STUDY OF THE ACOUSTIC PERCEPTION*

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The paper presents a theoretical and experimental study regarding the way in which a sound is perceived and space localization of a sound source. In the first part of the paper we refer to the anatomical and physiological structure of the hearing system. The paper continues with the presentation of a theoretical model of the way in which the relative position of the two ears given the sound source establish the alter of phase and amplitude difference. Theoretical considerations are tested on a phantom made of a model which has incorporated two microphones in the pavilion of the ear.

We can see two ways of acoustic perception varying with frequency: on low frequencies (hundreds of Hz), the localization of the source is made through perception of phase difference of acoustic sounds caused by the pathway difference. On high frequencies (kHz), the localization of the source is made through perception of amplitude difference on the ear level; the far off ear perceives a signal of lower amplitude. There is a good concordance between the theoretical and experimental results.

Key words: acoustic perception, pathway difference, localization of a source.

INTRODUCTION

The ear – left and right – is a symmetrical organ, which allows us to analyze the sounds from the environment, and the orientation and localization in space of a sonorous source. The physiological role of the acoustic analyzer is to capture the sonorous waves from the environment, to receive and code all in nervous impulses, carry them to the cortex and create the auditive sensation.

The acoustic annalyzer [1] inform us about the quality of sound (the intensity, the height), the way of propagation or the distance between the subject and the sonorous source. The vestibular, the visual and cutaneous analyzer take part in maintaining the equilibrum. The physiological stimulative of the auditive analyzer is the sound. Sounds are mechanical oscillations of particles in an elastic environment (air) which spread as longitudinal waves which induce successive dilatation and comprimation of the environment. The ear captures, receives, code in nervous impulse and guides to auditive cortex – the place

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where the auditive sensation is formed. The acoustical waves excite the human auditive organ producing the auditive sensation. The human auditive analyzer perceives and processes signals in the range of 16–20.000 Hz and an intensity of 1 dB.

The auditive analyzer is build in such a way that it contains a part that ensures the mechanical transmission of sound vibrations in the external ear, medium ear and less in the internal ear. The second part of the analyzer is represented by the neuro-sensitive device, that ensures the change of sound signal (mechanical) in the bioelectric potential. Such as any annalyzer, here we can see the intermediar segment or driving segment, made by nucleous and nervous fibres that ensure the transmission of the sound impulse to the central cortex – corresponding to the first temporal circumvolution.

Registering the electrical signals from auditive tract and from the auditive receivers from the cortex, we can see that some sound frequencies activate particular neurons from the cortex.

An important property of the auditive perception is sound source localization, getting their direction and distance. This study is possible because of the differences between different perception of the same sound by the two ears. The different ways of perception are caused by two factors: the way difference which is the difference between the ways of the two sound waves that reach at the two ears, and the difference of intensity applied on the two ears situated at a distance of 20 cm one from the other (Fig. 1). The way difference is :

$$\Delta = \frac{d}{2}\left(\theta_{rad} + \sin\theta^{0}\right)$$

where: $\theta_{rad} = 2\pi(\theta°/360°)$, which corresponds to a delay of

$$\tau = \Delta / v$$

where v is the sound speed.

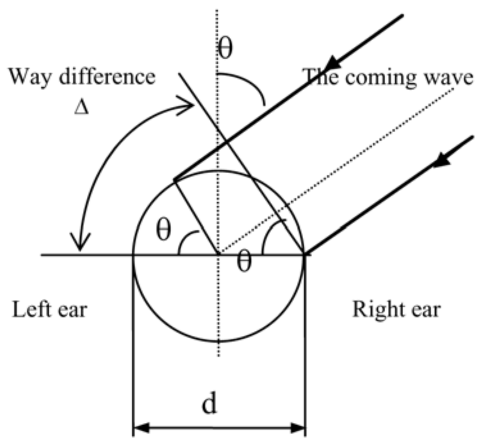
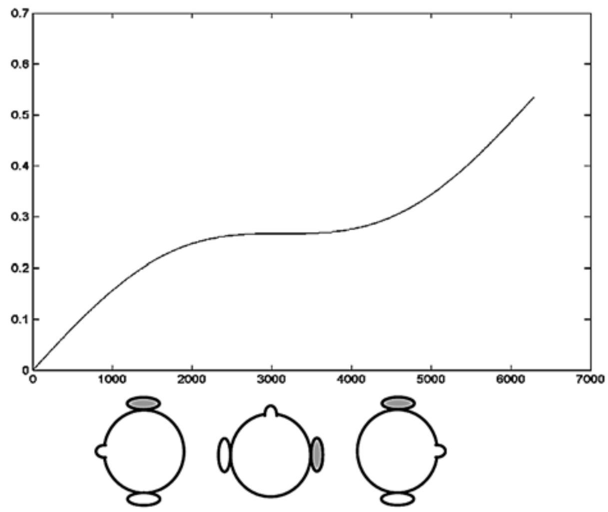


Fig. 1 – Localization of a source.

Fig. 2 – Graph representing the function $\Delta l/(d/2) = f(\theta)$. $\theta = 0\ldots\pi$.



We can use this method only for low frequencies or higher wavelength for which the diffraction is important.

The superior limit of frequency is for a frequency for whom diameter d is equal with $\lambda/2$ and corresponding to a phase difference of π or to a delay of half a period. For $d = 0.2$ m, the frequency is 850 Hz.

For the domain $f < 850$ Hz the directional location is made due to way difference or time lagging.

For high frequencies $f > 850$ Hz, the effect of diffraction is lower, because of the cranium inducing an acoustical shadow. So if the sound reaches from front, it will be the same acoustical pressure.

If the sound came from slanting, we get a higher pressure for the ear situated on the same direction as the coming wave. Concluding, in the range of high frequencies, the localization is made by a difference of sound intensity because of the diffraction on cranium.

MATERIALS AND METHOD

In Fig. 3 is presented the experimental set up.

For the experimental set up we used the block diagram from Fig. 4. In the ear pavilions of a pupett we put two condenser microphones.

The signals got from the two microphones are amplified with two identical amplifiers with the outputs connected on two channels of the oscilloscope. The puppet lay on a support that can turn in the horizontal plan with 360 degrees. The angle value is read on a scale.

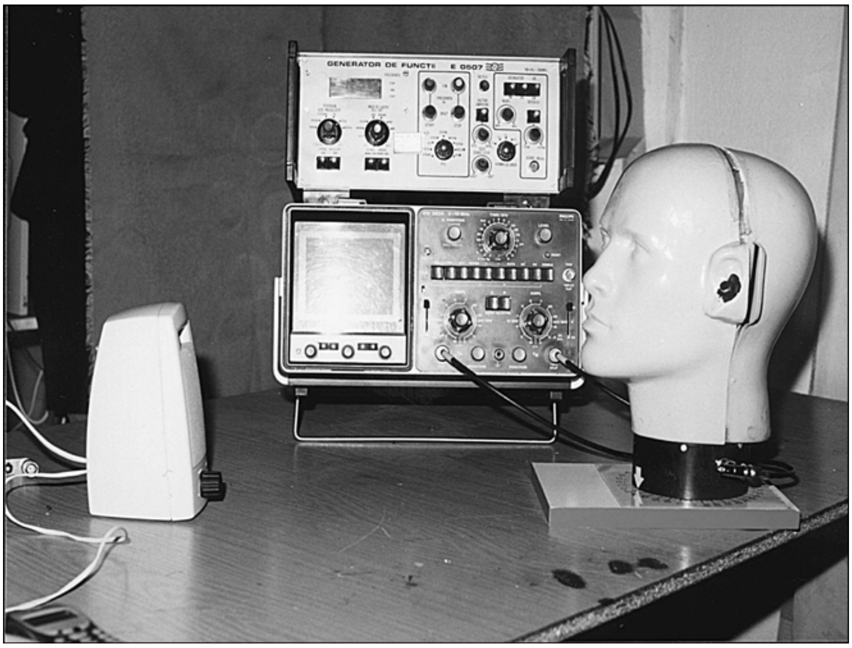


Fig. 3 – Experimental set up to study the acoustic perception.

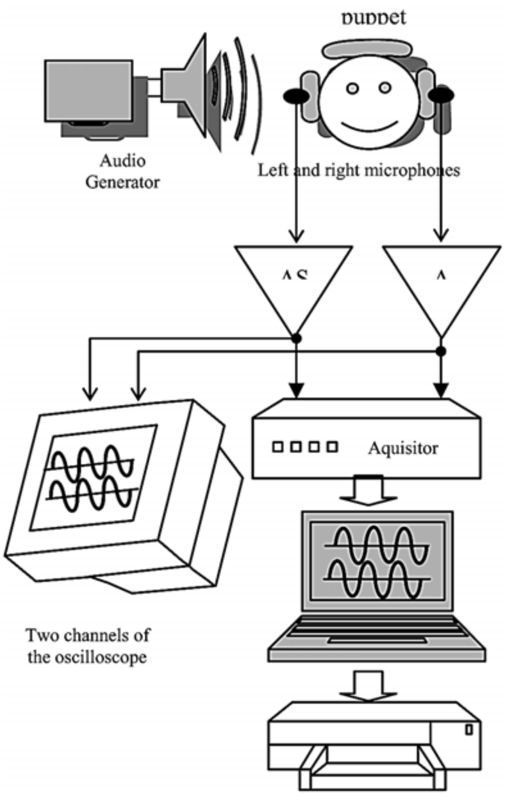


Fig. 4 – Block diagram of the experimental setup for acoustic perception.

The puppet is put ahead and on his axis of symmetry we found on which loudspeaker is the acoustic source. To the loudspeaker is applied a sinusoidal signal of audio frequency from a generator.

THE EXPERIMENT

The loudspeaker and the puppet are put one ahead the other on the same direction. Signals from the outputs of the two amplifiers are put simultaneously to the oscilloscope and of a data acquisition system controlled by a computer.

Using the cathode oscilloscope and having data acquisition, we can calculate phase difference among the two acoustic channels, for different angles of the puppet against the loudspeaker's axis and to different frequency of the generator, Fig. 5.

Through turning the puppet from one side and of another axis of symmetry, we can see the modification of polarity for the phase difference between signals for the two channels.

Knowing the frequency, we can calculate the way difference.

During the experiment we can emphasize another effect (interference, diffraction, etc.), caused as a matter of fact that the experiment is not in an aneroid room. The movement of a person or of an object around acoustic sources or puppet cause through incontrollable reflex acoustic waves some effects that can taint the experiment.

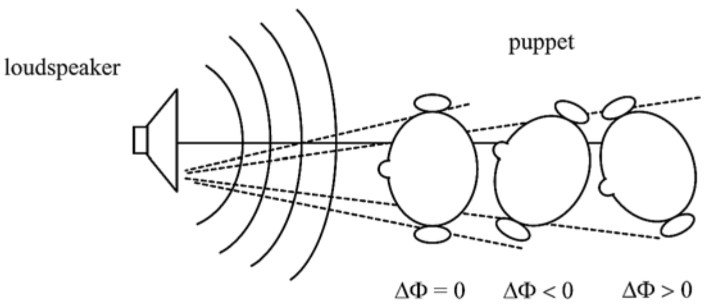


Fig. 5 – Appearance of the way difference function of sprocket puppet.

EXPERIMENTAL RESULTS

At low frequencies (hundred of Hz) the result consisted in a phase modification corresponding to the position of the two microphones, Fig. 5. According to the angle below the puppet "look" to the acoustical source, the phase difference can be positive or negative.

Turning the puppet with 180 degrees, the phase difference changes the sign, which indicates the possibility of source localization as much as ahead as the rearwards.

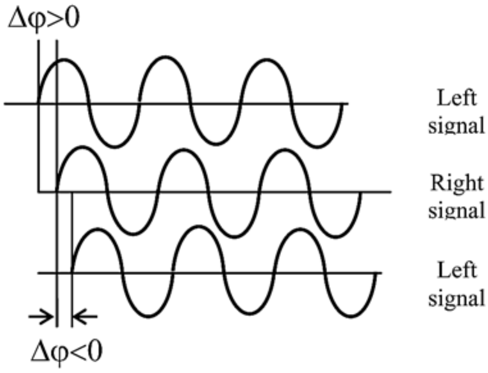


Fig. 6 – Phase difference between the two channels.

Raising the frequency, the way difference becomes higher than $\lambda/2$, becoming λ multiples, which correspond to $n\pi$ phase differences, retaining the perception of phase difference.

Due to the diffraction phenomena of the acoustic wave, which must arrive in the zone of shade of the beyond microphone, at high frequencies consisted of a decrease an amplitude of the sound. This way is explained the localization of sources of high frequencies through perception of amplitude difference. In Fig. 7 is represented the signals variation amplitude depending on frequency.

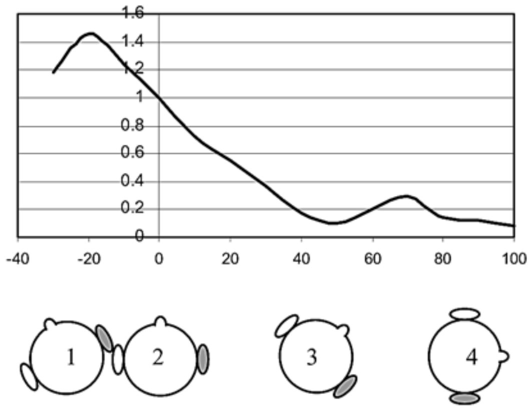


Fig. 7 – Relative variation of the signal intensity perceived by the right ear modifying θ angle (f = 10 kHz).

The diagram from Fig. 7 shows the dependence of the amplitude of the sound source function of the position of right ear for a 10 kHz frequency. Turning the head on the left is noticed the growth of the intensity of the sound further to an angle of 20 degrees, due to the fact that the ear has got closer to the sonorous source. Because the experiment was not made in an aneroidal room, the experimental results are easy influenced by minor reflexion and interferences.

To determine easier the frequencies on which there is a separation of sounds function of phase distortions perceived through amplitude variation, we represented the function $\Delta/\lambda = f(\theta)$ for different frequencies (Fig. 8).

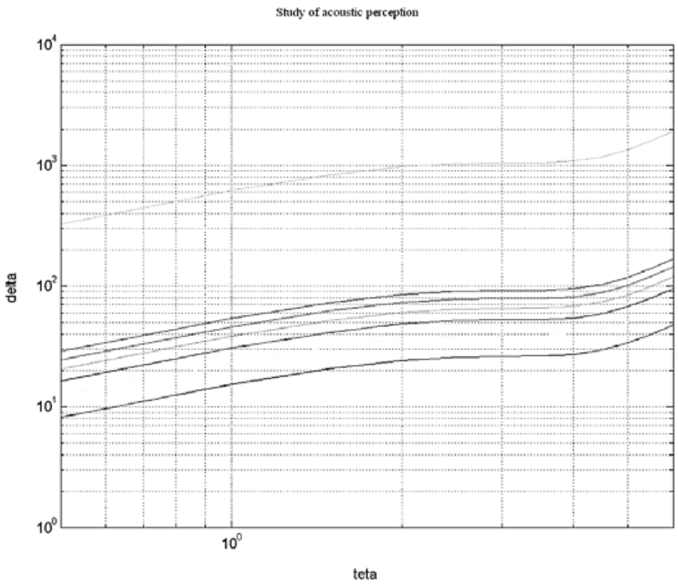


Fig. 8 – Representation of $\Delta/\lambda = f(\theta)$.

The localization of the sound source is made through perception of a phase difference for those frequencies on which $\Delta/(\lambda/2) = 1$.

CONCLUSIONS

The paper shows us the way in which a sound is perceived and localization of a source in space. The theoretical model is confirmed by the experimental results we have got. There are showed two distinct ways of perception, function of sound frequency. Also, we could see the differences induced by the distance between the two ears, from children to adults.

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