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The Causals of Headphones Tone Coloration Variations related on the Human Pinna Influence

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ABSTRACT

Head-related sound reproduction devices vary in transducers characteristics, the acoustic basic principle like open / closed / circum- or supra-aural systems. Furthermore the transducers de-/centred placement inside the earcup influences the tone quality. These headphone techniques were evaluated thousand times in comparison meanwhile. One creation with a spatial reproduction of sound was much more conspicuous statistically, because of a higher quantity recommended sound quality judgements as "to much" and "less high frequency range" parallely. This forced investigations to find the reason of those strange review accumulations. Four different headphone types were measured via seven testing persons by probe microphones in the auditory cannel. The research result shows an electro-acoustic cause for perceived tone coloration's of headphones by in the transducer positioning and the human pinna filtering efficiency.

1. INTRODUCTION

The two channel tone signal recording, transmission and reinforcing equipment should be developed to an adult audio system now. In the case of stereo headphones, two human outer ears **[1]** and scientific investigations in free- / diffus-field frequency response **[2]** brought actual optimized, binaural devices including a general advantage: Room acoustics factors are eliminated instead of a three dimensional loudspeaker rendering. Apart from this it seems to be a mystery to standardize evaluations of headphones tone quality in comparison tests at main acoustics institutes, standardizing groups or hifidelity or pro-audio journals. The results are much more subjective as objective fluctuating for instance looking for the best headphones. Some contra arguments for such blocked headphone test standardizing steps are:

- No actual existing standardized loudspeaker hearing test as reference.
- Doubts, that a higher quantity of users will proceed related standards.
- The existence of different methods to reproduce head-related sounds, which are not compatible to each other once and they are offering the in the head localization or spatial sound images.

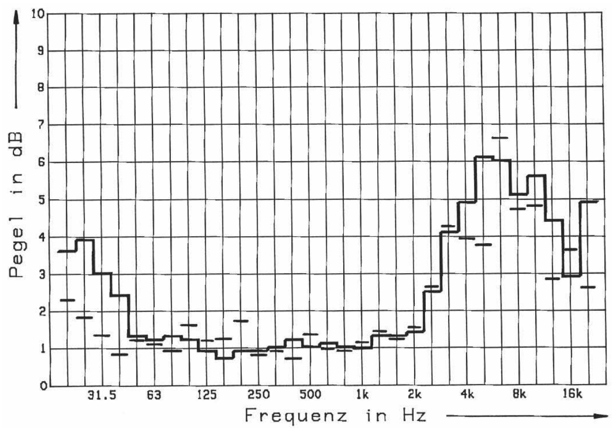

Figure 1: Shown outer ear third octave band variation based on two headphones measured by 8 and 16 persons each lined.

Another problem underlines headphone tone quality measurements: The individual varying head-related transfer functions (HRTF) regarding different testing person groups (each 8 or 16 persons involved; **Fig. 1**). Furthermore influence reinforcing characteristics of round or rectangular speaker forms, cloths or synthetic leather earpads open or closed and supra- or circum-aural headphone devices the investigation results (see **Fig. 2**). Therefor mean graphic curves of headphones broadband audio signal transmission can offer only a pre-view in auditory events and not sufficient information's for individual hearing humans.

Finally this contra-voting facts for an standardized headphone test will be summarized by the following found acoustic phenomena:

One acoustically similar realized dynamic headphone with a de-centric speaker placement nearby the pinna, which is to reproduce spatial sounds (no digital directional/binaural filter device **[3]** used). It was offered a surprising high variant judged (spatial) tone coloration's. This means, that during a long time hearing test comparison the headphone **type A** (see **Fig. 3** <> de-centric speaker) had a significant higher quantity of statements like "to much or less bass" and "to much or less high frequency events" apart from the headphone **type B** (centric speaker, but above damped for a de-centric sound source at the pinna shown in **Fig. 4**). So the headphone user was much more and statistically stabile satisfied or convinced with the headphone **type B**. In other words this pronounced tone coloration's critics in "plus" or "minus" fluctuations in a normal "neutral sound image" were much more often judged for the headphones **type A** apart from **type B**, which sound "more mean" over all human persons. So the mathematical addition judged results "+" and "-" of both models/types got "0" as sum.

This work was planned to find the electro-acoustic cause of this fluctuation phenomena in similar headphone for a spatial reproduction of sound.

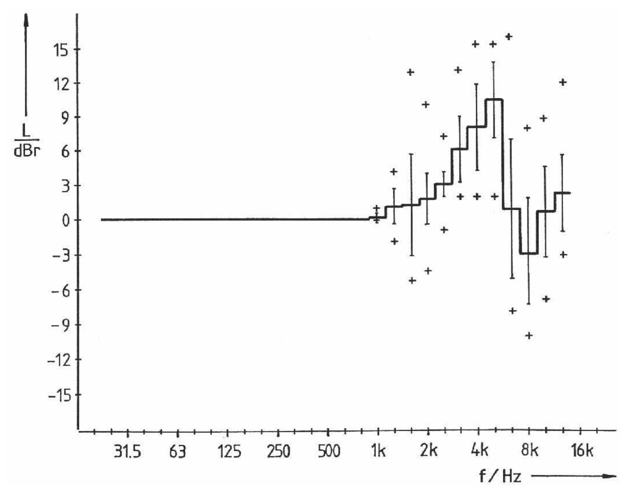

Figure 2: Transfer function comparison of coupler and dummy-head-measurements via 20 different headphones (lined), the third octave standard deviation "I" and there maximum variations shown by "+".

2. FOUNDATIONS OF THE RESEARCH

For the realization of the investigations were involved three female and four male normal hearing persons. Each person got an implant microphone, which was positioned 4 millimeters inside the auditory channel to measure the SPL directly in front of the eardrum. These persons put on four different headphones types, which were stimulated by White Noise testing signal at about 60 to 70 dB. The headphones were positioned at the outer ear maximum centered to reduce probable measuring errors in fluctuations by false placed sound sources. In this case the SPL deviation was important to control, which was at about 1 dB maximum value between 1 kHz to 5 kHz. The spectral analyses was selected at a frequency range among 1 kHz and 20 kHz because of the size and acoustic reflection/resonance function of the human pinna, which begins to work above 1 kHz acoustically. So it was a normalized procedure to retry the placements of this head-related sounding units two or three times. Furthermore it was possible to get a statistically stabile or significant 1/8 third-octave band width analyze result for each headphone in regards to the pinna de-emphases effects according the noise signal stimulation. Apart from this the headphone-pinna-frequency-responses were averaged over these measuring procedures and over the named 7 persons for the left and right side made separately; is was calculated also the standard deviation for each headphone shown in each figure!

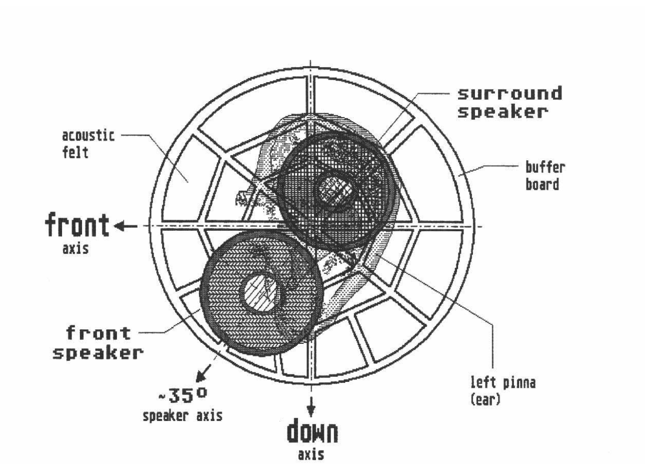

Figure 3: Principle of a circum-aural four channel headphone (type A) for in front localization with a main de-centric "FRONT speaker" placements based on **[3].** Furthermore a de-centric speaker to reproduce REAR tone signals in the vertical hearing plain.

For this investigations were used a supra-aural open (**type B1**), circum-aural closed (**type B2**) and two circum-aural open headphones (one as **type A3** and a common headphone **no. 4**). The headphone **type A3** was a circum-aural, open system with a de-centric speaker. The common headphone **no. 4** had a centric speaker placement in front of the outer ear. Important could be for the following context: The circum-aural headphone **type B2** and the headphone **no. 4** had a closing synthetic leather earpad, the headphone **type A3** had a velour earpad and the headphone **type B1** was made by a cloth surfacing earpad.

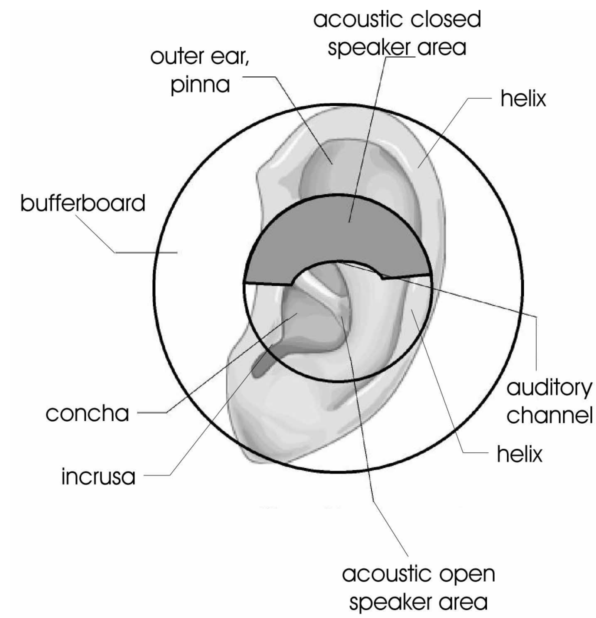

Figure 4: Principle of a circum-aural headphone (type B) for in-front-localization with a centric speaker placement based on **[3]**, but a de-centric sound source at the near-field of the outer ear.

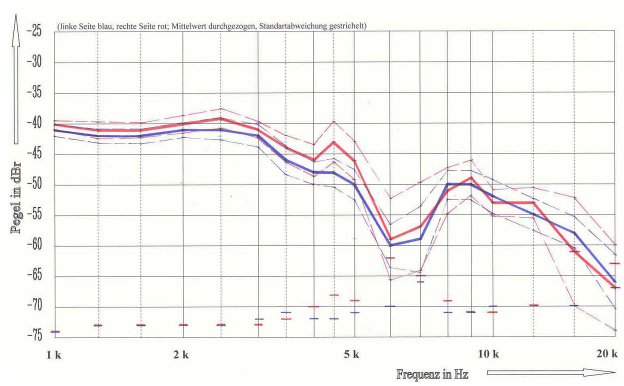

Figure 5: Diffus-field transfer function (DFTF) no. 4 of a circum-aural headphone with a centric speaker (lined); the standard deviation (dotted) and the maximum values (dashed); the left channel is colored blue and right is colored red.

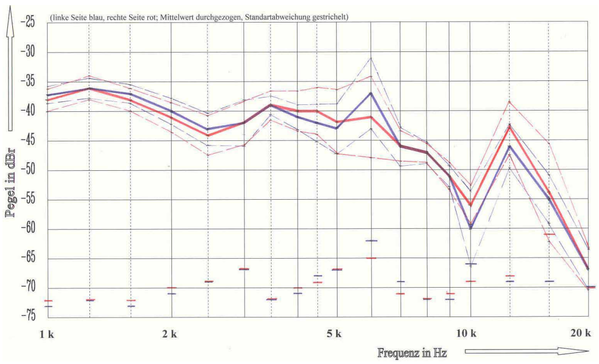

Figure 6: DFTF no. A3 of a circum-aural headphone with a de-centric speaker; the standard deviation (dotted) and the maximum values (dashed); the left channel is colored blue and right is colored red.

3. MEASUREMENT PROCEDURE

In **Figure 5, 6, 7, 8** are shown the resulting headphone-pinna-transmission-frequency- response (HPTFR) of all four headphone models. At this context is to point out, that the frequency range graphics of the upper last three thirds are including a frequency loss, which is to equalize by values of 1, 6, 12 dB at 12, 16, 20 kHz. So this curves show the registered probe microphone signals without any corrections including the microphone measurements own systematic tone signal error. The relevance of a correction by an equalization isn't important because of the main aspect to compare SPL as a function of the frequency and as relative comparison result between those four headphones. In short notes an overview of carried out spot checks in extraordinary resonance's, reflections and absorption effects regarding the headphone pinna device illustrated by the named **figures**:

- Headphone **type B1 (Fig. 7):** At frequencies about 2 and 10 kHz resonance's, which mark a brass shrill auditory event and roughness in the high frequency sound. Small notches at about 4 and 6 kHz. The mid's a linear beginning at 400 Hz, but for low frequencies (< 250 Hz) is a emphasis. Maximum relative statistically variances of 11 dB are presented at 4, 6, 16, 20 kHz (over 7 persons). The standard deviation not exceeds 5,7 dB and not falls short of 1,2 dB.
- Headphone **type B2 (Fig. 8):** At frequencies about 1, 6 / 4, 5 / 10 kHz third-octave broad resonance's, which mark a nasal, light brass shrill auditory event or a little bit roughness in the high frequency sound. Small notches at about 2,5 and 7 kHz for a touch of not hearing above. The mid's a linear beginning at 200 Hz to higher frequencies. Maximum relative statistically variances of 11 dB are presented at 6, 12 kHz (over 7 persons). The standard deviation not exceeds 6,6 dB and not falls short of 1,0 dB.
- Headphone **type A3 (Fig. 6):** At frequencies about 2 and 12 kHz resonance's, which mark small roughness in the high frequency sound. Small notches at about 2 and 10 kHz for a clear hearing not above. The mid's a linear beginning at 300 Hz to higher frequencies. Maximum relative statistically variances of 14 dB are presented at 6, 10, 16 kHz (over 7 persons). The standard deviation not exceeds 8,5 dB and not falls short of 1,7 dB.
- Headphone **type / no. 4 (Fig. 5):** At frequencies about 4 and 9 kHz resonance's, which mark unbalanced high frequency sound image. Broad notches between 6 and 7 kHz claims a dominant above hearing situation. The mid's a linear beginning at 300 Hz to higher frequencies. Maximum relative statistically variances of 14 dB are presented at 4, 16 kHz (over 7 persons). The standard deviation not exceeds 9,1 dB and not falls short of 0,7 dB.

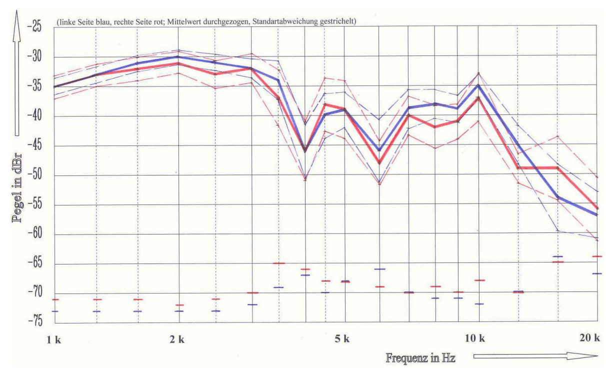

Figure 7: DFTF no. B1 of a supra-aural open headphone with a centric speaker, but de-centric sound source (lined); the standard deviation (dotted) and the maximum values (dashed); the left channel is colored blue and right is colored red.

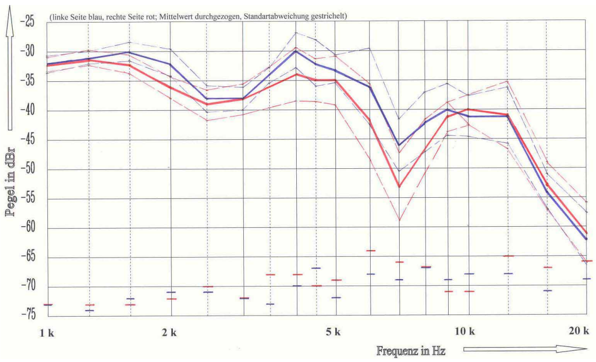

Figure 8: DFTF no. B2 of a circum-aural closed headphone with a centric speaker, but de-centric sound source (lined); the standard deviation (dotted) and the maximum values (dashed); the left channel is colored blue and right is colored red.

4. INVESTIGATION RESULTS

In a comparison of the above summarized results regarding the varying frequency range data's of the four tested headphones it is to elucidate, that the headphone **type B** evinced the smallest fluctuations. Whether it seems to relate on the centric placement of the headphone / speaker near by the pinna or not is to doubt: The headphone **type B1** works as a supra-aural system and could be out of place very simple. On the other hand it is also incomprehensible, why the headphone type / **number 4** based on a centric (5 cm) speaker placement offered the second highest fluctuations. The other headphones enacted smaller 4 cm and a de-centric sound source. Probably it is caused at the headphone **number 4** by the bigger speaker diameter and the larger acoustics influence surface at the outer ear (to imagine: directional filtering via helix, concha reflections / resonance's).

It is pointed out the preferred effect of a frontal hearing image situation via headphones as **type A3** and the much more efficient de-centric speaker placement nearby the pinna. As a negative connected result this headphones were much more spectral intensity fluctuating, which was combined with the above named attested higher quantity of unsteady tone quality judgements. In other words: People were much more *discontented statistically*. So this headphone **type A3** works together much more exactly or individually regarding the human anatomic outer ear surface as it realizes the **type B** including some elevation effects (hearing above or inside the head) at the auditory events. The maximum of an above inside the head localization produced the headphone **number 4**, which makes clear the typical directional band resonance at about 10 kHz, a linear frequency range lower 3 kHz and at the higher range above 3 kHz decreasing intensities (not pusher frontal frequency bands). Furthermore is to point out, that the headphone **type B** reinforces much more efficient the concha area of the outer ear. Against that the headphone **type A** reinforces the concha and the helix parallely (see de-centric speaker placement and the notched 10 kHz frequency range).

5. DISCUSSION - CONCLUSION

Thus the intention of the presented investigations brought a suggestive result: In comparison of four acoustically different headphone systems measurements illustrate exactly the subjective (at the beginning explained) stochastic higher quantity of tone coloration variations for *one* headphone, namely **type A3**. The **type B** is much more resistant against intra-individual pinna fluctuations regarding near-field reinforcing headphones. At the same context it is electro-acoustically proved the test persons rejection of headphones with the effect of an in the head localization of sounds or favored spatial / frontal sound images.

The extracted results are significant enough in spite of the small quantity in tested headphones and "only" seven human test objects. So the research cognition's should be reproducible on different locations by different test persons as well. As a main result beneath is to elucidate the exact placement of the headphone in use. So there miniature speakers must be put up on the outer ear left/right identical centered always. This minimizes superimposed headphone system-related and human anatomic artifacts.

6. REFERENCES

[1] Koenig, F., M.: Neuere Untersuchungen zur klang-beurteilenden Meßtechnik von Kopfhoerern. DAGA 1991, Page 857; further Literature at page 197.
[2] Blauert, J.: Spatial Hearing. The MIT Press Cambridge, Massachusetts London (1983).
[3] Koenig, F., M.: A new supra-aural headphone system for in front localization and surround reproduction of sound. 102. AES Convention Munich (1997), Preprint no. 4495.