Rating Airborne Sound Insulation in Terms of Time Structure of the Signal

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The airborne sound insulation quality of a construction is usually given by a single number rating. The procedure is given by the Standard ISO 717-1, taking into account the measured frequency dependent values of the airborne sound insulation. If the airborne sound insulation curve has a significant dip of 6 dB at a certain frequency range, the procedure of ISO 717-1 does not consider this event. However, in this investigation it is shown that, if there is at a certain frequency range a dip of 6 dB, even if the single number rating is not affected, the airborne sound insulation will be reduced subjectively. That is, a dip of 6 dB in the airborne sound insulation curve is an event in the time signal of the sound pressure level in the receiving room, which is able to contribute significantly in psychoacoustic calculations. The time dependent information of the transmitted signal through a partition is a very sensitive and important part for airborne sound insulation, but it is not considered in current regulations and standards. In this paper some of the important features are investigated in terms of time dependent information concerning psychoacoustic ratings like Loudness, Sharpness, Tonality or Specific Fluctuation Strength.

1 INTRODUCTION

Airborne sound sources produce noise, for example - speech, televisions and home entertainment systems. Airborne sound insulation is concerned in terms of reducing such sound transmission through separating floors and walls. In Europe the generally accepted Standards for the airborne sound insulation is EN 12354-1 [1] and EN ISO 717-1 [2], which calculate airborne sound insulation from measured data. Comparing single number quantities of airborne sound insulation with subjective estimated airborne sound insulation yield frequently to serious differences [3]. Both EN 12354-1 for prediction and EN ISO 717-1 for calculation are problematic due to the fact that the time dependent information is omitted. Time dependent

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information of the transmitted signal through a partition is an important part for airborne sound insulation, especially if the transmitted signal is transient. Examining time dependent psychoacoustic features of signals in relation to airborne sound insulation enables better subjectively related judgements [3]. As an initial approach, it has been shown in [4] that time dependent features of a signal influence strongly the subjectively judged quality of an airborne sound insulation. This paper describes experimental investigations into the sound transmission properties of a partition in terms of psychoacoustic features.

2 METHOD

The traditional approach to designing for noise control (sound insulation) in Europe and other countries pays insufficient attention to many important aspects of how sound is judged subjectively. Standards in Europe, North America and other countries consider only single number rating, which reduces the results at a number of frequencies to a single numerical value. In Europe Standard ISO 717-1 is used, where the procedure uses a reference curve shifted against the measured values. Such kinds of approach may not ensure satisfactory sound insulation because it fails to consider the time structure of the transmitted signal and hence the sound which is actually heard from residents. The sound signal has been analysed using software ArtemiS of HEAD acoustics V11.

2.1 Music and Noise Signals

In this study steady-state and non-steady-state signals have been considered. The steady-state signal is a broadband noise signal, namely pink noise. The non-steady-state signals, i.e. the transient signals, are three music samples, namely rap, rock and classic music. The three music samples were: rap music (Eminem, “Loose Yourself”), rock music (3 Doors Down, “Kryptonite”) and classic music, (Beethoven, “Symphony Nr. 9: Poco Allegro, Stringendo Il Tempo, Sempre Piu Allegro - Prestissimo”). All signals have a sound pressure level (SPL) of 85 dB and duration of 90 sec and 15 sec, respectively. The main concern in this investigation is the performance of some signals concerning specific fluctuation strength. These different types of signals are illustrated in Fig. 1 in which the specific fluctuation strength is shown before modification to simulate transmission through various walls.

2.2 Signal Processing

In order to investigate the time structure of a signal after transmission, two different damping values (R_w) and three different frequency dips in the frequency depending sound insulation have been selected. These different types of used damping is exemplarily illustrated in Fig. 2 where the idealised airborne sound insulation is shown as a function of frequency having a damping of 20 dB with a 6 dB dip at 100 Hz.

In Fig. 3 and 4 the power spectral density of the pink noise signal and “Beethoven” is depict having a damping of 20 dB with a 6 dB dip at 100 Hz, 800 Hz and 3150 Hz, respectively.

3 RESULTS

Figure 5 shows the results of the calculated specific loudness for the sound samples pink noise, Eminem, Beethoven und 3DoorsDown if a filter of 20 dB with a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively is used. In Fig. 6 results are depict using a filter of R = 60 dB. It is seen in both figures that the specific loudness does decrease if the damping increases. This is expected since damping is introduced and the receiving signal reduces as a result. The result provides in Fig. 5 shows that the reduced specific loudness of about 1 sone in the range from 100 to 800 Hz results from the procedure to keep the value of R constant. Loudness is reduced because of the fact, that a dip at higher frequencies had to be adjusted in the calculation of the single value of R, i.e. the frequency dependent values of R were increased. So, the loudness reduces in about the same amount as the damping increases, which is in agreement with theory. A dip at 100 Hz yields, however no change in loudness, whereas a dip at 800 Hz and 3150 Hz yield less loudness due to the "fitting" procedure to keep the R value constant and due to the procedure of ISO 717 using a shifted reference curve (see Fig.2). In other words, the reduction of specific loudness at higher frequency dips is not related to a certain psychoacoustic effect.

The specific fluctuation strength is shown in Fig. 7 when a filter of 20 dB with no dip and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively is used. In Fig. 8 results are given using a filter of R = 60 dB. In these figures it is seen that the specific fluctuation strength of the used music samples are quite different. Eminem reveals highest and 3DoorsDown smallest values of specific fluctuation strength. The overall figure of the specific fluctuation strength however does not change significantly, so the single number does not provide reasons for having an event in a certain frequency range. However, looking at the frequency dependent specific fluctuation strength, the introduced dip at 3150 Hz is clearly noticeable. This holds for pink noise (see Fig. 9), as well as for music type signals, e.g. "Eminem" (see Fig. 10).

The specific fluctuation strength vs. time for the music signal Eminem is shown in Fig. 11, which illustrates that the event of a 6 dB dip at mid and higher frequencies is visible for transient signals. In Fig. 12 pink noise and Eminem are compared, where it is seen that for pink noise, the event of a 6 dB dip at mid and higher frequencies is not evident.

In Fig. 13 and 14 the Fast Fourier Transform (FFT) of the signal "pink noise" and "Eminem" are depict. In Fig. 13 the effect of a 6 dB dip at 3150 Hz is evident. At 3150 Hz the sharp line representing the event of the frequency dip is clearly seen. On the other hand, in Fig. 14 where a music type signal is investigated, no such visible event is identifiably.

In Fig. 15 and 16 the measures sharpness and tonality, respectively are depict, where the used filter is 20 dB. It is seen in Fig. 15 that pink noise yields highest and Eminem lowest sharpness. In contrast to this, in Fig. 16 is the tonality shown. There, pink noise reveals lowest and Eminem/3DoorsDown highest values of tonality.

4 DISCUSSIONS AND CONCLUSIONS

The effect of a dip in the frequency dependent filter function has been shown. This is because at a certain frequency the damping curve or "filter" generated to simulate airborne sound insulation shows a reduced damping. Hence, in that frequency range the investigated signal is supposed to transmit more energy which might be seen in the presented PSD graphs (see Fig. 3 and 4). The dip investigated has a depth of 6 dB at frequencies of 100 Hz, 800 Hz and 3150 Hz, respectively. Investigating the signal in the time structure could reveal details which are important in the subjective estimation of airborne sound insulation. This can be seen especially at 3150 Hz. The investigation revealed that specific loudness und loudness vs. time does not show much difference in noise type signals like pink noise but does significantly change for transient signals like music type sound samples investigated in this study.

From theory it is expected that exploring a transient signal like music by computing FFT vs. time does not allow identifying a transient event like the "dip event" in the signal. However, using a noise type signal like pink noise, this "dip event" can be identified by analysing FFT vs.

time. Due to the investigated distinct dip in the frequency depending sound insulation, it might be thought, that a dip of 6 dB affect the two psychoacoustic measure sharpness and tonality. Results however show that sharpness and tonality are not much influenced by that dip event. Interesting is however, that pink noise has highest sharpness and Eminem lowest. In contrast to that, tonality reveals that Eminem has highest and pink noise lowest tonality.

By computing specific fluctuation strength it has been shown that at 800 Hz and 3150 Hz this “dip event” in the signals could be identified. However, computing specific fluctuation strength vs. time does not yield proper results in identifying the “dip event” in the signal using noise type signals like pink noise. In general, for noise type signals there is no clear effect visible on specific fluctuation strength on time scale. This is not surprising, since noise type signals are not transient structured. Transient signals like music have a significant time change with a non-random fluctuation like noise does. This fluctuation has been calculated using the psychoacoustic measure of the specific fluctuation strength. The results show that at mid and higher frequencies the “dip event” at a certain frequency is detectable using psychoacoustic measures. Comparison of specific fluctuation strength showed that airborne sound insulation is dependent on the source signal and its spectral and temporal characteristics [4].

It was reported in [5, 6] that: “*Although some measures were much better predictors of responses to one type of sound than were the standard STC and Rw values, no measure was remarkably improved for predicting annoyance and loudness ratings of both music and speech sounds.*” The results in this paper confirms that in general, approaches using single number ratings do not contribute to the need to judge the airborne sound insulation in terms of subjective ratings. Occupant satisfaction with the sound insulation between one's own unit and other adjacent units is in general determined by the transmitted signal. In other words, it is the sound in the receiver room and not a single number rating of the partition that will determine the sound insulation experienced by occupants.

5 REFERENCES

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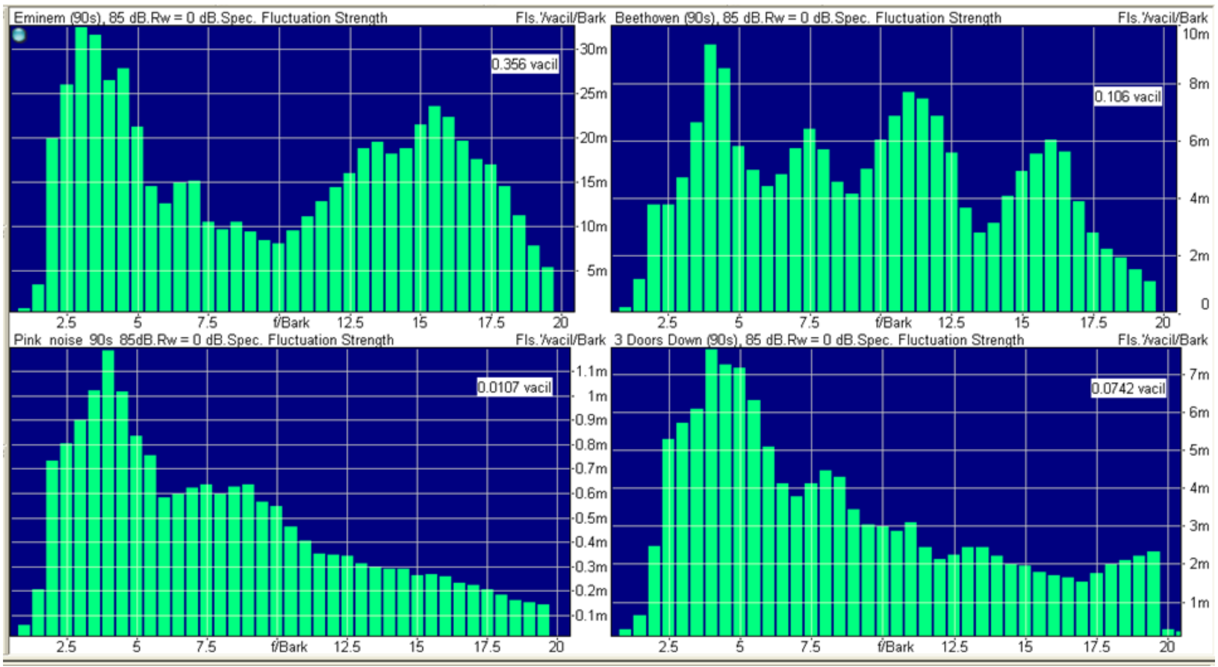

Fig. 1 – Specific fluctuation strength of three music samples, Eminem, Beethoven, and 3 Doors Down, compared with pink noise, where no filter is applied (i.e. R_w = 0 dB).

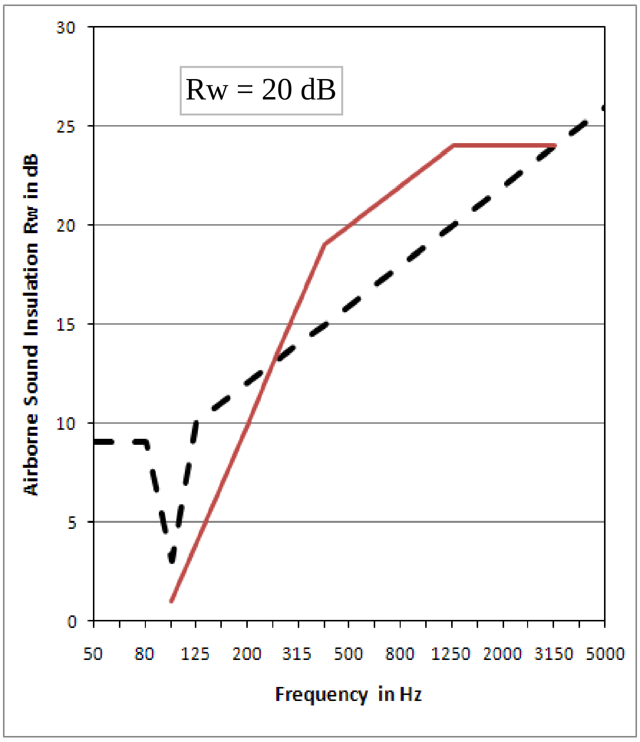

Fig. 2 – Idealised airborne sound insulation as a function of frequency, using an example R_w = 20 dB with a 6 dB dip at 100 Hz. The solid line is the reference curve given in EN ISO 717-1.

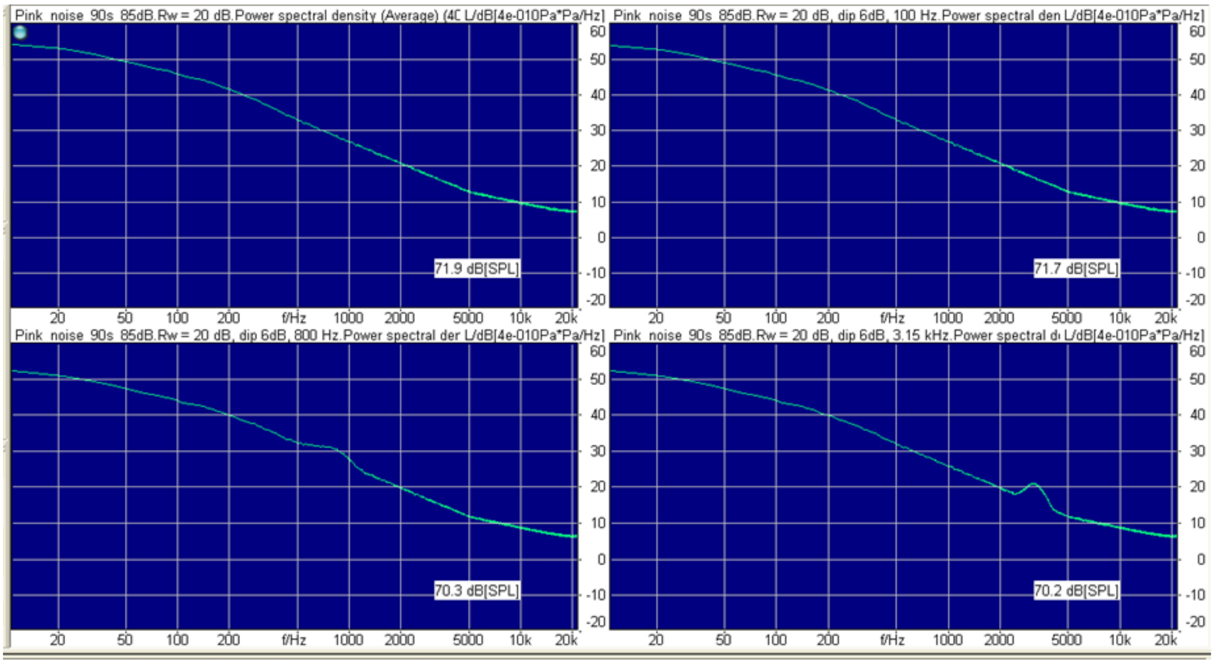

Fig. 3 – Power spectral density for the sound sample with pink noise, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.

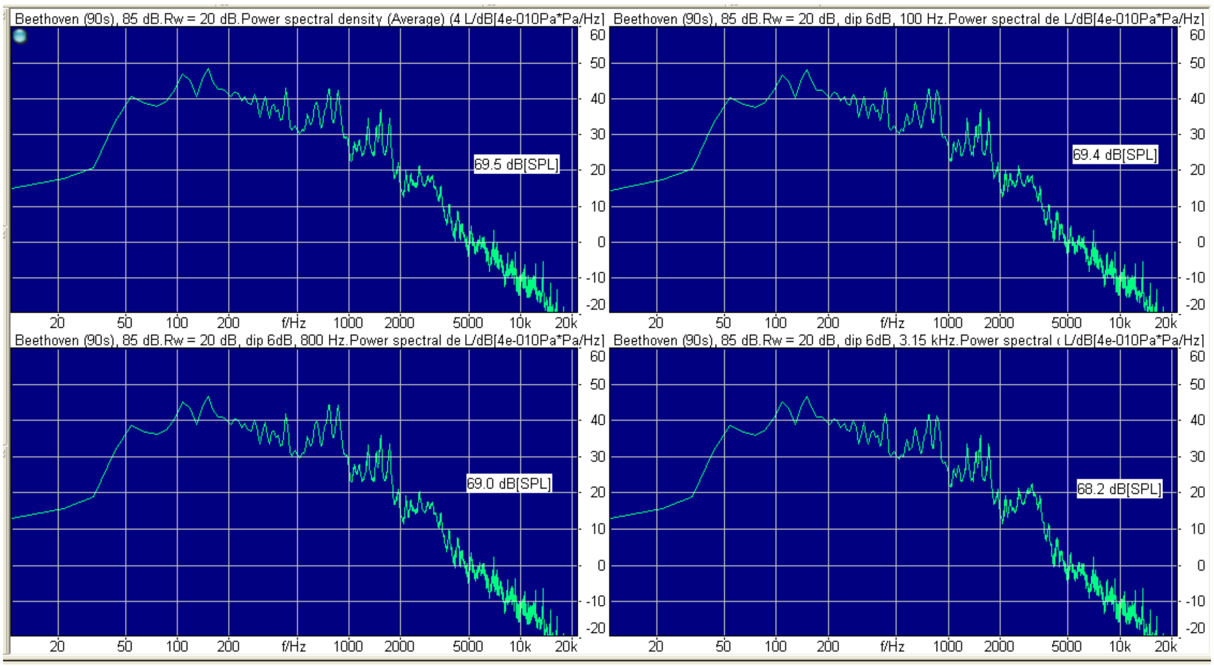

Fig. 4 – Power spectral density for the music sample Beethoven, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.

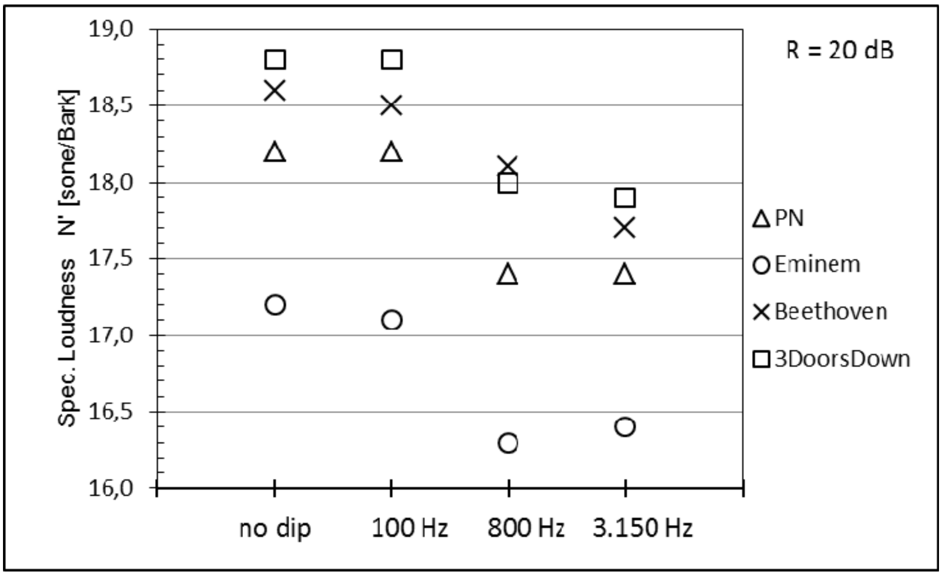

Fig. 5 – Specific loudness for the sound samples pink noise, Eminem, Beethoven and 3DoorsDown, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.

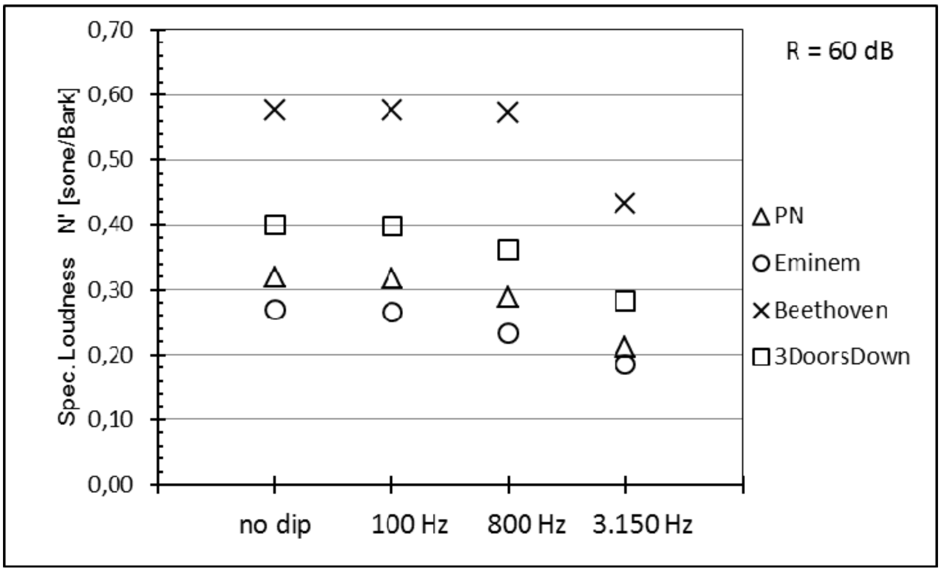

Fig. 6 – Specific Loudness for the sound samples pink noise, Eminem, Beethoven and 3DoorsDown, considering a filter of R_w=60 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.

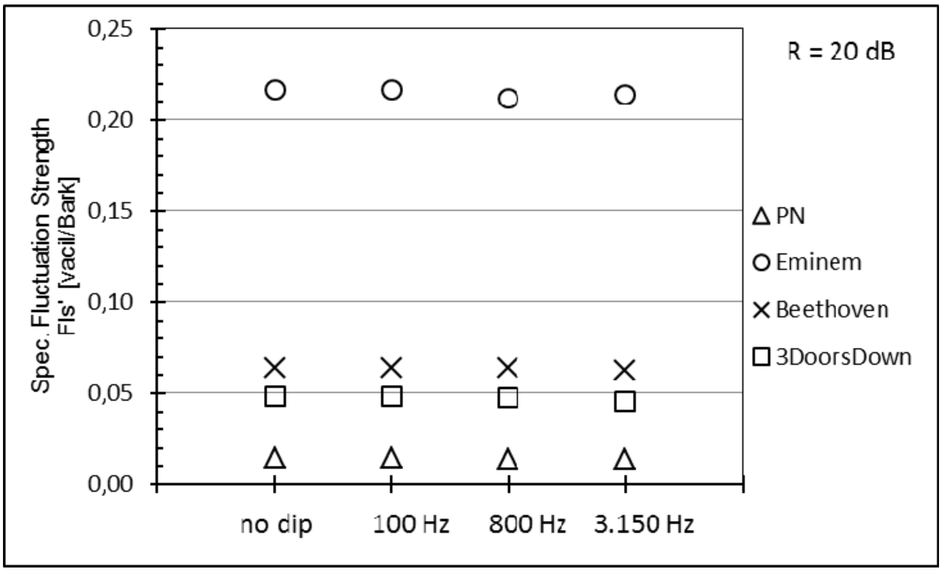

Fig. 7 – *Specific fluctuation strength for the sound samples pink noise, Eminem, Beethoven and 3DoorsDown, considering a filter of* R_w*=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.*

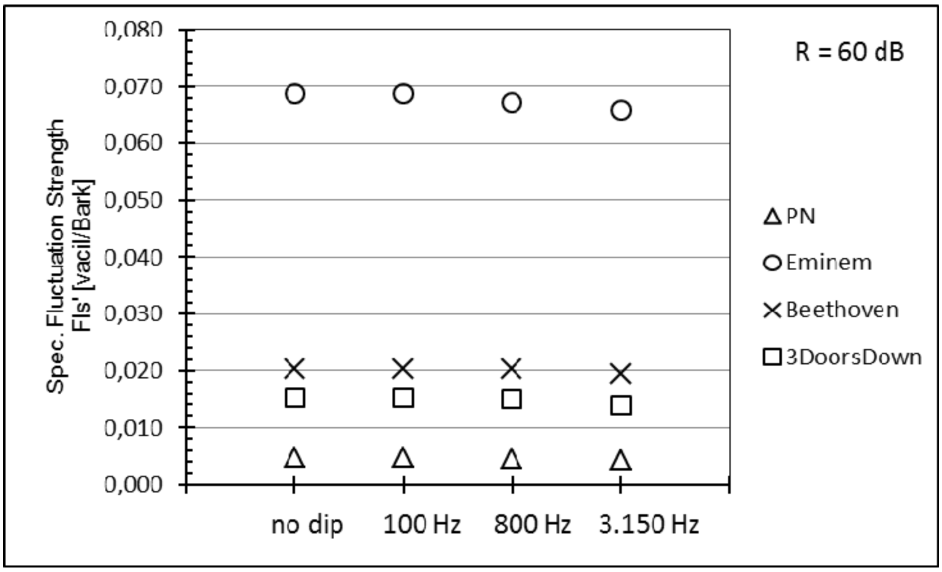

Fig. 8 – *Specific fluctuation strength for the sound samples pink noise, Eminem, Beethoven and 3DoorsDown, considering a filter of* R_w*=60 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.*

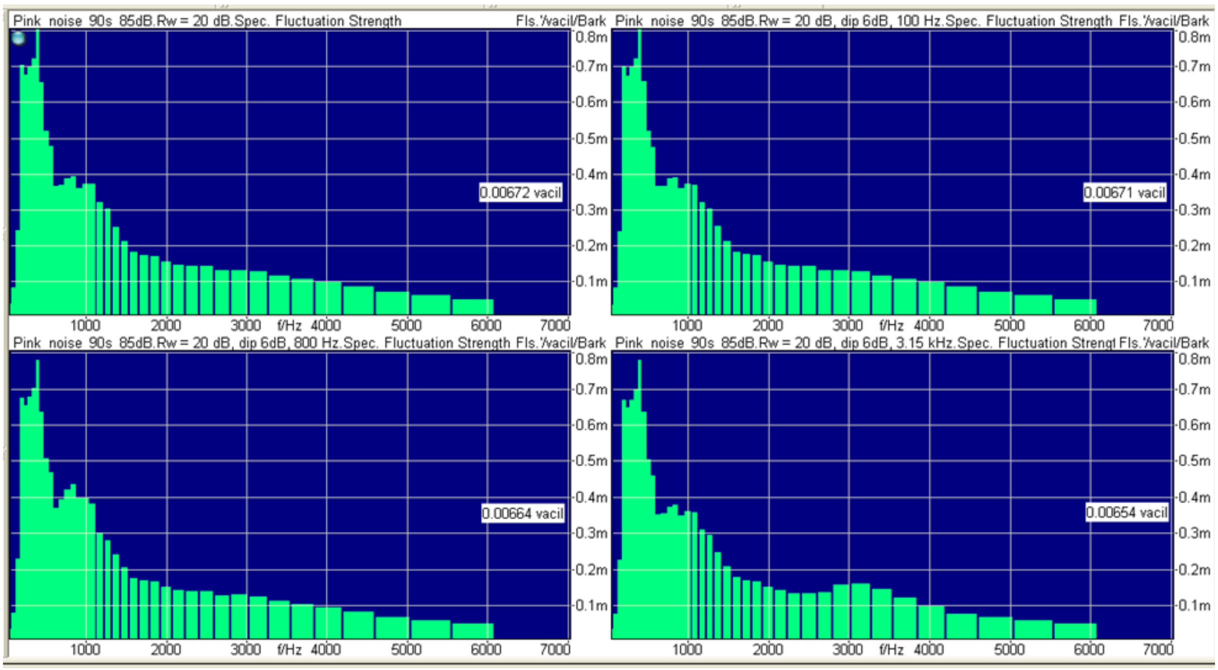

Fig. 9 – *Specific fluctuation strength for the sound sample pink noise, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.*

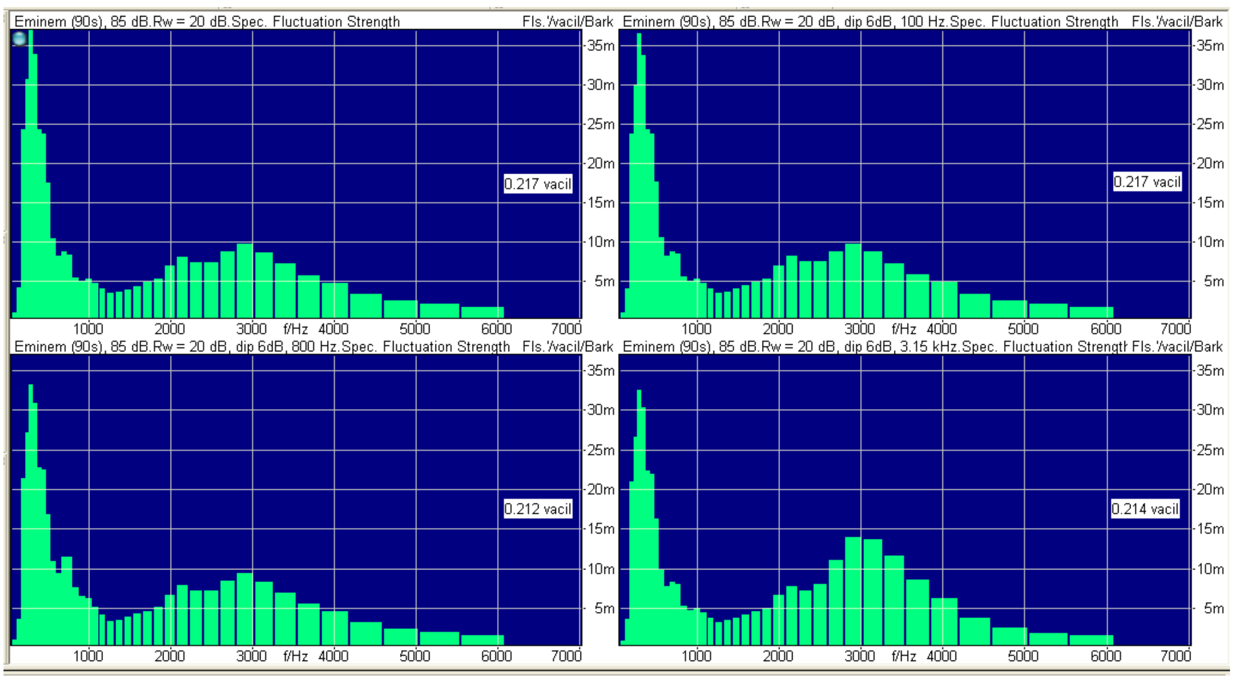

Fig. 10 – *Specific fluctuation strength for the sound sample Eminem, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.*

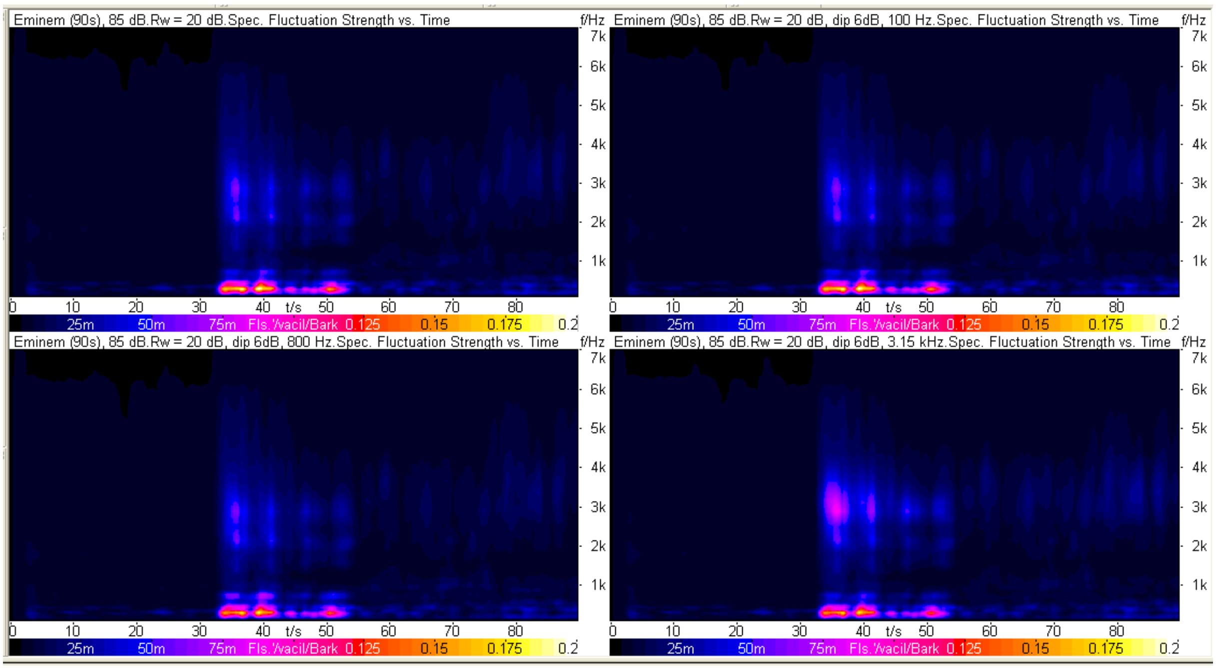

Fig. 11 – Specific fluctuation strength vs. time, with sound sample Eminem, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.

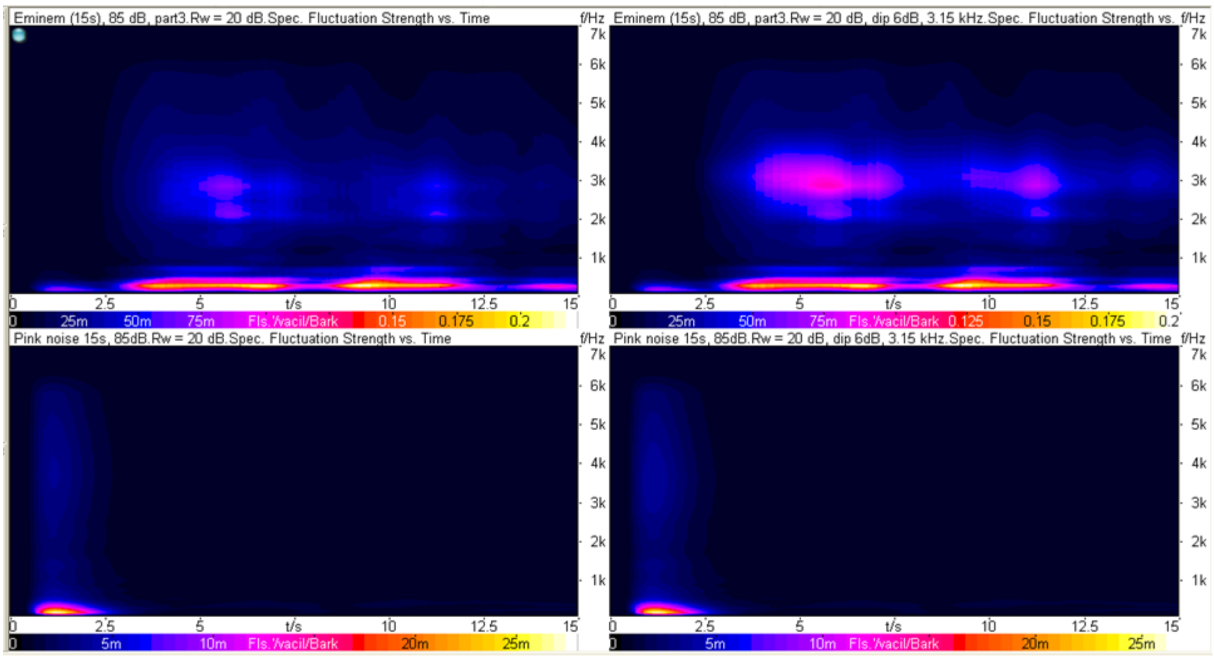

Fig. 12 – Comparison of specific fluctuation strength vs. time for Eminem and pink noise to demonstrate that pink noise reveal no effect for a frequency dip whereas Eminem does. Damping of the signal is 20 dB with a 6 dB dip at 3150 Hz.

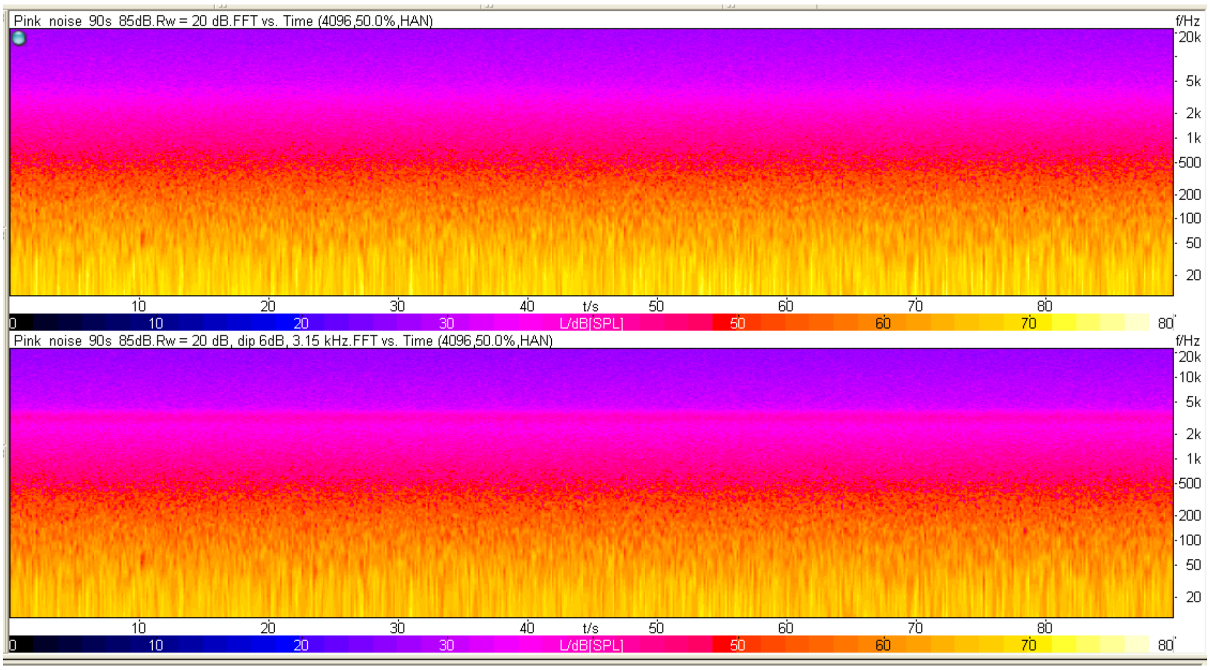

Fig. 13 – FFT vs. Time, with pink noise, with a filter of R_w=20 dB with no dip, and a 6 dB dip at 3150 Hz.

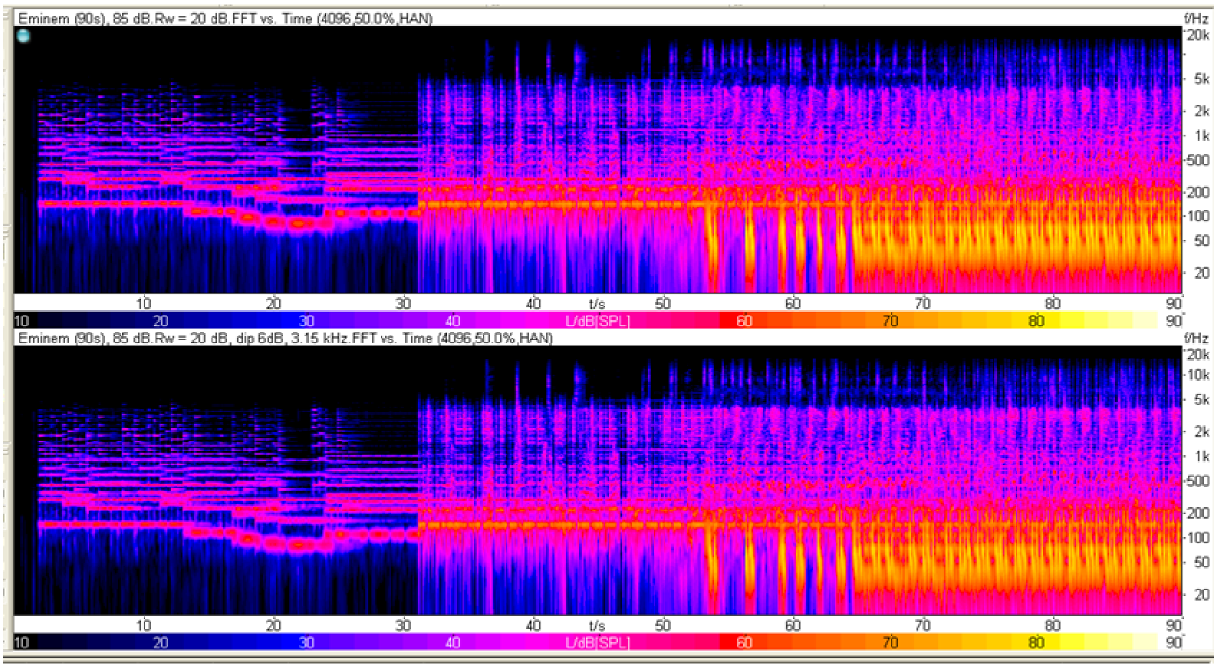

Fig. 14 – *FFT vs. Time, with Eminem, with a filter of R_w=20 dB with no dip, and a 6 dB dip at 3150 Hz.*

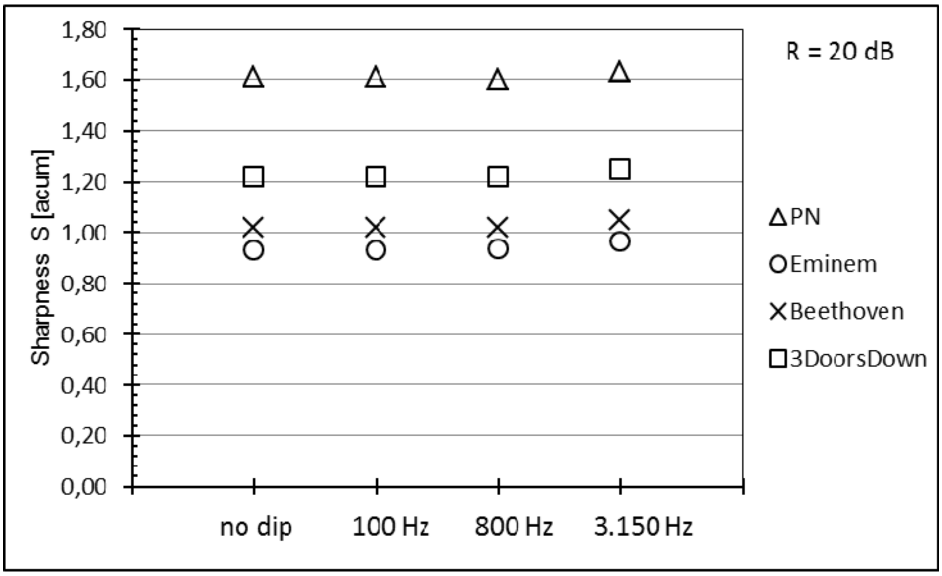

Fig. 15 – Sharpness for the sound samples pink noise, Eminem, Beethoven and 3DoorsDown, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.

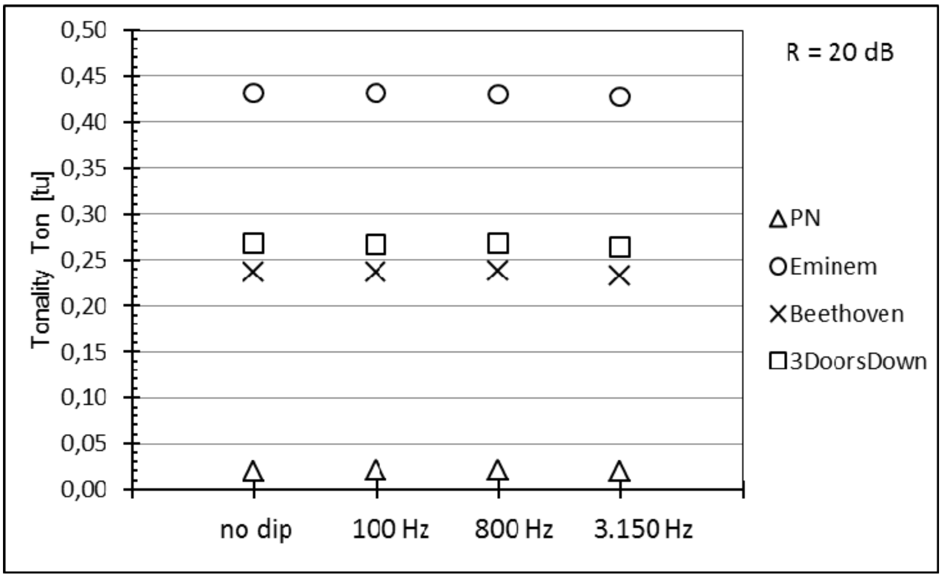

Fig. 16 – Tonality for the sound samples pink noise, Eminem, Beethoven and 3DoorsDown, considering a filter of R_w=20 dB with no dip, and a 6 dB dip at 100 Hz, 800 Hz, and 3150 Hz, respectively.