Audio Engineering Society
Conference Paper
Presented at the 21st Conference
2002 June 1–3 St. Petersburg, Russia

A special form of noise reduction

dr. Ronald M. Aarts 1), ir. H. Greten 2), ing. P. Swarte 3)
1) Philips Research. 2) Greten Raadgevende Ingenieurs 3) P.A.S. Electro-acoustics.
The Netherlands.

A special form of noise reduction.

Popmusic reproduction or reinforcement in disco's or poppodia on a very high sound pressure level is highly appreciated by the so called target group. For the neighbours, this can be very annoying, especially when these music sessions take place during the night. A poor sound insulation creates an inadmissable sound immission level in e.g. bedrooms. Noise reduction methods of a constructional nature are in most cases very expensive.

Two methods of active noise reduction are tried out in the sound system of a music school in The Netherlands and other premises: one by 'anti-sound' and the other is based on the phenomenon of the missing fundamental. One of the experiments with the results are discussed in the paper below. The latter is called 'dormant Bass' (dB).

Music (re-)production on a very high sound level gives a nice "kick" especially to young people. But for others who are annoyed by e.g. undesired sound immission in their houses , is this situation very troublesome. The sound isolation between adjacent houses and even buildings on some distance is in many cases unsatisfying. Constructional solutions to reduce the hinder are often very costly and take a considerable amount of time to be realized which is the cause for a temporary closing of the place.

An option is to make use of "active noise reduction". Two methods are discussed in this paper. They are tried out in a real but difficult situation.

The first method makes use of the so-called anti-sound; the second one is based on a new form of noise reduction called the "dormant Bass" (in short "dB").

"dB" is based on the principle of the "missing fundamental" well known from the psycho-acoustics. When a tone is filtered away from a musical signal and this tone is replaced by a complexity of tones with the harmonic overtones of the original tone, this complexity of tones is heard with a pitch which is equal of the pitch of the filtered tone.

1. Introduction.

In the café- and entertainment world, high sound levels are produced in almost all cases. Not the day over but at night when most people want to sleep. For those people the sound is evaluated as undesired noise. The sound insulation between the dwelling places and the sound producers is sometimes very poor. The governmental bodies like the inspection of the environment can force the sound producers to stop the music, to set a penalty in case of transgression of the (local) laws or even force them to close the premise.

Sometimes, the annoying sound follows paths which are unpredictable. Constructional measures are expensive and take time to be realized which causes a temporary closing of the premise. One is not willing or not able to make investments in these constructional solutions. The owner of the place has to make money before he can do these investments. He can do only when he has a full house every night. This situation leads to an uncertain process of hinder and penalties. The sound levels go sometimes far beyond 100 dB(A) a little bit later in the evening. By the way, these sound levels may be the cause of an immediate damage to the hearing of the visitors. The disk jockeys, the musicians and the personal of the place often wear hearing protectors; in The Netherlands this mandatory by law.

The above mentioned levels produced in the dwelling houses opposite of the discotheque a strong irritation which was reinforced by the interrupted character. The local environment was very quiet at night. The biggest part of the irritation is mainly generated by the rhythmic "thumping" which penetrates in the houses and the moment of the day in the late evening hours.

The spectrum of the "thumping" lies roughly between 50 Hz and 100 Hz. Beyond this spectrum, no transmission has been measured (see fig 1).

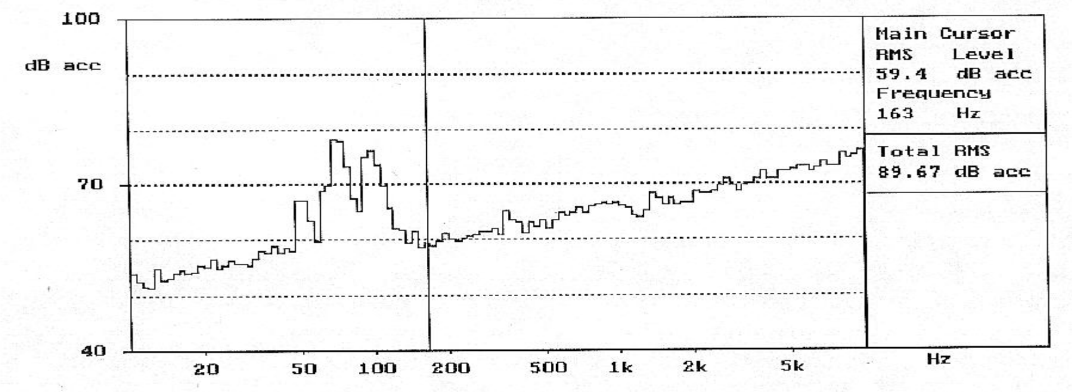


Fig 1. Excitation measurement (dB rel. 1µm/sec^2 ; this is valid for all following excitation measurements shown in this paper.)

At the moment of measurement, the level in the disco was 112 dB SPL. The excitation at 50 Hz was continuously present and caused by a factory in the neighborhood. There have never been complaints about this signal.

Fig 2 shows the background signal in the same dwelling room.

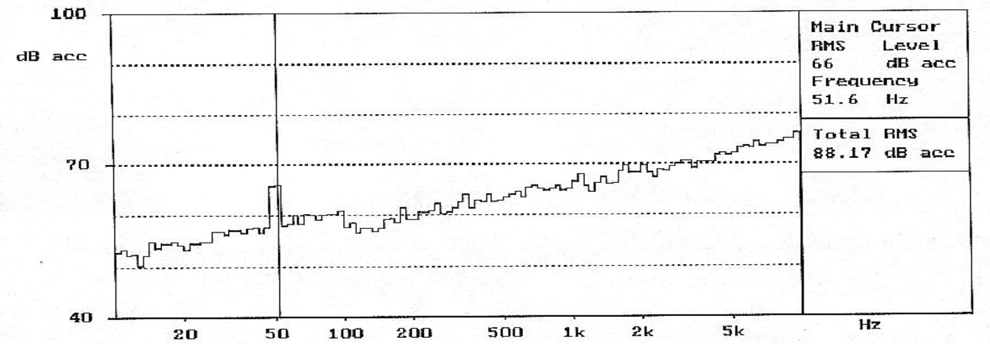


Fig 2. Background spectrum.

The measurements are made on the basis of excitations measurements. The hinder was mainly not caused by air sound but by vibrations which traveled through the soil into the houses. Of course, these vibrations were transferred into air sound by the constructions. The traveling paths were not known and very difficult to detect. That is why we have chosen for an electro-acoustical approach and not for constructional measures. Besides that, the success of constructional solutions are hard to predict and very costly.

The idea grow to cut out the disturbing part of the frequency spectrum. But this was judged to be intolerable from a musical point of view.

Two plans of attack have been set up and followed. The first one was to apply antisound with the goal to reduce the floor and wall vibrations and with the expectation that with this method the transmission of the annoying sound could be reduced in the same way.

The second method was based upon the principle of the "missing fundamental" whereby the perception of the pitch is not disturbed.

Both methods will be described together with the results and the conclusions in the following chapters (resp. chapters 2 and 3).

Both methods will be discussed in the epilogue (chapter 4).

2. Antisound.

In the conversations with the personnel of the disco annex pop stage, the idea about the application of antisound popped up. One has made some experiments with a phase shift of 180° between the two sub-woofers of the sound system for the (re)production of the signals with frequencies below 150 Hz. This gave the impression that this offered some reduction of the annoying levels which is fully declarable: one loudspeaker actively absorbs the sound produced by the other. The standing wave pattern fully changes. For the visitors this was no problem; the frequency characteristic in the room is nevertheless very place dependent.

Fig 3 shows such a characteristic taken on an arbitrary place in the room.

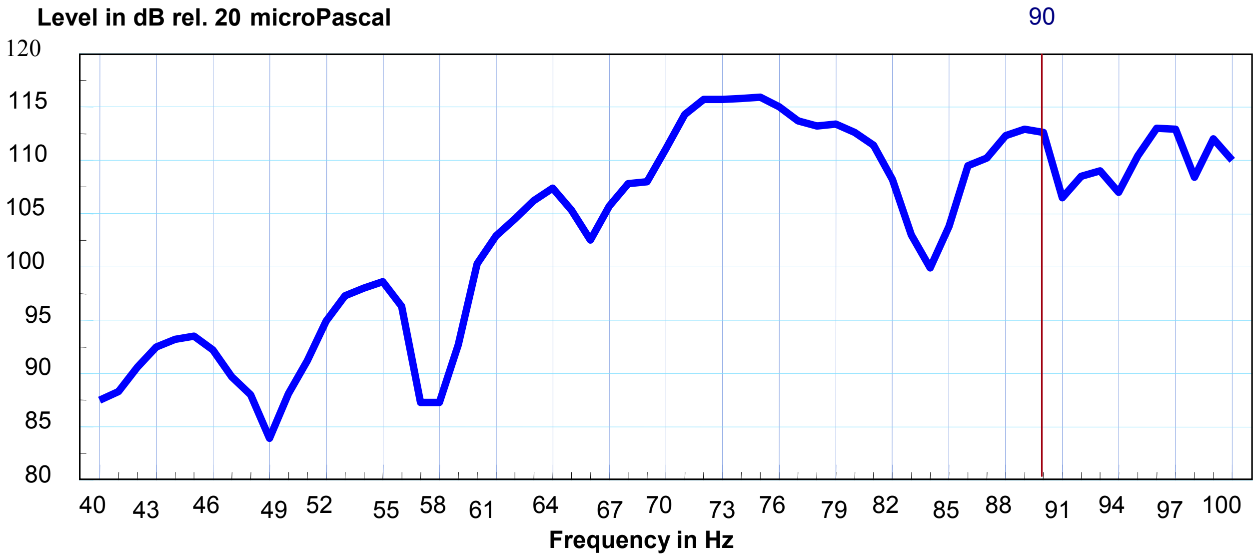


Fig 3. Sound spectrum on an arbitrary place in the room.

The place dependent characteristics of the transmission of the sound in the room led to the idea to place compensation loudspeakers in the room which were fed with the same signal as the subwoofers of the sound system but with a preset phase shift and amplitude so that the floor vibrations were highly reduced.

The measurements were executed with pink noise signals. Due to the fact that the problems mainly existed in the 90 and 100 Hz 1/3 octave bands, the experiments were done in those frequency bands. A separate loudspeaker is used for each 1/3 octave band. The set up is shown in the fig. 4. Each compensation loudspeaker produced the same average sound pressure level in the room.

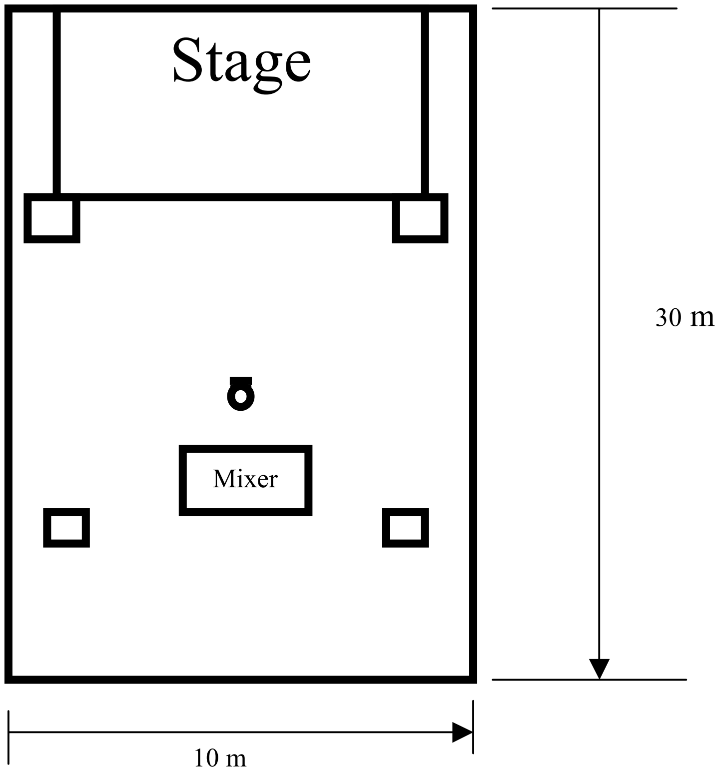


Fig.4 Positions of the loudspeaker and the measurement microphone.

Both the small squares at the corners of the stage (podium) indicate the places of the subwoofers, while the smaller squares in the room indicate the position of the compensation loudspeakers.

The sign of the microphone shows the place of the measurement microphone.

The presets of the phase shifts are shown in fig. 5. Each compensation loudspeaker was dedicated to one of the 1/3octave bands.

The phase shift is given in milliseconds related to the signals for the subwoofers. The measurements represent the respective excitation levels of the floor. The place of the measurement microphone was arbitrary but the experiment had to start.

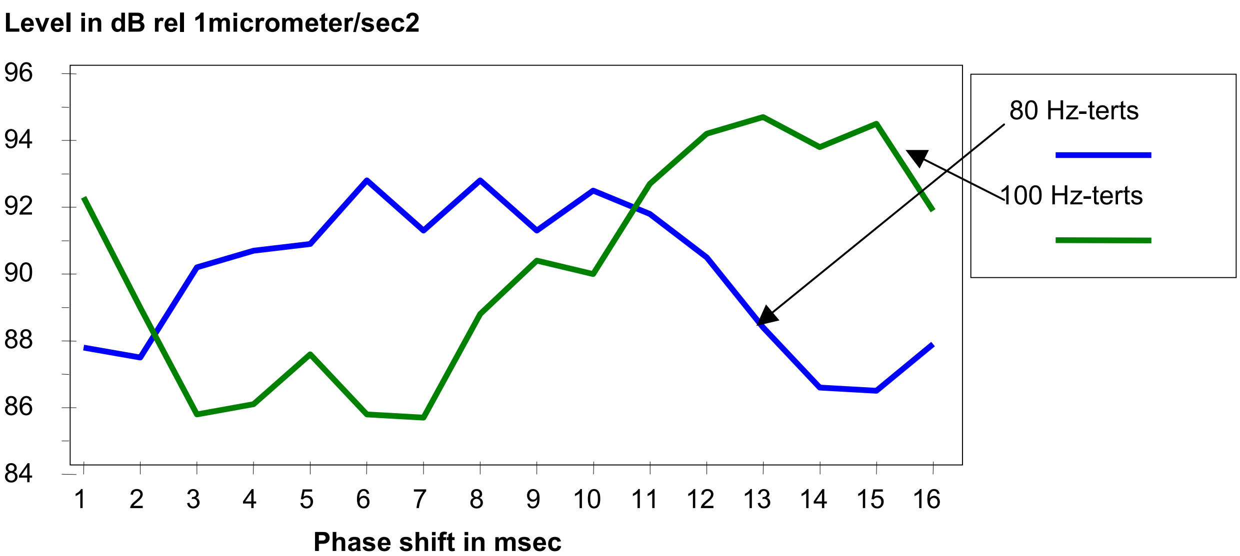


Fig. 5. Measurement of the excitations of the floor of the room as a function of the phase shift in the 1/3 octave bands of 80 Hz and 100 Hz.

The results of fig. 5 offered the hope that a reduction of the immission of the hindering sound in the dwelling places should exceed 6 dB.

It was not possible to constantly do the measurements in the houses. Therefore the measurements were executed on the soil just in front of the houses in order to check if the developed idea could lead to the set goal.

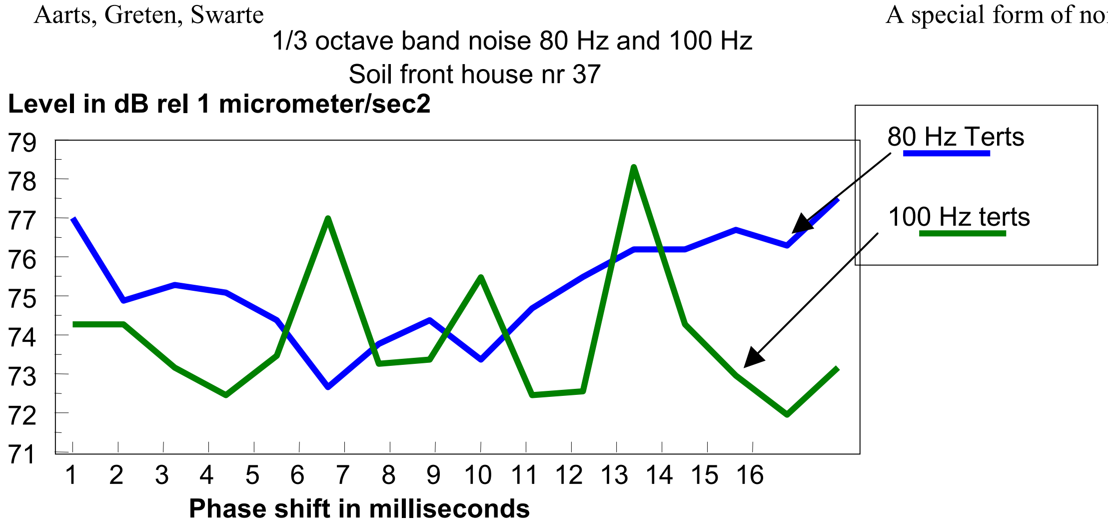
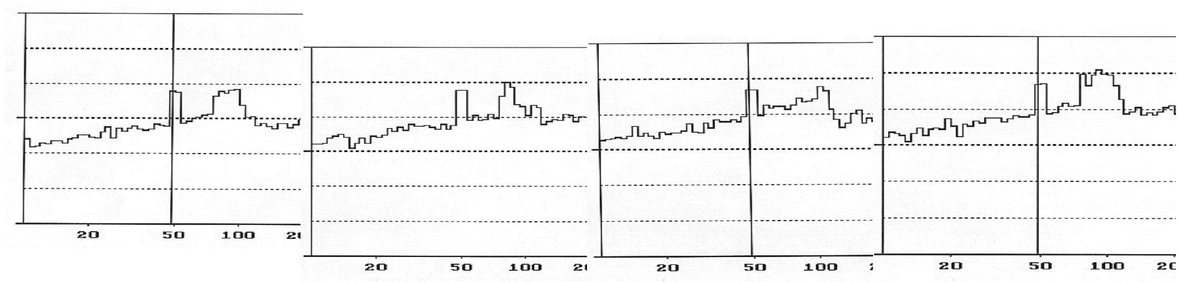


Fig. 6. Results of the system set up of fig 4.

The results of fig. 6 gave the onset to check the feasibility of this antisound method in the houses knowing that the behaviour in the 1/3 octave band of 100Hz seemed to include random effects.

The measurements of fig. 7 show the results in the houses.



Both system woofers on.

Both system woofers on + 80 Hz third noise with max. compensation.

Both system woofers on + 100 Hz third noise with max. compensation.

Both system woofers on + both compensation lsp's max. phase shift. (Taken some days later after the settings)

Fig.7. Measurements of the excitations of the floor of one of the houses. The pictures are shifted in order to eliminate the differences of the levels.

The most right-hand picture offers the impression that in this environment the principle of the antisound doesn't give the solution. The same measurements, but some days later, confirmed that conclusion. The transmission of the sound from the floor of the hall into the houses is ruled by several unknown factors. I. a. changing weather conditions were of a great influence. The path via the soil under the street was highly controlled by the humidity and the temperature.
Also the excitation of the walls and ceilings will play a big role in the transmission to the soil and thus to the dwelling houses. This process has proven to be very delicate due to unknown parameters.

The residents told a severe sinking of the road took place that some years ago. During structural alterations, they discovered rests of former houses or buildings. All this resulted in an advice to the local authorities to inspect the soil in the environment of both the houses and the discotheque. The places have a very rich history; during the 80-years war in the middle ages, the discotheque was a stable for 80 horses for the cavalry. The city itself was a military center and the residents created the possibilities to flee from the place via secret corridors.

The attack of the problems via antisound was left as it was due to the expected costs and time consumption.

3. The application of the principle of the "missing fundamental" as "dormant Bass" ("dB").

The concept of the "dB" processor is based on the principle of the missing fundamental, which can be described as follows.
The perceived pitch of a musical signal consisting of the fundamental frequency f_0 and its harmonics will be the same when the frequency f_0 is completely filtered out as the harmonics are still there. Fig. 8 shows an example of a composed signal where the fundamental is shown in a dashed way.

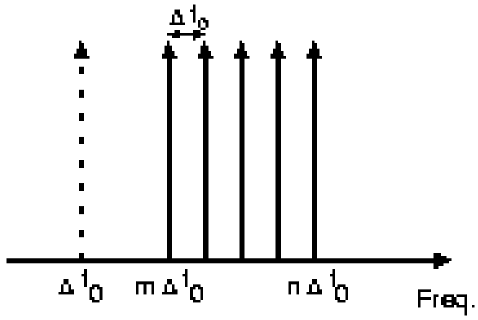


Fig. 8 The "missing fundamental". The perceived pitch of a composed musical signal doesn't change when the fundamental is taken out.

The incoming music signal is divided into two branches. The first one comprises a steep band cut filter (see fig. 9) taking the annoying frequencies away. The other branch consists of a complementary band pass filter which passes that frequencies through that are filtered out in the first branch. From that signal, the fundamental is cut out but the overtones or harmonics are calculated and shaped in the right sequence related to the fundamental and in such amplitude ratio's that the pitch is repaired or even emphasized. After these operations, the signals of both branches are mixed in the right proportions. The synthetic overtones may be mixed together with the eventually existing original overtones of the musical signal. Hardly any harm is done to the musical quality.

In the given situation, the lowest frequencies didn't cause any nuisance. A certain background noise level was always present (see fig. 7) and the sensitivity of the hearing is lower. In this way it was possible to stay within the limits of the law in the Netherlands even when the sound level in the hall reached 105 dB(A).

This process is only set up for the rejected frequency band. The frequencies below this band – so to say below 50 Hz – are not affected. So the "feeling" or "impact" of the music is not influenced and could evenly be enhanced by some decibells. In the described situation, these frequencies didn't cause any hinder.
.
The shape of the band rejection filter is shown in fig. 9. The slopes are very steep. The filter has been realized with a digital signal processor.

The output signal of the band cut filter channel and the output signal of the digitally filtered and sequentially to overtones processed frequencies are mixed together thus forming the output signal of the "dormant Bass".

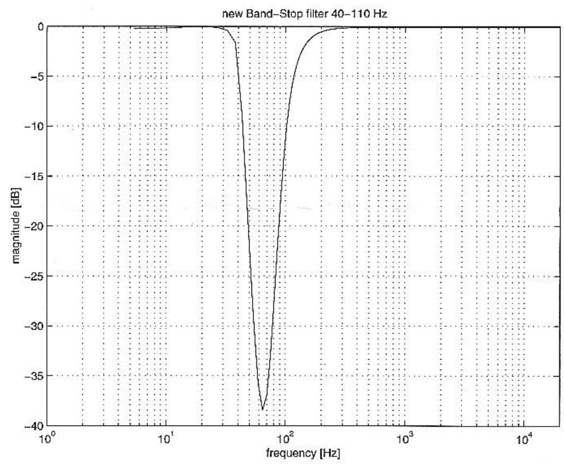


Fig. 9. Band rejection filter of the 'dormant Bass'.

By this measure, the the hinder was completely taken away, see fig. 10.

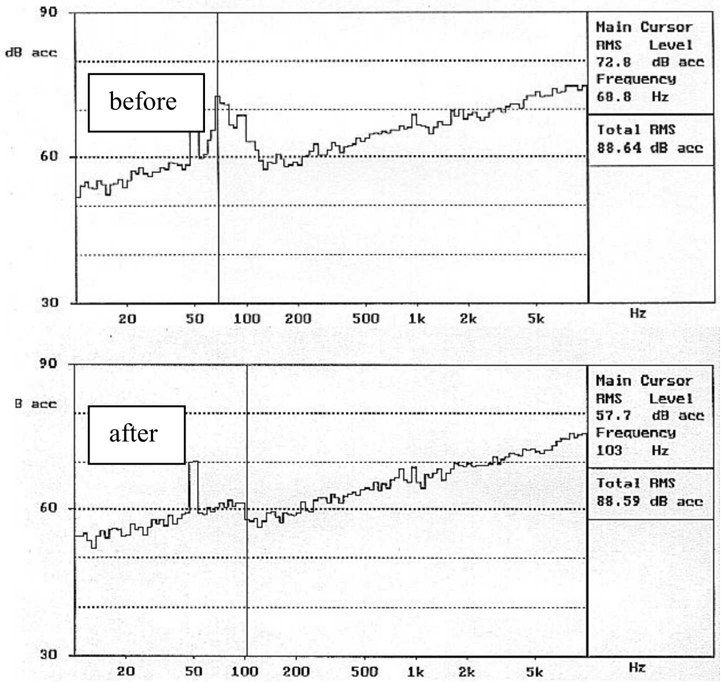


Fig. 10. The spectra of the excitations before and after the application of the “dormant Bass”.

The spectrum with the application of the “dB” just equals the background spectrum in the dwelling room.
Fig.11 shows the short term spectrum of a musical fragment with and without the “dB”. The hole in the spectrum can be clearly seen. Audio-wise one should do some effort to hear the difference. DJ’s will do in an A/B test, but a normal discotheque visitor will hardly notice any difference.

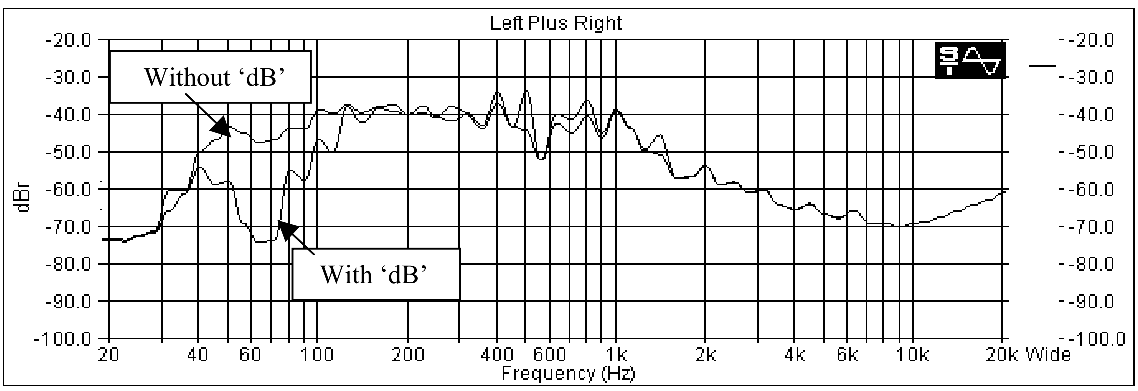


Fig. 11. Spectrum (short term) of the same music fragment with en without ‘dB’.

This solution has been chosen because the hinder ended in the most economical way.

4. Epilogue.

Both methods of attack led to a relevant reduction of the nuisance at the application of electro-acoustical systems by means of an electro-acoustical solution. The advantage is that the hinder is beaten at its origin. Besides that, this method is far more economic than structural alterations in the buildings.

In the described case, a double barrage should be constructed in the soil of the street with in between a big mass of concrete. An other possibility could be made in the form of a concrete box with its own foundation on three or four points free from the rest of the building containing the music hall.

The charm of antisound is that the quality of the sound is absolutely not affected. Only the standing wave pattern in the room has been changed. But the application of antisound is more delicate and must be tried out carefully. In practice this is a delicate and consequently a very time consuming process.

The charm of the application of the “dormant Bass” principles is the speed with what the equipment can be installed. During the feasibility measurements, the spectrum is judged to be adequate for “dB”-ing. The measurements of the transmission characteristics offer the (mathematical) information for the set up of the “dormant Bass”.

In both cases it is needed to again execute the feasibility measurements of the sound transmission when changes are made to the original sound system or changes in the interior or geometry of the room.

=========

References

A.J.M. Houtsma and J.L. Goldstein, The central origin of the pitch of complex tones: Evidence from musical interval recognition, *J. Acoust. Soc. Am.*, Vol. 51, 2 (Part 2), pp.520-529, 1972.
H. Helmholtz, *Die Lehre von den Tonempfindungen*, 1913 (6th printing), Friedr. Vieweg & Sohn, The 1st printing: 1863, English translation of the 4th German edition of 1877: On the Sensations of Tone, Dover, 1954.

B.C.J. Moore, *An introduction to the psychology of hearing*, Academic Press Inc., London New York, 4th Edition, 1997.

==========