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Noise Abatement

7.1 A SPECIAL KIND OF NOISE REDUCTION

Pop-music reproduction or sound reinforcement in discos or at concerts at a very high SPL is highly appreciated by the so-called 'target group' audience. For the neighbouring community however, this can be very annoying, especially when these music sessions take place during the night. A poor sound insulation (between adjacent houses, but also for buildings at some distance) creates an inadmissible sound emission level in, for example, bedrooms. Noise reduction methods of a constructional nature are, in most cases, very expensive, and also take a considerable amount of time to be realized. This often causes a temporary closing of the venue that creates the problem.

Another kind of option is to make use of 'active' noise reduction by signal-processing means. In Aarts *et al.* [7], two options are discussed, which were applied in a real-life situation of 'noise pollution'. The first method uses 'anti-sound', which will not be discussed here; the second method is based on low-frequency psychoacoustic BWE technology, as discussed previously in Chapter 2.

7.2 THE NOISE POLLUTION PROBLEM – CASE STUDY

As mentioned above, sound insulation between the community homes and sound-producing locations, such as clubs or entertainment venues, can be very poor. These places may produce SPLs that can go far beyond 100 dB(A) in the evening hours. At these levels, local authorities can force these 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 that are unpredictable, and venue owners are not willing, or not able, to make investments in constructional investigations and their solutions.

As a case example, we present a situation that existed at a club in The Netherlands, where high SPLs were produced in the dwellings opposite of the club. The irritation of the surrounding population was reinforced by the interrupted character of the disturbance (the rhythmic 'thumping' that penetrated into the houses) and the time of day (late evening). The spectrum of the 'thumping' was roughly 50–100 Hz. Beyond these frequencies, no

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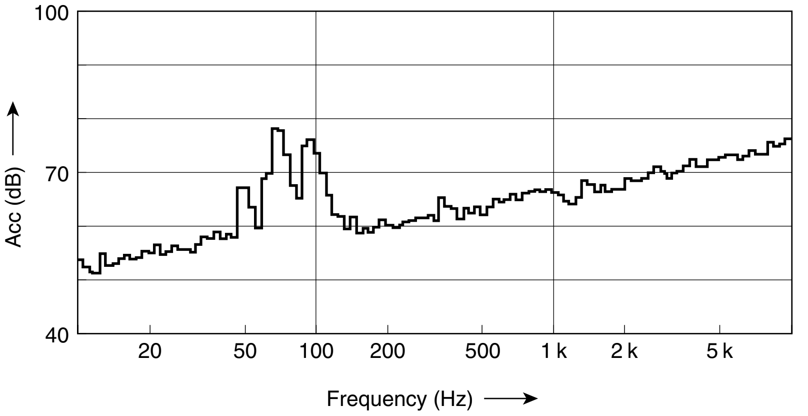

Figure 7.1 Structural excitation measurement (dB rel. 1 μm/sec²) in a room of a housing located near the club

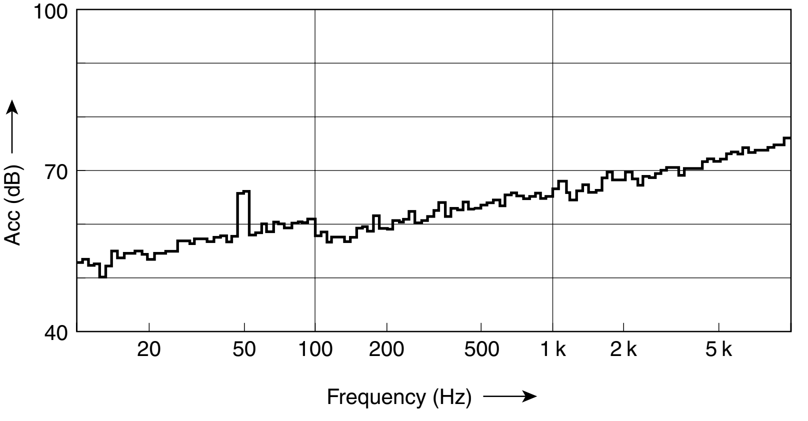

Figure 7.2 Structural background spectrum measurement (dB rel. 1 μm/sec²); same room as in Fig. 7.1. At the time of this measurement, there was no music production in the club (the excitation at 50 Hz was continuously present, and caused by a factory in the neighbourhood – there had never been complaints about this signal)

transmission had been measured, see Fig. 7.1. Note that this is a spectrum of structural vibration, not the spectrum as measured in air.

At the time of measurement, the SPL in the club was 112 dB. Figure 7.2 shows the background signal in the same room, when there was no disturbance from the music produced in the club. The annoyance was not caused by air transmission, but by vibrations that travelled through the soil, or other underground structures, into the houses. Of course, these vibrations were transformed to airborne sound by vibrations of the house construction. The transmission paths were not known and would have been very difficult to detect, which is why it was chosen to opt for an electro-acoustical/signal-processing approach and not for constructional measures.

A possible solution was to cut out the disturbing part of the frequency spectrum. However, this was judged to be intolerable from a musical point of view. The alternate method proposed was based on the principle of the ‘missing fundamental’ (see Sec. 1.4.5), whereby the perception of pitch is not disturbed when low-number harmonics are eliminated. The actual method closely follows the concept of low-frequency psychoacoustic BWE as discussed in Chapter 2. In the next section, we shall discuss the implementation and result of applying this method to the described situation.

7.3 THE APPLICATION LOW-FREQUENCY PSYCHOACOUSTIC BANDWIDTH EXTENSION TO NOISE POLLUTION

The concept of a noise-abatement low-frequency psychoacoustic BWE processor is based on the principles of pitch perception (Sec. 1.4.5). In summary, the perceived pitch of a signal consisting of a fundamental at f_0 and higher harmonics will not change when the fundamental at f_0 is completely removed. The remaining harmonics will still mediate the same strong pitch percept.

The algorithm follows the structure shown in Fig. 2.4 and the discussion presented there. The main application area that was considered there was for enhanced low-frequency reproduction on small loudspeakers. Thus, the goal was to emphasize all frequencies below a certain value, for example, 100 Hz. Here, the goal is to emphasize signals with pitches in the range 50–100 Hz by emphasizing their harmonics. Therefore, in the lower branch of Fig. 2.4, the input signal is processed by a band-stop filter of 50–100 Hz, see

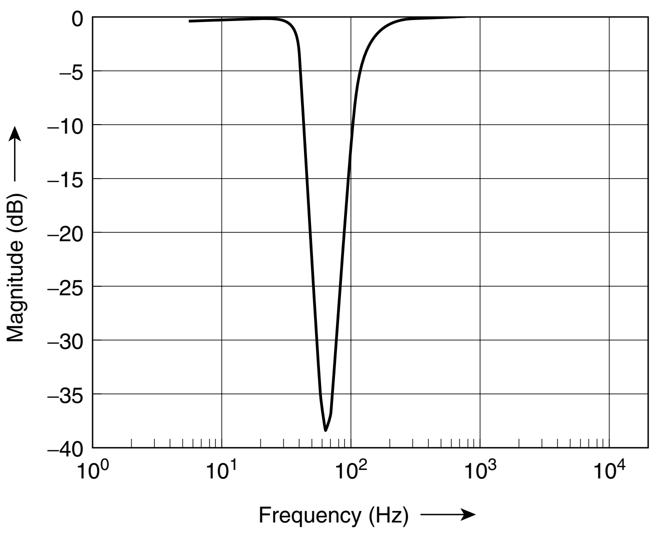

Figure 7.3 Band-stop filter for the low-frequency psychoacoustic BWE noise-abatement system. This filter eliminates the disturbing frequency components. This is compensated by a complementary filter that feeds into a non-linear device that generates a harmonics signal. This harmonics signal emphasizes the same low pitch of the bass sounds, but does not cause any disturbance in the neighbouring community

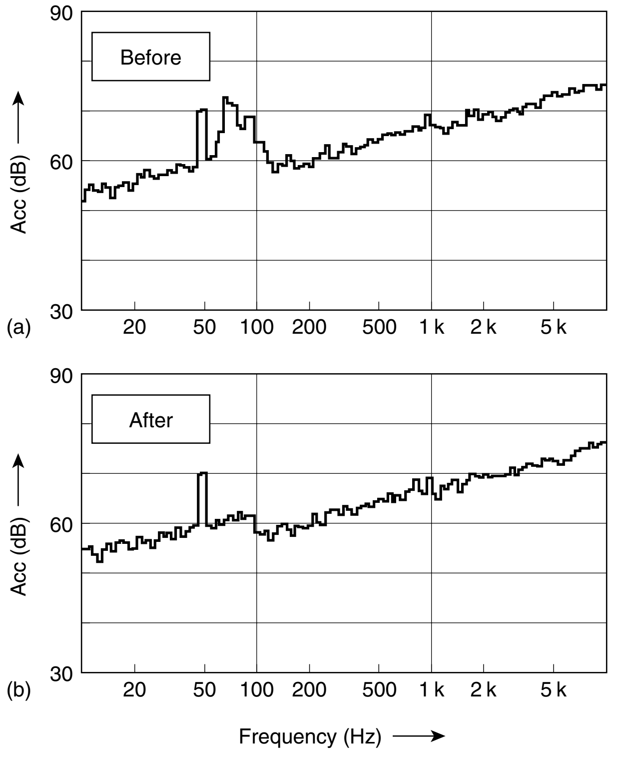

Figure 7.4 Structural excitation spectrum measurement (dB rel. 1 μm/sec^2) during music production in the club. The upper panel shows 'before', that is, without low-frequency psychoacoustic BWE noise-abatement processing. The lower panel shows 'after', that is, with low-frequency psychoacoustic BWE noise-abatement processing. Note that the peak around 100 Hz had been completely removed, while the perceptual difference between the two situations was judged to be small

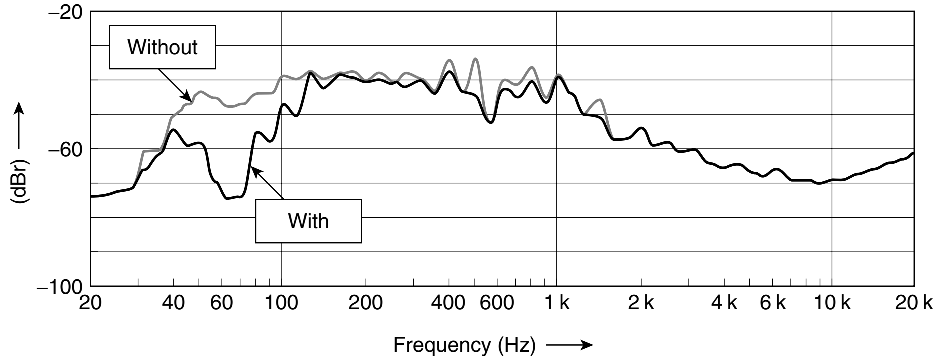

Figure 7.5 Short-term spectrum of representative music fragment measured (in air) in the club, with and without low-frequency psychoacoustic BWE processing

Fig. 7.3. This step eliminates the disturbing frequency components. To compensate for this, the upper branch generates harmonics of the bass input fundamental frequencies. The first filter complements the band-stop filter of the lower branch, thus it is a band-pass filter of 50–100 Hz. The NLD generates higher harmonics, and FIL2 shapes the thus-generated spectrum. An appropriate gain is applied to the harmonics signal after which it is added back to the band-stop-filtered input signal. Using this approach, it was possible to stay within the limits of the law in The Netherlands, even when the measured SPL in the club reached 105 dB(A). An additional advantage was that frequencies below 50 Hz did not cause annoyance and were thus not processed by dB. This is important as these very low frequency components add 'feel' or 'impact' to the music sensation, which is appreciated by the audience.

This procedure had completely removed the annoyance in the neighbouring houses. Although annoyance is a subjective variable, it is made plausible by comparing measurements shown in Fig. 7.4, which shows that the originally disturbing components between 50–100 Hz are removed after the dB processing. The quality of music as processed by the low-frequency psychoacoustic BWE noise-abatement system was judged to be sufficiently high such that this solution was adopted. The difference with the unprocessed sound could be heard, with some effort, when doing an informal A/B test (rapidly switching the processing on and off), but the club visitors would not normally notice any difference, in particular because the processing would always be turned on. Figure 7.5 shows an illustrative example of the difference between the short-term spectra of the same music signal with and without low-frequency psychoacoustic BWE processing.

In conclusion, low-frequency psychoacoustic BWE can be successfully applied to treat noise pollution problems as caused by entertainment venues or concerts, and so on, if the disturbing frequencies are relatively narrowband. The perceptual impairment is small, and the main advantages are low cost, rapid implementation, and robustness. The alternative method of constructional modifications can be very high cost, requires a much longer implementation period, and success is sometimes difficult to guarantee. For constructional measures, the advantage is obviously that the sound within the venue is not modified in any way, but the disadvantages would usually be more important than this minor advantage. Another signal-processing approach (discussed in the original treatment by Aarts *et al.* [7]) is using 'anti-sound', which only modifies the standing wave pattern inside the enclosure (but not the power spectrum of the sound) and thus attempts to minimize the SPL in those areas where acoustic energy is thought to propagate out of the enclosure, was found to be much more delicate and time consuming than the low-frequency psychoacoustic BWE approach.