INSTITUT NATIONAL des SCIENCES APPLIQUÉES

INSA ROUEN

Physics Project P6-3

STPI/P6-3/2008 – 049

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Studies and experiments in acoustics and psychoacoustics

À TAILLE
HUMAINE
À L'ECHELLE
DU MONDE

Submission date of report: ***20/06/08***

Reference of project: ***STPI/P6-3/2008 – 049***

Project name: ***Studies and experiments in acoustics and psychoacoustics***

Type de project: ***Experimental, Simulation***

Project objectives:

People, these days often complain how loud and noisy our surrounding has become. But they normally don't understand exactly how the concept of acoustics and to be more precise loudness works. This document reports the basic nuances of acoustics and further deals with a few selected topics such as Loudness and Franssen Effect.

Laboratory notebook number # **A 30236**

ACKNOWLEDGEMENTS

Our group has been fortunate to gain help and critical comments from several of our professors. We thank **Mr. Simon BUSBRIDGE** and **Mr. Le Tolouzan**, our project supervisors.

Our Special thanks to **Mr. Jean Baptiste CARPENTIER** (acoustics professor at IUT) for his support and understanding. We also thank other support teachers and our peers for helping us out at various instances.

We would also like to thank Mr. Simon DELAUNAY for giving his French outlook into our report.

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NOTATIONS, ACRONYMES

- dB: decibel
- SPL: sound pressure level
- Hz: hertz
- kHz: kilohertz

1. INTRODUCTION

Often people do not understand this branch of science and they are more than often ill-informed about acoustics and topics related to it. We chose this project so as to clear some of our existing doubts and to familiarize with the basics of acoustics. Acoustics remains largely unheard of until higher studies and hence the need of learning and understanding this vital branch of science as an engineering student is important as well as beneficial for our future endeavors.

In this project, we intend to work with the concept of loudness through the Fletcher Munson experiment. Further we plan to look into an interesting auditory illusion called Franssen Effect. By understanding these topics, we hope to comprehend the subjectivity in the hearing system of humans.

We also want to study the importance of psychoacoustics. In the growing field of medicine and engineering, we ought to understand the link between the brain and the hearing system of human body. We hope that the study of Acoustics will help us forge that link, in the form of psychoacoustics.

Another objective of this project is to understand the functioning of a team and find efficient means to produce the desired results. Our multinational group can face several problems as our working culture differs on various accounts. An Indian, a Romanian, and three Chinese, well one can so easily get lost in translation. We will try to organize ourselves in an orderly manner and try to keep aside our cultural differences and come together as one cohesive unit; by doing so we will hopefully accomplish our common goals.

The first step towards performing our project should be in the direction of Fletcher Munson experiment. We should research into the theoretical aspects of the experiment. By doing so we can figure out if or not the experiment is doable; if yes we should try to find what are the materials required and the actual procedure of the experiment. If the experiment is not feasible, we plan to find and work on some related topics and their applications.

We perceive this project to be an eye opener, to be very tough and demanding but at the same time, a very important and valuable experience.

RESUME

Souvent les gens ne comprennent pas cette branche de la science et sont très mal informés sur l'acoustique et les sujets qui y sont rattachés. Ce projet a pour but de dégager certains de ces doutes et de familiariser les étudiants avec quelques principes fondamentaux de l'acoustique. L'acoustique n'est majoritairement étudiée que lors des études avancées et spécialisées. Or l'apprentissage et la compréhension de cette importante branche de la science sont favorables pour l'avenir d'un élève ingénieur.

Ce rapport à pour but d'expliquer les principes fondamentaux de l'acoustique. Dans la section 3, nous y présentons l'expérience de Fletcher-Munson et le concept d'intensité. Dans la section 4, nous expliquons la provenance d'une illusion auditive appelée « l'effet de Franssen ».

Au cours de nos recherches, nous avons découverts l'importance de la psychoacoustique, laquelle a de nombreuses applications, notamment dans les domaines en pleine expansion de la médecine et de l'ingénierie. Ainsi, il était vital de comprendre le lien entre le cerveau et le système d'audition du corps humain.

Les audiogrammes ont eu de nombreuses conclusions et applications intéressantes. Premièrement, grâce à l'expérience d'enregistrement des audiogrammes, nous avons remarqué qu' Akshay BANSAL n'entendait pas bien les sons produits entre les fréquences de 3 kHz et 6 kHz. Ceci peut être clairement lu à partir de l'audiogramme. Cette expérience, en nous permettant de remarquer l'audition déficiente d'un membre de notre groupe, nous a clairement démontré l'utilité des audiogrammes.

Une autre conclusion intéressante est que nous avons réussi à identifier sur l'audiogramme une différence entre les sensibilités de l'audition en fonction des deux sexes. Concrètement, les femmes seraient plus sensibles aux hautes fréquences que les hommes. En comparant les audiogrammes de LORINTIU Oana et XING Weiling avec ceux des autres collègues masculins, nous avons remarqué que les audiogrammes des sujets féminins étaient plus proches du seuil d'audibilité que ceux des hommes.

Un autre objectif de ce projet était de comprendre le fonctionnement d'une équipe et d'obtenir des résultats. Dans de nombreuses occasions, notre groupe international a du faire face à différents conflits. Notre culture personnelle concernant le travail collectif a aussi différée et à de nombreuses occasions, nous avons étés en désaccord. Malgré cela, sur une période de quinze semaines, nous avons réussi à mettre de coté nos différences et à nous réunir en équipe afin d'accomplir un but commun.

Finalement, ce projet fut très difficile et contraignant lors de sa réalisation, mais constitue également une expérience de grande valeur pour nous tous.

2. METHODOLOGY / ORGANIZATION OF WORK

The organization and methodology that we adopted might be hard to explain as it was never very constant. Like all other projects, out project came to a stand-still several times in the initial phase as we were unable to work together as a cohesive unit.

We tried to divide the tasks between us in such a manner that it suited everybody. Hence, division was done while taking into consideration the time everybody had, the subjects they preferred and also the efficiency of their work.

As our project required a lot of theoretical research, we made two subgroups: the first one took care of the research and the second one was responsible for carrying out the experiments. We faced several difficulties here too, as some of the members didn't actually like to be confined to only one group. Thus there was a constant juggling of members between the two groups.

The first topic that we approached was The Fletcher-Munson experiment. The first two to three weeks, we concentrated on the theoretical part, thereby attaining a basic minimum level of understanding of related terms.

Mr. Busbridge advised us to further look into a few sites and topics related to acoustics. We then diverted our focus towards performing the Fletcher-Munson Experiment. We further divided our group into two, the first one comprising of Zhe, Cheng and Weiling and the second one of Akshay and Oana. The former group worked on the experiment and tried to put together the various instruments required and also to study the applications. The latter group tried to simulate another related experiment and was successful in finding online software on the following site: http://www.phys.unsw.edu.au/jw/hearing.html. This online software allowed us to make a start, though not a very conclusive and accurate one, but still it was a start.

All five of us performed the experiment separately and thus we had 5 different graphs. But in doing so, we undermined a few important factors, such as the different time at which we carried out the experiment, the different mental and physical state we were in, or the interfering background sounds that may be different for each of us. We understood that we had to be more cautious and approach our experiment with utmost care.

After learning a valuable lesson, we planned to carry on, and perform Fletcher-Munson Experiment. But, we found out that INSA doesn't house the required equipments for such an experiment. We were advised by Mr. Le Toulouzan, to approach the Acoustics Specialist at IUT of Rouen, Mr. Carpentier.

We fixed an appointment with him and explained him our project objectives and our problem. He agreed to help us out and guide us with out project. Unfortunately he informed us that Fletcher-Munson Experiment is out of our reach as it requires instruments that he didn't have and next we need to perform this experiment over a large number of people to actually find a concrete result.

Nevertheless, he explained that we could still approach the experiment by tracing out individual audiograms using an audiometer.

Mr. Carpentier allowed us to use the audiometer at IUT every Thursday. He explained the functioning and application of the device. The whole group performed the experiment at the same time in an isolated room, devoid of any background interfering sounds. Whence we had our individual values for both left and right ears, we started the analysis of the values by plotting graphs. Oana was mostly responsible for this part of the analysis. She worked really hard and tried to find out various methods by which one can trace a comprehensive graph. She tried various methods and then after a bit of research, she managed to find an inbuilt function in MS Excel which allowed her to trace the required graphs.

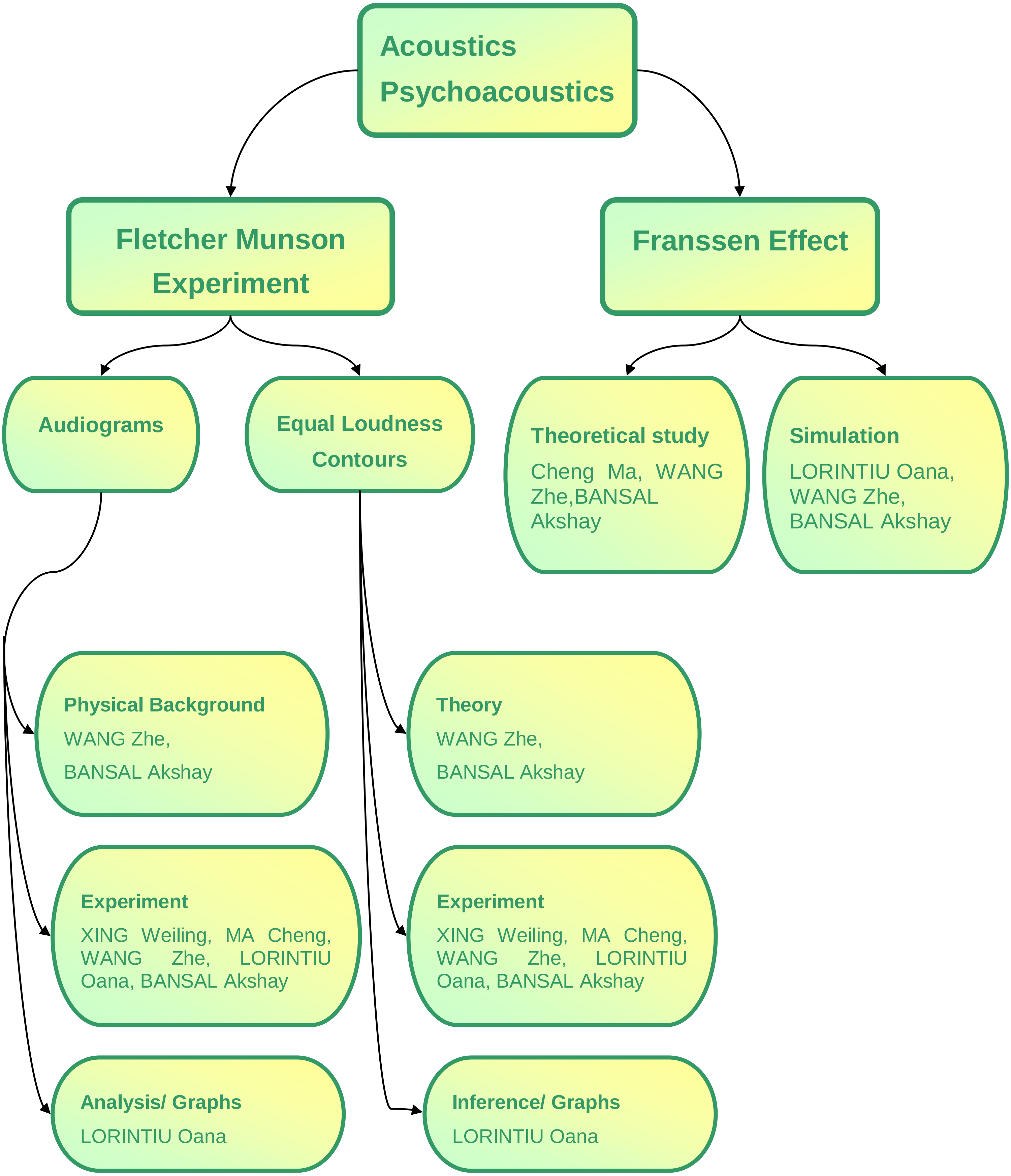
Meanwhile, Akshay and Zhe tried to work on another of the topics suggested by Mr. Busbridge, the Franssen Effect. Although the theory behind this effect is reasonably simple, but finding the right instruments to carry it out proved to be very tricky.

We approached Mr. Carpentier yet again and asked him for his help. But he was unaware of the effect and said he couldn't help us with the experiment. But he did tell us about online software via which we could possibly simulate the effect.

We found the software, called Audacity, which is frequently used by disc jockeys to mix and create music. We found this software useful when it allowed us to perform, our experiment. The simulation cum experiment was carried out by Oana, Zhe and Akshay in one of the isolated room of Residence Galois. We successfully carried out the simulation and found the illusion to be true.

To conclude, we were able to overcome initial discomfort and personal differences to work as a cohesive unit and achieve our goals. We understood the importance of projects and team work, which shall prove to be vital in our lives as engineers.

The following diagram summarizes the organization of our work and the methods applied on the whole: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3. WORK DONE AND RESULTS

3.1. Fletcher-Munson experiment

3.1.1. *Definitions and theoretical concepts* [1]

In order to understand very well the experiment of Fletcher-Munson, its use and applications it is very important to define some useful theoretical concepts. The subject acoustics was very new for us as we have never studied it before. Even if we heard of most of the physical notions used we still needed to take a closer look at them in order to fully understand the phenomenon.

3.1.1.1. DECIBEL (dB)

A unit of a logarithmic scale of power or intensity called the power level or intensity level. The decibel is defined as one tenth of a bel where one bel represents a difference in level between two intensities I1, I0 where one is ten times greater than the other. Thus, the intensity level is the comparison of one intensity to another and may be expressed as:

Intensity level = 10 log10 (I1 /I0) (dB)

For instance, the difference between intensities of 10^{-8} watts/m2 and 10^{-4} watts/m2, an actual difference of 10,000 units, can be expressed as a difference of 4 bels or 40 decibels.

Because of the very large range of SOUND INTENSITY which the ear can accommodate, from the loudest (1 watt/m2) to the quietest (10^{-12} watts/m2), it is convenient to express these values as a function of powers of 10. This entire range of intensities can be expressed on a scale of 120 dB.

The result of this logarithmic basis for the scale is that increasing a sound intensity by a factor of 10 raises its level by 10 dB; increasing it by a factor of 100 raises its level by 20 dB; by 1,000, 30 dB and so on. When two sound sources of equal intensity or power are measured together, their combined intensity level is 3 dB higher than the level of either separately. Thus, two 70 dB cars together measure 73 dB under ideal conditions. However, note that when the AMPLITUDE of a single sound is doubled, its level rises 6 dB.

0dB is defined as the THRESHOLD OF HEARING, and it is with reference to this internationally agreed upon quantity that decibel measurements are made. In some situations, such as tape recording, a given intensity level is assigned 0 dB, and other levels are measured in negative decibels in comparison to it.

Decibels may be qualified as dBA, dBB, dBC, indicating the weighting network of the SOUND LEVEL METER with which the measurement was made. The term became accepted in the 1920s and since then noise measurement has generally come to rely on the decibel scale and others derived from it.

These newer systems have brought environmental factors and frequency content to bear on the measurement of LOUDNESS. The PHON scale attempts to account for the subjective response of the ear to loudness, which is not possible with the decibel measurement of intensity. In annex nr. 1 you can see the typical average decibel levels (dBA) of some common sounds.

3.1.1.2. PHON

A unit used to describe the LOUDNESS LEVEL of a given sound or noise. The system is based on EQUAL LOUDNESS CONTOURS, where 0 phons at 1 KHz is set at 0 decibels, the THRESHOLD OF HEARING at that frequency. The hearing threshold of 0 phons then lies along the lowest equal loudness contour. If the intensity level at 1 KHz is raised to 20 dB, the second curve is followed.

It will be noted, therefore, that the relationship between the decibel and phon scale at 1,000 Hz is exact, but because of the way the ear discriminates against or in favor of sounds of varying frequencies, the phon curve varies considerably. For instance, a very low 30 Hz RUMBLE at 110 decibels is perceived as being only 90 phons.

It is important to realize that the phon is used only to describe sounds that are equally loud. It cannot be used to measure relationships between sounds of differing loudness. For instance, 40 phons is not twice as loud as 20 phons. In fact, an increase of 10 phons is sufficient to produce the impression that a SINE TONE is twice as loud.

For the purpose of measuring sounds of different loudness, the SONE scale of subjective LOUDNESS was invented (annex nr. 2). One sone is arbitrarily taken to be 40 phons at any frequency, i.e. at any point along the 40 phon curve on the graph. Two sones are twice as loud, e.g. 40 + 10 phons = 50 phons. Four sones are twice as loud again, e.g. 50 + 10 phons = 60 phons. The relationship between phons and sones is shown in the chart (annex), and is expressed by the equation:

Phon = 40 + 10 log2 (Sone)

3.1.1.3. SOUND PRESSURE LEVEL (SPL)

The term most often used in measuring the magnitude of sound. It is a relative quantity in that it is the ratio between the actual SOUND PRESSURE and a fixed reference pressure. This reference pressure is usually that of the THRESHOLD OF HEARING which has been internationally agreed upon as having the value .0002 dynes/cm^2.

SPL may be measured with a SOUND LEVEL METER weighted according to a specific frequency response pattern and termed SOUND LEVEL. The electro-acoustic equivalent to SPL is measured with a VU METER.

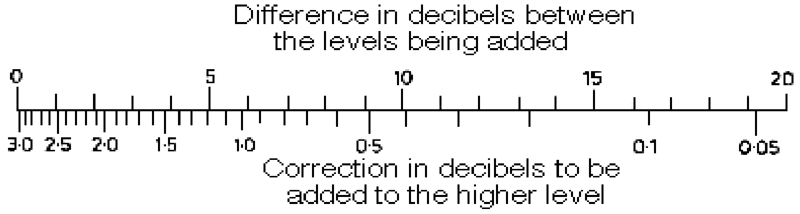
Because the square of the sound pressure is proportional to SOUND INTENSITY, SPL can be calculated in the same manner and is measured in Decibels.

$SPL = 10 \log (p^2/p^2_{ref}) = 20 \log (p/p_{ref})$

Where p is the given sound pressure and p_{ref} is the reference sound pressure.

Two SPL measurements in decibels may be combined with the aid of the following chart. The difference in decibels between the two readings is found on the upper scale, and the corresponding correction appears opposite it on the lower scale. This correction is added to the higher SPL to give the combined measurement. Multiple readings may be combined by repeating this process.

For example, equal SPL readings (0 on top scale) produce a 3.0 increase when combined. A 5 dB difference (say between 60 and 65 dB) produces a 1.2 dB increase (a total of 66.2 dB for the same example). A 10 dB difference requires a 0.4 dB correction, and so on.



3.1.1.4. Pure tone [2a]

A pure tone is a single frequency tone with no harmonic content (no overtones).

This corresponds to a sine wave. It is characterized by the frequency — the number of cycles per second, the wavelength — the distance the waveform travels through its medium within a period, and the amplitude — the size of the cycles.

3.1.1.5. A-weighting [2b]

A-weighting is the most commonly used of a family of curves defined in the International standard IEC61672:2003 and various national standards relating to the measurement of sound level, as opposed to actual sound intensity. The others are B, C, D and now Z weightings (see annex nr. 3).

Sound level, loudness and sound intensity are not the same things; indeed there is not even a simple relationship between them, because the human hearing system is more sensitive to some frequencies than others, and furthermore, its frequency response varies with level, as has been demonstrated by the measurement of equal-loudness contours. In general, low frequency and high frequency sounds appear to be less loud than mid-frequency sounds, and the effect is more pronounced at low pressure levels, with a flattening of response at high levels. Sound level meters therefore incorporate weighting filters, which reduce the contribution of low and high frequencies to produce a reading that corresponds approximately to what we hear. Loudness however requires the use of a loudness meter as described by Zwicker and others.

The curves were originally defined for use at different average sound levels, but A-weighting, though originally intended only for the measurement of low-level sounds (around 40-phon) is now commonly used for the measurement of environmental noise and industrial noise, as well as when assessing potential hearing damage and other noise health effects at all sound levels; indeed, the use of A-frequency-weighting is now mandated for all these measurements, although it is badly suited for these purposes, being only applicable to low levels so that it tends to devalue the effects of low frequency noise in particular.

3.1.1.6. Equal-loudness contour

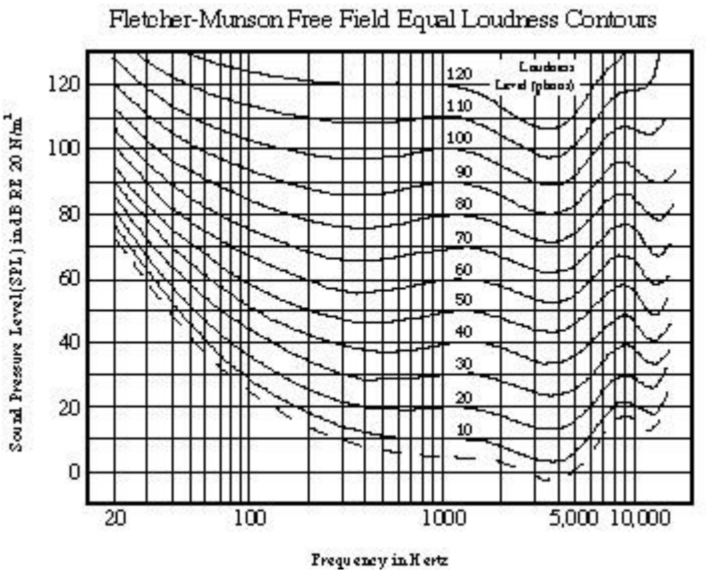
An equal-loudness contour is a measure of sound pressure (dB SPL), over the frequency spectrum, for which a listener perceives a constant loudness when presented with pure steady tones. The unit of measurement for loudness levels is the phon, and is arrived at by reference to equal-loudness contours. By definition two sine waves, of differing frequencies, are said to have equal-loudness level measured in phons if they appear equally loud to the average young person without significant hearing impairment.

3.1.2. Fletcher-Munson Equal Loudness Curves

3.1.2.a. Physical explanation

Humans don't hear all frequencies of sound at the same level. That is, our ears are more sensitive to some frequencies and less sensitive to other frequencies. Not only this, but the sensitivity changes with the sound pressure level (SPL). Let us take a look at the graph below. It is marked frequency of sound along the x axis (horizontally) and SPL along the y axis(vertically) . On the graph, there are a number of curved lines, each with a numerical associated with it (corresponding to the loudness level).

Let us start by observing the lowest solid line marked with a loudness level of 10 phons. From about 500Hz to roughly 1,500Hz the line is flat on the 10dB scale. This means that for us to perceive the sound being a loudness level (LL) of 10 phons, frequencies from 500Hz to 1,500 Hz must be 10dB. Looking further into the higher frequencies, say 5,000Hz, we notice the line dips here—that is to say that we perceive 5,000Hz to be 10 phons when the source is actually only 6dB. We need to be about 20dB to perceive 10,000Hz at the same level (10 phons). Hence it becomes fairly clear that our ear is more sensitive in the range of 2000Hz to 5000 Hz but not the same in the range of 6000 Hz and upper frequencies



Next we take a look at the lower frequencies i.e. around 100 Hz. To perceive 100Hz as loud as we do 1,000Hz (when the source is at 10dB), the 100Hz source must be calibrated to 30dB. Going farther down, a 20Hz signal must be nearly 75dB (65dB higher than the 1,000Hz signal). We can clearly see our ears are not very sensitive to the lower frequencies, even more so at lower SPL levels.

Why so? The physical notion of resonance explains the question. The resonance in ear and ear-canal amplifies frequencies between the range of 2,500Hz and 4,000Hz. Next the question arises why our ears can't hear every frequency at the same level? One reason could be that our ears are designed to be more sensitive here. While our ears are capable of hearing the lower frequencies, our body feels them more than we actually hear them. This is the reason why many people who are nearly or completely deaf can still enjoy music--they can still feel the low frequency content in their bodies.

We should notice here that with the increase in the overall loudness level, the low frequency curve lines flatten out. This is because, at higher SPL's, we are more sensitive to these lower frequencies. We also observe that with the increase of SPL, we tend to be less sensitive to the frequency range of 6000 Hz and above. This explains why soft music sounds less rich when compared to louder music, as the louder the music the more we perceive the lower frequencies, and thus better music quality.

A decibel meter (or SPL meter) measures the amplitude of sound. Cheap meters react to all frequencies equally, resulting in what's called a "flat response". More sophisticated and expensive SPL meters allow measurements to be taken with both "C-weighting" and "A-weighting". A-weighting is more close to resembling the frequency response of our ears (the lower end of the measurement device is rolled off, downward to simulate our lesser sensitivity to the low frequencies). C-weighting takes more of the lower frequencies into account, even though our ears don't hear them at the same level. Thus, it's best to make measurements with an A-weighting setting to know how our ears are responding to the sound. At the same time, it's interesting to flip the switch to look at the C-weighted response as well--this helps to observe in the low frequencies we don't hear, but feel.

3.1.2.b. Experimental determination [3]

The human auditory system is sensitive to frequencies from 20 Hz to a maximum of around 20,000 Hz, although the hearing range decreases with age. Within this range, the human ear is most sensitive between 1 and 5 kHz, largely due to the resonance of the ear canal and the transfer function of the ossicles of the middle ear.

Equal-loudness contours were first measured by Fletcher and Munson using headphones. In their study, listeners were presented with pure tones at various frequencies and over 10 dB increments in stimulus intensity. For each frequency and intensity, the listener was also presented with a reference tone at 1000 Hz. The reference tone was adjusted until it was perceived to be of the same loudness as the test tone. Loudness, being a psychological quantity, is difficult to measure, so Fletcher and Munson averaged their results over many test subjects to derive reasonable averages. The lowest equal-loudness contour represents the quietest audible tone and is also known as the absolute threshold of hearing. The highest contour is the threshold of pain.

In order to do a first experiment and plot some equal loudness curves we decided to use a website using a program simulating the Fletcher-Munson experiment. Each of the five students of the group did the experiment. We used the website http://www.phys.unsw.edu.au/jw/hearing.html. For better results we used reasonably good quality headphones that enclosed our ears completely and tried to seal out external noises. Ordinary loudspeakers and especially the small ones that come with computers, have such poor response, particularly at low frequency and are so much affected by interference effects and resonances that results obtained with them are useless. They may also be damaged by low frequencies.

Procedure

- We minimized any background noise: turn off machinery, close windows etc.
- We plugged the headphones into the soundcard output and put them on, making sure that they seal well around your ears.
- In the 1 kHz column, we chose a panel about halfway down. We had to listen to it and check that (i) it is not uncomfortably loud and (ii) it is considerably louder than the background noise. Once we have made a choice, this became the reference sound.

- In the 750 Hz column, we had to click the panel next to the reference panel. If we found that it is less loud than the reference sound, we clicked on the panel that is 3 dB louder, still at 750 Hz. Next we hag to go back to the reference sound and compare. We kept doing this until we were satisfied that the 750 Hz and the 1 kHz sounds were equally loud. (We found it difficult to judge equal loudness for different pitches, but because loudness is by definition subjective, there is no person or machine that can do it for us.)
- Next we found a sound at 500 Hz whose loudness equals that of the reference sound at 1 kHz.
- We did the same for 375, 250 Hz etc, all the way down to 30 Hz, at all times using 1 kHz as the reference.
- Next we found a sound at 1.5 kHz that equals the loudness of the 1 kHz reference and continued to 2, 3 etc up to 16 kHz.
- The chart showed the sounds that we have chosen as having equal loudness.

The curves that we obtained are attached in the annex nr. 4.

3.1.3. Audiograms

3.1.3.a Introduction

The following thing that we planned to do was to perform the Fletcher-Munson experiment on our own as we found that the curves plotted using the internet program weren't conclusive and accurate enough. We realized we can't analyze them. Most of us chose different reference sounds and we also did the experiment on several days at different times. All these factors influenced the results a lot as the background noise may have differed as well as our mental and physical state. In this kind of experiment where everything is relative and subjective these modifications have a great impact on the results.

Thus, in order to finish our experiment we talked to an acoustics professor, Ms Carpentier who offered to help us. We presented him our project and our objectives and asked him whether he could help us to simulate the Fletcher-Munson experiment. Unfortunately, he explained us that it is impossible to do the experiment as, firstly, we don't have the necessary equipment and neither does he and, secondly, because this experiment has to be done on a big number of persons in order to get true equal loudness contours. Nevertheless, he proposed us a related experiment, the measurement of audiograms for each of us using an audiometer.

3.1.3.b Physical Background

Audiogram [4]

An audiogram is an efficient way of representing a person's hearing loss. Mostly, the audiograms cover the limited range of 100Hz to 8000Hz (8 kHz). This frequency range is the most important range required for clear understanding of speech, and they help in plotting the threshold of hearing relative to a standardized curve that represents 'normal' hearing, in dBHL. They are completely different from the equal-loudness contours, which are a set of curves representing equal loudness at different levels, as well as at the threshold of hearing, and in absolute terms measured in dbSPL (sound pressure level).

In Audiograms, the frequency (in Hz) is along the horizontal axis, and is most commonly on a logarithmic scale, while on the vertical axis, lays the linear dBHL scale. Normal hearing is classified as being between -10dBHL and 15dBHL, although 0dB from 250Hz to 8 kHz is deemed to be 'average' normal hearing.

For humans and other mammals, hearing thresholds can be observed by using behavioral hearing tests or physiological tests. Audiometry is an example of such behavioral hearing test and results in an audiogram.

For human beings the test incorporates different tones being presented at a specific frequency i.e. pitch and intensity or loudness. When the person subjugated to the test hears the sound, he/she indicate to the tester by either raising their hand or by pressing a button. But the same test for children brings a bit childishness with it. Normally they use a toy; for e.g. they are particularly taught to put the man inside the shark's jaw when they hear the corresponding sound.

Audiograms and diagnosing types of hearing loss

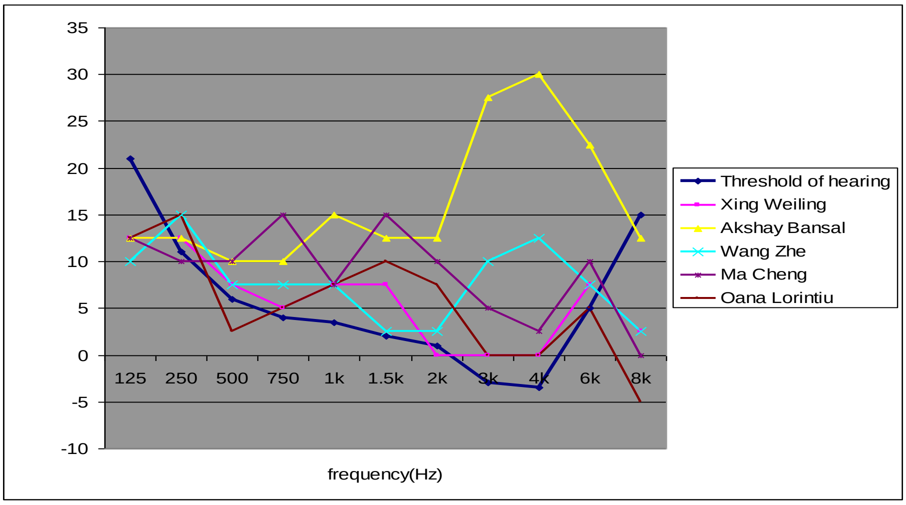
Ideally speaking an audiogram would show a straight line, but in practice everyone is slightly different, and small variations are considered normal. Larger variations, especially below the norm, may indicate hearing impairment which occurs to some extent with increasing age, but is also possible if exposed to regular high noise levels; for e.g. living near an airport might give one's audiogram an artistic touch, other examples might include short exposure to very high sound levels such as gunshot or music in either a loud band or clubs and pubs. Hearing impairment may also be the result of certain diseases such as otosclerosis or Meniere's disease and these can be diagnosed from the shape of the audiogram. Thus the audiograms empower us with a tool to pinpoint and rectify any hearing disability as

3.1.3.c Measurements

An audiometer is used to produce an audiogram. This equipment presents different frequencies to the person subjected to the test. Highly calibrated headphones are used in a specific acoustically designed room, at different levels. The levels are, however, not absolute, but weighted with frequency relative to a standard graph known as the minimum audibility curve which is intended to represent a 'normal' hearing. This is not the best threshold found for all subjects, under ideal test conditions, which is represented by around 0 Phon or the threshold of hearing on the equal-loudness contours, but is standardized in an ANSI standard to a level somewhat higher at 1 kHz.

Mr. Carpentier let us use the audiometer from the IUT University every Thursday. He further explained us its working and also the applications of audiograms.

We used an isolated chamber at IUT and the audiometer, AS208. All the five members of the group carried out the experiment at the same time, in order to have similar environment. The measurements were done at 125 Hz, 250 Hz, 500 Hz, 750 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz and 8 kHz. The audiograms that we obtained in comparison with the threshold of hearing curve are shown below. In the annex there are several graphs showing separately the audiograms for the left and right ear, as well as the audiograms of the average for every student in part. As a reference we also plotted in Microsoft office Excel the threshold of hearing curve which you can see in the annex nr.5. But, the audiograms are represented just on the segment of the threshold curve from 125 Hz to 8 kHz because of the impossibility to make measurement for all the points we used to plot the reference curve.



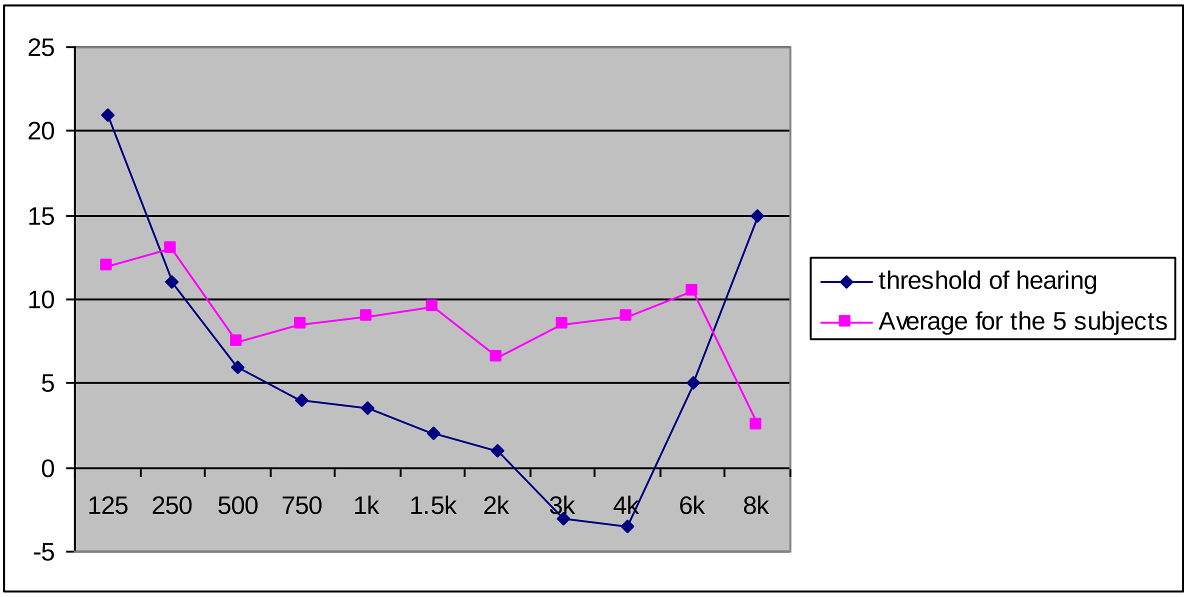
Frequency(Hz)/ SPL (dB)	Weiling Xing	Akshay Bansal	Zhe WANG	Cheng MA	Oana Lorintiu
125 Hz	12.5	12.5	10	12.5	12
250 Hz	12.5	12.5	15	10	15
500 Hz	7.5	10	7.5	10	2.5
750 Hz	5	10	7.5	15	5
1 kHz	7.5	15	7.5	7.5	7.5
1.5 kHz	7.5	12.5	2.5	15	10
2 kHz	0	12.5	2.5	10	7.5
3 kHz	0	27.5	10	5	0
4 kHz	0	30	12.5	2.5	0
6 kHz	7.5	22.5	7.5	10	5
8 kHz	2.5	12.5	2.5	0	-5

3.1.3.d Conclusions

The audiograms had several interesting conclusions and applications. Firstly, during the experiment we noticed that Akshay Bansal didn't hear well the sounds produced between the frequencies of 3 kHz and 6 kHz, which can be seen very clearly on the graph from the annex nr. 6. This experiment helped us notice a hearing deficiency of a member of the group and, thus, we really saw the use of audiograms.

Another interesting consequence is that we managed to notice on the graphs that there is a difference in sensitivity of hearing between the male and female. We noticed that women have a higher sensitivity for higher frequencies than men. By comparing the graphs of LORINTIU Oana and XING Weiling (annex nr.6) with the graphs of the male colleagues (annex nr. 6) one can notice that the audiograms of the female subjects are closer to the threshold of hearing.

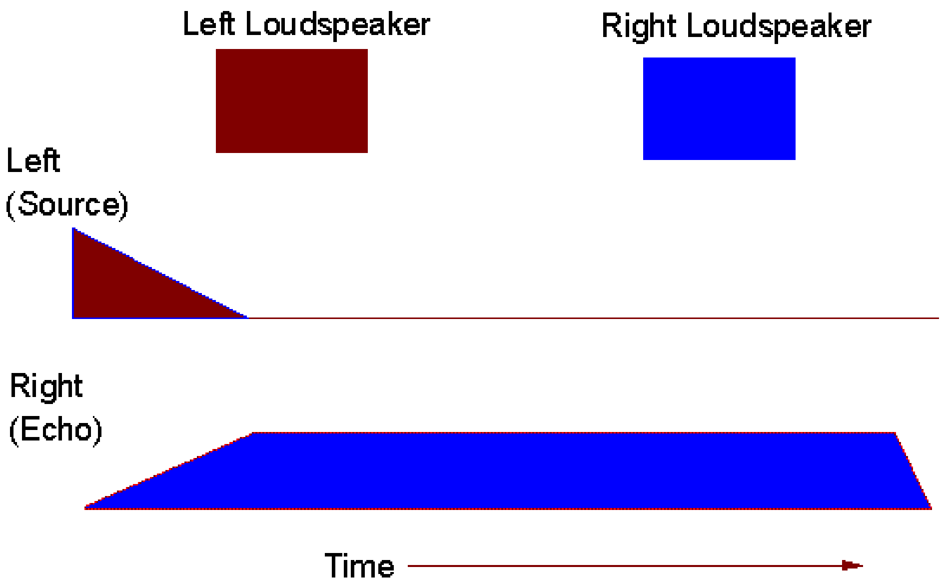
Finally, we plotted the graph shown below showing the average curve of all the 5 students of the group. Even if it is supposed to be more similar to the threshold of hearing curve it is normal to have a big difference between the two. As one test subject has a hearing problem it clearly modified the average.



4. FRANSSEN EFFECT

4.1. Introduction [5]

The Franssen Effect is a strong auditory illusion demonstrating the power of the first arriving information in establishing the location of a sound source. The general stimulus configuration for the Franssen Effect is shown in the figure beneath.



FRANSSEN EFFECT

A sound is turned on abruptly at one loudspeaker and is then turned off slowly (with a linear offset ramp). As this sound is going off, the sound is turned on at the other loudspeaker with the same envelope (with a linear onset ramp).

In this case, almost all listeners report that the sound is always located at one loudspeaker. And this is the loudspeaker to which the brief tone was presented. That is, you hear the full time of sound coming from the location of the loudspeaker that only presented the sound for several seconds at the beginning. Or put another way, you hear the tone coming from a loudspeaker that is no longer presenting any sound. However, the location that you perceived as the sound's source is the loudspeaker that presented the sound first, and thus its location seems to dominate your perception of the sound's location.

In public demonstrations the tone is often left on for many seconds while the person presenting the demonstration removes the wires from the loudspeaker that everyone is pointing to as the source of the sound. Even with no wires going to the loudspeaker (or in some cases, even with the loudspeaker removed from the room), the audience still reports that the source of the sound is at the location of the (missing) loudspeaker.

The acoustics of the room in which the demonstration is being played will affect the strength of the illusion. For instance, it does not work in an anechoic room.

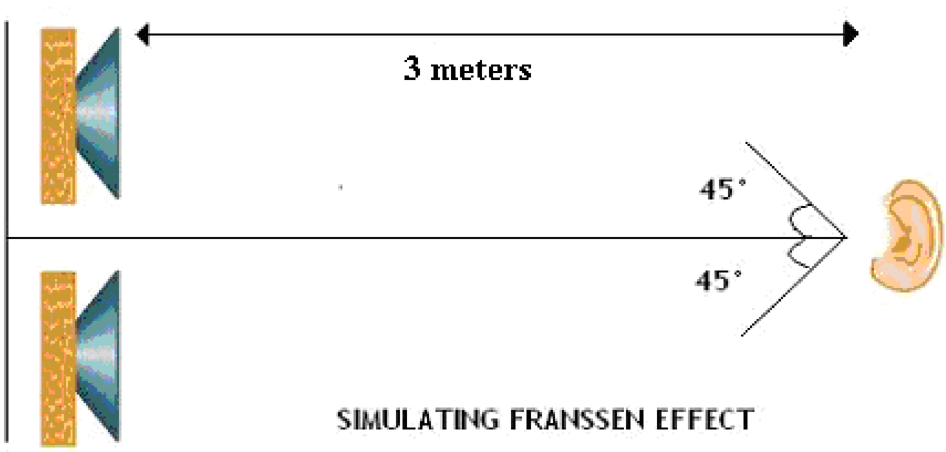
Notice: The effect can only be heard if the sounds are presented to two loudspeakers. The loudspeakers should be placed at about +45 degrees (right) and -45 degrees (left), where 0 degrees is straight ahead. The listener should be about 3 feet from the loudspeakers. The exact configuration is probably not important, as long as the loudspeakers are not too close together and the listener either too close or too far away.

4.2. Simulation of Franssen effect

We contacted Mr. Carpentier yet again for his advice regarding this experiment. Unfortunately, he was unaware of this effect. After briefing him the effect, he suggested an online software called AUDACITY. This software is often used by Disc Jockeys for mixing music and adding effects to sounds and music. We successfully managed to simulate the Franssen Effect using this software.

We generated two sounds of similar amplitude and frequency. In order to create the illusion, the first sound was restricted to the left speaker and the second one to the right. Next we used some effects such as Cross fade in and cross fade out to improve the sound quality. Finally we were able to simulate this effect in a separated room in our residence.

Firstly we chose one of our members to test it, but it did not work on her as she already knew the correct positioning of the speakers and was able to differentiate the source of the sounds generated by Audacity. To overcome this problem, we tested it on a fellow student who was blindfolded before she entered the room and was unaware of the position of the speakers. She told us that she did not see any change of source and also that all the sound that came was only from the left speakers. This confirmed the Franssen effect of auditory illusion.



5. CONCLUSIONS AND PERSPECTIVES

During the course of our project, we carefully studied the loudness curves. We illustrated their functioning with the help of several audiograms. Next we carried out Franssen Effect, thus learning about one of the auditory illusions.

The audiograms had several interesting conclusions and applications. One of the direct consequences of the experiment was detection of a hearing deficiency of Akshay Bansal as depicted in his individual audiogram. We found out that he has problems hearing in the range of frequencies from 3 kHz to 6 kHz (see annex nr. 6)

Thus, our experiment helped us notice a hearing deficiency of a member of the group and, thus, we really saw the use of audiograms.

Another interesting inference that we can draw from the audiograms is the difference in sensitivity of hearing between the male and female. We noticed that women have a much better sensitivity for higher frequencies than men. By comparing the graphs of LORINTIU Oana and XING Weiling (annex nr.6) with the graphs of the male colleagues (annex nr. 6) one can notice that the audiograms of the female subjects are closer to the threshold of hearing.

The group faced several difficult tasks in the beginning but we were able to overcome them with collective effort and team spirit. To conclude, we were able to overcome initial discomfort and personal differences to work as a cohesive unit and achieve our goals. Thus understanding the importance of projects and team work shall prove to be vital in our lives as engineers.

As indicated, we were unable to carry out the Fletcher-Munson experiment. But over the time, we were able to simulate several other experiments related to it and by doing so could understand the gist of the Fletcher-Munson experiment. if in future , another group takes this project, we suggest that in order to carry out the actual Fletcher-Munson experiment, we could perhaps setup the circuit system and also carry out a massive analysis of a few hundred subjects, i.e. to say to have at least 500 different graphs, which might prove to be very hectic and gigantic.

Also we got to appreciate the vastness of the this branch of science and if somebody wants to delve further, he/she can look into other interesting topics such as the Robinson-Dadson curves which are the actual certified loudness curves since 2003. One can also do a check into the loudness level in our surrounding environment and see why younger people like our fellow groupie – Akshay, have minor hearing defects. We could perhaps use a sound level meter, which measures the sound pressure level and is often used while checking for any noise pollution.

6. BIBLIOGRAPHY / REFERENCES

Since the libraries at Mont Saint Aignan and Madrillet do not house books or journals concerning our project topics, we had to revert back to internet. Following are some of the links that we utilized for the theoretical research and also for certain simulation.

[1] http://www.sfu.ca/sonic-studio/handbook/Equal_Loudness_Contours.html

(last visited on 20/04/08)

[2a] http://en.wikipedia.org/wiki/Pure_tone(last visited on 03/05/08)

[2b] http://en.wikipedia.org/wiki/A-weighting(last visited on 03/05/08)

[3] http://en.wikipedia.org/wiki/Equal-loudness_contour(last visited on 12/04/08)

[4] http://en.wikipedia.org/wiki/Audiogram(last visited on 23/05/08)

[5] http://www.parmly.luc.edu/parmly/franssen.html (last visited on 05/06/08)

We used the following site for our first experiment on equal loudness curves

http://www.phys.unsw.edu.au/jw/hearing.html

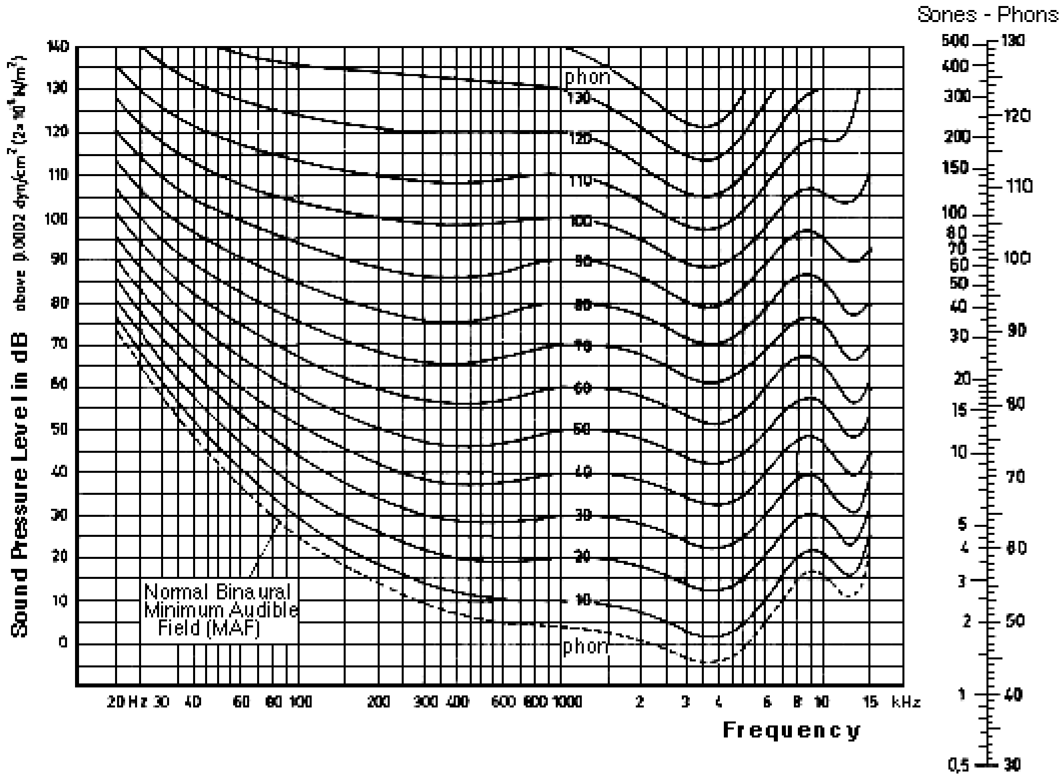
7. ANNEX

7.1. Technical documentation

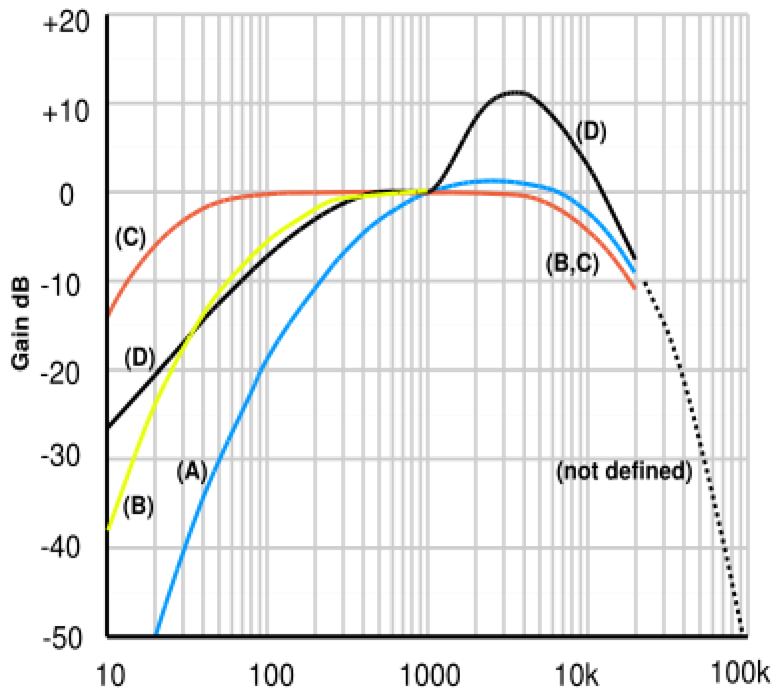
Annex nr. 1

Threshold of hearing	0 dB	Motorcycle (30 feet)	88 dB
Rustling leaves	20 dB	Foodblender (3 feet)	90 dB
Quiet whisper (3 feet)	30 dB	Subway (inside)	94 dB
Quiet home	40 dB	Diesel truck (30 feet)	100 dB
Quiet street	50 dB	Power mower (3 feet)	107 dB
Normal conversation	60 dB	Pneumatic riveter (3 feet)	115 dB
Inside car	70 dB	Chainsaw (3 feet)	117 dB
Loud singing (3 feet)	75 dB	Amplified Rock and Roll (6 feet)	120 dB
Automobile (25 feet)	80 dB	Jet plane (100 feet)	130 dB

Annex nr.2



Annex nr. 3



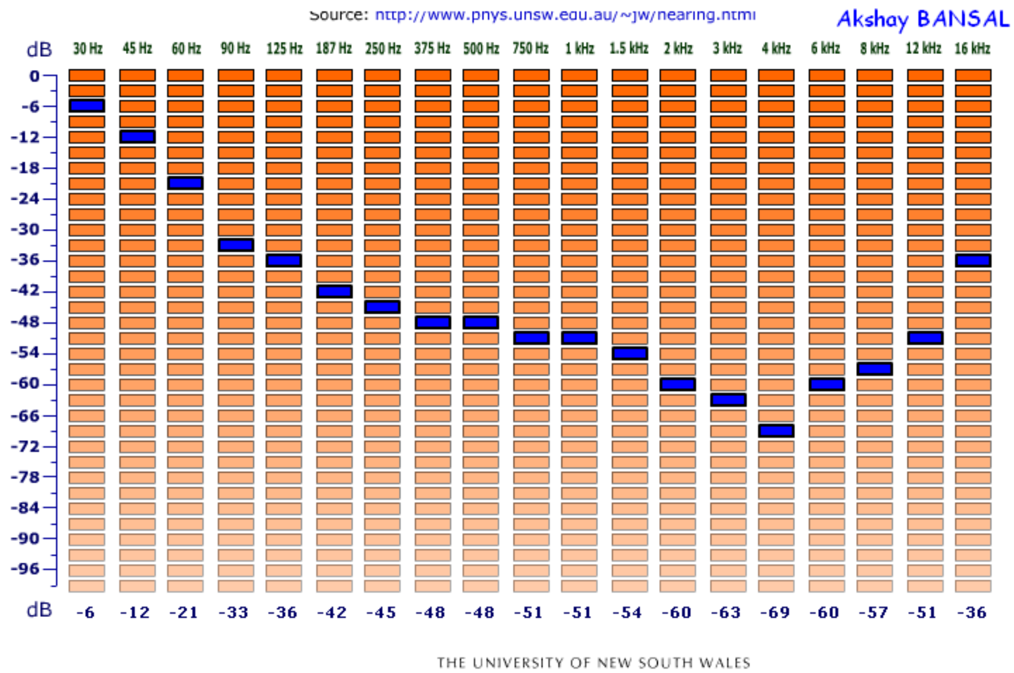
A-weighting (blue), B (yellow), C (red), and D-weighting (blk)

7.2. Graphs

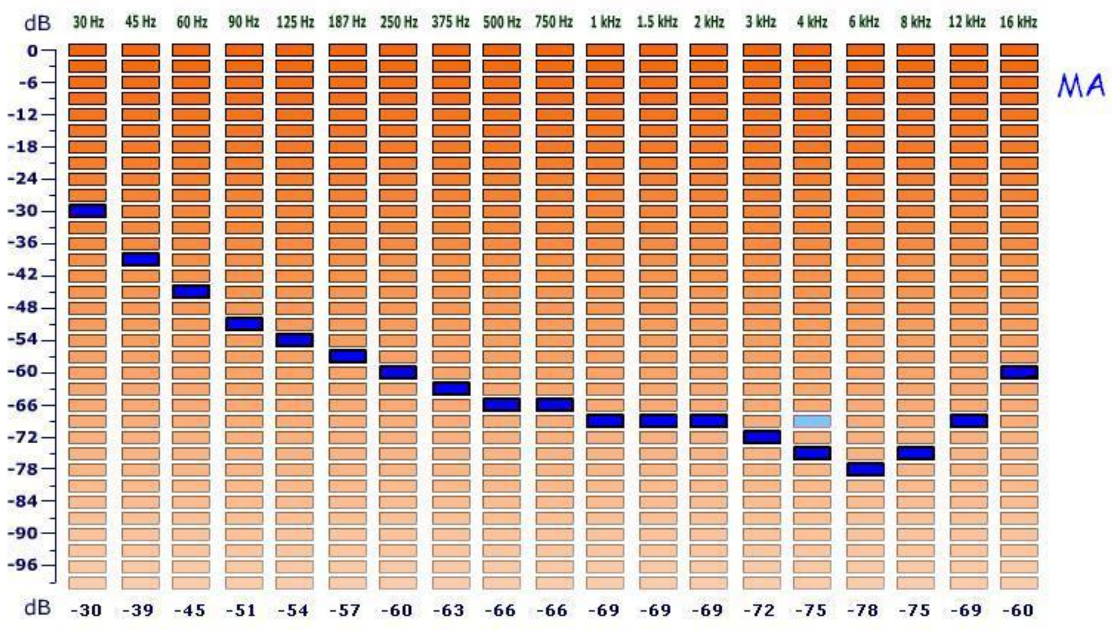
Annex nr.4

Internet graphs:

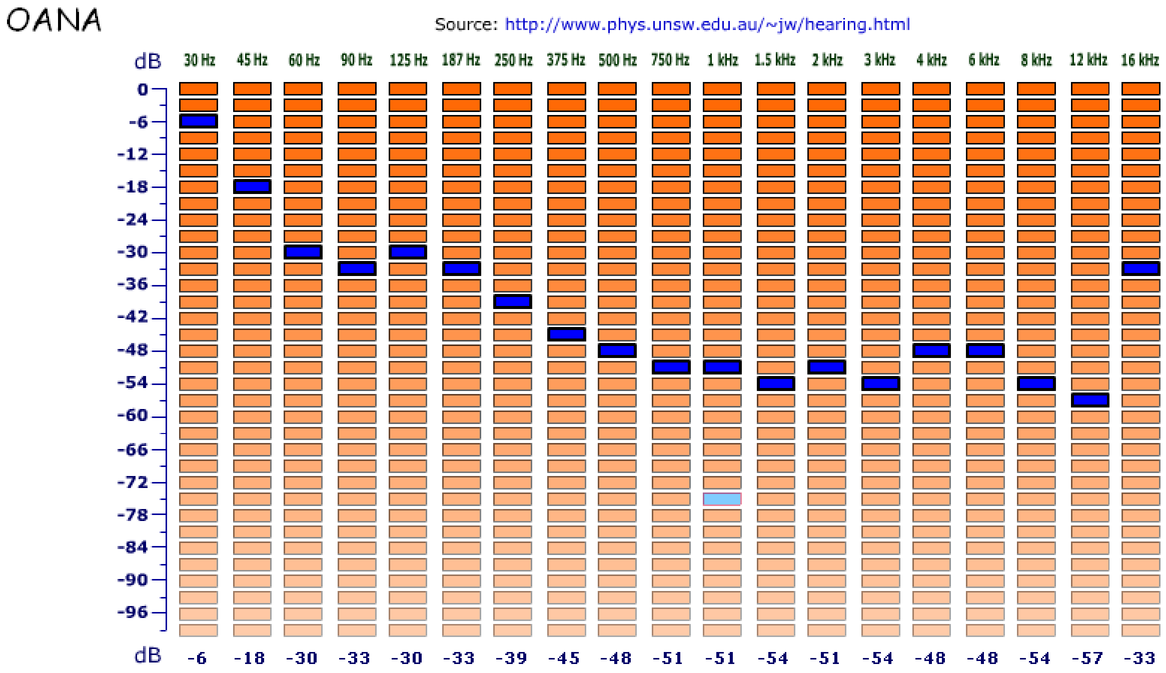
1. Subject no.1: Akshay BANSAL



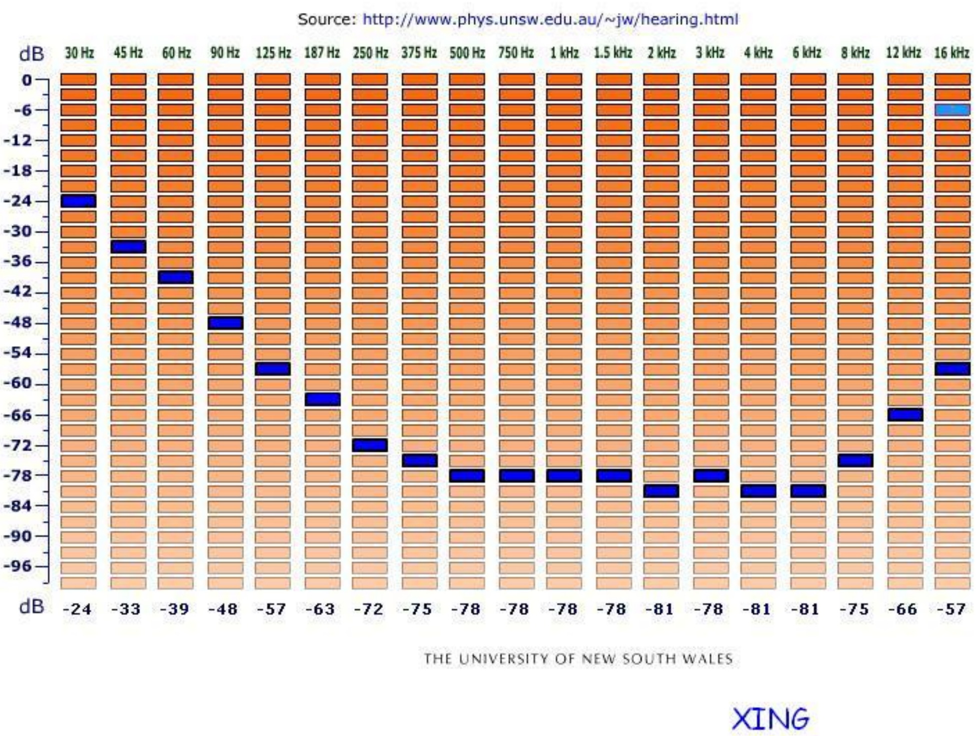
2. Subject no.2: Cheng MA



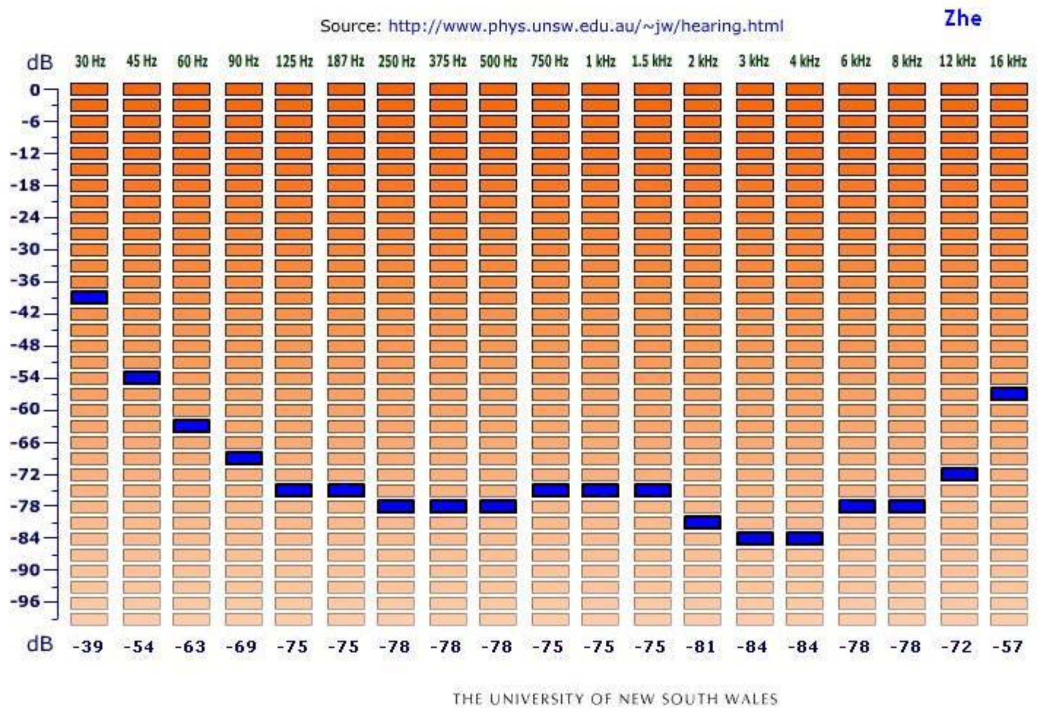
3. Subject no.3: Oana LORINTIU



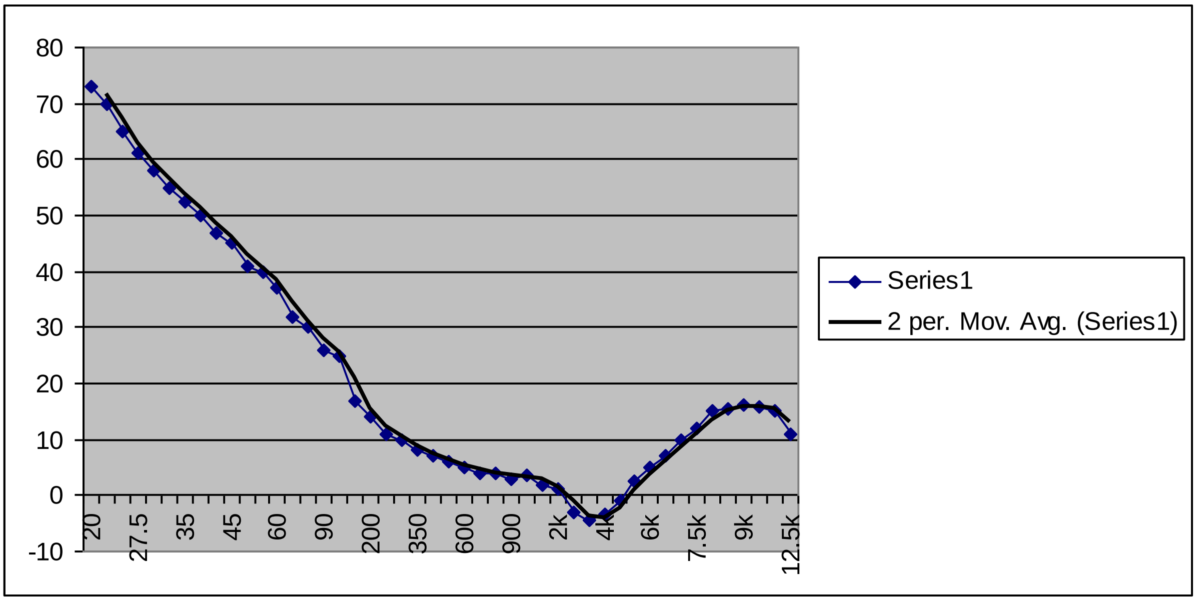
4. Subject no.4: Weiling XING



5. Subject no.5: Zhe WANG



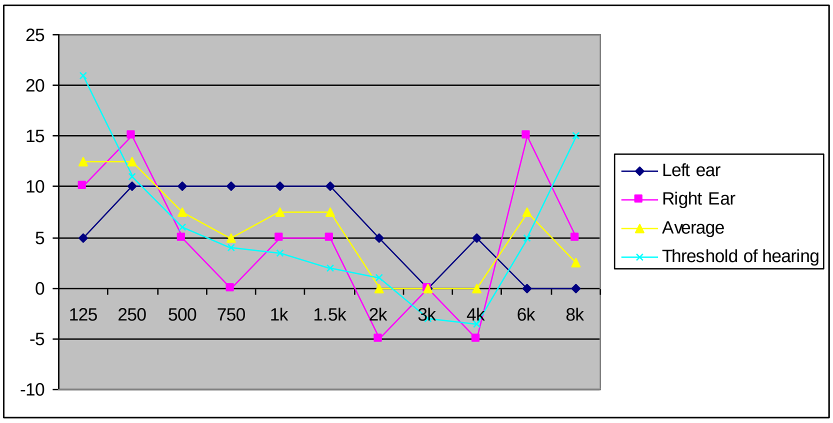
Annex nr. 5



Annex nr. 6

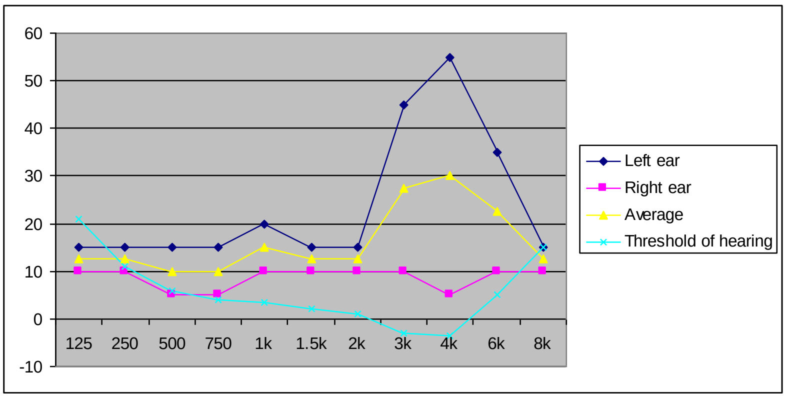
1. Subject no.1: Weiling XING

	Left ear	Right ear	Average
125 Hz	5	10	12.5
250 Hz	10	15	12.5
500 Hz	10	5	7.5
750 Hz	10	0	5
1 kHz	10	5	7.5
1.5 kHz	10	5	7.5
2 kHz	5	-5	0
3 kHz	0	0	0
4 kHz	5	-5	0
6 kHz	0	15	7.5
8 kHz	0	5	2.5



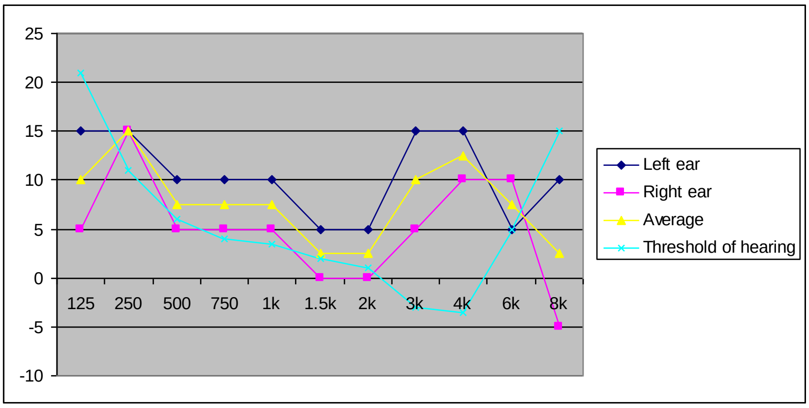
2. Subject no.2: Akshay BANSAL

	Left ear	Right ear	Average
125 Hz	15	10	12.5
250 Hz	15	10	12.5
500 Hz	15	5	10
750 Hz	15	5	10
1 kHz	20	10	15
1.5 kHz	15	10	12.5
2 kHz	15	10	12.5
3 kHz	45	10	27.5
4 kHz	55	5	30
6 kHz	35	10	22.5
8 kHz	15	10	12.5



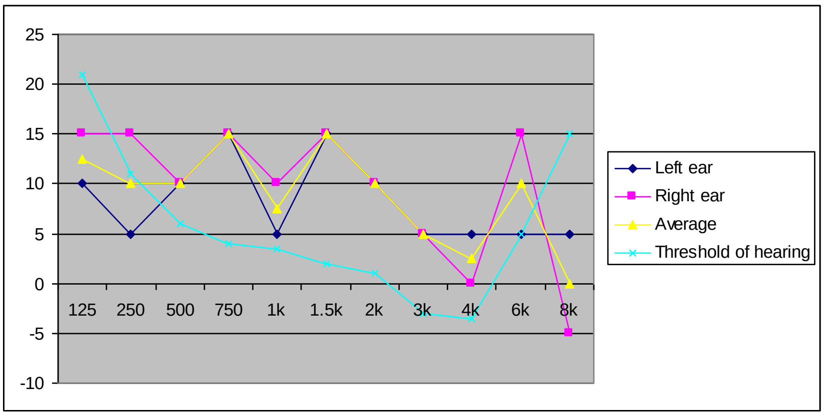
3. Subject no.3: Zhe WANG

	Left ear	Right ear	Average
125 Hz	15	5	10
250 Hz	15	15	15
500 Hz	10	5	7.5
750 Hz	10	5	7.5
1 kHz	10	5	7.5
1.5 kHz	5	0	2.5
2 kHz	5	0	2.5
3 kHz	15	5	10
4 kHz	15	10	12.5
6 kHz	5	10	7.5
8 kHz	10	-5	2.5



4. Subject no.4: Cheng MA

	Left ear	Right ear	Average
125 Hz	10	15	12.5
250 Hz	5	15	10
500 Hz	10	10	10
750 Hz	15	15	15
1 kHz	5	10	7.5
1.5 kHz	15	15	15
2 kHz	10	10	10
3 kHz	5	5	5
4 kHz	5	0	2.5
6 kHz	5	15	10
8 kHz	5	-5	0



5. Subject no.5: Oana LORINTIU

	Left ear	Right ear	Average
125 Hz	15	10	12.5
250 Hz	15	15	15
500 Hz	5	0	2.5
750 Hz	15	0	5
1 kHz	10	5	7.5
1.5 kHz	10	10	10
2 kHz	10	10	7.5
3 kHz	0	0	0
4 kHz	0	0	0
6 kHz	5	5	5
8 kHz	-5	-5	-5