

Assessment of repeated measurements on the CAPA software

Jean-Sébastien
NIEL

December 2012

CAPA is a software used for the monitoring of the attenuation of hearing protectors.

This study will examine the repeatability of measurements of hearing thresholds using the CAPA method.

HPD Efficiency monitoring
F-101.1



Table of contents

1	INTRODUCTION	3
1.1	CAPA	3
1.2	Test objectives	3
2	EQUIPMENT AND METHODS	3
3	RESULTS OBSERVED	4
4	APPENDIX 1 : ASSESSMENT OF IMPACT ON THE PNSA	6
5	APPENDIX 2 : INDIVIDUAL RESULTS	7

1 Introduction

1.1 CAPA

The CAPA software developed by HearingProTech helps to control the effectiveness of intra-aural hearing protectors. Thus, if an employee exposed to noise uses his hearing protectors properly for 100% of the duration of noise exposure, he will be perfectly protected.

The measure is based on the principle of a subjective audiogram test, i.e., the research on hearing thresholds (minimum sound pressure level that must be imposed for the sound to be heard by a subject). To measure the attenuation of a hearing protector, CAPA calculates the difference between hearing thresholds with and without hearing protectors worn by the user. The attenuation in dB is recorded by an octave band.

To address the hearing thresholds, the system emits sounds characteristic of the desired frequencies via headphones. The intensity of the emitted sound increases. As soon as the user perceives the signal, he signals using a buzzer.

1.2 Test objectives

This study measures the repeatability of the CAPA system, i.e., changes in results from one measurement to another on the same subject.

For this, we will study CAPA's measurements of hearing thresholds of a subject. The hearing threshold is the measurement done without using hearing protectors. Thus, there shall be no changes in measurements related to hearing protectors.

2 Equipment and methods

To measure the attenuation of a hearing protector, CAPA calculates the difference between hearing thresholds with and without hearing protectors worn by the user.

We hypothesize that the measurement of hearings thresholds performed without hearing protectors is more sensitive to external disturbances. In this study, and in this case, we will take up the most unfavorable case of the repeatability of measurements.

To observe the repeatability, we will perform 4 measurements for each ear over 19 subjects. The group is composed of 9 women and 10 men.

The average interval between two measurements is 6.7 days, for a maximum of 14 days.

The tests are performed in a room with enhanced soundproofing. However, the room is not designed to deal with structure-borne noise transmitted through the floor.

The table below shows the ambient noise levels in the room in silence (no artificial noise added):

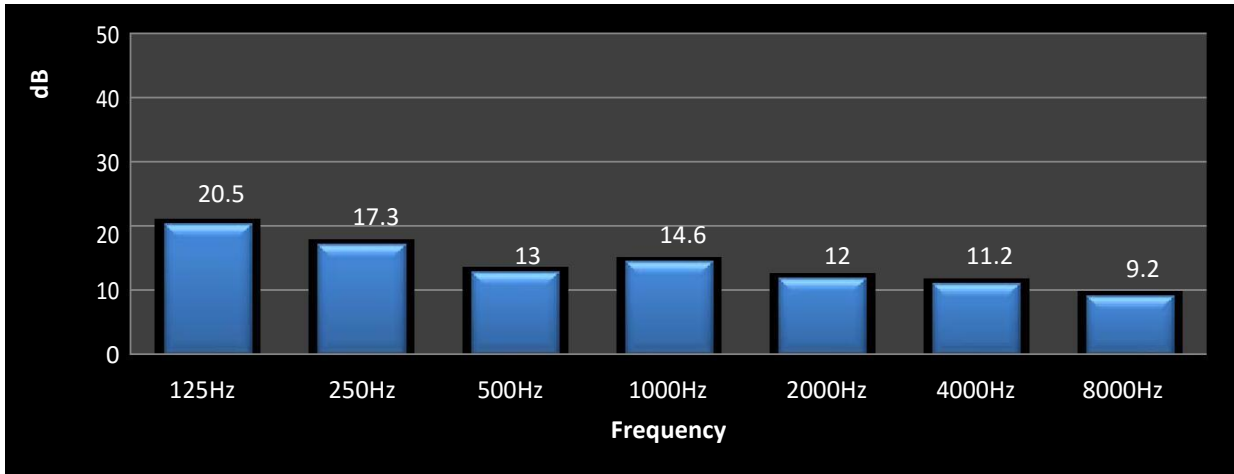


Figure 1: Sound recorded in the acoustic room

3 Results observed

The graph (Figure 2) shows the average standard deviations by frequency for all subjects on CAPA measurement without using hearing protectors.

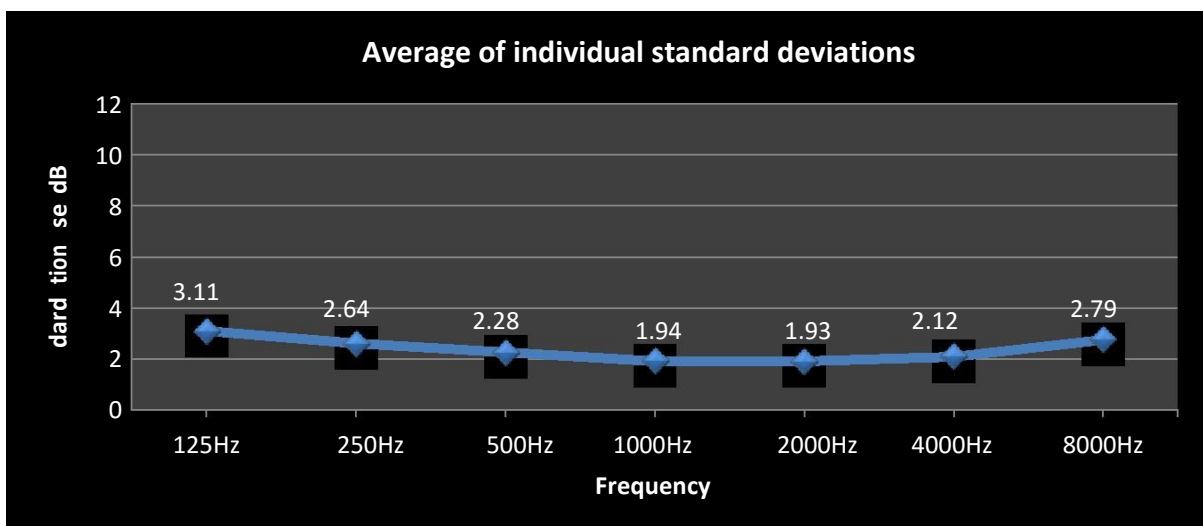


Figure 2: Average observed standard deviation

Repeatability is correct with average deviations between measurements between 1.94 dB (2kHz) and 3.11 dB (125Hz).

It is noted that the most significant differences are observed on extreme frequencies that are more difficult to be identified by the user.

The impact is limited, given the weighting of PSNA calculated by the CAPA method. The PSNA is an attenuation index calculated by CAPA by taking the weighting of SNR into account. As a recap, the SNR (Single Number Rating) is the total attenuation coefficient, which is a weighted average of the attenuation at all measured frequencies and for a given population.

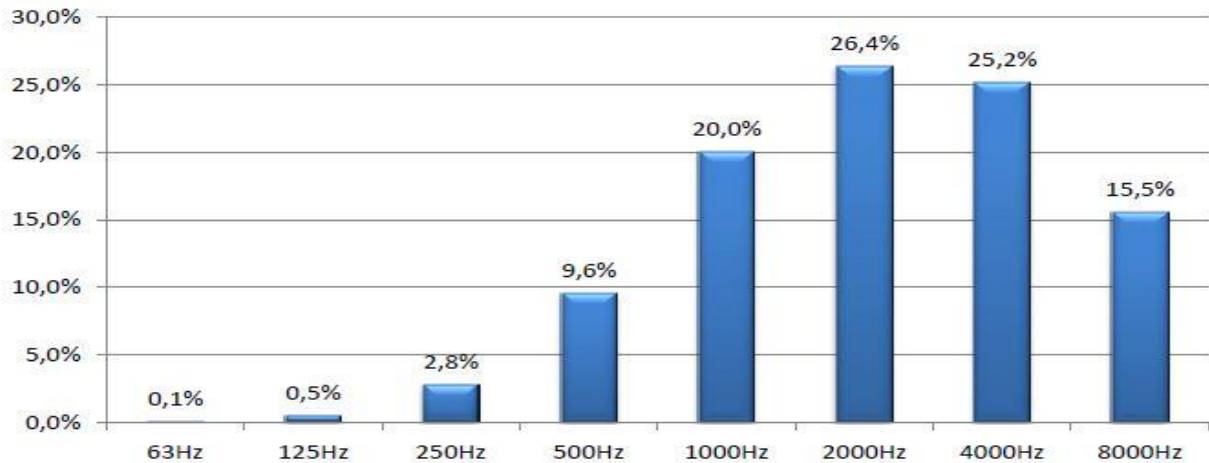


Figure 3 Weighting the SNR according to the frequencies, the percentage represents the weight of each frequency in the calculation of SNR

As we see in the graph above, the weighting of SNR favors medium and high frequencies. Three frequencies express approximately 70% of the SNR index (1000Hz, 2000Hz, and 4000Hz). It is the same for PSNA.

According to the observed results, these three frequencies are more repeatable. Inaccuracies of measurements at other frequencies are offset when calculating the PSNA.

4 Appendix 1: Assessment of impact on the PSNA

It is difficult to accurately assess the variations on the PSNA, since they depend on the attenuation curve specific to the hearing protector. Take an example to evaluate the impact of variations in measurement in the calculation of PSNA. It is assumed here that only the measurement without hearing protectors varies from one test to the other:

Frequency	125	250	500	1000	2000	4000	8000	PSNA
Theoretical average attenuation (dB)	17,9	20,2	25,4	29,6	34,2	38,6	37,2	29,8

Table 1: Average attenuation of hearing protectors COTRAL Micra XS 30

We subtract the standard deviations observed in this study to obtain:

Frequency	125	250	500	1000	2000	4000	8000	PSNA
Attenuation with variation	14,7	17,3	23,1	27,6	32,2	36,5	34,4	28

Table 2: Attenuation of hearing protectors with differences

In this example, the PSNA may vary by 1.8 dB between 2 measurements.

5 Appendix 2: Individual results

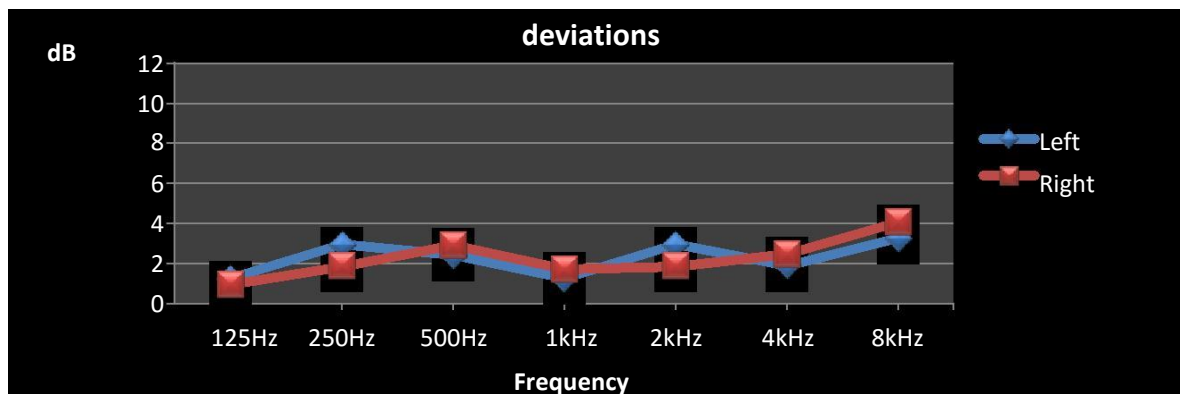
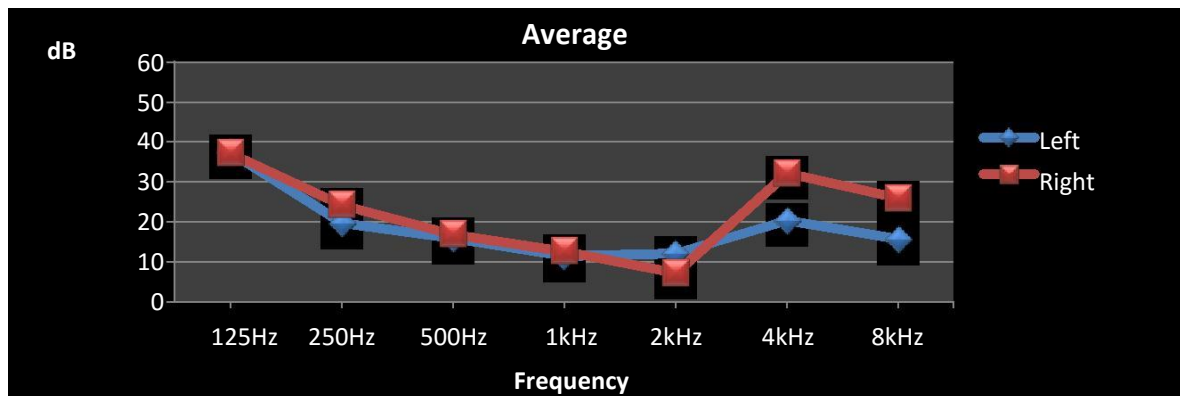
Subject 1:

Left ear:

Freq.			500				8000
Test 1 of 26/11/2012	39	23	15	12	13	23	16
Test 2 of 23/11/2012	38	21	18	13	11	19	18
Test 3 of 14/11/2012	36	16	18	11	16	21	18
Test 4 of 6/11/2012	37	19	13	10	9	19	11
Average	38	20	16	12	12	21	16
Standard deviation	1,3	3	2,4	1,3	3	1,9	3,3

Right ear:

Freq.			500				8000
Test 1 of 26/11/2012	38	24	20	13	10	31	29
Test 2 of 23/11/2012	36	27	13	15	6	31	30
Test 3 of 14/11/2012	37	23	17	11	7	36	23
Test 4 of 6/11/2012	38	23	18	12	6	31	22
Average	37	24	17	13	7,3	32	26
Standard deviation	1	1,9	2,9	1,7	1,9	2,5	4,1



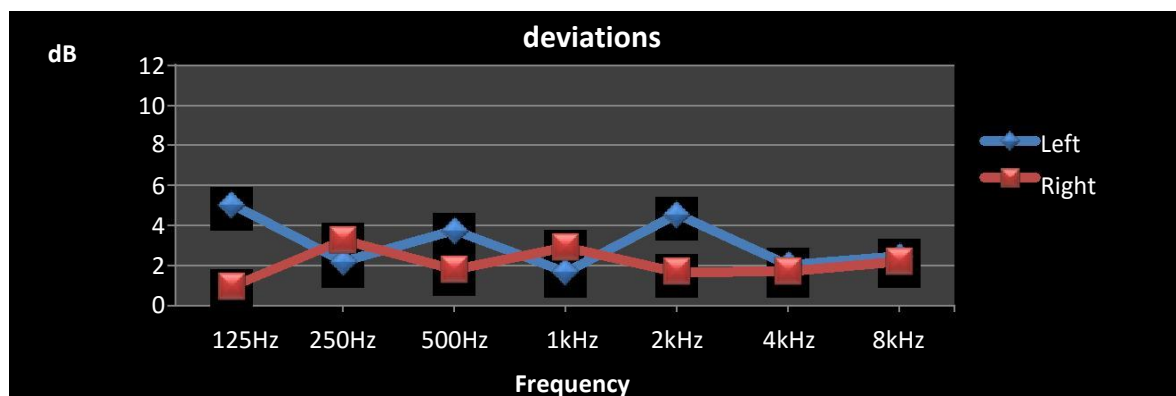
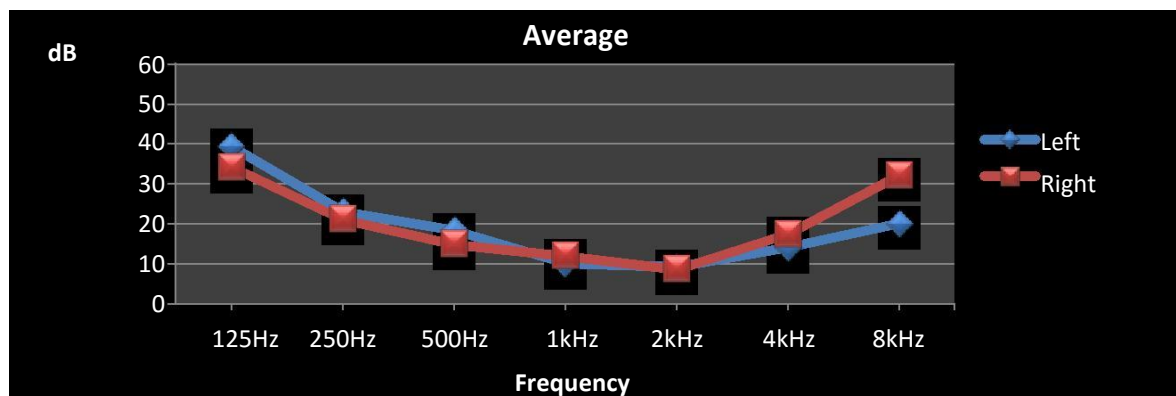
Subject 2:

Left ear:

Freq.			500			8000	
Test 1 of 26/11/2012	36	24	13	8	6	12	20
Test 2 of 19/11/2012	37	25	19	11	16	16	23
Test 3 of 15/11/2012	38	20	21	10	8	16	21
Test 4 of 12/11/2012	47	24	21	12	7	13	17
Average	40	23	19	10	9,3	14	20
Standard deviation	5,1	2,2	3,8	1,7	4,6	2,1	2,5

Right ear:

Freq.			500			8000	
Test 1 of 26/11/2012	34	19	17	9	9	15	30
Test 2 of 19/11/2012	33	19	14	15	7	18	33
Test 3 of 15/11/2012	35	26	16	10	8	19	31
Test 4 of 12/11/2012	35	21	13	14	11	18	35
Average	34	21	15	12	8,8	18	32
Standard deviation	1	3,3	1,8	2,9	1,7	1,7	2,2



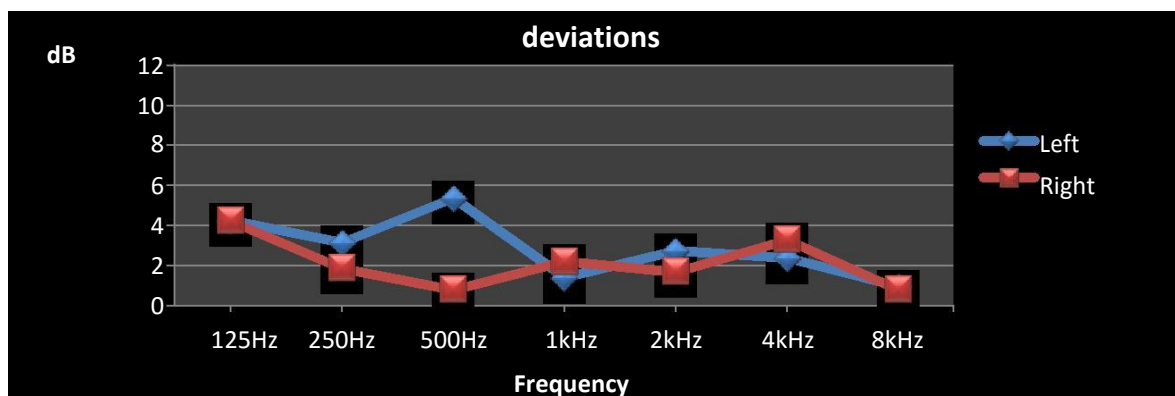
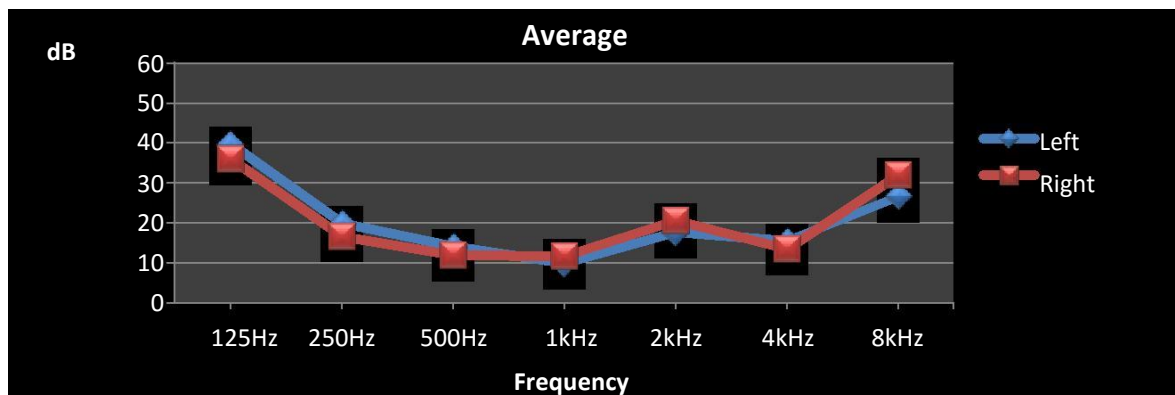
Subject 3:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 30/11/2012	38	18	16	9	15	14	27
Test 2 of 27/11/2012	41	21	9	12	21	15	28
Test 3 of 16/11/2012	35	17	11	9	19	14	26
Test 4 of 07/11/2012	45	24	21	10	16	19	26
Average	40	20	14	10	18	16	27
Standard deviation	4,3	3,2	5,4	1,4	2,8	2,4	1

Right ear:

Freq.			500				8000
Test 1 of 30/11/2012	32	18	11	11	23	9	31
Test 2 of 27/11/2012	33	18	13	10	21	13	32
Test 3 of 16/11/2012	38	14	12	11	20	16	32
Test 4 of 07/11/2012	41	17	12	15	19	16	33
Average	36	17	12	12	21	14	32
Standard deviation	4,2	1,9	0,8	2,2	1,7	3,3	0,8



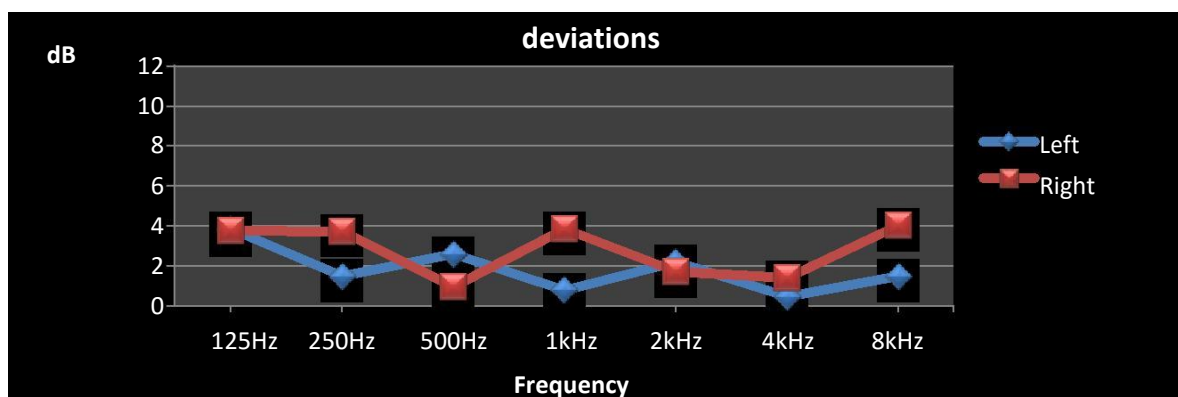
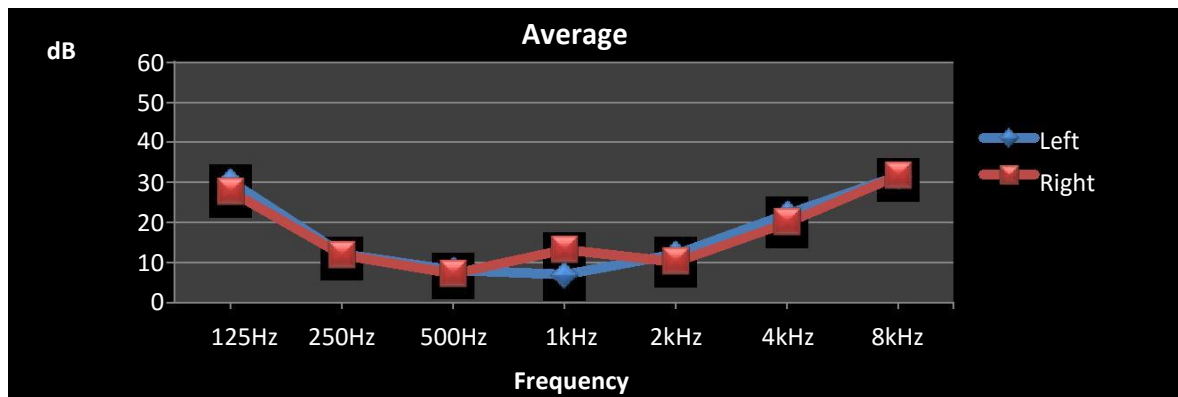
Subject 4:

Left ear:

Freq.			500			8000	
Test 1 of 29/11/2012	32	11	8	7	15	23	30
Test 2 of 22/11/2012	25	11	6	6	11	22	31
Test 3 of 15/11/2012	34	13	12	8	13	22	33
Test 4 of 05/11/2012	30	14	7	7	10	22	33
Average	30	12	8,3	7	12	22	32
Standard deviation	3,9	1,5	2,6	0,8	2,2	0,5	1,5

Right ear:

Freq.			500			8000	
Test 1 of 29/11/2012	28	8	8	17	12	19	34
Test 2 of 22/11/2012	25	11	7	16	11	19	36
Test 3 of 15/11/2012	33	17	8	9	8	22	27
Test 4 of 05/11/2012	25	12	6	11	10	20	30
Average	28	12	7,3	13	10	20	32
Standard deviation	3,8	3,7	1	3,9	1,7	1,4	4



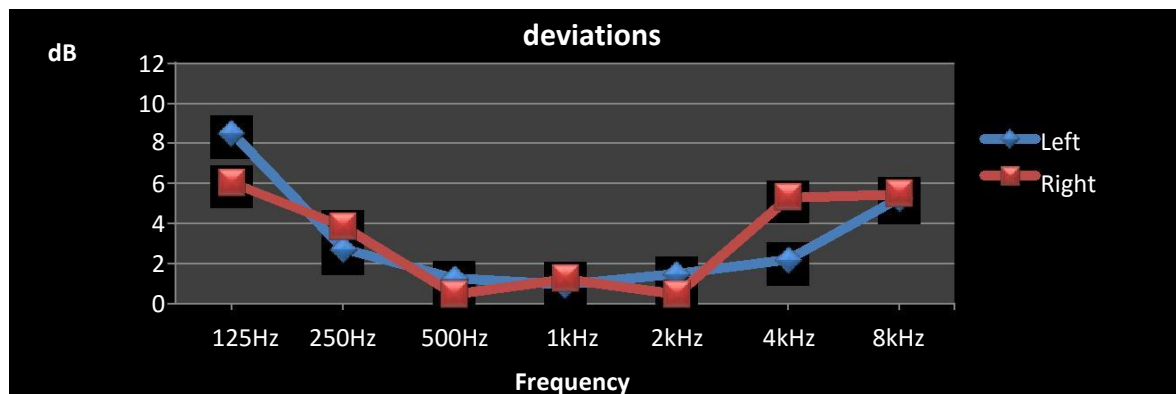
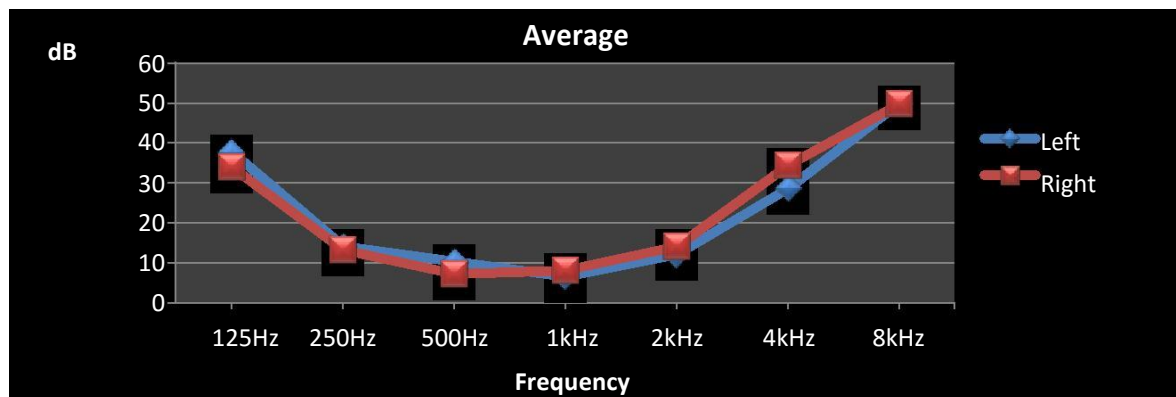
Subject 5:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 26/11/2012	31	11	9	6	10	28	53
Test 2 of 19/11/2012	33	16	11	6	13	27	49
Test 3 of 13/11/2012	50	13	10	7	13	28	55
Test 4 of 05/11/2012	37	17	12	8	13	32	43
Average	38	14	11	6,8	12	29	50
Standard deviation	8,5	2,8	1,3	1	1,5	2,2	5,3

Right ear:

Freq.		500				8000	
Test 1 of 26/11/2012	28	11	7	8	14	34	46
Test 2 of 19/11/2012	31	11	8	10	14	41	45
Test 3 of 13/11/2012	35	12	7	8	14	35	51
Test 4 of 05/11/2012	42	19	7	7	15	28	57
Average	34	13	7,3	8,3	14	35	50
Standard deviation	6,1	3,9	0,5	1,3	0,5	5,3	5,5



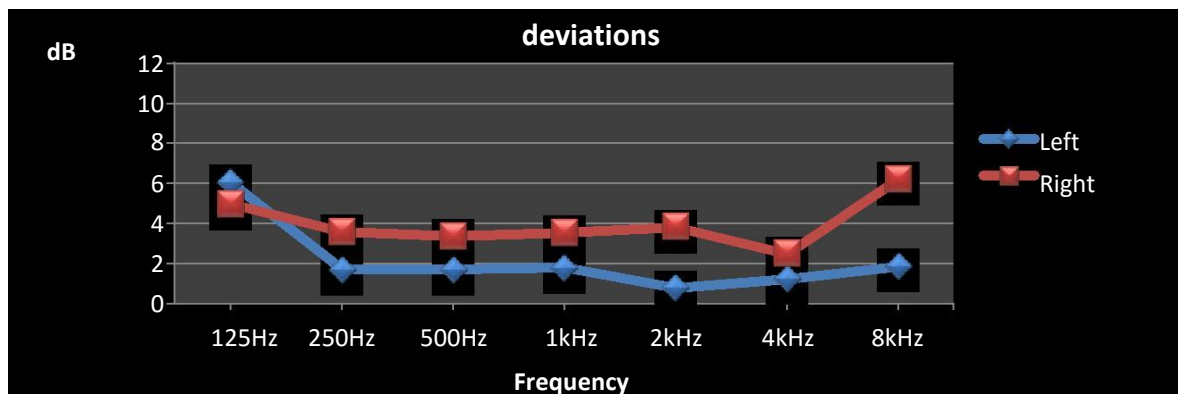
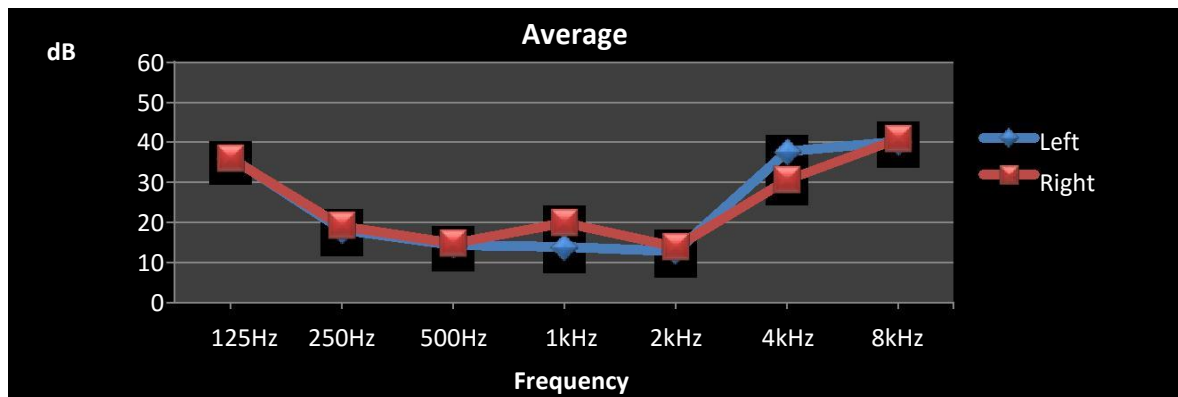
Subject 6:

Left ear:

Freq.			500			8000	
Test 1 of 30/11/2012	45	16	13	12	12	38	40
Test 2 of 19/11/2012	34	19	16	13	13	38	43
Test 3 of 15/11/2012	31	20	13	15	13	39	39
Test 4 of 12/11/2012	35	18	16	16	14	36	39
Average	36	18	15	14	13	38	40
Standard deviation	6,1	1,7	1,7	1,8	0,8	1,3	1,9

Right ear:

Freq.			500			8000	
Test 1 of 30/11/2012	39	17	20	17	9	28	44
Test 2 of 19/11/2012	30	16	13	18	17	31	38
Test 3 of 15/11/2012	34	24	14	20	13	30	34
Test 4 of 12/11/2012	41	20	13	25	17	34	48
Average	36	19	15	20	14	31	41
Standard deviation	5	3,6	3,4	3,6	3,8	2,5	6,2



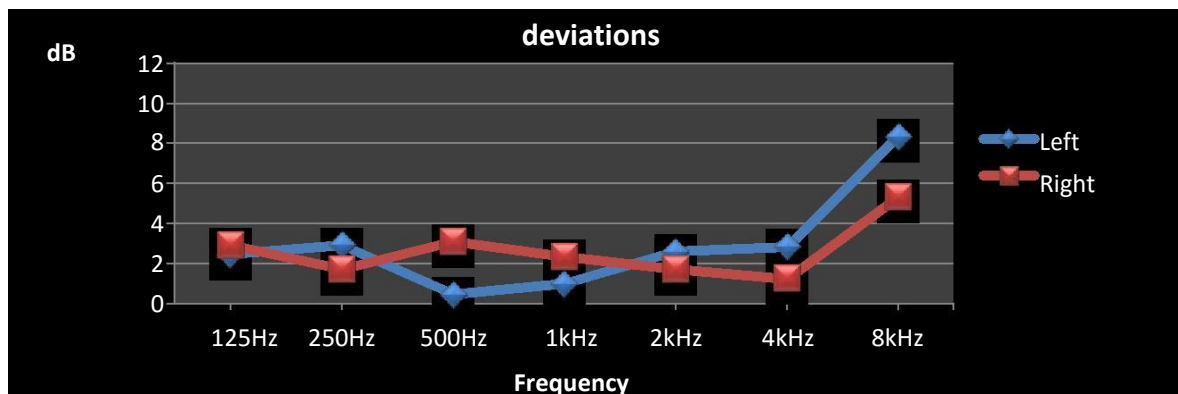
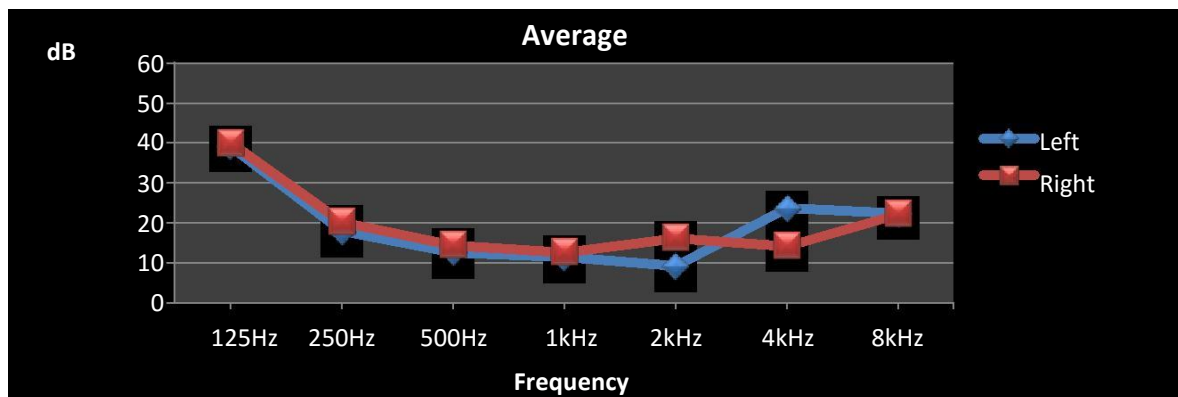
Subject 7:

Left ear:

Freq.			500			8000	
Test 1 of 26/11/2012	38	21	13	11	9	23	27
Test 2 of 19/11/2012	38	14	12	13	8	20	30
Test 3 of 12/11/2012	43	19	13	11	13	26	22
Test 4 of 12/11/2012	38	18	13	11	7	26	11
Average	39	18	13	12	9,3	24	23
Standard deviation	2,5	2,9	0,5	1	2,6	2,9	8,3

Right ear:

Freq.			500			8000	
Test 1 of 26/11/2012	37	18	19	11	17	14	29
Test 2 of 19/11/2012	44	20	14	13	14	14	18
Test 3 of 12/11/2012	40	21	13	11	18	13	24
Test 4 of 12/11/2012	39	22	12	16	16	16	18
Average	40	20	15	13	16	14	22
Standard deviation	2,9	1,7	3,1	2,4	1,7	1,3	5,3



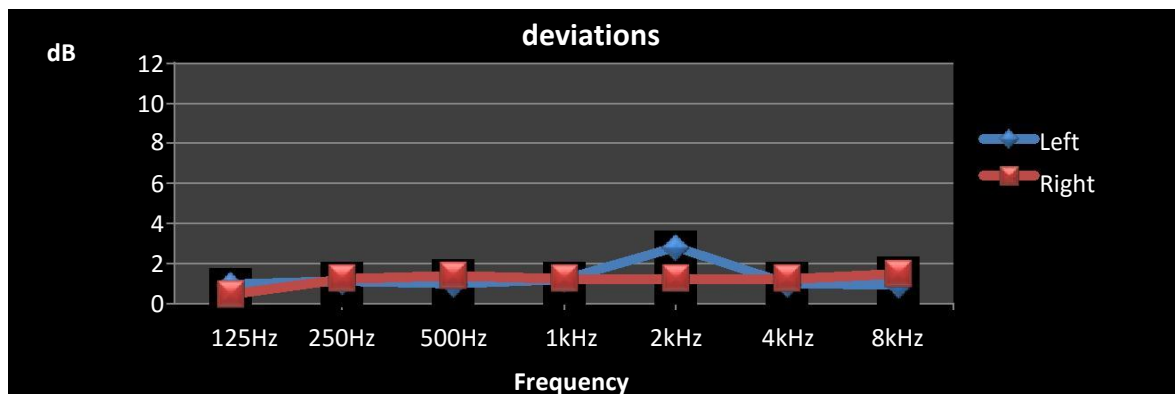
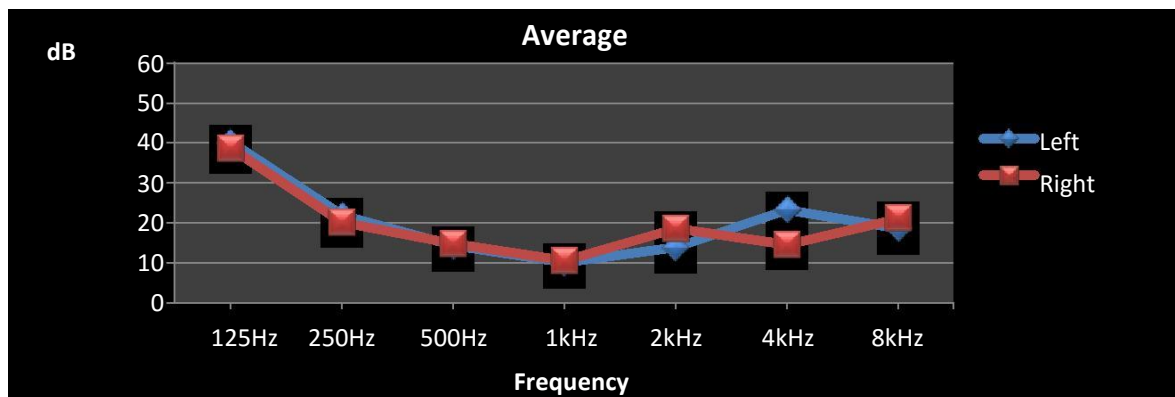
Subject 8:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 26/11/2012	39	21	14	9	18	22	20
Test 2 of 19/11/2012	40	21	16	12	14	24	19
Test 3 of 12/11/2012	41	23	14	10	12	24	18
Test 4 of 12/11/2012	41	23	14	10	12	24	18
Average	40	22	15	10	14	24	19
Standard deviation	1	1,2	1	1,3	2,8	1	1

Right ear:

Freq.		500		8000			
Test 1 of 26/11/2012	38	19	13	9	17	13	22
Test 2 of 19/11/2012	39	22	15	12	20	16	19
Test 3 of 12/11/2012	39	20	16	11	19	15	22
Test 4 of 12/11/2012	39	20	16	11	19	15	22
Average	39	20	15	11	19	15	21
Standard deviation	0,5	1,3	1,4	1,3	1,3	1,3	1,5



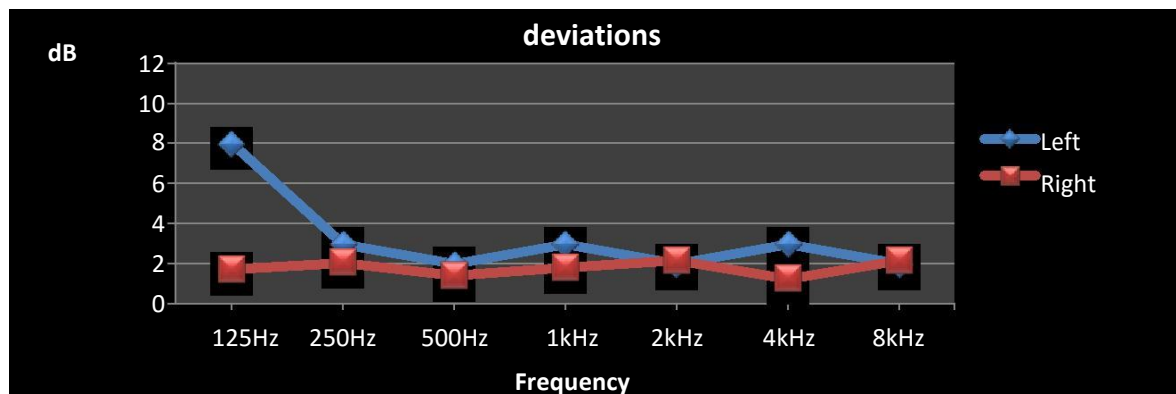
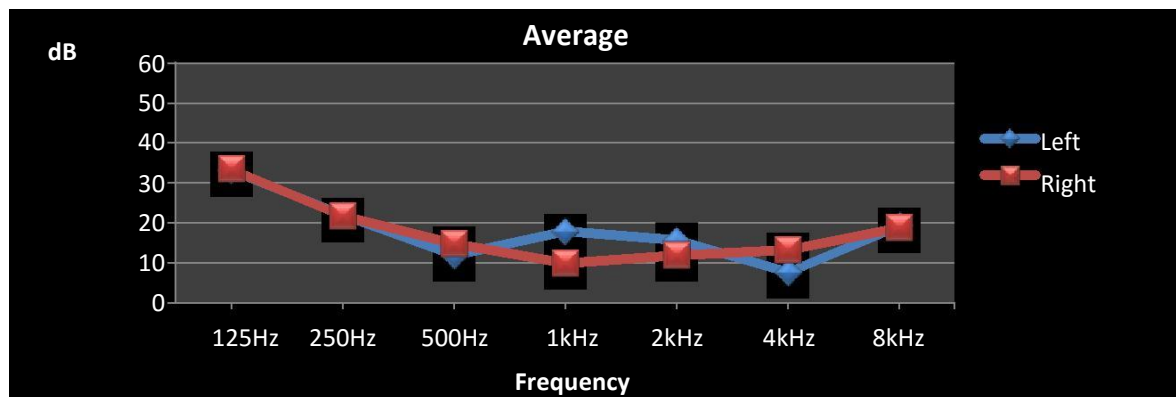
Subject 9:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 27/11/2012	28	22	11	18	15	6	19
Test 2 of 21/11/2012	36	21	13	17	16	9	19
Test 3 of 13/11/2012	35	21	11	17	15	8	21
Test 4 of 07/11/2012	34	24	13	20	17	8	19
Average	33	22	12	18	16	7,8	20
Standard deviation	3,6	1,4	1,2	1,4	1	1,3	1

Right ear:

Freq.			500				8000
Test 1 of 27/11/2012	31	20	13	8	9	13	16
Test 2 of 21/11/2012	34	20	15	12	12	15	19
Test 3 of 13/11/2012	35	23	16	11	13	12	20
Test 4 of 07/11/2012	34	24	16	9	14	13	21
Average	34	22	15	10	12	13	19
Standard deviation	1,7	2,1	1,4	1,8	2,2	1,3	2,2



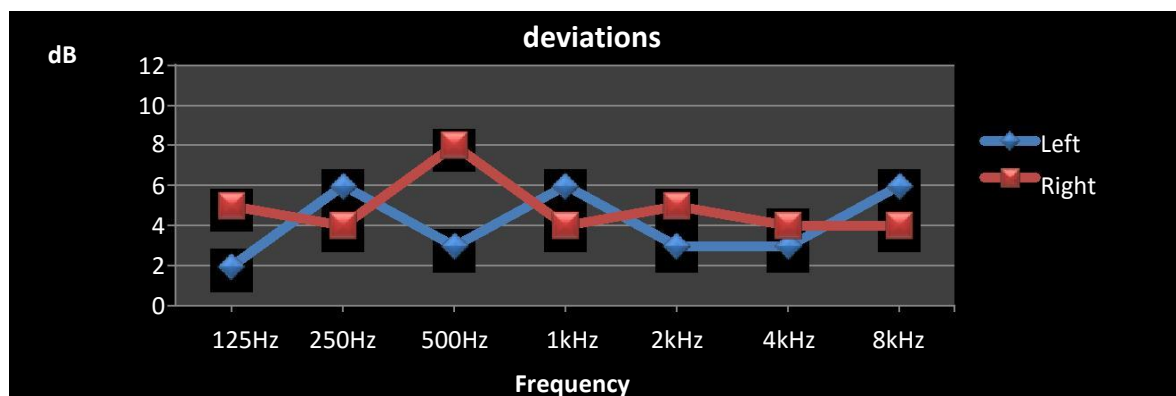
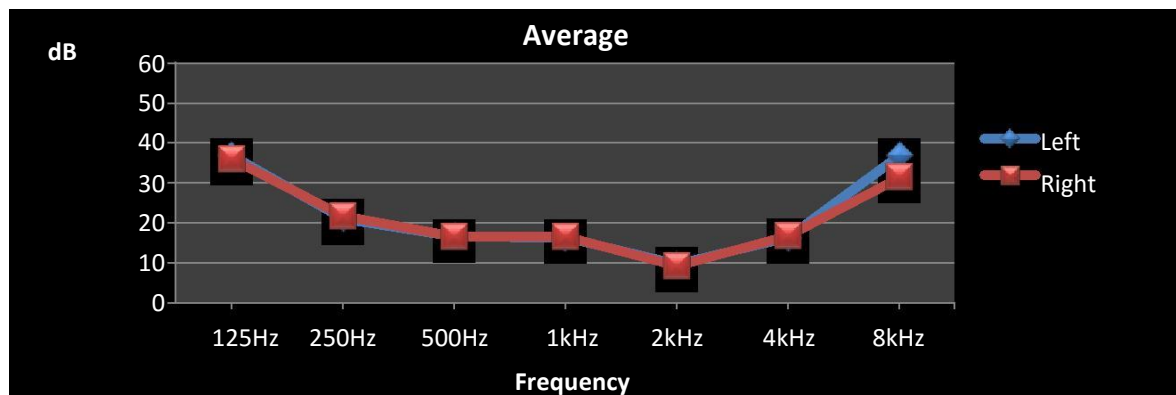
Subject 10:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 26/11/2012	38	23	18	20	9	16	37
Test 2 of 19/11/2012	36	24	18	16	11	18	41
Test 3 of 12/11/2012	36	20	16	16	11	17	35
Test 4 of 07/11/2012	38	18	15	14	8	15	35
Average	37	21	17	17	9,8	17	37
Standard deviation	1,2	2,8	1,5	2,5	1,5	1,3	2,8

Right ear:

Freq.		500				8000	
Test 1 of 26/11/2012	38	24	20	18	8	15	32
Test 2 of 19/11/2012	38	22	21	17	13	18	34
Test 3 of 12/11/2012	35	20	13	18	8	16	30
Test 4 of 07/11/2012	33	21	13	14	8	19	30
Average	36	22	17	17	9,3	17	32
Standard deviation	2,4	1,7	4,3	1,9	2,5	1,8	1,9



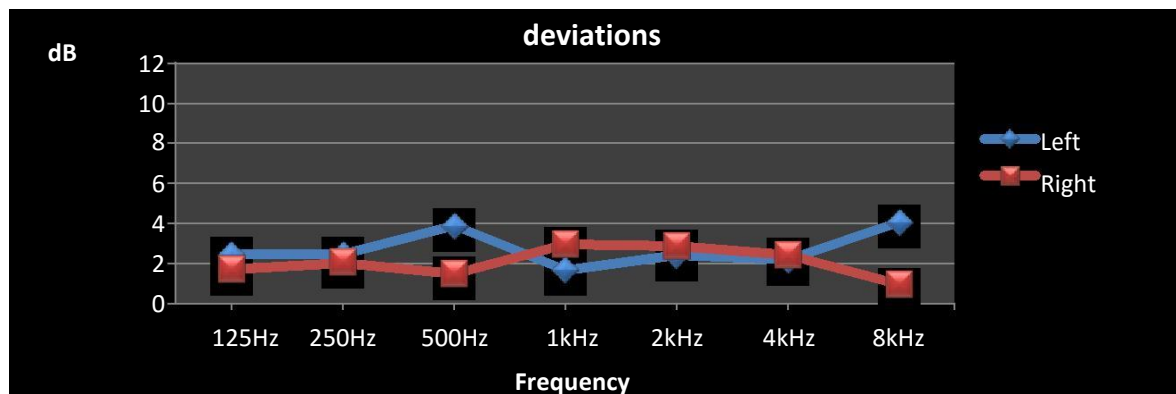
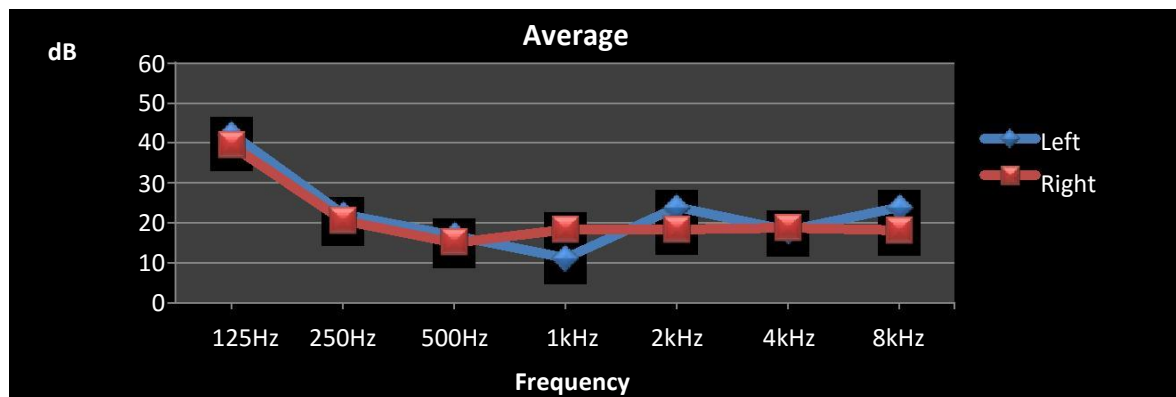
Subject 11:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 29/11/2012	41	21	19	12	21	16	24
Test 2 of 22/11/2012	41	21	21	13	26	21	29
Test 3 of 16/11/2012	46	26	16	9	23	17	19
Test 4 of 15/11/2012	41	21	12	11	26	19	24
Average	42	22	17	11	24	18	24
Standard deviation	2,5	2,5	3,9	1,7	2,4	2,2	4,1

Right ear:

Freq.		500				8000	
Test 1 of 29/11/2012	38	21	16	17	16	18	19
Test 2 of 22/11/2012	41	23	13	21	21	21	19
Test 3 of 16/11/2012	38	18	16	15	16	16	17
Test 4 of 15/11/2012	41	21	16	21	21	21	18
Average	40	21	15	19	19	19	18
Standard deviation	1,7	2,1	1,5	3	2,9	2,4	1



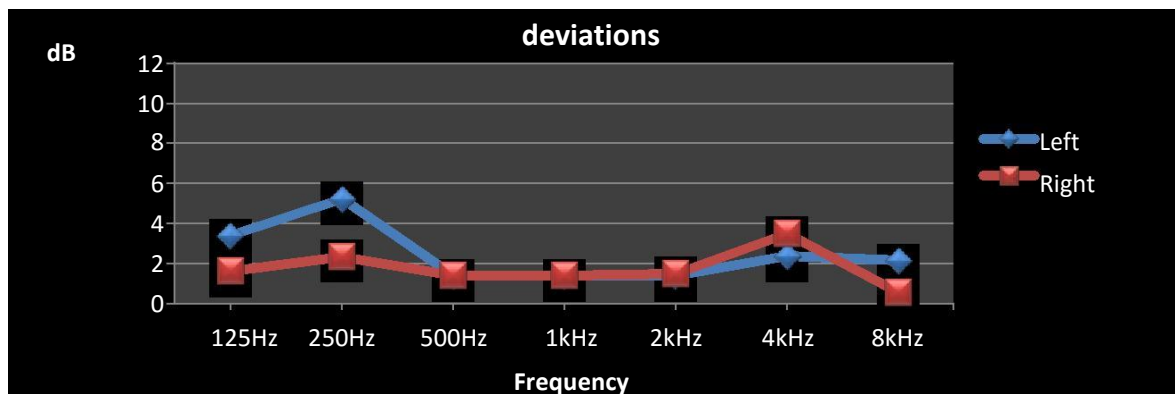
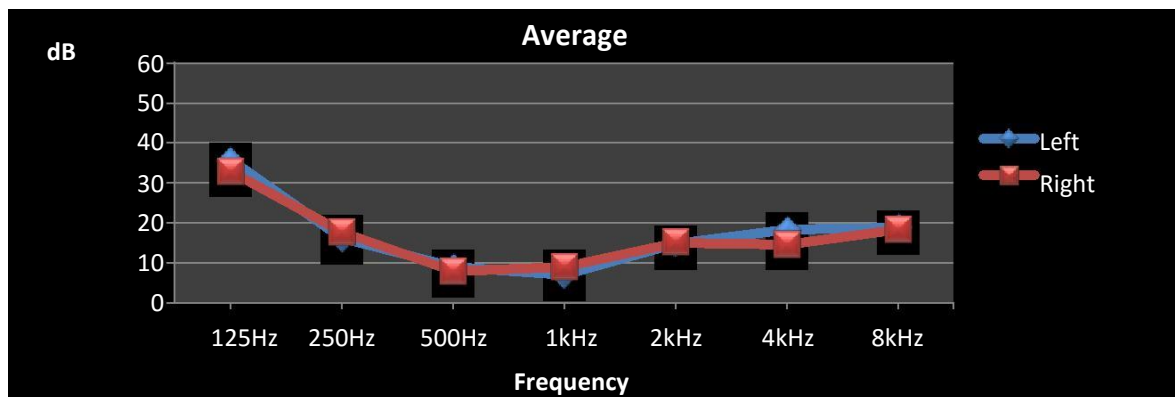
Subject 12:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 29/11/2012	31	15	8	6	13	16	16
Test 2 of 22/11/2012	37	24	8	7	16	21	21
Test 3 of 14/11/2012	36	13	11	6	16	20	20
Test 4 of 09/11/2012	39	13	9	9	15	17	19
Average	36	16	9	7	15	19	19
Standard deviation	3,4	5,3	1,4	1,4	1,4	2,4	2,2

Right ear:

Freq.			500				8000
Test 1 of 29/11/2012	33	18	8	8	16	13	19
Test 2 of 22/11/2012	31	21	7	8	17	19	19
Test 3 of 14/11/2012	33	16	10	9	14	11	18
Test 4 of 09/11/2012	35	16	7	11	14	16	18
Average	33	18	8	9	15	15	19
Standard deviation	1,6	2,4	1,4	1,4	1,5	3,5	0,6



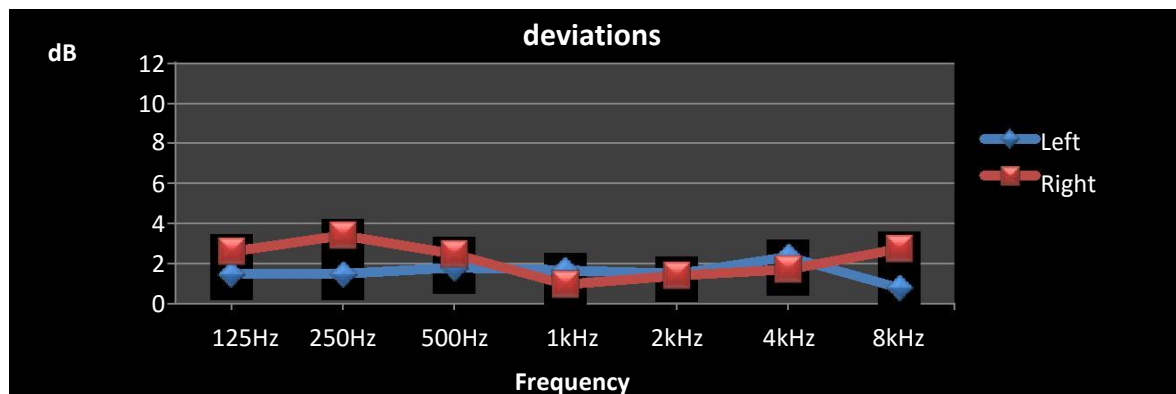
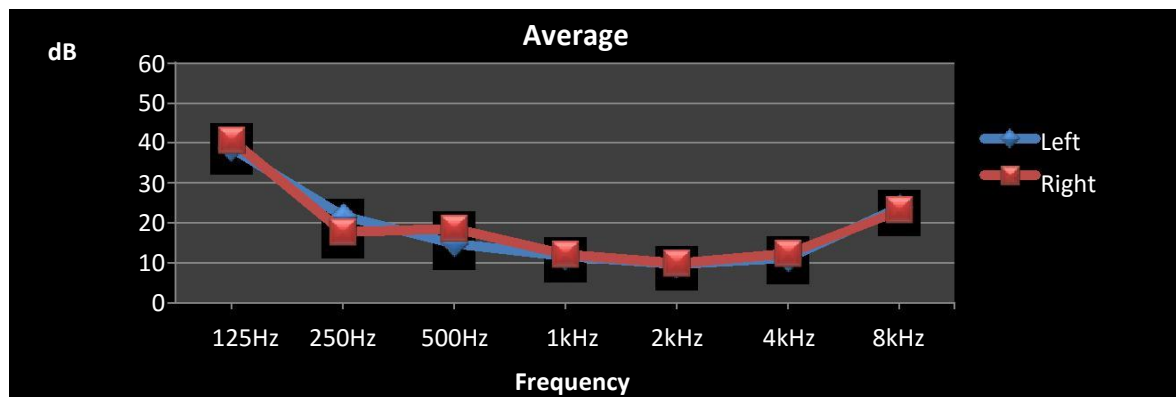
Subject 13:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 29/11/2012	38	21	14	11	11	13	24
Test 2 of 23/11/2012	41	23	17	14	11	11	24
Test 3 of 14/11/2012	38	23	13	10	8	8	23
Test 4 of 05/11/2012	38	20	16	12	9	13	25
Average	39	22	15	12	9,8	11	24
Standard deviation	1,5	1,5	1,8	1,7	1,5	2,4	0,8

Right ear:

Freq.		500				8000	
Test 1 of 29/11/2012	39	21	22	13	11	14	26
Test 2 of 23/11/2012	43	19	19	13	11	13	25
Test 3 of 14/11/2012	38	18	18	12	8	13	22
Test 4 of 05/11/2012	43	13	16	11	10	10	20
Average	41	18	19	12	10	13	23
Standard deviation	2,6	3,4	2,5	1	1,4	1,7	2,8



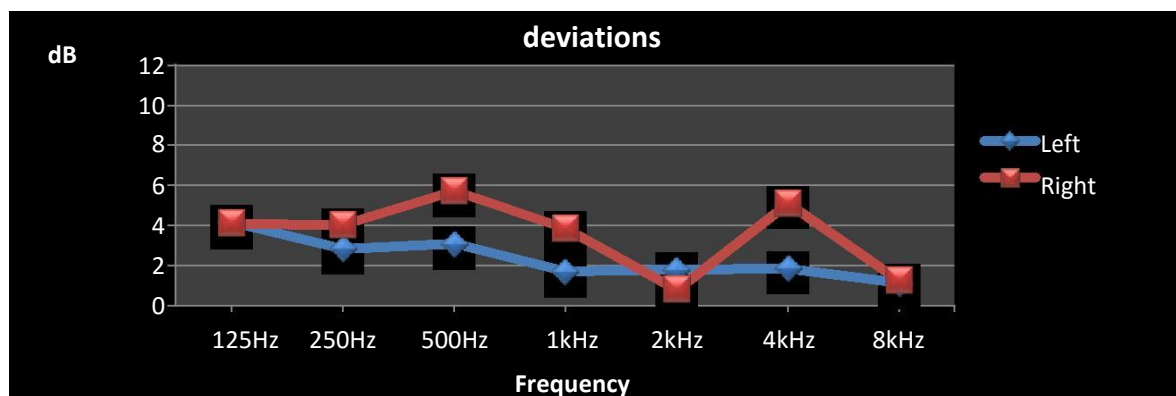
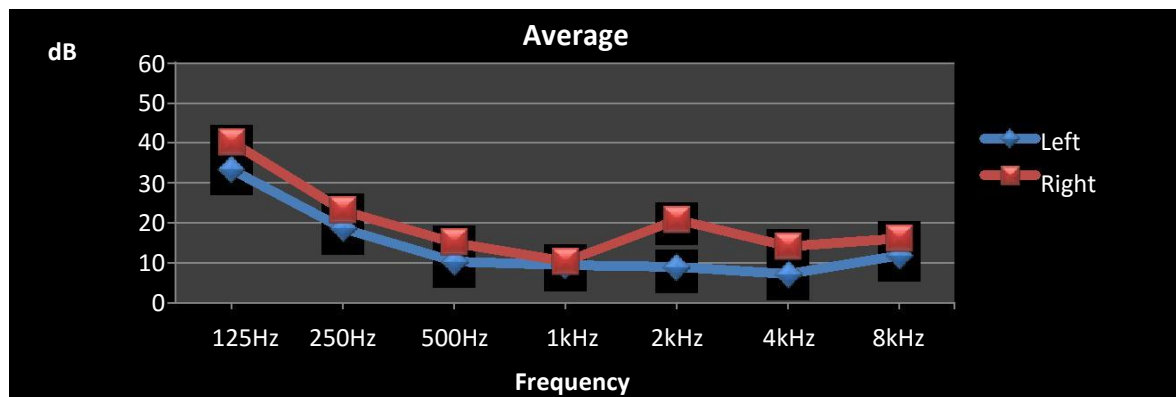
Subject 14:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 28/11/2012	36	19	8	8	11	6	11
Test 2 of 21/11/2012	29	15	9	11	8	6	13
Test 3 of 14/11/2012	31	19	10	8	10	7	11
Test 4 of 07/11/2012	38	22	15	11	7	10	13
Average	34	19	11	9,5	9	7,3	12
Standard deviation	4,2	2,9	3,1	1,7	1,8	1,9	1,2

Right ear:

Freq.			500				8000
Test 1 of 28/11/2012	35	19	12	7	22	9	16
Test 2 of 21/11/2012	39	21	10	9	21	11	18
Test 3 of 14/11/2012	44	28	23	16	21	20	15
Test 4 of 07/11/2012	43	25	16	10	20	17	16
Average	40	23	15	11	21	14	16
Standard deviation	4,1	4	5,7	3,9	0,8	5,1	1,3



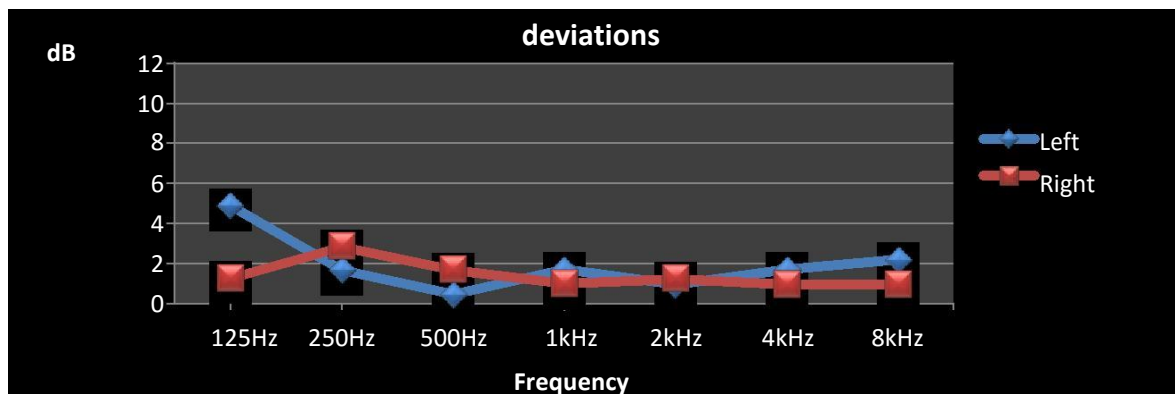
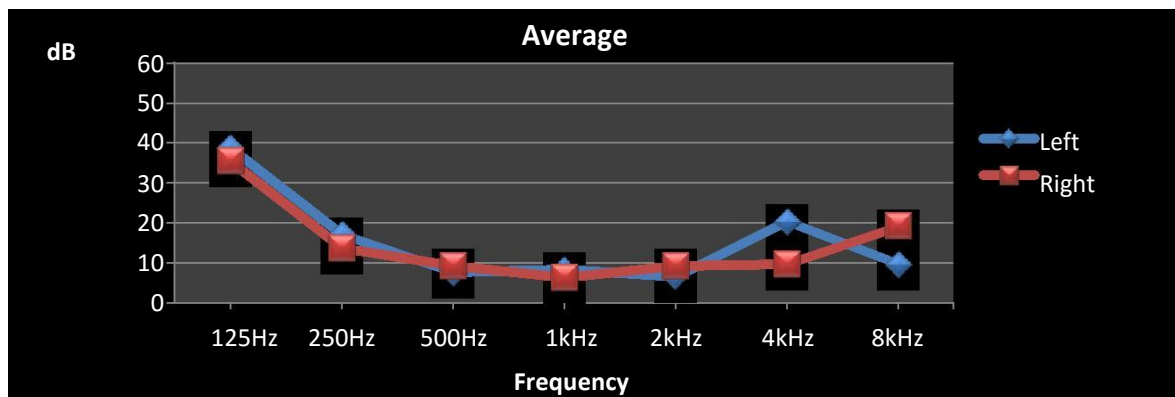
Subject 15:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 30/11/2012	35	17	8	9	8	19	9
Test 2 of 21/11/2012	37	19	7	6	7	22	7
Test 3 of 14/11/2012	46	18	8	9	6	22	12
Test 4 of 09/11/2012	37	15	8	10	6	19	11
Average	39	17	7,8	8,5	6,8	21	9,8
Standard deviation	4,9	1,7	0,5	1,7	1	1,7	2,2

Right ear:

Freq.		500				8000	
Test 1 of 30/11/2012	36	16	11	6	9	9	20
Test 2 of 21/11/2012	35	13	9	6	9	9	20
Test 3 of 14/11/2012	34	10	7	8	11	11	18
Test 4 of 09/11/2012	37	16	10	6	8	10	19
Average	36	14	9,3	6,5	9,3	9,8	19
Standard deviation	1,3	2,9	1,7	1	1,3	1	1



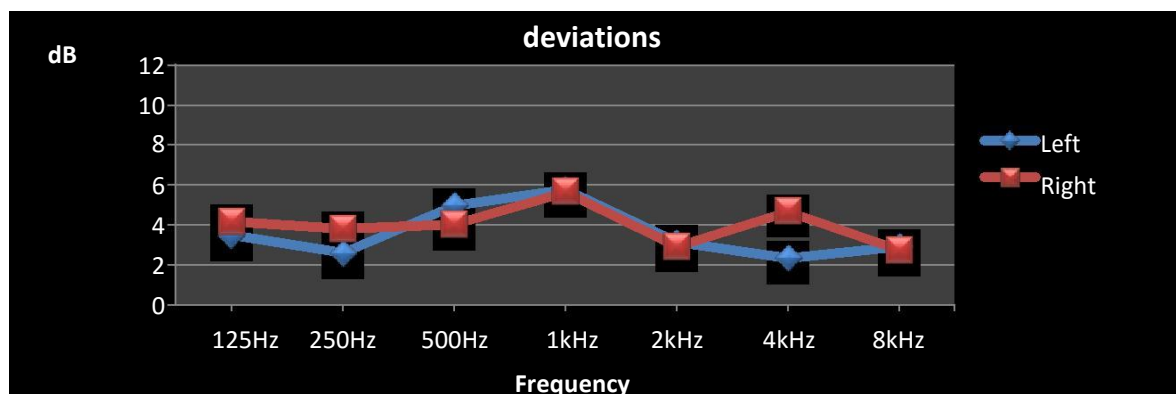
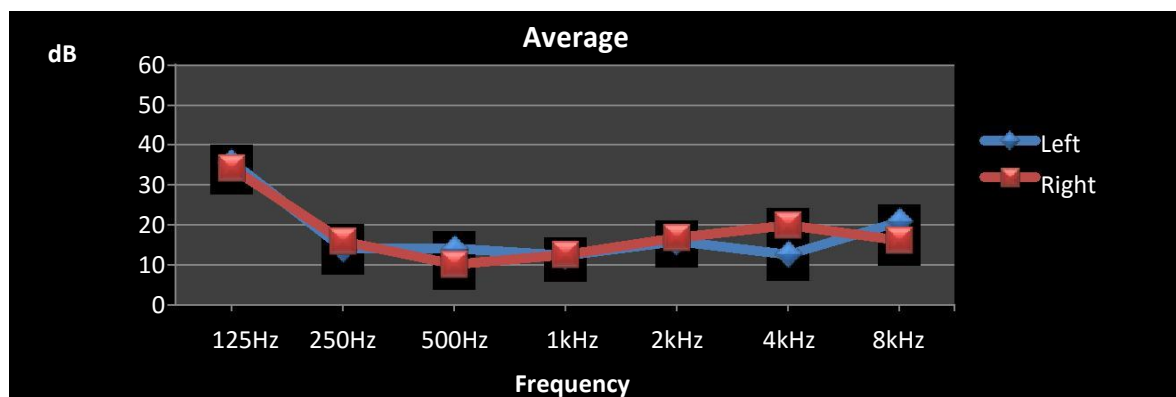
Subject 16:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 29/11/2012	32	13	9	8	13	11	21
Test 2 of 22/11/2012	37	18	14	10	14	11	17
Test 3 of 15/11/2012	34	14	13	11	17	13	24
Test 4 of 07/11/2012	40	12	21	21	20	16	22
Average	38	20	16	12	12	21	16
Standard deviation	1,3	3	2,4	1,3	3	1,9	3,3

Right ear:

Freq.			500				8000
Test 1 of 29/11/2012	37	13	8	8	13	18	13
Test 2 of 22/11/2012	36	17	10	11	20	15	18
Test 3 of 15/11/2012	28	13	7	11	17	21	15
Test 4 of 07/11/2012	36	21	16	21	18	26	19
Average	37	24	17	13	7,3	32	26
Standard deviation	1	1,9	2,9	1,7	1,9	2,5	4,1



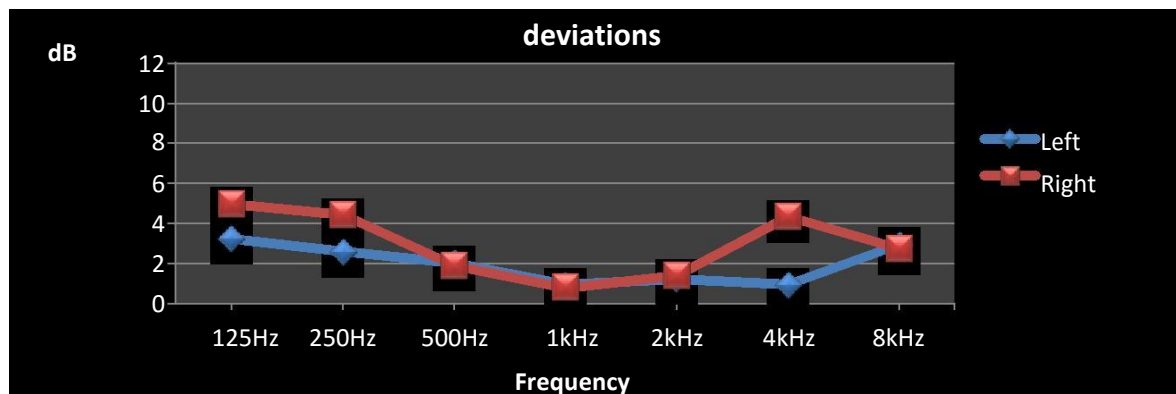
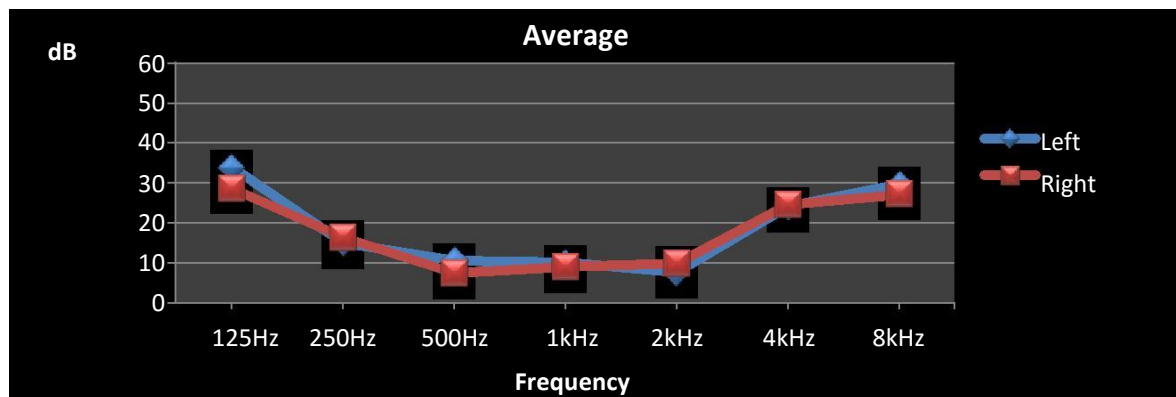
Subject 17:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 30/11/2012	34	13	12	11	8	24	27
Test 2 of 23/11/2012	34	17	9	9	8	25	34
Test 3 of 16/11/2012	30	13	9	11	6	23	29
Test 4 of 07/11/2012	38	18	13	10	9	25	29
Average	34	15	11	10	7,8	24	30
Standard deviation	3,3	2,6	2,1	1	1,3	1	3

Right ear:

Freq.		500				8000	
Test 1 of 30/11/2012	28	15	6	10	9	23	26
Test 2 of 23/11/2012	32	19	8	8	10	24	30
Test 3 of 16/11/2012	22	11	6	9	9	21	24
Test 4 of 07/11/2012	33	21	10	9	12	31	29
Average	29	17	7,5	9	10	25	27
Standard deviation	5	4,4	1,9	0,8	1,4	4,3	2,8



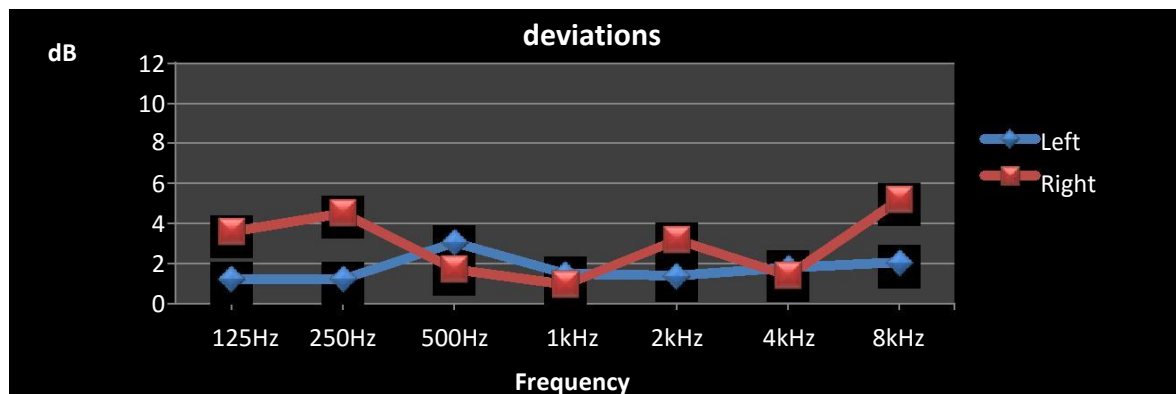
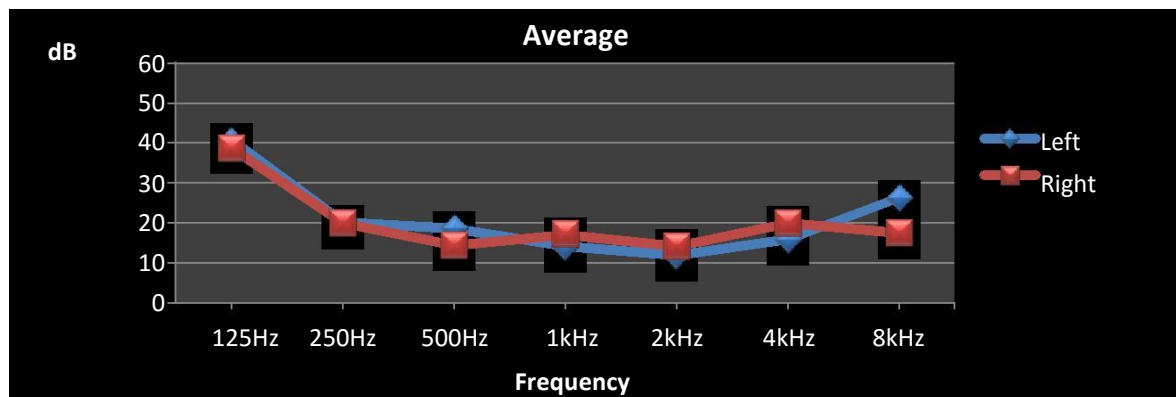
Subject 18:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 29/11/2012	39	20	17	15	14	17	26
Test 2 of 22/11/2012	42	19	16	13	11	14	24
Test 3 of 16/11/2012	41	20	23	13	11	18	27
Test 4 of 14/11/2012	41	22	19	16	12	15	29
Average	41	20	19	14	12	16	27
Standard deviation	1,3	1,3	3,1	1,5	1,4	1,8	2,1

Right ear:

Freq.		500				8000	
Test 1 of 29/11/2012	36	17	13	18	13	21	15
Test 2 of 22/11/2012	37	16	13	17	12	21	12
Test 3 of 16/11/2012	44	26	16	16	19	18	24
Test 4 of 14/11/2012	38	21	16	18	13	20	19
Average	39	20	15	17	14	20	18
Standard deviation	3,6	4,5	1,7	1	3,2	1,4	5,2



Subject 19:

Left ear:

Freq.	125	250	500	1000	2000	4000	8000
Test 1 of 19/09/2012	36	28	18	9	13	17	33
Test 2 of 18/09/2012	36	26	17	11	11	16	28
Test 3 of 12/09/2012	38	30	16	11	13	18	30
Test 4 from 07/09/2012	37	22	14	9	13	16	40
Average	37	27	16	10	13	17	33
Standard deviation	1	3,4	1,7	1,2	1	1	5,3

Right ear:

Freq.			500				8000
Test 1 of 19/09/2012	32	21	11	11	14	24	26
Test 2 of 18/09/2012	36	19	11	14	14	24	23
Test 3 of 12/09/2012	34	21	11	13	16	25	24
Test 4 from 07/09/2012	30	18	8	12	16	25	29
Average	33	20	10	13	15	25	26
Standard deviation	2,6	1,5	1,5	1,3	1,2	0,6	2,6

