LABORATORY OF ELECTROACOUSTICS

EXERCISE 3.

Pure tone audiometry for air conduct and bone.

The purpose of the exercise:

The aim of the exercise is to learn the methodology of audiometric measurements, and in particular the methods for determining the threshold level of hearing for air and bone conduction using an audiometer with fixed frequencies.

1. Laboratory tasks

1.1. Getting to know the audiometer's operating manual and its parameters [1].
1.2. Getting to know the audiometric measurements methodology [2,3].
1.3. Measurements of hearing thresholds for air conduction.
1.4. Determination of the threshold level of hearing for bone conduction with the use of an audiometer with fixed frequencies.

2. Tasks to be performed in the report

The report should analyze the received audiograms by determining:

3.1. The average PTA loss (Pure Tone Average) for airborne function based on threshold values (HTL) for three frequencies: 500 Hz, 1000 Hz and 2000 Hz:

$$PTA = \frac{HTL_{500} + HTL_{1000} + HTL_{2000}}{3} \quad [dB\ HL]$$

3.2. Calculate the hearing loss using the following table on the basis of the PTA value.

Hearing loss [dB HL]	Classification of hearing loss	Difficulties in verbal communication
0 - 15	Normal hearing	-
>15 - 25	Minimal	Slight Difficulty
>25 - 40	Light	Difficulties with quiet or distant hearing speech; difficulty understanding
40 - 55	Moderate	Common problems with understanding normal speech
>55 - 70	Moderately serious	There are problems with understanding loud speech
>70 - 90	Serious	Frequent problems with understanding loud speech
>90	Deep (auditory debris)	Almost total deafness

3.3. Calculate the air-bone gap ABG (Air-Bone Gap), also known as the cochlear reserve for the frequency of 1000 Hz, as the difference between the values of hearing thresholds for air conduction (HTL_{AC})and bone conduction (HTL_{BC}):

$$ABG = HTL_{AC} - HTL_{BC} \ [dB]$$

3.4. Characterize the shape of the audiometric contour according to the following criteria:

Flat audiogram - thresholds do not differ more than 20 dB in the entire frequency range.
Increasing audiogram - low frequency thresholds at least 20 dB higher than for high frequencies.
Falling audiogram - high frequency thresholds at least 20 dB higher than for low frequencies.
Slope audiogram - inclination 20 dB / octave.

3. Methodology of measurement

3.1. Turning on and off measuring tones.

The measuring tone should be continuous and its duration should be from 1 s to 2 s. After signaling by the examined person that he / she hears the tone, the time interval between successive pitch presentations should be chosen randomly, but it can not be shorter than time tone duration. Measuring tones should be given from a frequency of 1000 Hz upwards. Then, tons should be given from the frequency of 1000 Hz down.

3.2. Teaching the person of the measurement procedure.

One voice should be given a tone with a frequency of 1000 Hz and a hearing level that provides clear hearing, e.g. 40 dB. Decrease the tone level every 20 dB until the subject does not hear the tone. Then increase the tone level every 10 dB until the subject hear a tone. Re-enter the last level. If the answers match predictions, the familiarization with the measurement procedure is completed. If the answers do not match, repeat the process of familiarizing with the measurement procedure. If the second attempt is also unsuccessful, repeat the instructions to the subject.

3.3. Measurements of the threshold level of hearing without applying the masking signal by the simplified method with the increasing level.

Step 1: For the tone of 1000 Hz, the level is lower by 10 dB from the level at which the examined person signaled the hearing in the trial measurement. When a person confirms that he or she does not hear at this reduced level, the level is increased in 5 dB increments until he / she hears the signal back.

Step 2: The measurement from step 1 is repeated until two of the three responses indicate that the tone is heard at the same level. This value should be written to the audiogram template using the recommended mark.

Step 3: The next measurement should be carried out at the next frequency of the measurement tone at the hearing level determined at the previous frequency, repeating step 1 and 2. Perform one-ear measurement for frequencies from 1000Hz to maximum frequency. Then from the frequency of 1000 Hz to the minimum frequency.

Step 4: At the end of the test, repeat the measurement at a frequency of 1000 Hz. If the result of the repeated measurement at 1000 Hz for a given ear does not differ from the first measurement by more than 5dB, the second ear can be measured. If the difference is 10 dB or greater, repeat the measurement for all frequencies until 5 dB conformance is achieved. The test should not exceed the time limit (eg 20 min).

Step 5: Continue the procedure to complete the measurements of both ears.

3.4. Determination of the threshold level of hearing for bone conduction with the use of an audiometer with fixed frequencies.

Bone conduction thresholds are obtained in a very similar way as for air conduction, but using a different type of transducer. In this case a transducer is used to generate skull vibrations and direct stimulation of the cochlea. Theoretically, bone conduction thresholds are a reflection of the cochlear function, without taking into account the state of the external and middle ear. Therefore, if a person has the normal function of the middle ear one day and the disorder in the middle ear next, hearing for bone conduction will not change, while for air conduction these functional changes will be visible.

In the case of accurate determination of the hearing threshold for uninterrupted hearing, in the audiometry with bone conduction it is required to mask the ear that is not subject to examination.

Due to the occlusion effect (change, usually an increase in the level of hearing of the signal transmitted to the inner ear by bone conduction when on or in the external auditory canal a handset or ear-hole is placed, forming in the outer ear a closed air space, this phenomenon occurs most at low frequencies) the ear being examined for bone conduction should not be closed (see Fig. 1c).

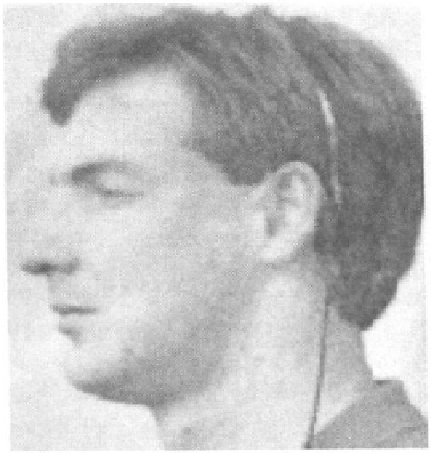
3.5. Measurements of the threshold level of hearing with the masking signal by the simplified method with the increasing level.

The level of masking signal for individual frequencies should be equal to the hearing threshold of the masked for air conduction at a given frequency increased by 30 dB. The procedure for measuring the hearing level threshold for bone conduction is the same as for the air conduction, where the range of measurement frequencies is limited by the parameters of the bone handset.

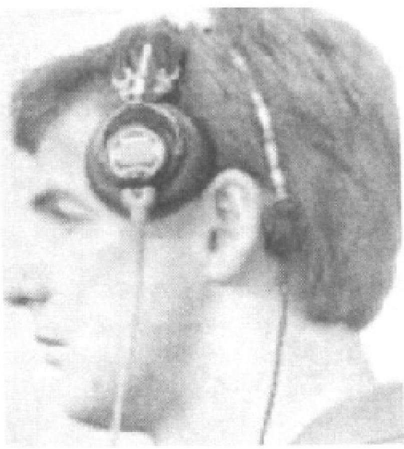
4. Issues to prepare

4.1. Ear structure
4.2. Sound volume perceptron
4.3. Construction of a tone audiometer

a)



b)



c)

Fig.1. The method of placing the headphones in determining the bone conduction threshold: a) absolute, b) relative without masking, c) relative with masking.

Literature

[1] User manual for the tested audiometer
[2] PN-EN ISO 8253-1 Acoustics. Methodology of audiometric measurements. Part 1: Tone audiometry for air and bone conduction
[3] PN-EN 26189 Acoustics. Measurement of tone threshold in air conduction for hearing protection
[4] PN-EN 60645-1 Electroacoustics - Audiological devices. Part 1: Tone-operated audiometers
[5] Dobrucki A., Electroacoustics, Lecture

Appendix A

At the base of audiometric measurements are two physical quantities: sound pressure level and frequency. They correspond to the subjective quantities associated with the listener's feeling, namely the volume and pitch of the sound.

The hearing organ is characterized by an extremely wide dynamic range, understood as the ratio of maximum to minimum pressure values for a given frequency. For the frequency of 1000 Hz, the hearing threshold is 20 μPa (to visualize how small it is, we can compare it to the normal static pressure, which is 10^5 Pa), while the pain threshold is 20 Pa. Hence, the dynamics of the hearing organ for this frequency is 10^6. The use of absolute units at such large signal spans is uncomfortable, hence the decibel measures are most often used to describe acoustic signals. Decibel (dB) describes the ratio of two numbers expressed in a logarithmic measure. It should always be determined exactly what the physical quantity is and what value of this quantity was taken as the reference value.

For sound pressure, the reference value is p_0 = 20 μPa and the sound pressure level (SPL) is expressed as:

$$L_p = 20\log(p/p_0) \text{ dB SPL}; \; p_0 = 20\ \mu\text{Pa}$$

Investigations of changes in the sensitivity of hearing as a function of frequency led to the drawing of a family of curves defined as equal volume or isophonic curves. They are presented in Fig.1.

Each of the curves is a collection of points corresponding to the values of the sound pressure level of the producing tones, in the human with normal hearing, the same impression of the volume level. The concept of volume level introduced is a quantity that is a comparative measure of sound volume in relation to the volume of the reference sound for which the 1000 Hz tone was adopted. The volume level unit is a fon. On the OX axis, the frequency of the tones has been applied.

Between the curves corresponding to the thresholds of discomfort and audibility and the lines drawn for the limiting values of the frequency limiting the range of hearing (20 Hz, 20 kHz) there is an audibility area.

Measurements of the perception of speech and music sound allowed to locate the hearing areas of these sounds within the auditory field (see Figure 2). The so-called the reserve zone is used most often when listening to sounds in conditions of high acoustic background levels.

In Fig. 1 and 2, frequency values are plotted on the OX axis. In audiometric tests, we usually use tonal signals or speech signals.

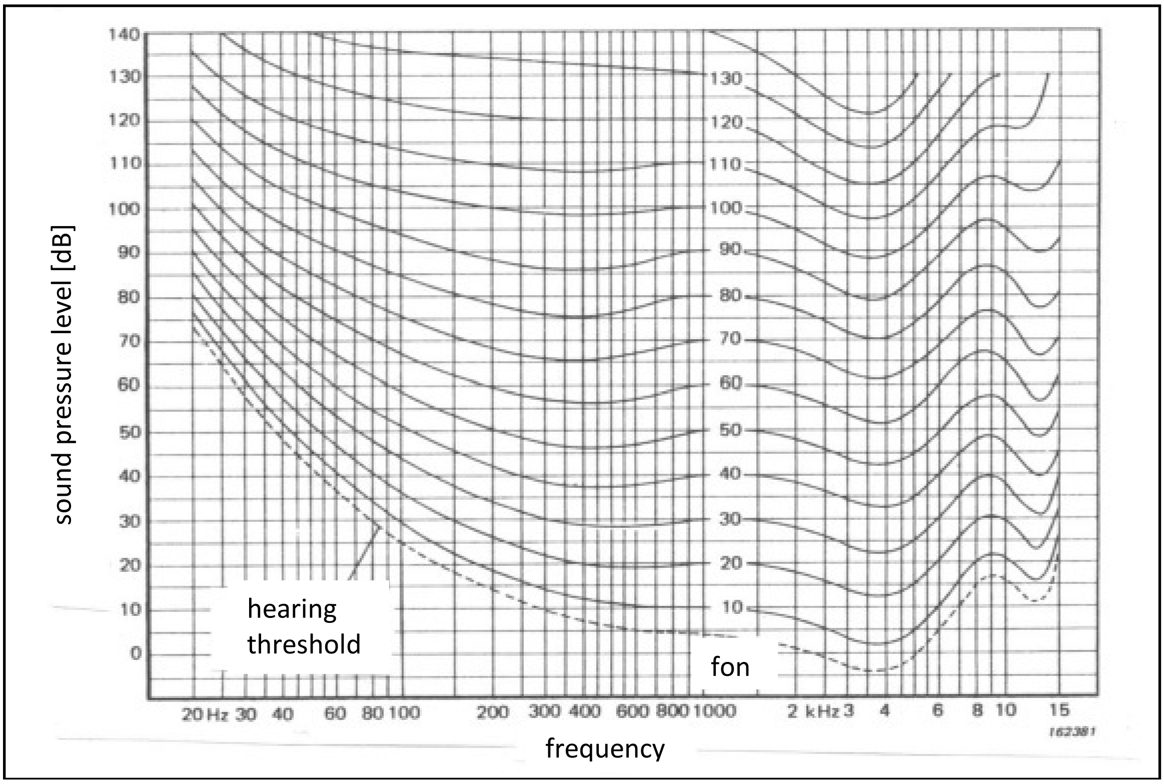


Fig. 1 Equal volume curves for tones.

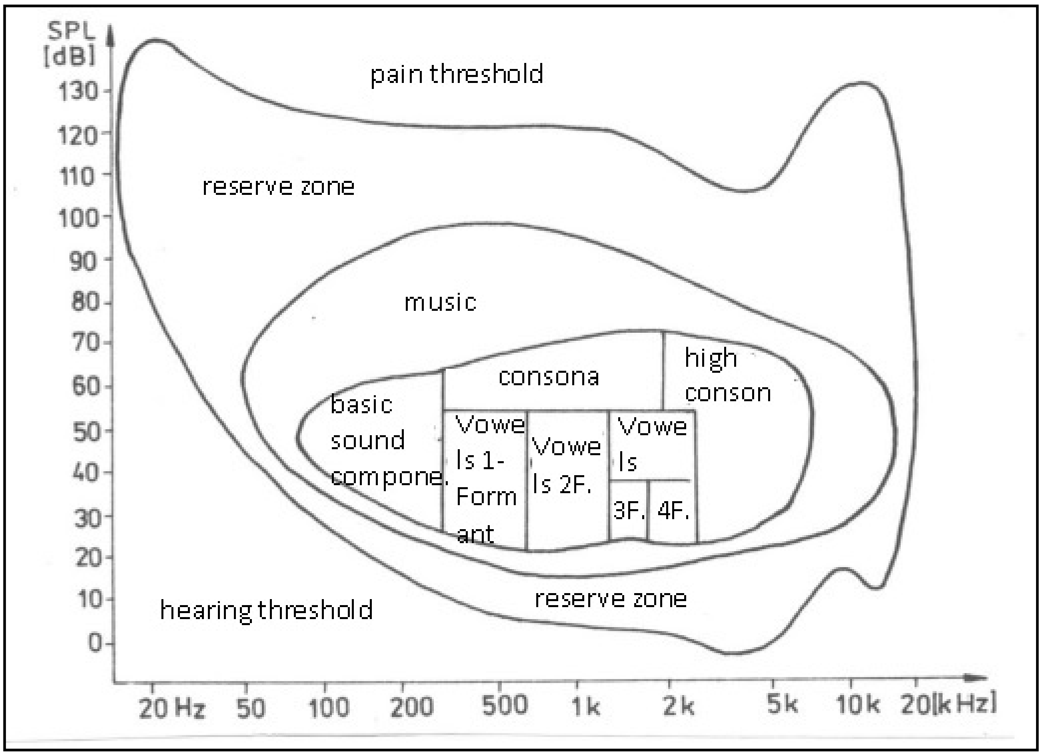


Fig. 2 Area of audibility with marked areas of speech and music perception.

The basis for audiometric measurements is Weber-Fechner's law, which says that in order for the impression to increase by constant values, the stimulus must increase in a constant relation. This means that the sensation of stimuli increases in arithmetic progression when their value changes in geometric progression. In other words, the stimulus is a logarithm of

the size of the stimulus. This is another justification for adopting a decibel scale on the axis representing the sound pressure.
Similarly, the frequency axis is described by octave frequency values, i.e. frequencies whose quotient is equal to 2 or 0.5. Individual values of octave frequencies are normalized and can be determined from dependencies:

$$f_0 = 1000x10^{0,3n}$$

where: n - integer (for typical octave frequency range of audiometers from 125 to 8000 Hz, n <-3, 3>).

Audiogram tone

The purpose of tonal audiometry is to determine the hearing threshold in the range of audible frequencies important for interpersonal communication. The hearing threshold is usually measured for a series of discrete sinusoidal signals. The purpose of tonal audiometry is to determine the smallest pressure level of such a sinusoidal signal that the listener can "hear clearly". When the threshold is measured for several different sinusoidal frequencies, the results are graphically represented in the frequency - pressure level to illustrate how the sensitivity threshold changes over the entire frequency range. This graph is called the audiogram. In tonal clinical audiometry thresholds are usually measured in the frequency range from 125 Hz to 8 kHz. Within this range, thresholds are determined every octave in the range below 1000Hz and every octave in the range above 1000Hz. Hence the audiometric frequencies in conventional tone audiometry are 125, 250, 500, 1000, 1500, 2000, 3000, 4000, 6000 and 8000 Hz.
To determine changes in the audibility threshold, the obtained results should be compared with an equivalent normal sound pressure level threshold. By normal threshold level, we mean the modal value (most frequently occurring) of threshold pressure levels obtained on the basis of studies of a sufficiently large number of people, both sexes, aged from 18 to 30 years. Calculation of hearing loss using two frequency-dependent curves is cumbersome, as well as making it difficult to compare different auditory thresholds. Thus, the audiogram is created most often using the so-called an American schedule, in which the normal reference threshold values are depicted with a straight line of 0 dB HL.
This decibel scale of sound pressure levels is called the hearing level and is referred to as the HL scale. The audiogram is a graph of the listener's threshold levels for different test frequencies, where the frequency is given in Hz, and the hearing threshold is expressed in the HL dB scale. Fig. 3 shows an example of such a graph. The zero line running horizontally at the top of the graph is the sound pressure level corresponding to the standard normal hearing for each of the test frequencies. The measurement results are placed downwards from the zero line, except when the measured values exceed the average hearing threshold. Then they are applied above the 0 dB HL line.

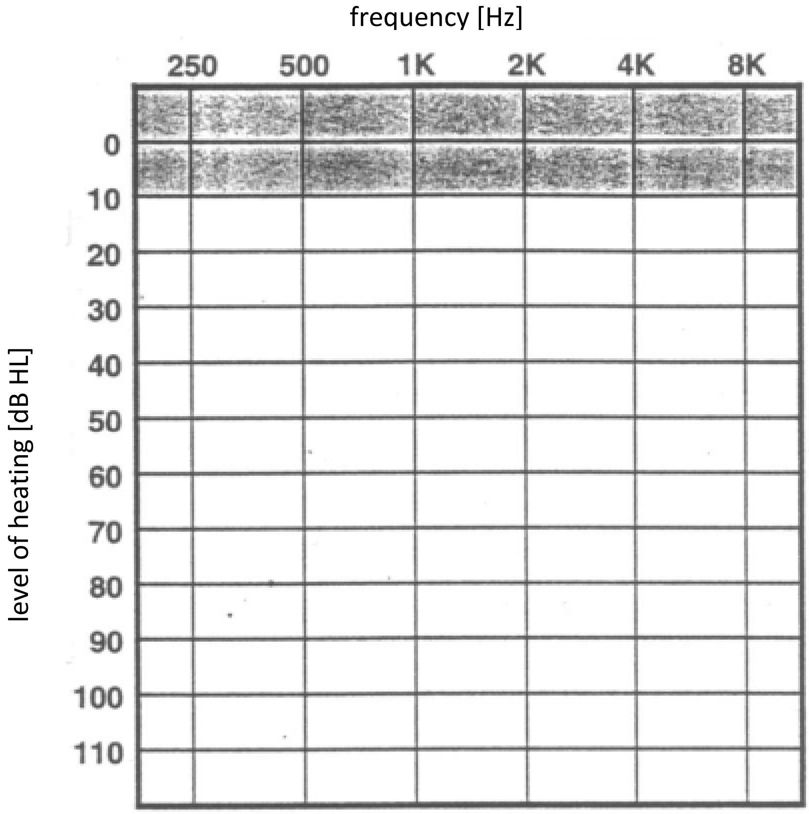


Fig. 3. Audiogram: OX axis - octave frequencies (Hz),
OY axis - hearing level (dB HL).