Kurt Heutschi, Acoustics I, 2011-09-19

Exercise A1-6: Acoustical measurements

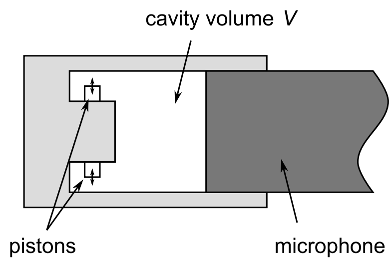
1. a) The measurement of an acoustical event yields unfiltered 67 dB, with the A-filter inserted 68 dB. What can be concluded regarding the spectral content of the signal?
b) The measurement of an acoustical event yields 90 dB(C) with C-weighting and 70 dB(A) with A-weighting. What can be concluded regarding the spectral content of the signal?

2. At the end of a measurement the sound level meter indicates 50 dB Leq and 70 dB L_E or SEL. How long did the measurement last?

3. A single impulse of height 1 Pa (RMS) and duration 10 ms is investigated. Calculate the maximum value of the momentary sound pressure level with the time constants FAST and SLOW and the event level L_E or SEL.

4. An octave band analysis of a broadband stochastic signal is performed with help of a sound level meter with adjustable octave band filter. Thus at a time only one octave can be evaluated. How long does it take to get all octaves from 125 Hz to 4 kHz analyzed with an accuracy of ± 1 dB (90% probability)?

5. A pistonphone mounted on a microphone produces a sound pressure level of 124 dB under reference ambient pressure at sea level (1013 hPa). The enclosed cavity V has a volume of 20 cm^3, the diameter of each of the two oscillating pistons that generate the pressure variation is 3 mm. Calculate the maximum excursion (amplitude of the oscillation) of the pistons and calculate the produced sound pressure under reference conditions but at a height of 500 m above sea level.



Solutions to Exercise A1-6

1.
a) the dominating frequency range is 1..8 kHz. b) there are strong low frequency components.

2.
$10\log(\frac{1}{T}) = -20$ dB $\rightarrow T = 100$ s

3.
the continuous sound pressure level after 10 ms is found as:

$$L(10\mathsf{ms}) = 10\log\left(\frac{1}{RC}\int_0^{10\mathsf{ms}}\frac{1\mathsf{Pa}^2}{p_0^2}e^{\frac{\tau-10\mathsf{ms}}{RC}}d\tau\right)$$
$$= 10\log\left(\frac{1}{RC}\frac{1}{p_0^2}\int_{-0.01}^{0}e^{\frac{\tau}{RC}}d\tau\right) = 10\log\left(\frac{1-e^{\frac{-0.01}{RC}}}{p_0^2}\right)$$

Alternatively the algorithm for the evaluation of the moving square average may be used:

$$x^2_{\mathsf{rms}}(t+\Delta t) \approx x^2_{\mathsf{rms}}(t) + \frac{x^2(t+\Delta t) - x^2_{\mathsf{rms}}(t)}{\frac{RC}{\Delta t}}$$

As the length of the impulse is much smaller than the two time constants 125 ms and 1000 ms, the sampling interval can be chosen as $\Delta t = 10\mathsf{ms}$. With this:

$$x^2_{\mathsf{rms}}(10\mathsf{ms}) \approx \frac{1\mathsf{Pa}^2}{\frac{RC}{10\mathsf{ms}}}$$

With *FAST* the maximum level reaches 83 dB, with *SLOW* the maximum is 74 dB.

4.
The specified accuracy makes a value for the degrees of freedom of $n = 2BT = 100$ necessary.

	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
B [Hz]	88	175	350	700	1400	2800
T [s]	0.6	0.3	0.1	0.1	0.0	0.0

The total analyzing time sums up to 1.1 sec.

5.
It is:

$$PV^\kappa = \mathsf{constant} \quad \rightarrow \quad \frac{\Delta P}{P} \approx -\kappa\frac{\Delta V}{V} \quad \mathsf{for} \quad \Delta P \ll P$$
$$\rightarrow p_{\mathsf{rms}} \approx \kappa\frac{\Delta V}{V}P\frac{1}{\sqrt{2}}$$
$$\Delta V = 2 \cdot \mathsf{piston.area} \cdot \mathsf{max.excursion} \qquad (1)$$

with $p_{\mathsf{rms}} = 31.7$ Pa (124 dB), $\kappa = 1.4$, $V = $ 2E-5 m^3 and $P = 101300$ Pa follows $\Delta V =$ 6.3E-9 m^3. With the area of the piston = 7.1E-6 m^2, the maximum excursion is = 0.44 mm. Normal pressure at a height of 500 m above sea level may be estimated by 1013000-500$\times$12 = 95300 Pa. The sound pressure generated by the pistonphone is proportional to the absolute pressure. With $\frac{P_{500m}}{P_{0m}} = 0.941$ follows a value of the sound pressure level of 123.5 dB.