Underwater noise assessment in the Messina Strait – Italy

An underwater acoustic environmental characterization from the Kobold turbine

Results at October 2007

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CIBRA
Centro Interdisciplinare di Bioacustica e
Ricerche Ambientali
dell'Università di Pavia - Italia

Introduction

In July 2007 Nauta-rcs was asked to perform an underwater acoustic noise level assessment in the Messina Strait (Italy) in order to create a baseline noise profile for this environment. CIBRA - Centro Interdisciplinare di Bioacustica e Ricerche Ambientali of the Pavia University, also offered supervision to this assessment, and offered help and instruments.

These data were needed to compare standard noise levels in the area with new readings as those obtained with an operational Kobold turbine. Kobold turbine is a patented energy producing floating system today under tests in the Messina Strait.

Messina Strait is a small, rather deep and with heavy ship traffic strait that separates the most southern peninsular Italy from Sicily. The strait connects south Mediterranean Sea with Tyrrhenian Sea.

The measures

Underwater noise measures were taken in two days (July 10 and 11, 2007) at -16 and -30 meters. The sensor was set tight to a mooring cable towards East (day 10) and NE (day 11).

An ITC 8073 calibrated hydrophone was used as an underwater sensor, while surface acquisition and recording was carried out using a Sinus Messtechnik SAMURAI workstation (Harmonie interface and SAMURAI - SINUS Acoustic Multichannel Universal Real-time Analysis Instrument).

The system acquired signals for about 20 hours. Recordings and measures cover from 11.50 to 21.30 on day 10 and from 16.00 to 2.00 in the next morning starting on day 11.

The analysis

The Samurai system helps the operator with semi-automatic extraction of noise parameters. Data tables used during this analysis report intensity levels with 1/3 of octave frequency resolution and 1/10th of a second time resolution.
All levels can also be reported with linear frequency resolution, while the uncompressed audio recording is also retained.

The results

To help the understanding of the following results we must consider the peculiar environment in which those readings were taken.
The Strait is cyclically involved in a massive water flow from the South Mediterranean up to the Tyrrhenian Sea and back, and the low frequency component (up to 20/40Hz, most of which comes from flow noise) is normally the most intense part of the signal. Among all the samples the lowest intensity values at 25Hz were around 78dBs while the strongest were around 155dBs (all dBs are re to 1uPa). This is "doubling" factor is probably due to the flow noise and so it should be considered as natural feature of this area.

More interesting, from the management point of view, is the variability in other frequency ranges, where shipping noise is typically present.
Some samples (K18-1 for example) show noise peaks in frequencies from 160Hz to 500Hz, where in some periods we go from a 90dB baseline to a 128dB level.

Other samples (k18-2) show noise peaks in a bit lower frequencies, at around 80Hz. Here we go from a 85dB baseline, to a 128dB peak.
Many samples show a similar behaviour in a frequency range that goes from about 100Hz up to 500Hz. This noise is probably generated by large ships that cross the Strait, even in far distance.

Much smaller ships (even outboards), or nearer large ships, add to this noise other peaks, usually well visible between the 1000Hz and the 2000Hz boundary. Some samples go, in these ranges, from a 100dB baseline to a 138dB limit (K16-6).

Kobold experimental platform

Underwater acoustic samples taken according to the following scheme:

		subset	date and start time		sample duration	
Sample Name:	**Kobold16**	1	10/7/07 15.58		3600 s	
		2	10/7/07 16.58		3600 s	
		3	10/7/07 17.58		3600 s	
		4	10/7/07 18.58		3600 s	
		5	10/7/07 19.58		3600 s	
		6	10/7/07 20.58		3600 s	
		7	10/7/07 21.58		3600 s	
		8	10/7/07 22.58		3600 s	
		9	10/7/07 23.58		3600 s	
		10	11/7/07 0.58		3424.94 s	
	Kobold18	1	11/7/07 11.50		3600 s	
		2	11/7/07 12.50		3600 s	
		3	11/7/07 13.50		3600 s	
		4	11/7/07 14.50		3600 s	
		5	11/7/07 15.50		3600 s	
		6	11/7/07 16.50		3600 s	
		7	11/7/07 17.50		3600 s	
		8	11/7/07 18.50		3600 s	
		9	11/7/07 19.50		3600 s	
		10	11/7/07 20.50		1453.26 s	

This sampling was aimed at determining a baseline scheme for future reference.
All readings were taken with NO TURBINE ROTATION (all rotating parts were stopped).

For each subset four graphs show a summary of the 60′ period.

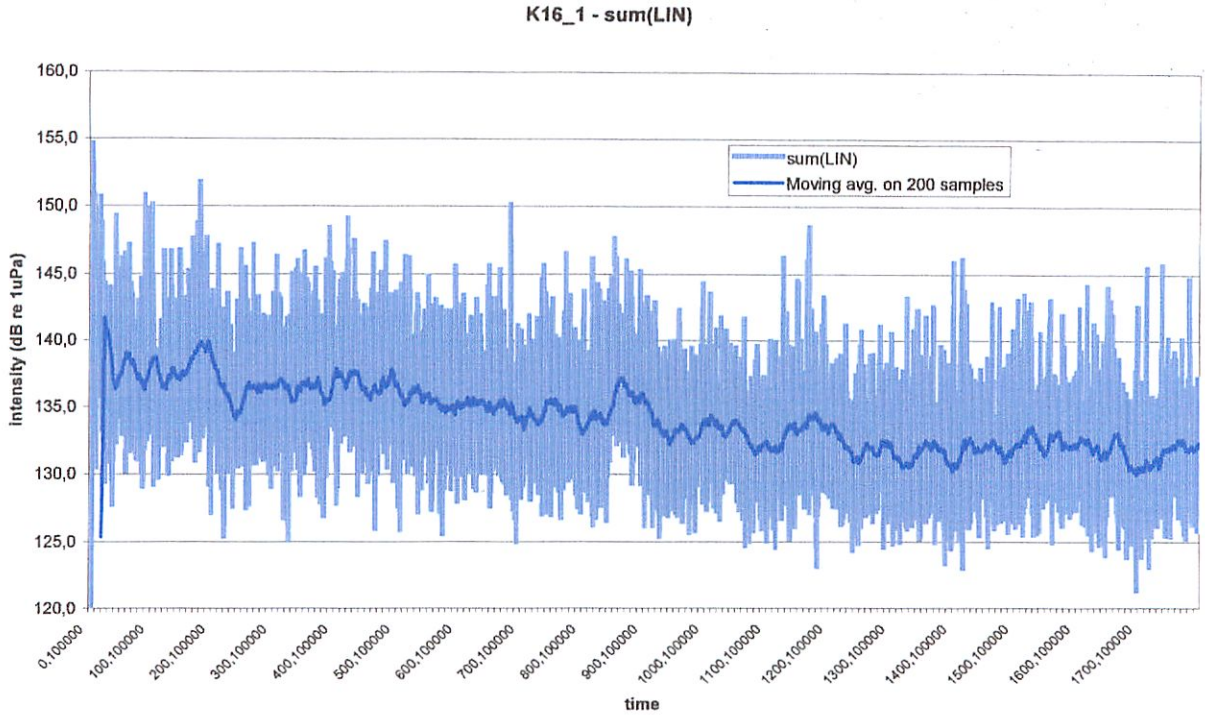
The first two graphs (30′ each) show time (x) *vs.* intensity (y). Time is in seconds and is referred to the recording start as in the above table.
Frequency is in dB (re 1uPa) and is in RMS (root mean square), so it is an overview of the overall acoustic energy in the water, second by second, regardless its frequency components. This value is indicated as SUM(LIN), and a moving average over 200 samples (20 seconds) is also indicated.
These plots help understanding the timeline of the sample showing when peculiar events have occurred.

The third plot (Level over frequency) show the minimum, maximum and average intensity value in the 1hr period of the sample.
It helps understanding how variable was the signal over the sample period, and how frequent were peak events. If the AVG line is sticked to the MIN line (as in upper frequencies usually), it means that peak events were rather rare and with low overall weight.

The fourth plot show MIN/MAX and AVG lines over a 5min period, plot one over the other. It is a graph that duplicates the previous, with much higher time resolution.

Some other graphs are added in the following pages, and are explained therein.

K16-1


K16_1 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
155,0
150,0
145,0
140,0
135,0
130,0
125,0
120,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
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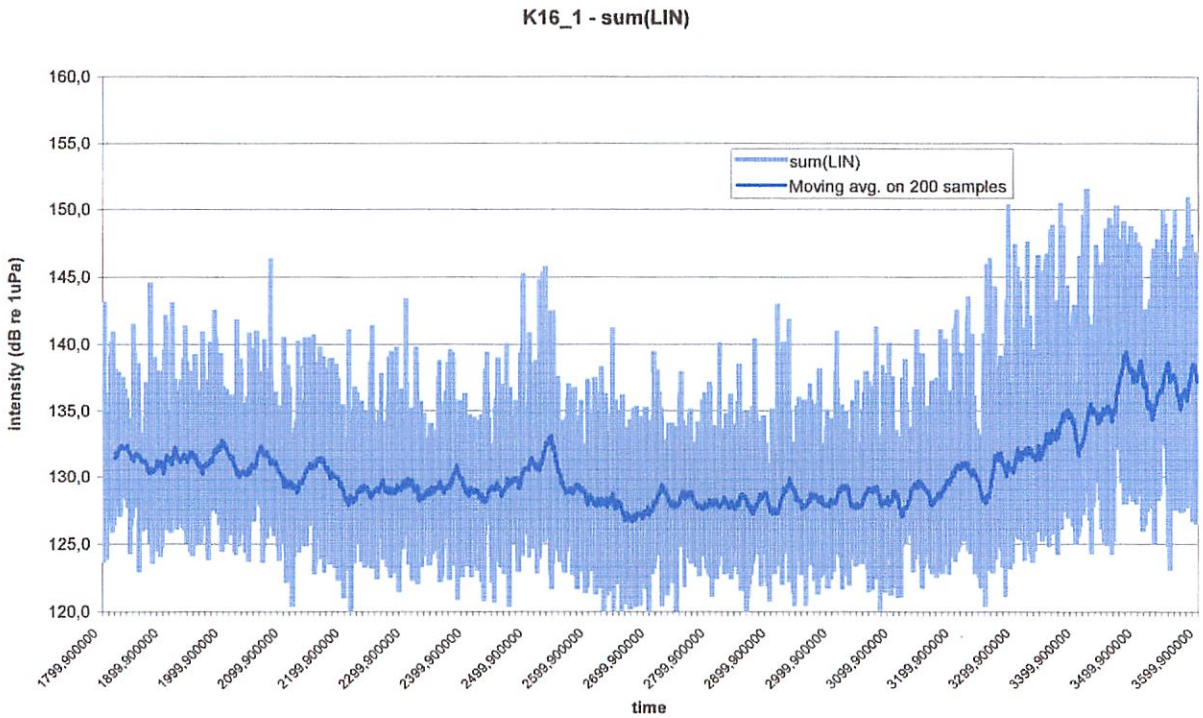
1500,100000
1600,100000
1700,100000
time


K16_1 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
155,0
150,0
145,0
140,0
135,0
130,0
125,0
120,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
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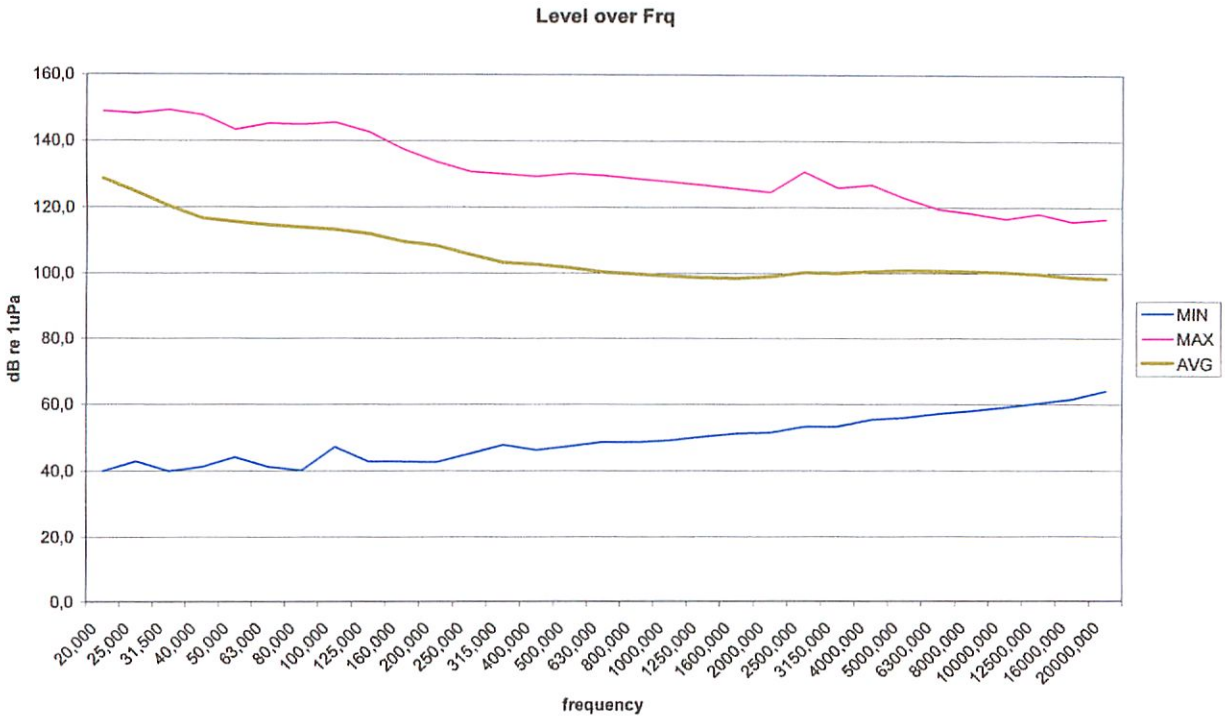
3599,900000
time


Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
MIN
MAX
AVG
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
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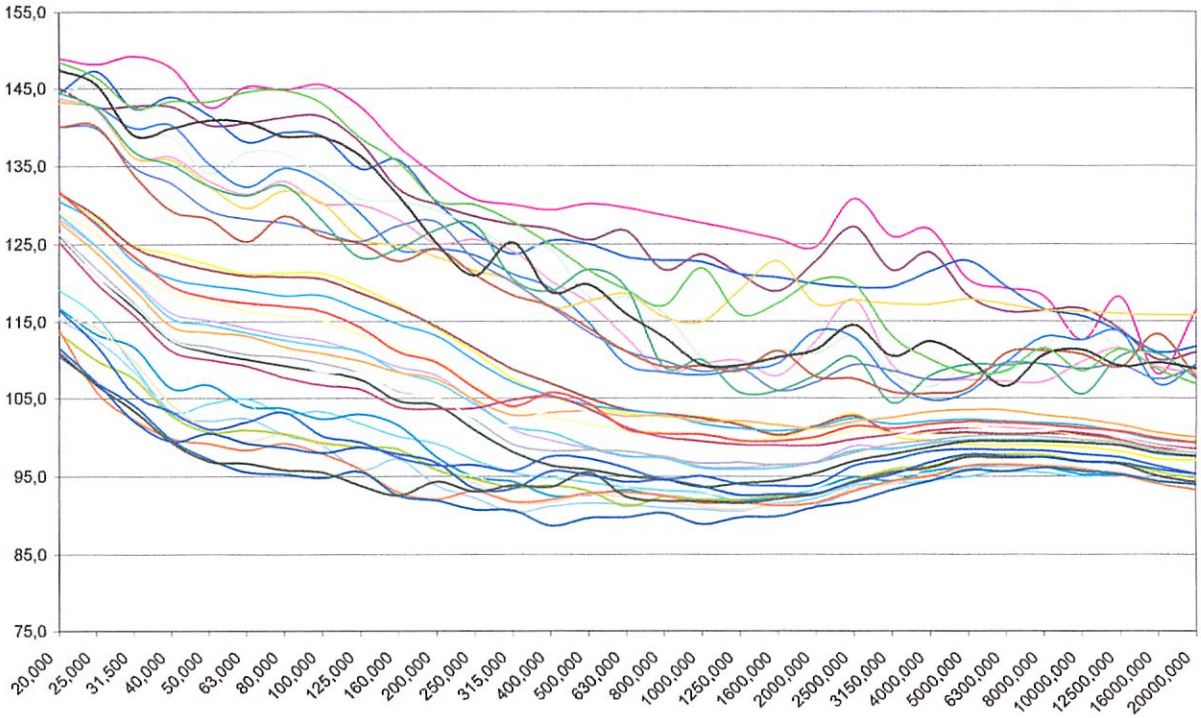
16000,000
20000,000
frequency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145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
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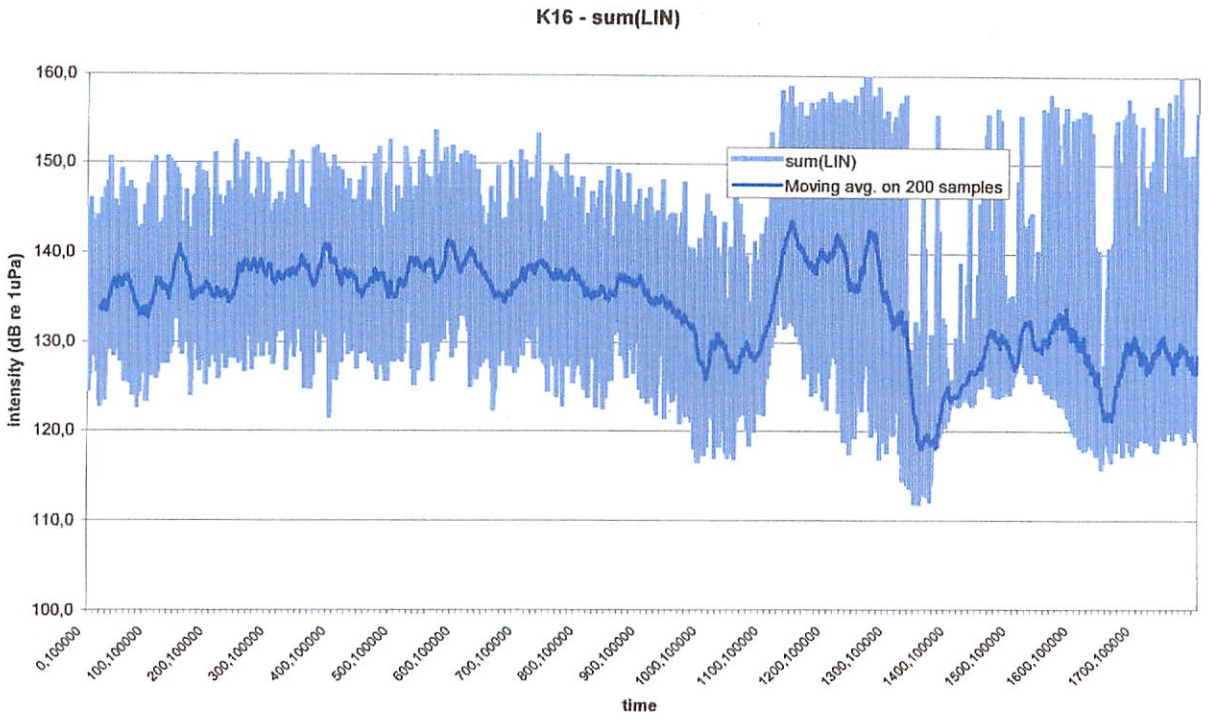
20000,000

K16-2


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
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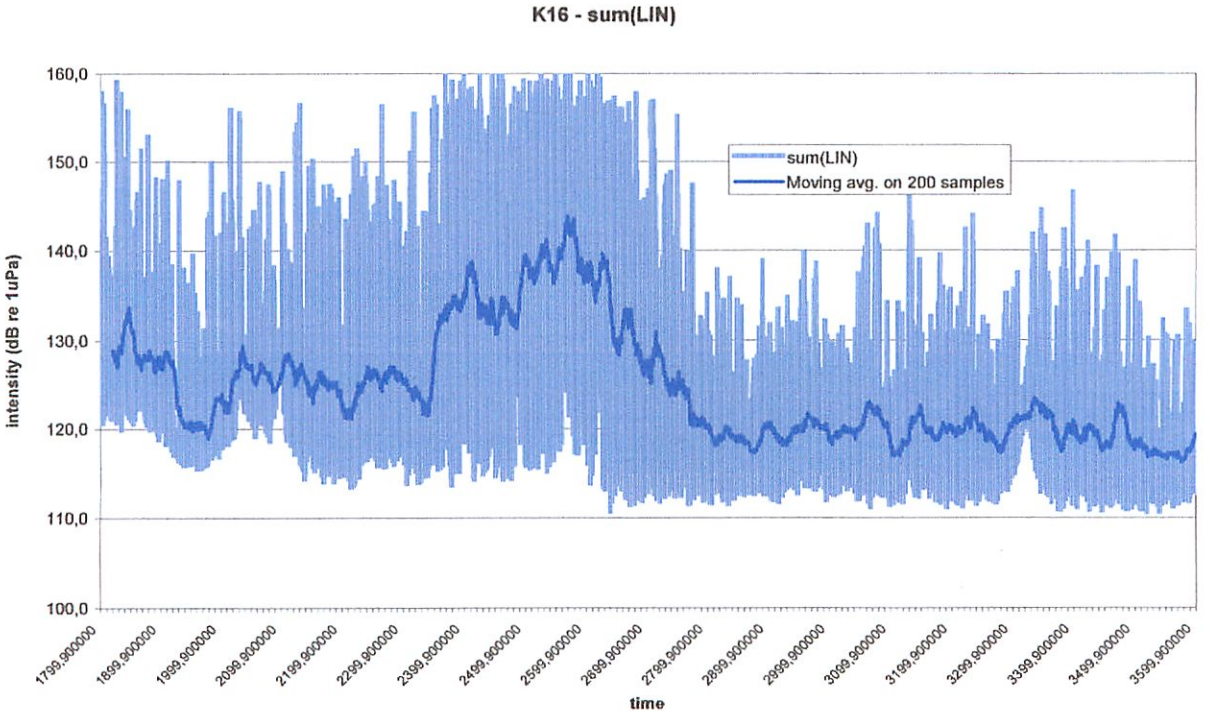
1500,100000
1600,100000
1700,100000
time


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
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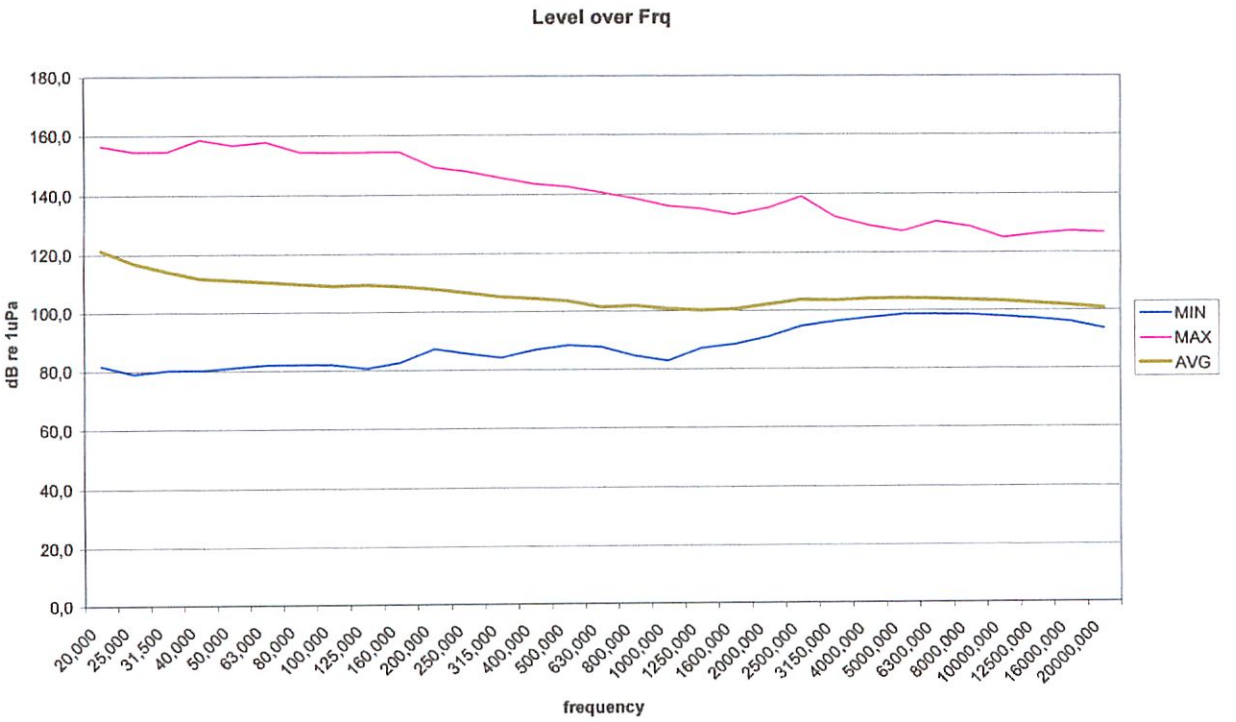
time


Level over Frq
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
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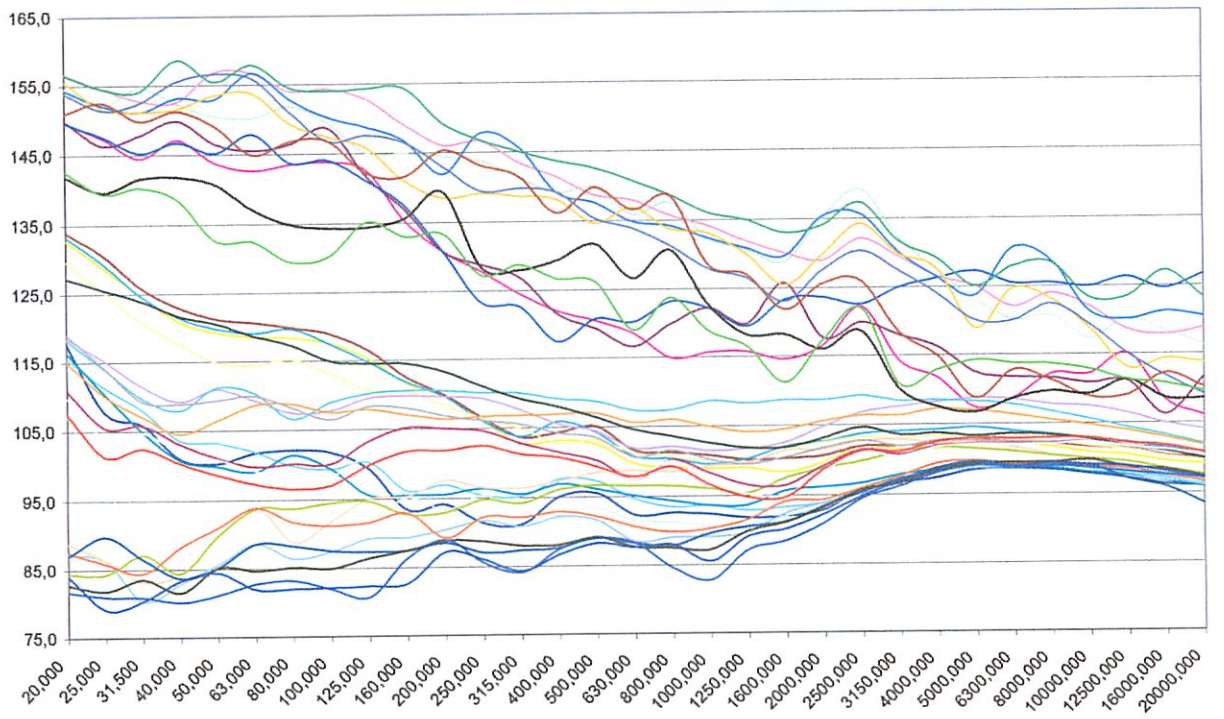
20000,000
frequency
MIN
MAX
AVG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155,0
145,0
135,0
125,0
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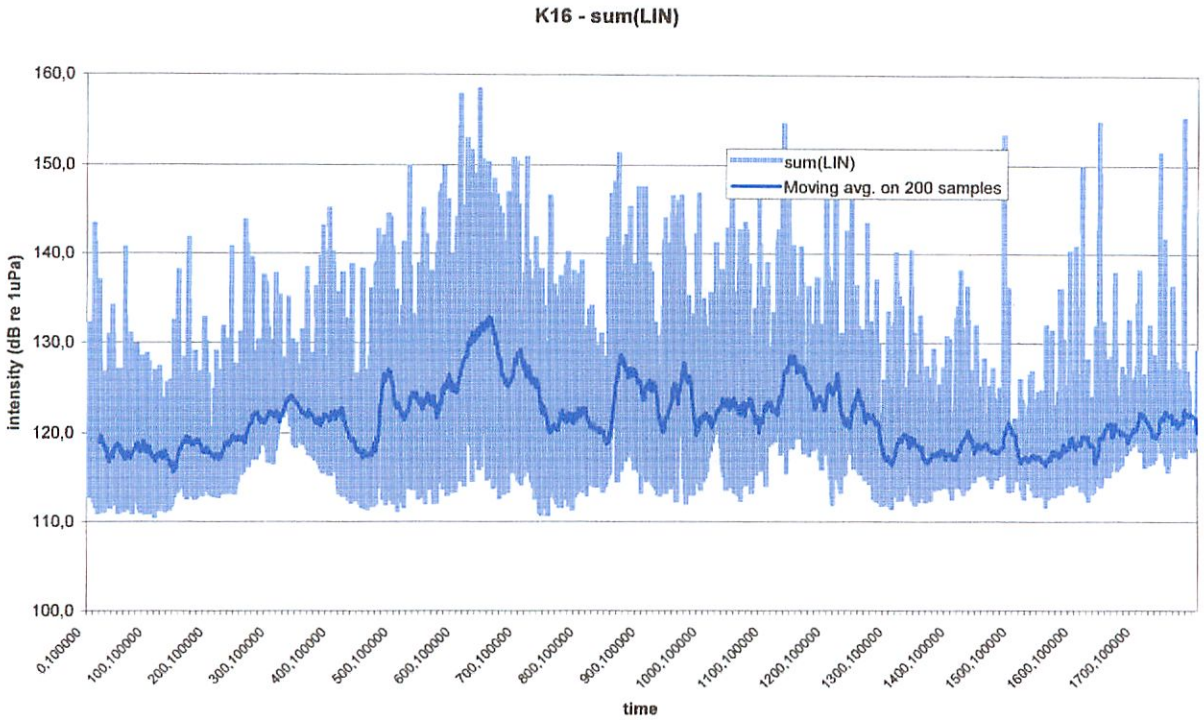
20000,000

K16_3


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
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150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
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1000,100000
1100,100000
1200,100000
1300,100000
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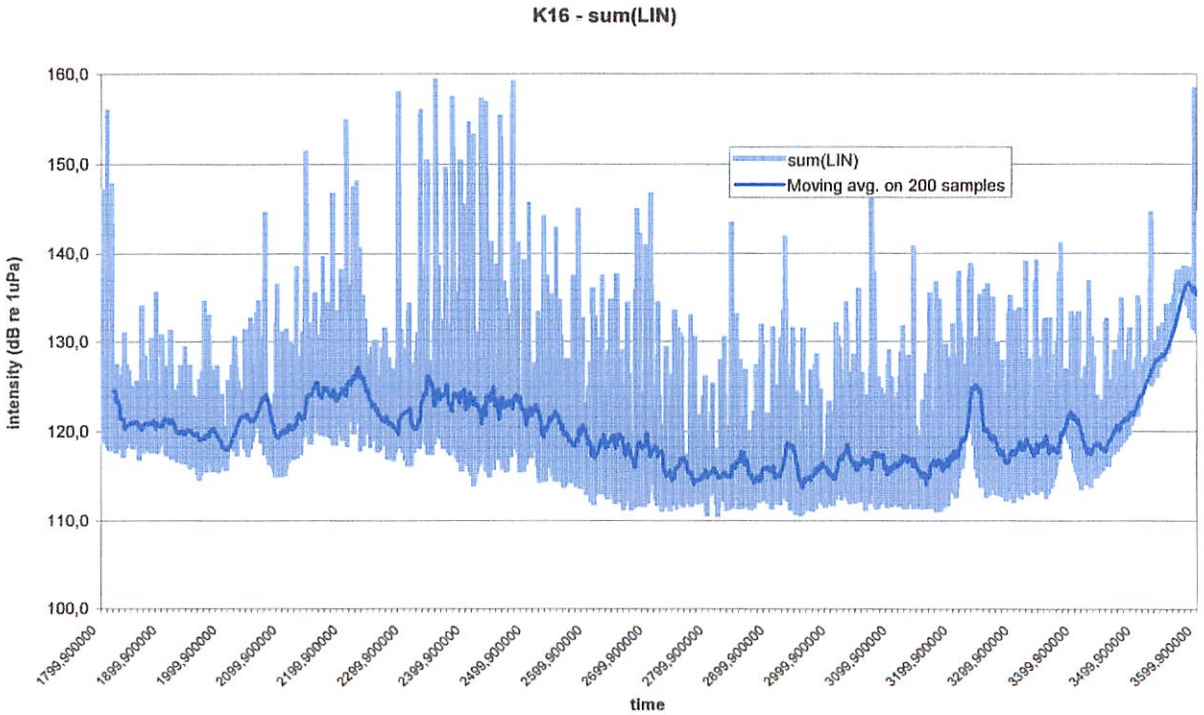
1500,100000
1600,100000
1700,100000
time


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
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150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
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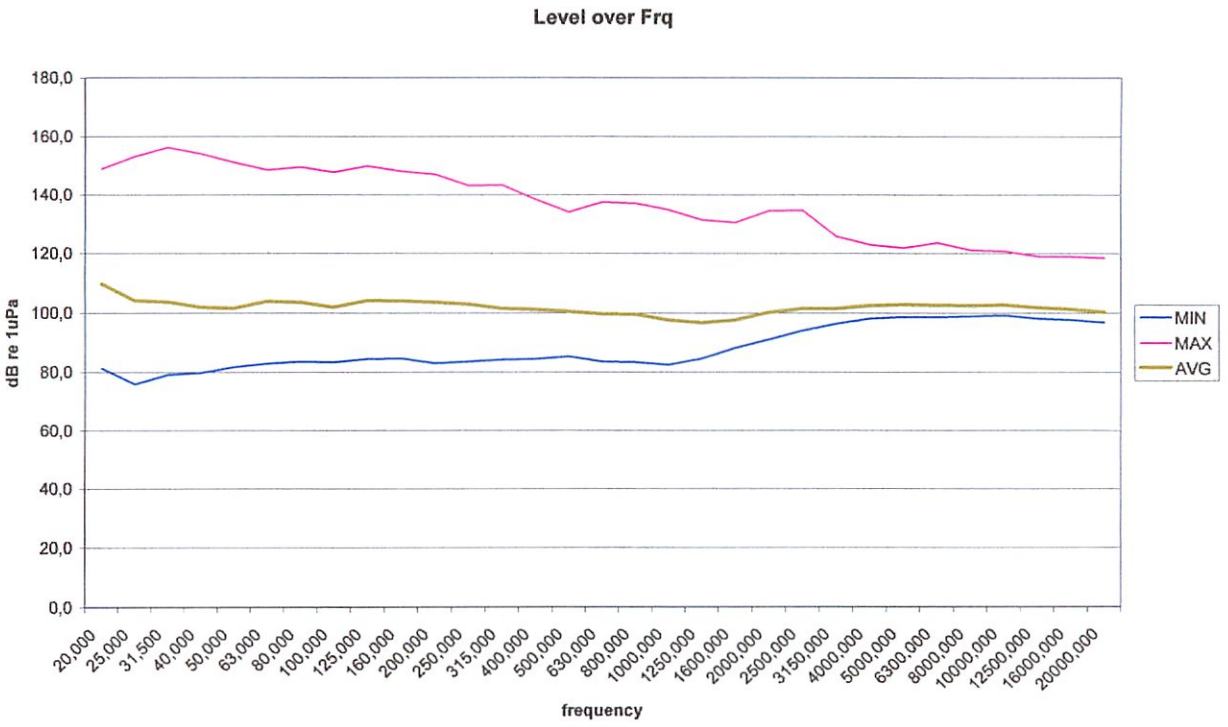
3499,900000
3599,900000
time


Level over Frq
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
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2000,000
2500,000
3150,000
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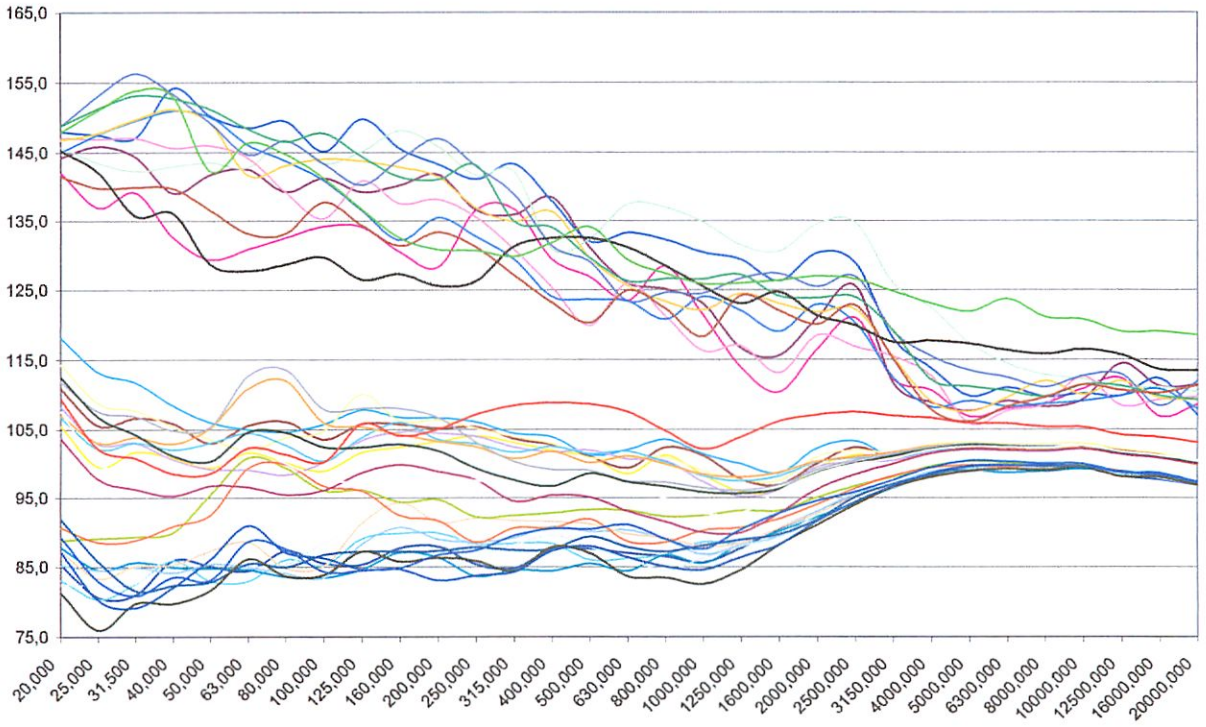
frequency
MIN
MAX
AVG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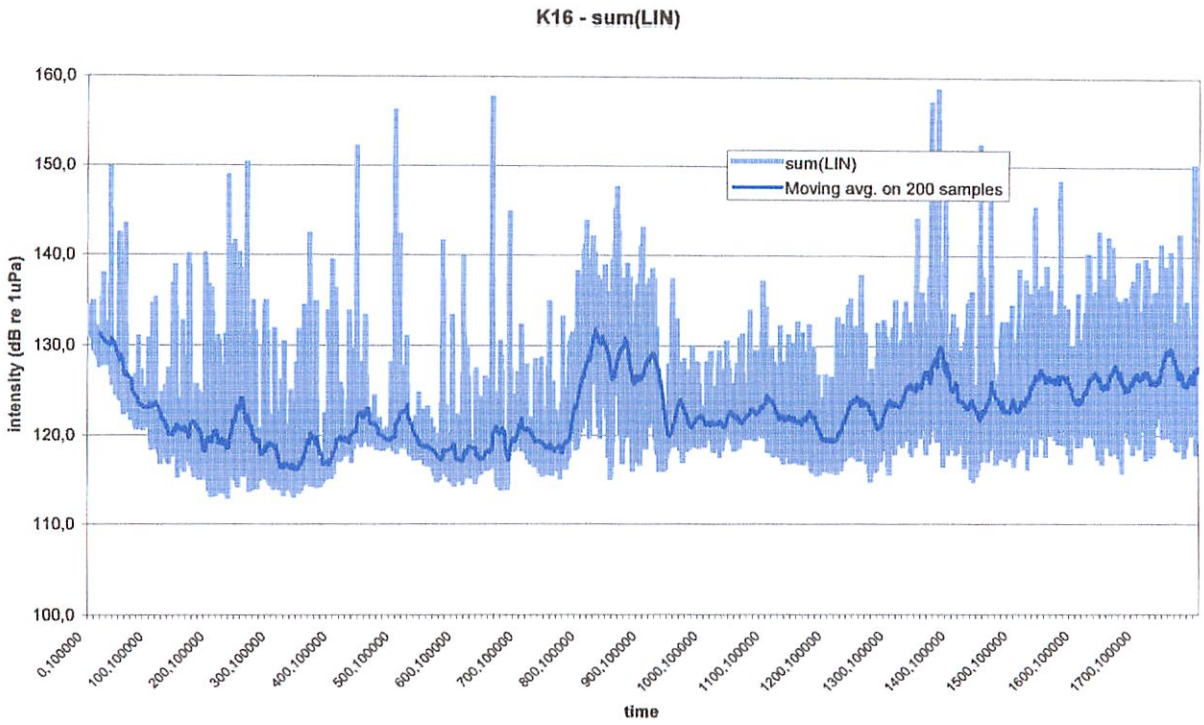
K16_4


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
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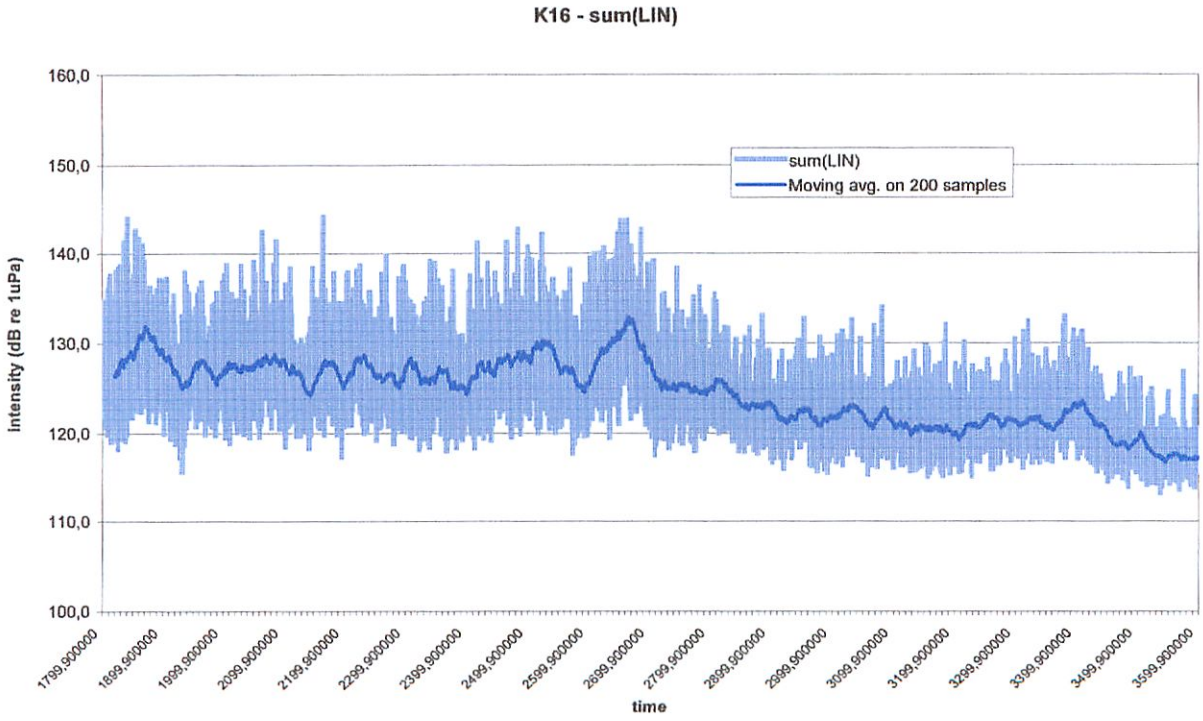
1500,100000
1600,100000
1700,100000
time


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
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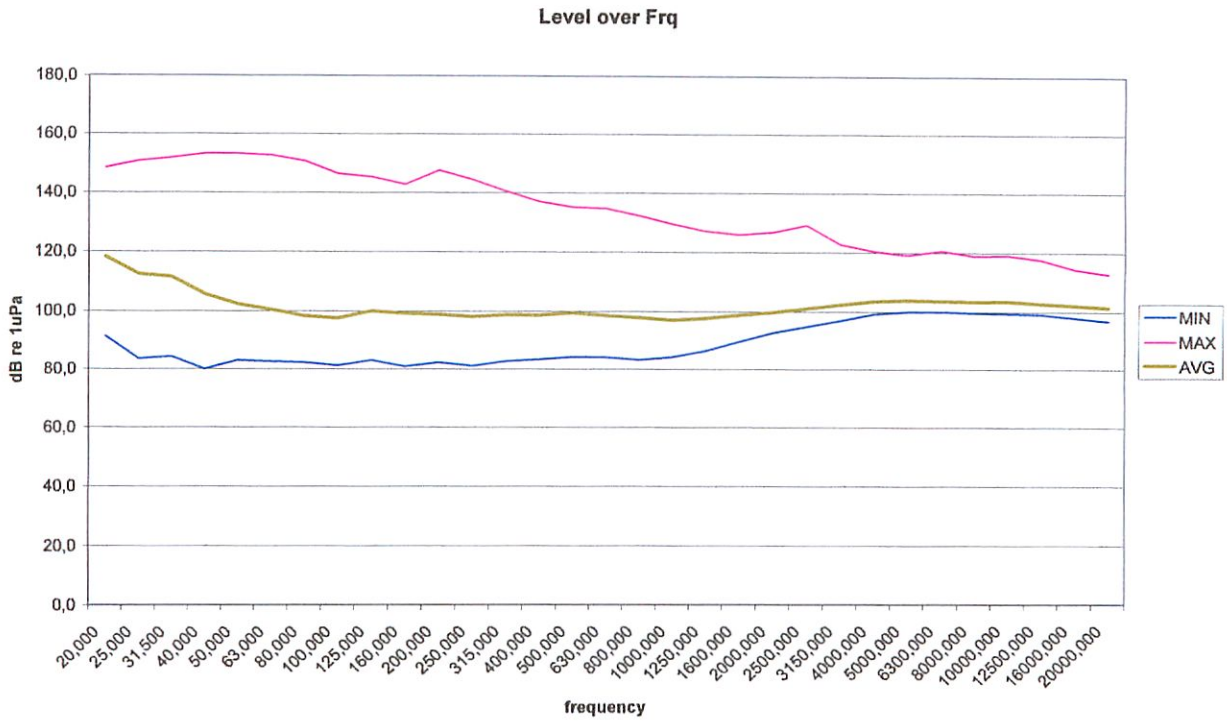
3499,900000
3599,900000
time


Level over Frq
dB re 1uPa
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
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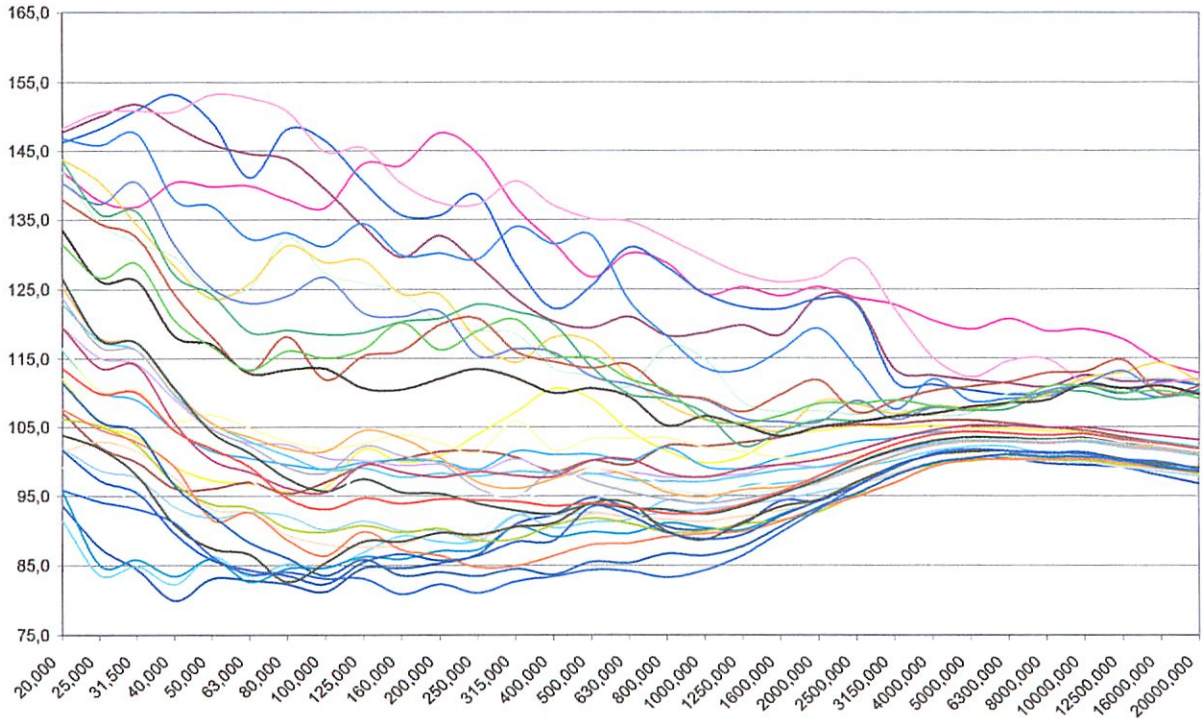
20000,000
frequency
MIN
MAX
AVG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63,000
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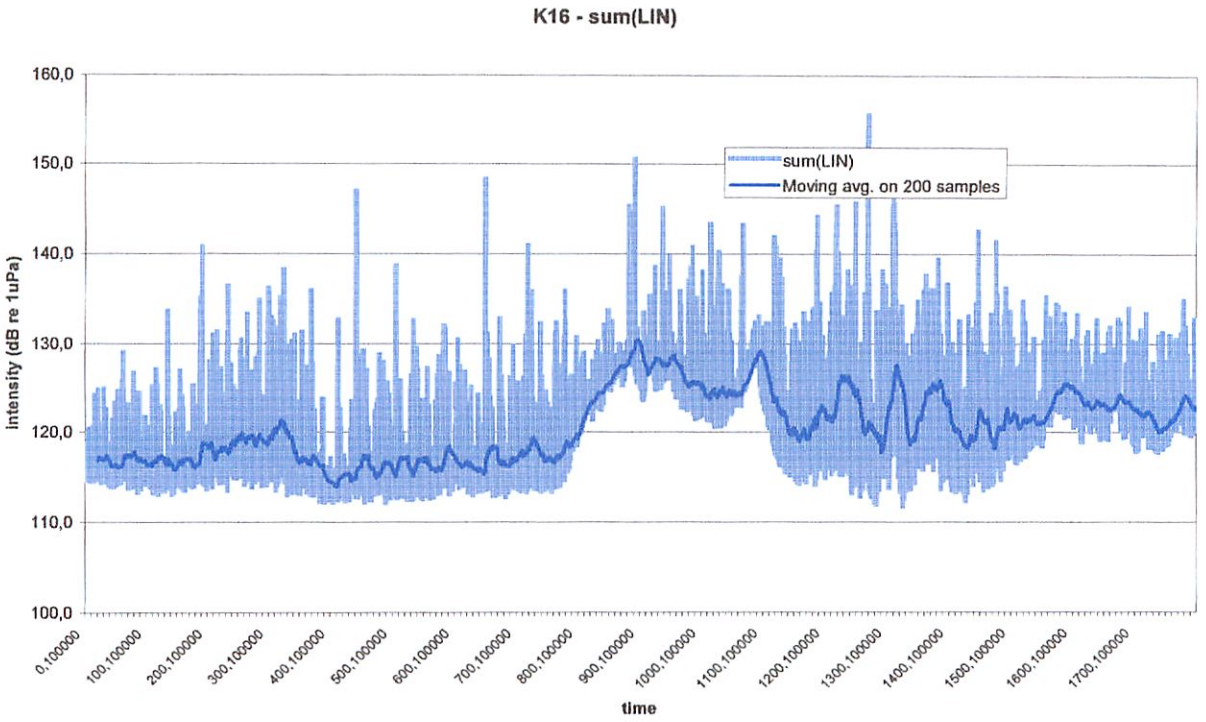
20000,000

K16_5


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
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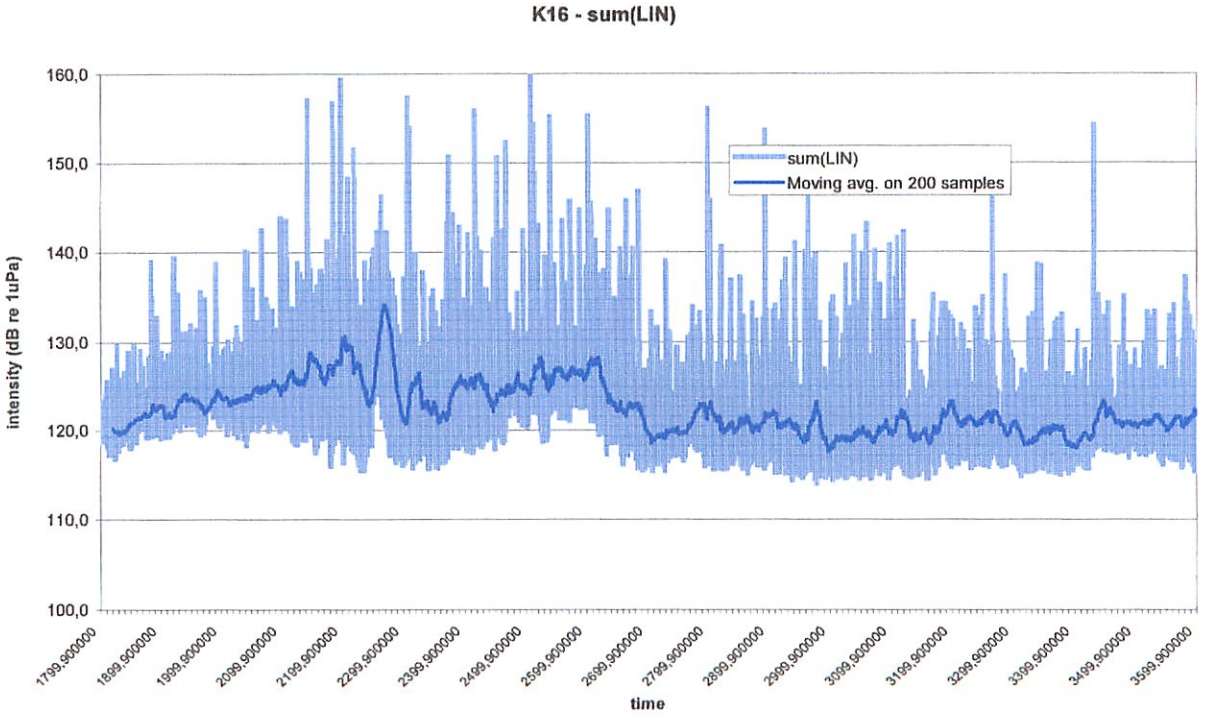
1500,100000
1600,100000
1700,100000
time


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
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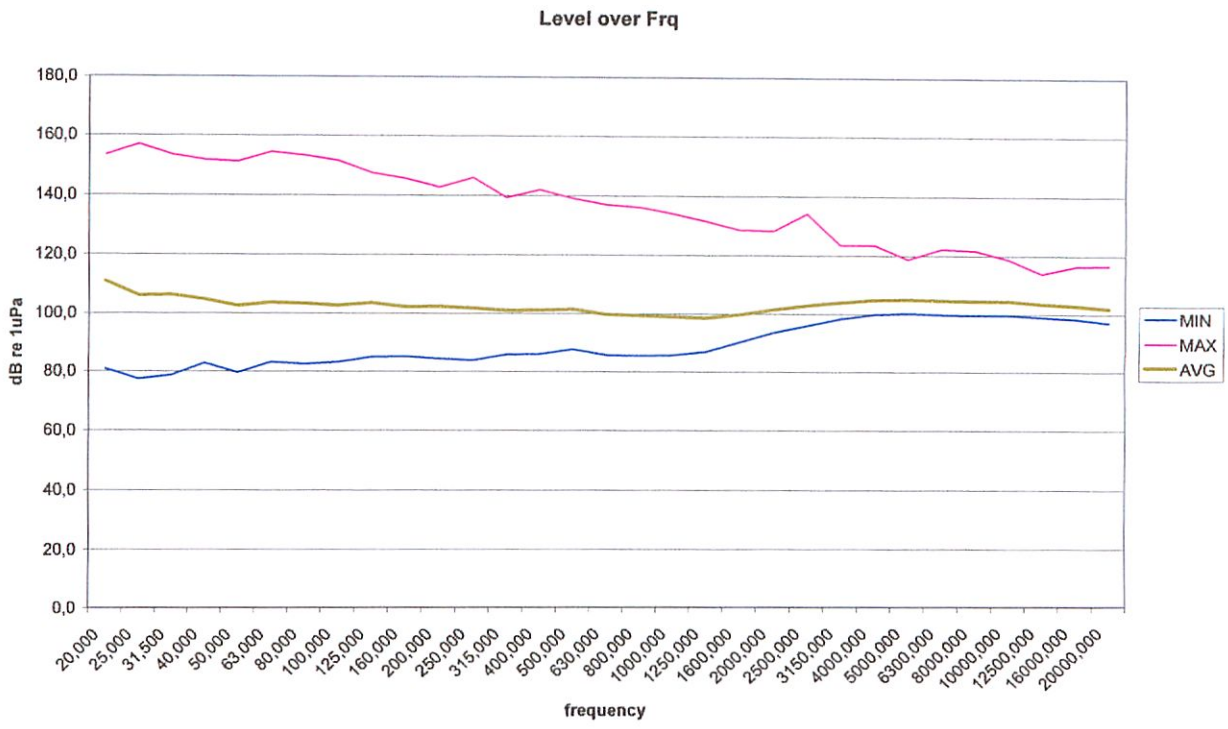
3499,900000
3599,900000
time


Level over Frq
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
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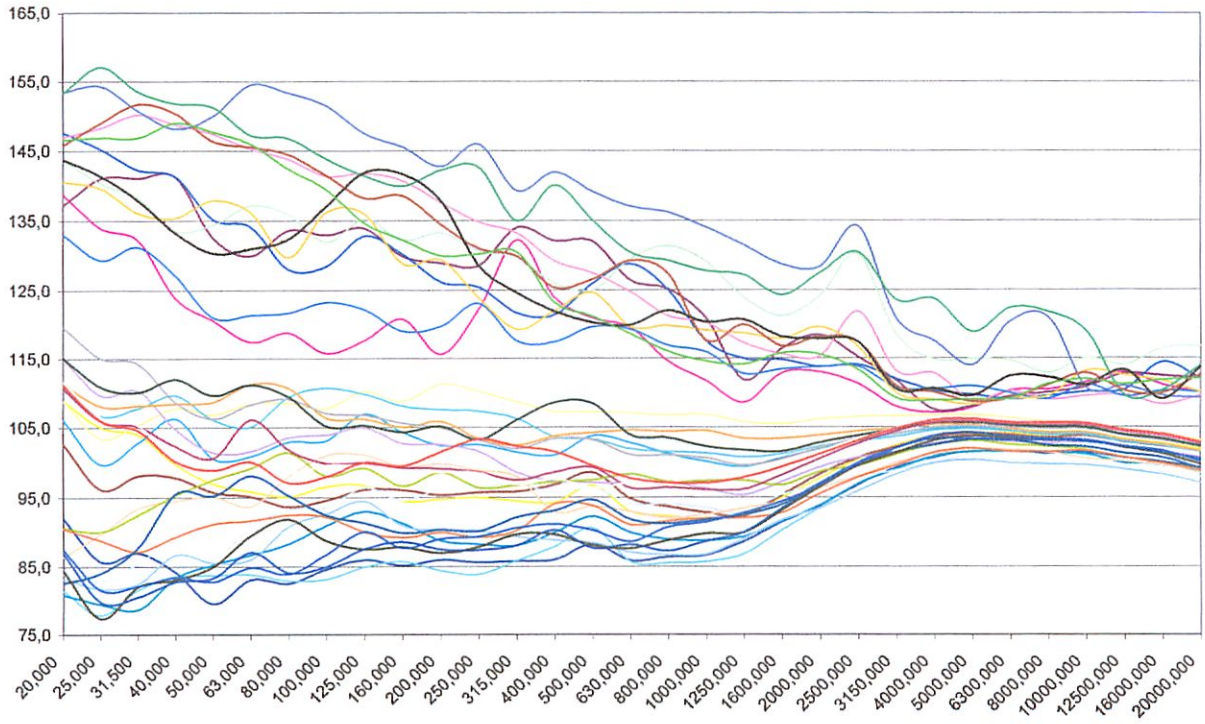
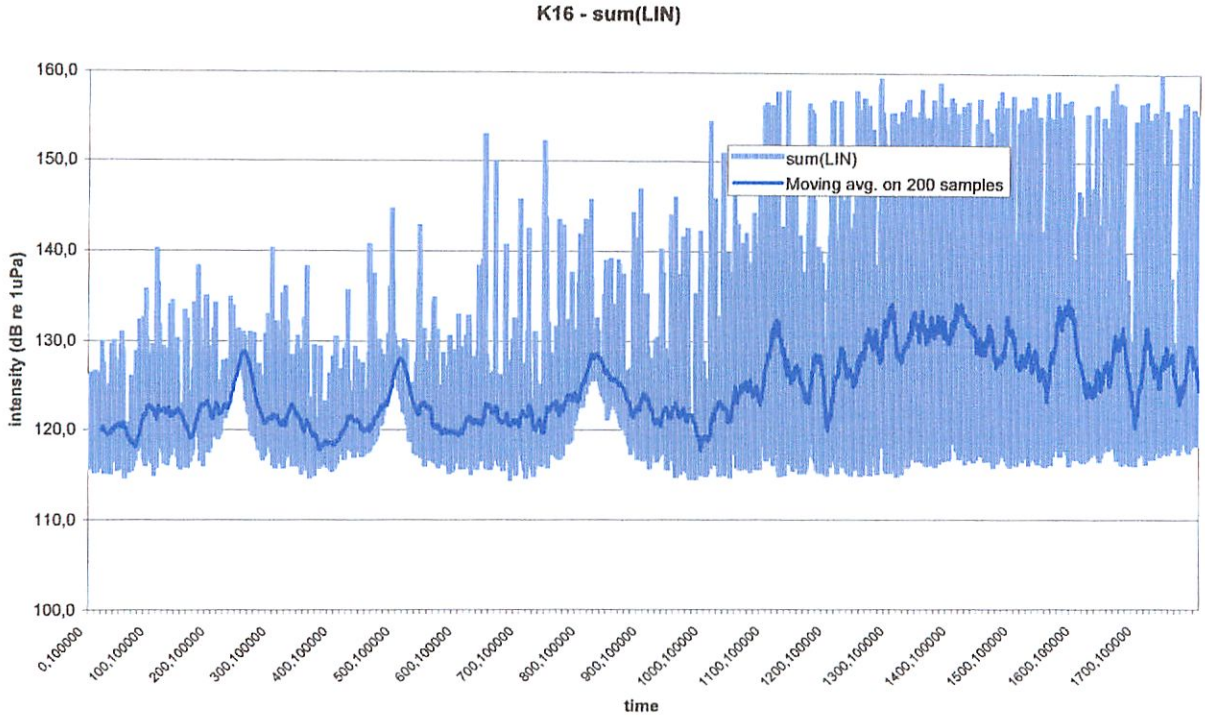
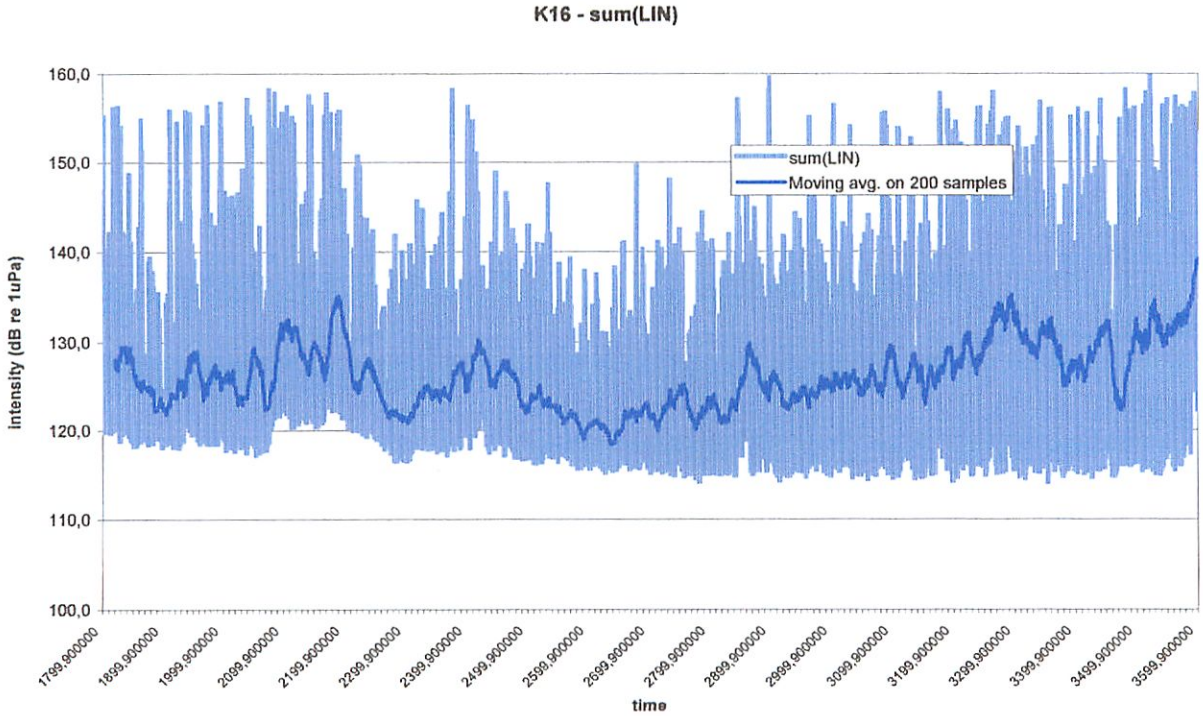
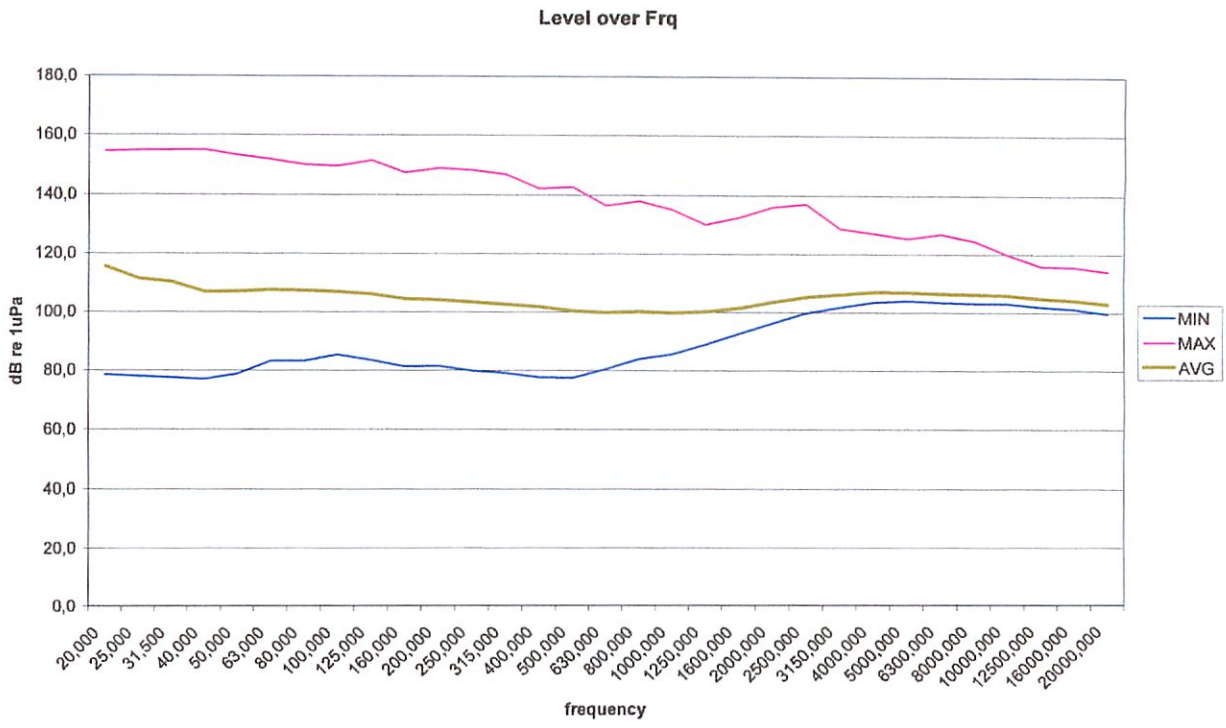
20000,000
frequency
MIN
MAX
AVG

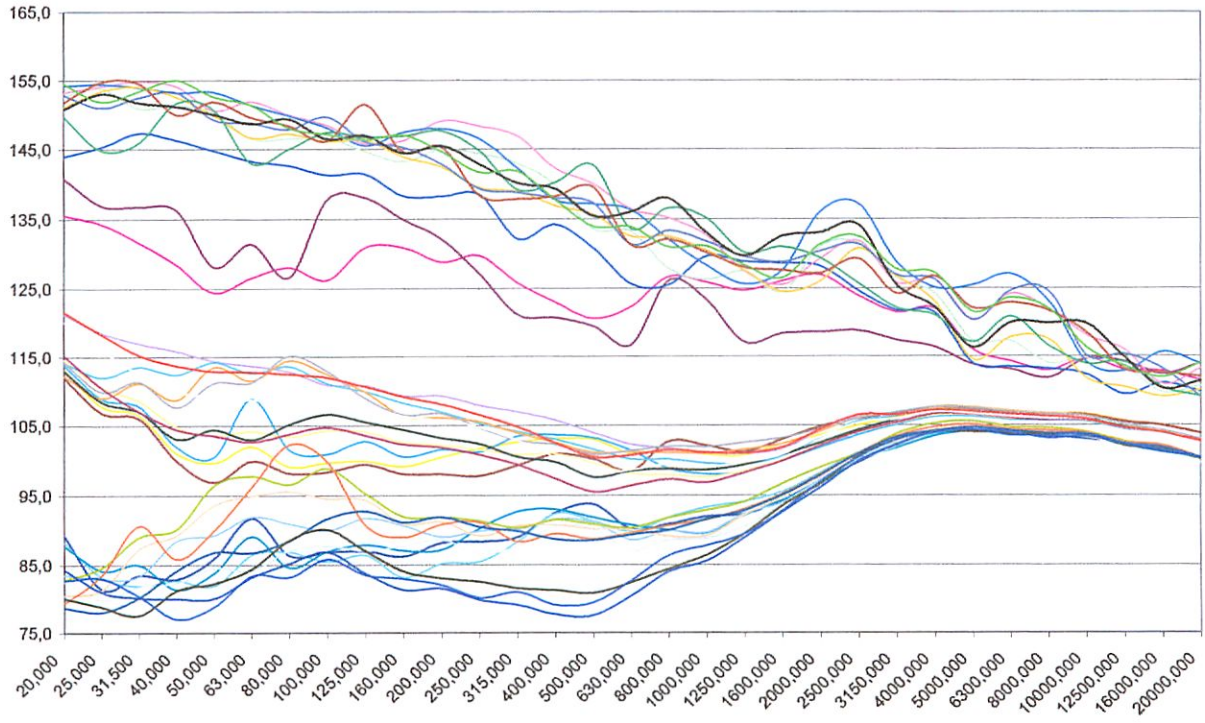

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K16_6

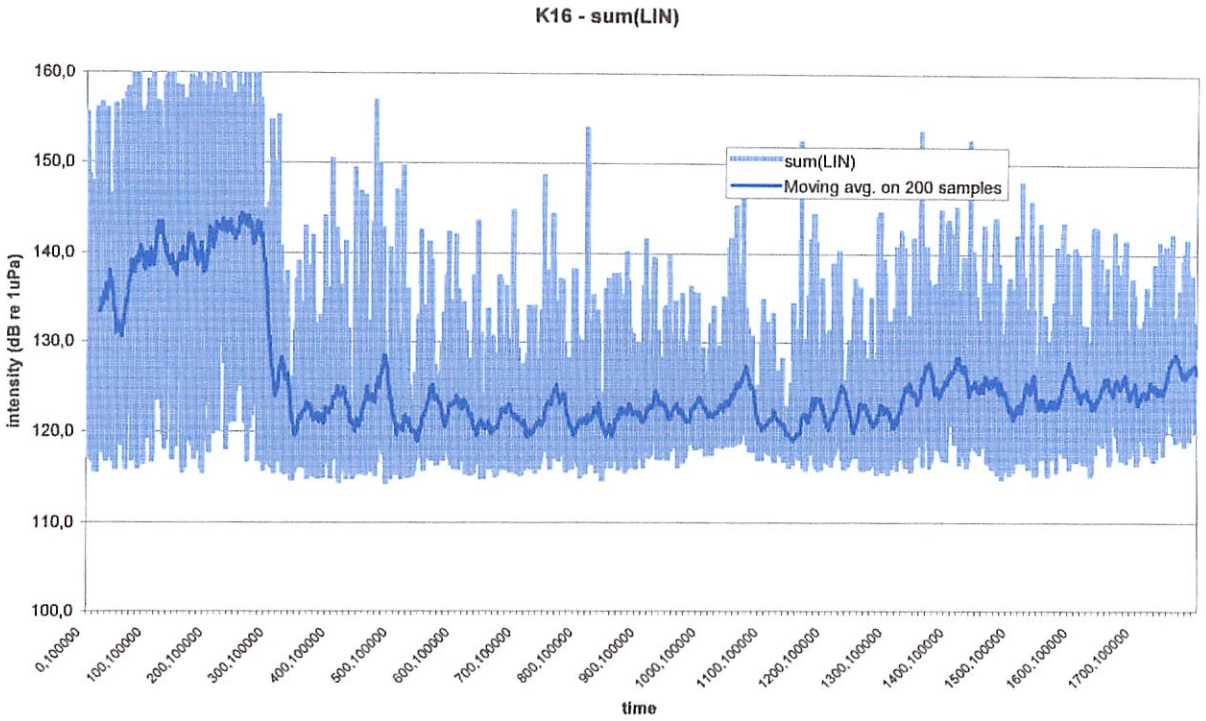

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

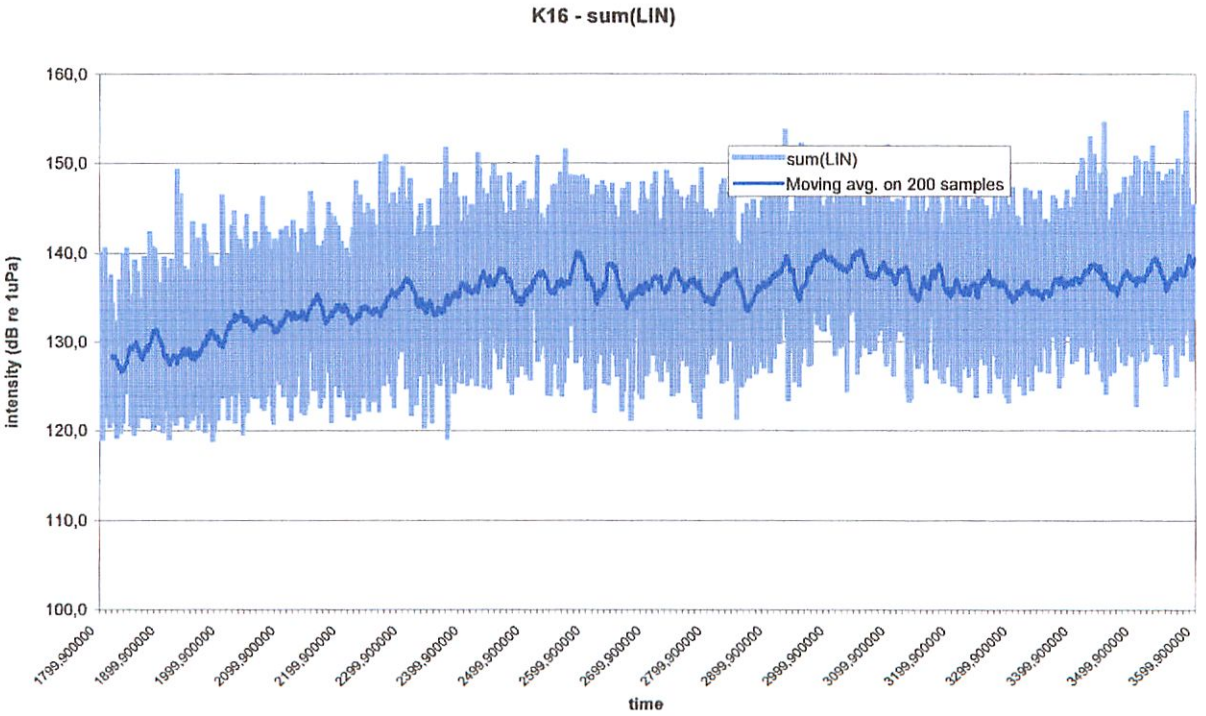

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

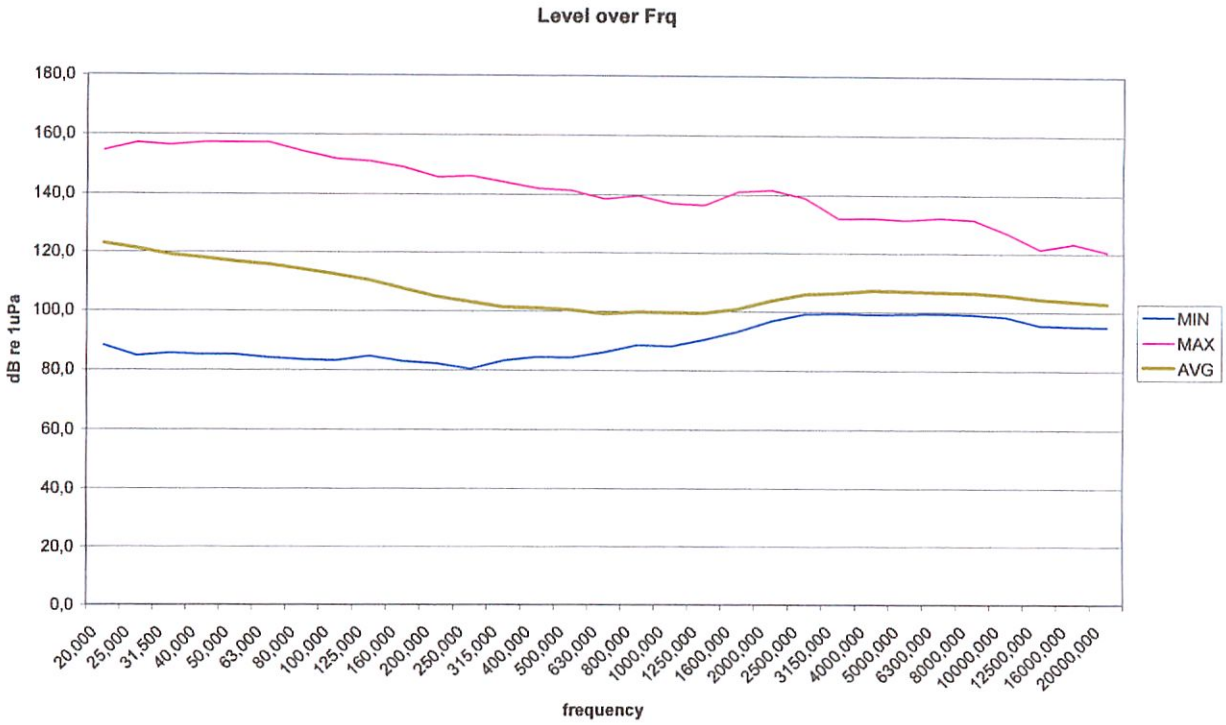

Level over Frq
dB re 1uPa
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

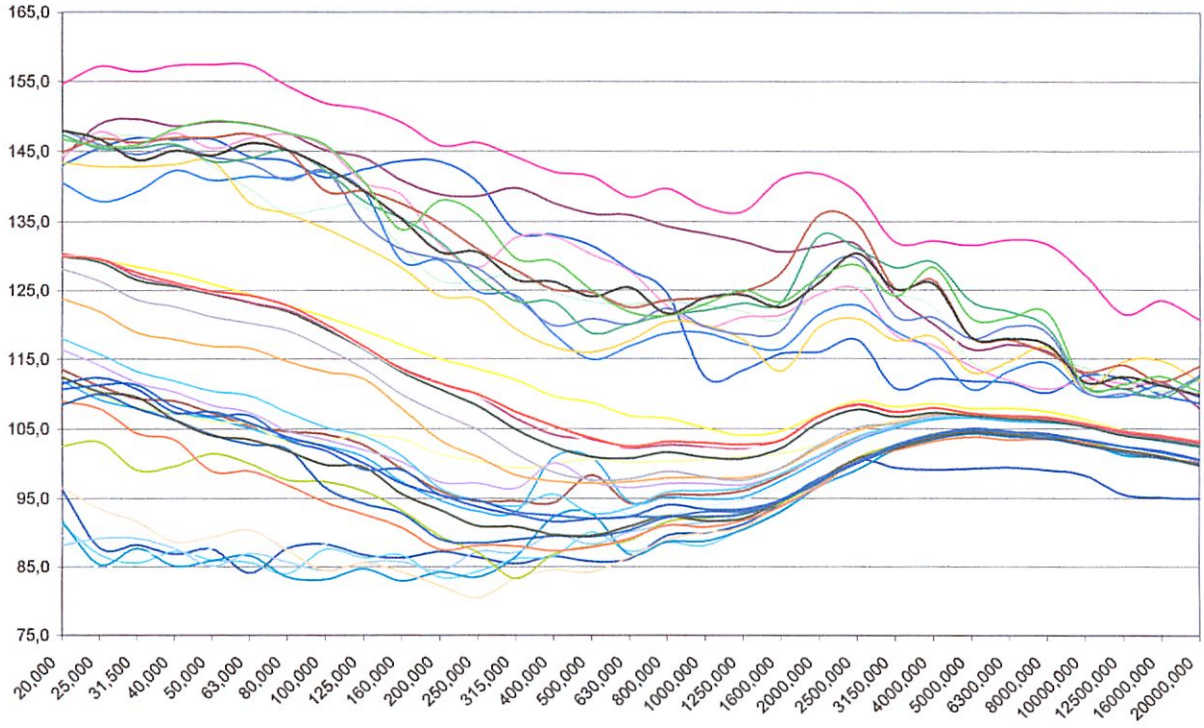

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K16_7

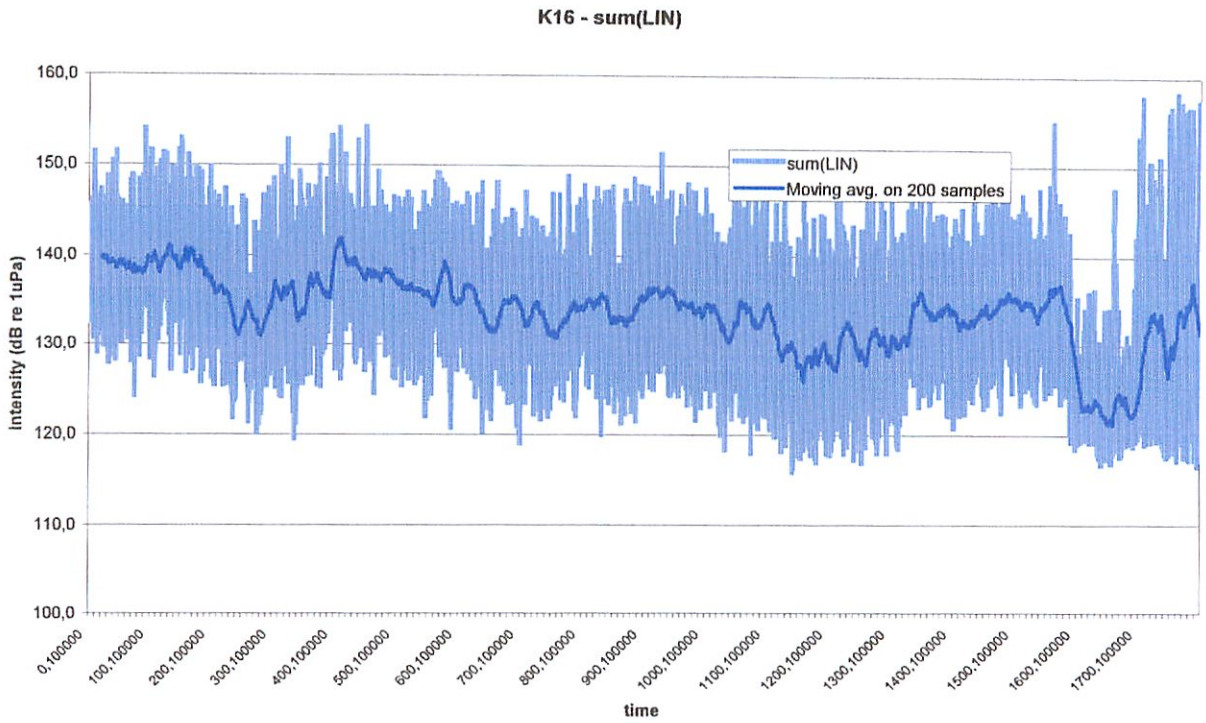

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

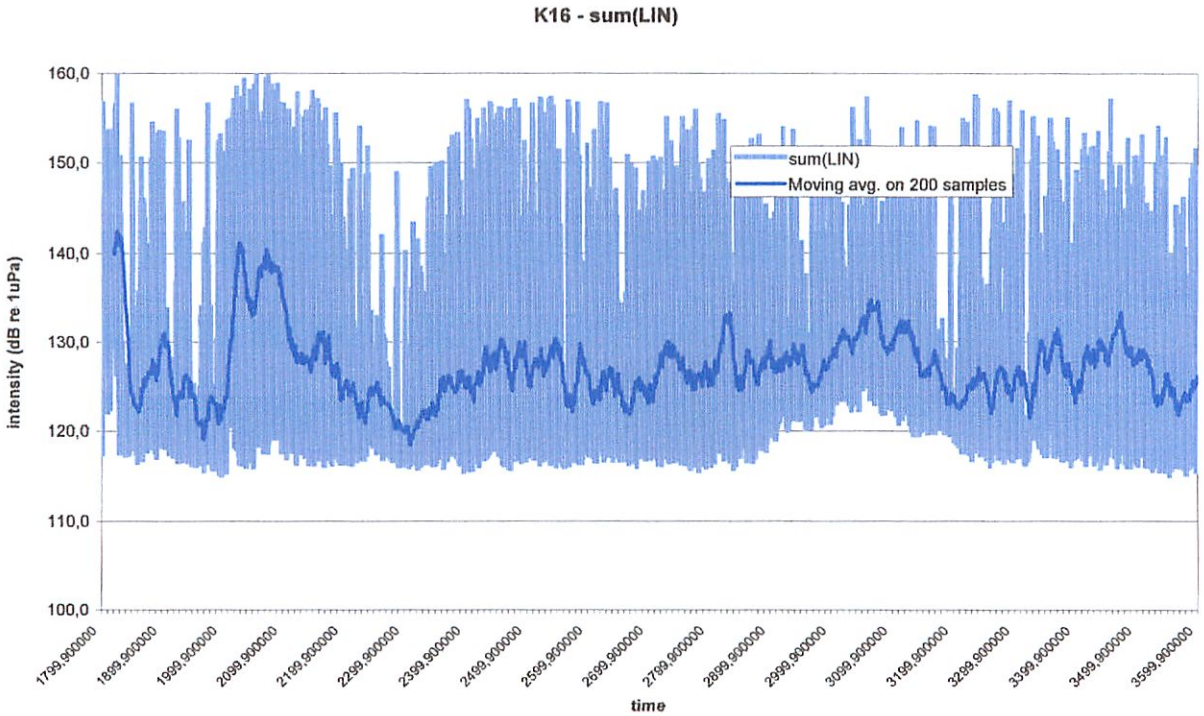

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

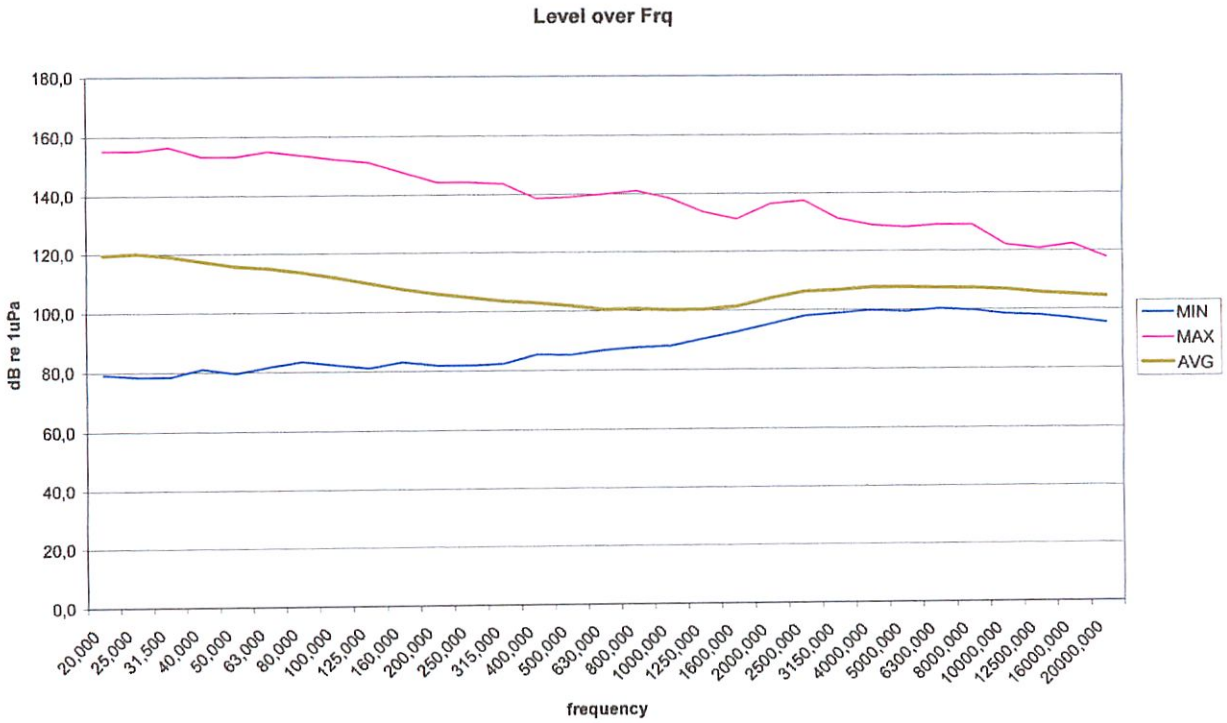

Level over Frq
dB re 1uPa
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

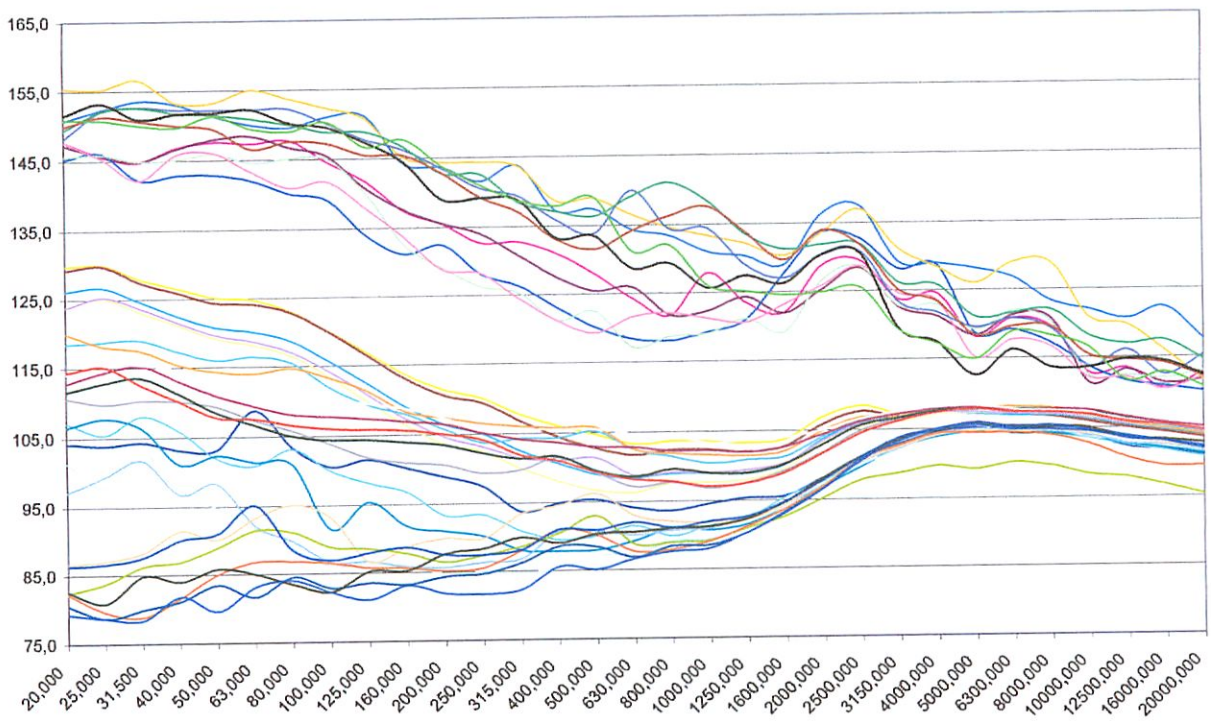

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K16_8

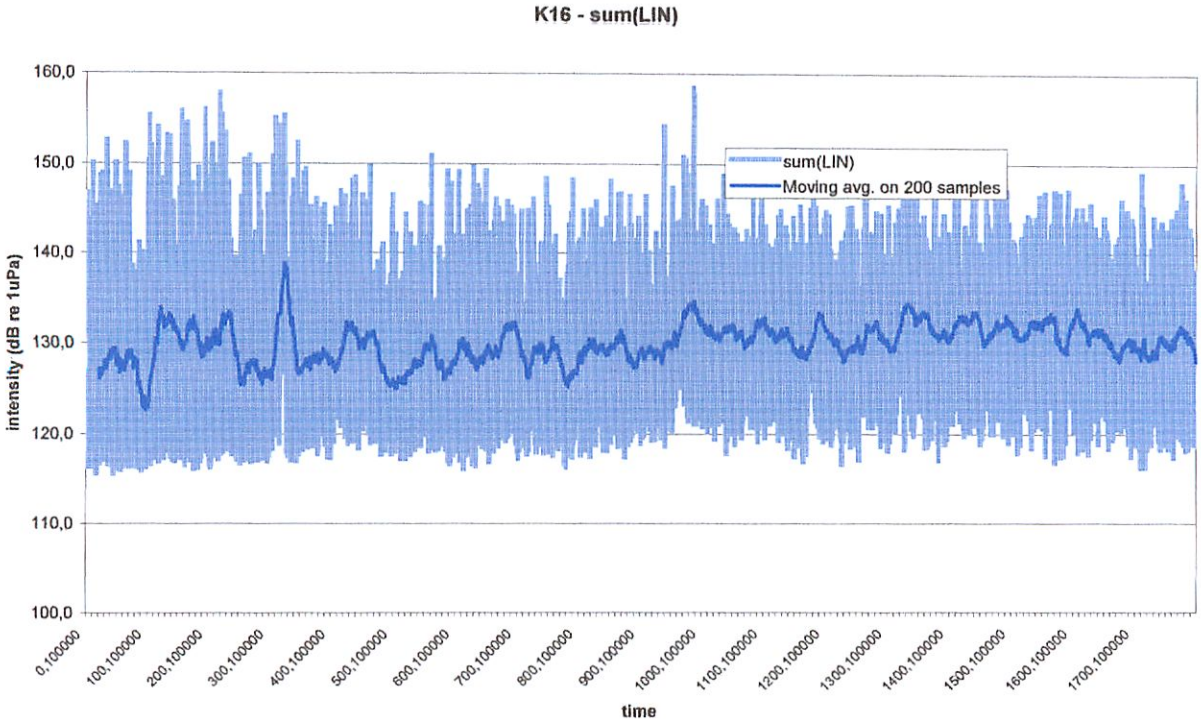

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

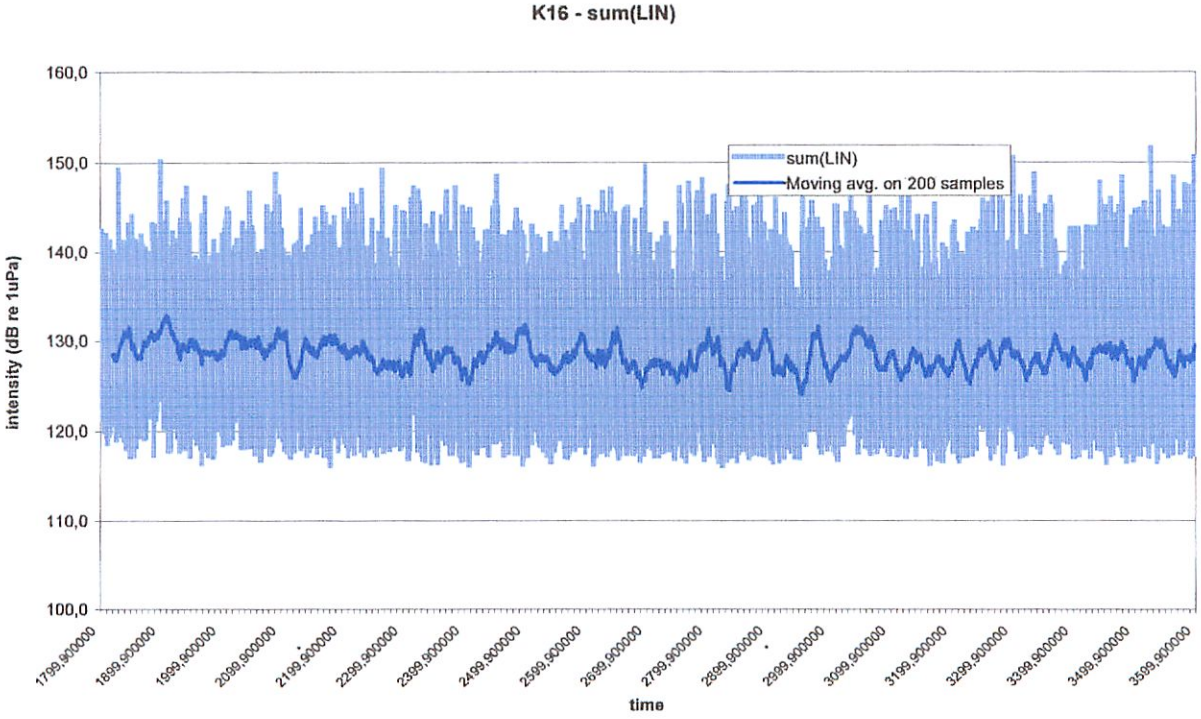

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

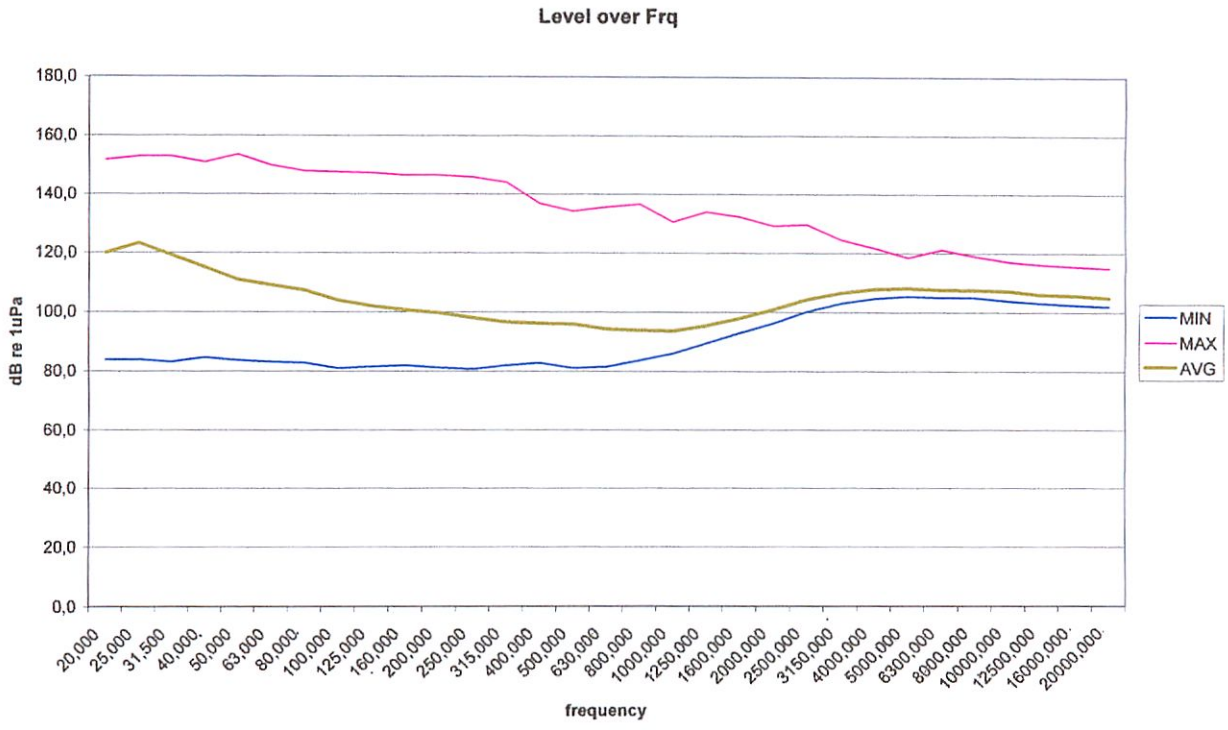

Level over Frq
dB re 1uPa
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

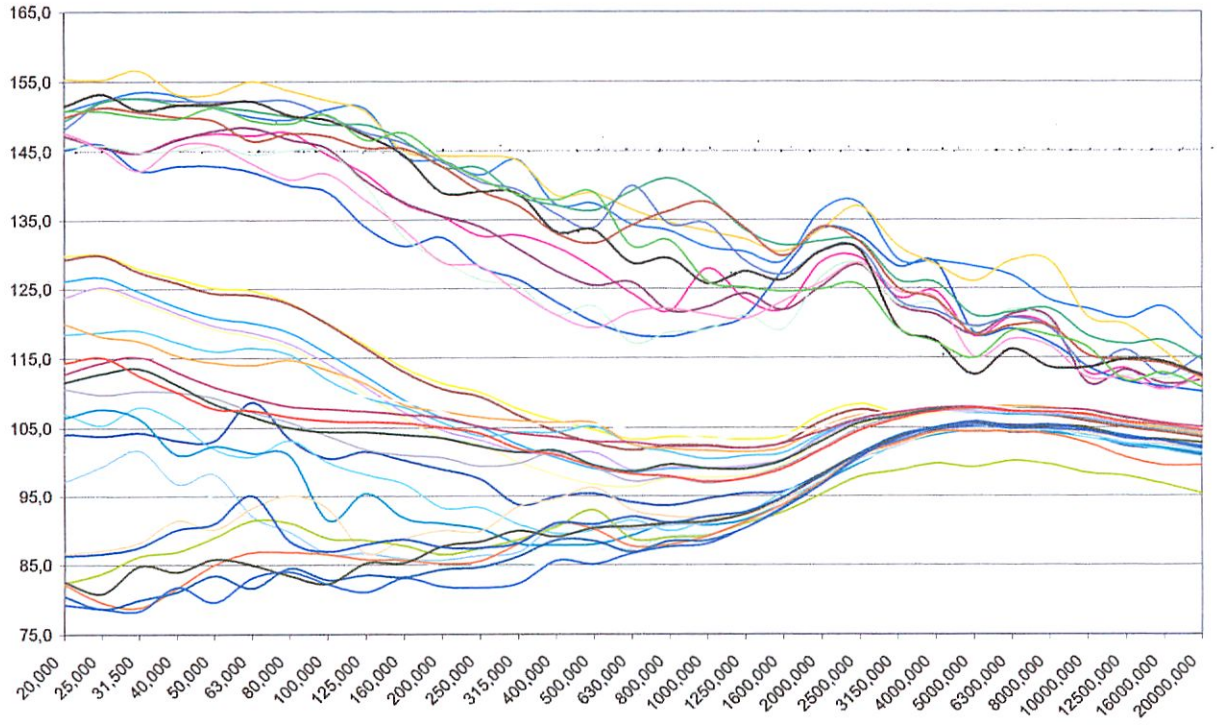

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K16_9

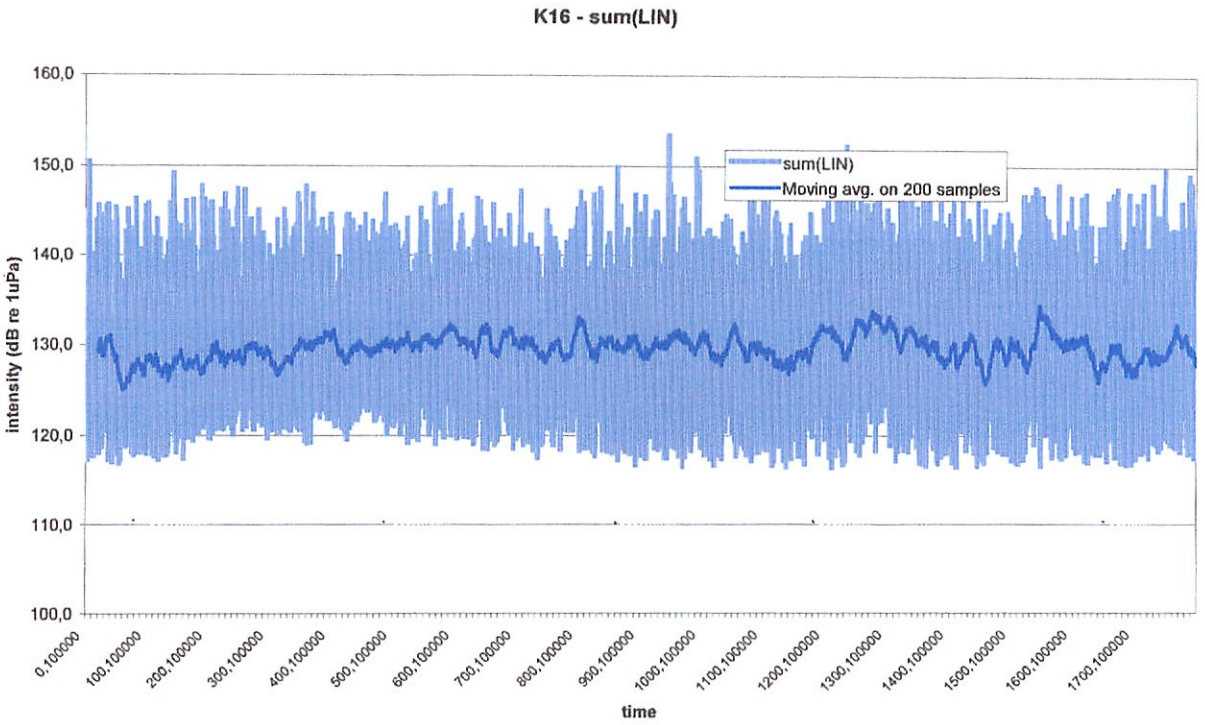

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

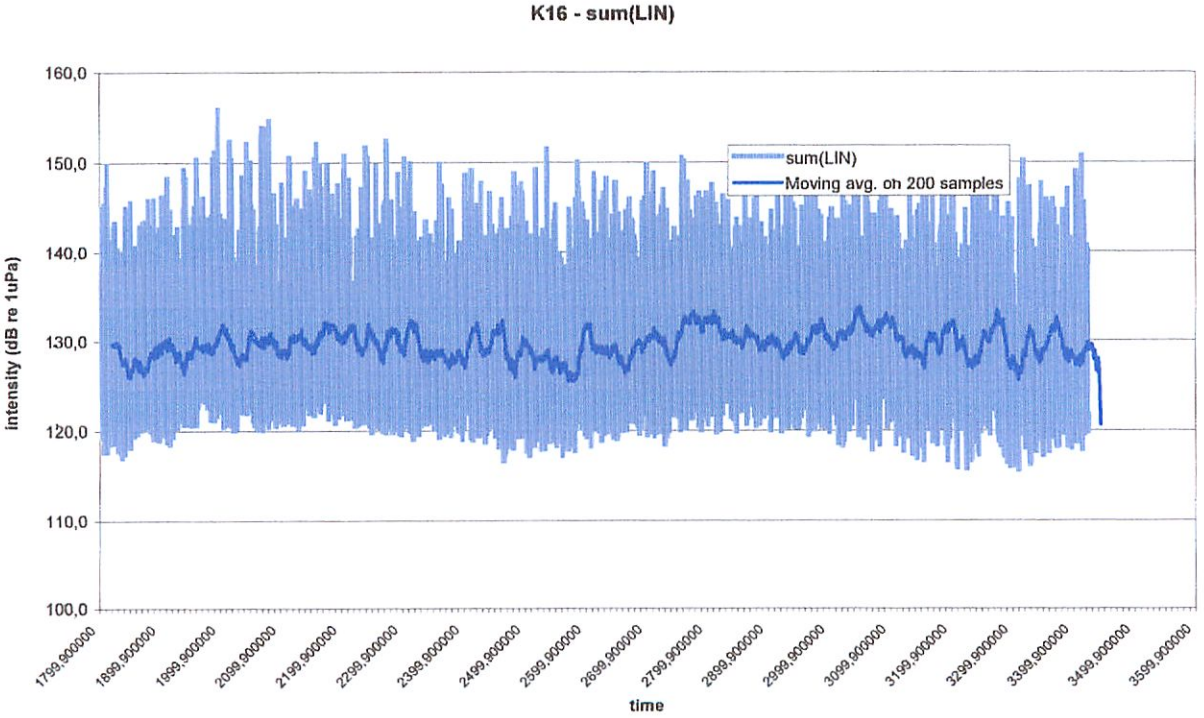

K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

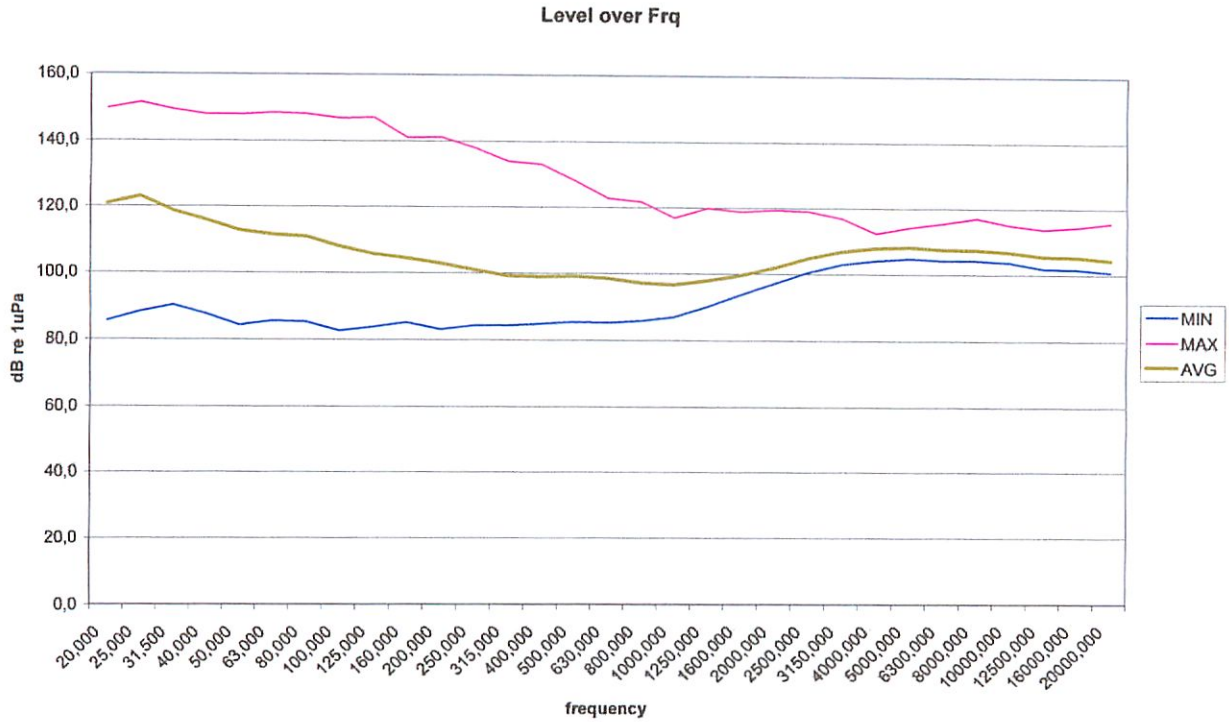

Level over Frq
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
MIN
MAX
AVG
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency


165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K16_10


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time


K16 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time


Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
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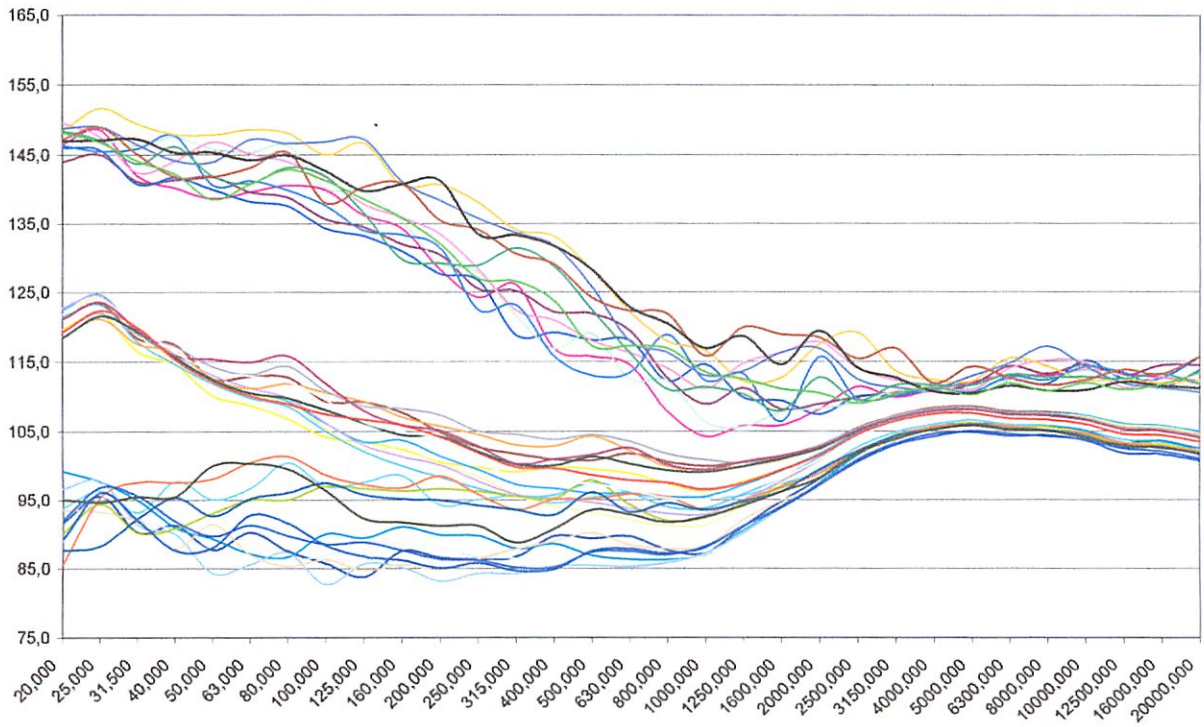
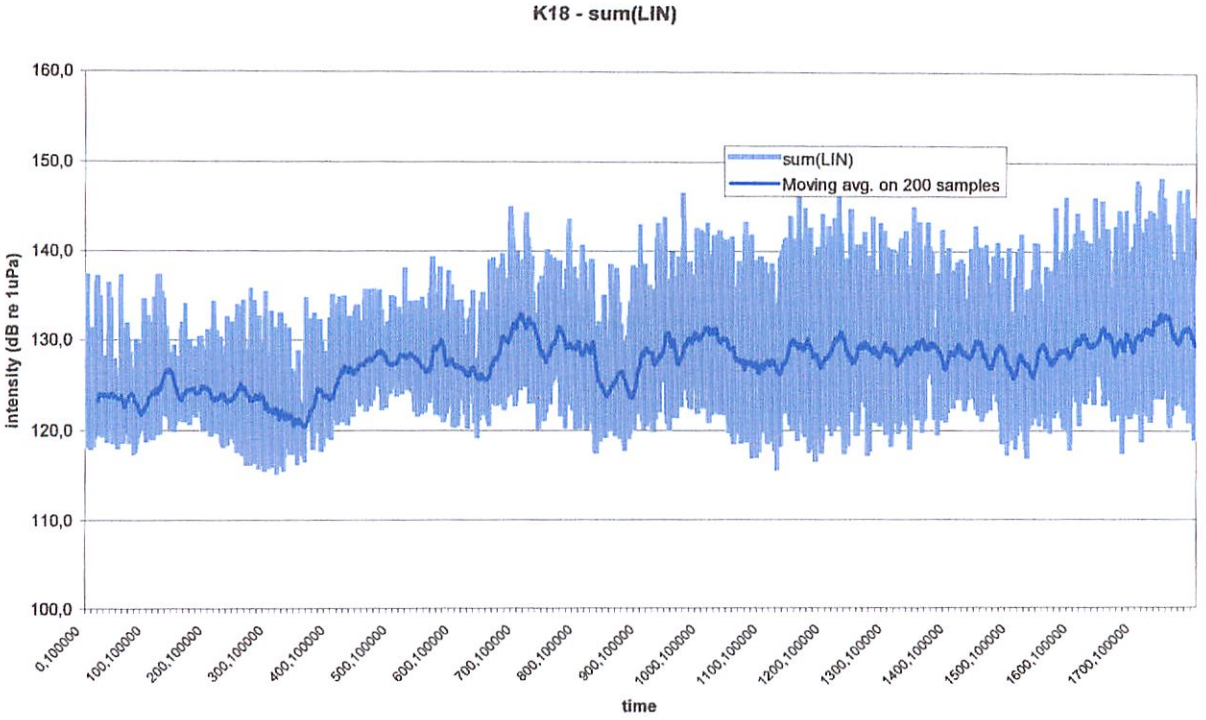
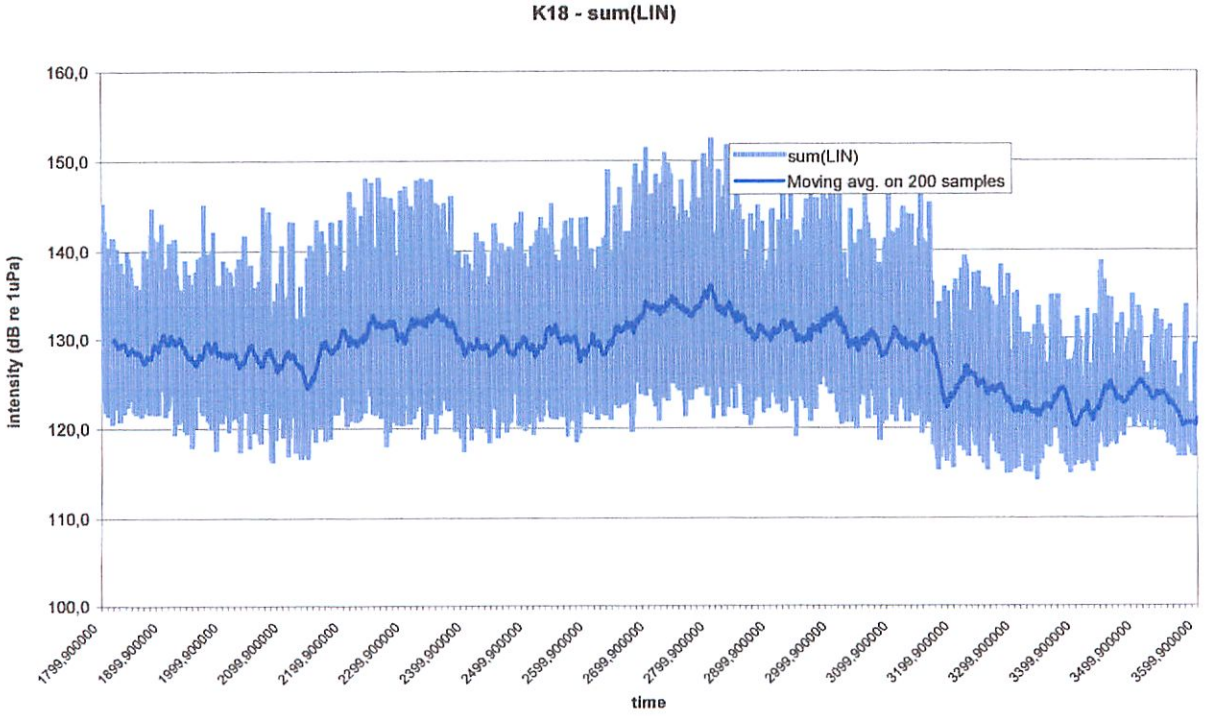
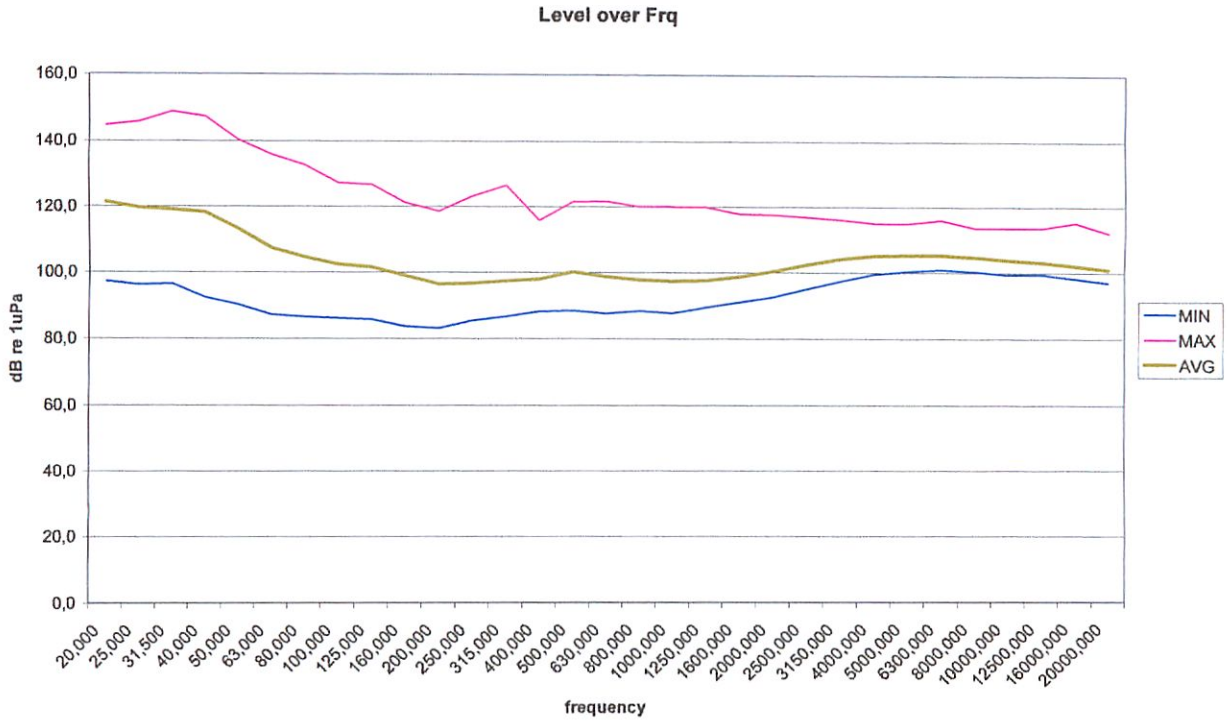
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

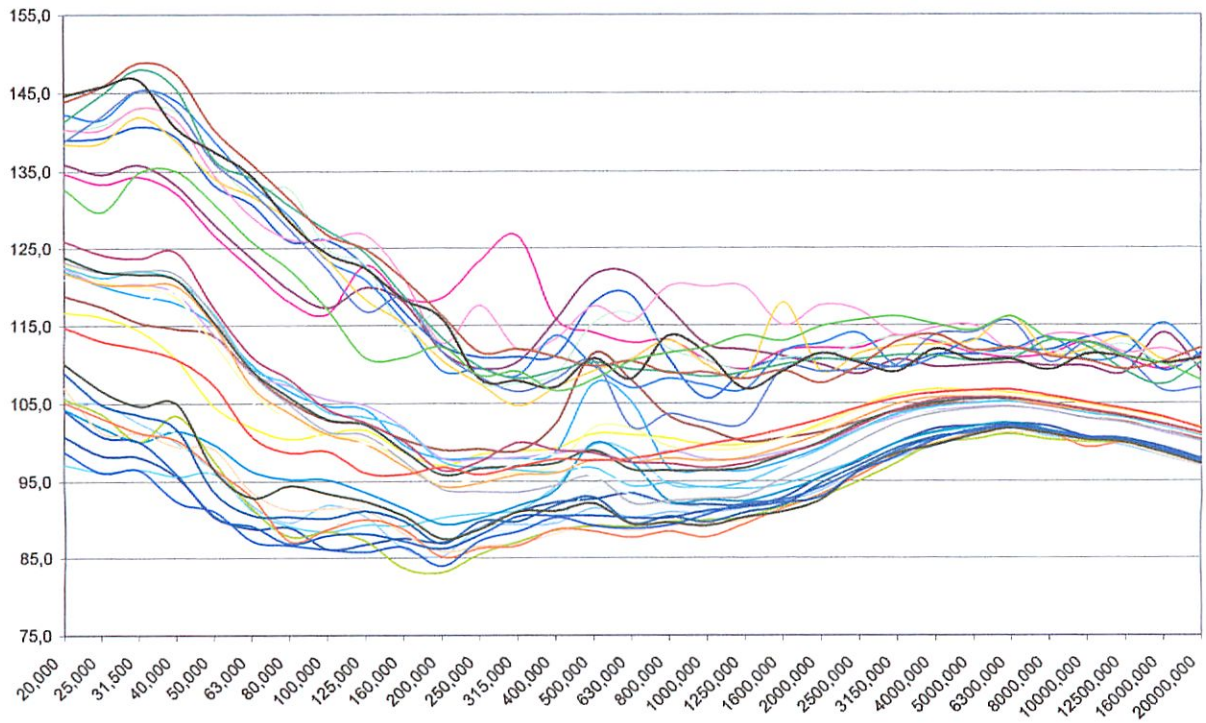

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_1

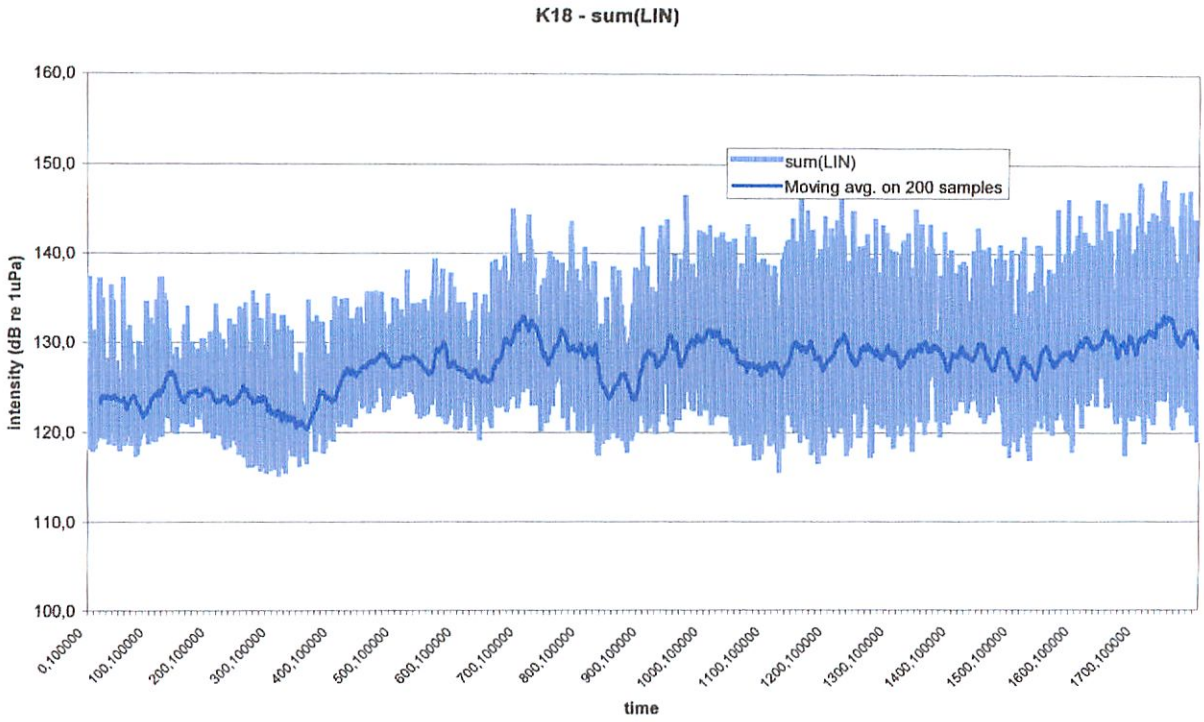

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

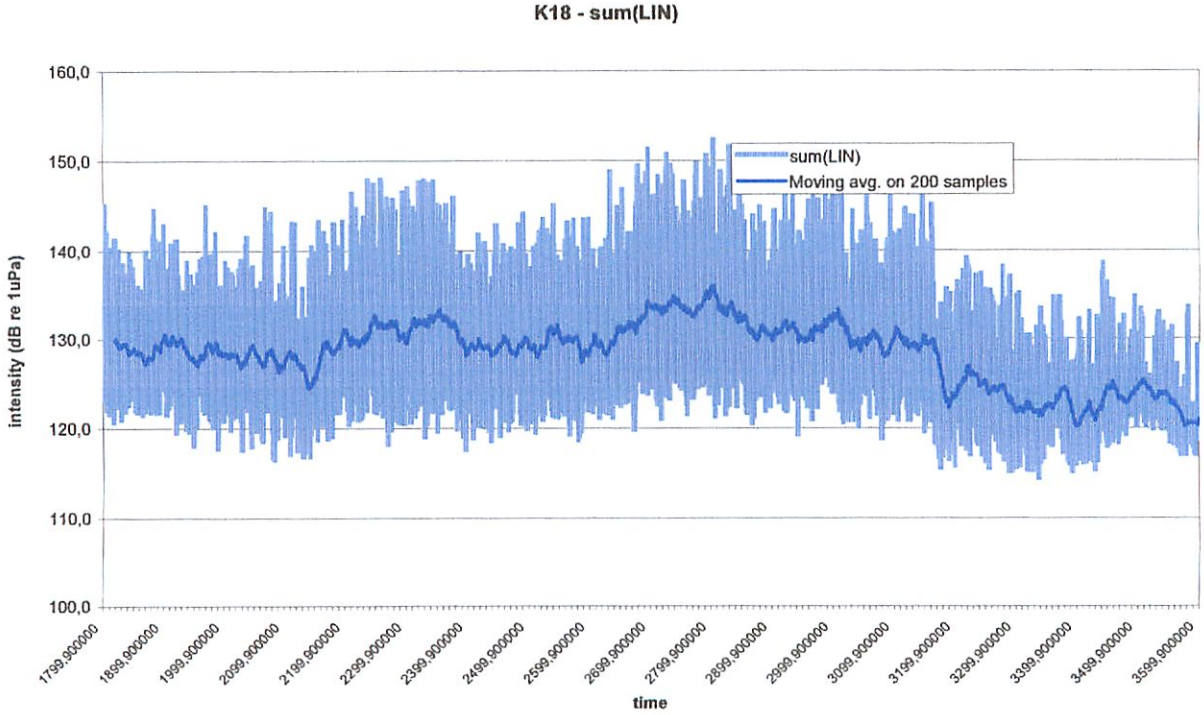

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

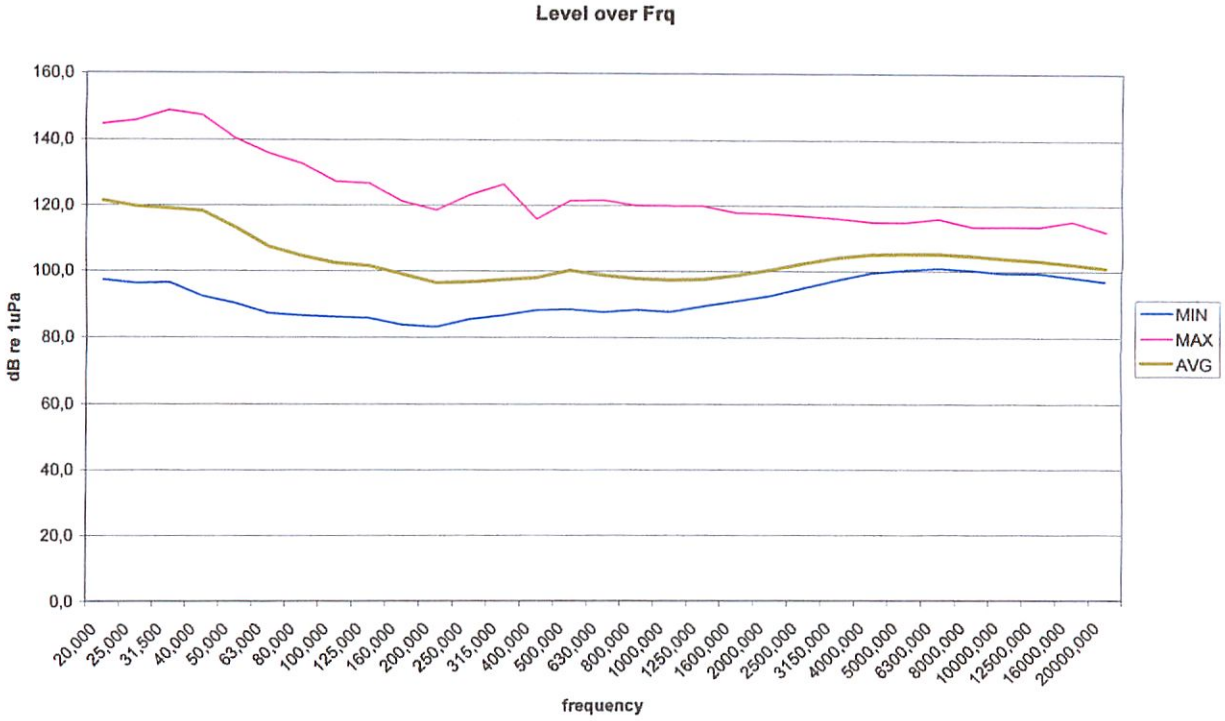

Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

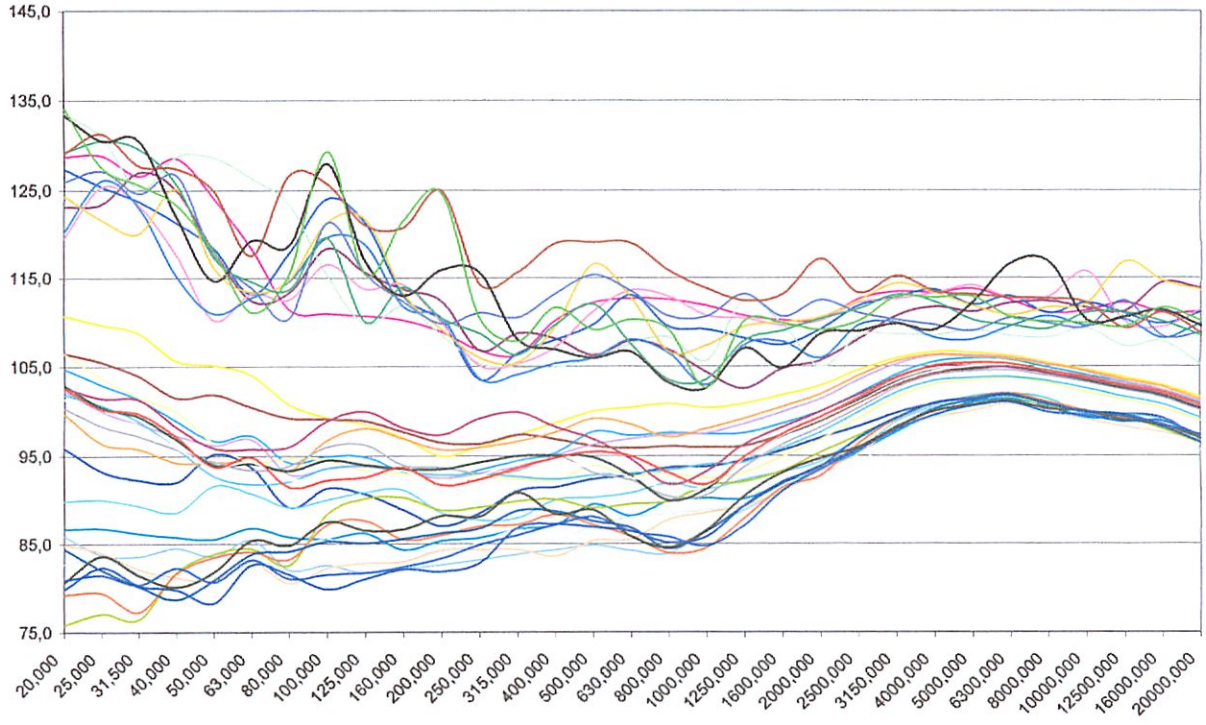

155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_2

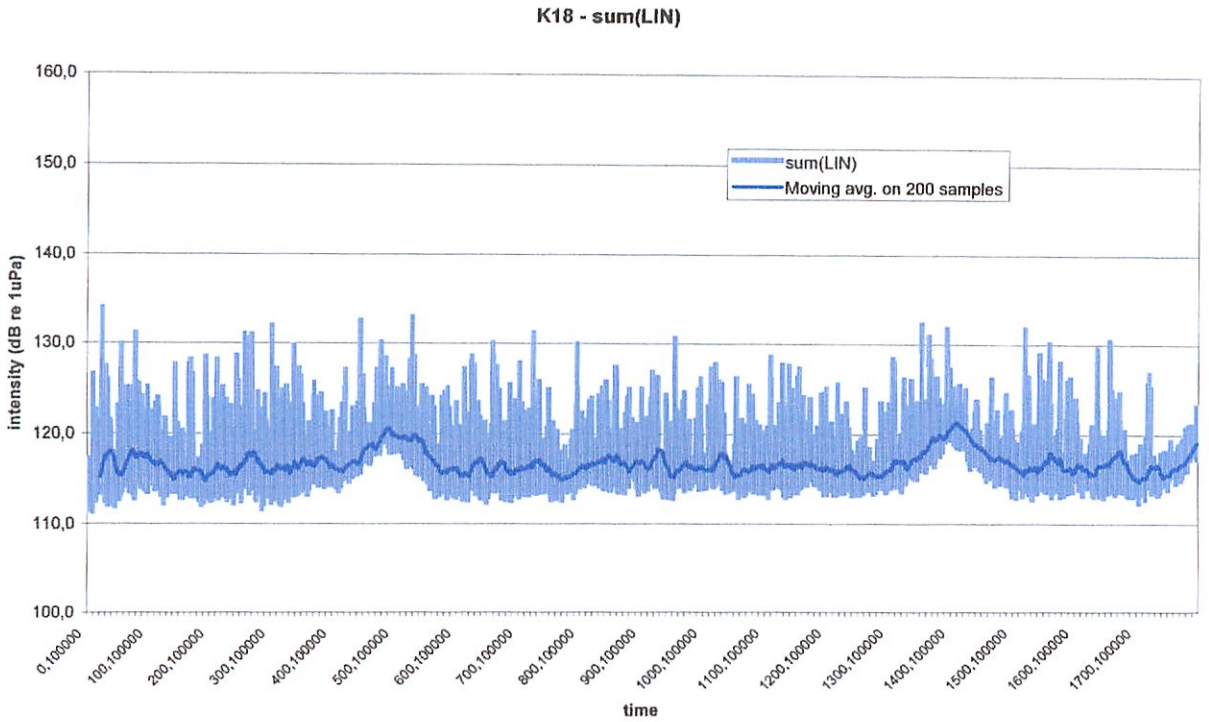

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

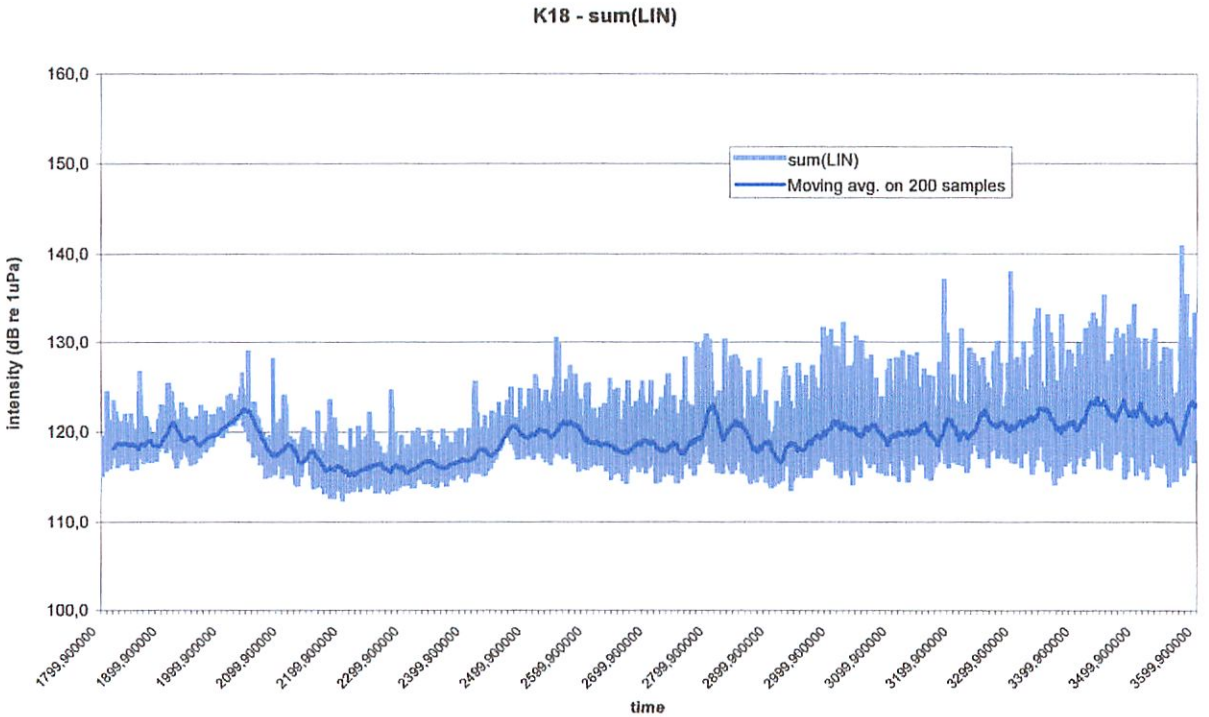

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

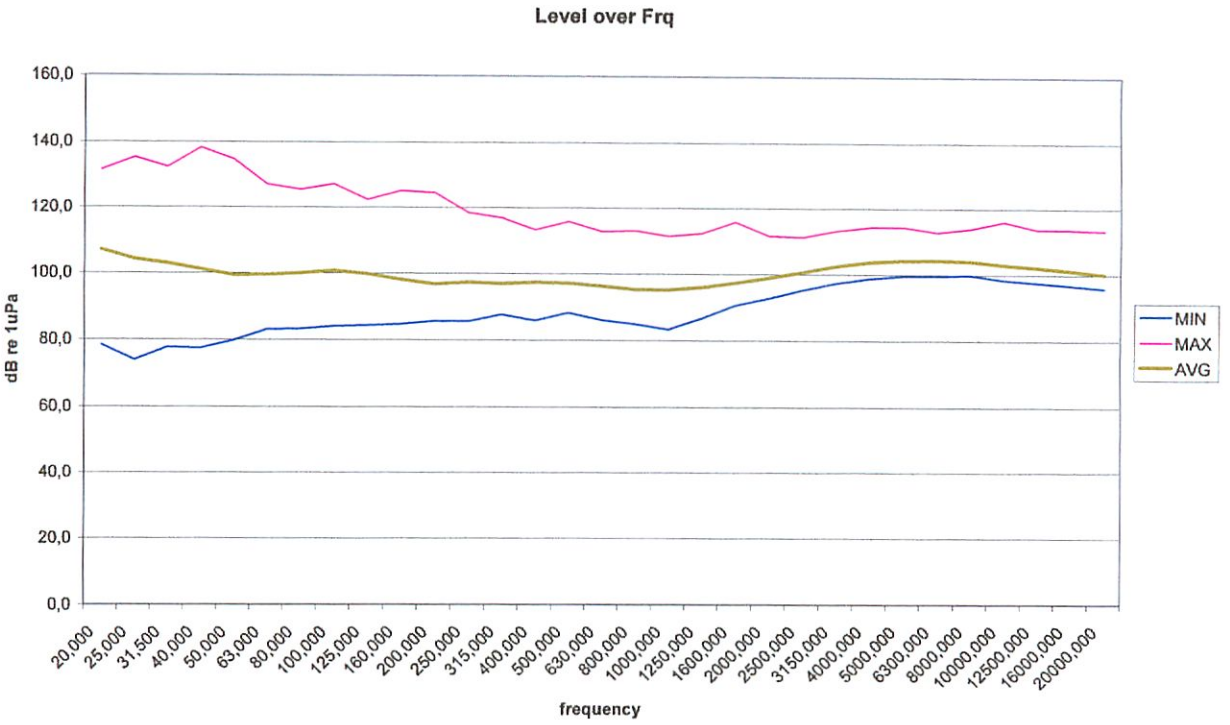

Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

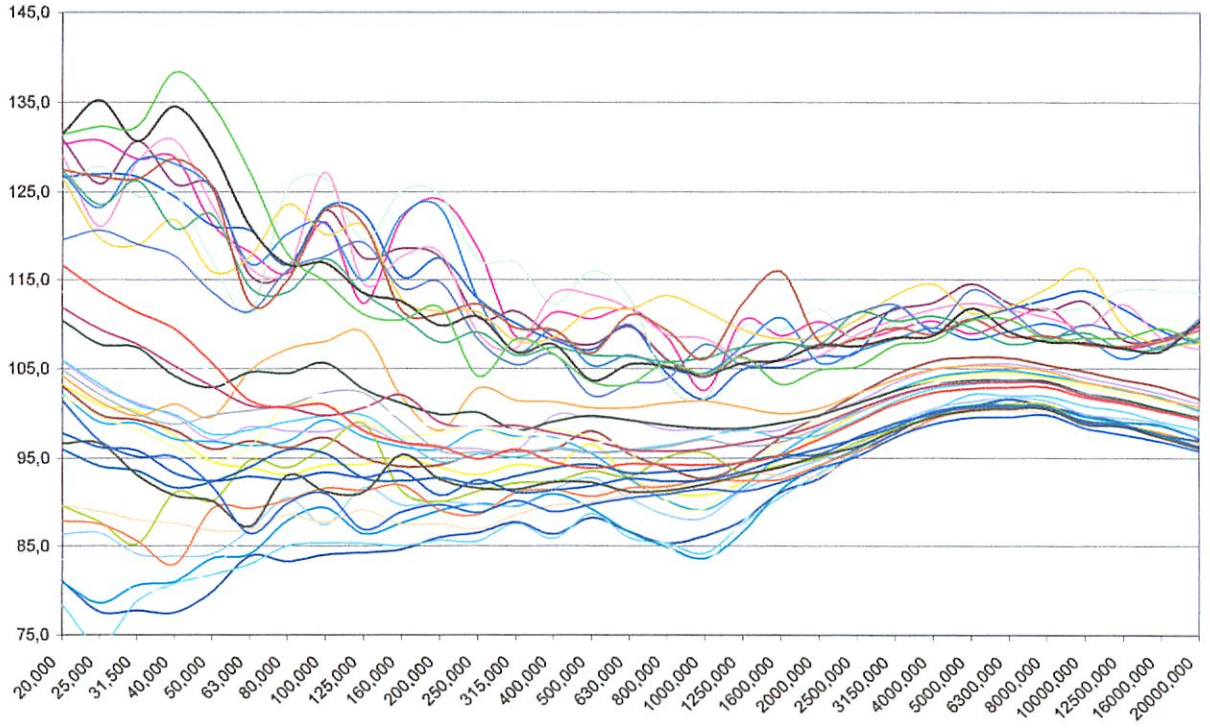

145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_3

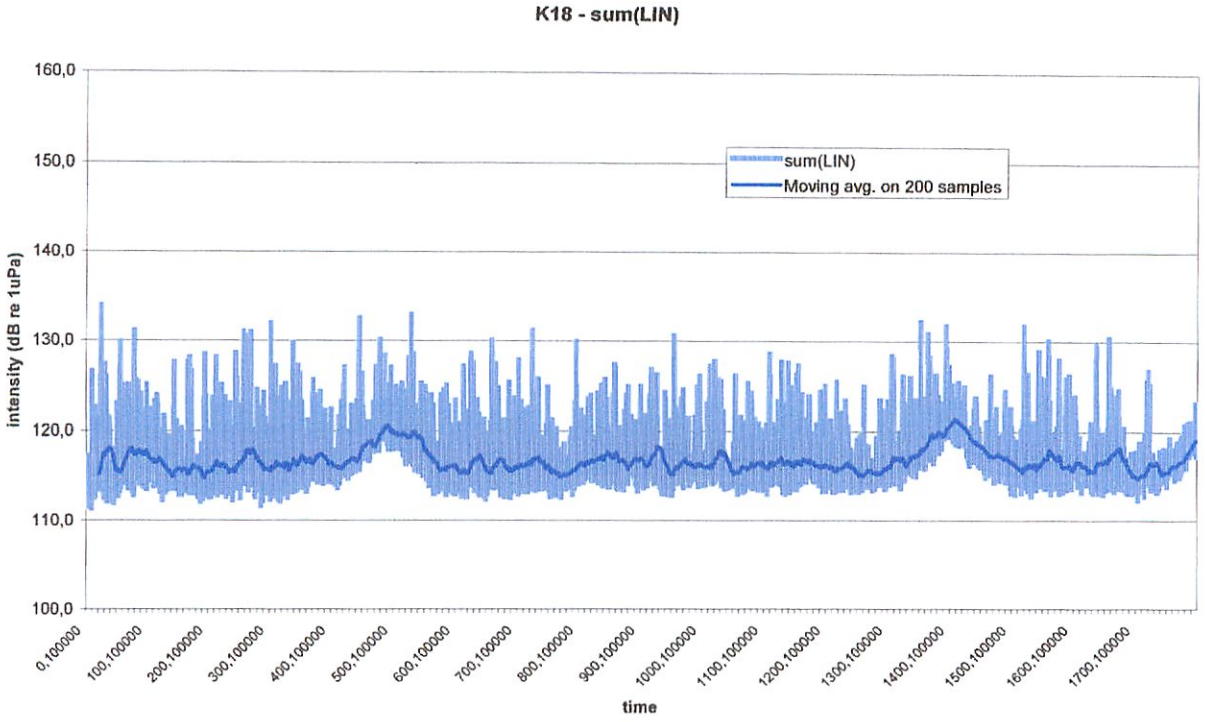

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

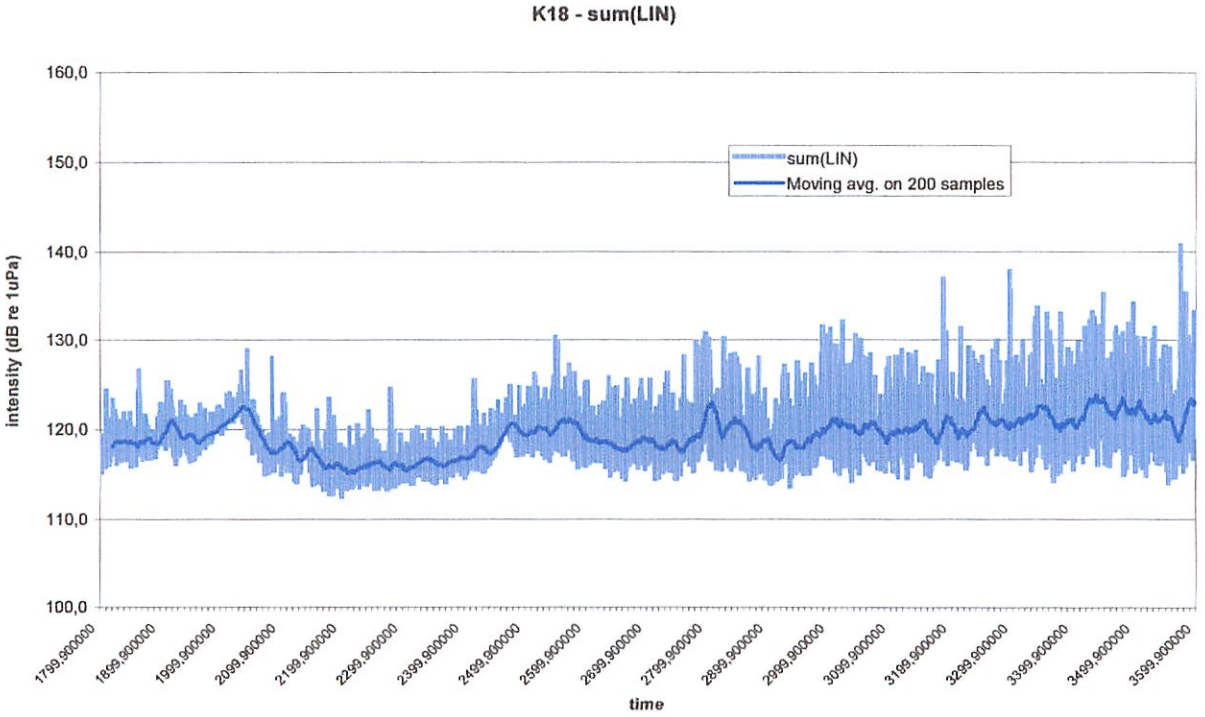

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

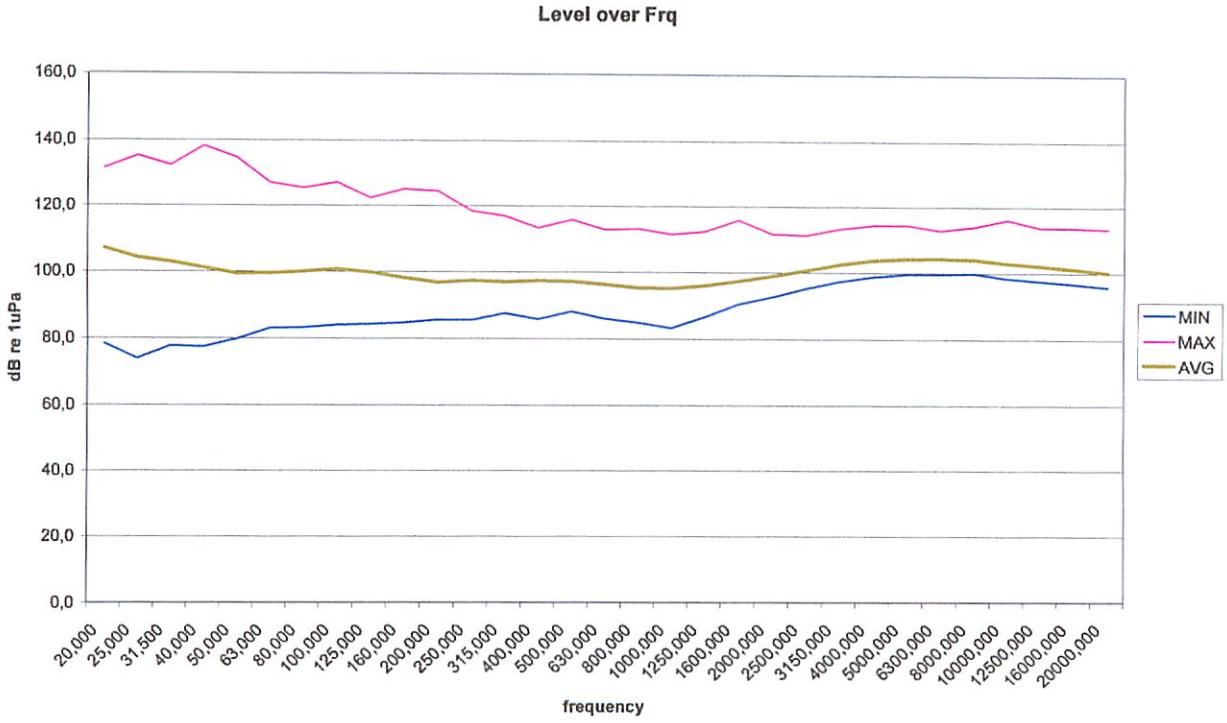

Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

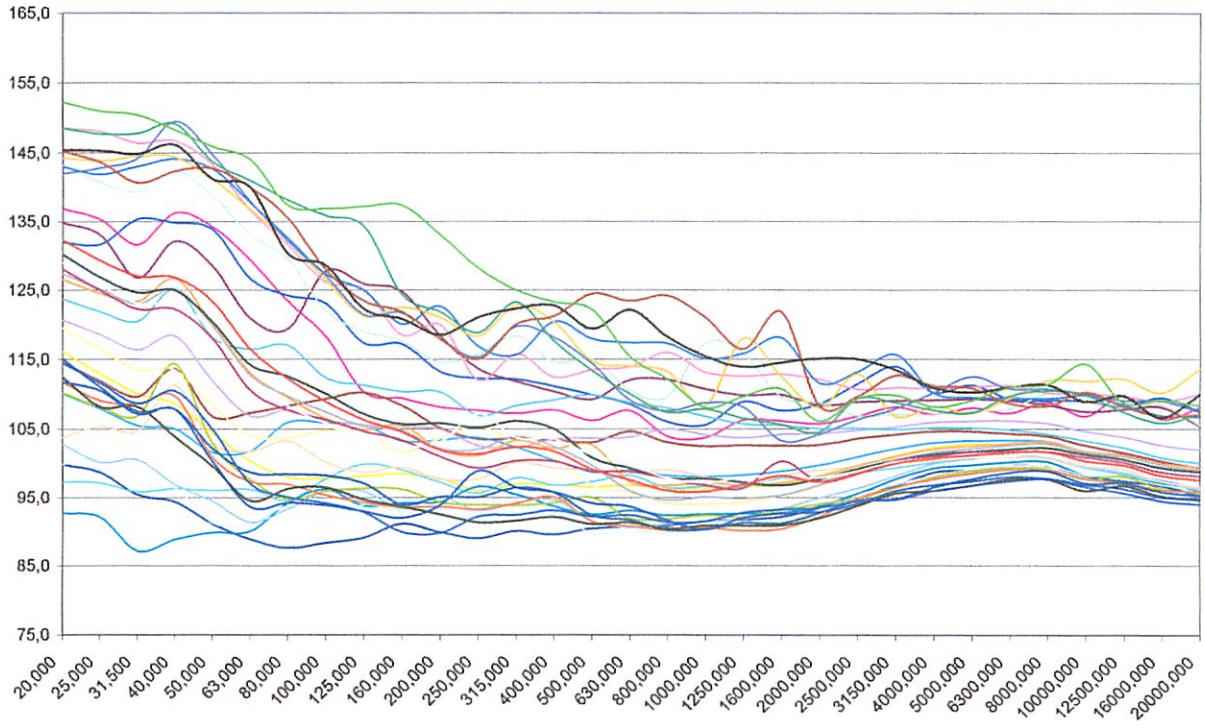

145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_4

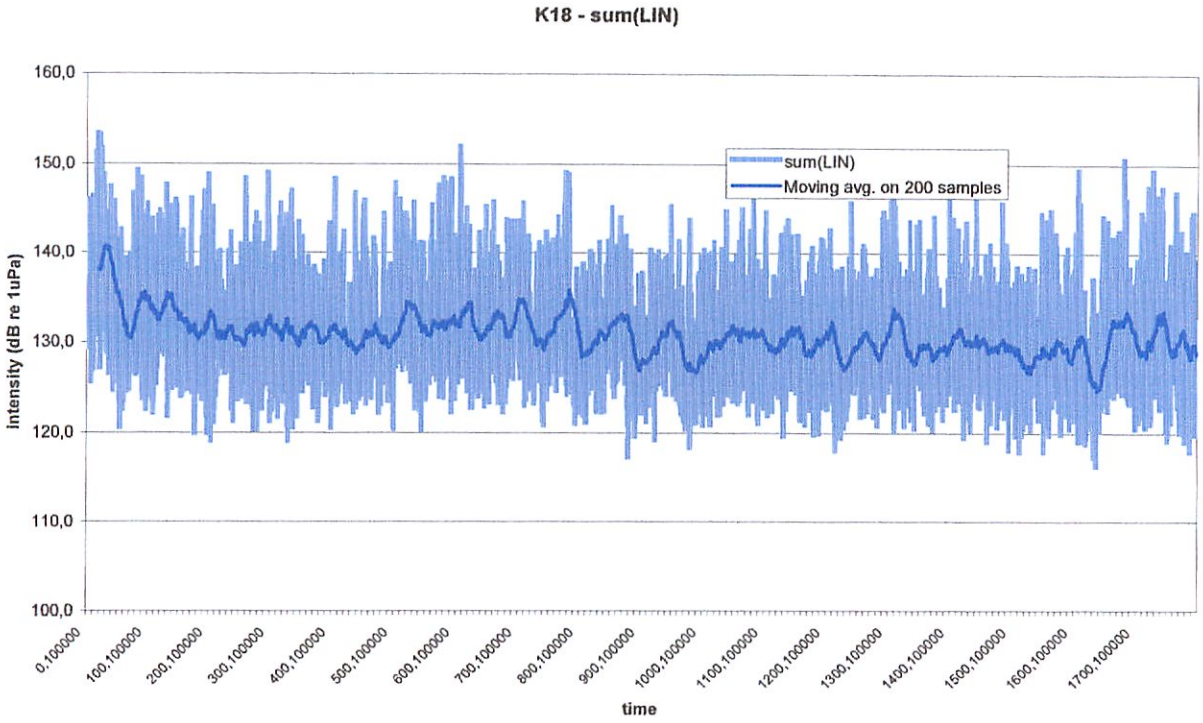

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

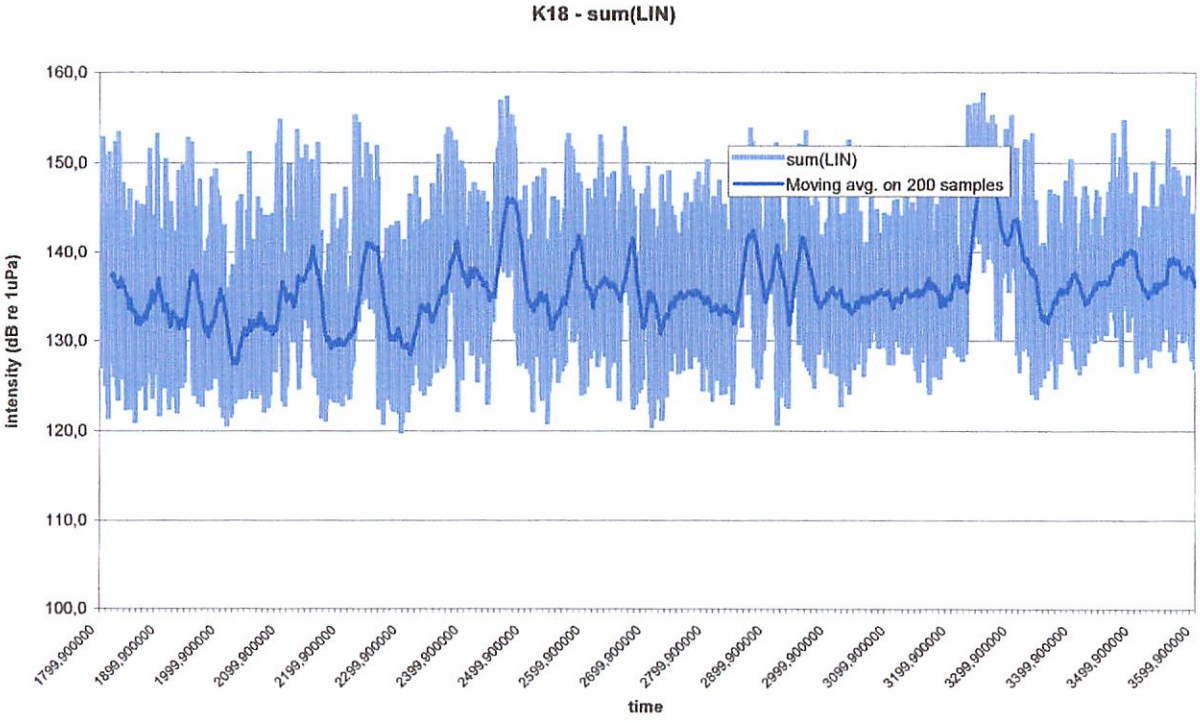

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

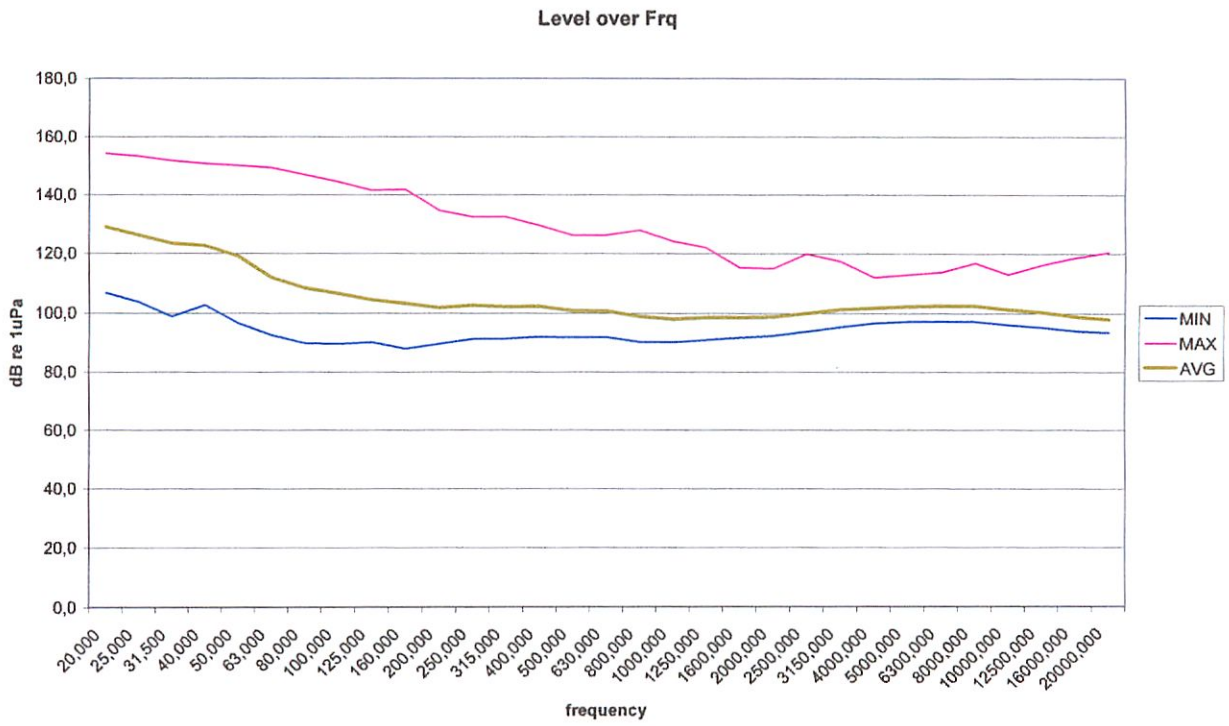

Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

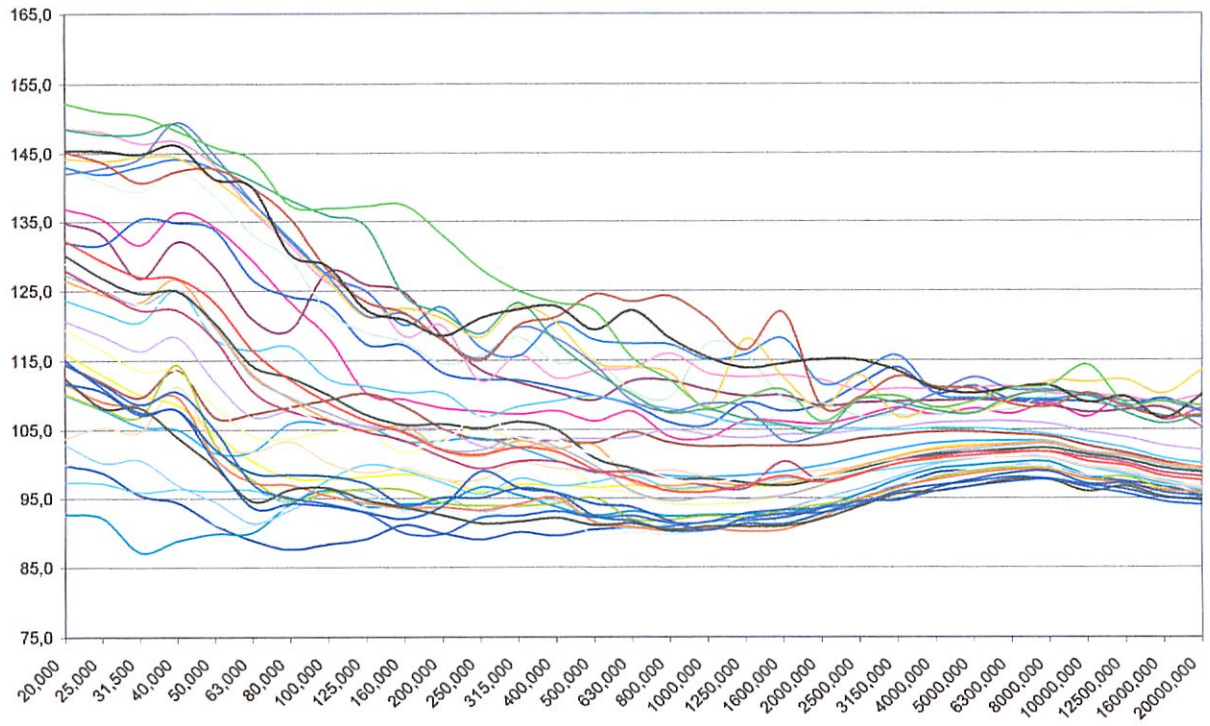

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_5

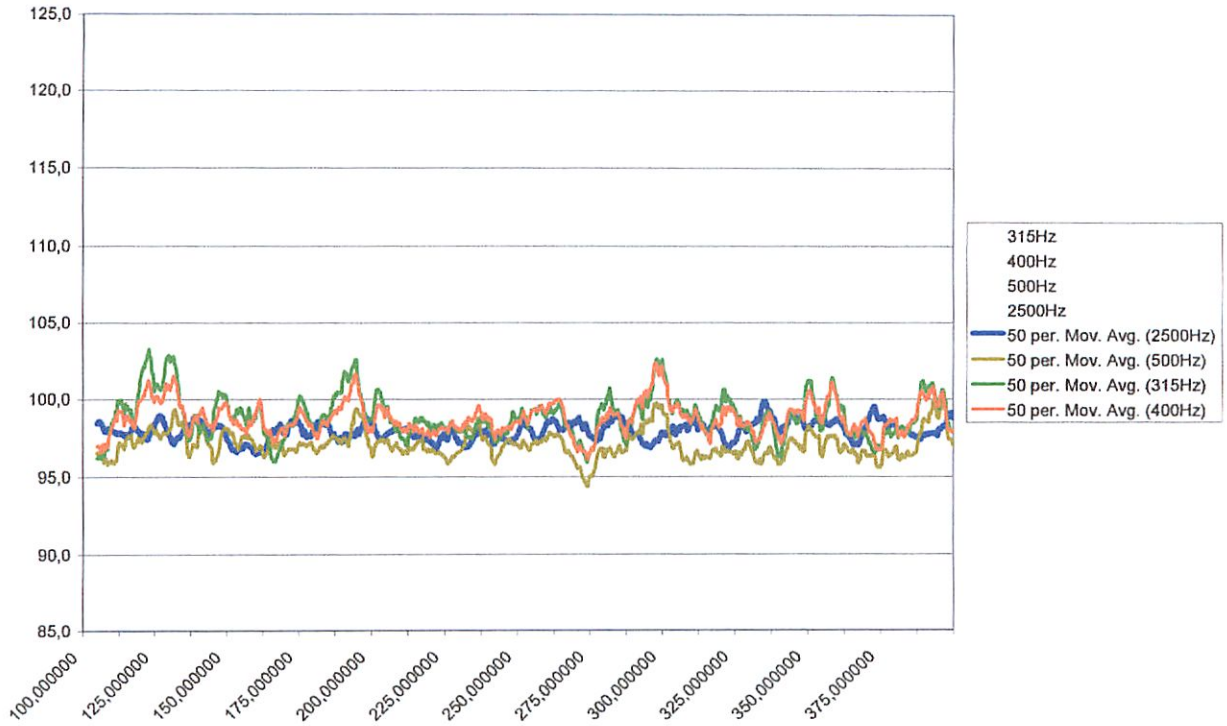

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
Intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time


K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
Intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time


Level over Frq
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

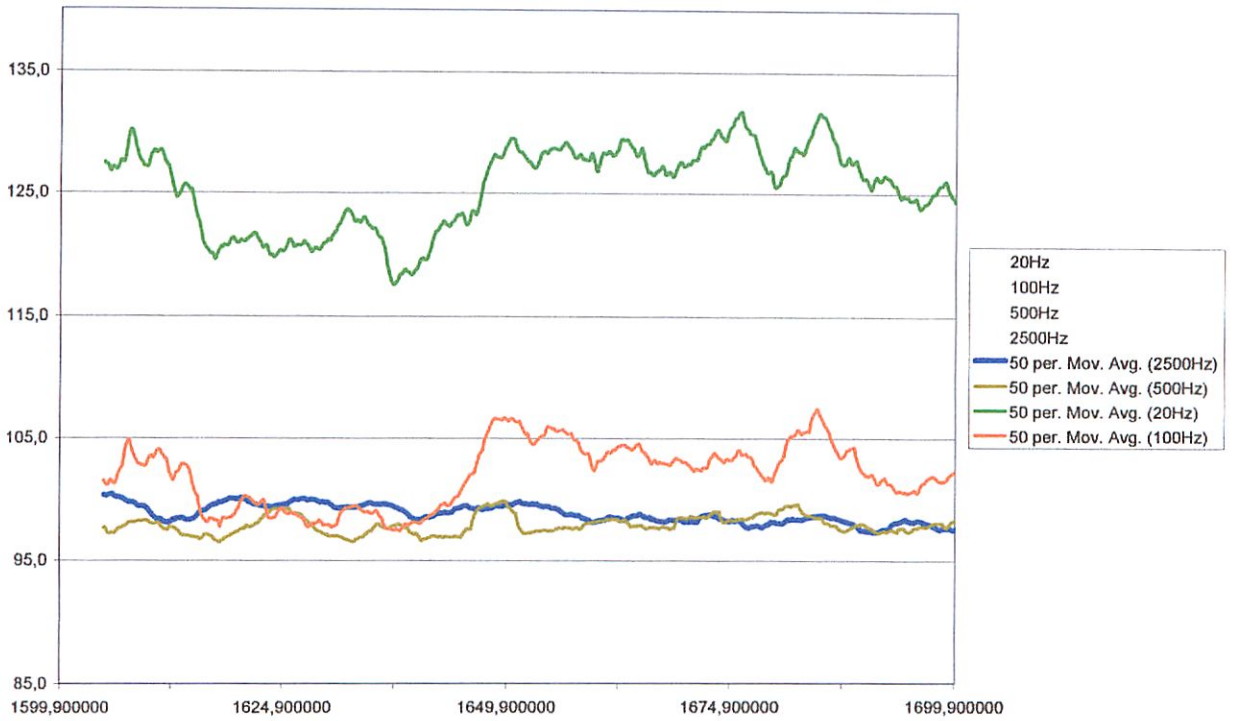

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

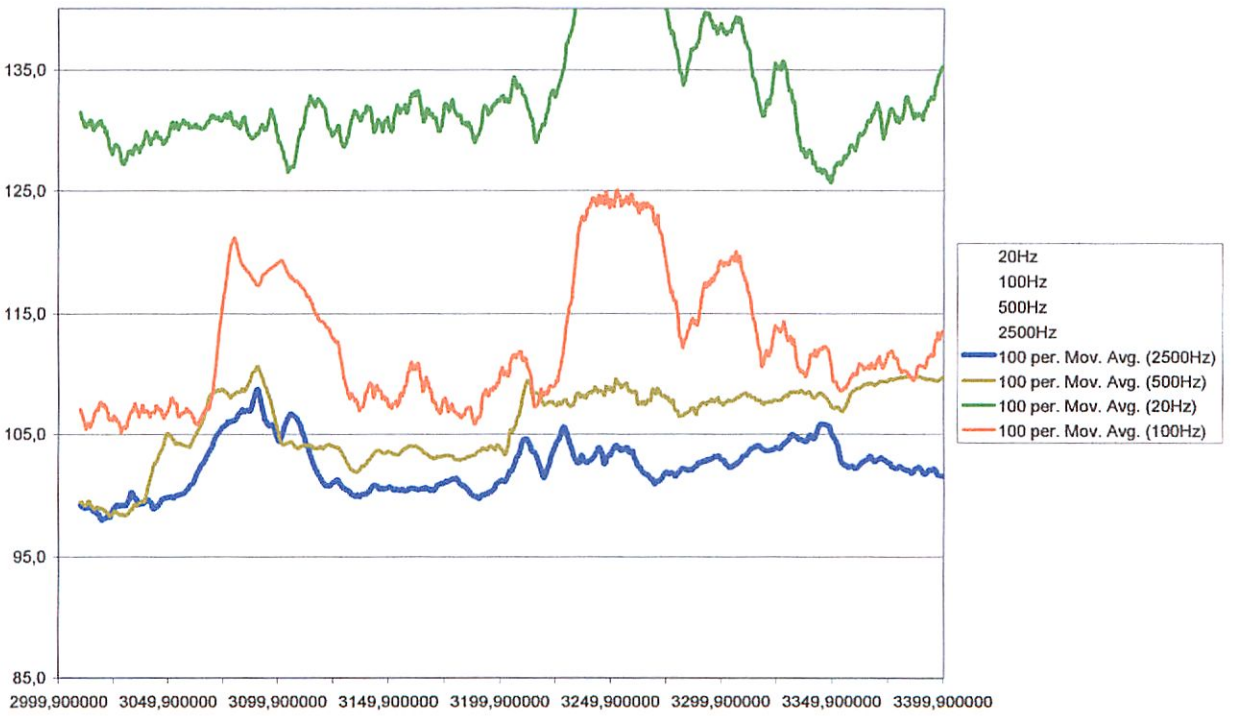
The following graph (taken from k18-5) shows a 40" period (x axis) and the behaviour of four frequencies in the period. We can observe that while low range shows a similar trend (peaks at 125, 200 and 300), the 2500Hz line follows a totally different path.



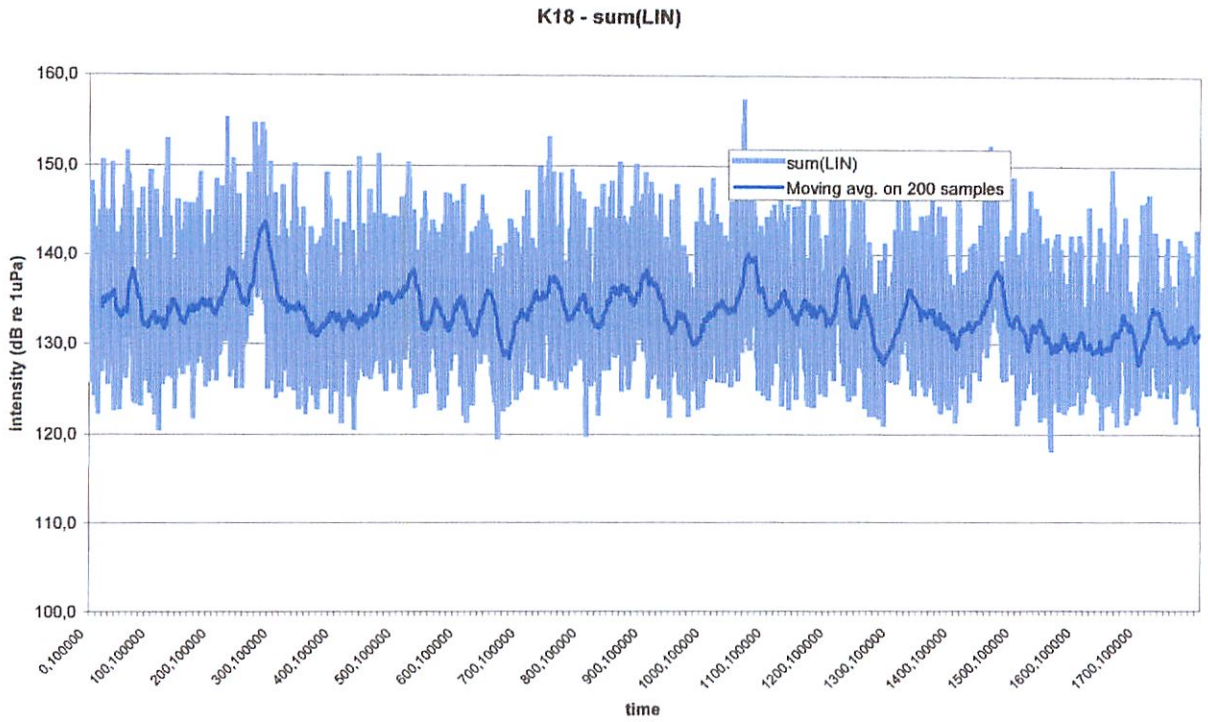
The following graphs (also taken from k18-5) shows a 10" period (x axis) and the behaviour of four frequencies (20Hz, 100Hz, 500Hz, 2500Hz).

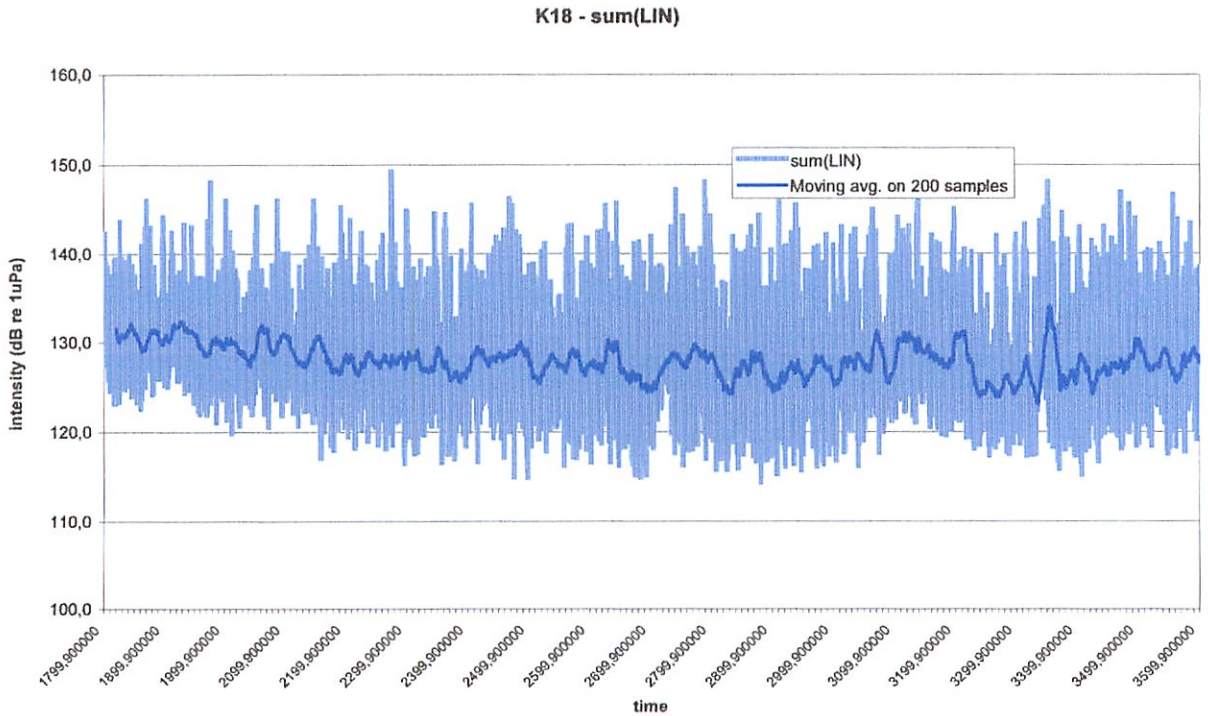
It is easy to observe how some events influence all the lower part of the spectrum (event at sample 1650), while other events (as the one starting at sample 3050) involve the low frequencies, the 2500Hz band, but not the 20Hz line.

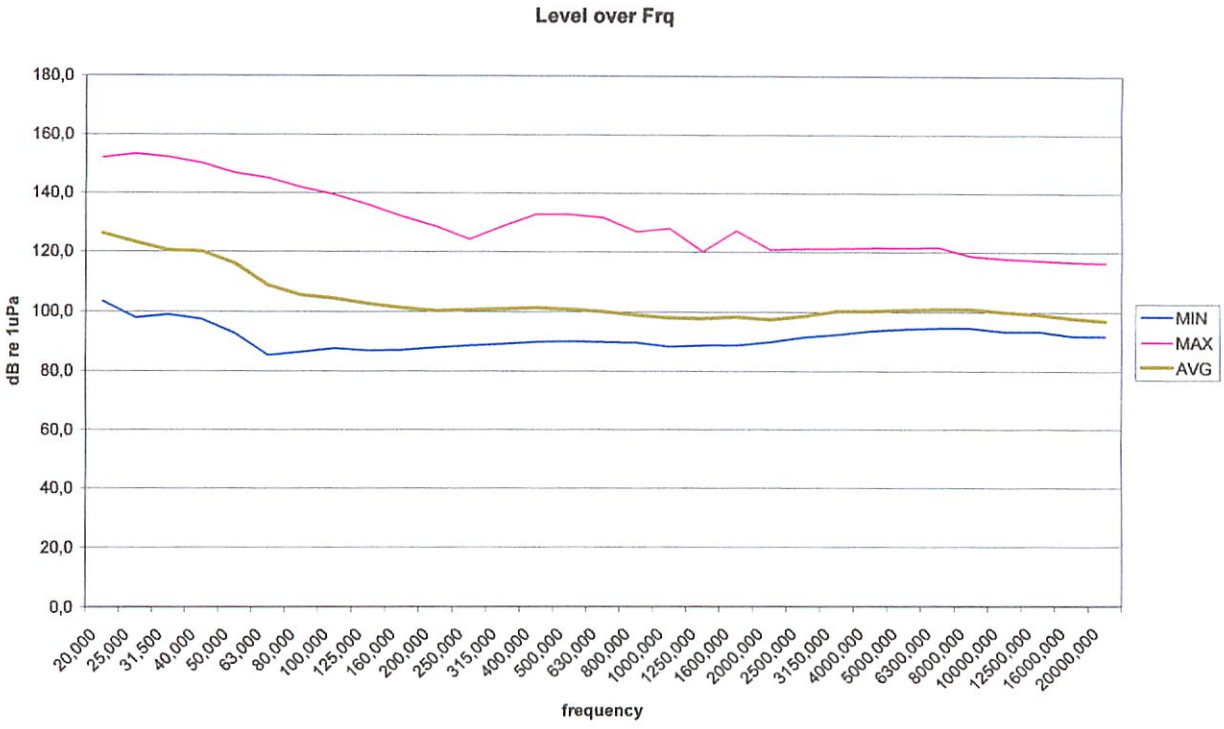

135,0
125,0
115,0
105,0
95,0
85,0
1599,900000
1624,900000
1649,900000
1674,900000
1699,900000
20Hz
100Hz
500Hz
2500Hz
50 per. Mov. Avg. (2500Hz)
50 per. Mov. Avg. (500Hz)
50 per. Mov. Avg. (20Hz)
50 per. Mov. Avg. (100Hz)

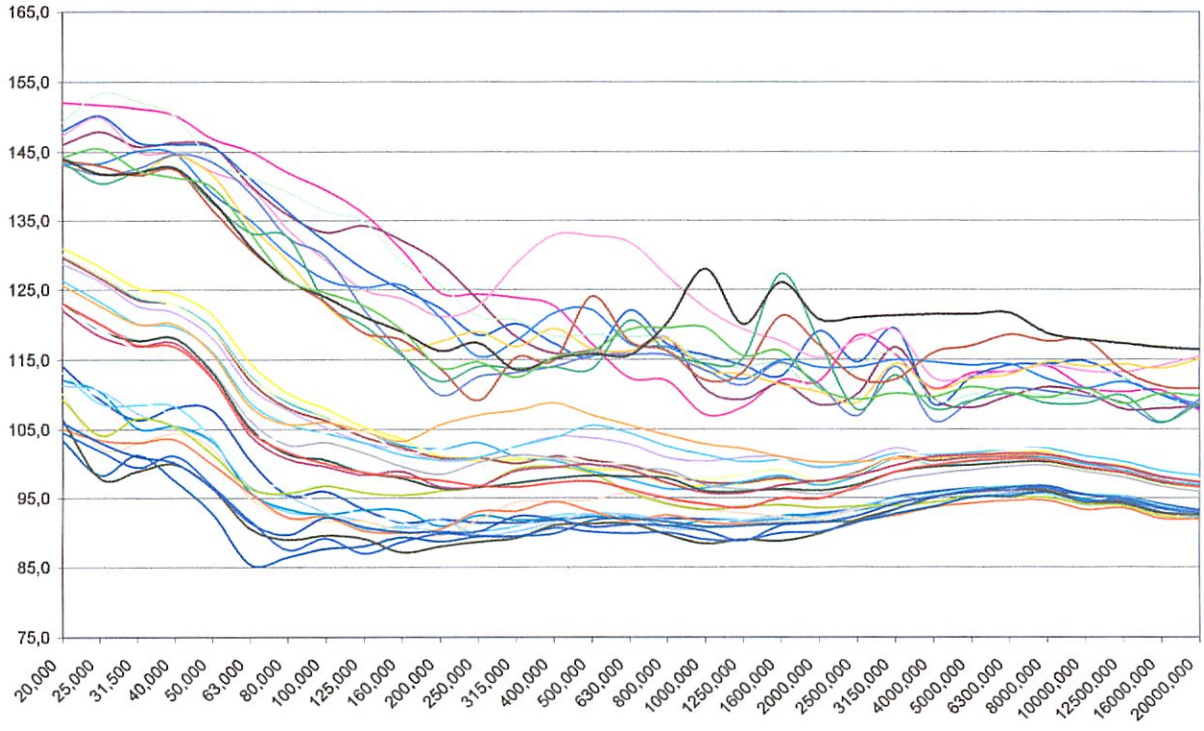

135,0
125,0
115,0
105,0
95,0
85,0
2999,900000
3049,900000
3099,900000
3149,900000
3199,900000
3249,900000
3299,900000
3349,900000
3399,900000
20Hz
100Hz
500Hz
2500Hz
100 per. Mov. Avg. (2500Hz)
100 per. Mov. Avg. (500Hz)
100 per. Mov. Avg. (20Hz)
100 per. Mov. Avg. (100Hz)

K18_6

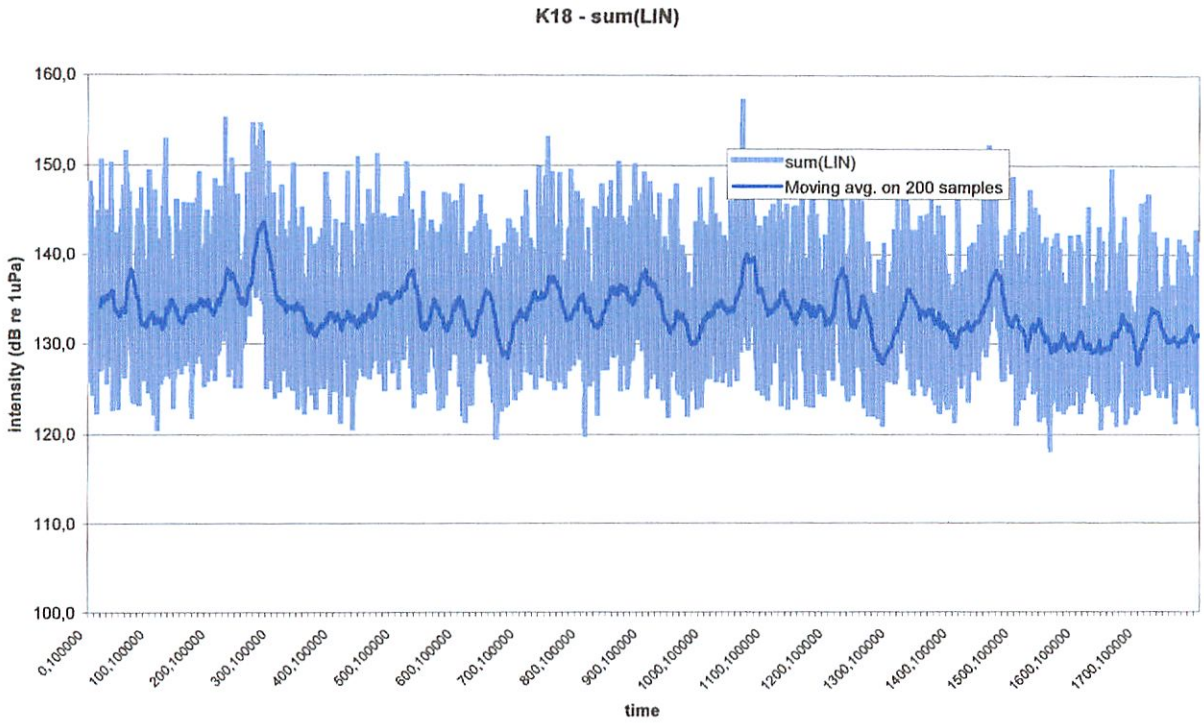

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

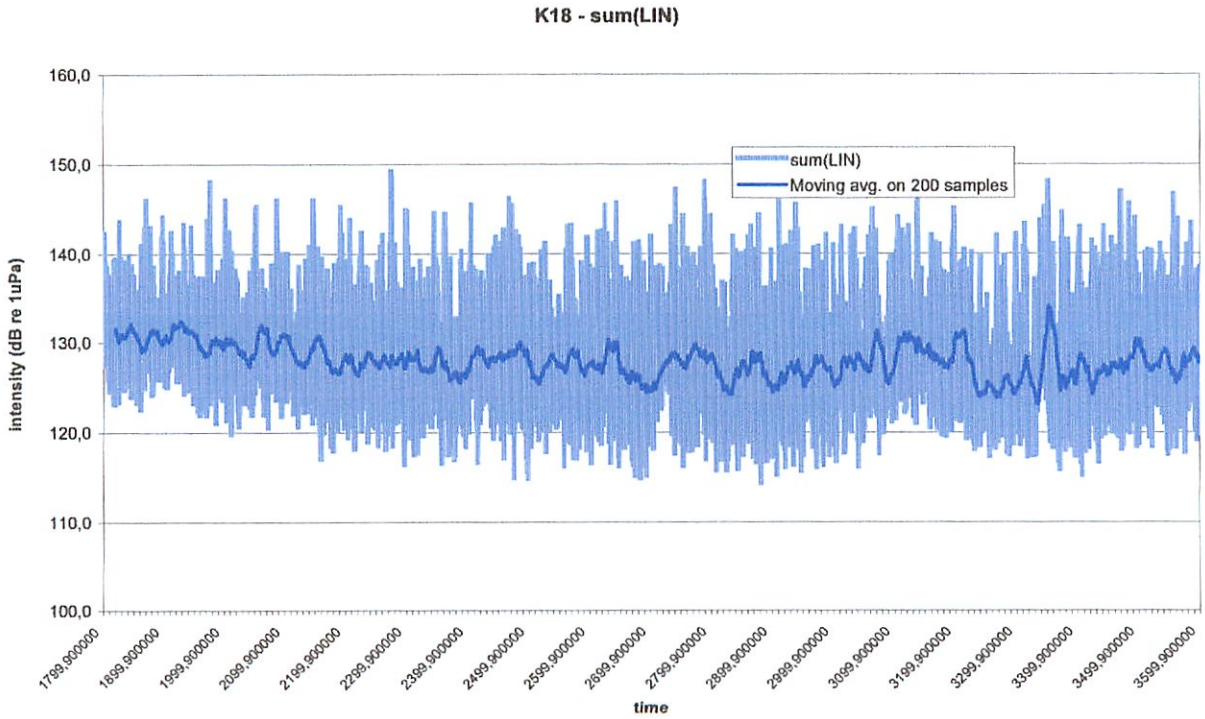

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

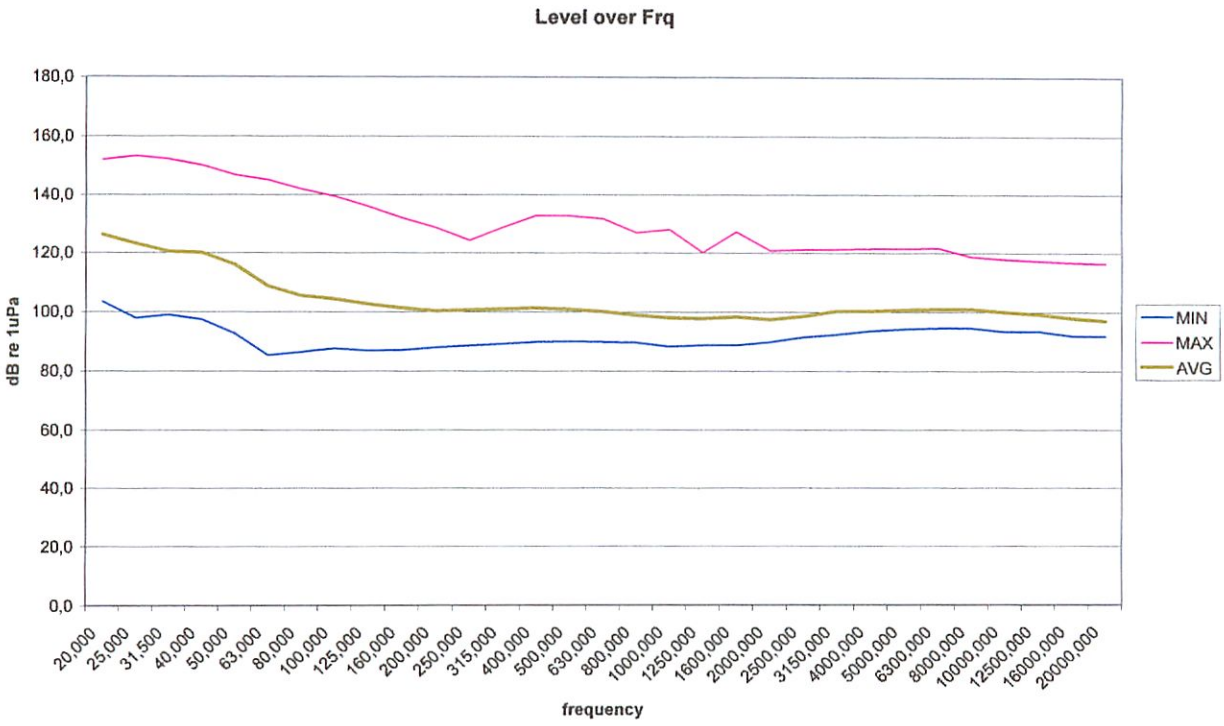

Level over Frq
dB re 1uPa
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

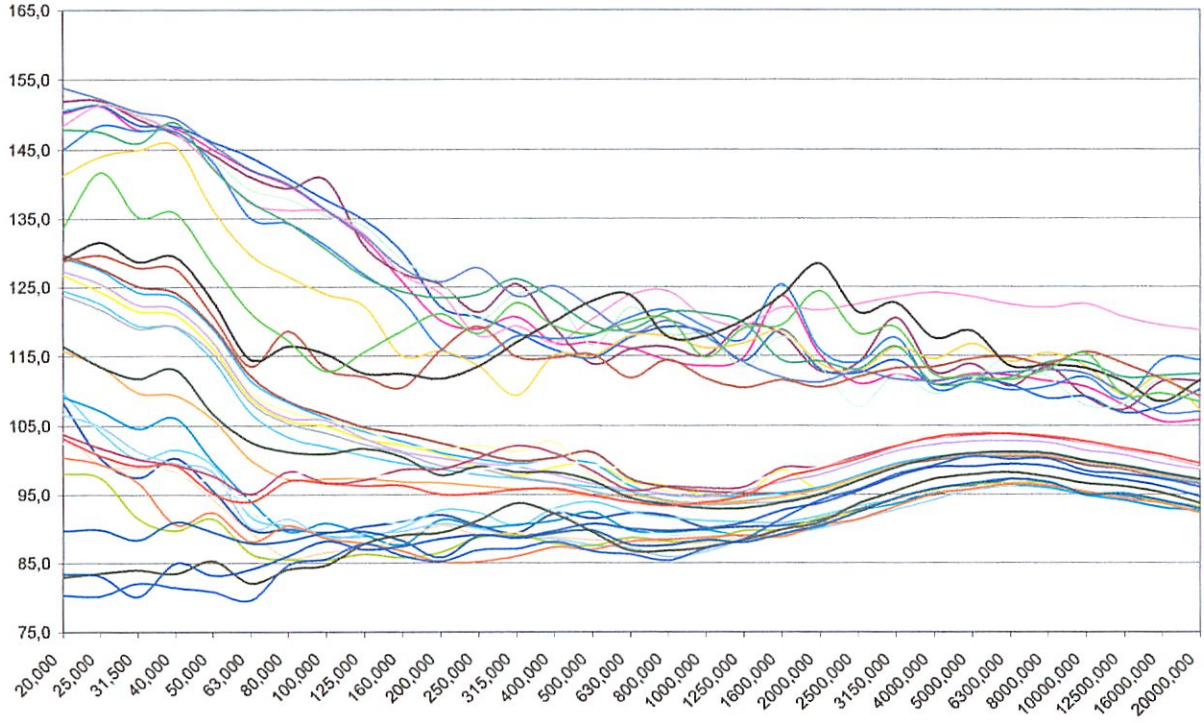

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_7

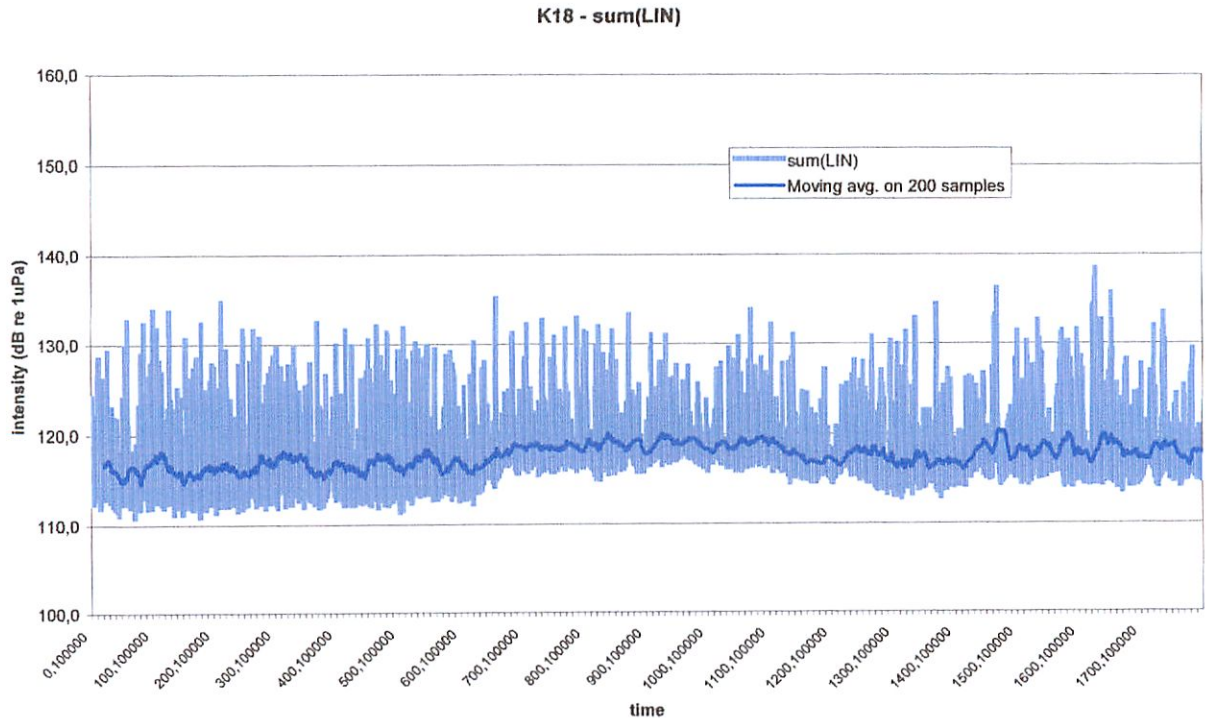

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

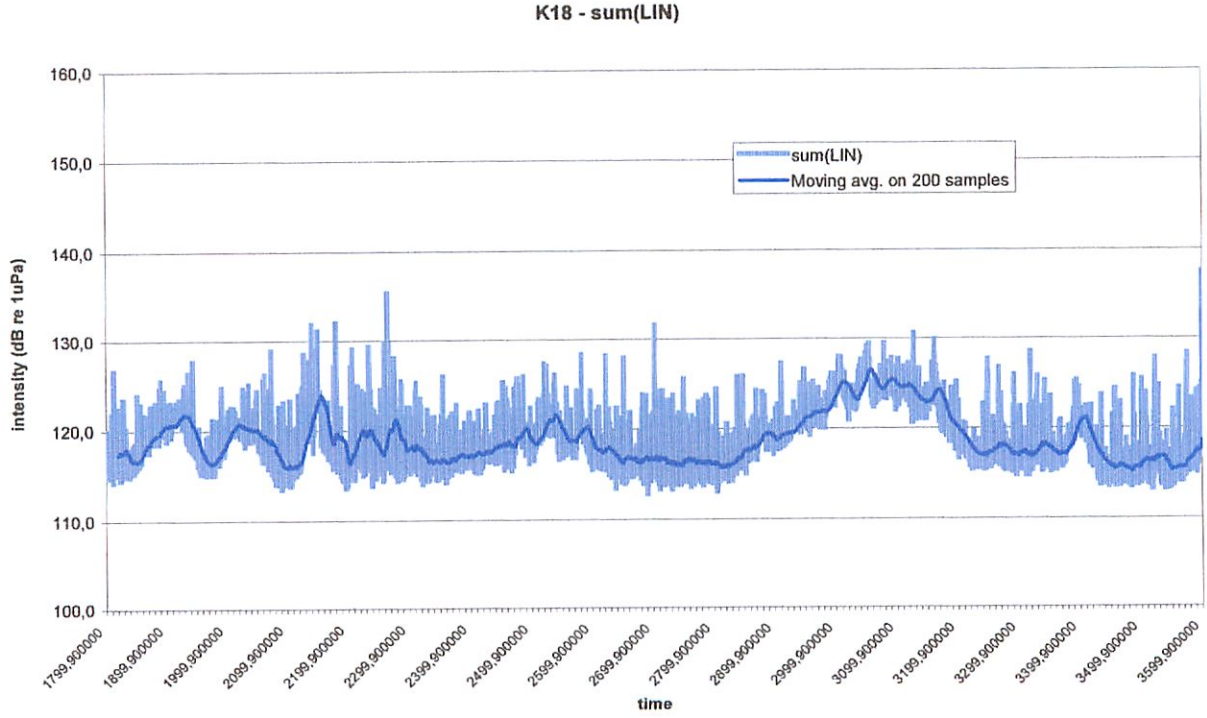

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

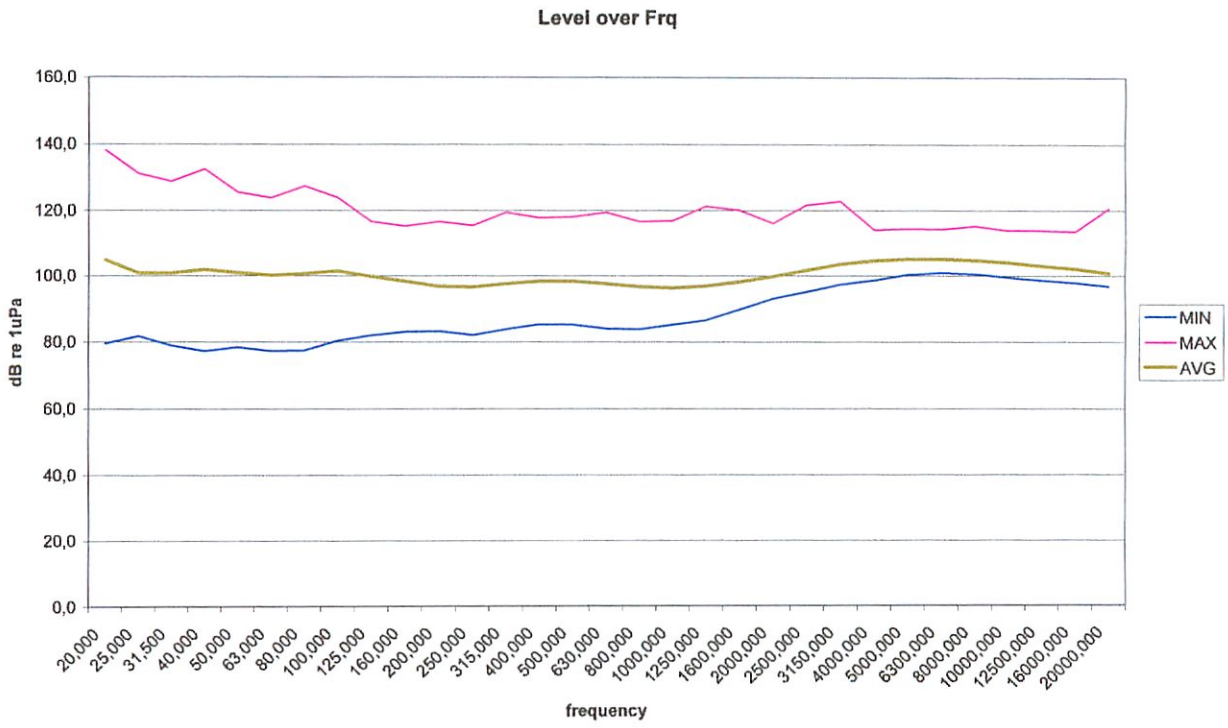

Level over Frq
dB re 1uPa
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

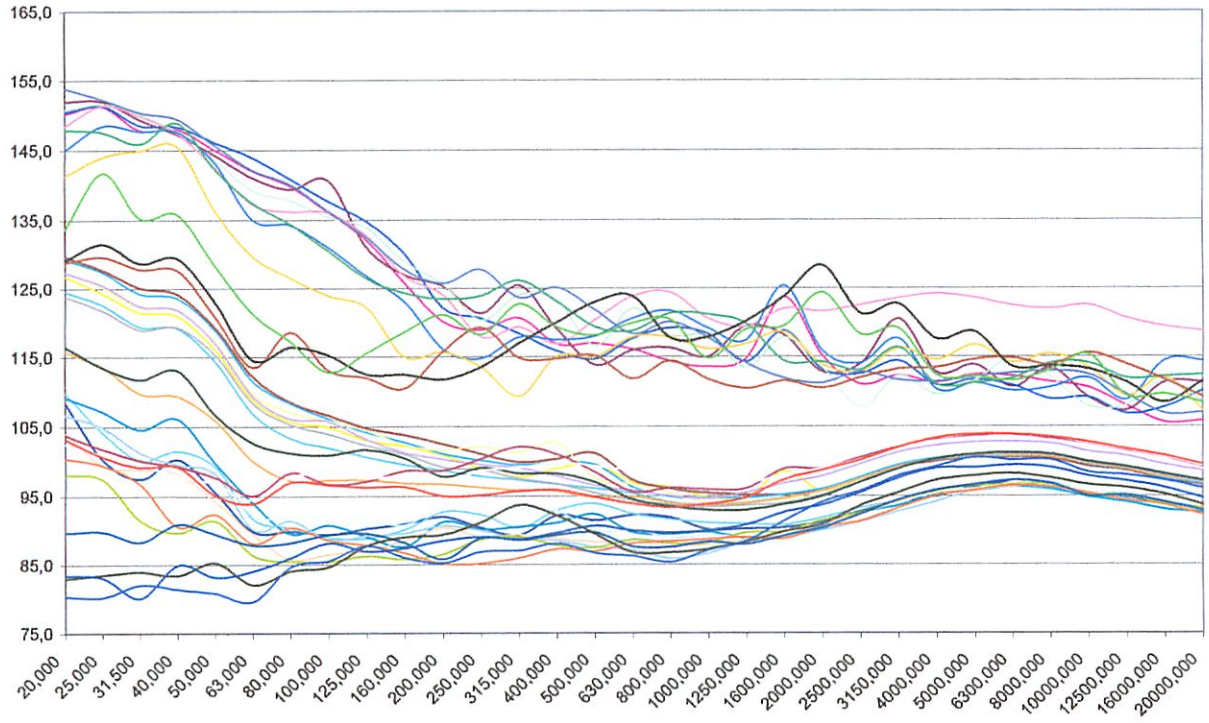

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_8

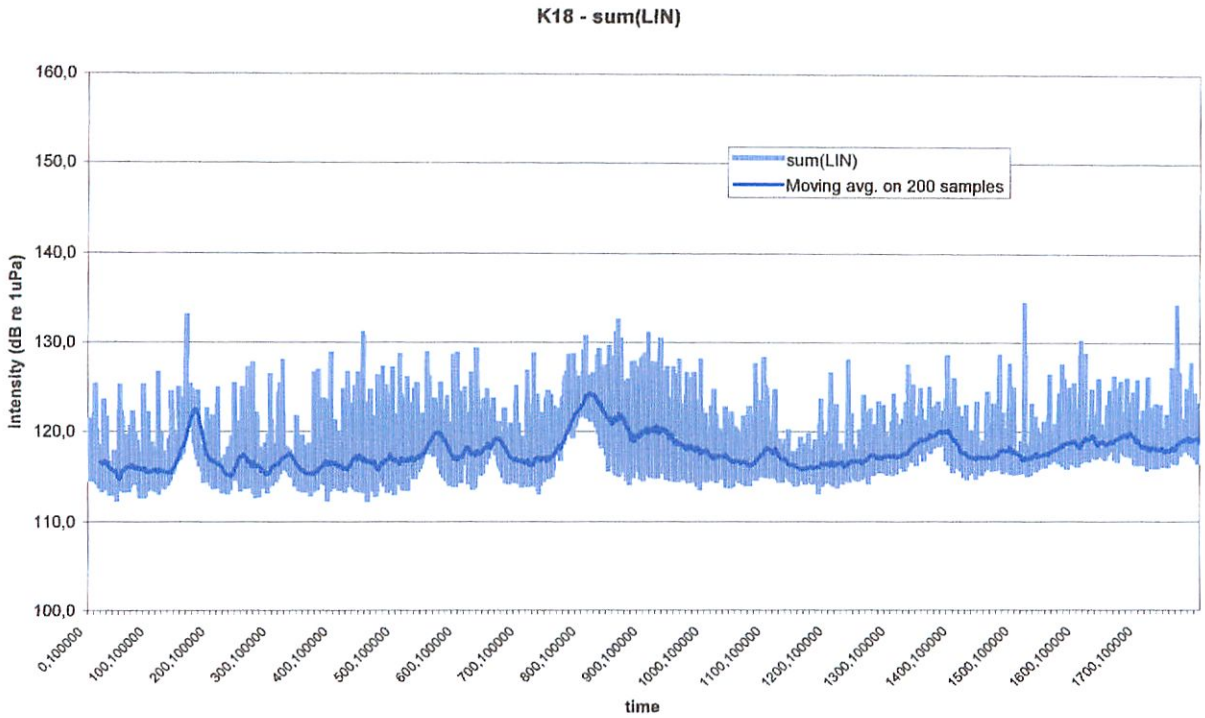

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time

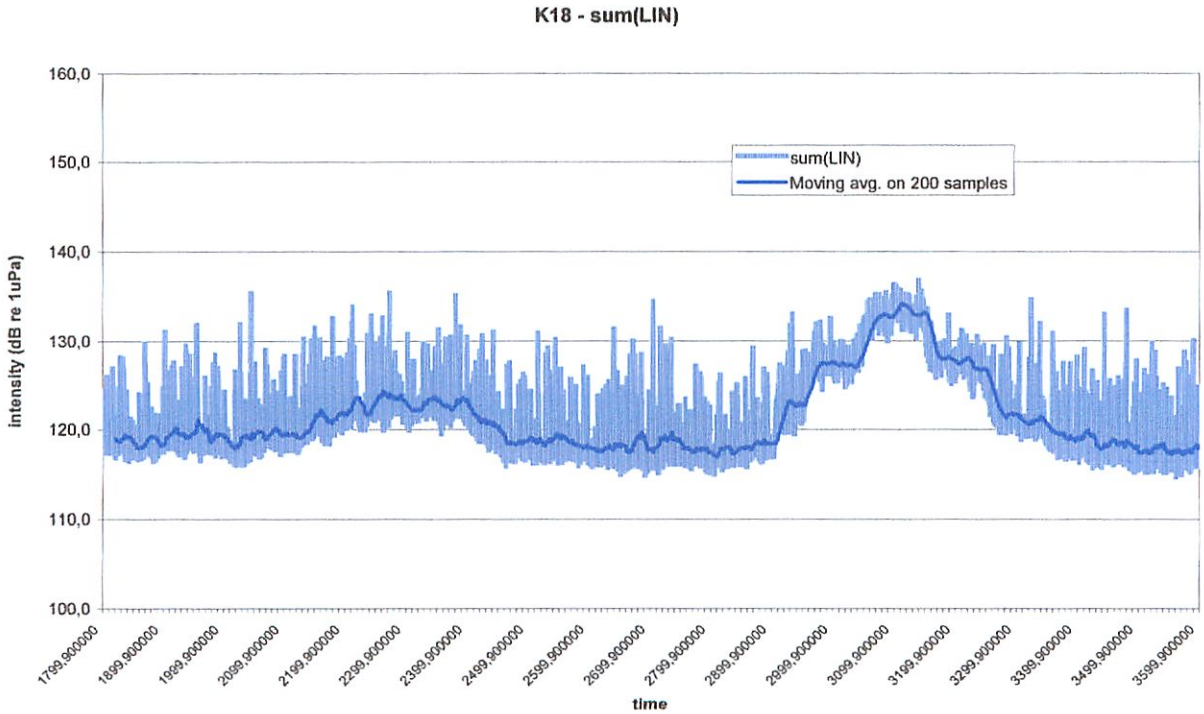

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

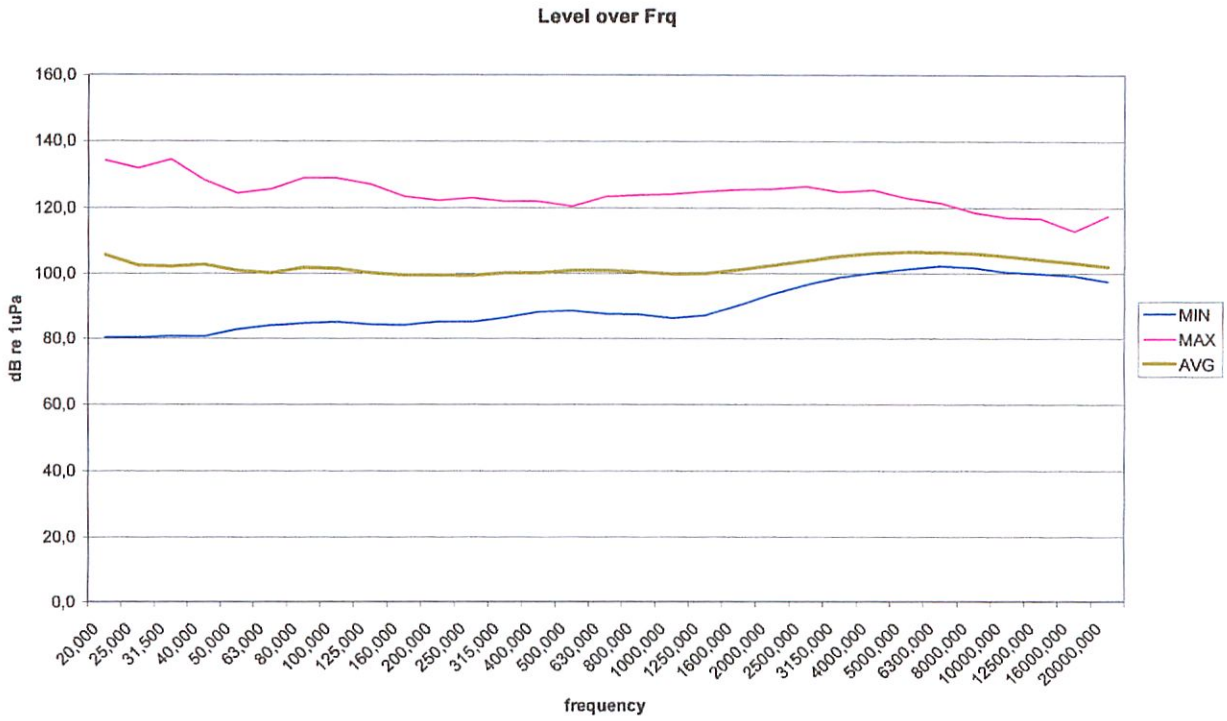

Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG

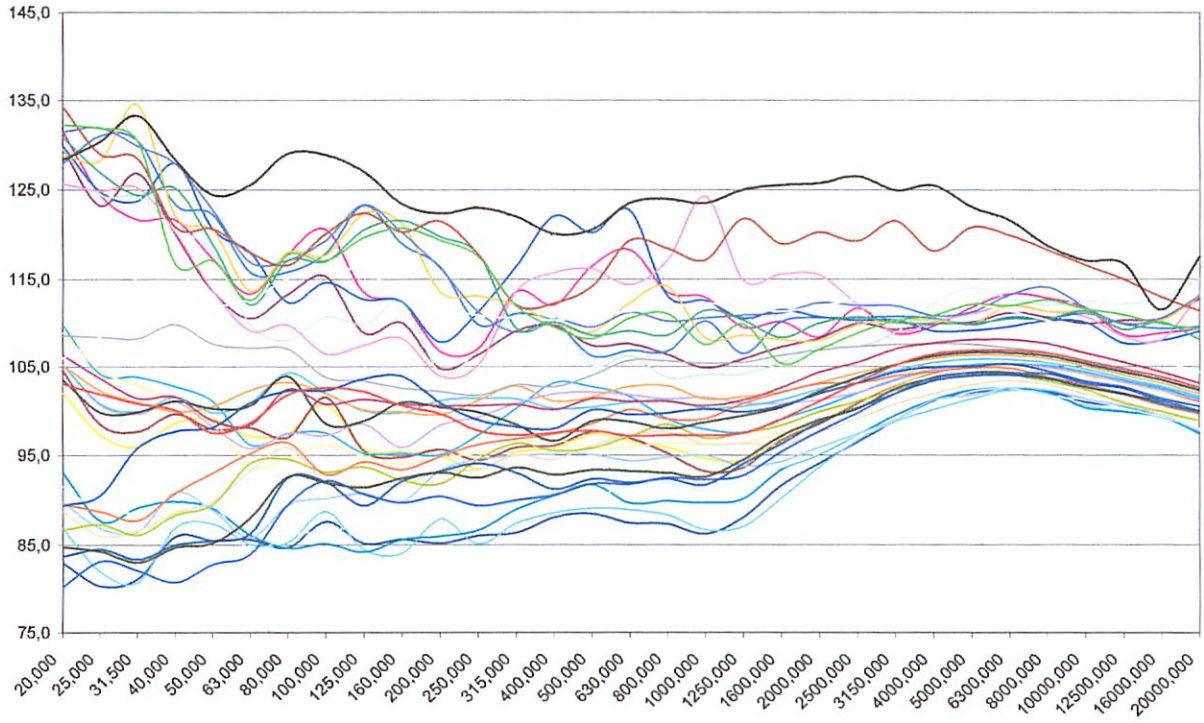

165,0
155,0
145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

K18_9

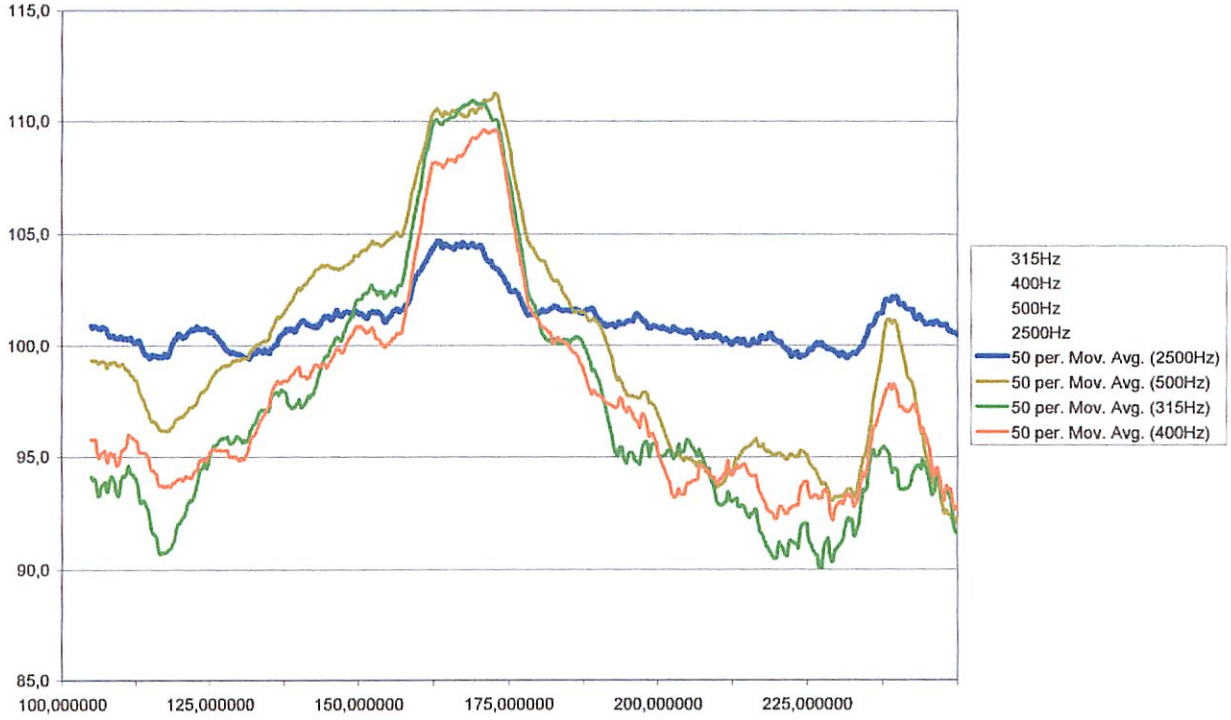

K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time


K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
1799,900000
1899,900000
1999,900000
2099,900000
2199,900000
2299,900000
2399,900000
2499,900000
2599,900000
2699,900000
2799,900000
2899,900000
2999,900000
3099,900000
3199,900000
3299,900000
3399,900000
3499,900000
3599,900000
time

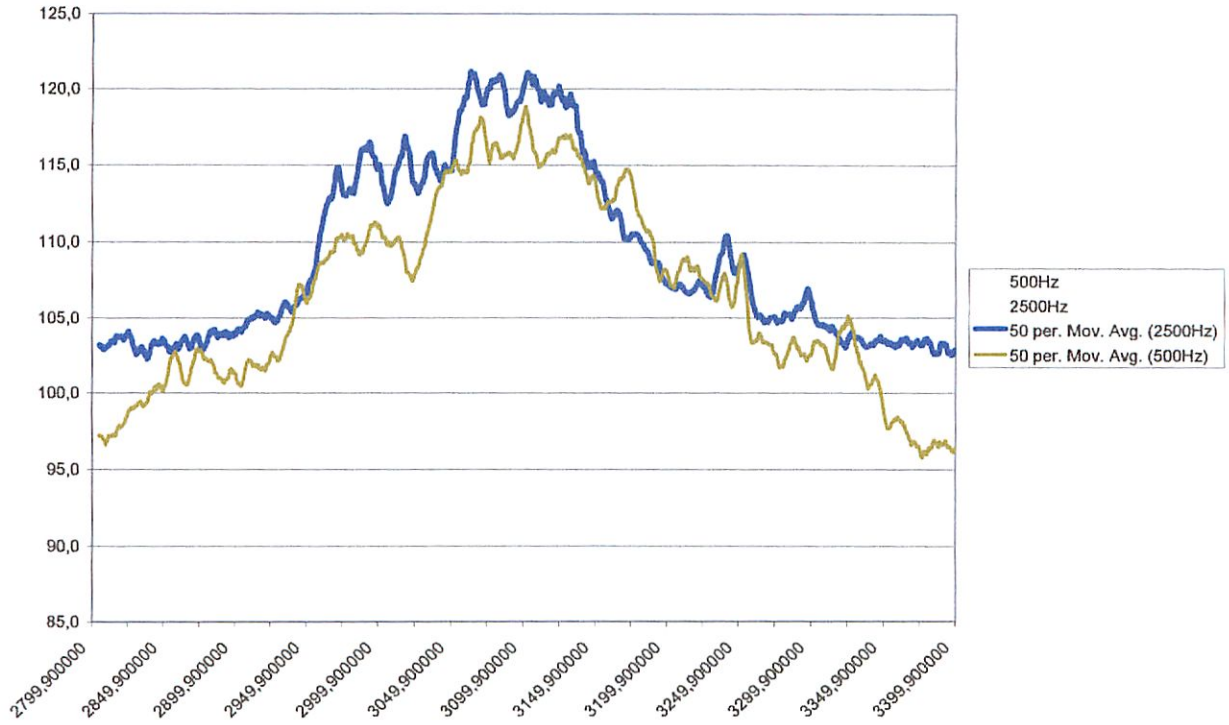

Level over Frq
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
dB re 1uPa
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency
MIN
MAX
AVG


145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000

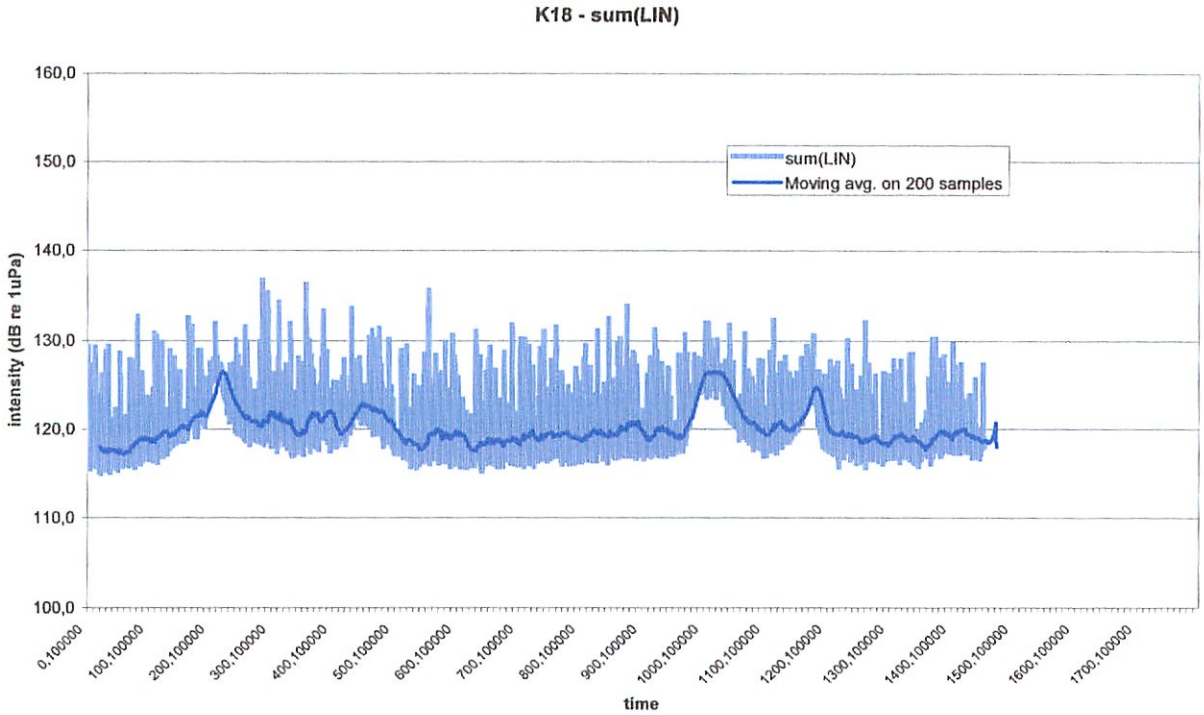
The following graph (taken from k18-9) shows a 25" period (x axis) and the behaviour of four frequencies (315Hz, 400Hz, 500Hz, and 2500Hz). It shows as major events, probably also due to acoustic propagation issues, influence different spectrum parts.

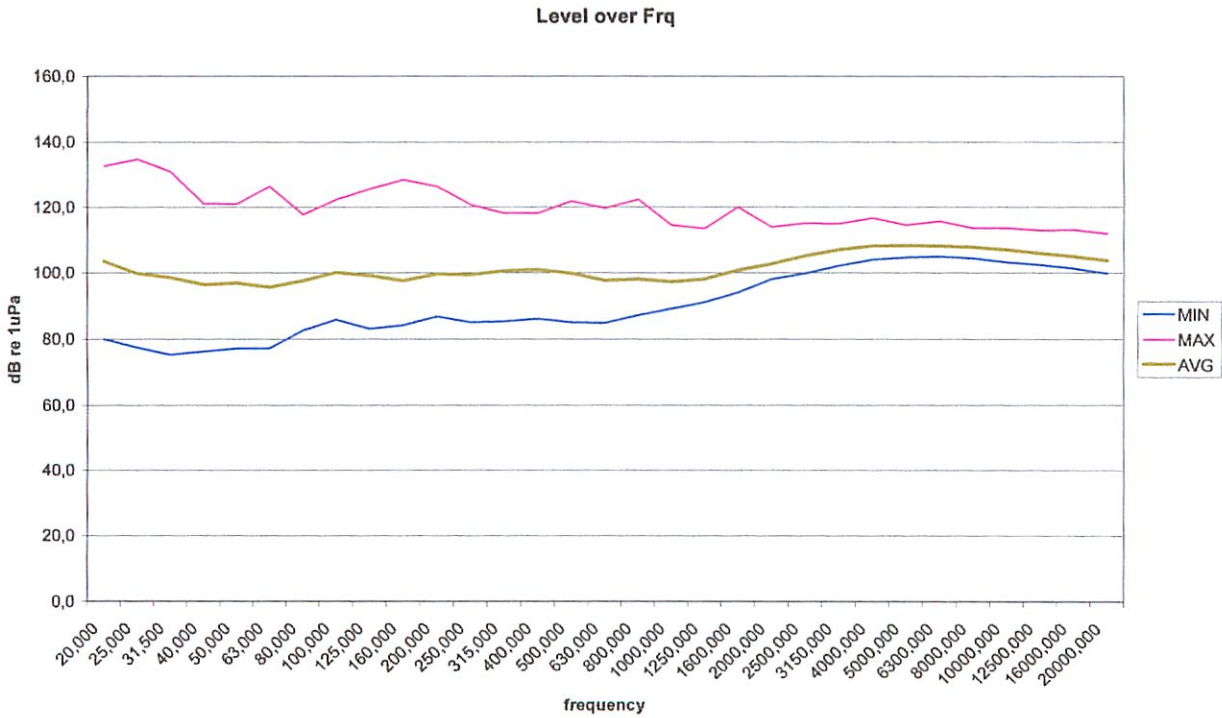


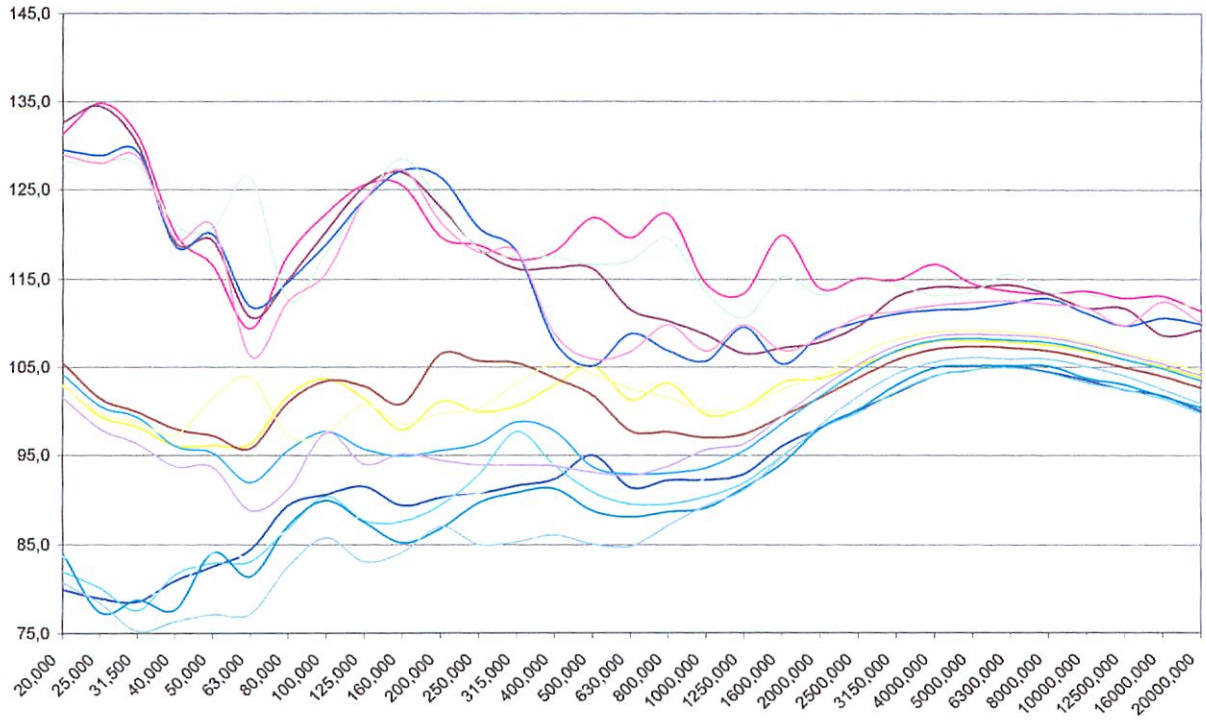
The following graph (taken from k18-5) shows a 60" period (x axis) and the behaviour of two frequencies that move accordingly to a fast, non impulsive, wideband event.


125,0
120,0
115,0
110,0
105,0
100,0
95,0
90,0
85,0
2799,900000
2849,900000
2899,900000
2949,900000
2999,900000
3049,900000
3099,900000
3149,900000
3199,900000
3249,900000
3299,900000
3349,900000
3399,900000
500Hz
2500Hz
50 per. Mov. Avg. (2500Hz)
50 per. Mov. Avg. (500Hz)

K18_10


K18 - sum(LIN)
sum(LIN)
Moving avg. on 200 samples
intensity (dB re 1uPa)
160,0
150,0
140,0
130,0
120,0
110,0
100,0
0,100000
100,100000
200,100000
300,100000
400,100000
500,100000
600,100000
700,100000
800,100000
900,100000
1000,100000
1100,100000
1200,100000
1300,100000
1400,100000
1500,100000
1600,100000
1700,100000
time


Level over Frq
dB re 1uPa
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
MIN
MAX
AVG
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000
frequency


145,0
135,0
125,0
115,0
105,0
95,0
85,0
75,0
20,000
25,000
31,500
40,000
50,000
63,000
80,000
100,000
125,000
160,000
200,000
250,000
315,000
400,000
500,000
630,000
800,000
1000,000
1250,000
1600,000
2000,000
2500,000
3150,000
4000,000
5000,000
6300,000
8000,000
10000,000
12500,000
16000,000
20000,000