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Building-up Principles of Auditory Echoscope for Diagnostics of Human Middle Ear

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Abstract—The building-up principles of diagnostic unit for determining the acoustic impedance with enhanced accuracy have been formulated using a case study of developing a laboratory prototype of auditory echoscope. This unit enables us to assess the condition of human middle ear both qualitatively and quantitatively and also determine the appropriate parameters by measuring the coefficient of acoustic reflection from tympanic membrane.

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INTRODUCTION

Auditory echoscope is a medical device for early (functional) objective diagnosis of hearing disorders that is applied both for diagnostics of human middle ear without the participation of sensorineural system [1] and for the selection of materials of ossicles prostheses in tympanoplasty [2].

Based on the measured frequency relationship of the coefficient of acoustic reflections from tympanic membrane, it is possible to determine the tympanic membrane flexibility (m/N), resonance frequencies of the mechanical system of ear (Hz), weight of auditory ossicles (mg), the ratio of the active component of the mechanical impedance of ear to the air impedance, the transformation coefficient of the acoustic pressure produced by auditory ossicles into the cochlea liquid, and also the norm parameter representing an invariant of the human middle ear under normal conditions [3].

The proposed echoscope possesses a series of advantages as compared to multifrequency impedance meters, including the reactance ones that are now widely used for diagnostics of human middle ear. These advantages include the following:

– absence of the closed space of external auditory passage between the ear insert and tympanic membrane and, consequently, an enhanced accuracy of determining the acoustic impedance and differentiation of inter-subject deviations of different parameters of ear from the average deviations due to disorders in the middle ear system;

– much lower time-average levels of acoustic pressure;

– absence of a pneumatic system that may result in the damage of the hearing mechanism of newborns.

The principle of operation of auditory echoscope implies the emission of short sound pulses into a tube of small diameter (small as compared to the sound wavelength at the selected frequency) and determination of the coefficient of acoustic reflection from the tympanic membrane by comparing the sound amplitude and echo signal amplitude. Determination of the remaining parameters listed above is performed on the basis of the reflection coefficient frequency characteristic obtained.

Acoustic part of the auditory echoscope consists of flexible tubular sound duct, earphone and microphone. One end of the sound duct is inserted into the external ear canal, while an acoustic probe without a pneumatic actuator is inserted into the second elastic input of the duct. Variation of the norm parameter and resonance frequency (both in the process of rapid movements, for example swallowing movements, and in the process of slower manipulations, e.g., medical tests) can be obtained by varying the frequency and the repetition time of pulses applied to the telephone (earphone).

If necessary, the characteristic of the reflection coefficient of the human middle ear tympanic membrane as a function of time and frequency $\chi(f, t)$ can be recalculated into the values of parameters of the vibrating system of the middle ear: flexibility of the ear drum, weight of auditory ossicles, and the transformation coefficient of the ear drum pressure into cochlea.