

FREQUENCY-DIFFERENCE LIMENS WITH EXTREMELY SHORT TONAL DURATION

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A Soviet Russian paper (1) (Soviet Physics Acoustic 1960) deals with the same subject under nearly the same title. The results given in this Soviet Russian paper correspond very well with the prognoses which I published in my book "Physics of Hearing" (2). Therefore I shall confine myself to the discussion of these results, whereby figure 1 of this publication approximately corresponds with figure 3 of the Soviet Russian paper.

A tone, for example, 1000 Hz. is applied in short pulses to the ear of a person with normal hearing. The pulse duration (abscissa in figure 1) is varied and for each pulse duration the corresponding difference limen is measured which just leads to a frequency variation which can be discriminated. With a very long pulse (for example 500 msec) the difference limen equals 3-4 Hz. Therefore the tone 1000 Hz can easily be discriminated from the tone 995 Hz, as with a continuous tone. With a very short tonal pulse of, for example 5 msec. duration, a tone of 970 Hz produces the same hearing impression as a tone of 1000 Hz. The frequency discrimination threshold is entered in figure 1 as ordinate.

2 bending points can clearly be seen (at 18 msec. and at 180 msec.), a fact which is expressly referred to in the Soviet Russian paper. Thus 3 phases can be made out, viz. phase 1 from 0-18 msec., phase 2 (18—180 msec. and phase 3 (exceeding 180 msec.). In the Soviet Russian paper, the cause of these 3 phases is discussed. Phase 2 (180 msec.) is so long that the two authors think it impossible to suppose a mechanical cause, for example a pure mechanical built-up process as an explanation of this phase 2 and the authors write: "The fact that T 2 (the end of phase 2) is very large (180 msec.) and obviously does not depend on the signal frequency prompts the assumption that it reflects a certain time constant for the functioning of the nerve section of the auditory system."

Thus, in the two authors' opinion, phase 2 is to be related to a nervous process. On the other hand, phase 1 is said to correspond with the purely mechanical built-up process of the basilar membrane. The length of phase 1 is, as can be derived from the Russian paper, about 100 msec. at 100 Hz and about 10 msec. at 10,000 Hz, i.e. the merely mechanical built-up process in our cochlea is said to amount to 10 oscillations at 100 Hz and to 100 oscillations at 10,000 Hz.

Our basilar membrane (BM) is a fleshy organ which oscillates in a room filled with liquid. For the built-up and slow-down process perhaps 3 oscil-

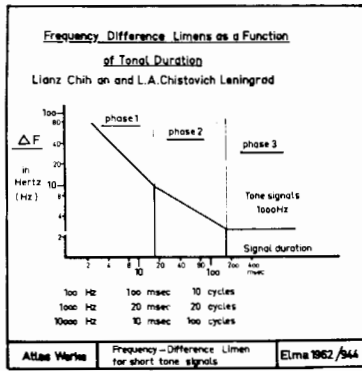


Fig. 1

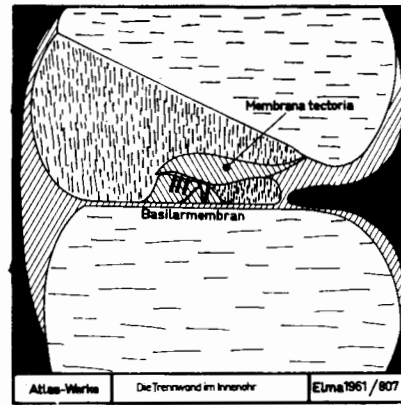


Fig. 2

Fig. 1: The ordinate is formed by the frequency difference which leads to a just discernible change in the hearing impression of the tonal height.

Fig. 2: Cross section of the human inner ear.

lations can be supposed; even 5 oscillations are still conceivable, but 10 oscillations are unlikely and 100 oscillations quite impossible. Thus the time, too, of phase 1 of 18 msec. is already too long in order to be explained by a mere mechanical built-up process of the BM.

One can therefore hold the opinion that this might be the case of nervous (or central) processes. One must not write, however, that as these processes cannot be built-up processes of the BM we hold the proof for it that it must be nervous (or central) processes. According to the new theory of hearing in my book "Physics of Hearing" it is started from the fact that the purely mechanical interplay between basilar membrane (BM) and the tectorial membrane (Mt) represent the proper hearing process in our inner ear.

Figure 2 shows a cross section of the human inner ear. The Mt can be conceived as a tongue which rests on the BM under slight pressure. The natural frequency of the Mt will be around 10—20 Hz. The BM as partition wall between stapes and the oval window must follow the stimulating frequency. Thus the BM realizes forced oscillations. In general, the Mt cannot follow up sound frequencies. It is pushed aside by the vibrating BM, and this the more so, the bigger the oscillation amplitude.

If a so-called Langenbeck noise is applied to an ear (see the widely schematized presentation in figure 3), the BM (lower figure) will oscillate in a very complicated form. The Mt will not be able to follow up these complicated oscillations. Therefore, the Mt is pushed aside throughout its length, whereby this lateral displacement must be proportionate to the oscillation amplitude. After a preliminary sonic excitation the Mt returns to its resting position relatively slowly according to its own elasticity. The time or 180 msec. (phase 2) thereby corresponds with the time required in order to push the Mt to its final lateral position.

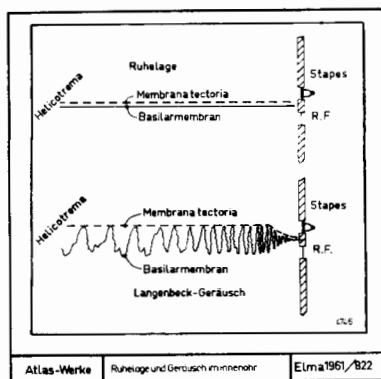


Fig. 3

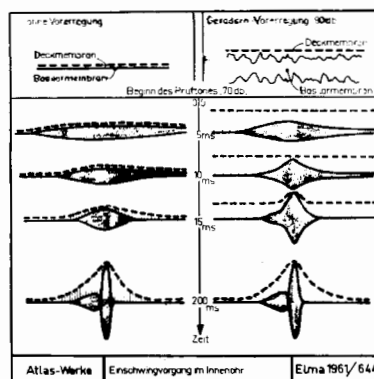


Fig. 4

Fig. 3: Widely schematized presentation of basilar membrane and tectorial membrane. Above: resting position .

Below: Effect of a so-called Langenbeck Noise.

Fig. 4: Left column: tonal pulse acting on a reposed ear.

Right column: tonal pulse after preliminary noise stimulation.

Phase 1 corresponds with the beginning of this process. In the left representation of figure 4, a tonal pulse fits the reposed inner ear. On the BM a travelling oscillation is formed with a relatively broad maximum. This maximum pushes aside the Mt. After about 18 msec. the oscillating form on the BM becomes so sharp, that the Mt gets loose from it so that only the center of the maximum touches the Mt within the oscillating zone.

Within the time of 0—18 msec. only a crack impression is obtained, i.e. pulses of 5—15 msec duration produce a hearing impression which correspond with a crack with tonal characteristic. At 18 msec. is the discrimination threshold from a crack to a tonal impression, so that with a pulse of for example 25 msec. duration a crack-tone sequence is clearly experienced subsequently at about the same intensity.

Only after 180 msec. the Mt is completely pushed aside, whereby the travelling oscillation on the BM has changed into a form which I have denominated as resonance eddy (working oscillation). Then the travelling oscillation is small in comparison with the resonance eddy so that in the drawing Fig. 4, bottom left and right, only the resonance eddy was presented.

If the measurements are repeated which were described in the Soviet Russian paper and which led to results according to figure 1 of this paper but if thereby the tonal pulse is not actuating on a reposed ear, but on an ear which was previously subject to a relatively strong sound excitation (see fig. 4 top right), completely different results are obtained. With this measuring process, according to an arrangement indicated by Lüscher and Zwislocki (3), a signal is applied to the ear in connection with a noise as preliminary stress. This noise to be for example 80 db and of 200 msec. duration and the signal tone for example 1000 Hz 60 db 10 msec. duration. First of all it will be found

that there is a time zone of silence. As preliminary excitation the noise pushed the Mt completely aside during its 200 msec. duration. When the noise is ended, the oscillation of the BM is decelerated immediately and very quickly. The Mt, however, slides back only relatively slowly. In the meantime, the tone pulse is switched on. The BM, free from the decelerating influence of the Mt completes the building up process very quickly, so that the Mt fits at the peak of the resonance eddy. The first hearing impression is in this case therefore a tonal one and no crack impression, whereby, however, about 180 msec. will pass until the final hearing impression is obtained.

This presentation complies with the new theory of hearing. Unfortunately, there still is no audio-experiment which unequivocally furnished proof of the correctness of the theory. The clearness of its presentation, however, only supports this new theory of hearing.

LE SEUIL DIFFÉRENTIEL DE FRÉQUENCE POUR DES TONS D'UNE DURÉE EXTRÊMEMENT COURTE

Peu après avoir fait inscrire le présent mémoire, l'auteur a appris qu'un travail russe portant sur le même sujet et donnant les résultats obtenus avait été publié. Les auteurs du travail russe sont déçus que dans ce cas d'impulsions tonales très réduites, (jusqu'à 18 msec), le caractère de l'impression auditive est déterminé par des phénomènes mécaniques et que des phénomènes d'origine nerveuse sont à la base des durées de 180 msec, nécessaires pour obtenir toute la netteté de la sensibilité de fréquence.

L'auteur du présent mémoire attire l'attention sur une nouvelle théorie qu'il a lui-même décrite en détails dans un livre appelé «Physik des Hörens» (Physique de l'ouïe). Dans ce livre, on admet que le concours mécanique de la membrane basilaire et de la membrane tectorienne produit le phénomène d'audition dans notre oreille interne. La membrane basilaire soumise à des oscillations, oscille en accord avec la fréquence imposée. La membrane tectorienne ne peut pas suivre et est repoussée dans une position latérale par la membrane basilaire oscillante.

Grâce à cette nouvelle théorie d'audition, il est beaucoup plus facile d'expliquer pourquoi des impulsions tonales sont identifiées par une oreille comme étant des cliquettements et que la même oreille perçoit cette impulsion sous forme d'un ton lorsqu'elle a préalablement été soumise à un bruit.

Literature :

- 1) Liang Chih-an and L. A. Chistovich: Sov. Phys. Acoustics (Engl.) 6, 75.80, 1960.
- 2) H. Kietz: Physik des Hörens, Verlag Schwiefert, Bremen 1960.
- 3) Lüscher and Zwislocki: J. Acoust. Soc. Am. 21, 135—139, 1949.

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DISCUSSION:

Azzi:

Dr Kietz has mentioned a test in which very short bursts of tone are sent to the patient's ear through headphones at an intensity of 70 dB over threshold. Most certainly these short bursts of tone are reproduced by the headphones with an extremely strong content of transients, so much so that the original shape of these bursts must be considered completely altered. I should like to ask to Dr Kietz if he bore this fact in mind and also what type of headphones he has used. Thank you.

Kietz:

Dr Azzi is quite right. We have to consider the onsets which are connected with such short pulses of tones. However, I believe that I have succeeded in avoiding such onsets or, strictly speaking, I have obtained a good control over these transients. Tomorrow I can demonstrate these tests in the showroom of the Atlas-Werke, and I would be very pleased to discuss these questions with Dr Azzi at this opportunity. I can prove that I obtain the same results no matter whether a transmitter for air sound or for bone conduction is used.