Urban Acoustics

Week 2 Tutorial
Conceptual questions
Calculation of L_{eq},L_{Aeq},L_{day},$L_{evening}$,L_{night},L_{den}

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Conceptual questions

Question 1 :

- Environmental noise may cause various health effects. Explain whether equivalent noise levels below 50 dB(A) can affect health.

Answer

- Yes. Refer page 58, Environmental noise pollution. Refer page 58 and 64, Burden of disease from environmental noise.

TABLE 3.2 Summary of Effects and Threshold Levels for Effects of Nocturnal Noise Where There Is Sufficient[a] Evidence Available

Effect		Indicator	Threshold [dB]
Biological effects	Change in cardiovascular activity	–[b]	–[b]
	EEG awakening	$L_{Amax,inside}$	35
	Motility, onset of motility	$L_{Amax,inside}$	32
	Changes in duration of various stages of sleep, in sleep structure and fragmentation of sleep	$L_{Amax,inside}$	35
Sleep quality	Waking up in the night and/or too early in the morning	$L_{Amax,inside}$	42
	Prolongation of the sleep inception period, difficulty in getting to sleep	–[b]	–[b]
	Sleep fragmentation, reduced sleeping time	–[b]	–[b]
	Increased average motility when sleeping	$L_{night,outside}$	42
Well-being	Self-reported sleep disturbance	$L_{night,outside}$	42
	Use of somnifacient drugs and sedatives	$L_{night,outside}$	40
Medical conditions	Environmental insomnia[c]	$L_{night,outside}$	42

[a]This means that a causal relation has been established between exposure to night noise and a health effect.
[b]Although the effect has been shown to occur or a plausible biological pathway could be constructed, indicators or threshold levels could not be determined.
[c]Environmental insomnia is the result of diagnosis by a medical professional while self-reported sleep disturbance is essentially the same, but reported in the context of a social survey.
Source: WHO (2009).

Conceptual questions

Question 2 :

- Explain why noise maps according to the European Noise Directive are currently produced by calculations rather than by using measurement results.

Answer

- To get detailed measured noise maps, the measurements would be prohibitively expensive and time-consuming. Refer chapter 2.5.6, ‘Environmental noise pollution.’ That’s why measurements are only used locally to validate the calculation results.

Conceptual questions

Question 3 :

For what adverse health effects is the L_{den} indicator a good metric?

Answer:

Overall annoyance. Refer page 31 of ‘Environmental noise pollution’.

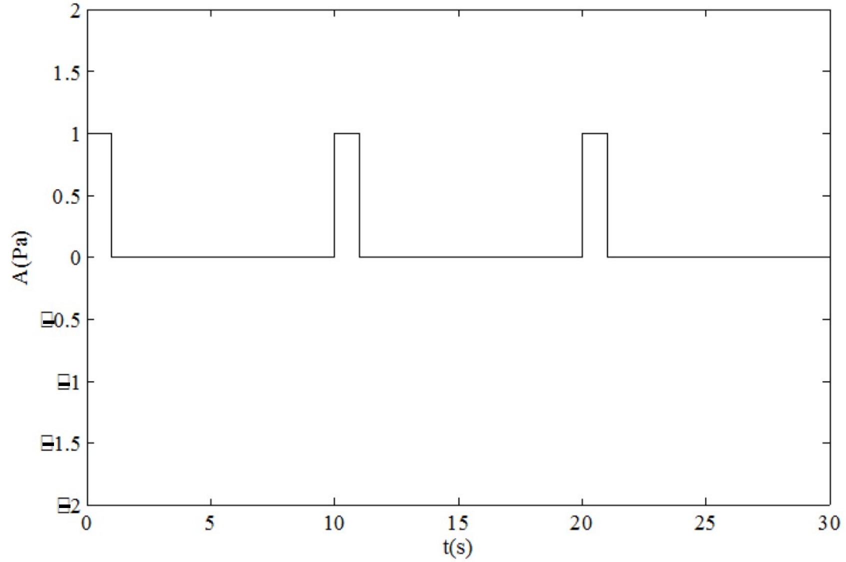
Exercises

<u>Exercise 1:</u>

An emergency signal has a periodicity of 10 s and can be described as

$$p(t) = A\sin(\omega t) \qquad \text{with} \qquad A = \begin{cases} 1 & \text{for } 0<t<1 \\ 0 & \text{for } 1<t<10 \end{cases}$$

with the time t, the angular frequency $\omega=2\pi f$, $f=1000$ Hz, the amplitude of the signal A. In the figure below, the amplitude is shown as a function of time.



Exercises

<u>Exercise 1:</u>

a) What is the equivalent sound pressure level $L_{eq,T}$ of this signal when averaging over the first 5 s of this signal, i.e. T = 5 s?

<u>Answer :</u>

$$L_{eq,T} = 10\log_{10}\left(\frac{\frac{1}{T}\int_0^T p^2(t)\,dt}{p_{ref}^2}\right)$$

Integration period T = 5 s
Reference pressure p_{ref} = 2×10^{-5} Pa

$$L_{eq,5} = 10\log_{10}\left(\frac{\frac{1}{5}\int_0^5 p^2(t)\,dt}{p_{ref}^2}\right)$$

Exercise 1:

a) What is the equivalent sound pressure level $L_{eq,T}$ of this signal when averaging over the first 5 s of this signal, i.e. T = 5 s?

Answer :

Now, decompose the integral: $$\int_0^5 p^2(t)\,dt = \int_0^1 p^2(t)\,dt + \int_1^5 p^2(t)\,dt = \frac{A^2}{2}$$

And replace:

$$L_{eq,5} = 10\log_{10}\left(\frac{\frac{1}{5}\int_0^5 p^2(t)\,dt}{p_{ref}^2}\right) = 10\log_{10}\left(\frac{\frac{1}{5}\times\frac{A^2}{2}}{p_{ref}^2}\right) \approx 84.0\,\mathrm{dB}$$

Exercises

b) What is $L_{eq,T}$ with T = 100 s? Why is this value lower or higher than the result of a)?

$$L_{eq,100} = 10 \log_{10}\left(\frac{\frac{1}{100}\int_0^{100} p^2(t)\,dt}{p_{ref}^2}\right)$$

Since the period of the emergency signal is 10 s, we can rewrite the integral as

$$\int_0^{100} p^2(t)\,dt = 10\times\left(\int_0^{1} p^2(t)\,dt + \int_1^{10} p^2(t)\,dt\right) = 10\times\left(\frac{A^2}{2}+0\right) = 10\times\frac{A^2}{2}$$

Now, replace:

$$L_{eq,100} = 10 \log_{10}\left(\frac{\frac{1}{100}\times 10\times\frac{A^2}{2}}{p_{ref}^2}\right) \approx 81.0\,\mathrm{dB}$$

Exercises

b) What is $L_{eq,T}$ with T = 100 s? Why is this value lower or higher than the result of a)?

$$L_{eq,5} \approx 84.0\,\mathrm{dB}$$

$$L_{eq,100} \approx 81.0\,\mathrm{dB}$$

so $L_{eq,5} > L_{eq,100}$

Here, the two values are different because $L_{eq,100}$ is computed over whole periods (100 s is a multiple of the signal period of 10 s), while $L_{eq,5}$ is computed over a truncated period (5 is not a multiple of 10). In other words, here only the remainder of the ratio between T and the signal period matters (a.k.a., the modulo operator: 5 modulo 10 = 5, while 100 modulo 10 = 0).

You can check that $L_{eq,10} = L_{eq,100}$, since 10 modulo 10 = 100 modulo 10 = 0.
This is a special property of *periodic* signals. We also have $L_{eq,10} < L_{eq,5}$, because within a period the integration if performed over a longer time for $L_{eq,10}$, which decreases the average since the signal is 0 between 5 and 10 seconds.

Bottom line: for impulsive/short noise (shorter than T), longer integration time = lower L_{eq}, but not necessarily true for longer signals (e.g., continuous noise)

Exercises

<u>Exercise 2:</u>

Two friends have their student flat along different roads of the city. Both are annoyed by road traffic noise at home. They are curious who of them suffers from the highest noise level. They decide to measure the equivalent sound pressure level in the open window of each of their flat, in $L_{eq,j}$ (dB), with j the octave band index. The results are listed in Table below. We can consider the level to be the level incident to the facade of their flat. For comparing their results, they decided to compare the single number equivalent level by energetically adding the levels of all octave bands.

Exercises

Exercise 2:

Octave band middle frequency (Hz)	$L_{pj,eq}$ Erik (dB)	$L_{pj,eq}$ Martijn (dB)
63	52	56
125	49	53
250	52	52
500	51	51
1000	56	53
2000	49	46
4000	40	37
8000	35	32

a) Compute the level L_{eq} (dB) at the facades of the student apartments of Erik and Martijn.

Exercises

Answer 2a):

Octave band middle frequency (Hz)	$L_{pj,eq}$ Erik (dB)	$L_{pj,eq}$ Martijn (dB)
63	52	56
125	49	53
250	52	52
500	51	51
1000	56	53
2000	49	46
4000	40	37
8000	35	32

$$L_{eq} = 10 \log_{10} \left(\sum_{pj=1}^{n} 10^{\frac{L_{pj,eq}}{10}} \right)$$

$n =$ Total number of octave bands

Exercises

Answer 2a):(continuation)

$$L_{eq}=10\log_{10}\left(\sum_{pj=1}^{n}10^{\frac{L_{pj,eq}}{10}}\right)$$

$$L_{eq,Erik}=10\log_{10}\left(10^{\frac{52}{10}}+10^{\frac{49}{10}}+......+10^{\frac{35}{10}}\right)\approx 60.1\,\mathrm{dB}$$

$$L_{eq,Martijn}=10\log_{10}\left(10^{\frac{56}{10}}+10^{\frac{53}{10}}+......+10^{\frac{32}{10}}\right)\approx 60.5\,\mathrm{dB}$$

Exercises

Exercise 2:

Octave band middle frequency (Hz)	$L_{pj,eq}$ Erik (dB)	$L_{pj,eq}$ Martijn (dB)
63	52	56
125	49	53
250	52	52
500	51	51
1000	56	53
2000	49	46
4000	40	37
8000	35	32

b) Who has the highest level when computing L_{Aeq} (dB(A)), i.e. taking into account A-weighting in the calculations?

Exercises

Frequency (Hz)	A-Weighting Correction (dB)
31.5	-39.4
63	-26.2
125	-16.1
250	-8.6
500	-3.2
1kHz	0
2kHz	1.2
4kHz	1
8kHz	-1.1
16kHz	-6.6

<u>Answer 2b):</u> Add A-Weighted correction to $L_{pj,eq}$

$$L_{Aeq} = 10 \log_{10} \left(\sum_{pj=1}^{n} 10^{\frac{L_{pj,eq} + W_{pj}}{10}} \right)$$

Octave band middle frequency (Hz)	$L_{pj,eq}$ Erik (dB)	$L_{pj,eq}$ Martijn (dB)
63	52	56
125	49	53
250	52	52
500	51	51
1000	56	53
2000	49	46
4000	40	37
8000	35	32

Exercises

Answer 2b): (continuation)

$$L_{Aeq,Erik} = 10\log_{10}\left(10^{\frac{52-26.2}{10}} + 10^{\frac{49-16.1}{10}} + \ldots\ldots + 10^{\frac{35-1.1}{10}}\right) \approx 57.8\,\text{dB(A)}$$

$$L_{Aeq,Martijn} = 10\log_{10}\left(10^{\frac{56-26.2}{10}} + 10^{\frac{53-16.1}{10}} + \ldots\ldots + 10^{\frac{32-1.1}{10}}\right) \approx 55.4\,\text{dB(A)}$$

Erik has the highest level

c) Finally, Erik notices that his measurement took 30 minutes while Martijn only has measured for a period of 10 minutes. What correction should we apply to the measured levels to compared them in a fair way?

Answer 2c) : There is no way to correct this. If they still have the recordings, they could both take the first 10 minutes to compute the noise level. But we can assume that the comparison is still quite fair if the road traffic noise is continuous.

Exercise 3:

The yearly averaged sound pressure levels due to noise from road traffic L_{day}, $L_{evening}$ and L_{night}, should be computed at the facade of a hospital. Table 2 shows the hourly averaged values.

Hourly averaged equivalent sound pressure levels at the facade of the hospital.

Hour	L_{Aeq} (dB(A))	*Hour*	L_{Aeq} (dB(A))	*Hour*	L_{Aeq} (dB(A))
0-1	44	8-9	72	16-17	68
1-2	42	9-10	70	17-18	72
2-3	42	10-11	65	18-19	62
3-4	43	11-12	65	19-20	55
4-5	46	12-13	68	20-21	53
5-6	55	13-14	63	21-22	50
6-7	68	14-15	62	22-23	48
7-8	70	15-16	63	22-24	44

Exercises

Exercise 3:

Hourly averaged equivalent sound pressure levels at the facade of the hospital.

Day : 07:00-19:00
Evening : 19:00-23:00
Night : 23:00-07:00

Hour	L_{Aeq} (dB(A))	*Hour*	L_{Aeq} (dB(A))	*Hour*	L_{Aeq} (dB(A))
0-1	44	8-9	72	16-17	68
1-2	42	9-10	70	17-18	72
2-3	42	10-11	65	18-19	62
3-4	43	11-12	65	19-20	55
4-5	46	12-13	68	20-21	53
5-6	55	13-14	63	21-22	50
6-7	68	14-15	62	22-23	48
7-8	70	15-16	63	22-24	44

a) Compute L_{day}, $L_{evening}$ and L_{night} from Table .

Logarithmic mean of the hourly levels:

$$L_{day} = 10 \log_{10}\left(\frac{10^{\frac{70}{10}} + 10^{\frac{72}{10}} + \ldots\ldots + 10^{\frac{62}{10}}}{12}\right) \approx 68.1\,\text{dB(A)}$$

Exercises

Exercise 3:

a) Compute L_{day}, $L_{evening}$ and L_{night} from Table .

$$L_{evening} = 10\log_{10}\left(\frac{10^{\frac{55}{10}} + 10^{\frac{53}{10}} + \ldots\ldots + 10^{\frac{48}{10}}}{4}\right) \approx 52.3\,\mathrm{dB(A)}$$

$$L_{night} = 10\log_{10}\left(\frac{10^{\frac{44}{10}} + 10^{\frac{44}{10}} + \ldots\ldots + 10^{\frac{68}{10}}}{8}\right) \approx 59.3\,\mathrm{dB(A)}$$

b) Compute L_{den}

$$L_{den} = 10\log_{10}\left(\frac{1}{24}\left[12\times 10^{\frac{L_{day}}{10}} + 4\times 10^{\frac{L_{evening}+5}{10}} + 8\times 10^{\frac{L_{night}+10}{10}}\right]\right) \approx 67.9\,\mathrm{dB(A)}$$