Al-Mustaqbal University College
Department of Medical Instrumentation Techniques Engineering
Class:Third
Subject: Medical Instrumentation (II)
Lecturer: Forqan Ali Wahhab
Lecture: Audiometer

1. Audiometer

Audiometry is the technique to identify and quantitatively determine the degree of hearing loss of a person by measuring his hearing sensitivity, so that suitable medical treatment or one of the appropriate hearing aids and assistive devices can be prescribed. In audiological investigations, the hearing sensitivity is tested for pure tones, speech or other sound stimuli. The result, when plotted graphically, is called an audiogram. The electronic instrument used for measuring the hearing threshold level is called an audiometer. Using it, the test tones of different frequencies and levels are generated and presented to the patient and hearing thresholds are determined on the basis of patient s response. The auditory system and its disorders are described. Different audiometric tests, techniques and various audiometers are discussed.

Fig1. Audiometer

2. Purpose

An audiometer typically transmits recorded sounds such as pure tones or speech to the headphones of the test subject at varying frequencies and intensities, and

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records the subject's responses to produce an audiogram of threshold sensitivity, or speech under standing profile.

3. Disorders of the Auditory system

Our system of hearing comprises of two sections viz. a peripheral section which is our ear and a central section located in the brain which carries the sensation from the ears to the auditory area of the cerebral cortex. The auditory area of the cerebral cortex (called auditory cortex) is the area of the brain, which is dedicated to and specialised in interpreting the sound which comes to our ears. The ear receives the sound in the form of sound energy, which is a form of vibration. This vibrating energy enters the external part of the ear (called external auditory meatus) and vibrates the ear drum (technically known as tympanic membrane). This vibration of the tympanic membrane is picked up by a chain of small bones called malleus, incus and stapes, which conduct this vibration to a specialised organ called cochlea .The cochlea is the transducer of the hearing system. The function of the cochlea is to convent the vibratory energy into electrical energy. Once this has been achieved, this electrical energy enters the nerve of hearing (called auditory nerve) and carries the sensation through different parts of the brain to the auditory cortex, where the sensation of sound is analysed and interpreted. For proper hearing each and every part of this system right from the external auditory meatus to the auditory cortex has to be normal.

4.1 Auditory system

A disorder in any of them will cause deafness. The ear has three sections viz.- the external auditory meatus, the middle ear and the inner ear, as shown in Fig.1. The external ear is the area from the pinna (technically called auricle) to the ear drum.

The middle ear is from the ear drum to the cochlea, it consists of the three small bones called ossicles which are placed in a closed space (called tympanum) filled with air. The inner ear is the portion of the ear deeper to this and it houses the transducer (called cochlea) and also the organ of balance (called vestibular labyrinth).**Fig.**

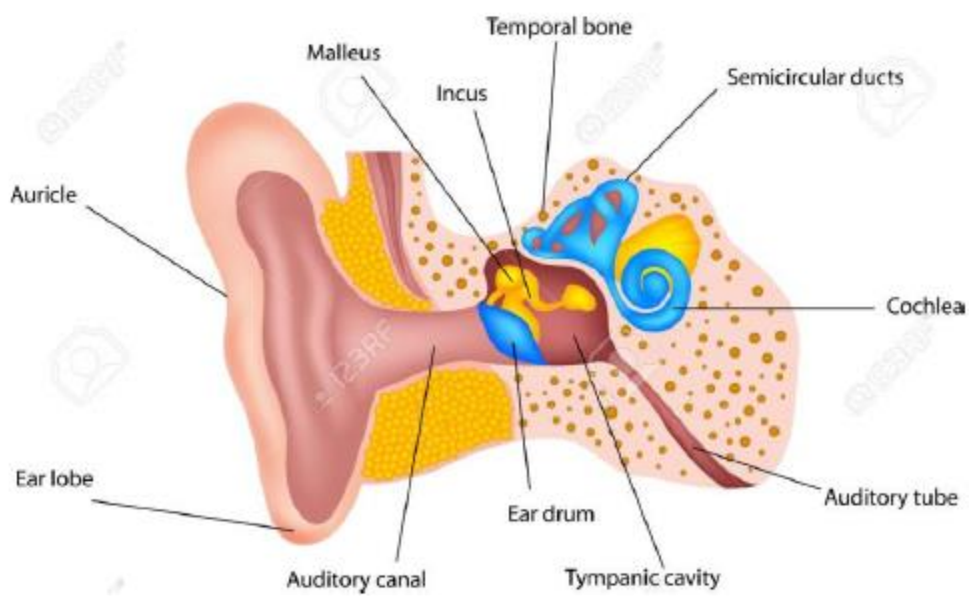

Fig. 2. The organ of hearing, consisting of the outer ear (auricle and pinna), the middle ear (ossicles) and the inner ear (cochlea).

When sound reaches the inner ear through the eardrum, this phenomenon is called air conduction. This is the usual path of sounds to reach the eardrum. Sound, particularly in the low frequency range, may reach the inner ear via the bones in the head rather than from the eardrum, this phenomenon being called bone conduction. The normal process via the ear canal is called air conduction. Wearing earplugs results in a greater percentage of the sound heard coming from bone conduction. Normally only a small fraction of sound is received in this way; however, deaf people whose inner ear still functions normally may be able to hear sound conducted to the ear in this way, for instance by holding between the teeth a wooden rod connected to a vibrating object.

4.2. Sound perception

Sound is generated in nature whenever an object vibrates in an elastic medium like air. Sounds in nature are complex and not pure tone or sine waves . However, all complex sounds can be considered as a mixture of different pure tone sounds of different frequencies. The ear is not equally sensitive to all frequencies, particularly in the low and high Frequency ranges. The frequency response over the entire audio range has been charted, originally by Fletcher and Munson in 1933, with later revisions by other authors, as a set of curves showing the sound pressure levels of pure tones that are perceived as being equally loud . The curves are plotted for each 10 Db rise in level with the reference tone being at 1 kHz, also called loudness level contours and the Fletcher-Munson curves, as shown in Fig.2. The lowest curve represents the threshold of hearing, the highest the threshold of pain.

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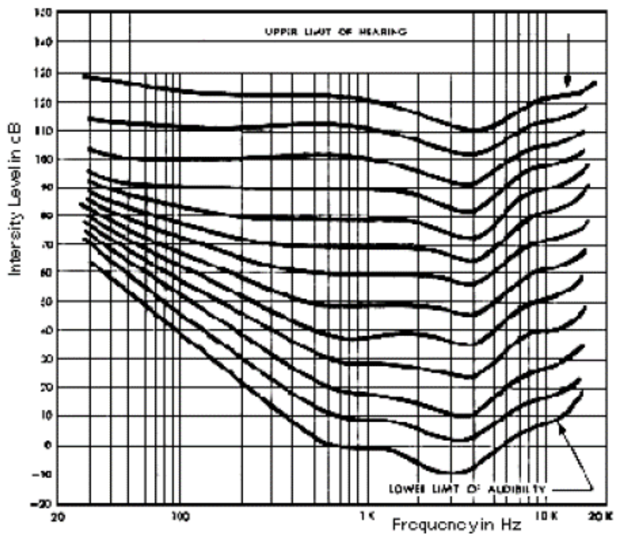

Fig.3 Curves based on the studies of Fletcher and Munson showing the response of the human hearing mechanism as a function of frequency and loudness levels.

The curves are lowest in the range from 1 to 5 kHz, with a dip at 4 kHz, indicating that the ear is most sensitive to frequencies in this range. The intensity level of higher or lower tones must be raised substantially in order to create the same impression of loudness. The phon scale was devised to express this subjective impression of loudness, since the decibel scale alone refers to actual sound pressure or sound intensity levels.

Although human hearing ranges from 20 Hz to 20 kHz, there is little speech information above 8000 Hz, and perception of frequencies below 100 Hz is increasingly tactile in nature, making them difficult to assess. Also, the loss of hearing sensitivity is observed first at high frequency (8 kHz) and later on as the loss progresses, its effect is observed in the mid-frequency region (1-2 kHz) as well. By the time the loss is observed in the low frequency region, the subject will be near to deafness. Hence, audiometric tests carried out in the low frequency region do not give any significant information about hearing loss. Therefore, audiologists routinely test only in the range of 250-8000 Hz, often in octave steps. Standardized frequencies tested include 250, 500, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz. This represents octave intervals, by convention, but intervening frequencies may also be tested. In acoustic measurements, sound level is often given in dB, taking sound pressure of 20 microPa as the reference level, and is known as sound pressure level (SPL). Sound level dB SPL = 20 log (measured sound pressure / 20 microPa)

However, in audiometry the sound level of pure tones is given in dB by taking average hearing threshold of normal hearing young adults as the reference, and is known as hearing level (HL).

Sound level dB HL = **20 log**

(measured sound / average threshold of normal hearing)

The hearing threshold is frequency dependent, and hence SPL corresponding to a given HL varies with frequency. Intensity levels in audiometers are indicated in HL.

Table 1 gives the dB SPL (dB HL) threshold values of a normal person for standard frequencies. The "0 dB" hearing level in audiometry is a modal value derived from a large population of normals. Normal values for auditory thresholds were defined by the International Standards Organization (ISO) in 1984. These values are derived from large population studies of normal adults 18-30 years of age.

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Table 1 Threshold values in dB SPL for 0 dB HL (ISO, 1984)

Frequency (Hz)	250	500	1k	1.5k	2k	3k	4k	6k	8k
dB SPL	25.5	11.5	7	6.5	9	10	9	10.5	13

Since both HL and SPL are logarithmic units, a certain increment in HL corresponds to the same value increment in SPL.

4. Audiogram

An audiogram is a plot of threshold intensity versus frequency. The intensity scale in HL increases downwards, and hence the audiogram resembles like an attenuation response, a lower point on the audiogram indicating higher loss. A typical audiogram (dB HL vs. frequency graph) comparing normal and impaired hearing is shown in Fig.4. The dip or notch at 4 kHz as shown, or at 6 kHz, is asymptom of noise-induced hearing loss.

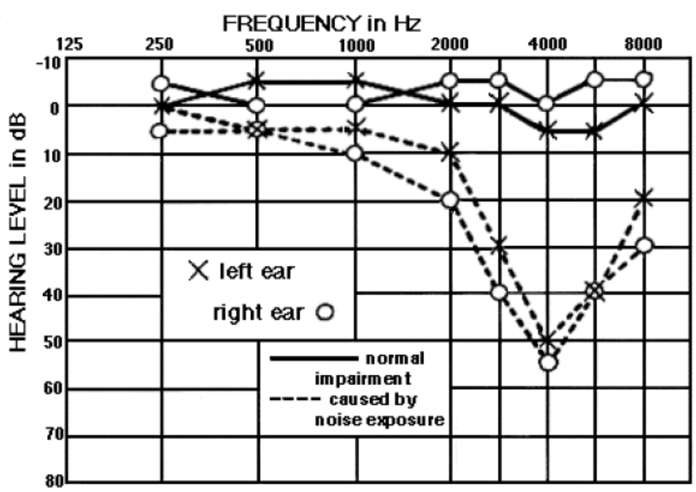

Fig. 4 Audiogram of normal ears and impaired ears.

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Most thresholds are approximately 0 dB HL for a normal ear. Points below 0 dB HL on the scale denote louder threshold levels, whereas those above, expressed in negative decibels with respect to the zero level, are less intense levels which, because of individual hearing differences, some people may normally hear. Four separate curves can be obtained - right ear air conduction (AC), right ear bone conduction (BC), left ear AC, and left ear BC. This comprises the audiogram. The symbols used on most audiograms are:

x - left air conduction

o - right air conduction

5. The block diagram of an audiometer

Fig. 5. shows a block diagram of a basic audiometer.

1. The oscillator provides a controllable frequency range from 250 Hz to 8 kHz.

2. The equalization circuit provides frequency dependent attenuation and provides different amount of attenuation for different output devices used (headphone, loudspeaker, and vibrator).

3. The attenuator should be capable of controlling the output sound level over a desired range in steps of 5 dB.

4. The noise generator provides wide band noise, which has energy spectrum equally distributed over the test frequency range i.e. up to 8 kHz.

5. The power amplifier provides the output power of the sound level available from the headphones and the bone vibrator.

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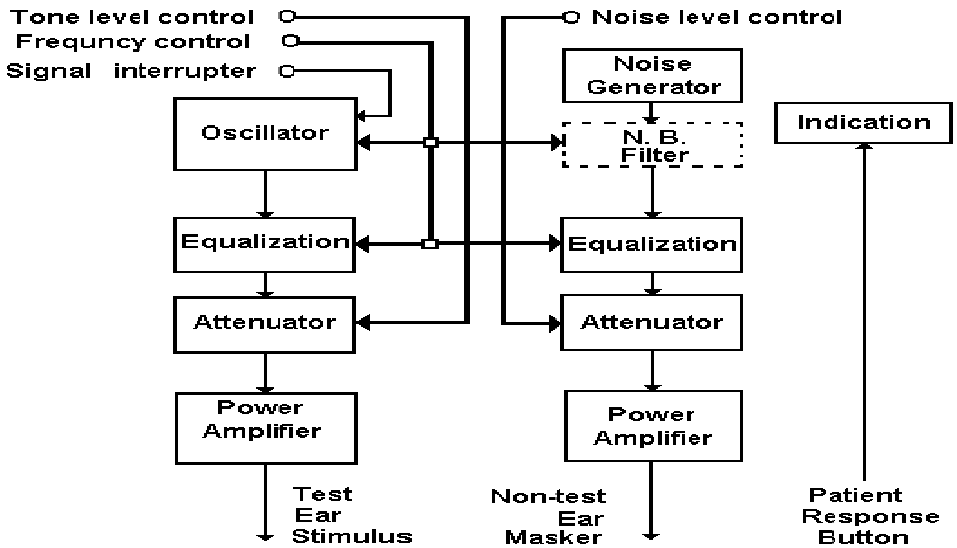

Fig5. block diagram of a basic audiometer.

6. Types

There are two types of audiometric techniques, subjective type and objective type.

In subjective test, the patient has to respond when he hears the presented sound. Subjective type audiometric test involves presentation of systematically varying acoustic stimuli to the subject and recording the responses.

Objective test only requires co-operation from the patient towards attachment of the measuring electrodes or probes.

There are different audiometeric procedures depending on the stimuli used

1. Purposes

It is specialized equipment, which is used for the following:

1. The identification of hearing loss in individuals

2. The quantitative determination of the degree and nature of such a loss.

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1) Groups

Divided into two main groups according to type of stimulus:

1. Pure- tone audiometer
2. Speech audiometer

6.1. Pure- tone audiometer

- **Specifications:**

1. used in routine tests, most widely used technique for determining hearing loss.
2. Generate test tones in octave steps from **125 to 8000** Hz.
3. The signal intensity ranging from **-10 dB to +100** dB .

- **Advantages:**

1. The simplest type of auditory stimulus.
2. It can be specified accurately in terms of frequency and intensity.
3. High degree of precision.
4. Wide frequency range compared to speech tests
5. Changes in threshold sensitivity can be monitored more accurately with pure-tone than speech tests.

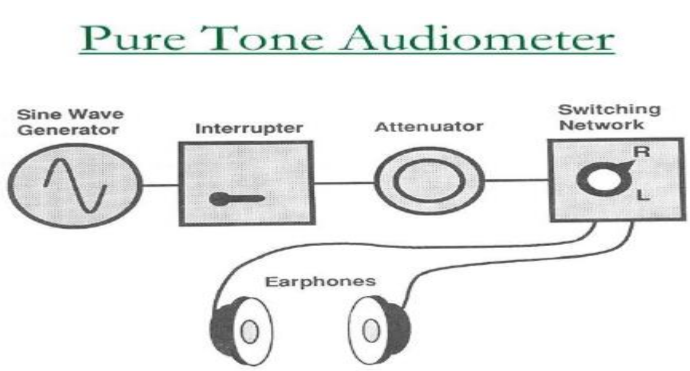

Fig 6. Pure tone audiometer block diagram

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- Principle of work

* Head phones are worn by the subject and a set of responses is obtained for air-conducted sounds directed to each ear in turn.

* A bone conductor vibrator can then be attached to the head at the center forehead position to see whether the hearing threshold improves.

* To avoid stimulation of the ear not under test with the vibrator, it can be temporarily made deaf by introducing a suitable masking noise in the non-test ear via an earphone.

6.2 Speech Audiometer

- **Purpose:**

1. Important before prescribing hearing-aids

2. Determining the deterioration of speech understanding of patients (frequency range **300 – 3000 Hz**).

3. Evaluate the performance of hearing aids.

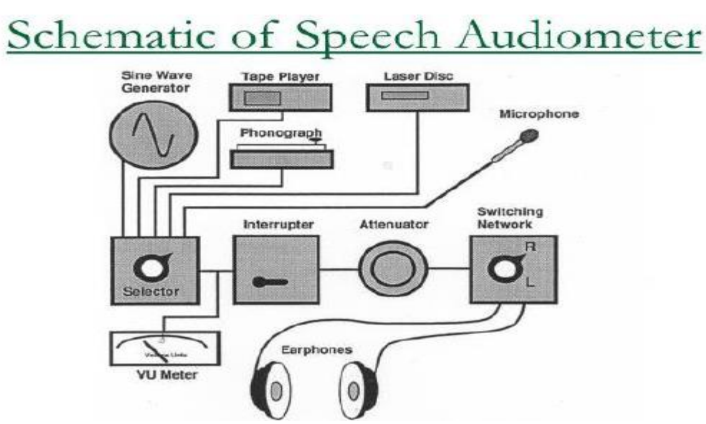

Fig .6. Speech audiometer block diagram

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