Psychoacoustic uncertainty analysis of an acoustical transfer path

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Abstract

An uncertainty analysis of acoustical systems is usually performed for identification of the physical quantities such as sound pressure or sound energy. It is rarely used, however, for evaluation of psychoacoustic factors. In this study, it was implemented an uncertainty model with an acoustical transfer function and with a signal from an electric engine noise as tonal input excitation. Then it is introduced a variation in sensor positioning as input uncertainty. In order to study the influence of sensor positioning on psychoacoustic measures, a simulation and objective uncertainty models are used, and then the subjective cues represented in the psychoacoustic measures are investigated.

Introduction

Transfer path analysis (TPA) is a well-known method to trace the flow of airborne and structure-borne energy from the excitation sources to the given receiver in the frequency domain. Transfer path measurement involves arrangement of a measurement chain, positioning of the sensors and actuators, adjustment of the excitation force, etc. In the process of transfer path measurement, input uncertainties are introduced to the target pressure and vibration via repositioning of sensors and actuators, environmental changes, and deviation in structure of the system.

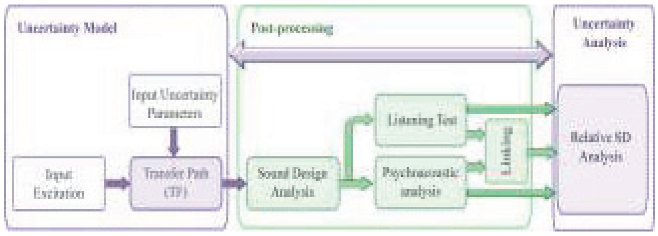
In vehicles, a transfer path measurement could be arranged from the engine excitation to the passenger compartment. In this case, the actuator is a shaker to imply the impact of engine on the structure of the system and sensor is a microphone inside the vehicle cabin to measure the sound pressure level.

A possible question here is that how the input uncertainty changes influence the psychoacoustic parameters (sound quality metrics) inside the passenger compartment. This question can be answered by the following analyzing step:

Uncertainty modeling: analyzing the uncertainty of the vibro-acoustical system with variety input excitations.

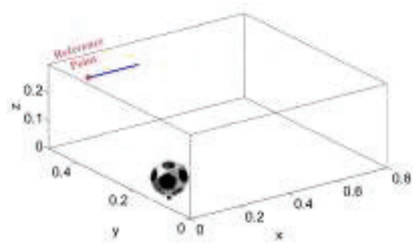
Post-processing: providing the post processing of the uncertainty model.

Uncertainty analysis: linking the deviation analysis of the objective and subjective outputs of the post-processing step to the uncertainty model.



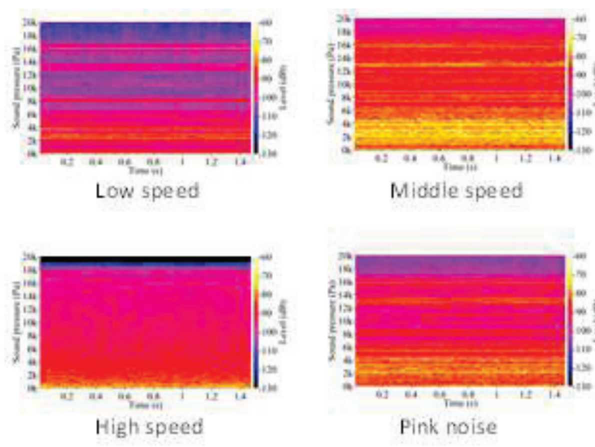
Case Study

The case study is the uncertainty analysis of the psychoacoustic parameters within a simple acoustical transfer path with the sensor displacement.



Input Excitation

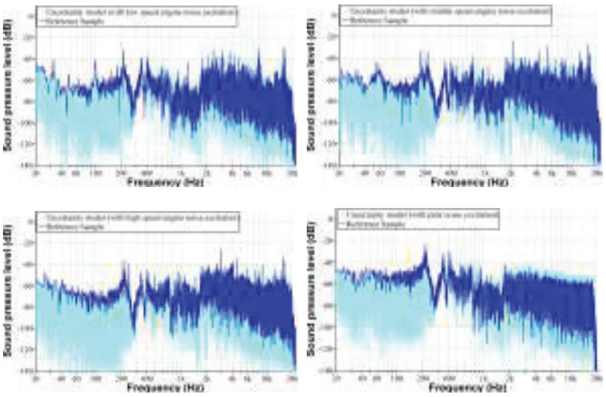
The input excitations are grouped in two categories of tonal and broadband excitation. A sample of electric engine noise at low, middle and high speed is used as tonal noise, and pink noise as a broadband excitation. The electric engine is a permanent magnet synchronous machine (PMSM), series 19, model 1920.



Uncertainty Parameters

A broad range of input uncertainty parameters could be realized during the transfer path measurement, among which, sensor positioning is one of the most expected uncertainty sources. In this study, the sensor positioning in the measurement line inside the enclosure is simulated as the input uncertainty. The line displacement facilitates the perception analysis in the feature study.

In total 211 transfer paths are calculated within the receiver line inside the box with displacement resolution of 1 mm from the reference point. The transfer path of 211 samples are plotted in the following figure for each type of the input excitations, the dark blue color indicates the TF of the reference sample.

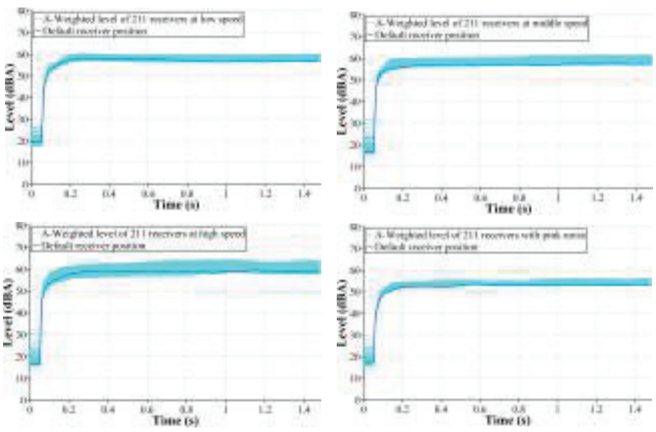


Psychoacoustic Analysis

Psychoacoustic is the field which connect the sound stimulus and the hearing sensation [1]. Thus understanding the feature of hearing organ is an essential step in the psychoacoustic analysis. Psychoacoustic concept rates according to 17 parameters [2]. The purpose of this study is to look into the influence of input uncertainties on the most important psychoacoustics parameters, e.g: Level, Loudness, sharpness, fluctuation strength and roughness.

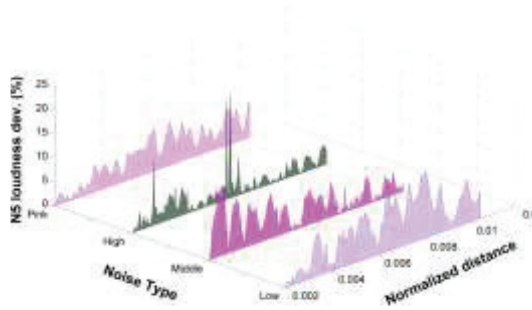
Level Uncertainty Analysis

The A-Weighted level is plotted in time for each group of input excitations. With the normalized samples, the A-weighted analysis gives approximately 60 dBA, for the system with engine noise excitations, and 50 dBA for pink noise excitation.



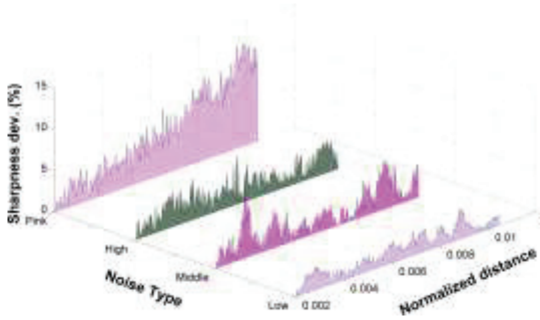
Loudness Uncertainty Analysis

The 5% percentile loudness (N5) of each sample with respect to the reference sample is calculated and presented in the following figures. The vertical axis is calibrated to the geometrical length of the acoustical system, and the deviation is calculated in percentages:



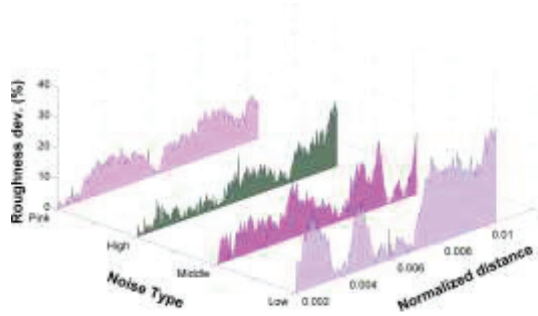
Sharpness Uncertainty Analysis

The sharpness deviation in each sensor position is obtained via calculation of the single sharpness value and the deviation of each sample from the reference sample.



Roughness Uncertainty Analysis

The deviation of the single value of the roughness in compare with the reference sample is calculated in each distance and illustrated in the following figure:



Conclusion

The Impact of the sensor positioning uncertainties on the acoustical transfer path measurement with four types of input excitations was obtained, and then its influence on the psychoacoustic parameters was investigated. The relative deviations of the psychoacoustic parameters (level, loudness, sharpness, fluctuation strength and roughness) were obtained and the results were discussed.

Reference

[1] FASTL, H. and ZWICKER, E. (2007). Psychoacoustics: facts and models. Vol. 22. Springer Science & Business Media

[2] PEDERSEN, T. H. (2008). "The Semantic Space of Sounds". In: Delta (cit. on p. 78).