Practical Use of an Audiometer Based on a Computer Software for Hearing Loss Screening

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Abstract. The project aimed at developing a software audiometer for hearing loss screening. The proposed software is definitely based on the internal peripherals of the computer without any externals devices. It has functionality to test patient's hearing by generating pure-tones and masking signal for air-conducted or bone-conducted stimuli. Practical hearing losses measurements of hard and normal of hearing patients have been done in order to evaluate the performances of the proposed software. The hearing measurements have been assisted with ENTs specialized Doctors. The obtained audiograms have been compared with those of classical audiometers AC33 and AC50

Keywords: Audiometers, Hearing Losses.

1 Introduction

Audiometry is a medical technique, dealing with measurement of hearing. Given the physical dimension of a sound stimulus, it is possible to measure the response caused by that stimulus. There are different kinds of audiometers, according to their characteristics: pure-tone and speech, manual and automatic. There are also different devices that vary in complexity and in their frequency and intensity ranges [1].

Hearing loss screening is an issue of fundamental social importance. Generally, people delay wearing hearing aids because they are not aware of the deterioration progress and get used to living with hearing difficulties [2].

The main purpose of this work is to develop a software audiometer under windows (98/2000&Xp) based on the internal peripherals of the computer (sound card) without any external devices. It has functionality to test patient's hearing by generating pure-tones and masking signal for air-conducted or bone-conducted stimuli.

The developed software, named CAUM (Computer AUdioMeter) is an updated version of the prototype presented at [3] that includes the bone conduced functionality. The finalized version will be proposed for hearing losses screening of scholar pupils.

The paper presentation is organized in several points. At first, we explain the audiometric test procedure used to find the hearing loss threshold of the patient. In the second point, we present in details the design procedure of the proposed software.

Then, we present the obtained audiograms with a comparison to those of classical audiometers AC50 and AC33. Finally, we give a conclusion to our work.

2 Audiometric Test

The principal audiometric test entails measuring the auditory thresholds for pure tones. Results indicate the minimum Sound Pressure Level (SPL) that evoke the minimal auditory sensation within the frequency range between 125 and 8000 Hz.

International standards define the SPL threshold values for normal hearing, and after normalisation, relate them to 0 dB Hearing Loss (HL).

Threshold increments up to 25 dB HL, although irrelevant for medicolegal purposes, may be valuable for diagnostic purposes [4]. Two separate measures of the hearing threshold, respectively air-conducted (through an earphone) or bone-conducted (a vibrator on the forehead or the mastoid process) stimuli, permit the distinction between two main kinds of hearing losses: conductive and sensorineural.

The first show a normal bone-conducted and an elevated airconducted hearing threshold. The second show equal values of the two thresholds. There are also mixed hearing losses, which have elements of both conductive and sensorineural losses [3].

When a marked difference exists between the hearing thresholds of the two ears, noise masking is needed for the better ear, in order to ensure that a sensation evoked in the better ear does not interfere with the sensation elicited in the worse ear. Clinical pure-tone audiometry, such as the psychoacoustical tests, is based on a stimulus response behavioural model, which requires active cooperation and attentive attitude by the subject being tested.

Simulators, individuals with low levels of vigilance and reduced attention may give unreliable results, i.e., a hearing threshold poorer than the actual threshold or one excessively variable at retest. Three to five-year-old children can reliably perform pure-tone audiometry: Younger children can be examined by special conditioning procedures [3].

3 Design of the Software Audiometer

The main purpose of this project is to develop a software version of an audiometer able to generate pure-tones and masking signal (white noise) for air-conducted or bone-conducted stimuli using a computer equipped with a standard sound card without any external devices. The designed software must be able to be calibrated for any sound card [3]. The idea is to estimate the power ability of a simple sound card to generate sufficient SPLs by the means of specialized loads (TDH39P headphones for air-conduced or B-71 radioear (Vibrator) for bone-conducted). The frequency range is depending on the selected stimuli (air-conducted or bone-conducted). The particular frequencies are: 125, 250, 500, 1k, 2k, 4k and 8k for the air-conducted and: 250, 500, 1k, 2k and 4k for bone-conducted stimuli. In order to achieve our goal, we have made many practical experiences; we will resume them in the next paragraph.

The first idea in order to reproduce the behavioural of the audiometer workstation is to record all the generated sounds from a classical audiometer using a microphone and to replicate them using computer software. Let’s consider the classical audiometer (AC50) equipped with the desired load (TDH39P headphone for air-conduced or B-71 radioear for bone-conduced) like a black box, where the inputs are frequency and intensity. The range of the used frequencies are listed above according to the conduction (air or bone conduced). The selected intensities are varying according to the test mode and the frequency used. For each pure tone and masking signal, we record directly the sounds at the output using a microphone with good quality in order to be replicated again using the computer software. Unfortunately, we have found that the replayed sounds don’t match the desired loudness principally because of the microphone - headphone distance. Also, the recording of the test sounds at low intensities is not possible because of the background noise and the microphone quality. The second ideal in order to avoid the recording problems is to use directly the line in port of the sound card. For each test (choice of intensity and frequency), we have to acquire directly the sounds at the output of the TDH39P headphones or the B-71 radioear.

Unfortunately also, we have found that the replayed tones don’t match the desired loudness, principally because of the miss match impedances between the two loads used and the line in port of the sound card which causes acquisition losses.

The passage to the acoustic measurements using a Sound Pressure Level meter seems to be a good idea to avoid the acquisition losses. The operation consists in denoting the measured SPLs in dBSPL for all the test sounds in order to be regenerated automatically using the computer software.

Regrettably, the acoustic measurements need a silent room and the measurements less than 40 dBSPL are not possible. Although, the measured sounds suffer from a poor precision, and can’t be trusted to made audiometric tests. We have made many tries for such experience but results were not satisfying.

The last solution is to make measurements of voltages across the two loads in order to obtain the corresponding SPLs using a digital oscilloscope. We have started by evaluating the higher limit range of the output voltage of a standard sound card for each frequency using the TDH39P Telephonics headphone and the B-71 radioear. The loads used are generally complex and present a certain frequency response in the audible range. The second step is to measure the voltage at the output for each test frequency across the two loads using the classical calibrated audiometer AC50.

These voltages give as the corresponding thresholds of the SPLs that can be generated by a computer equipped with a standard sound card. The intensities range start by 0 dB or less and end to the SPLs thresholds.

The SPLs thresholds of the test frequencies respectively for the TDH39P headphones (in blue) and the B21 radioear (in red) are represented in Fig. 1. The same experience is done to obtain the SPL threshold of the white noise used as a masking signal.

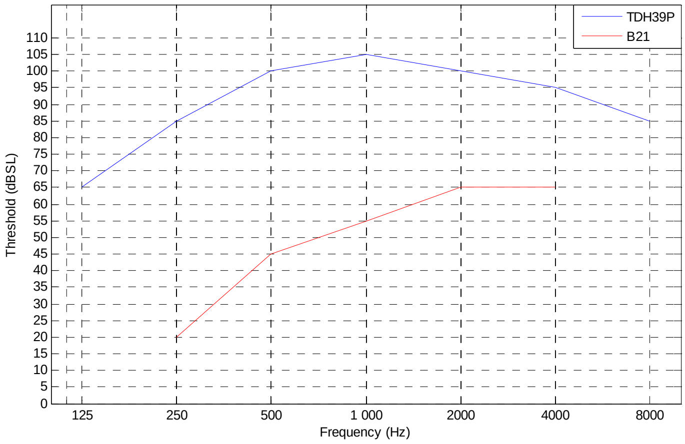


Fig.1: Loudness thresholds of a standard card sound over frequency using TDH39P and B71 loads

Using the SPLs limits of all selected frequencies, we can obtain the lowers ones by the linearization of the SPLs logarithmic values and perform conversion to the corresponding voltages in order to synthesize the test sounds according to the desired SPLs. The test signals (pure tones and masking signal) are synthesized at a sampling frequency of 44.1 kHz and sounded as 24 bit outputs sounds.

The designed audiometer has the following characteristics:

- Pure tone audiometer (a single frequency heard at one time).
- Frequencies ranges:
  - Air-conduced: 125, 250, 500, 1000, 2000, 4000 and 8000 Hz.
  - Bone-conduced: 250, 500, 1000, 2000 and 4000Hz.
- Intensity range for both air and bone conduction vary for each frequency starting from 0 dB to the SPLs thresholds given by Fig. 1.
- The attenuation (or augmentation) is in 5 dB steps.
- Masking white noise from 0 to 105 dB.
- Operation modes: manual.
- Patient response by hand switch.
- Test headset TDH39P headphones and B-71 radioear (vibrator).

The prototype version is designed under matlab and presented in Fig. 2. The software interface, named CAUM, provides a convivial system which facilitates the task for the operator and thus the patient. All controls are mouse driven (point and click). Tests are carried out using simple orders for a better comprehension. The possibility of returning backward for repeating some tests makes possible to carry out precise evaluations. The results can be transferred to an excel file in order to be achieved.

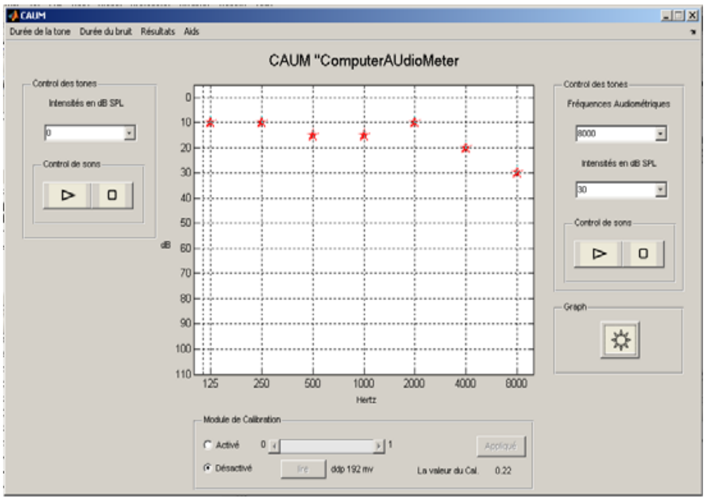


Fig. 2: Computer Audiometer software user interface

4 Experimental tests and comparisons

Audiometric tests have been done using our software audiometer (CAUM) on many patients from different ages and sexes and compared to those of AC33 and AC50 classical audiometers with the assistance of Pr Zmirli and Dr Benia, ENTs and associates researchers in CDTA. The obtained audiograms using our software version were certified at Beni Messous hospital by Pr Zmirli, the ENT department manager.

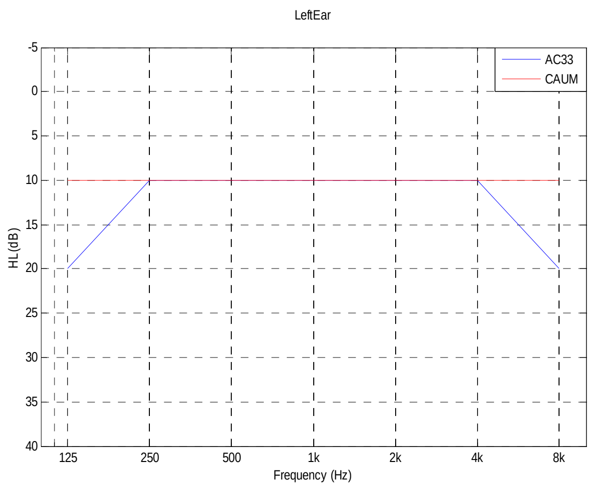
The hearing losses measurements of some samples are presented in Fig. 3, 4 and 5.

The first patient is a male young candidate at an age of 15 years (Fig. 3). The second one is a female in the 40th age (Fig. 4). The third one is an old man at an age of 74 years (Fig.5).

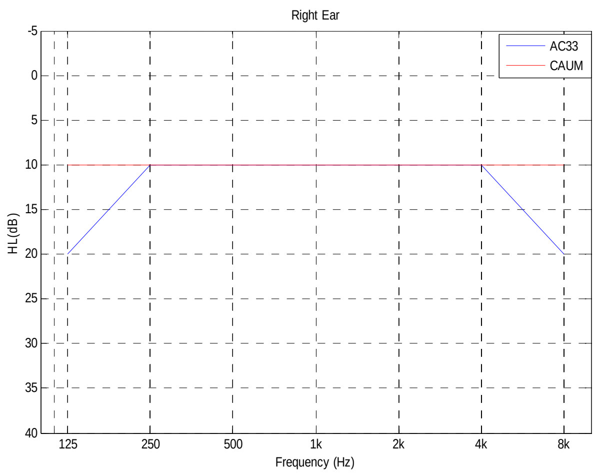
The hearing losses measurements were done using AC33, AC50 and the software version audiometers. It is clearly shown in the Fig. 3 that the obtained audiograms using both AC33 and CAUM have the same behavioral except for the first and the last frequency test where the error of measurement in both cases is around 10 dB.

The same result for the second and the third audiograms presented in Fig. 4 and 5 using respectively the AC50, AC33 classical audiometers and the software version CAUM is obtained; where the absolute error of measurement is at maximum 10dB. It is an acceptable error rate that can normally be obtained using two classical audiometers. According to the obtained audiograms (about 40 cases), we can say that the CAUM audiometer presents a satisfactory results compared to the classical audiometers AC33 & AC50 and can be trusted to be used for hearing losses screening of scholar pupils. It presents a fundamental social importance related to the medical field.

Our software presents two limitations. The first one is the presence of a background noise related to the sound card. This noise is generally around 5 dB SPL. It can influence the perception of tone in same order. Generally, these cases do not affect the clinical diagnostics since the perception of 5 dB loudness over tests frequencies is considered as high perception without hearing loss. The second limitation is its restricted ability to generate pure tones higher than the SPLs thresholds calculated above (according to a classical sound card) especially for the bone conduced case.

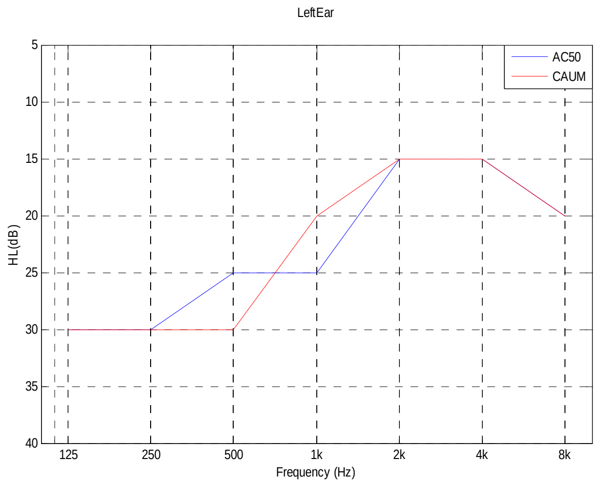


(a) Left ear

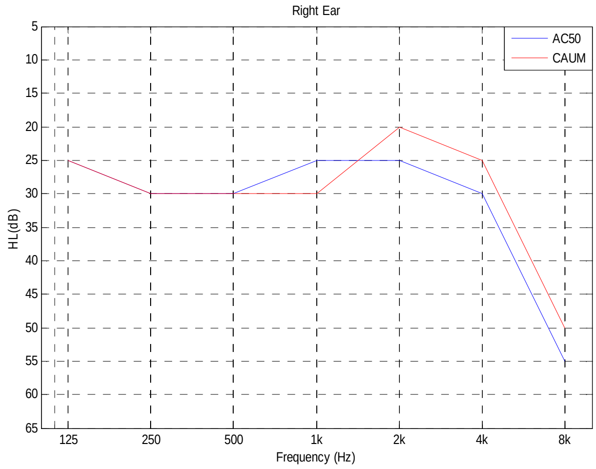


(b) Right ear

Fig. 3: An example of hearing losses measurements using AC33 and CAUM audiometers (patient 1)

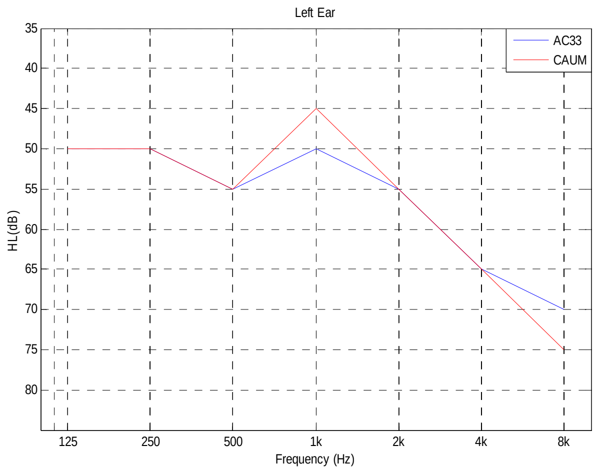


(a) Left ear

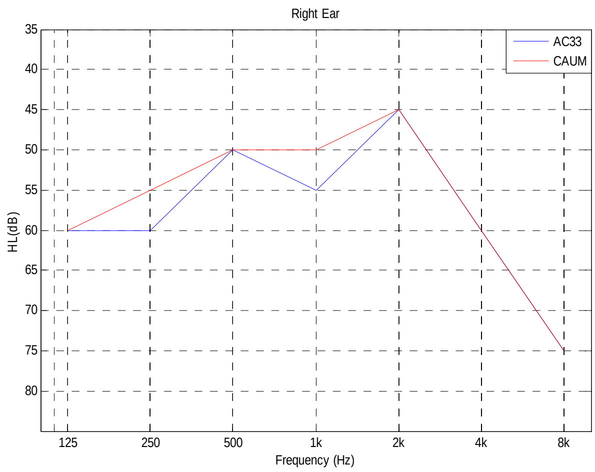


(b) Right ear

Fig.4: An example of hearing losses measurements using AC50 and CAUM audiometers (patient 2)



(a) Left ear



(b) Right ear

Fig.5: An example of hearing losses measurements using AC33 and CAUM audiometers (patient 3)

5 Conclusion

In this paper, we have presented a software version of an audiometer used for hearing loss screening named CAUM; “Computer AUdioMeter” able to make air or bone conduced stimuli. Hearing losses measurements have been done at Beni Messous hospital. The audiograms obtained by the CAUM audiometer have been compared with those of two classical audiometers AC33 and AC50. We have obtained satisfactory results in the both cases. The software version was examined as a regulated audiometer by verifying the functions and the performance compared with a calibrated classical audiometer and thus was certified at the ENT service. It can be used for hearing losses screening of scholar pupils. The price of the device would be much lower than that of classical audiometers providing the same variety of audiometric examinations.

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References

1. Martinez-Bbez, C.A.,,Borjbn, L.F., Noyola, A.: Manual and automatic programmable audiometer. International Conference of the IEEE Engineering in Medicine and Biology Society, vol. 13, no. 4, pp. 1915-1916, 1991.
2. Norio Nakamura: Development of mobile audiometer for screening using mobile phones. The 26th Annual International Conference of the IEEE EMBS, pp. 3369- 3372, USA (2004).
3. Ykhlef, F., Benzaba, W., Bendaouia, L.,: Computer audiometer for hearing testing. The IEEE International Conference on Advances in Electronics and Micro-electronics, pp. 111-114, (Spain) 2008.
4. Alessandro Martini: Genes, Hearing, and Deafness from Molecular Biology to Clinical Practice. Thomson Publishing Services, (United Kingdom) 2007.