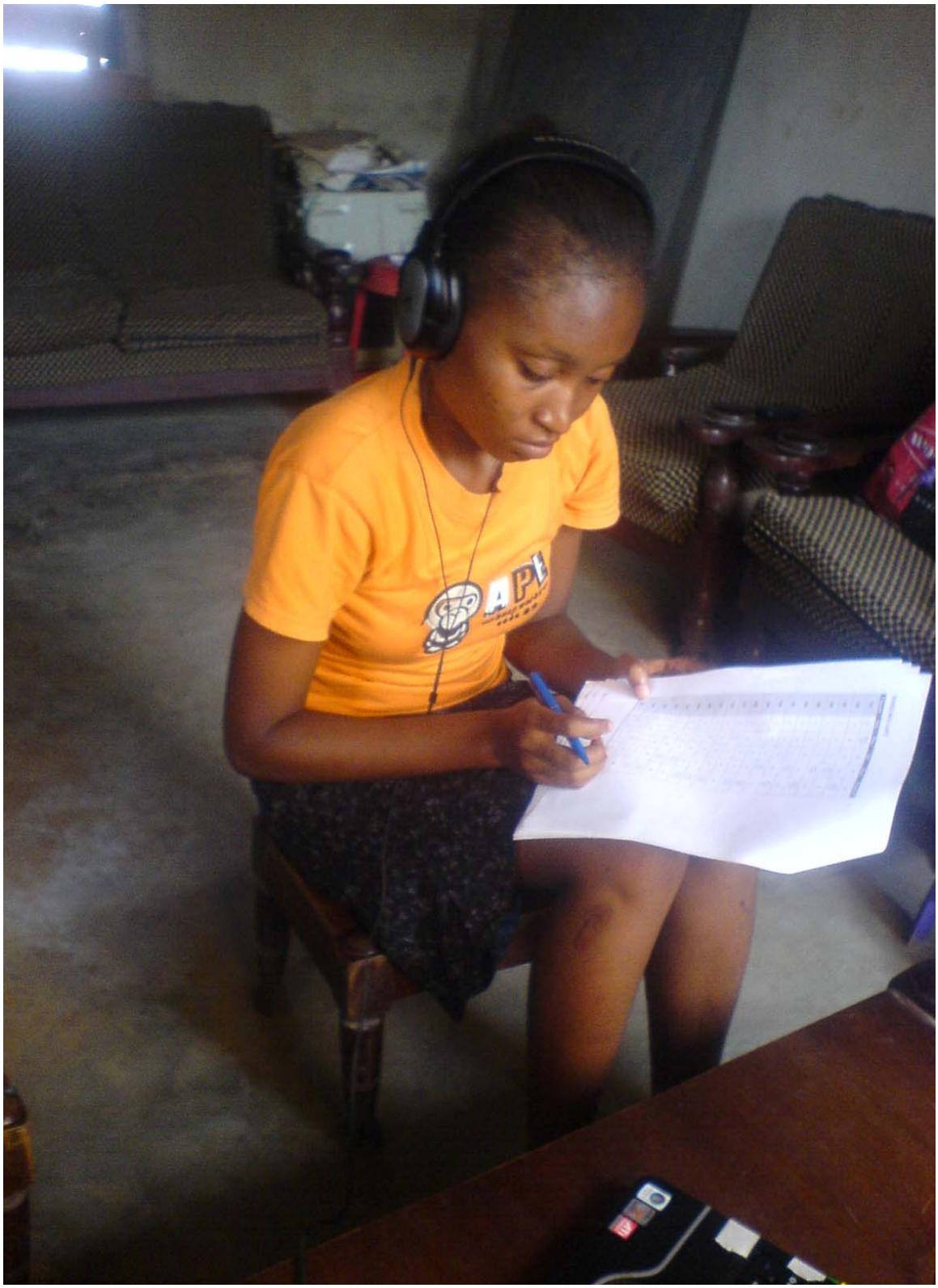
Native Female Igbo Speaker doing the Subjective Test

Native Female Igbo Speaker doing the Subjective Test

Native Female Igbo Speaker doing the Subjective Test

Native Male Igbo Speaker doing the Subjective Test

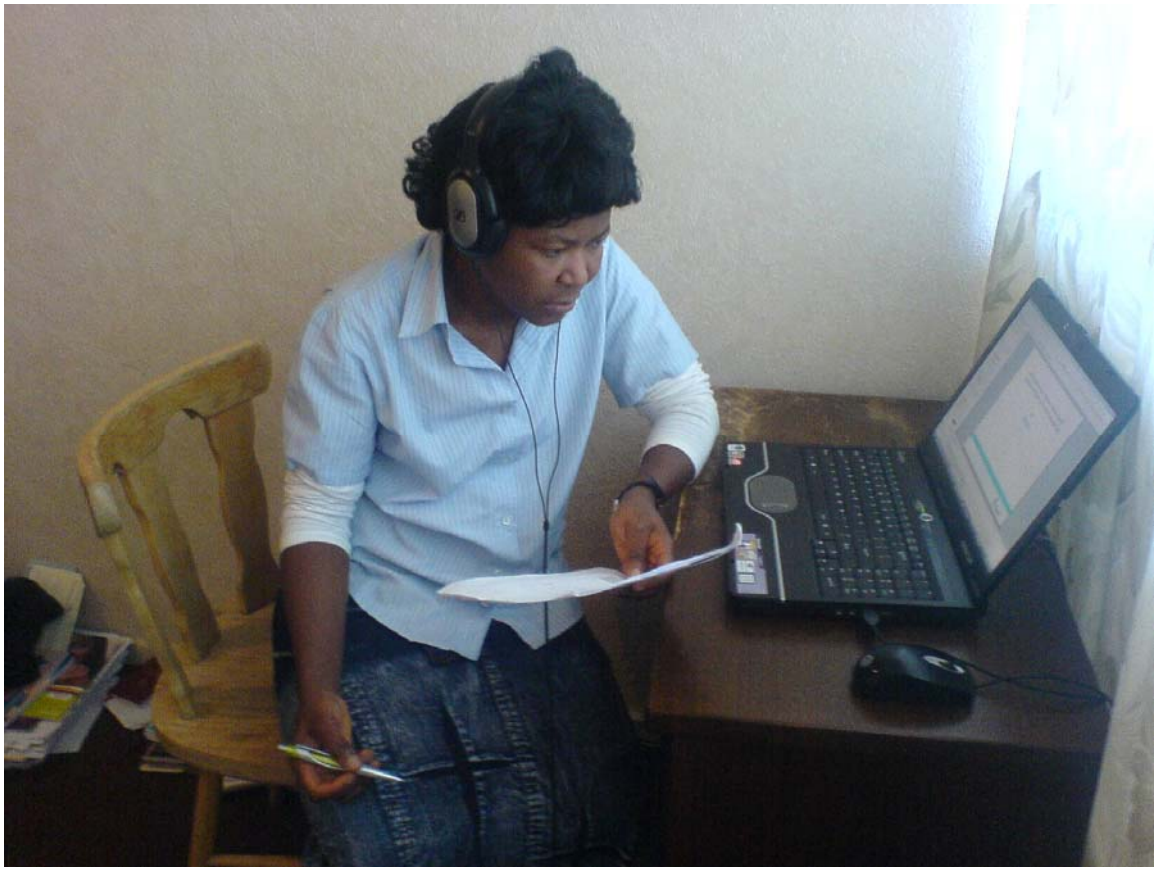
Native Female Igbo Speaker doing the Subjective Test



Native Female Igbo Speaker doing the Subjective Test

Native Male Igbo Speaker doing the Subjective Test

Native Female Igbo Speaker doing the Subjective Test



Native Female Igbo Speaker doing the Subjective Test