APPLICATION NOTE

About this document

Content

This document is the fifth of five application notes on transfer path analysis (TPA). It provides guidance on how to validate the TPA model and calculated results to increase confidence in the data obtained.

Target group

The following text is primarily intended for (potential) ArtemiS SUITE users who would like to learn more about the types of tests available in this software.

Questions?

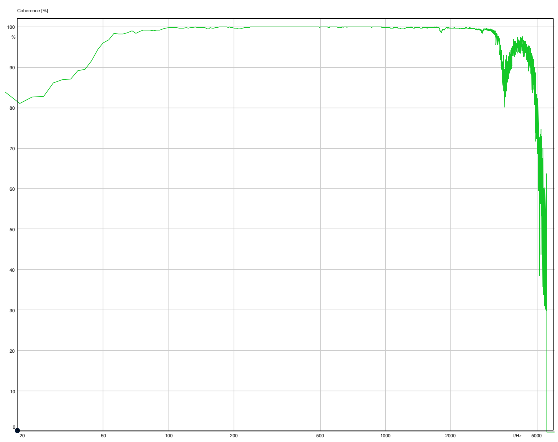
Do you have any questions? Your feedback is appreciated!
For questions on the content of this document: Imke.Hauswirth@head-acoustics.com
For technical questions on our products: SVP-Support@head-acoustics.com

Transfer path analysis – result validation

In order to verify the measured data and the calculated models and to find out where their limits are, the TPA results have to be validated. There is no universal procedure for this validation, but some methods and tools are available to estimate the validity within a reasonable amount of time.

High quality of the measurement data

The first requirement for good TPA results refers to the measurements performed: good results are based on good measurement data. In addition to the analysis of the time signals and resulting transfer functions, it is the coherence and the signal-to-noise ratio, for example, that provide important information on the quality of the acquired data. (Further explanations on how to perform the measurements in practice can be found in Application Note TPA – Part 4).

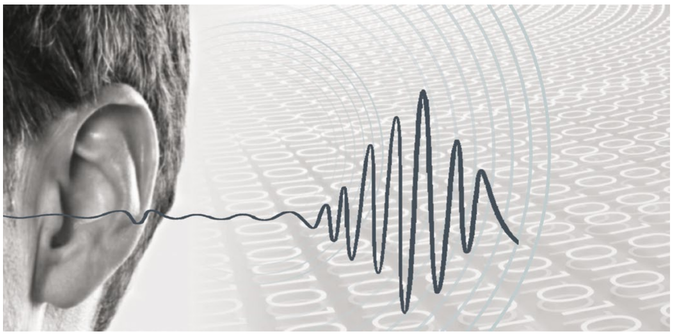


Coherence over frequency of an impact hammer

1. Validation of the TPA model

Comparison: measured and synthesized sounds

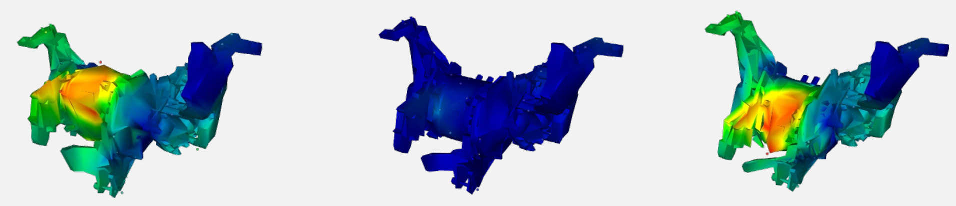
In order to check the validity of the TPA results of a real system, the first step is to sum the individual sound components and to compare the calculated overall sound with the sound measured at the receiver position. For this purpose, the sounds are investigated by performing technical measurement analyses. Furthermore, sounds must also be listened to so that they can actually be evaluated as a match. The human sense of hearing is a very precise analyzer. By listening, for example, frequency ranges in which interference occurs can be identified. If there is a discrepancy between calculated and measured sound, the TPA model needs to be adjusted. Possible "adjustment controls" for doing this are matrix regularization, overdetermination (more response points than excitation points), definition of submatrices (division of the model into independent subsystems), and a suitable selection of transfer functions (measured with hammer, steel or plastic tip or a composite function).



Comparative listening of synthesis and original sound

Root cause analysis

However, good agreement between synthesis and measurement alone is not sufficient as a quality indicator. If synthesis and measurement agree well, the important transfer paths must be identified and a root cause analysis performed. Root cause analysis is an elementary part of TPA and allows the system under investigation to be understood and, for example, to trace the cause of a noise problem. In doing so, the relevant path from the source to transfer paths to the resulting noise contribution is investigated. This provides important information as to whether the disturbing noise is caused by the source or by the transmission, and here a distinction can be made between whether the sensitivity or the structure is causing the disturbing noise. If the problem is structural, a modal analysis can subsequently help to find the causes of the problem, e.g., by assigning the cause to a specific vibration mode.

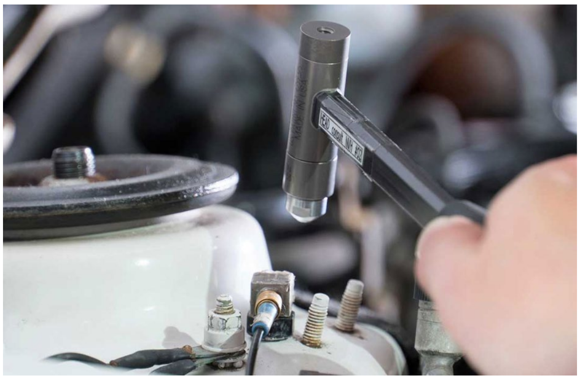


Vibration modes of a powertrain

2. Modifications and validation measurements

Validation measurements

In order to further validate the TPA model, validation measurements are recommended to be performed on the critical transfer paths. For this purpose, impact hammer tests are performed again, with the impact positions slightly different from the original ones, but still located on the selected cutting plane. Furthermore, as in the previous measurements, all acceleration sensors are also recorded. However, the measured accelerations are not used to determine transfer functions, but are instead considered as new operational measurements and convolved with the previously determined apparent mass. This allows a new force excitation (which is unknown to the TPA model) to be synthesized and compared to the force excitation recorded during the validation measurement.



Validation measurement using an impact hammer

In addition, further receiver sensors can be positioned. These are used to determine an additional receiver transfer function which can then serve to synthesize a vibration at this receiver point.

This procedure is also applicable to the airborne sound paths. For this purpose, validation measurements are performed with the volume velocity source.

Machine Learning

Given the fact that the TPA model depends on many parameters that may be unknown at the time of model definition, it may be helpful to benefit from the concept of “machine learning”. To this end, the measurements that were performed as part of the TPA Project can be divided into the categories “training data” and “test data”.

- Training dataset: This dataset is used to determine the transfer functions and set up the TPA model. “Adjustment controls” for the training are: regularization, overdetermination, submatrices, and selection of the transfer functions.
- Test dataset: This dataset consists of the collected operational data.
- Validation dataset: This dataset is used to optimize the TPA model.

Overfitted models

If the TPA model actually performed very satisfactorily, but fails in the validation measurements, this is an indication that the TPA model is overfitted to the training data. If the model is overfitted, it is working “too well” for the training data but inadequately for unknown data. In most cases, the cause of overfitting is an insufficient dataset for training. When collecting additional data, it is important to ensure that these are representative of the complexity of the system under investigation. Thus, the goal is not to simply collect more data. Instead, data are to be collected that provide additional information and comprehensively represent the complexity of the system.

Verification by modification

Furthermore, the TPA results can be directly verified by performing measurements after the test object has been physically modified. This method is more time consuming, but can significantly increase confidence in the TPA model. With this method, for example, the transfer path which has been identified as being crucial for disturbing noise at the receiver position is physically modified (e.g., by adding additional mass, attaching an absorber weight). Afterwards, a new operational measurement is performed. Based on the new operational measurement, a new receiver noise is synthesized which is then again compared to the measurement on the modified product. If the prediction shows the same tendency as the measured sound, the TPA model has been confirmed.

Next generation sound optimization

Our application notes on transfer path analysis demonstrate the holistic approach HEAD acoustics uses. This enables us even in very complex systems to identify the essential characteristics of noise generation, to develop targeted solutions and to integrate them into the product development process at the earliest possible stage.

HEAD acoustics' portfolio includes multichannel measurement technology, structural analysis and TPA software, as well as services ranging from project implementation to know-how transfer to method development.

How can we support you? Contact us at: sales@HEAD-acoustics.com