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FREQUENCY SCALE AND CRITICAL STRIPS OF THE AUDITORY SYSTEM

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The auditory system of perception is characterized by a number of the special features, which, probably, are oriented to the optimum or close to it processing of external sound signals. Clear that the criteria of optimality are determined by the level of analysis and perception of signals, i.e., they have hierarchical nature. On the periphery of the auditory system, where is conducted the primary the processing of signals, as this criterion can be used the estimation of errors in isolation and measurement of the parameters of the input signals, for example, of frequency and the intensity. These errors will depend on the organization of the structure of this part of the auditory system. In the report is analyzed the connection between the frequency scale and the critical strips of auditory system, on the assumption that this dependence is determined by the algorithms of the analysis of serrated sound signals.

Introduction

The periphery of auditory system answers for the primary the processing of sound signals and include [1]:

external, average, inner ear;

auditory nerve;

the first levels of neuron working.

Are known allocation of frequencies along the length of the basic membrane of inner ear, frequency scale, received by man, dependence of width of critical zone on the received frequency, and so the distribution of sensing elements, hair cells along the length of the membrane. Let us isolate the special feature of processing sound signals on the periphery of the auditory system:

The basic membrane of inner ear forms the nonlinear frequency scale, close to the logarithmic;

The resonance properties of the points of basic membrane are relatively low and on their basis it is not possible to explain the resolution of auditory system in the frequency;

Sensitive hair cells are evenly distributed along the length of basic membrane;

To each frequency corresponds the critical strip, in which the signal is received as single whole.

It is possible to assume that these special features were formed in the process of evolution [2], ensure the smallest losses of information with the formation of the parametric description of signal in the auditory system.

To one degree or another these special features are used in the algorithms of the compression of sound signals, but these algorithms do not make it possible to reveal the special feature of voice signals, to establish their difference from others.

of the rumor

Critical strip is connected with each frequency of analysis of the auditory system of perception. It is considered that in each strip the signal is received as single whole. However, this perception depends on the relationship of amplitudes and frequencies of the components of signal. Usually critical strip is evaluated according to the results of the perception of signal, which consists of the sum of two sinusoidal components of different amplitude. The dependence of width of critical zone on its central frequency can be determined by the relationship:

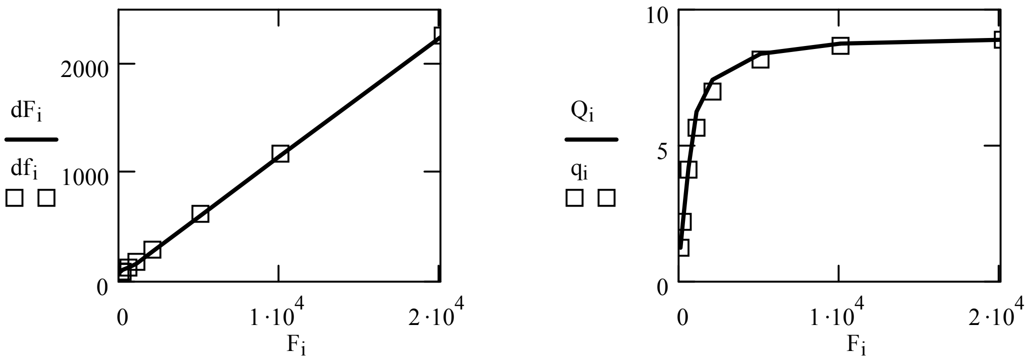
$$dF_i = \alpha \cdot F_i + b, \tag{1}$$

where k – the number of critical strip;

F_i – the central frequency of critical strip;

α – constant of proportionality;

b – displacement. where k – number of critical strip;



a) б)

Fig.1. Dependence of critical strip a) and quality b) on the central frequency Fi Hz, where dfi- critical strip in Hz [1]; dFi- approximation (1); Qi and qi- quality; $\alpha = 0{,}109$; $b = 69{,}1$.

In fig.1 are represented the dependences of critical strip and quality of the points of the basic membrane of inner ear. Quality was calculated as the ratio of central frequency to the critical strip.

Frequency scale and the critical strip of the rumor

We will consider that the point on the basic membrane of inner ear with the resonance frequency corresponds to each central frequency of critical strip F_i. Let us assume that a quantity of filters is n, which are plotted in the section of the basic membrane, which corresponds to this critical strip constantly. Then, the displacement of the resonance frequency of adjacent filter with the number will be determined by the value

$$\Delta F(i-1) = \frac{dF_{i-1}}{n} = \frac{\alpha}{n} \cdot dF_{i-1} + \frac{b}{n}. \qquad (2)$$

This assumption can be treated so [3], that a quantity of hair cells on the average, that fall into one critical strip, constantly this is ensured by the fact that the frequency scale, formed in the auditory system, is determined by the distribution of resonance frequencies along the length of basic membrane, and width of critical zone depends on resonance frequency.

Consequently, the sequence of the resonance frequencies of the system of filters, i.e., the distribution of resonance frequencies along the length of basic membrane, will be determined by the following recursion relation:

$$F_i = F_{i-1} - \Delta F(k-1) = \left(1 - \frac{\alpha}{n}\right) \cdot F_{i-1} - \frac{b}{n}. \qquad (3)$$

Sequential application of this formula gives:

$$F_i = \left(1 - \frac{\alpha}{n}\right)^i \cdot F_0 - \frac{b}{n} \sum_{i=0}^{k-1} \left(1 - \frac{\alpha}{b}\right)^i, \qquad (4)$$

where F_0 – the higher frequency of analysis, i.e., the resonance frequency of filter with the number $i = 0$.

Converting this expression, we will obtain

$$F_i = F_0 \cdot A^i + \frac{b}{\alpha} \cdot \left(A^i - 1\right), \qquad (5)$$

where $A = \dfrac{n - \alpha}{n}$.

Let us designate

$$A = e^{-c\cdot\Delta x}, \tag{6}$$

where $c -$ constant of proportionality;

$\Delta x -$ the distance between the adjacent resonances on the basic membrane.

Then it is possible to write down:

$$F(x) = F_0 \cdot e^{-c\cdot x} + \frac{b}{\alpha} \cdot \left(e^{-c\cdot x} - 1\right), \tag{7}$$

where $x = \Delta x \cdot k -$ the coordinate of points along the length of the basic membrane of inner ear.

It is considered that the higher frequency of analysis for the auditory system is equal $F_0 = 20000$ Hz, and lower - $F_H = 20$ Hz. The length of basic membrane comprises $x_m = 35$ mm. This makes it possible to determine the value of the coefficient c.

$$c = \frac{1}{x_m} \cdot \ln \frac{\alpha \cdot F_0 + b}{\alpha \cdot F_H + b}. \tag{8}$$

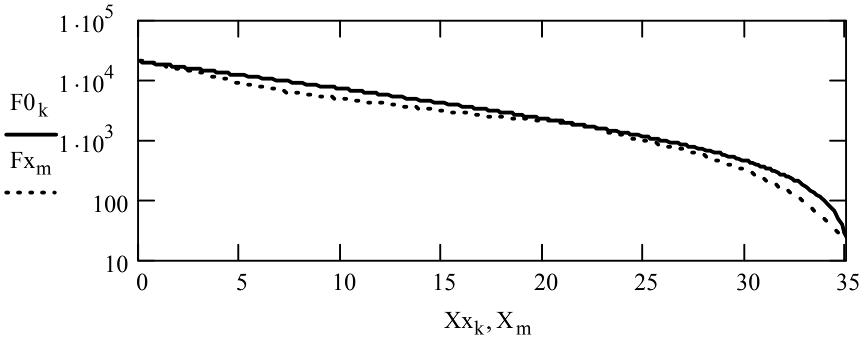
Expression (8) makes it possible to determine the position of resonance F_p on the basic membrane, i.e., the coordinate x_p

$$x_p = \frac{1}{c} \cdot \ln \frac{\alpha \cdot F_0 + b}{\alpha \cdot F_p + b}. \tag{9}$$

The obtained expression establishes functional dependence between width of critical zone and frequency scale. The obtained dependence makes it possible to conduct the simulation of the mechanisms of simultaneous masking and to explain the special feature of the perception of the sound signals, whose components fall into the critical strip. In ris.2 are represented the results of the computed values of the resonance frequencies of the points of basic membrane and the frequency scale, which is formed in this case with the perception of sound signals. Comparison with the experimental data makes it possible to draw the conclusion that the scale of the received frequencies and the critical strips of auditory system are connected with direct functional dependence.

Conclusion

The established dependences between the frequency scale and the critical strips of rumor make it possible to conduct the simulation of such special features of processing the signals in the auditory system, which are connected with the concepts of simultaneous and sequential masking.



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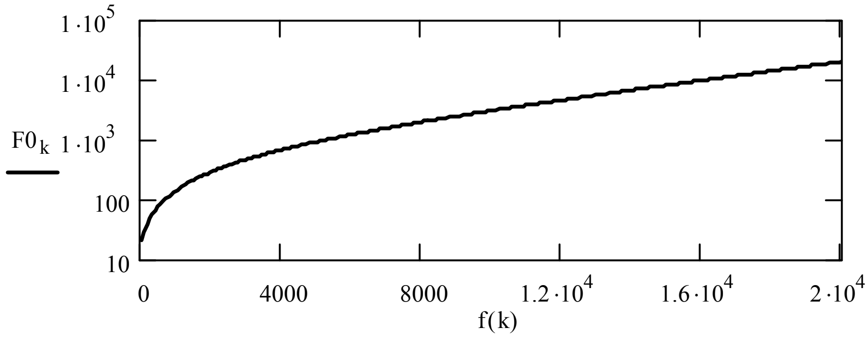

б)

Fig.2. The resonance frequencies of the points of basic membrane a) and frequency scale b),
where $F0-$ the resonance frequencies, calculated by formula (7);
$Fx-$ resonance frequencies according to the data [1];
$Xx, X-$ the coordinate of the points of basic membrane.

Simultaneous and sequential maskings can be considered as the mechanisms, which make it possible to isolate the informative sections of signal on the plane time - frequency or time - the coordinate of the points of basic membrane. These mechanisms are connected, probably, with this concept as the body of uncertainty, which widely is used in the radar [4].

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