APPLICATION NOTE

About this document

Content

This document is the third of three application notes on spatial hearing and binaural measurement technology. This application note explains when recording equalization is necessary for binaural recordings and introduces the different types of equalization.

Target group

This document is intended for acousticians who are interested in the aurally-accurate recording of sound signals. Especially users who want to know more about recording equalization of binaural recordings can benefit from the information provided.

Questions?

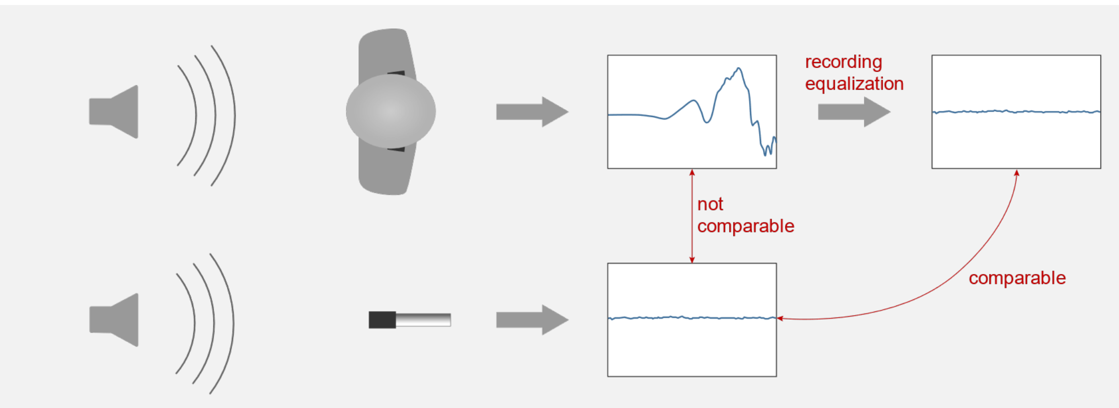
Do you have any questions? Your feedback is appreciated!
For questions on the content of this document: Imke.Hauswirth@head-acoustics.com
For technical questions on our products: SVP-Support@head-acoustics.com

Equalization of artificial head recordings

Introduction

Due to its outer geometry, an artificial head changes a sound field in a comparable way to human beings. These changes are intentional, as they allow humans to perceive sounds binaurally when listening to artificial head recordings[1]. Due to these changes, however, the recordings are not directly comparable with measurement microphone recordings. In order to make the artificial head recording comparable with measurement microphone recordings for technical measurement analysis, recording equalization is required.

A recording equalization is a filter that is applied to the recorded signal during recording. This filter is referred to as *equalization filter* because the sound that was previously altered (distorted) by the artificial head is equalized again by this filter, and thus made comparable with conventional measurement microphone recordings.



[1] The advantages of the binaural recording technology are summarized in the second chapter of the application note „Binaural recording using an artificial head".

1. Compatibility through recording equalization

Changes in the sound field

While the sensitivity of sound recording in a measuring microphone is independent of the direction of sound incidence, an artificial head changes the sound field with its geometry based on the human anatomy. These spectral and level changes, which occur both directionally and non-directionally, are not errors but desirable. They enable aurally-accurate playback, allowing humans to listen to sounds as if they were in the original sound field. Figure 1 shows the directional and non-directional changes in the sound field caused by the artificial head.

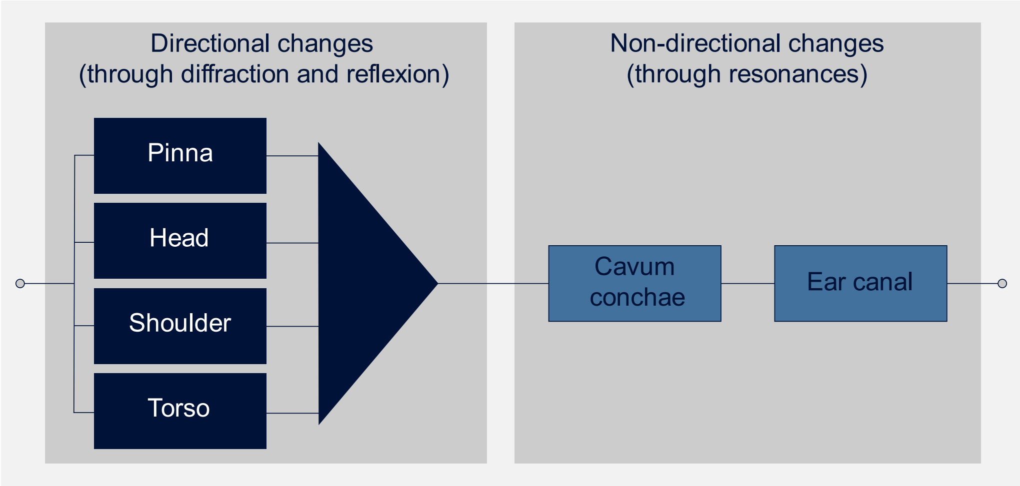


Figure 1: Directional and non-directional changes in the sound field

Compatibility with measuring microphone

However, due to linear distortions caused by the artificial head's head-related transfer function, the artificial head signals are not compatible with conventional measuring microphones. This means, for example, that the A-weighted sound pressure level cannot be measured usefully with a non-equalized artificial head measurement system. A simple spectral analysis is also not meaningful. And proven psychoacoustic analyses, like loudness calculation according to Zwicker, are based on a recording that is comparable to a measuring microphone.

Thus, for the purpose of analysis, the directional and/or non-directional changes need to be subtracted (equalized) from the artificial head recording, resulting in a sensitivity level comparable to that of a conventional measuring microphone and achieving measurement compatibility between artificial head recordings and conventional recordings.

Interface for loudspeaker playback

In addition, equalization creates an interface that allows the user to perform tone-color neutral playback not only via headphones, but also through a stereo loudspeaker system.

2. The different types of equalization

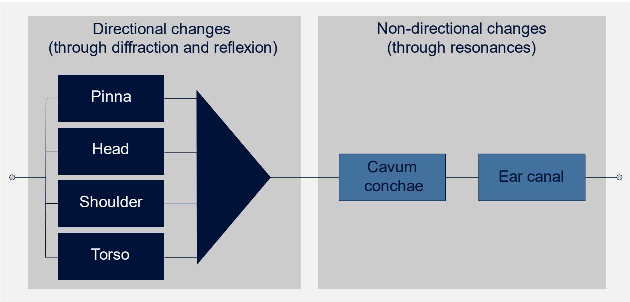
Three recording equalizations

The filter curve required to make an artificial head recording comparable to a microphone recording differs depending on the direction of sound incidence. For example, a different filter is required for sound arriving directly from the front than for sound arriving from all sides. HEAD acoustics offers three different recording equalization options for the artificial head measurement system:

- **Free Field (FF):** sound incidence from the front in an anechoic environment with the sound source located at least 3 m away from the artificial head at the height of the artificial head ears. The recording equalization for this sound field situation can be determined in terms of measurement technology by using an appropriate measurement setup in a free field.
- **Diffuse Field (DF):** sound incidence from all directions with the same spectrum. The recording equalization for this sound field situation can be determined in terms of measurement technology by using an appropriate measurement setup in a diffuse field.
- **Independent of Direction (ID):** equalization of directional resonances of the cavum conchae and ear canal entrance. This recording equalization can only be determined mathematically.

Free-field and diffuse-field equalization

In free-field conditions and sound incidence from the front, an FF-equalized artificial head exhibits a frequency-independent transfer function. A DF-equalized artificial head in diffuse sound field conditions exhibits a frequency-independent transfer function. In both sound field situations, the non-directional transmission properties are taken into account. With FF equalization, the directional transmission properties for sound incidence from the front are also equalized, while, in the case of DF equalization, additional filtering is performed for the complex superposition of all directional parameters. Both equalizations therefore contain not only non-directional but also directional parameters - the FF equalization for exactly one direction of sound incidence and the DF equalization as an integral over all directions of sound incidence.



ID equalization

These two types of equalization can be contrasted with another type, a directionally neutral equalization that is independent of the sound field. Based on a system-theoretical description of the artificial head outer ear, it involves only the correction of the non-directional parameters, i.e., the resonances generated by the cavum conchae cavity and the ear canal entrance. Since this equalization only corrects the non-directional changes, it is called ID equalization (Independent of Direction).

Comparison of the types of equalization

The differences between the three types of equalization are not great. The differences between the head-related transfer functions of individual subjects are sometimes much greater than the differences caused by the individual types of equalization. Figure 2 shows the individual equalizations of an HMS IV.

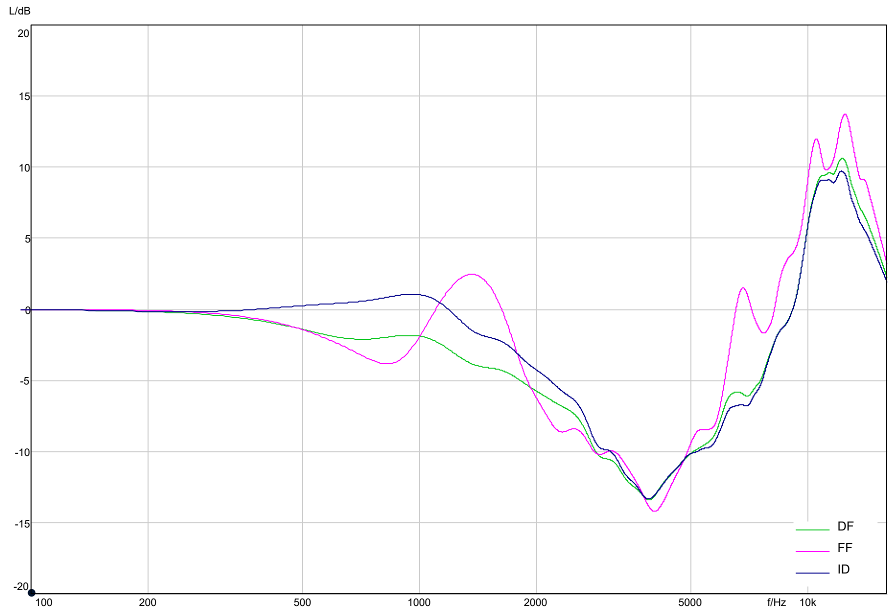


Figure 2: Individual equalizations of an HMS IV

In all three types of equalization, the main contribution results from the equalization of the resonances in the cavum conchae and the ear canal entrance. Independent of the direction, these resonances amplify the sound impression in the spectral range above 3 kHz and have to be corrected by all of the types of equalization by using appropriate filters with exactly inverse transfer functions. This means that the curves of the three types of equalization are basically quite similar.

Differences occurring in FF equalization are caused by the fact that in this equalization, components are equalized that specifically arise in the case of sound incidence exactly from the front in the free field due to diffraction and reflection at the upper body, shoulder, head, and auricle. This results in some sharp dips and rises in FF recording equalization.

Difference between DF equalization and ID equalization

With DF equalization, the components arising from diffraction and reflections are equalized and averaged over all directions of sound incidence. The sharp dips as with FF equalization due to individual reflections are no longer present. This also applies to ID equalization, in which only non-directional influences are equalized. Thus, DF equalization is very similar to ID equalization. The main difference between DF equalization and ID equalization is the broad boost of about 3 dB in the frequency domain around 1 kHz (see Figure 3), i.e., this domain is lowered to a greater extent with a DF-equalized artificial head than with an ID-equalized artificial head.

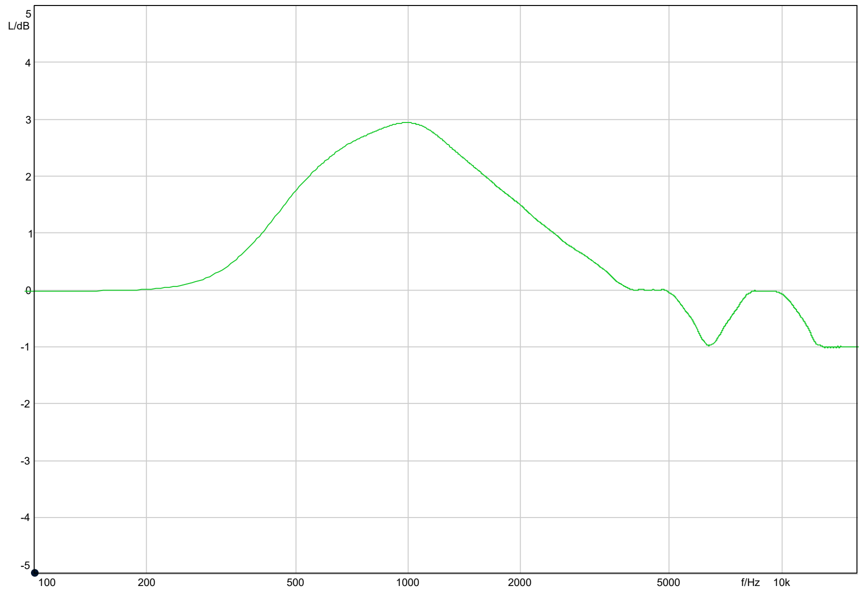


Figure 3: Differential curve between ID and DF equalization

3. Selection of the recording equalization

Fundamental rule

Comparability with measurement microphone recording only exists if the correct equalization is used for the present sound situation. Thus, in principle, the sound field situation present during the measurement must always be taken into account when choosing the appropriate equalization.

Use of the FF equalization

FF equalization allows for exact measurement specification, and the reproducibility and repeatability of free-field measurements are very high. When measuring with an artificial head with sound incidence exactly from the front, a significant dip occurs due to a refection in the cavum conchae. An FF equalization for an artificial head microphone therefore requires a corresponding amplification of this frequency region. However, this reflection is greatly reduced by even a slight change in the direction of sound incidence. Figure 23 illustrates this fact with the example of changing the head-related transfer function of an individual test subject when the sound source in the horizontal plane is deflected by 2° from the median plane.

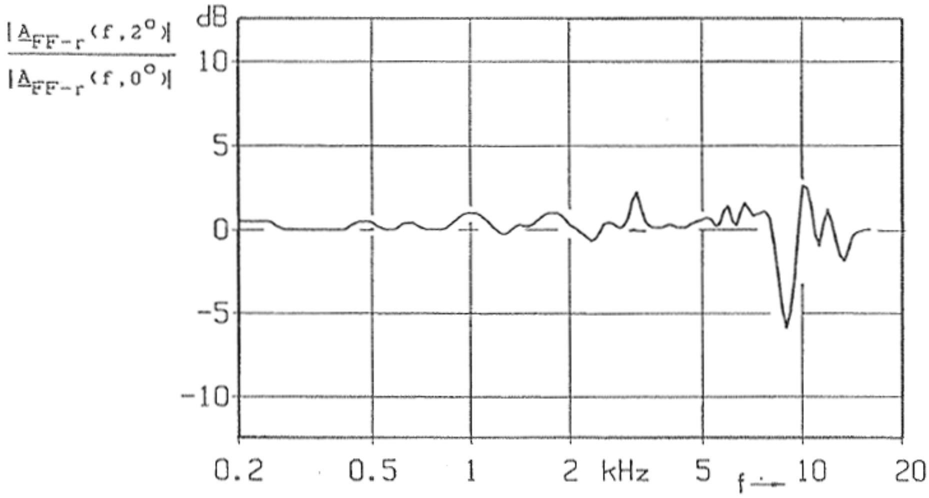


Figure 4: Change in the magnitude of the head-related transfer function of an individually measured test subject when the sound source is deflected by 2° from the median plane (Genuit: Ein Modell zur Beschreibung von Außenohrübertragungseigenschaften, Dissertationsschrift, 1984 [A model for describing head-related transfer function properties, PhD thesis, 1984])

In the case of FF-equalized recordings of sound sources which are located in the free field but not exactly in front of the artificial head, an unnatural increase of the amplified frequency domain usually occurs during the measurement evaluation. This also applies, for example, to an outdoor pass-by measurement. The FF equalization would only be correct for the moment when the car is exactly in front of the artificial head. However, this is not possible due to the dimensions of the vehicle.

Use of DF equalization

DF equalization could be used to circumvent this error. However, compared to the free field, a physical diffuse field is poorly reproducible. Furthermore, real diffuse fields are difficult to realize in practice and occur only very rarely.

Use of ID equalization

In summary, the following recommendation can be made for the selection of equalization: FF equalization can be used for measurements in anechoic chambers (sound source with low extension (small size) directly in front of the artificial head at a distance of at least 3 m). DF equalization can be used for measurements in diffuse sound fields, such as may occur in a concert hall. For other sound field situations (e.g., measurements in road traffic or in the interior of a vehicle), ID equalization can be used, since these sound fields do not really correspond to either the free field or the diffuse field.