Subjective and objective characterisation of tonal components in tyre/road noise

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Introduction

An important factor for the generation of tyre/road noise is the geometry of the tread pattern. The pattern noise is a tonal component of the tyre/road noise with speed dependent frequency. A perceivable pattern noise leads to a decreased quality rating in a subjective evaluation of tyre/road noise.

In order to find an objective measure for the subjectively perceived pattern noise, different tyre/road noises are evaluated in a paired comparison test.

The subjective evaluation of pattern noise can be referred to objective parameters calculated from the signal with and without an aurally adequate signal analysis.

Pattern noise

Pattern noise is generated at the contact area between tyre and road while rolling. It is speed dependent and occurs, according to the distribution of of tread pattern elements, around the 60th order of the tyre revolution. This order range is called the first pitch harmonics.

As shown in [1] the pattern noise strength increases with increasing level of the first pitch harmonics.

Subjective evaluation of pattern noise

Signals

The signals are one tyre/road noise recording and modifications of this signal. The recording was done with an artificial head on the front passenger seat while the car is coasting and spans a decrease in speed of 10 km/h.

The modifications are the amplification of the first pitch harmonics by 0.5 and 1 dB. Also the spectral shape of the first pitch harmonics is changed: a range of one third around the mean of the first pitch harmonics is amplified by 2 or 4 dB or a range of two third around the mean of the first pitch harmonics is amplified by 4 dB. Then the whole first pitch harmonics is attenuated to the prior level. Altogether twelve signals are evaluated.

In order to eliminate the influence of the overall level on the judgment, it is held constant.

Subjects

The evaluation of pattern noise is done by subjects untrained in evaluating tyre/road noise. Ten subjects take part in the experiment.

Subjective evaluation

In a paired comparison experiment a ranking and Thurstonian scale values according to the judged pattern noise strength are obtained. As shown in [2] the method of paired comparison is adequate for the evaluation of pattern noise by untrained subject.

The experiment is carried out in a soundproof chamber. The signals are presented via headphones. The subjects' task is to decide, which of the two signals presented contains the stronger pattern noise. The subjects can repeat the signals as often as they need to be sure of the answer. Each subject performs four complete paired comparisons.

Analysis

First the data sets are checked for consistence. In the further analysis only data sets with a coefficient of consistence greater or equal 0.7 are regarded.

From the consistent data sets Thurstonian scale values are calculated. These values represent the signals on a scale of subjectively perceived pattern noise strength. There the signal with the least pattern noise has the scale value "0".

Thurstonian scale values

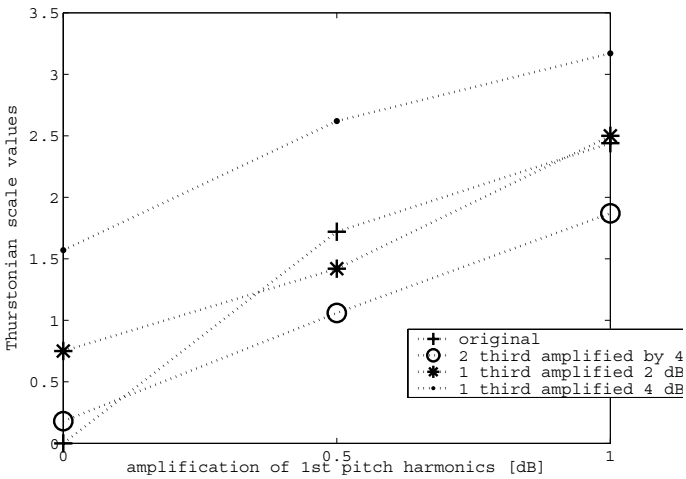

Figure 1: Thurstonian scale values in dependence of the amplification of the first pitch harmonics for each spectral shape.

The Thurstonian scale values are plotted against the amplification of the first pitch harmonics for each spectral shape in figure 1. It can be seen that for each spectral shape the Thurstonian scale value increases with increasing amplification of the first pitch harmonics. So these data are in line with the findings of [1].

Also a connection between the different spectral shapes and the Thurstonian scale values can be seen. The modified spectral shapes show the same ranking across all three levels of the first pitch harmonics. Only the original spectral shape is an exception, since it's evaluated pattern noise strength compared to the other spectral shapes varies.

Relation to objective signal parameters

Level of the first pitch harmonics

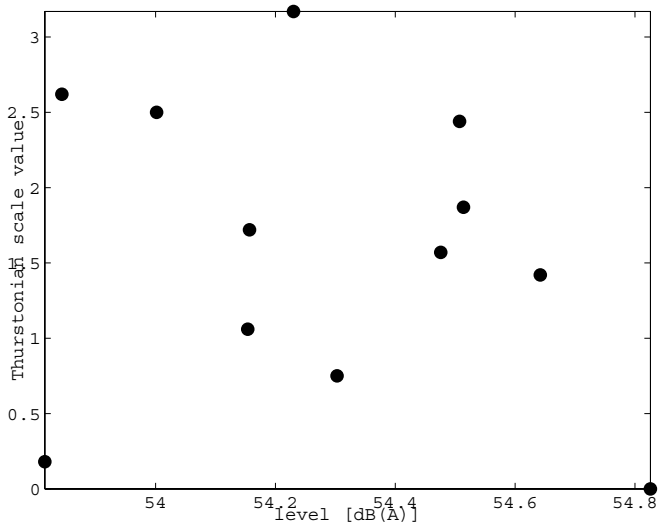

Figure 2: Thurstonian scale values in dependence of the level of the first pitch harmonics. There is no significant correlation (r=-0.23).

The mean order spectrum of the left and right channel is calculated. In the range of the first pitch harmonics the level is calculated as the root mean square.

Though for each spectral shape the different levels of the first pitch harmonics are distinguished, over all spectral shapes there is no correlation between the level of the first pitch harmonics and the Thurstonian scale values.

Level of the first pitch harmonics of the frequency tracks of the signal

With the software VIPER (Cortex Instruments) frequency tracks are calculated from the signals. They represent tonal components of the tyre/road noises and are calculated according to the aurally adequate signal analysis in [3]. From the frequency tracks order spectra are calculated. In the range of the first pitch harmonics the level is calculated as the root mean square. This value represents the level of the tonal components of the first pitch harmonics.

The Thurstonian scale values are significantly correlated with the level of the first pitch harmonics of the order spectrum of the frequency tracks. Therefore the pattern noise strength is related to the level of the tonal components of the first pitch harmonics.

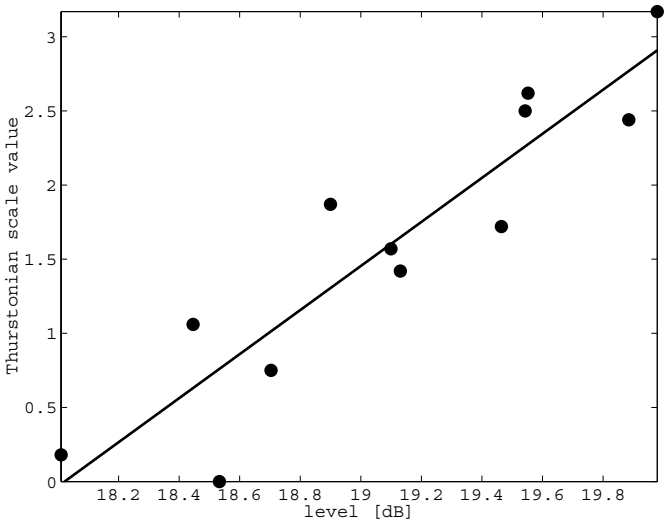

Figure 3: Thurstonian scale values in dependence of the level of the first pitch harmonics of the contours of the signal. There is a significant correlation (r=0.91*).

Conclusion

The already known relation between the level of the first pitch harmonics and the pattern noise strength holds only in the case of a constant spectral shape of the first pitch harmonics. If also the spectral shape is varied, the level of the first pitch harmonics represents not properly the amount of perceived pattern noise.

Since the pattern noise is a tonal component of the first pitch harmonics, there is a relation between the level of the tonal components of the first pitch harmonics and the pattern noise strength. This parameter correlates with the subjective evaluation, if the level and the spectral shape of the first pitch harmonics are varied. Therefore these parameters are both represented by the level of the tonal components of the first pitch harmonics.

References

[1] Buss, S., Weber, R., Liederer, W. (2002). Objektivierung des subjektiv wahrgenommenen Profilgeräuschs in Reifen-Fahrbahn-Geräuschen. In: Fortschritte der Akustik - DAGA 2002.

[2] Buss, S., Weber, R., Liederer, W. (2003). Wahrnehmung des Profilgeräuschs in Reifen-Fahrbahn-Geräuschen. In: Fortschritte der Akustik - DAGA 2003.

[3] Mummert, M. (1998). Sprachkodierung durch Konturierung eines gehörangepaßten Spektrogramms und ihre Anwendung zur Datenreduktion. VDI-Fortschrittberichte, Reihe 10, VDI-Verlag, Düsseldorf. Dissertation, München.