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# Temporal aspects of airborne sound insulation and how it affects the subjective estimation

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Standardised methods exist for measuring the sound insulation of a partition wall or a ceiling. A number of indexes have been defined; each offers various benefits for different situations. All have, however, in common that they have to be obtained using a steady-state sound signal, usually pink noise, and compared against a reference curve as defined in ISO 717-1. This procedure results in a single number rating yielding a sound insulation index. Sound insulation, however, is supposed to protect people's well-being and health, mentally and physically, in real life situations. Since the currently used descriptors are based on steadystate signals, this paper aims to show the effect using non-steady-state signals in describing airborne sound insulation. For this reason, a comparison is made between using conventional broadband noise signals, including pink or white noise, and using music signals, including classic and rap music. Some indices commonly used to describe airborne sound insulation are discussed and consequently, comparisons with subjectively judged values of airborne sound insulation are made. Some psychoacoustic predictors have also been considered, examining the impact of temporal fluctuating signals to the resulting sound insulation. In the presentation some preliminary results will be presented on this on-going study.

## 1. INTRODUCTION

In order to derive a measure of sound insulation, current standards and regulations are in general based on the difference in sound levels from one side of a partition (e.g. a wall) to the other, indicating the sound transmitted through the partition. Acoustic tests relate sound loss through a partition at various frequencies then average the results to provide a single absolute value number. Basically, there are two different approaches for a single number rating. The first is a comparison with a reference curve which is used in most European countries following the procedure of ISO 717, Acoustics – Rating of sound insulation in buildings and of building elements (1996), yielding the quantities: $R_w$, $R'_w$, $D_{n,w}$, and $D_{nT,w}$. The second is the A-weighted level difference $R_A$, $D_{nAT}$. However, in common they all have to be obtained using a steady-state sound signal. On the other hand, in real life, sound is hardly steady-state; instead it is a non-steady-state sound signal. What we hear and what we judge is a sound level intruding our ear and thus, it is important to examine this sound level. In this study, therefore, the transmitted sound level, i.e. the sound signal, has been analysed using different types of signals, i.e. steady-state and non-steady-state signals.

## 2. SIGNALS

The steady-state signals used in this research are three broadband noise signals, namely pink noise, white noise and grey noise. All steady-state signals have a SPL of 85 dB. In Figure 1 the power spectral density of these signals are shown.

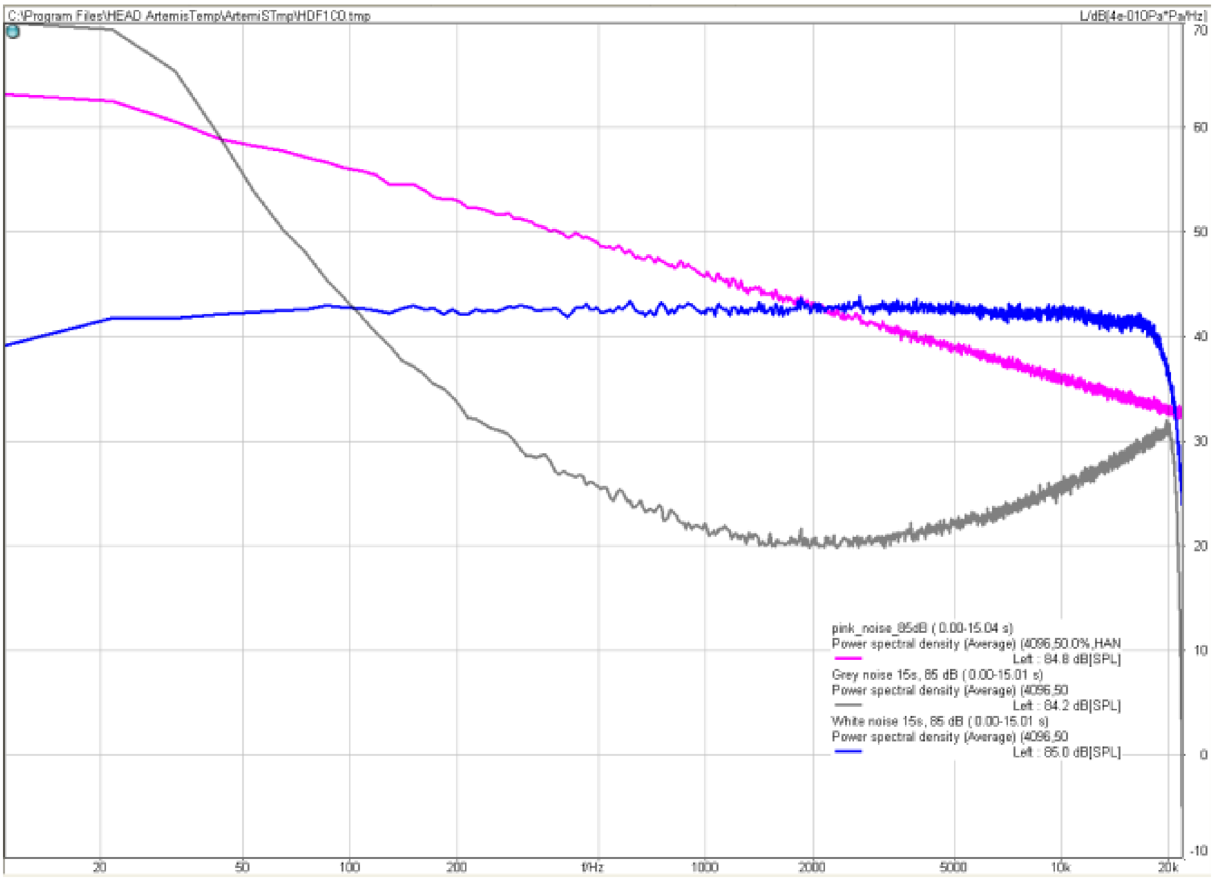


**Figure 1**. Power spectral density (PSD) of pink, white and grey noise as a function of frequency in the range of 20 to 20k Hz.

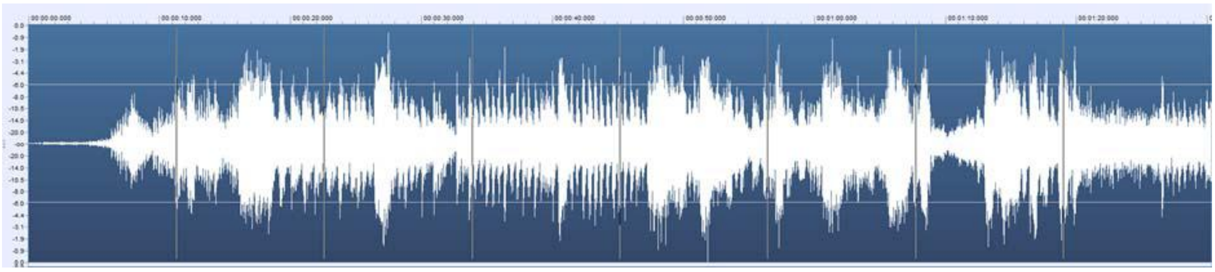

**Figure 2**. Time signal of Beethoven Symphony Nr. 9, with SPL of 85 dB, duration of 90 s.

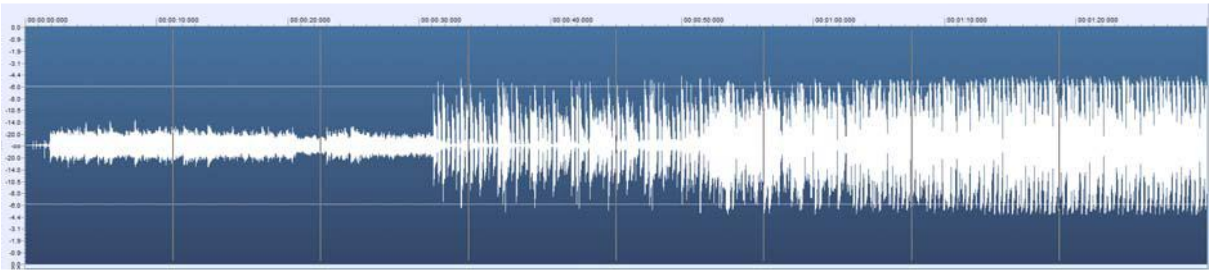

**Figure 3**. Time signal of Eminem - Lose yourself, with SPL of 85 dB, duration of 90 s.

The non-steady-state signals used in this research are two music samples, namely classic and rap music. The chosen classical music was Beethoven: Symphony Nr. 9: Poco Allegro, Stringendo Il Tempo, Sempre Piu Allegro - Prestissimo, and the rap music was: “Eminem” with the song: “Loose Yourself“. All non-steady-state signals have a SPL of 85 dB. The time structures of the signals are shown in Fig. 2 and Fig. 3.

## 3. TRANSMITTED SIGNAL

In order to study the transmitted signal passing through a partition, a filter has to be chosen to simulate the sound insulation. For this reason a partition is regarded as a signal filter to the unprocessed sound signal which has a SPL of 85 dB. The filters, i.e. the coefficients of the built transfer function, are generalised damping coefficients in the frequency range 50 to 5k Hz characterising the frequency dependent R-values. No dips in the filter function are introduced in this investigation, i.e. the R-values are continuously rising with increasing frequency. The R-values are varied from 10 to 60 dB in step of 10 dB, which are shown in Fig. 8. It can be seen that grey noise gives highest receiving SPL whereas the lowest level is obtained using white noise. It is also interesting to note that using Eminem as a source signal leads to higher receiving SPL than Beethoven.

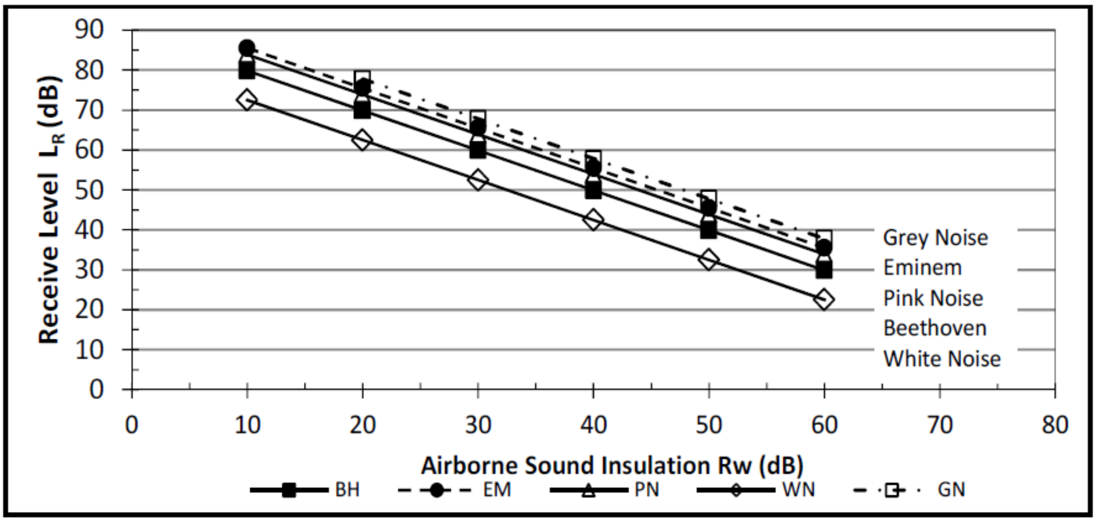


**Figure 4**. Different source signals in terms of SPL, filtered with filter functions of 10 to 60 dB in steps of 10 dB, with source signal of 85 dB. Grey noise yields highest and white noise lowest receiving level.

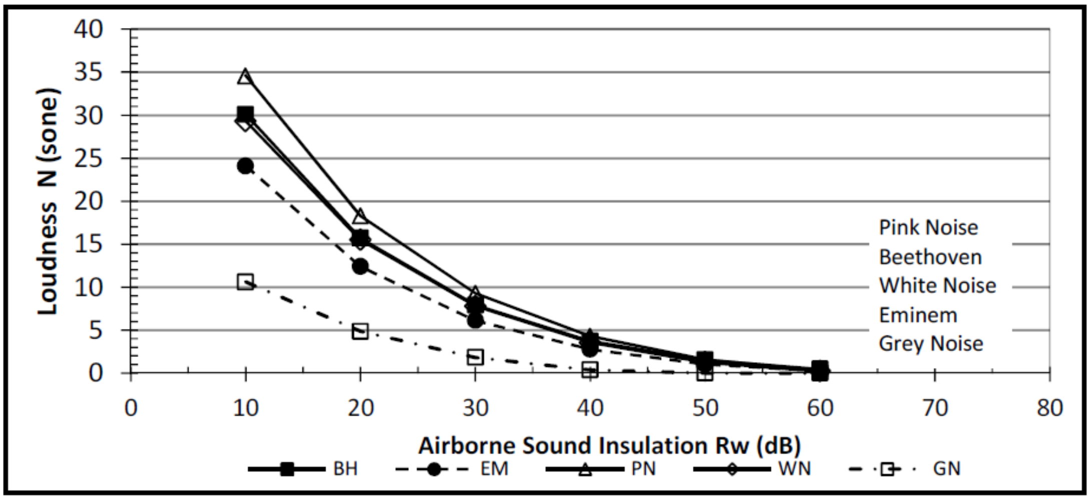


**Figure 5**. Different source signals in terms of SPL, filtered with filter functions of 10 to 60 dB in steps of 10 dB, with source signal of 85 dB. Pink noise yields highest and grey noise lowest loudness.

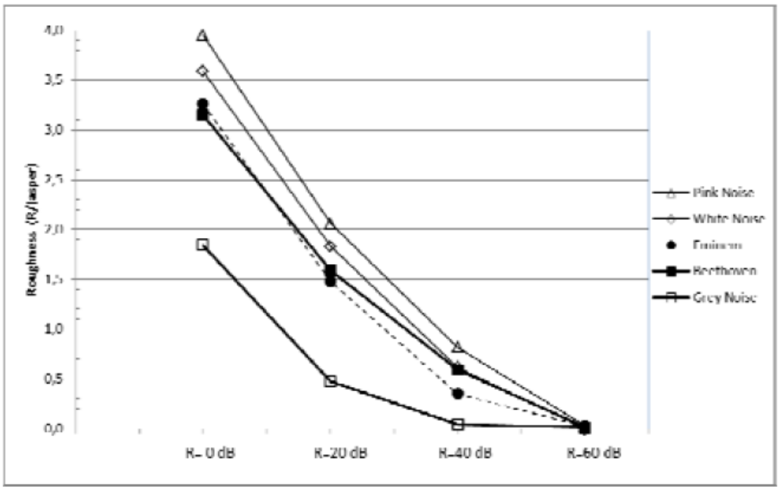


**Figure 6**. Comparison of roughness of different source signals filtered with filter functions of 0 dB, 20 dB and 60 dB. Pink noise yields highest and grey noise lowest roughness.

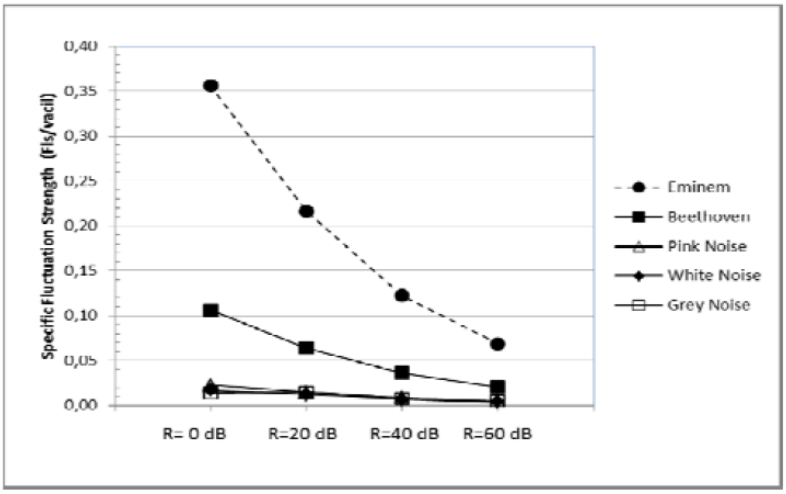


**Figure 7**. Comparison of specific fluctuation strength of different source signals filtered with filter functions of 0 dB, 20 dB and 60 dB. Eminem yields highest and grey noise lowest specific fluctuation strength.

## 4. SUBJECTIVE ESTIMATION OF THE TRANSMITTED SOUND

In this initial experiment a small number of nine persons, five women and four men, were asked to listen to some sound samples via headphone (Sennheiser HD 280 pro) and judge the sound by answering pre-coded questions. The sound samples offered to the subjects started with a reference signal with a SPL as a first unfiltered sound sample. The R-values, i.e. the sound insulation index, were then varied from 20 to 50 dB in steps of 10 dB, and also with a maximum damping of 56 dB. The source signals as mentioned above were used. The subjects were asked to select one of the following answers: 0 - *I do not hear a sound*; 1 - *I can hear a weak sound*; 2 - *I hardly hear a sound*; 3 - *Yes I can hear a sound but not easily*; 4 - *Yes I can hear a sound when concentrate on it*; 5 - *Yes I can hear a sound*; 6 - *Yes I can clearly hear a sound*.

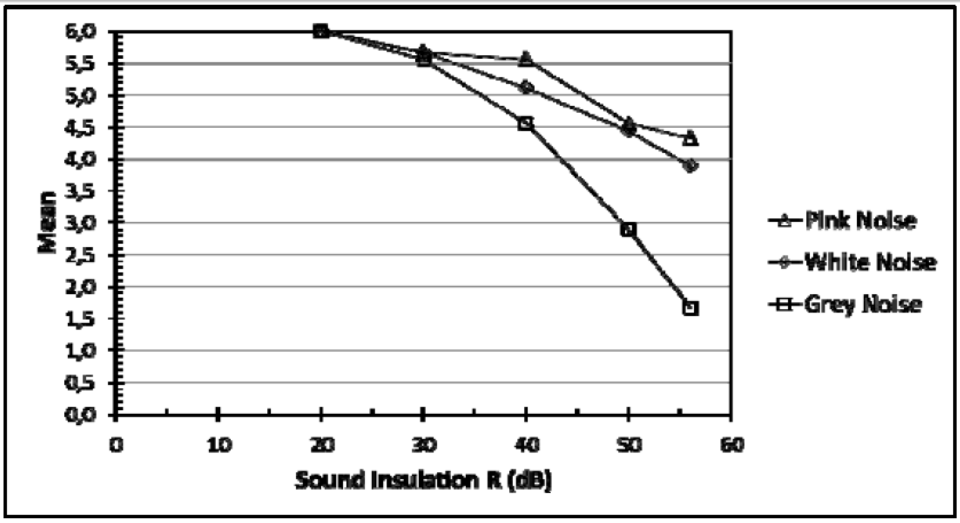


**Figure 8**. Mean of response distribution for data samples of white -, pink -, and grey noise, respectively.

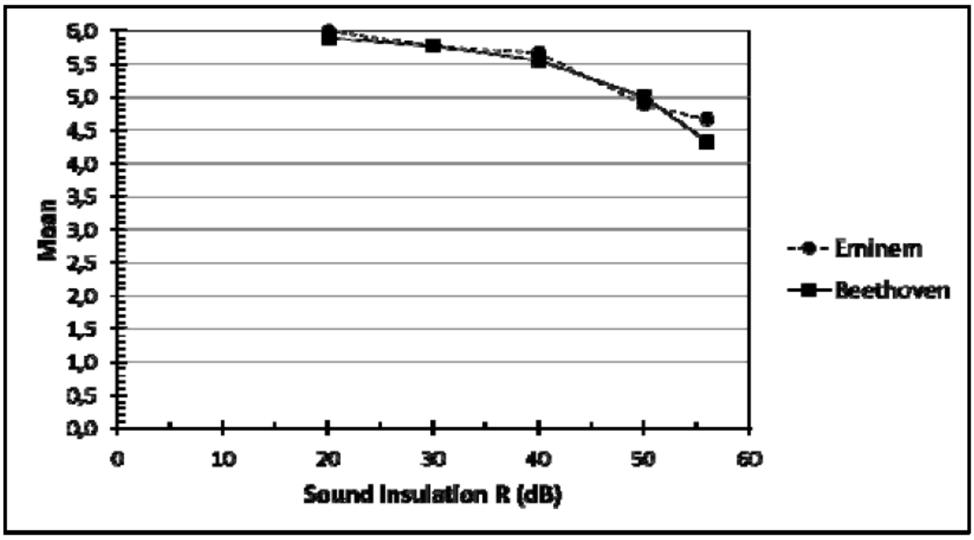


**Figure 9**. Mean of response distribution for data samples of Eminem and Beethoven.

In order to quote "*I hear a weak sound*" a damping of 50 dB was needed for all sound signals and in the case of "*I do not hear a sound*" the subjects scored this using pink noise and music for a damping of 56 dB. In the case of white noise and grey noise the subjects still did quote, even for a damping of 56 dB. Eminem was judged "louder" than Beethoven. The music group was judged as: "*can hear / can clearly hear*", while the noise group was judged as: "*can hear when concentrate on it / can hear*". The two groups differ in judgment by one chategory, which means noise samples are judged not as loud as music sound samples.

## 5. CONCLUSIONS

The preliminary results of this on-going study imply that the heard sound after being transmitted through a filter which is supposed to be a dividing partition is depending on the unfiltered source signal. This result implies, that using pink noise as a test signal in order to measure the sound insulation does not relate well with heard sound. It also turned out in this research, that using loudness as a measure to describe the intrusive sound does not describe the subjectively estimated impression properly. The time structure of the signal seems to play a massive part in the subjectively judged sound. This was seen by the comparison of fluctuation strength. It seems that the subjects required higher insulation using music as a source signal.

## 6. REFERENCES


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