LABORATORY OF ELECTROACOUSTICS

EXERCISE 2.

Measurement and analysis of the sound pressure level.

Equipment: laptop, Reaper/Audacity software, amplifier, speaker, sound level meter SVAN 955 with microphone, acoustic calibrator

The purpose of the exercise:

Perform the measurement of sound pressure level parameters using a sound level meter. Correction curves A, C and Z, time constantslow, fast and impulse, equivalent, maximum and peak level (LAeq, LAmax, LCpeak), octave band and 1/3 octave band.

1. Determining the position of the sound source and measuring point

2. Calibrate the sound level meter

3. Measurement of several selected signals

    a. white noise (sample 1)

    b. pink noise (sample 2)

    c. shaped noise (the similar level of dB (SPL) but different spectra (sample 3-6)

    d. non-stationary signal, e.g. train, hammer noise (sample 7-8)

4. Analysis of measurements

For each measured signals perform the following actions:

- for a and b: what is the theoretical spectrum of white noise and pink noise and what is the theoretical spectrum in octave bands,
- import logger in octave bands in the range 63 Hz – 8 kHz,
- calculate the equivalent value (average) for each octave bands,
- correct the A and C curves (in octave bands),
- calculate the level in the full range for Z [dB(SPL)], A [dB(A)] and C [dB(C)],
- compare the results for different samples: spectra in octave bands, total level for Z, A and C,
- for measurements 3.d.: consider the parameters LAeq, LAmax and LCpeak

Manual of sound level meter:

http://svantek.co.uk/wp-content/uploads/2015/06/svan_958_user_manual1.pdf

Octave band and 1/3 octave band

Single full frequency range value of sound level is often inaccurate. Sometime the frequency character must be analyzed. That is why the octave bands (and 1/3 octave bands) have been developed. The whole frequency range is divided into sets of frequencies called bands.Each band covers a specific range of frequencies.

An octave band is created by frequency filtration with a specific bandpass filter whose upper frequency (f_g) divided by the lower frequency (f_d) equals 2.

An 1/3 octave band is created by frequency filtration with a specific bandpass filter whose upper frequency (f_g) divided by the lower frequency (f_d) equals $\sqrt[3]{2}$. Each octave band consist of three 1/3 octave bands.

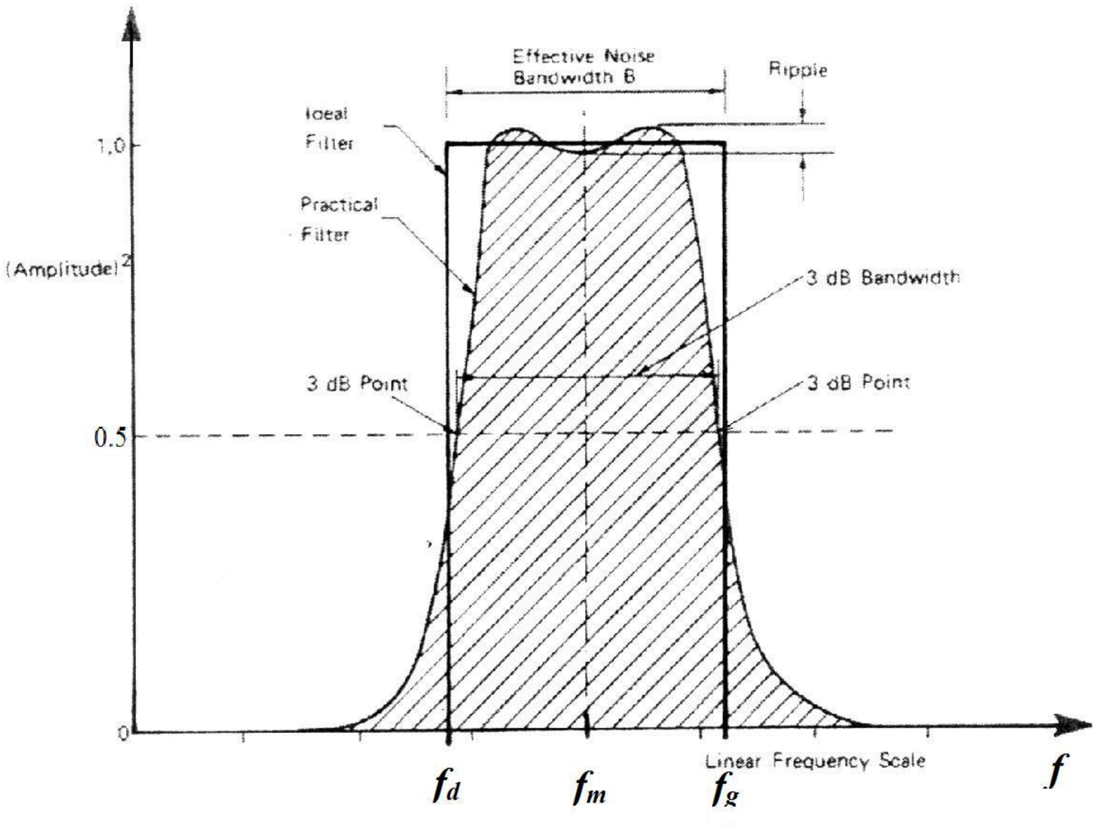

Figure 1. Frequency characteristics of the band pass filter; f_d, f_g - lower and upper limit frequency, fm - middle frequency, B – bandwidth

The center frequency (fm) of the octave and 1/3 octave bands are strictly defined (<u>showed in the table 1 and 2</u>).

It is worth noting that following octave bands (and 1/3 octave bands) have different absolute bandwidth ($f_g - f_d$), but equal relative bandwidth (f_g / f_d).

Table 1 Lower, middle and upper limit frequency of 1/3 octave band filters

1/3 octave number	fd	fm	fg
1	11,1 Hz	12,5 Hz	14,0 Hz
2	14,3 Hz	16 Hz	18,0 Hz
3	17,8 Hz	20 Hz	22,4 Hz
4	22,3 Hz	25 Hz	28,1 Hz
5	28,1 Hz	31,5 Hz	35,4 Hz
6	35,6 Hz	40 Hz	44,9 Hz
7	44,5 Hz	50 Hz	56,1 Hz
8	56,1 Hz	63 Hz	70,7 Hz
9	71,3 Hz	80 Hz	89,8 Hz
10	89,1 Hz	100 Hz	112,2 Hz
11	111,4 Hz	125 Hz	140,3 Hz
12	142,5 Hz	160 Hz	179,6 Hz
13	178,2 Hz	200 Hz	224,5 Hz
14	222,7 Hz	250 Hz	280,6 Hz
15	280,6 Hz	315 Hz	353,6 Hz
16	356,4 Hz	400 Hz	449,0 Hz
17	445,4 Hz	500 Hz	561,2 Hz
18	561,3 Hz	630 Hz	707,2 Hz
19	712,7 Hz	800 Hz	898,0 Hz
20	890,9 Hz	1 000 Hz	1 122,5 Hz
21	1 113,6 Hz	1 250 Hz	1 403,1 Hz
22	1 425,4 Hz	1 600 Hz	1 795,9 Hz
23	1 781,8 Hz	2 000 Hz	2 244,9 Hz
24	2 227,2 Hz	2 500 Hz	2 806,2 Hz
25	2 806,3 Hz	3 150 Hz	3 535,8 Hz
26	3 563,6 Hz	4 000 Hz	4 489,8 Hz
27	4 454,5 Hz	5 000 Hz	5 612,3 Hz
28	5 612,7 Hz	6 300 Hz	7 071,5 Hz
29	7 127,2 Hz	8 000 Hz	8 979,7 Hz
30	8 909,0 Hz	10 000 Hz	11 224,6 Hz
31	11 136,2 Hz	12 500 Hz	14 030,8 Hz
32	14 254,4 Hz	16 000 Hz	17 959,4 Hz
33	17 818,0 Hz	20 000 Hz	22 449,2 Hz

Table 2 Lower, middle and upper limit frequency ofoctave band filters

Octave number	fd	fm	fg
1	11,3 Hz	16 Hz	22,6 Hz
2	22,3 Hz	31,5 Hz	44,5 Hz
3	44,5 Hz	63 Hz	89,1 Hz
4	88,4 Hz	125 Hz	177 Hz
5	177 Hz	250 Hz	354 Hz
6	354 Hz	500 Hz	707 Hz
7	707 Hz	1000 Hz	1414 Hz
8	1414 Hz	2000 Hz	2828 Hz
9	2828 Hz	4000 Hz	5657 Hz
10	5657 Hz	8000 Hz	11314 Hz
11	11314 Hz	16000 Hz	22627 Hz

A, C, Z correction curve

The sound pressure level expressed in dB (SPL) does not give information related to how people hear. It means that sound pressure level is not related to loudness (fig 2). For example the hearing threshold for 1000 Hz is 0 dB(SPL) and for 50 Hz is about 40 dB(SPL).

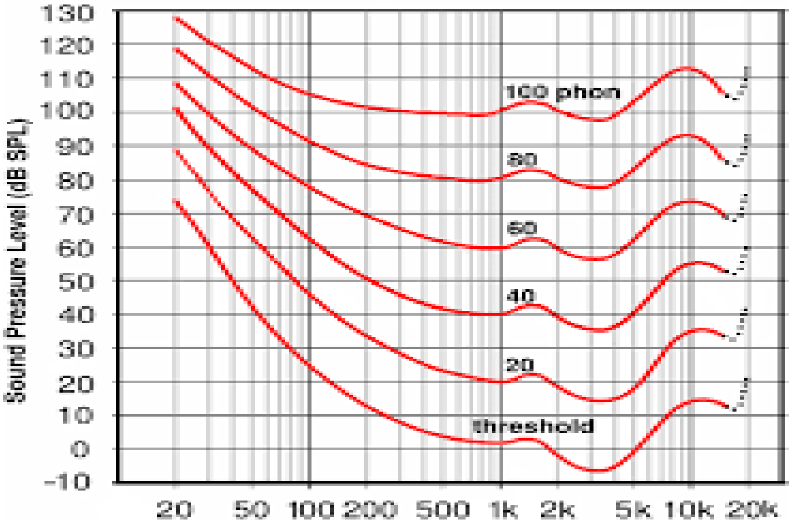

Figure 2 Equal-loudness contours.

The sound level meters need to imitate the properties of the human ear. For this reason the sound level A and C are used. The sound level is the rms value of the sound pressure corrected according to the correction curve A or C according to the formula:

$$L_{A,C} = 10\lg\left(\sum_{i=1}^{N} 10^{0.1\ L_i + K_{A,C}}\right),\ \ \text{dB},$$

where: L_i - the level of effective sound pressure value in the i-th frequency band,

$K_{A,\ C}$ - correction value according to the correction curve A or C,

N - number of frequencies.

There is more than two correction curves however A and C is the most commonly used.

Sound level meters have built-in A and C corrective filters frequency characteristics are inverted "upside down" and smooth isophonic curves, which correspond to:

1. correction curve A - 40 phonemes,
2. correction curve C - 100 phonies,
3. Z correction curve is linear curve (no correction).

On the figure 3 different correction curves are shown. In the table 3 the value of A and C correction in octave band are shown.

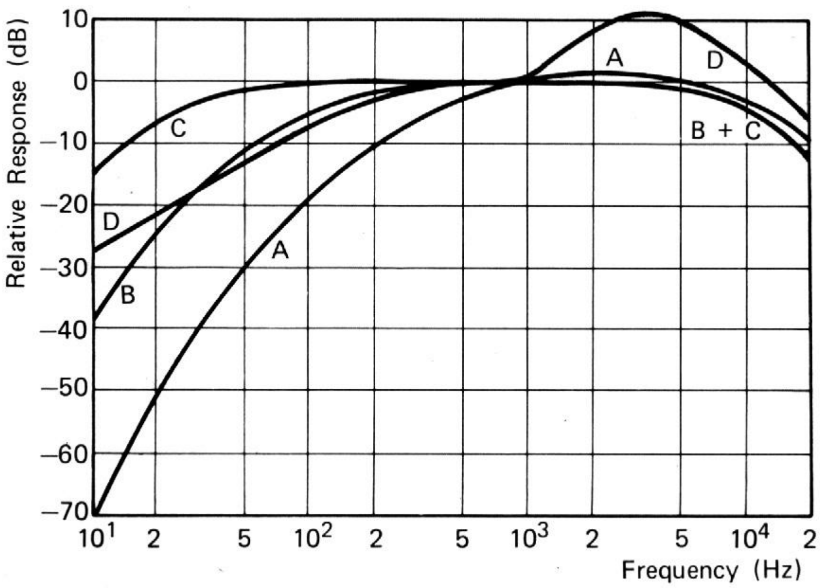

Figure 3 Correction curves A, B, C, D.

Table 3 A and C correction value for octave band.

Center Frequency [Hz]	Effective Band [Hz-Hz]	A Weighting [dB]	C Weighting [dB]
31,5	22,1 - 44,2	-39.4	-3.0
63	44,2 - 88,4	-26.2	-0.8
125	88,4 - 177	-16.1	-0.2
250	177 - 354	-8.6	0
500	354 - 707	-3.2	0
1000	707 - 1 414	0	0
2000	1 414 - 2 828	1.2	-0.2
4000	2 828 - 5 657	1.0	-0.8
8000	5 657 - 11 314	-1.1	-3.0
16000	11 314 - 22 628	-6.6	-8.5

Calculation the equivalent level and summing decibels

Equivalent level is an "energy average" of measurement results in following second:

$$Leq = 10log_{10}\left(\frac{1}{n}\right)\sum_{i=1}^{n} 10^{0,1L_i}$$

Excel formula: 10*log10(AVERAGE(10^(0,1*[range])))

Full range level is the "energy sum" of whole octave bands:

$$Leq = 10log_{10}\sum_{i=1}^{n} 10^{0,1L_i}$$

Excel formula: 10*log10(SUM(10^(0,1*[range])))

These are array functions. Press **CTRL+SHIFT+ENTER** instead **ENTER**

Time	Sound Pressure Level in octave bands [dB(SPL)]								Full band
[hh:mm:ss]	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz	8k Hz	[dB(SPL)]
00:00:01	39,5	40,7	41,6	40,7	41,0	40,1	34,0	31,8	48,7
00:00:02	39,0	39,3	41,1	40,2	41,1	41,0	33,5	32,0	48,4
00:00:03	38,1	38,8	43,7	42,1	41,3	40,6	33,5	32,2	49,2
00:00:04	41,6	37,4	41,9	41,0	41,7	40,9	33,9	31,4	49,0
00:00:05	41,8	38,7	43,3	40,8	41,9	41,2	33,5	31,8	49,5
00:00:06	39,9	40,4	42,1	41,1	43,5	41,0	35,7	34,1	49,6
00:00:07	40,9	38,6	42,6	40,3	40,9	40,7	36,3	32,5	49,0
00:00:08	39,5	39,1	41,9	41,0	41,6	41,0	34,4	31,8	48,8
00:00:09	39,0	39,8	42,5	41,0	40,9	40,1	33,6	32,4	48,7
00:00:10	40,1	39,1	41,6	40,6	41,3	40,2	34,3	32,3	48,6
Equivalent level [dB(SPL)]	**40,1**	**39,3**	**42,3**	**40,9**	**41,6**	**40,7**	**34,4**	**32,3**	**49,0***
Equivalent level [dB(A)]	13,9	23,2	33,7	37,7	41,6	41,9	35,4	31,2	**46,3***
A curve	-26,2	-16,1	-8,6	-3,2	0	1,2	1	-1,1	
C curve	-0,8	-0,2	0	0	0	-0,2	-0,8	-3	

Full range level is sum of octave band level
10*log10(SUM(10^(0,1*[range]))))

Equivalent level is average of results
10*log10(AVERAGE(10^(0,1*[range])))

Sound level A:
result in current octave band
+ A correction value

*This value could be calculated in two ways:

1) Calculate the equivalent level in each octave bands ("energy average" of subsequent seconds) and than sum those results ("energy sum" of octave bands)

2) Sum the values of octave bands for every seconds of the measurement and than calculate the equivalent level