

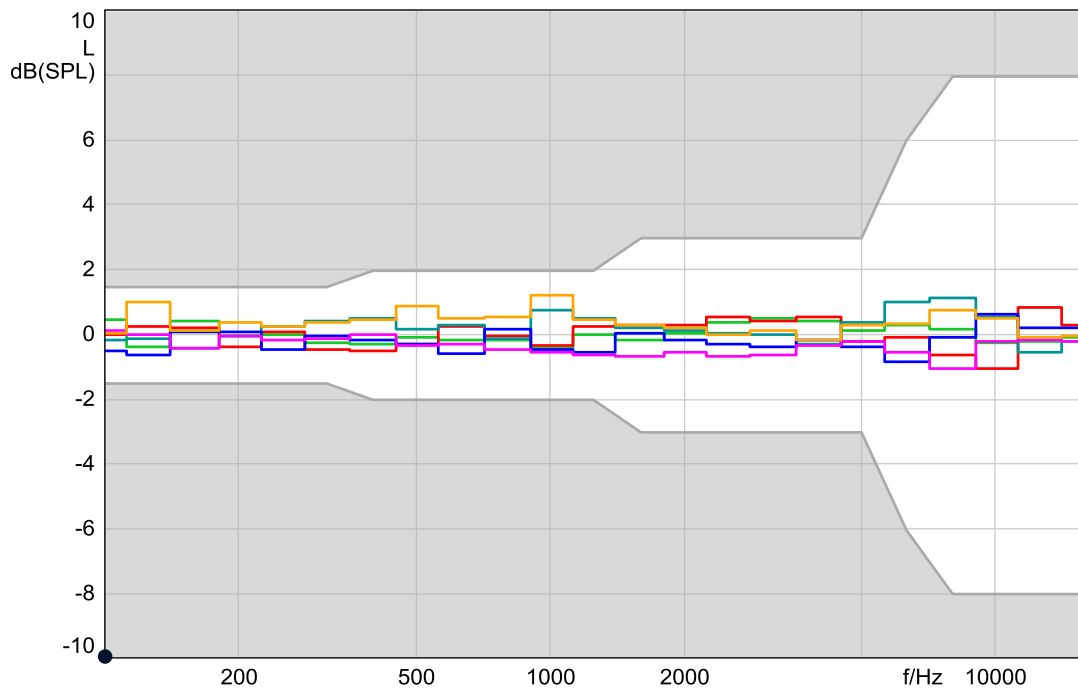
## Comparability of recordings made with measurement systems from HEAD acoustics

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### 1. Comparability of measurements with different artificial heads

When several artificial head sound data recordings are to be compared, it cannot always be assumed that all have been recorded with the same artificial head measurement system. However, since the HMS III artificial head is a calibrated system, it is guaranteed that recordings made with different artificial heads of this type, under identical measurement conditions, are comparable.

To prove comparability, recordings of the same sound source in a diffuse sound field were made with six HMS III artificial heads from different production years. Figure 1.1 shows the differences between the individual recordings and the average of all recordings (only the left channel of each recording is shown). The 3<sup>rd</sup> octave analysis of these differences shows that the frequency response characteristics of different HMS III artificial heads are very similar, proving that measurements recorded with different measurement systems are indeed comparable. Below 500 Hz, the variations are within a tolerance range of +/-1 dB, and above 500 Hz in a tolerance range of +/-1.5 dB.



**Figure 1.1:** Comparison of the response characteristic of six different artificial heads (Difference to the mean value, left artificial head channel); in addition, the tolerances for the response characteristic in the free field specified by IEC 959 are shown as gray curves.

Below 200 Hz, any observed differences are only caused by the measuring setup and not by differences between the artificial heads.

In order to determine these tolerances, the measuring position must be identical for all artificial heads. Otherwise, a comparison would only show the uniformity or lack of uniformity of the sound field, but not the differences in the response characteristic of the artificial heads.

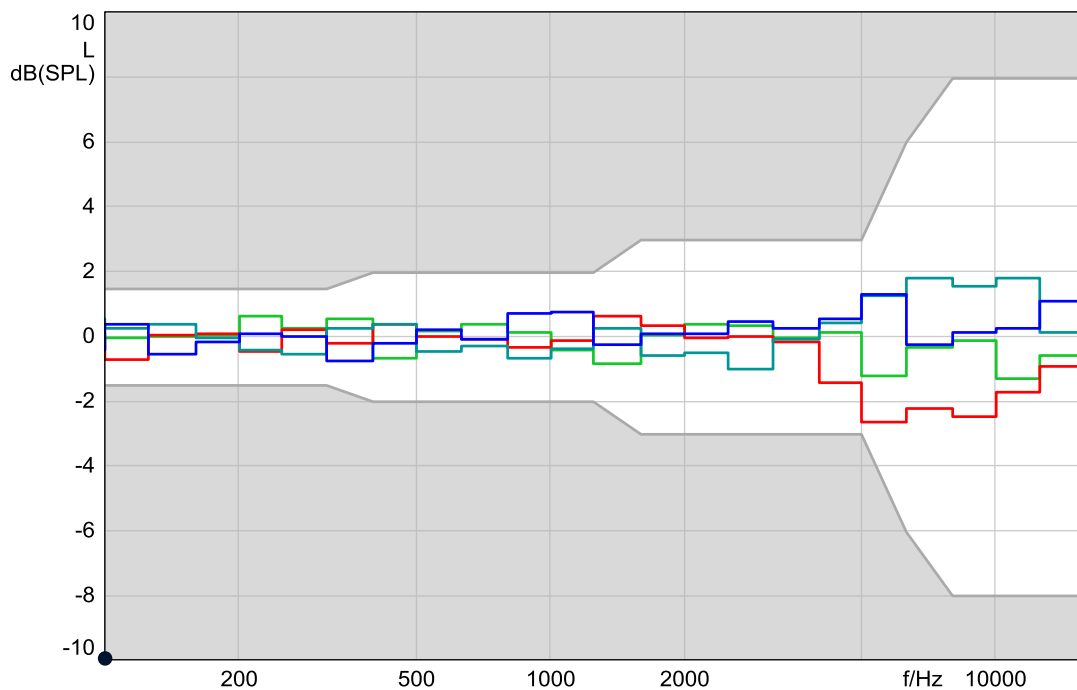
The artificial heads of the fourth generation (HMS IV.0 and HMS IV.1) are subject to the same tolerances, since the production of the components determining the transfer function, such as the head shell, the shoulder unit and the shape of the ears, are subject to the same variations as for the HMS III. Furthermore, the applicable conditions and quality standards for the calibration of the HMS IV artificial heads are identical to those for the HMS III as well.

## 2. Comparability of BHM measurements

### 2.1 Comparability of measurements made with a binaural head microphone (BHM) worn by different persons

Figure 2.1 shows the differences between four BHM recordings, each compared to the average of all recordings. The recordings were made with a BHM that was worn by four different people in a reverberating environment (mixture of direct sound and reflections). All were standing at the same, precisely defined position within the sound field. The diagram shows that below 5 kHz the curves exhibit little difference. Above 5 kHz, the differences increase to values of about 5 dB. These differences are caused by the different statures of the wearers of the BHM. Even small differences in the physiognomy of the persons change the transfer characteristics and thus the recordings.

Furthermore, the positioning of the binaural head microphone on the head of the wearer, and the positioning of the wearer himself, has considerable influence on the measurements. This means that in order to achieve a high degree of comparability between measurements, the wearer of the BHM should take great care to wear it in exactly the same way for all measurements. Furthermore, it is very important to check the position of the BHM within the sound field and keep it as constant as possible, especially when different people are wearing the BHM.



**Figure 2.1:** Comparison of measurements made with a BHM worn by four different persons (Each curve represents the difference to the mean value of the right channel of a person's measurement); in addition, the tolerances for the response characteristic in the free field specified by IEC 959 are shown as gray curves.

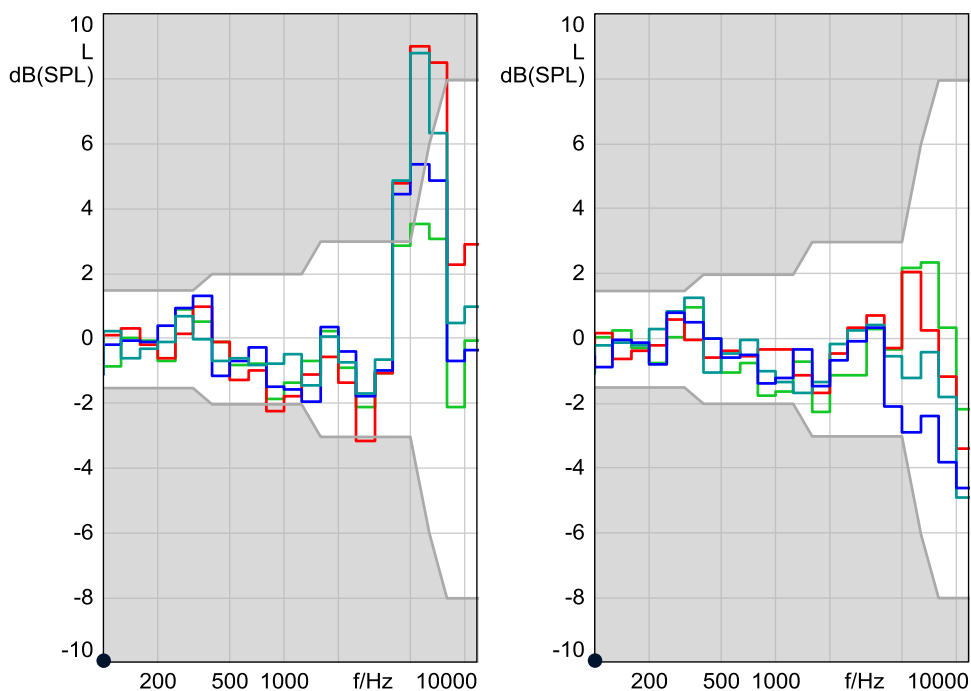
The sound field in the interior of a vehicle can exhibit very strong local differences in frequency and sound level due to resonances, proximity effects and modal and reflective behavior due to the small size of the cabin relative to the wavelengths of sound. If acoustic measurements are made with a BHM worn by two persons of very different stature, and the positioning of the microphones is not checked, considerable differences in the frequency distribution of the recordings can result. This does not mean, however, that measurements made with the BHM are generally not comparable. If it is used correctly, the BHM absolutely allows making reproducible measurements.

## 2.2 Comparability of artificial head and BHM measurements

To achieve comparability between BHM measurements and artificial head measurements (HMS III and HMS IV), the ID equalizations (independent of direction) of the binaural head microphone have been designed to match those of the HMS III/HMS IV artificial head.

Some time ago, this adjustment was done so that a BHM placed on an artificial head showed the same response characteristic after ID equalization as an HMS III/HMS IV artificial head with ID equalization. During the further development of the BHM, however, it was found that this equalization was not really practical, as in real-life use the BHM is not worn by an artificial head, but by people. Therefore, the equalization was redesigned. This time, measurements with several people were made and an average equalization was calculated from the results, which guarantees that a recording made with a BHM worn by an “ideal standard person” in a distributed-sound field environment shows the same response characteristic as an ID-equalized HMS III artificial head.<sup>1</sup>

Figure 2.2 shows a 3<sup>rd</sup> octave analysis of the differences between BHM recordings and an ID-equalized artificial head recording. The BHM was worn by four different people (red, turquoise, purple and yellow curve). The curves in the left diagram show the comparison between the artificial head recording and recordings with the BHM that were made with the old ID equalization. The right diagram shows measurements with the new, improved equalization. With this equalization, the measurements with the BHM match the reference artificial head measurement very well, so that the calculated differences are lower and the tolerance is no longer exceeded.



**Figure 2.2:** Differences between artificial head and BHM recordings using the old (left diagram) and the new BHM equalization (right diagram); in addition, the tolerances for the response characteristic in the free field specified by IEC 959 are shown as gray curves.

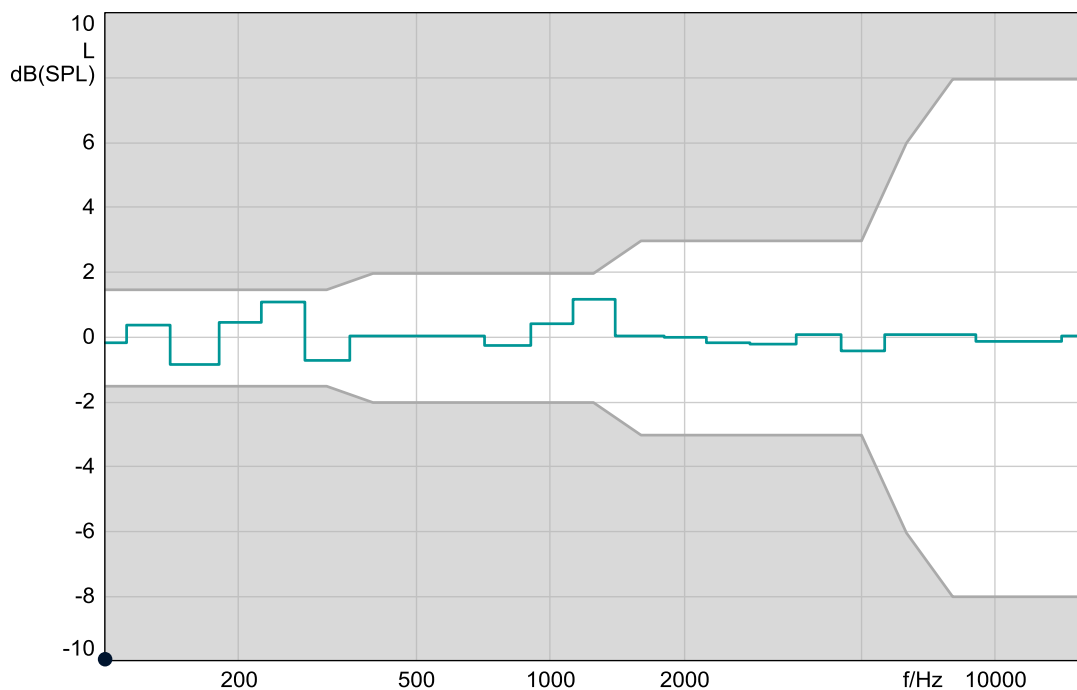
<sup>1</sup> Binaural head microphones with the new equalization were shipped as of October, 2002.

### 3. Comparability of measurements with a HEAD Seat Mount IV and a HEAD Torso Box IV

In order to demonstrate the comparability between measurements with an HMS III artificial head mounted on a HEAD Seat Mount IV (HSM IV) and measurements with the head mounted on the HEAD Torso Box IV (HTB IV), test measurements were made with the following setup:

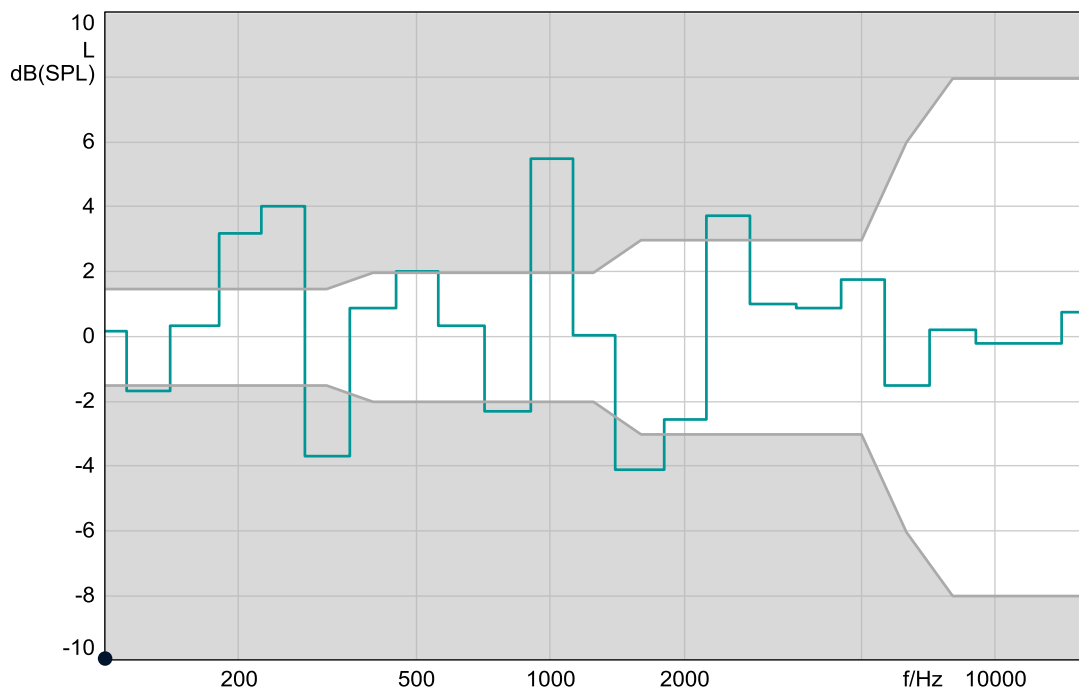
A vehicle cabin was exposed for 10 seconds to a vehicle interior sound that had been recorded during a measurement drive at 150 km/h (93 mph). An HMS III was mounted on an HTB IV and placed on the front passenger seat. Then a recording of the vehicle interior sound was made. The head was set to ID equalization, which is best suited for recordings in a vehicle cabin. Before the comparison measurement with the HMS III mounted on an HSM IV could be performed, the exact position of the head in the sound field had to be determined. Then the comparison measurement was made, for which the artificial head was mounted on the HSM IV and brought into the same position in the cabin as before. All artificial head settings, such as the ID equalization, were left unchanged. The recording of the vehicle interior sound was repeated with this setup.

Figure 3.1 shows the difference between the 3<sup>rd</sup> octave spectra of the two recordings. It is clearly visible that the differences are very small. Only around 300 Hz and 1300 Hz, differences in the region of 1 dB can be found.



**Figure 3.1:** Comparison between measurements with HMS III on HSM IV and HMS III on HTB IV; in addition, the tolerances for the response characteristic in the free field specified by IEC 959 are shown as gray curves.

For a valid comparison, the positioning of the head must be reproduced extremely accurately. If the experimenter neglects this requirement and positions the head inaccurately, significant differences between the measurements far in excess of those due to the mounting means can result. To demonstrate this, figure 3.2 shows a comparison between the two measurements with a deliberately incorrect positioning of the head. The figure clearly shows that the incorrect positioning leads to big differences at frequencies above 180 Hz.

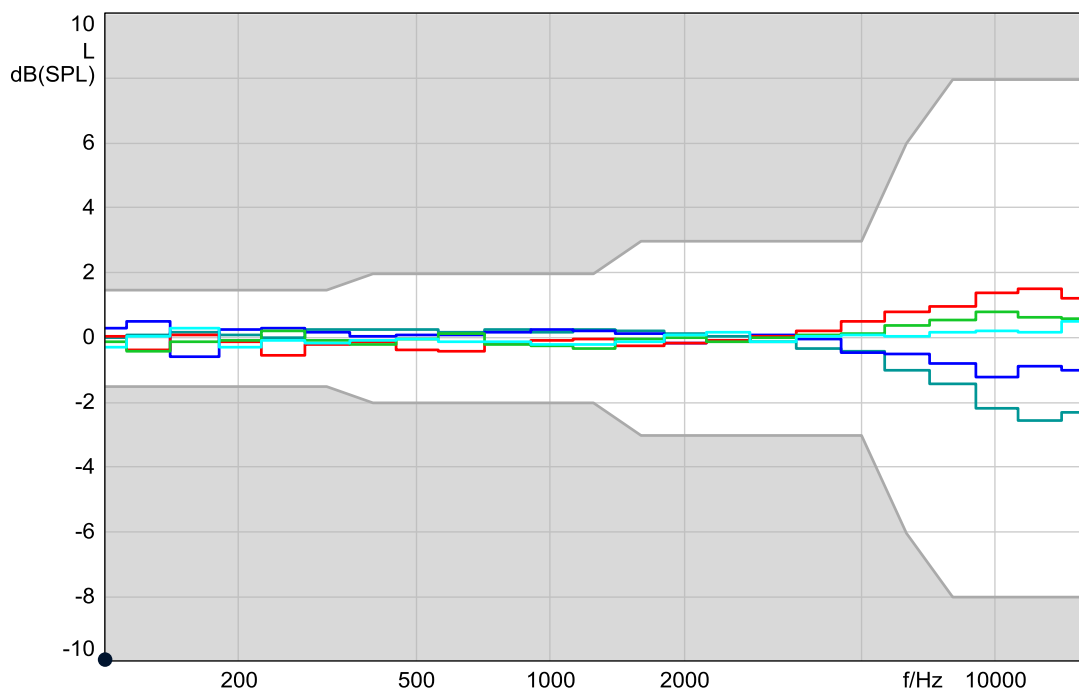


**Figure 3.2:** Comparison between measurements with HMS III on HSM IV and HMS III on HTB IV, without exact positioning; in addition, the tolerances for the response characteristic in the free field specified by IEC 959 are shown as gray curves.

A comparative measurement using a new HTB V and the equally new HSM V would show similar deviations.

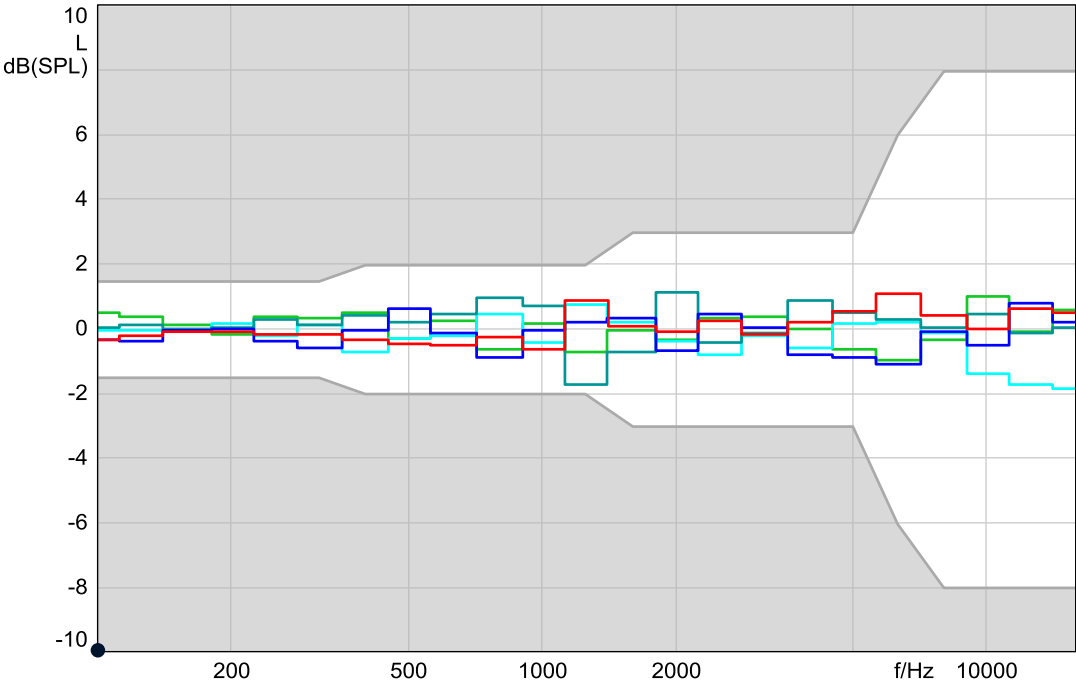
### 4. Comparability of BHS I measurements (Binaural Head Set I on Squadriga I)

Figure 4.1 shows the results of the 3<sup>rd</sup> octave level analysis of BHS I measurements recorded in a diffuse sound field. The diagram shows the recordings of five different headsets, each related to the average value of these five measurements. The results clearly show that the deviations between the individual headsets are very small in the range below 5 kHz and become larger only for higher frequencies. For these measurements, the headsets were not worn by different persons, but placed on the same artificial head always.



**Figure 4.1:** Comparison of the response characteristic of five different BHS I headsets (Difference to the mean value, left BHS channel); in addition, the tolerances for the response characteristic in the free field specified by IEC 959 are shown as gray curves.

If the headset is worn by different persons, the deviations increase. The differences in the response characteristic are caused by the wearers' different physiques and different positions of the headset on the wearers' heads. Figure 4.2 shows the response characteristic of a BHS I. The same BHS I was worn by five different persons in an office-like environment. The sound source was located in front of the persons. The differences to the mean value of these five measurements are shown in figure 4.2 as a third octave band analysis (left channels only). Again, the differences are smaller in the low frequency range than for higher frequencies.

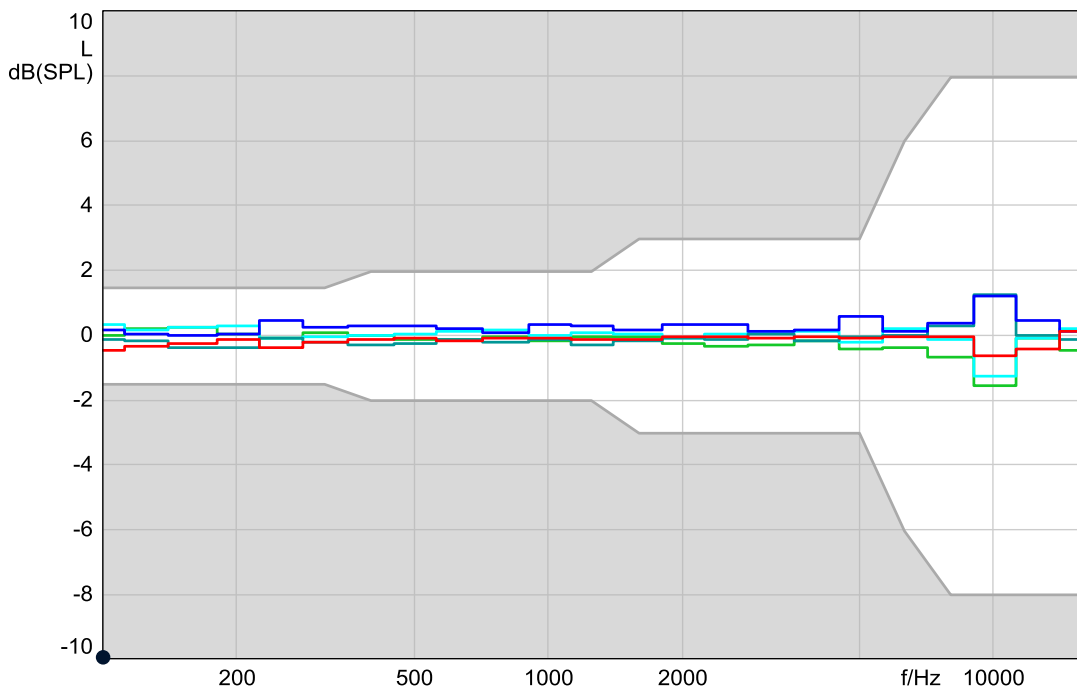


**Figure 4.2:** Comparison of the response characteristic of a BHS I worn by five different persons (Difference to the mean value, left BHS channel); in addition, the tolerances for the response characteristic in the free field specified by IEC 959 are shown as gray curves.



### 5. Comparability of BHS II measurements (Binaural Head Set II on BHS input of SQuadriga II)

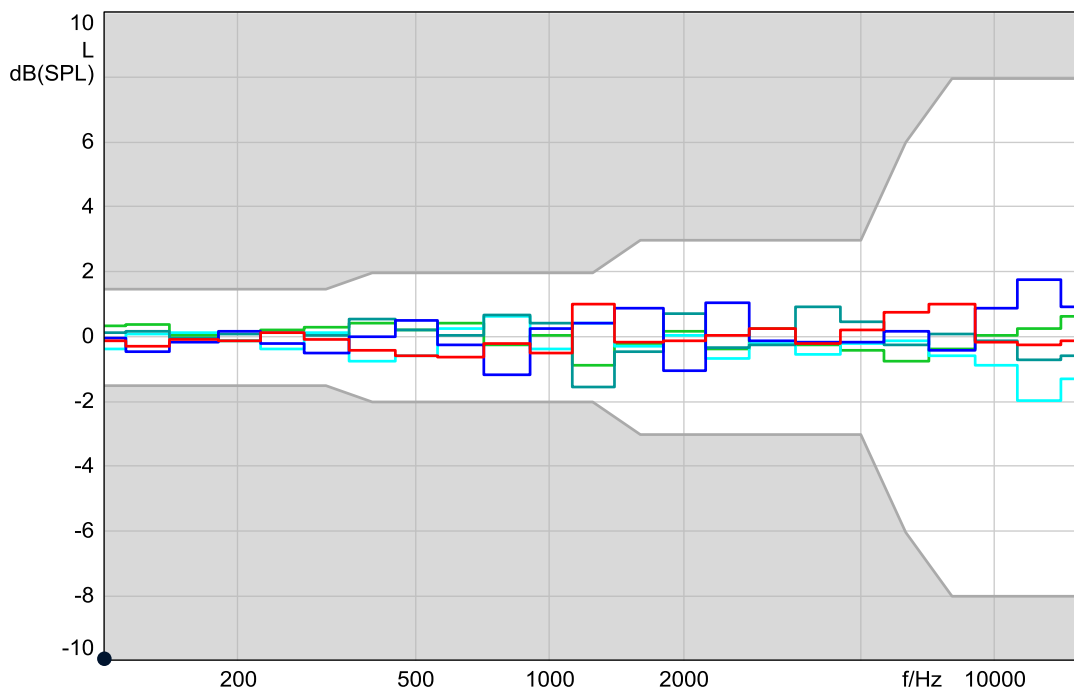
Figure 5.1 shows the results of the 1/3 octave level analysis of BHS II measurements recorded in the same diffuse sound field as the BHS I measurements shown in figure 4.1. The diagram shows recordings of five different headsets, each referred to the average of these five measurements. Just as in the BHS I measurements, the different BHS II headsets were not worn by different persons, but were all placed on the same artificial head. The enhanced technology of the BHS II (custom recording equalization for each BHS II specimen) allowed the differences between the curves to be reduced in comparison to the BHS I measurements (compare figures 4.1 and 5.1).



**Figure 5.1:** Comparison of the response characteristic of five different BHS II headsets (difference to the average, left channels only); in addition, the tolerance limits according to IEC 959 for the response characteristic of an artificial head in a free field are shown as gray curves.

Figure 5.2 shows the response characteristic of a BHS II worn by five different persons in an office-like environment. The sound source was located in front of the persons. The figure shows the differences to the average of these five measurements as a 1/3 octave analysis (left channels only). The measurement was performed in the same way as the measurements with a BHS I shown in figure 4.2.

The differences in the response characteristic between these measurements are caused by the different shapes of the persons and the different positioning of the headset on their heads and occur to the same degree in the BHS II and BHS I measurements. Therefore, the differences between the curves of a BHS II (figure 5.2) and a BHS I (figure 4.2) are comparable. Again, the differences are smaller at low frequencies than at higher frequencies.



**Figure 5.2:** Comparison of the response characteristic of a BHS II worn by five different persons (difference to the average, left channels only); in addition, the tolerance limits according to IEC 959 for the response characteristic of an artificial head in a free field are shown as gray curves.

Do you have any questions or remarks? Please write to:  
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We look forward to receiving your response!