Information on this document

Content

For a correct sound analysis and judgment, it is important to perform both the binaural recording and the playback of the binaural recordings properly. This Application Note points out possible sources of error and explains what should be taken care of when recording and playing back binaural sound files. In addition, the last chapter describes some aspects that can influence sound perception.

Target group

This document is intended for users of binaural recording and playback devices, in particular HEAD acoustics devices.

Questions?

Do you have any questions? Your feedback is appreciated!
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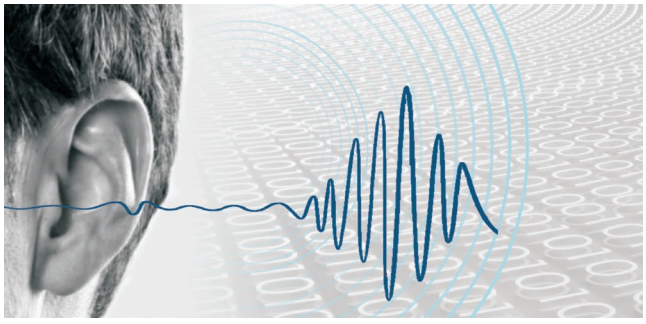
For technical questions on our products: SVP-Support@head-acoustics.com

Binaural recording, playback and evaluation – important notes

1. Advantages of binaural recording

The human hearing as an analyzer

For the evaluation of sounds and a targeted noise optimization, it is often insufficient to consider only a technical measurement analysis such as the A-weighted sound pressure level or a spectrogram. The analyzer „human hearing“ should also be consulted for noise rating. However, the playback of a conventional microphone recording is often inadequate for sound evaluation with the human ear.
Only with binaural measurement technology can sounds be recorded and played back in such a way that listeners perceive them as if they were themselves present in the corresponding sound field. Due to the processing of both ear signals, the human hearing can recognize different directions of sound incidence and select different

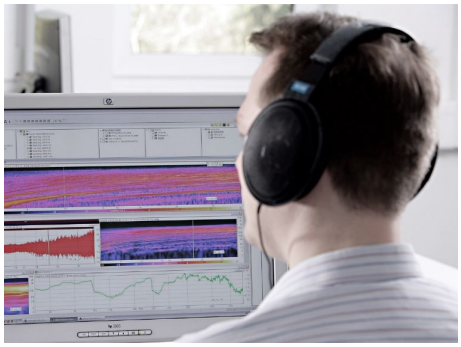


sound sources. Hearing also features high resolution in the frequency and time domains. Binaural measurement technology, with its transmission properties comparable to those of humans, thus allows conventional measurement technology to be extended by incorporating human hearing as a measurement instrument.

Acoustic archive

The sounds could of course be listened to and judged directly at the time of occurrence. However, in many situations this is not possible for technical or organizational reasons; for example, if several people are to judge the same sound from the driver's seat. In addition, recording the sounds with an artificial head allows for the creation of an "acoustic archive", which makes it possible, for example, to compare the interior noise of a series-production vehicle to that of a prototype which has already been recycled.

Combining vision and hearing in analysis



Furthermore, recording a sound has the advantage that, in addition to analyzing the sound with the human ear, the sound data can be subjected to computer-based measurement and analysis. This combination of analyzing through both vision and hearing optimizes sound diagnosis and facilitates targeted sound design.

Correct equalization during recording

Recording equalization

With its external geometry, an artificial head changes a sound field in a way comparable to that of a human being. These changes are intentional, as they allow humans to perceive sounds binaurally when listening to the artificial head recording. Due to these changes, however, the recordings are not directly comparable to measurement microphone recordings. In order to make the artificial head recordings comparable with measurement microphone recordings during measurement analysis, recording equalization is required. Artificial head measurement systems from HEAD acoustics provide three equalization types: Equalization for the standardized sound fields (free field and diffuse field) and an equalization affecting only the direction-independent components of the sound. This equalization type is called *Independent of Direction* (ID) and is suitable, for example, for the interior of vehicles, where neither a diffuse field nor a free field exists.

Figure 1 shows an example of the individual equalization filters for an HMS IV artificial head measurement system.

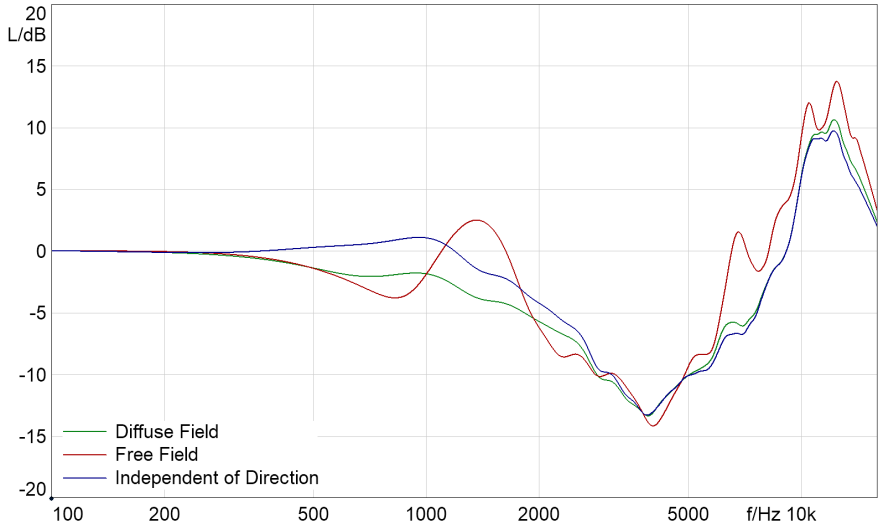


Figure 1: Individual equalization of a HMS IV

Selecting a suitable artificial head

Artificial head for sources far from or close to the ear

In addition to selecting the correct equalization for the corresponding sound field, a suitable artificial head must be selected. HEAD acoustics basically offers two groups of artificial heads. One group is only suitable for measurements of sound sources far from the ear, while the other group can be used for measurements of sound sources close to the ear, i.e., sound sources directly at the ear. An artificial head that has been optimized for the tasks common in the field of NVH is only suitable for far-ear measurements and cannot be used for near-ear sound sources.

Therefore, an NVH artificial head cannot be used to check a measurement and playback chain, in which a headphone is placed on an artificial head. The ear impedance of an NVH artificial head differs considerably from that of a human ear. As a result, headphones that enclose the ears of the artificial head, for example, show a different transmission behavior on the artificial head ear than on a human ear, thus falsifying a control recording. Such a measurement setup can only be used for comparative measurements and not for the determination of absolute values.

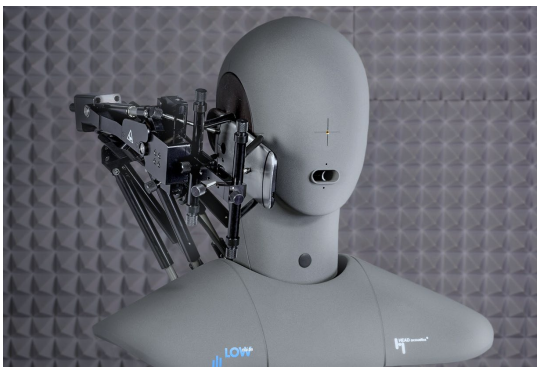


Figure 2: HMS II.3

For measurements close to the ear, HEAD acoustics offers special artificial heads that are used, for example, for measurements of telephone terminals. In sound fields close to the ear, the acoustic load impedance of the ear interacts with the source impedance of the sound source. For this reason, the artificial head is equipped with a replica of ear canal impedances and eardrum impedances for measuring the transmission characteristics of sound sources close to the ear. As soon as the sound source is no longer directly at

the ear, the feedback effects are negligible and an artificial head for sound sources far from the ear can be used.

When using an artificial head for the measurement of headphones, special care must also be taken regarding the positioning of the headphone. Since it is difficult to place the headphone in exactly the same position for each measurement, it is necessary to make several measurements, repositioning the headphone each time. The measurements can then be averaged, if necessary, using appropriate structure averaging techniques.

2. Binaural playback

Reasons for playback equalization

For several reasons, equalization is also needed for playback via headphones: First, the filtering previously performed during recording equalization must be reversed. Second, it must be taken into account that - to put it simply - the sound passes through two ears: the ear of the artificial head during sound recording and the ear of the listener during playback. This distorts the perceived character of the recorded sound and must be corrected by appropriate filtering. Only with calibrated and equalized playback can aurally-accurate playback be achieved, so that the full benefit can be derived from binaural recordings.

For the playback of binaural recordings, HEAD acoustics offers a suitable playback system (e.g., *lab*P2). These systems apply a filter during playback to ensure aurally-accurate playback of the binaural signals.

Figure 3: Playback module labP2

The significance of correct playback equalization

Errors in not using a playback filter

If the correct playback equalization is not applied, e.g., by playing the recording via a simple sound card, the playback will be distorted spectrally, and the listener's impression will no longer match the original sound field. Figure 4 shows the frequency-dependent error at the listener's ears when listening to an equalized binaural recording without applying the correct playback equalization, in relation to the level of a correctly equalized playback. The example was made with a *lab*P2 and a headphone HD VII.

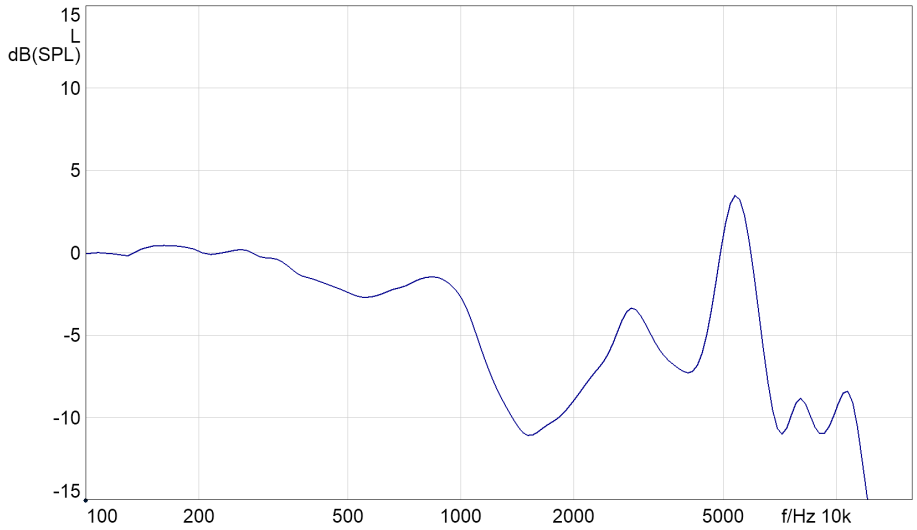


Figure 4: Error at the listener's ears when playing back without correct equalization (example)

The curve will look different for different headphone models. But in any case, it will be frequency-dependent and not negligible.

For accurate and efficient work, the entire recording and playback chain must therefore be matched. Otherwise, the playback will be incorrect across the entire frequency range, leading to changes in the sound perception. And with inaccurate sound perception, reliable sound optimization is not possible.

Notes for aurally-accurate playback

For an aurally-accurate playback, the following must be taken into account:

- If the playback device applies individual playback filters for a specific headphone, this headphone should be connected to the playback device. At HEAD acoustics, the individual playback filters are specifically determined for a specific headphone. The serial number of the headphone for which a headphone output is calibrated can be found above the output connector. The serial number of the matching headset can be found on the back of a SQuadriga/SQobold unit.
- Aurally-accurate playback can only be achieved with a playback equalization that corresponds to the recording equalization. This means that if ID equalization was used for recording, ID playback equalization must be set for playback. Each headphone you purchase together with a playback system from HEAD acoustics comes with a complete set of custom-created equalization filters, including three binaural filters (free field, diffuse field and Independent of Direction).

Other factors affecting sound perception

Even if the playback is performed correctly regarding the technical aspects, a number of environmental factors, the listener's expectations or the playback order can have an undesired effect on the judgment. The acoustician listening to the sounds or the experimenter conducting a listening test should know and take care of the following aspects in order to obtain a valid judgment of the sounds.

Context effects during playback

- The **context of the playback** can have a considerable influence on the judgment of a sound. This can have several reasons:

- **The acoustic characteristics of the recording location differ from those of the playback location:**
  Listeners may be unsettled by discrepancies between the understood acoustics of the experimental room surrounding them and the acoustics of the room in the recording to which they are listening. This is especially true for untrained listeners who are listening to an artificial head recording for the first time. For example, listeners sitting in a large room with sound-reflecting walls will expect sounds with some degree of reverberation. Thus, sounds recorded in an anechoic chamber will not meet the listeners‘ expectations and will be evaluated differently. This effect can best be avoided by ensuring that the recording and playback locations are similar in terms of their acoustic properties. If this is not possible, a training phase before the actual jury test can help the participants to get used to the listening situation. This effect is not due to a technical error of the binaural system, it is due to the remarkable multisensory signal processing of the human brain.

- **The test environment does not fit the sound:**
  Some publications describe tests where sounds were presented both at the location of origin (e.g., in a vehicle cabin) and in a listening room. The comparison of the results of the two test series exhibits considerable differences in some areas. These differences were not caused by a technically incorrect playback, but by the listeners’ different expectations due to the respective environment. Noise from the interior of a vehicle is perceived as very loud by many participants when played back in a quiet room. The same noise, played back in a vehicle cabin, is perceived as less loud by many participants. Just like matching acoustic characteristics, a suitable environment causes an appropriate expectation of the listener and thus a realistic judgment of the sound. For the playback of vehicle interior noise, HEAD acoustics has developed the SoundCar, where vehicle interior noise can be listened to and judged in a real vehicle cabin. In certain cases, an appropriate environment can also be created by a suitable visualization. e.g., using a still image, a movie or an animated scenery on a monitor. A careful selection of the images is important, as they have an influence on the judgment.

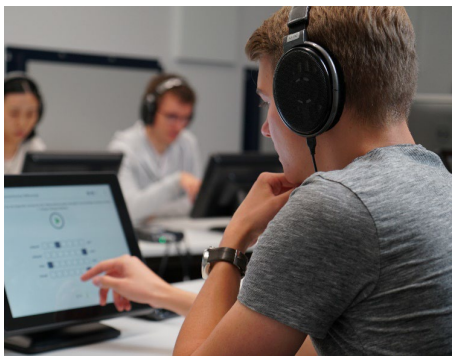
- **Vibrations affect the perception of sound:**
  If airborne and structure-borne sound occur at the same time, e.g., in the interior noise of a vehicle, the structure-borne sound can influence the judgment of the airborne sound. In the SoundCar, the steering wheel and the driver’s seat can be caused to vibrate by means of shakers, allowing an adequate playback of the structure-borne sound. This makes the playback of noise even more realistic. The additional presentation of vibrations can lead to either a better or a worse judgment of the sound. In many cases, this depends on whether or not the vibrations are perceived as “matching” the sound.

Notes on the A/B comparison

- **The playback of sounds in an A/B comparison can influence the judgment**. When a participant is presented test signals in an A/B comparison, the participant is able to identify even small changes, e.g., in the signal level, and includes them in the judgment. In practice, such direct A/B comparisons are hardly possible. For example, in reality the noise of a certain type of aircraft cannot be compared immediately, to the noise of another type, since it takes some time until the first plane passes by. Usually, the human hearing system relies on certain patterns in sounds for identification. These patterns can be stored in long-term memory and used for the judgment. In an A/B comparison, on the other hand, it is also possible to use the sound pressure level information stored in short-term memory for the judgment. This can lead to different judgments in listening tests compared to reality. This fact must be taken into account in the design of listening tests. If a listening test is meant to examine the capabilities of human hearing to detect differences in parameters like frequency or signal level, a test design with A/B comparisons is appropriate. In most cases, when evaluating the quality or the annoyance of noise, an evaluation without direct comparison, i.e., with a time gap between presentations, is more suitable.

General notes on evaluations performed by test participants

When conducting listening tests, it will probably not be possible to take all of the above aspects into account in all cases. However, the experimenter should be aware of these effects and consider them in evaluating the results. That way, distortions in the sound judgments can be interpreted and accounted for appropriately. Furthermore, it is important to point out that a participant who is influenced, for example, by an unrealistic environment, is not doing something “wrong”. The participant’s expectations will always affect their sound judgments in a specific form, because the participants cannot abstract their perceptions from their expectations and thus cannot make uninfluenced judgments. This means that such errors cannot be “corrected” by the participant, but only by an appropriate test design.



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