Акустичні прилади та системи

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The Study of the Possibility of Usage of the Sokolov's Criteria for Assessing the Results of Directed Influence on the Auditory System of a Biological Object

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***Abstract*—In this work the possibility of using the Sokolov criterion for assessing the results of directed influence on the auditory organ of a biological object was considered. Guinea pigs were used as a test object because the structure of their auditory organ is largely similar to a human one. As an effect of directed influence on the auditory canal the impact of oto-active drugs on test specimens was used, which was estimated via implementation of distortion product otoacoustic emission. To evaluate the possibility of using the criterion arrays of experimental results that have not yet been processed have been used. Study represents comparatory analysis of two groups of data sets – pre- and post-criterion application. The comparison was made in two categories — the mean value and the confidence interval.**

Ref.8, fig.7.

Keywords — otoacoustic emission; distortion product; biological object; objective audiology; Sokolov's criterion.

I. Introduction

From one to three percent of newborns and infants acquire a pathology of hearing before, during, or after birth [1]. This is the reason for the development of new methods of screening for hearing loss in humans, including the use of the caused otoacoustic emission (OAE).

During auditory hearing screening of newborns, the normal condition of the auditory canal is confirmed or not confirmed.

The advantages of this method include:

- objectivity;
- the possibility of early implementation (for newborns).

The aim was to evaluate the possibility of processing the results of study of the human auditory channel during audiological screening via OAE with usage of the Sokolov`s criteria, in particular for the correction of input data arrays.

II. Materials and Methods

The phenomenon of the OAE, which is the basis of the method was discovered by David Kemp [2]. Distortion product otoacoustic emission (DPOAE) is produced by the cochlea of the inner ear as a response to the acoustic effect. DPOAE is produced by a pair of clean tones at frequencies f1 and f2 that are ejected into the auditory passage. Nonlinear properties of the cochlear of the inner ear, in the ear canal, in addition to the submitted tones, arise their intermodulation distortions of the third order (product of distortion). As a rule, only the most powerful one is registered — at a frequency of 2f1 — f2. The optimal ratios for frequencies f2 and f1 are as follows: up to 8 kHz — about 1.22, above 8 kHz — 1.15. The most commonly used intensities are: for f1 — 65 dB SPL (sound pressure level), for f2 — 55 dB SPL [3].

Guinea pigs were used as experimental objects in this study. They were used because their auditory tract has only minor differences from the human one — the presence of oval and round windows, albeit on different planes [4]. It should also be noted that the number of turns of the cochlear ranges from 3.25 to 4.25, and the system of the hammer-anvil-stacker is augmented by an additional bond. It is also worth noting the differences in the structure of hypothympanum and mesothympanum [5].

This article examines the complex of the results of research of hearing properties of guinea pigs via usage of otoacoustic emission frequency distortion products. Each case under consideration is a combination of the results of the study of each of the ears for eight guinea pigs at 6 frequencies – 2 kHz, 4 kHz, 6 kHz, 8 kHz, 10 kHz, 12 kHz, a total of 96 results on the experiment.

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The numerical results of the experiments were evaluated as follows: for each of the frequency groups used, the average amplitude was determined, and after the determination of the deviation, a confidence interval for each of the experiments was found. The confidence interval is the range of values in which the probability of the next similar experiment will lie with 95% probability, that is σ = 1.96 ≈ 2 for p = 0.05.

TABLE 1. CHARACTERISTICS OF THE CRITERION OF THE TEST PASSAGE BY Y.K. SOKOLOV

Frequency, kHz	2	4	6	8	10	12
Sound pressure level, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88

TABLE 2. GROUPS OF RESULTS

Number	Name of a group
1	Therapeutic effect of 7 days during intramuscular exposure to a drug
2	Therapeutic exposure of 7 days during intramigal exposure to a drug
3	Therapeutic exposure of 7 days during intraperitoneal exposure to a drug

TABLE 3. NOT-EDITED DATA ARRAY

Frequency, kHz	2	4	6	8	10	12
SPL, test 1, dB	-15	-20	-20	-16	-17	-15
SPL, test 2, dB	-15	-20	-20	-16	-16	-14
SPL, test 3, dB	-15	-20	-20	-16	-12	-13
SPL, test 4, dB	-15	-20	-20	-16	-12	-13
SPL, test 5, dB	-15	-20	-20	-11	-11	-13
SPL, test 6, dB	-15	-20	-20	-11	-9	-12
SPL, test 7, dB	-10	-20	-16	-10	-9	-11
SPL, test 8, dB	-8	-20	-16	-10	-9	-11
SPL, test 9, dB	-5	-20	-12	-9	-9	-8
SPL, test 10, dB	2	-19	-12	-9	-7	-4
SPL, test 11, dB	3	-19	-11	-9	3	5
SPL, test 12, dB	3	-14	-11	-8	3	13
SPL, test 13, dB	7	-8	-11	-5	3	14
SPL, test 14, dB	7	-5	-10	-1	7	14
SPL, test 15, dB	7	-5	-4	16	15	14
SPL, test 16, dB	12	7	4	25	24	26

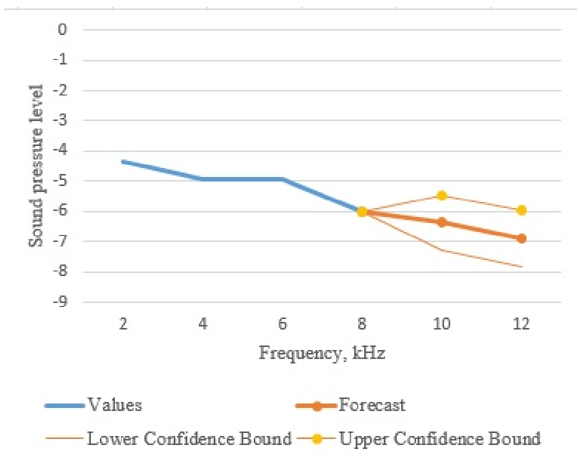

Fig. 1 Sokolov's criterion

Criterion of Sokolov is shown in Table 1. It should be noted that its value for frequencies of 10 kHz and 12 kHz was established by the approximation method (Fig. 1). Criterion's previous application case and comparison to test results is presented in study [7] and paper [8] represents practical implementation of said test results.

After that, each of the frequency groups was corrected by the Sokolov's criterion [6], which caused the change in the mean and confidence interval of the experiment. The results were compared before and after the correction to determine the effect of the criterion on the outcome of the research.

Research results were obtained via usage of the «Otoread» device manufactured by «Interacoustics». Said results later were processed with "Excel" software to estimate mean value and confidence interval. In the same time results were organized in the orderly fashion and after that equalization to criterion had taken place.

Criterion in meantime was obtained via "GetData" application and later approximated by "Excel" where needed. "Excel" was also used to create studies' graphs.

III. RESULTS

The paper examined 3 independent groups of results (experiments). Group names are listed in Table 2. Named groups were selected because they have large number of results, which will be corrected with the application of the criterion.

The processing of the results was carried out as follows — in the initial array of experimental data, before the subsequent processing, were evaluated in accordance with the criterion. So, those cases where the value of SPL was lower than critical, were subjected to editing, which was to equate their values to the values of the criterion. After that, the average value and the confidence interval for the edited data are calculated. Table 3 and Table 4 show the pre- and post-edited data arrays, respectively.

Also data arrays were organized in the order of ascension to provide better comprehension.

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TABLE 4. EDITED DATA ARRAY

Frequency, kHz	2	4	6	8	10	12
SPL, test 1, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 2, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 3, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 4, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 5, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 6, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 7, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 8, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 9, dB	-4.34	-4.95	-4.92	-6	-6.37	-6.88
SPL, test 10, dB	2	-4.95	-4.92	-6	-6.37	-4
SPL, test 11, dB	3	-4.95	-4.92	-6	3	5
SPL, test 12, dB	3	-4.95	-4.92	-6	3	13
SPL, test 13, dB	7	-4.95	-4.92	-5	3	14
SPL, test 14, dB	7	-4.95	-4.92	-1	7	14
SPL, test 15, dB	7	-4.95	-4	16	15	14
SPL, test 16, dB	12	7	4	25	24	26

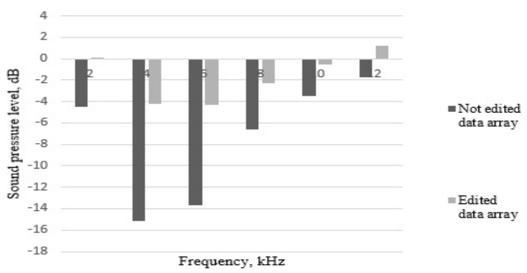

Fig.2 Therapeutic effect of 7 days during intramuscular exposure to a drug, mean value

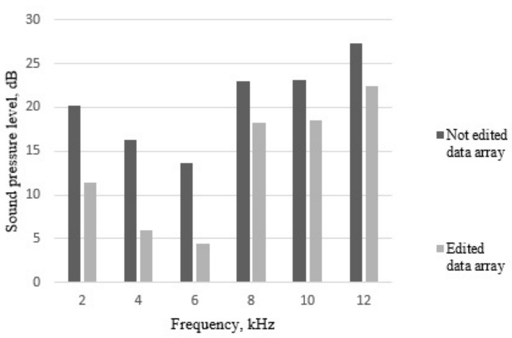

Fig. 3 Therapeutic effect of 7 days during intramuscular exposure to a drug, confidence interval

Negative SPL test values in presented tables are showing that acquired test results are below the standard reference sound pressure (20 µP) [3].

A. Therapeutic effect of 7 days during intramuscular exposure to a drug

Experimental graphs are shown in Figure 2 and Figure 3, for mean value and confidence interval, respectively.

By comparing the results of the mean values for the frequency ranges before and after the application of the criterion, we can see that they correlate as follows: relative to the initial result, the value of average sound pressure level for 2 kHz is higher by 4.62 dB, for 4 kHz is higher by 10.98 dB, for 6 kHz is higher by 9.38 dB, for 8 kHz is higher by 4.31 dB, for 10 kHz is higher by 2.96 dB, for 12 kHz is higher by 3.01 dB. Thus, the largest increase of the mean value is observed for the ranges 4 kHz and 6 kHz, the smallest — for 10 kHz and 12 kHz, which also is in equal scale, and for the 2 kHz and 8 kHz the increase is approximately equal.

For absolute mean values results are next: relative to the initial result, the absolute value of average sound pressure level for 2 kHz is lower by 4.38 dB, for 4 kHz is lower by 10.98 dB, for 6 kHz is lower by 9.38 dB, for 8 kHz is lower by 4.31 dB, for 10 kHz is lower by 2.96 dB, for 12 kHz is lower by 0.5 dB. So, the largest decrease of the absolute mean value is observed for the ranges 4 kHz and 6 kHz, the smallest — for 12 kHz, and for the 2 kHz and 8 kHz the decrease is approximately equal. Also, in comparison with mean value there is minor deviation in value for frequency of 2 kHz and major for 12 kHz. This fact is explained by transition from negative to positive of mean value of both data sets at specified frequencies.

For the confidence interval, the result is the following: relative to the initial result, the absolute sound pressure level value for 2 kHz is lower by 8.85 dB, for 4 kHz is lower by 10.28 dB, for 6 kHz is lower by 9.18 dB, for 8 kHz is lower by 4.68 dB, for 10 kHz is lower by 4.68 dB, for 12 kHz is lower by 4.98 dB. Highest decrease is observed for 4 kHz, lowest – for 8-12 kHz, which is also almost equal.

Actual results are presented in Table 5.

Thus is observed that the implementation of the criterion raised mean value for all frequency ranges (the largest change is observed for 4 kHz and 6 kHz and for 2 kHz and 10 kHz is observed the change of the sign) and lowered confidence interval with characteristics akin to before mentioned mean value.

B. Therapeutic exposure of 7 days duringintramigal exposure to a drug

Experimental graphs are shown in Figure 4 and Figure 5, for mean value and confidence interval, respectively. Actual results are presented in Table 6.

By comparing the results of the mean values for the frequency ranges before and after the application of the criterion, we can see that they correlate as follows: relative to the initial result, the value of average sound pressure level for 2 kHz is higher by 3.48 dB, for 4 kHz is higher by 9.86 dB, for 6 kHz is higher by 8.95 dB, for 8 kHz is higher by 4.63 dB, for 10 kHz is higher by 2.05 dB, for 12 kHz is higher by 2.94 dB. Thus, the largest increase of the mean value is observed for the ranges 4 kHz and 6 kHz, the smallest — for 10 kHz and 12 kHz, which also is in equal scale, and for the 2 and 8 kHz the increase is approximately equal.

TABLE 5. DATA CHANGES AFTER EDITING

Frequency, kHz	2	4	6	8	10	12
Change in the mean value of sound pressure level, dB	4.62	10.98	9.38	4.31	2.96	3.01
Change in the absolute mean value of sound pressure level, dB	-4.38	-10.99	-9.38	-4.31	-2.96	-0.5
Change in the mean value of sound pressure level for the confidence interval, dB	-8.85	-10.28	-9.18	-4.68	-4.68	-4.98

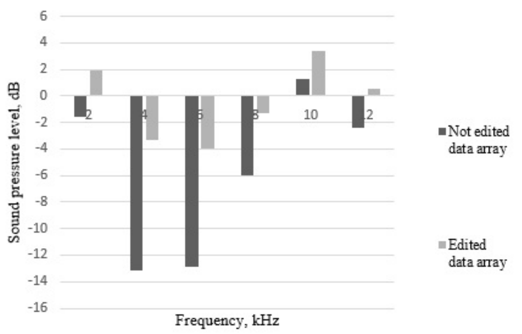

Fig. 4 Therapeutic effect of 7 days during intramigal exposure to a drug, mean value

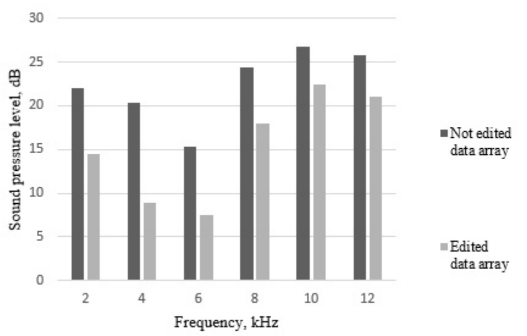

Fig. 5 Therapeutic effect of 7 days during intramigal exposure to a drug, confidence interval

TABLE 6. DATA CHANGES AFTER EDITING

Frequency, kHz	2	4	6	8	10	12
Change in the mean value of sound pressure level, dB	3.48	9.86	8.95	4.63	2.05	2.94
Change in the absolute mean value of sound pressure level, dB	0.35	-9.86	-8.95	-4.63	2.05	-1.81
Change in the mean value of sound pressure level for the confidence interval, dB	-7.48	-11.42	-7.80	-6.44	-4.25	-4.85

For absolute mean values results are next: relative to the initial result, the absolute value of average sound pressure level for 2 kHz is higher by 0.35 dB, for 4 kHz is lower by 9.86 dB, for 6 kHz is lower by 8.95 dB, for 8 kHz is lower by 4.63 dB, for 10 kHz is higher by 2.05 dB, for 12 kHz is lower by 1.81 dB. So, the largest decrease of the absolute mean value is observed for the ranges 4 kHz and 6 kHz, the smallest — for 12 kHz, and for the 2 kHz and 10 kHz the increase is observed. Also, in comparison with mean value there is minor deviation in value for frequency of 2 kHz and major for 12 kHz. This fact is explained by transition from negative to positive of mean value of both data sets at specified frequencies.

For the confidence interval, the result is the following: relative to the initial result, the absolute sound pressure level value for 2 kHz is lower by 7.48 dB, for 4 kHz is lower by 11.42 dB, for 6 kHz is lower by 7.8 B, for 8 Hz is lower by 6.44 dB, for 10 kHz is lower by 4.25 dB, for 12 kHz is lower by 4.85 dB. Highest decrease is observed for 4 kHz, lowest – for 10 kHz and 12 kHz, which is also almost equal.

So it is observed that the implementation of the criterion raised mean value for all frequency ranges (the largest change is observed for 4 kHz and 6 kHz, and for 2 kHz and 10 kHz is observed the change of the sign) and lowered confidence interval for all frequency ranges.

C. *Therapeutic exposure of 7 days during intraperitoneal exposure to a drug*

Experimental graphs are shown in Figure. 6 and Figure. 7, for mean value and confidence interval, respectively. Actual results are presented in Table 7.

By comparing the results of the mean values for the frequency ranges before and after the application of the criterion, we can see that they correlate as follows: relative to the initial result, the value of average sound pressure level for 2 kHz is higher by 4.62 dB, for 4 kHz is higher by 9.8 dB, for 6 kHz is higher by 10.27 dB, for 8 kHz is higher by 7.25 dB, for 10 kHz is higher by 4.21 dB, for 12 kHz is higher by 4.34 dB. Thus,

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the largest increase of the mean value is observed for the ranges 4 kHz and 6 kHz, the smallest — for 10 kHz and 12 kHz, which also is in equal scale, and for the 2 kHz, 10 kHz and 12 kHz the increase is approximately equal.

For absolute mean values results are next: relative to the initial result, the absolute value of average sound pressure level for 2 kHz is lower by 4.62 dB, for 4 kHz is lower by 9.8 dB, for 6 kHz is lower by 10.27 dB, for 8 kHz is lower by 7.25 dB, for 10 kHz is lower by 4.21 dB, for 12 kHz is lower by 4.34 dB. So, the largest decrease of the absolute mean value is observed for the ranges 4 kHz and 6 kHz, the smallest — for 12 kHz.

For the confidence interval, the result is the following: relative to the initial result, the absolute sound pressure level value for 2 kHz is lower by 8.01 dB, for 4 kHz is lower by 13.44 dB, for 6 kHz is lower by 10.41 dB, for 8 kHz is lower by 7.86 dB, for 10 kHz is lower by 6.9 dB, for 12 kHz is lower by 5.53 dB. Highest decrease is observed for 4 kHz, lowest – for 10-12 kHz. Also for 4 kHz and 6 kHz all results of experiment were lower than the criterion and were replaced with the criterion's critical value, thus have no deviation.

It was observed that the usage of the criterion raised mean value for all frequency ranges (the largest change is observed for 4 kHz 6 kHz and 8 kHz) and lowered confidence interval for all frequency ranges, for 4 kHz 6 kHz even dropped it to zero.

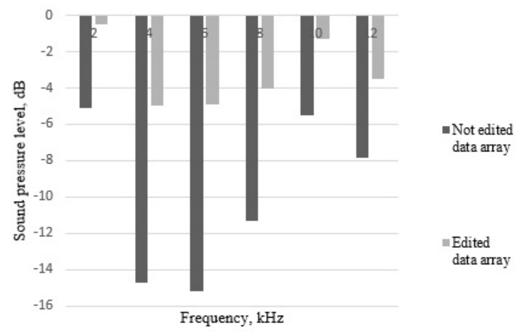

Fig. 6 Therapeutic effect of 7 days during intramigal exposure to a drug, mean value

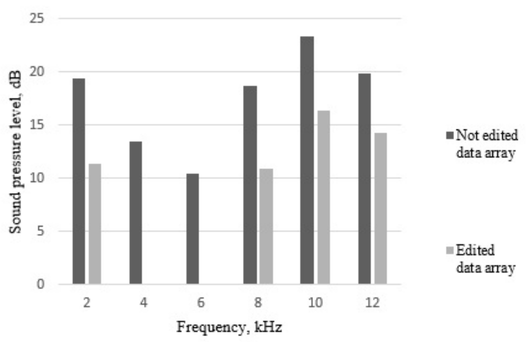

Fig. 7. Therapeutic effect of 7 days during intramigal exposure to a drug, confidence interval

TABLE 7. DATA CHANGES AFTER EDITING

Frequency, kHz	**2**	**4**	**6**	**8**	**10**	**12**
Change in the mean value of sound pressure level, dB	4.62	9.80	10.27	7.25	4.21	4.34
Change in the absolute mean value of sound pressure level, dB	-4.62	-9.80	-10.27	-7.25	-4.21	-4.34
Change in the mean value of sound pressure level for the confidence interval, dB	-8.01	-13.44	-10.41	-7.86	-6.90	-5.53

CONCLUSIONS

The outcome of the usage of criterion, presented in this article, shows the rapid increase of mean value and decrease in confidence interval of the observed test groups. Fig.2 and Fig. 4 display that the change of sign of SPL's value for certain frequency bands was registered. Aforementioned downfall of confidence interval value shows grows of the accuracy of acquired mean values of frequency bands. For frequency groups with results, which all are below the criterion's value was observed the complete loss of confidence interval's value. Also there is noteworthy fact that most prominent change of attributes happened to frequency bands with largest number of changed values (Table 3 and Table 4; Figure2, Figure 4, Figure 6, Figure 7).

The results of a study show a promising chance for further implementation of Sokolov's criterion in evaluation of results of hearing testing, acquired via DPOAE. Direct effect of said implementation – increment of mean value and decrement of confidence interval, apart from the obvious upgrade of the accuracy of the processing of experimental data allow bypassing of one of the steps in raw data evaluation [7], [8].

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Дослідження можливості використання критерію Соколова для оцінки результатів направленого впливу на слухову систему біологічного об’єкту

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***Анотація*—Від одного до трьох відсотків новонароджених та немовлят набувають патологію слуху до, під час, або після народження.**

Під час проведення аудіологічного скринінгу слуху новонароджених підтверджується або не підтверджується нормальний стан слухового каналу.

Аудіологічний скринінг слуху новонароджених є обстеженням, при якому автоматизованим методом підтверджується або не підтверджується нормальна функція органу слуху. Серед важливих переваг отоакустичної емісії є те, що цей метод є об'єктивним, тобто мінімізує можливість помилки, що викликана людським фактором, а також може застосовуватись вже з перших днів життя, що дає методу значну перевагу над суб'єктивними методами, що вимагають активної кооперації пацієнта.

Одним із сучасних методів аудіологічного дослідження стану слуху є метод, що оцінює отоакустичну емісію на частоті продукту спотворення, що продукується завиткою внутрішнього вуха спонтанно або в якості відклику на акустичний вплив.

Піддослідними об’єктами виступали морські свинки. Вони були використані через те, їх слуховий тракт має лише незначні відмінності від людського.

У роботі розглянуто комплекс результатів дослідження слуху морських свинок при використанні отоакустичної емісії на частоті продукту спотворення. Кожен розглянутий випадок являє собою сукупність результатів дослідження кожного з вух для восьми морських свинок по 6 частотам — 2 кГц, 4 кГц, 6 кГц, 8 кГц, 10 кГц, 12 кГц, загалом 96 результатів на дослід.

Чисельні результати дослідів оцінювались наступним чином — для кожної із використовуваних частотних груп було встановлено середнє значення амплітуди, а після визначення відхилення було виявлено довірчий інтервал для кожного із дослідів. Після цього кожна із частотних груп піддавалась корекції критерієм Соколова, що спричиняло зміну середнього значення та довірчого інтервалу досліду. Далі проводилось порівняння результатів до та після корекції з метою виявлення характеру впливу критерію на результат досліджень.

Обробка результатів велась наступним чином – у вихідному масиві даних експерименту перед подальшою їх обробкою проводилось нормування згідно критерію. При цьому ті випадки, коли значення рівня звукового тиску було нижче критичного, піддавались редагуванню, що полягало у прирівняні їх значень до значень критерію. Після цього проводився обрахунок середнього значення та довірчого інтервалу для відредагованих даних.

У даній роботі було перевірено можливість обробки результатів дослідження стану слухового каналу людини при проведенні аудіологічного скринінгу за використанням отоакустичної емісії на частоті продукту спотворенн япри застосуванні критерію Соколова, зокрема для корекції вхідних масивів даних.

Результати дослідження, представлені в даній статті, показують швидке зростання середньої величини і зниження довірчого інтервалу спостережуваних тестових груп. Зазначене падіння значення довірчого інтервалу показує зростання точності отриманих середніх значень частотних діапазонів.

Бібл. 8, рис. 6.

Ключові слова — отоакустична емісія; частота продукту спотворення; біологічний об'єкт; об'єктивна аудіологія; критерій Соколова.

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Исследование возможности использования критерия Соколова для оценки результатов направленного воздействия на слуховую систему биологического объекта

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***Аннотация*—В данной работе рассмотрена возможность использования критерия Соколова для оценки результатов направленного воздействия на слуховой орган биологического объекта. Подопытными объектами были морские свинки, строение слухового органа которых близко к человеческому. В качестве эффекта направленного воздействия на слуховой канал было использовано влияние ото активных медицинских препаратов на испытуемые образцы, что было оценено методом оценки слуха при помощи отоакустической эмиссии на частоте продукта искажения. Для оценки возможности использования критерия были изучены массивы экспериментальных результатов, которые еще не подвергались обработке. В работе приведен сравнительный анализ двух групп массивов данных — до и после применения критерия. Сравнение было выполнено по двум категориям — среднему значению и доверительному интервалу.**

Библ. 8, рис. 7.

Ключевые слова — отоакустическая эмиссия; частота продукта искажения; биологический объект; объективная аудиология; критерий Соколова.