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TNO report

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Measurements of underwater background noise Maasvlakte 2

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Summary

A new harbour and industry area ‘Maasvlakte 2’ (MV2) will be built as an expansion of the Port of Rotterdam. One of the licence conditions for Maasvlakte 2 is the investigation of the underwater sound produced during its construction [1]. In order to perform such an investigation of underwater acoustics three measurement campaigns were proposed [2].The first of these campaigns is the measurement of underwater acoustic background noise.

The proposed measurements of background noise (see also [3]) were performed between September 8 and 15, 2008 in the absence of MV2 construction activities.

From the measured data sound pressure levels (SPLs) for 1/3-octave bands in the frequency range between 20 Hz and 80 kHz have been determined.

Typical 1/3-octave sound pressure levels determined at 100 Hz, 1 kHz, and 10 kHz are 114±6, 105±6, and 90±6 dB re 1 μPa^2, respectively (the corresponding average spectrum levels are 100±6, 82±6, and 57±6 dB re 1 μPa^2/ Hz, respectively).

High frequency noise measurements (above 40 kHz) were dominated by non-acoustic effects that were most likely caused by electric systems.

For frequencies below 40 kHz the measured SPLs were found to depend on the varying shipping conditions. Significant effects of shipping conditions were observed in the frequency range from 20 Hz up to 40 kHz. These effects were most strongly present for frequencies between 50 Hz and 10 kHz, and decreased in magnitude with frequency, above a frequency of about 5 kHz.

Correlations of the SPLs with wind speed have been examined. Both positive and negative correlations were observed depending on the shipping conditions. Strong positive correlations with wind speed were observed for high frequencies.

These observations indicate that above about 10 kHz, in the case of not too heavy shipping conditions, wind-generated noise, e.g. caused by the breaking of waves, may contribute significantly to the measured background noise.

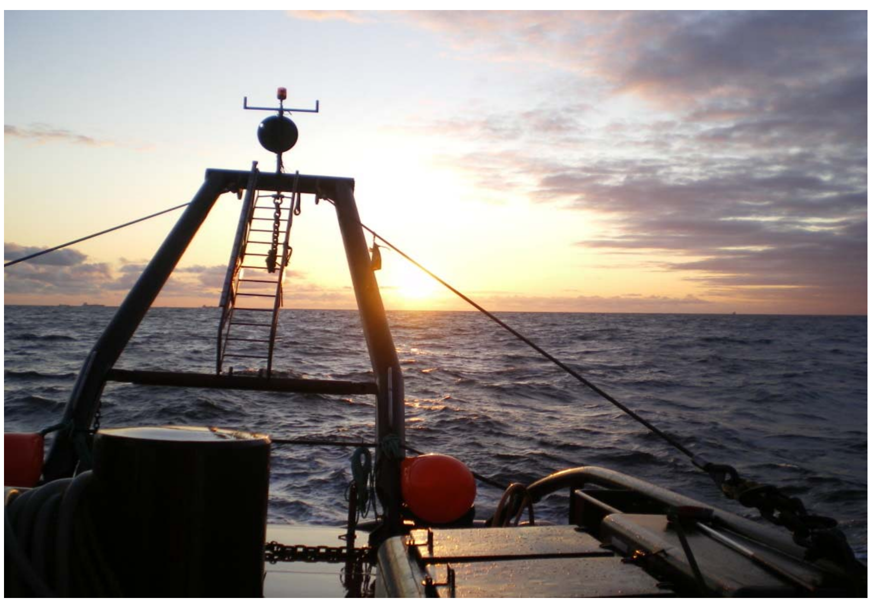

Figure 1.1 View of the North Sea from the measurement ship ‘Mon Desir’ located in the vicinity of the Maasvlakte 2 area.

Contents

Abbreviations

ADC	Analogue-Digital Converter
AIS	Automatic Identification System
KNMI	Koninklijk Nederlands Meteorologisch Instituut
MER	Milieueffectrapport
MMSI	Maritime Mobile Service Identity
MV2	Maasvlakte 2
RF	Radio Frequency
SPL	Sound Pressure Level
UPS	Uninterrupted Power Supply

1 Introduction

The Port of Rotterdam is expanding to meet the growing demand to accommodate large cargo vessels. A new harbour and industry area ‘Maasvlakte 2’ (MV2) will be built. The ‘Milieueffectrapport Aanleg Maasvlakte 2’ (MER) provides a preliminary environmental impact assessment of the underwater sound produced during the construction of MV2 [1]. One of the licence conditions for Maasvlakte 2 is the actual investigation of the underwater sound produced during its construction. The main reason for such an investigation is to enable biologists to assess the effect of the underwater sound on sea animals, in particular harbour seals and harbour porpoises. Specific activities to be investigated are the dredging, transport, and deposition of sand. As described in the report ‘Measurement plan underwater sound Maasvlakte 2’ [2] the investigation of underwater acoustics is to be performed in three measurement campaigns. The first of the three campaigns is the measurement of background noise, which should take place during a period of one week in the absence of MV2 construction activities. The objective of these measurements is to determine the amount of background noise for 1/3-octave frequency bands (or smaller) in the frequency range between 20 Hz and 80 kHz and to investigate the statistics of these data.
Future measurements in the presence of MV2 construction activities can then be compared with the background noise measurements.
The measurements were carried out between September 8 and 15, 2008, according to [3].The recorded data were analysed afterwards. The present report describes these measurements and the results of the data analysis. The underwater noise levels are known to depend on environmental conditions, such as shipping, and weather conditions. For this reason it was investigated to what extent variations of the measured levels are related to some of these conditions that are generally considered to be relevant in this respect: the shipping conditions and the wind speed.

2 Definitions

2.1 Sound pressure level

The sound pressure level (SPL) is a measure of the average squared acoustic pressure defined by

$$SPL(T) \equiv 10\log_{10}\left[\frac{1}{T}\int_0^T p^2(t)dt\right], \qquad \text{Equation 2-1}$$

where T is the duration of considered time interval and p is the acoustic pressure in units of µPa (1 µPa is taken as the reference pressure). The SPL is expressed here in units of dB re 1 µPa^2.
The SPL can be obtained in the frequency domain by performing a Fourier transform of the pressure. Considering again a time interval of duration T the Fourier amplitude for a frequency $f_n = n/T$, with $n \in 0,1,2,...$, is given by

$$q(f_n, T) = \frac{2}{T}\int_0^T p(t)\exp[-in2\pi t/T]\,dt\,. \qquad \text{Equation 2-2}$$

For the sequence of all amplitudes for frequencies within a band with minimum frequency $f_{\min}$ and maximum frequency $f_{\max}$ the SPL is given by

$$SPL(f_{\min}, f_{max}, T) = 10\log_{10}\left[\frac{1}{2}\sum_j |\, q_j(T)\,|^2\right], \qquad \text{Equation 2-3}$$

where the index j labels the Fourier amplitudes for frequencies between $f_{\min}$ and $f_{\max}$.

2.2 1/3-Octave bands

There are two ANSI and ISO approved approaches to determine the exact centre frequencies for 1/3-octave bands. Both approaches use a centre-band frequency of 1000 Hz as a basis. In the first approach (the so-called base-ten approach) the ratios of centre-band frequencies for adjacent bands equal $10^{\pm 1/10}$. In the other approach (the so-called base-two approach) the ratios of centre-band frequencies equal $2^{\pm 1/3}$. The lower and upper edge-band frequencies are obtained by multiplying the centre-band frequencies by $2^{-1/6}$ and $2^{1/6}$, respectively. The differences between the centre-band frequencies of both approaches are maximally in the order of 1% in the considered frequency range between 20 Hz and 80 kHz. In the present analysis the base-two approach is used to determine the 1/3-octave bands. In practice the frequency bands are often indicated by using nominal rather than exact centre-band frequencies.

3 Experimental setup

During a period of one week underwater acoustic background noise was measured at approximately the proposed location [3]: X = 563,000 m, Y = 5,758,000 m (projection ED50, Zone UTM 31U).This location is within the area that is indicated in Figure 3.1 by the letter Z. The choice for this location was motivated by the conditions specified in the measurement plan [2]: ‘Z should be located within a range of 5 km from the sand borrow and reclamation areas, at a site where measurements are allowed’.

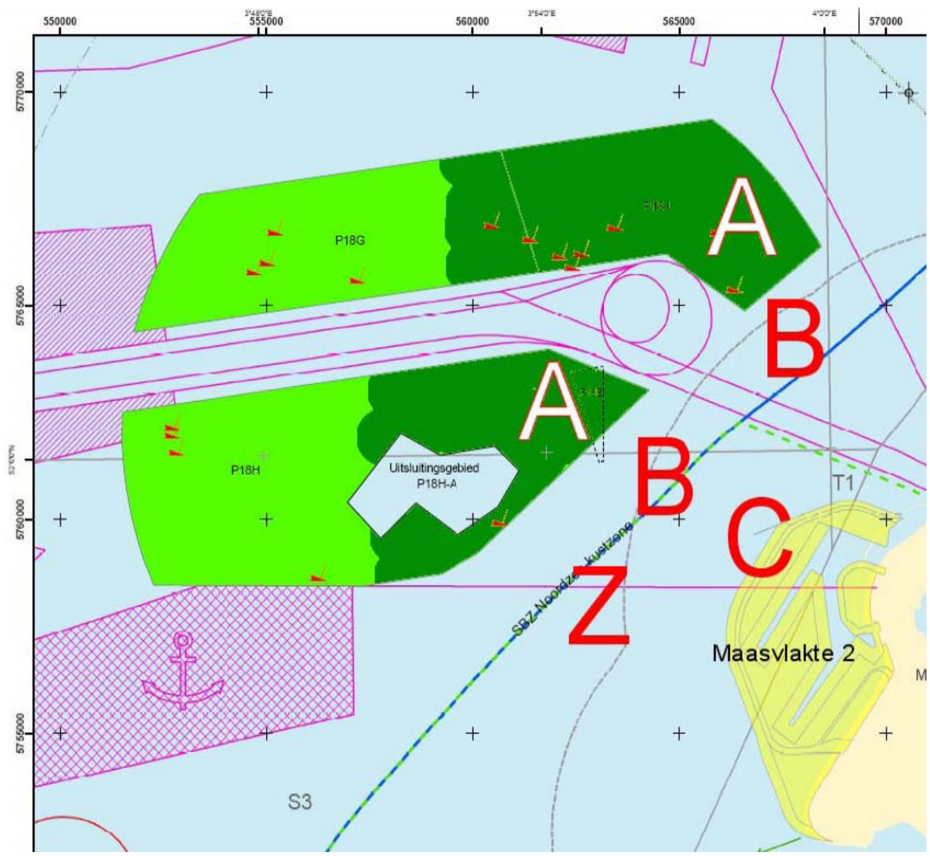

Figure 3.1 Area map with Maasvlakte 2 and the dredging areas (green). The big letters indicate the areas for source level measurements of A) the dredging; B) the transport and C) the dumping of sand. Z denotes the area for the noise background measurements [2].

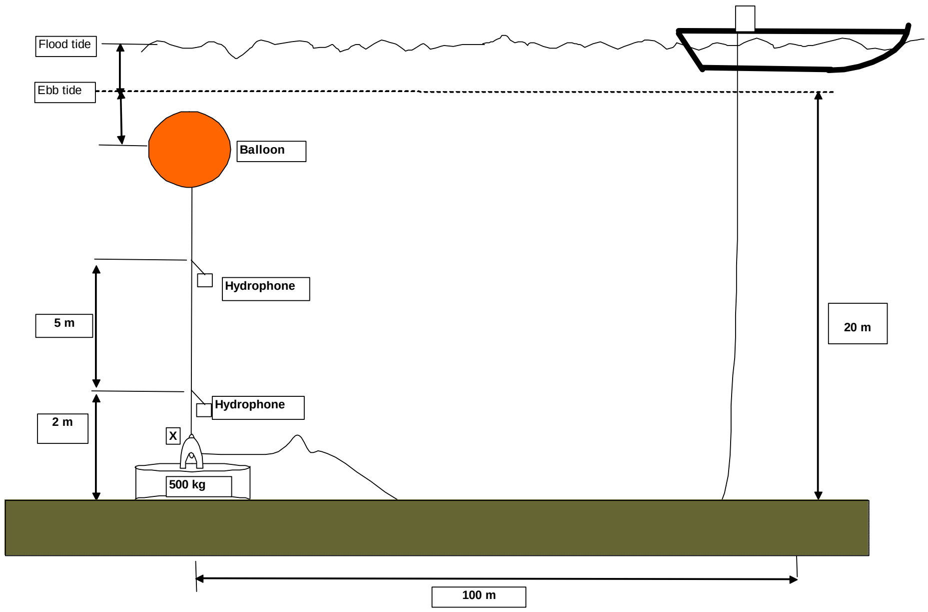

Figure 3.2 Schematic side view of the measurement setup. Two hydrophones were placed at about 7 m and 2 m above the sea bottom. The dept of the water layer varied with the tide.

A schematic view of the measurement setup can be found in Figure 3.2. Sound was recorded by using two hydrophones. One of the hydrophones was placed at about 2 m height from the sea bottom. This choice was motivated by the fact that seals and porpoises spend most of the time near the bottom when foraging [2]. In order to also perform a measurement at an alternative depth, the other hydrophone was placed at a height of about 7 m from the sea bottom. The upper hydrophone also functioned as a back-up of the lower one. The hydrophones were attached to a cable that was kept in position by using a 500 kg weight on the sea bottom and a balloon with upward force. The output signals of the hydrophones were transferred to the measurement platform by using two 150 m long cables. The measurement platform was the ship 'Mon Desir' (see Figure 3.4). The ship was anchored at a distance of approximately 80-100 m from the hydrophones in order to reduce possible sound contributions from the ship. The ship itself was kept as silent as possible during the measurement campaign.

3.1 Signal conditioning and data acquisition

Both the lower hydrophone (CH1) and the upper hydrophone (CH2) contain a preamplifier/buffer for optimal signal transport over 150 m of cable. The output of each hydrophone was conditioned by using an amplifier, a high-pass filter, and low-pass filters. The resulting signal was offered to a data-acquisition system, which performed the conversion of the analogue signals to 16-bit digital data, and the storage of these data. The signal conditioning and data acquisition chain is illustrated by the diagram in Figure 3.3.

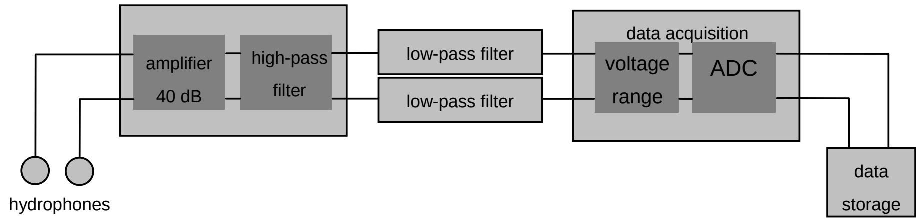

Figure 3.3 Flow diagram for the signal conditioning and data acquisition chain.

The applied amplifier and filter settings are specified in Table 3.1. The data-acquisition system was programmed so as to take data for an interval of six seconds during each measured minute (i.e., with a duty cycle of 10 %) with a sample frequency of 303 kHz. The settings of the low-pass filters were chosen such that signals with frequencies above halve the sampling frequency were strongly suppressed. As a result, effects from aliasing were strongly suppressed as well.
The raw data recorded during each 6 s interval were stored on a hard disk in binary format. For each of these binary files a log file was stored containing information on the date and time of the measurement, the used sample frequency, and the voltage range settings of the ADC (analogue-digital converter).

Table 3.1 Specification of the applied amplifier and filter settings.

Amplifier		
Gain	40 dB	
High-pass filter		
Cut-off frequency	22.4 Hz (at -3 dB)	
Low frequency attenuation slope	18 dB / octave	
Low-pass filter		
	CH1	CH2
Cut-off frequency	90 kHz (at -6 dB)	90 kHz (at -3 dB)
High frequency attenuation slope	96 dB / octave	24 dB / octave

3.2 Power supply

In order to provide power to the electronic equipment an aggregate was used.
Two aggregates were available on the measurement ship. Apart from the ship aggregate an additional vibration isolated aggregate was available. The aggregate that was determined to be the most silent was used as power supply whereas the other was used as a spare. A UPS (Uninterrupted Power Supply) system, i.e. battery backup, was used in combination with the aggregate in order to protect the electronics against unexpected power disruptions.

3.3 Online monitoring of data quality

An automated script performed online analyses of the data recorded for both channels. These so-called ‘quick analyses’ resulted in plots of time-series of the conditioned voltages and the corresponding power spectral densities, which were updated on screen and stored to files every minute in order to enable the measurement crew to directly monitor the quality of the recorded data.

3.4 Monitoring of environmental conditions

The environmental conditions in and around the measurement area were documented by the measurement crew in an acoustic logbook (see Appendix B). Potentially important events, such as close ships passing by, rainstorms, etc. were noted. Moreover, notes were made of the wind speed, the temperature of the sea and the air. In addition more detailed weather information for the measurement period was provided by the KNMI (Koninklijk Nederlands Meteorologisch Instituut) so that possible effects from weather conditions could be investigated (see section 4.4).
Measurements of the sound-speed profile for varying depths were performed and the resulting data were stored and included in the logbook.
An AIS (Automatic Identification System) receiver was used in order to have an overview of ships in the vicinity of the measurements. The AIS log-files were stored so that possible effects from shipping could be investigated when analysing the recorded data (see section 4.3).

Figure 3.4 Image of the measurement ship ‘Mon Desir’.

4 Data analysis

As described in section 3, underwater acoustic background noise was registered by using two hydrophones. The two corresponding output signals (transferred in channels ‘CH1’ and ‘CH2’) were amplified and filtered and then converted to 16-bit data to be stored in binary files. This section describes the analysis of the recorded data.
Before the recorded data were analysed first a selection of these data was made (see section 4.1). From the selected data the sound pressure levels (SPLs) in 1/3-octave frequency bands between 20 Hz and 80 kHz were determined (see section 4.2).
The relation between the obtained sound pressure levels with environmental conditions was investigated. Since shipping and wind conditions are known to be relevant for the amount of underwater noise, representative information about these conditions was collected and the correlations of the measured noise with these environmental conditions were considered in the data analysis.
In order to investigate the effect from shipping first quantitative measures of the shipping conditions were established. These shipping measures are introduced and discussed in section 4.3. The wind speed is considered to be the most accessible parameter when investigating the effects from wind conditions. The available wind speed data are described in section 4.4. Effects from the measurement system itself were investigated as well. These are described in section 4.5.

4.1 Data selection

From the measurements (each recorded during 6 s per minute) a selection of was made to be used in the data analysis. The decisions about the exclusion of measurements from this selection were partly based on the data quality information stored per measurement by the online monitoring script. Recorded data for which the notes in the digital logbook indicated a suspicious data quality were excluded from the selection. In some cases data were recorded also when the ship ‘Spirit’ (transferring the measurement crew to the measurement ship) was approaching the measurement ship or manoeuvring in its vicinity. These data were excluded from the selection as well.

4.2 Determination of sound pressure levels in 1/3-octave bands

From the data recorded for CH1 and CH2 sound pressure levels (SPLs) in 1/3-octave bands were determined. The following steps were taken to convert the stored 16-bit data into SPLs for 1/3-octave bands:

- The 16-bit data were converted to time series of voltages by using the information on the set voltage range of the ADC and the sample frequency.
  The resulting time series for each measurement corresponds to a time interval of 6 seconds.
- A discrete Fourier-transform was applied to each of the time series of voltages covering 6 s, which resulted in the corresponding sequence of frequency components. In the Fourier-transform a time weighting was performed by using a Hann window.
- The frequency components of the voltages were converted to frequency components of the acoustic pressures registered by the hydrophones. This was done by accounting for the frequency dependent calibration of the hydrophones and the applied amplification factor.
- From the sequences of frequency components of the acoustic pressures the 1/3-octave sound pressure levels were determined by using Equation 2-3.

Each determined SPL value is based on a time interval of about 6 seconds (recorded per minute, i.e., with a duty cycle of 10 %). An overview of the obtained SPLs is presented in section 5.1.

4.3 Measures of shipping conditions

In order to investigate to what extent shipping has affected the measured background levels several measures for the shipping conditions were determined. Various shipping factors are likely to play a role:

- The number of ships in the vicinity of the measurement
- The distances between the ships and the location of the measurement
- The source level of each ship depending on, e.g., the propeller, the engine, or pumping activity.

The source level for each ship is unknown. However, information on the number of ships and the distances of these ships with respect to the measurement platform is available. The locations, speeds, and MMSI (Maritime Mobile Service Identity) identification numbers of ships registered by the AIS system at distinct time stamps were extracted from the AIS logs. From this information the positions and speeds for each ship as a function of time were determined by using interpolation methods. Then a selection (varying with time) was made of ‘moving ships’ (i.e., ships with a speed higher than 1 m/s). A sub-selection was made for ships outside the harbour.
By using the determined trajectories of selected ships the following measures of shipping were determined for each measured minute:

- The distance to the nearest ship (*ND*)
- Weighted sums N_n over the selected ships:

$$N_n = \Sigma_i \; r_i^{-n}, \quad \text{with } n = 0, 1, 2, 3, \qquad \text{Equation 4-1}$$

where i labels the selected ships, r_i is the distance of each ship with respect to the measurement platform and the corresponding weighting factors equal $(1/r_i)^n$. Which of these measures is most representative for the shipping noise depends on the propagation properties of the underwater sound. For instance, in the case of spherical spreading loss the spreading of the noise per ship is described as $10 \log_{10} (r_i^{-2})$, whereas in the case of cylindrical spreading loss the description of spreading contains a $10 \log_{10} (r_i^{-1})$ term.

In order to determine to what extent the determined SPLs are correlated with the shipping measures introduced above, the corresponding correlation coefficients have been determined.[1] Moreover, by imposing different requirements on the measure N_2, subsets of noise measurements were obtained, each representative for different shipping conditions. Each subset of measurements was analysed separately. The results of these analyses are presented and discussed in section 5.2.

[1] It is noted that these shipping measures take into account the number of ships and the distances from these ships with respect to the measurement location. However, ships with different source levels are treated in the same way. Therefore, when considering the relation between one of these measures and the SPL, the varying source level per ship is expected to result in a variation of the SPL also at a fixed value of that shipping measure.

4.4 Effects from wind

In order to investigate to what extent the factor wind has affected the measured background noise the correlations between the wind speed and the measured noise levels were determined. For this purpose weather information provided by the KNMI was used.
Two sets of wind-speed data in the vicinity of the noise measurements were available. One set was measured at the location 'Hoek van Holland', and the other set at the location 'Lichteiland Goerree'. Although the first location is nearer to the location of the noise measurements, it is situated on land, whereas the second location is on the open sea. For this reason the second location is considered to be more representative for the location of background noise measurements.
The provided wind-speed data represent the hourly averages of the wind speed in units of m/s rounded-off to whole numbers. The distributions of the wind speed for the full period of the noise measurements are displayed in Figure 4.1.
Since the available wind-speed values are averages over time intervals of one hour duration each, the values of the SPL and the shipping measure N_2 were averaged over the same time intervals, so that correlations between these averages could be investigated. For this purpose the wind-speed data measured at 'Lichteiland Goerree' have been used.
The coefficients representing the correlations between the average wind speed and the average SPLs were determined. This was done after imposing different requirements on the average value of the shipping measure N_2 in order to account for varying shipping conditions (the imposed requirements are $N_2^{av} < 0.15$ km^{-2}, $0.15 < N_2^{av} < 0.3$ km^{-2}, $0.3 < N_2^{av} < 0.35$ km^{-2}, and $N_2^{av} > 0.35$ km^{-2}, where N_2^{av} denotes the average value of N_2). The results obtained from this analysis are presented and discussed in section 5.3.

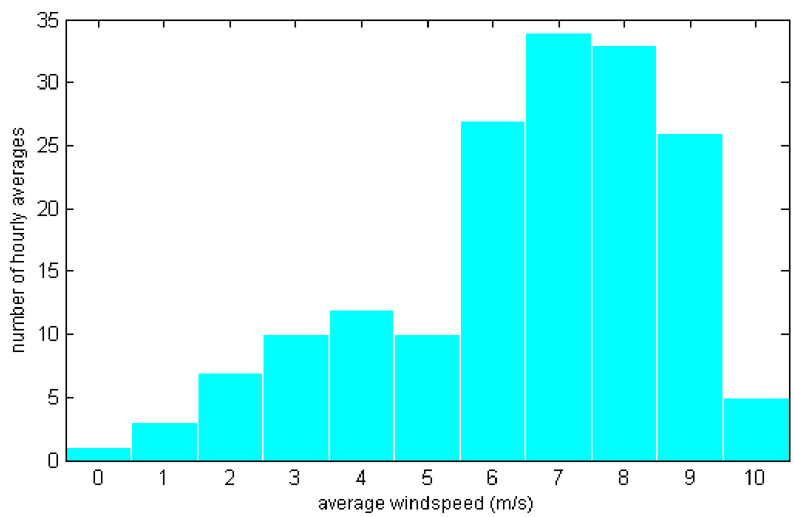

Figure 4.1 Histogram of the hourly averages of the wind speed measured at 'Lichteiland Goerree' during the time period of background noise measurements.

4.5 System effects

Effects of noise caused by the measurement system itself were investigated in several ways. One way was to evaluate the measured data and to look for changes of the measured level coinciding with changes of the conditions or settings of the experimental setup. Such changes in noise level are likely to be caused by the system itself. Moreover, signatures of system noise were looked for, such as relatively high levels in specific frequency intervals that had remarkably small variations in time.
For the measured noise levels in the highest three frequency bands (with nominal centre frequencies of 50, 63, or 80 kHz) the following effects have been observed:

- High measured levels in the highest three frequency bands that turned out to be related to a cable connector problem.
- Reoccurring high levels in the 80 kHz band.
- A constantly high noise level in the 63 kHz band.

These effects were observed for the measured data of both CH1 and CH2. However, the noise levels were in all cases higher for CH1 than for CH2. A more detailed description of these effects can be found in Appendix A.
The other way of investigating system noise was to analyse data taken under laboratory conditions by examining the signals prior to entering the recording system with a spectrum analyser. It was found that there was a noticeable 63 kHz component.
After switching off all equipment, this component was still seen on the spectrum analyzer. It is concluded that RF (Radio Frequency) interference in conjunction with low RF shielding and suppression could be the reason for noticing these components in the recorded data.
The system effects discussed above are most likely all caused by electronic system. During future measurements a better RF shielding and suppression for the electronic system can possibly reduce these system effects.

5 Results

5.1 Overview

An overview of the determined sound pressure levels in 1/3-octave levels for the total measurement period and both hydrophones is given by the spectrograms in Figure 5.1. As can be seen already in these overview plots similar trends are present in the results for both hydrophones. However, the results for CH1 (lower hydrophone) cover a longer measurement period. For CH2 (upper hydrophone) the measurements had to be ended earlier as a result of a failure of its signal cable due to the weather conditions (see Appendix B). As discussed in section 4.5 system effects are present dominating the obtained noise levels in the highest frequency bands for both CH1 and CH2.
These effects are clearly visible in Figure 5.1. In the following only the results for CH1 are discussed excluding these highest frequency bands.

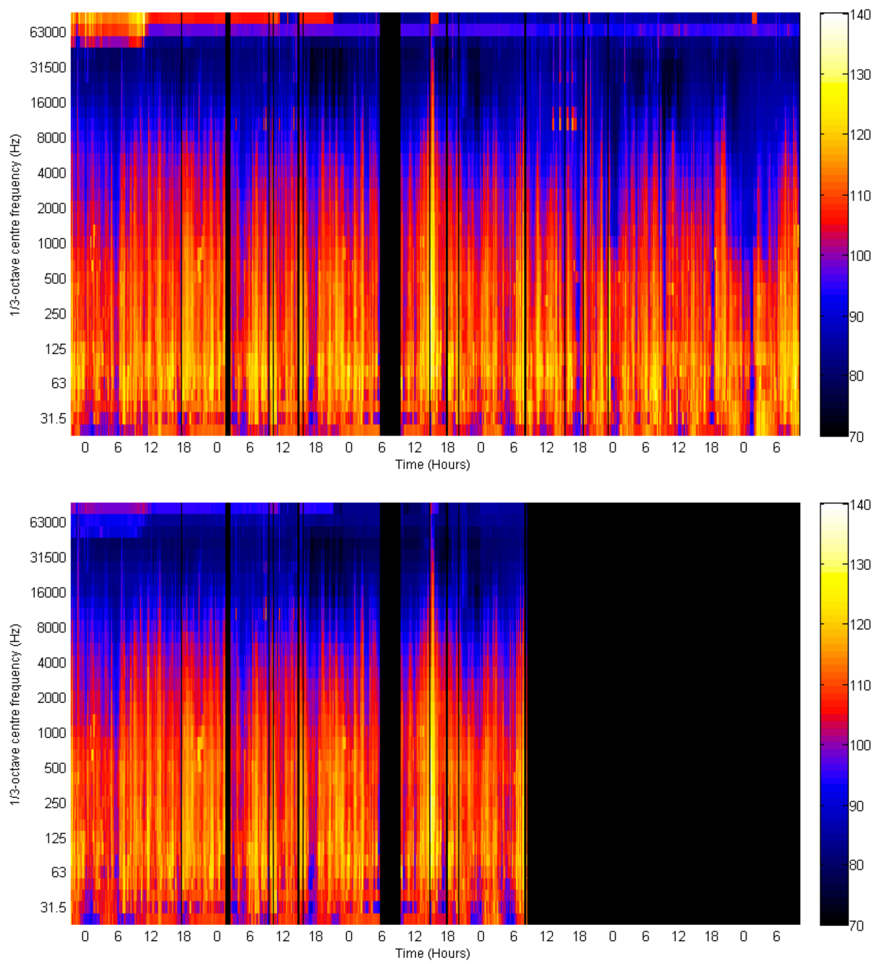

Figure 5.1 Overview of the sound pressure levels [dB re 1 μPa^2] in 1/3-octave bands versus time, determined for hydrophone channels CH1 (upper plot) and CH2 (lower plot).

The determined SPLs for CH1 are plotted against the centre-band frequencies in Figure 5.2. The results for all individual measurements are plotted in light grey.
Per 1/3-octave band the difference between the minimum and the maximum value of the SPL is up to about 50 dB large. In the same figure the corresponding percentiles P_5, P_{16}, P_{50}, P_{84}, and P_{95} are drawn. Each percentile indicates the percentage of measurements for which the SPL has a lower value than the percentile: 5%, 16%, 50%, 84%, and 95%, respectively. From the percentiles P_5 and P_{95} it follows that for a subset containing 90% of the measurements the difference between maximum and minimum SPL is maximally about 20 dB, whereas the small remaining set of only 10 % of the measurements is responsible for the larger variations. The SPLs were averaged per 1/3-octave band in two different ways. One way was to determine the mean squared pressure for the complete set of measurements and then the corresponding SPL.
The other way was to determine the mean of the SPLs that were determined first for all measurements separately. The key difference between both approaches is that the former approach uses the arithmetic mean of the mean square pressures per measurement, whereas in the latter approach uses the geometric mean of the mean square pressures per measurement, i.e., the arithmetic mean of their logarithms.
The mean values determined in both ways are displayed in Figure 5.2.
In the case of normally distributed SPL measurements the percentile P_{50} has to coincide with the mean SPL, which is indicated in Figure 5.2 by the green solid line. As can be seen in this figure the mean SPL agrees well with P_{50} for all 1/3-octave bands.
Furthermore, in the case of normally distributed SPL measurements the level at one standard deviation below or above the mean coincides with the percentiles P_{16} or P_{84}, respectively (this implies that for 68% of the measurements the SPL would be within one standard deviation from the mean value). As can be seen in Figure 5.2 for the 1/3-octave levels with centre frequencies up to about 10 kHz the percentiles P_{16} and P_{84} agree fairly well with the levels at one standard deviation from the mean (green dotted lines). The deviations observed for higher frequencies indicate that above about 10 kHz the SPL is not normally distributed.
Table 5.1 lists the mean values and standard deviations of the SPL in 1/3-octave bands. The corresponding spectrum levels are listed in this table as well.

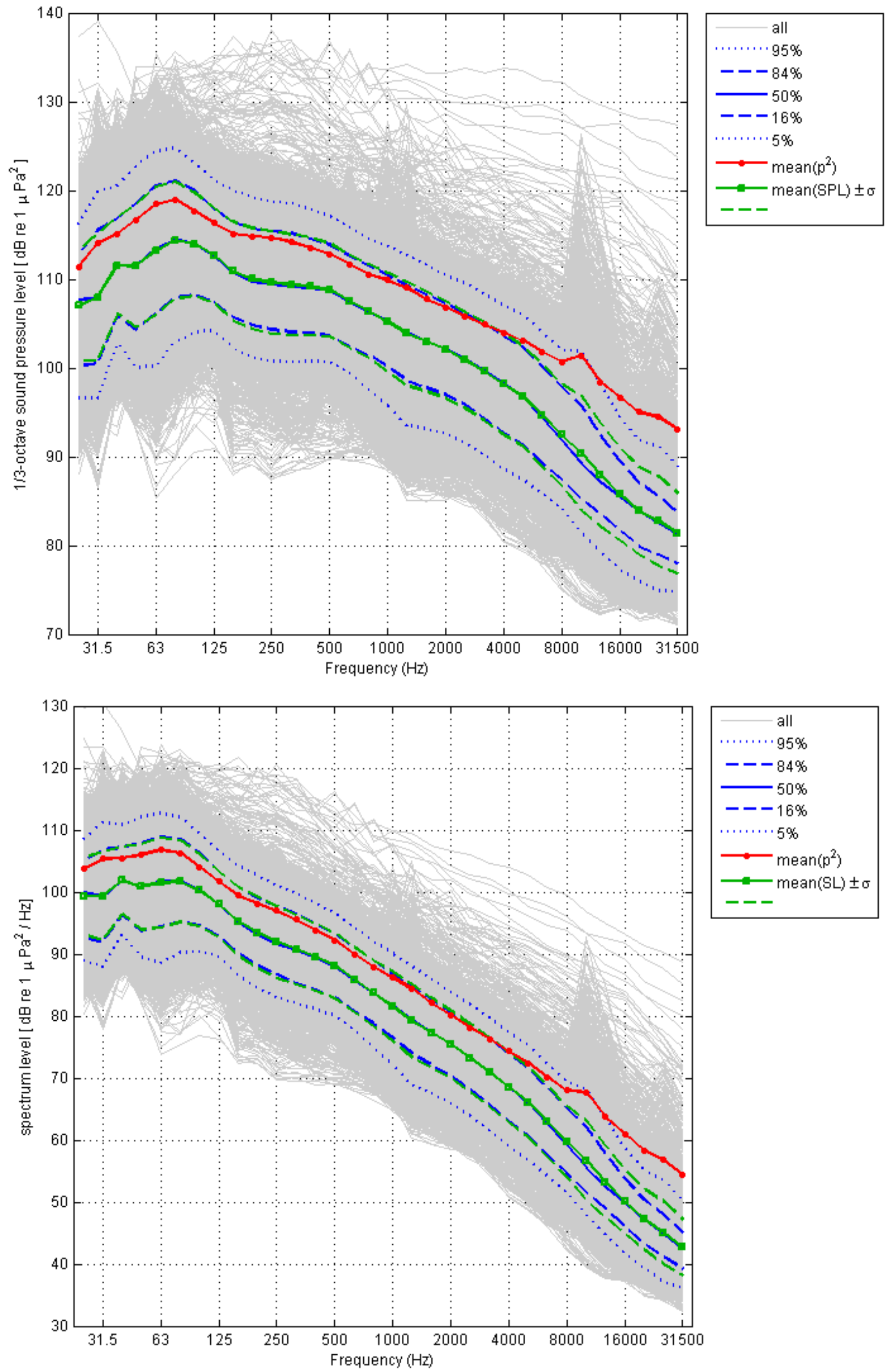

Figure 5.2 Sound pressure levels in 1/3-octave bands for CH1 (upper panel) and the corresponding spectrum levels averaged over each band (lower panel). The results of all individual measurements are represented by the light grey lines. The blue dotted, dashed, and solid lines represent the percentiles P_5, P_{16}, P_{50}, P_{84}, and P_{95}. Average values of the noise levels over all measurements are represented by the red line (average p^2) and the green solid line (average SPL). The levels at ±1 standard deviation from the latter average are represented by the green dashed lines.

Table 5.1 Sound pressure levels and mean spectrum levels determined in 1/3-octave frequency bands. The listed values represent the measured levels averaged over the frequency bands and the uncertainties represent the standard deviations of the levels in these bands.

Nominal centre-band frequency (Hz)	Sound pressure level (dB re 1 μPa^2)	Spectrum level (dB re 1 μPa^2 / Hz)
25	107 ± 6	100 ± 6
31.5	108 ± 7	99 ± 7
40	112 ± 5	102 ± 5
50	112 ± 7	101 ± 7
63	113 ± 7	102 ± 7
80	114 ± 7	102 ± 7
100	114 ± 6	100 ± 6
125	113 ± 5	98 ± 5
160	111 ± 6	95 ± 6
200	110 ± 6	94 ± 6
250	110 ± 6	92 ± 6
315	109 ± 6	91 ± 6
400	109 ± 5	90 ± 5
500	109 ± 5	88 ± 5
630	108 ± 5	86 ± 5
800	106 ± 5	84 ± 5
1000	105 ± 6	82 ± 6
1250	104 ± 6	79 ± 6
1600	103 ± 6	77 ± 6
2000	102 ± 5	75 ± 5
2500	101 ± 5	73 ± 5
3150	100 ± 6	71 ± 6
4000	98 ± 6	69 ± 6
5000	97 ± 6	66 ± 6
6300	95 ± 6	63 ± 6
8000	93 ± 6	60 ± 6
10000	90 ± 6	57 ± 6
12500	88 ± 6	53 ± 6
16000	86 ± 5	50 ± 5
20000	84 ± 5	47 ± 5
25000	83 ± 5	45 ± 5
31500	81 ± 5	43 ± 5

5.2 Effects of shipping conditions on the amount background noise

As described in section 4.3 several measures of shipping were determined: the distance *ND* to the nearest ship and the weighted sums N_0, N_1, N_2, and N_3 that are defined by equation 4.1.
Figure 5.3 shows the scatter plots of the measured sound pressure level versus these shipping measures. The scatter plots are shown for three distinct 1/3-octave bands with centre frequencies of 125 Hz, 2 kHz, and 32 kHz. The scatter plots of SPL versus N_2 are shown for more frequency bands in Figure 5.4. The plots in Figure 5.3 and Figure 5.4 suggest that the sound pressure level is correlated with the logarithms of the measures of shipping.
However, large differences of the SPL are also observed for fixed values of each of these shipping measures. For instance, for N_2 larger than 1 km^{-2} remarkably large differences of the SPL are observed, up to 50 dB. The large differences at fixed values of the shipping measure most likely illustrate the effect of variations of the source level per ship, which can be caused by ship manoeuvres and by the fact that different kinds of ships were passing by at short distances (below 1 km), for example: a cargo vessel, a pilot vessel, or a speed boat. As discussed in section 4.3 such variations in source level are not accounted for by the determined measures for shipping conditions.

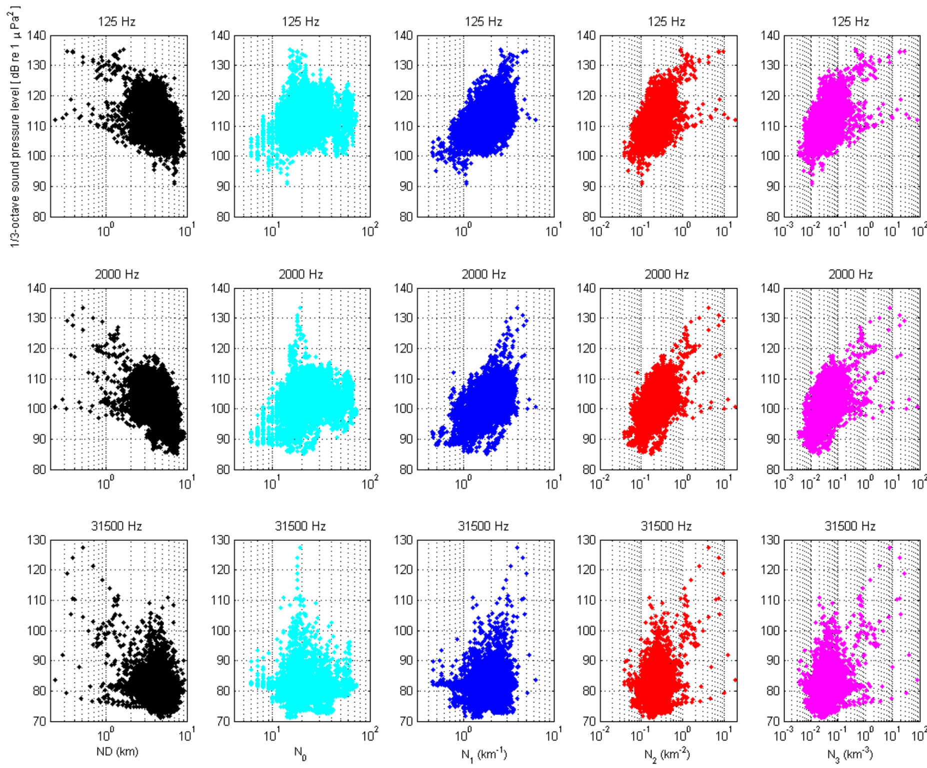

Figure 5.3 Scatter plots of the sound pressure level versus the shipping measures *ND*, N_0, N_1, N_2, and N_3 (from left to right, respectively). The scatter plots are displayed for the 1/3-octave bands with centre frequencies 125 Hz, 2 kHz, and 32 kHz (from up to down, respectively).

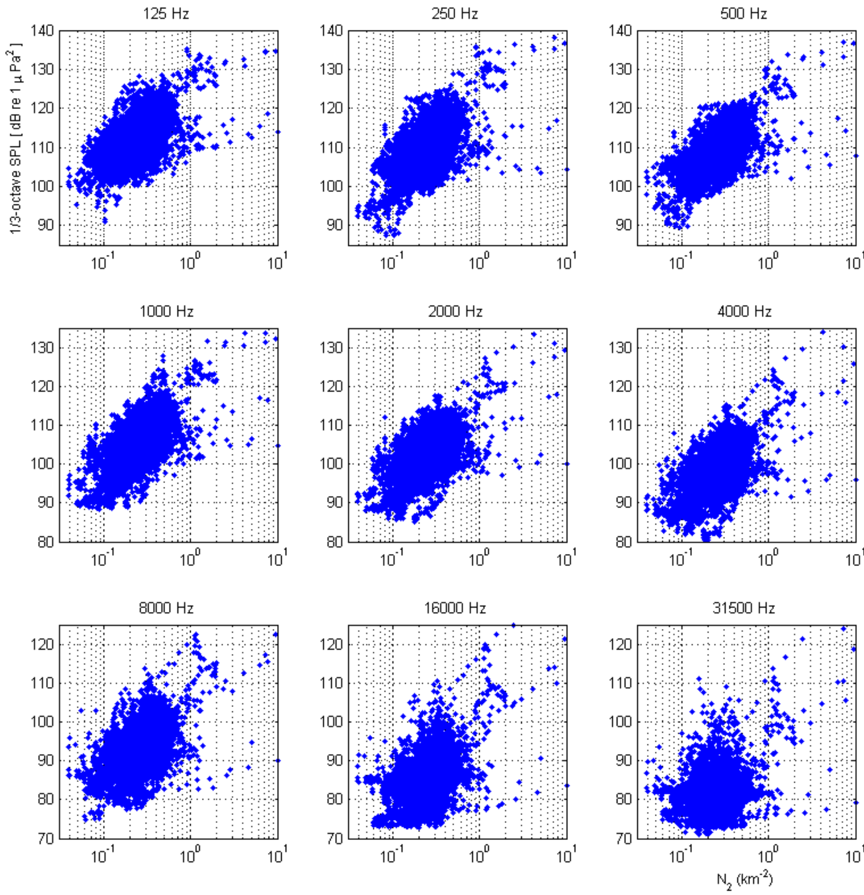

Figure 5.4 Scatter plots of the sound pressure level versus the shipping measure N_2. The various plots display the results for distinct 1/3-octave frequency bands.

The actual statistical correlations between the logarithms of these measures and the SPL have been determined for all 1/3-octave frequency bands. The results are displayed in Figure 5.5. As can be seen in this plot for all shipping measures the correlations coefficients are clearly positive, in particular in the frequency range from 50 Hz to 8 kHz. The corresponding p-values indicate that these non-zero correlations are statistically significant. The correlations tend to decrease in magnitude with frequency, above a frequency of about 5 kHz.

Subsets of noise measurements for different shipping conditions each have been obtained by imposing requirements on the value of $\log_{10}(N_2)$. These requirements have been chosen such that six subsets were obtained, each containing about 1200 measurements. In Figure 5.6 a histogram of $\log_{10}(N_2)$ is shown. The dashed vertical lines separate the obtained subsets in this plot.

The measured SPLs in 1/3-octave bands have been evaluated separately for these subsets. Figure 5.7 displays for each subset all measured SPLs and the results of a statistical analysis of this subset. The average SPLs of all subsets are displayed together in Figure 5.8. As expected, because of the observed correlations between the SPL and N_2, the averages of the SPL increase for increasing values of N_2.

The percentiles displayed in Figure 5.7 indicate to what extent the SPLs vary within each of these subsets. These variations may be partly caused by the variation of the source level of individual ships, which is not accounted for by the measures of shipping determined in the present analysis.

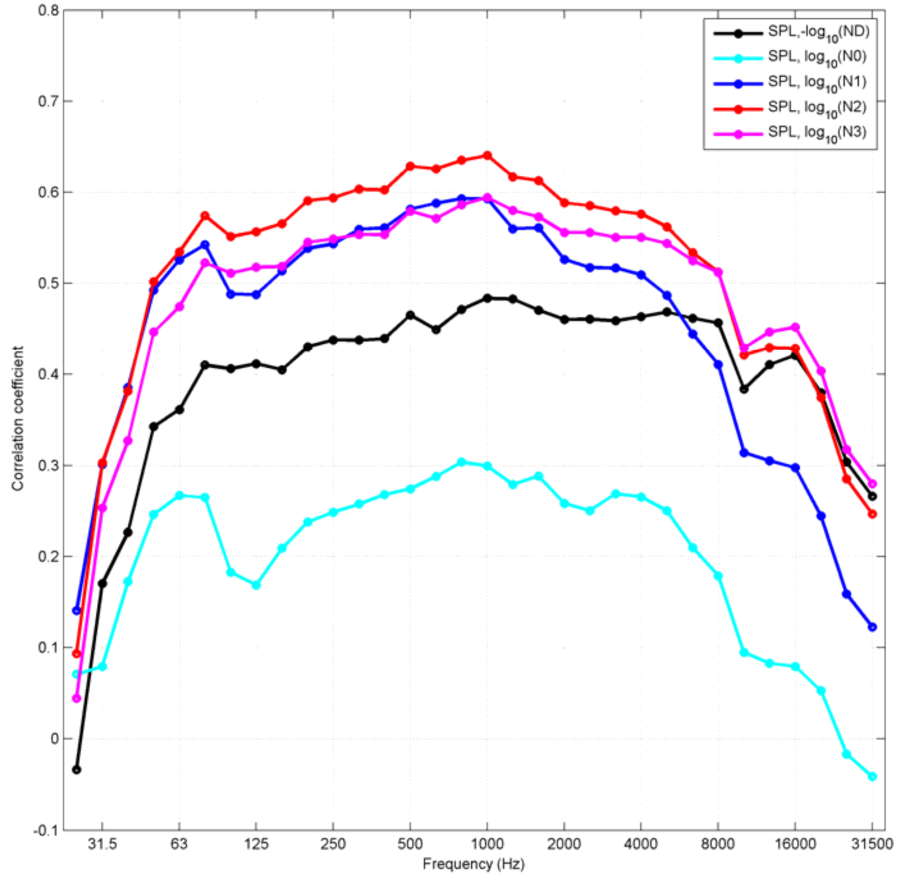

Figure 5.5 Correlation coefficients representing the correlations of the sound pressure level in various 1/3-octave frequency bands with the logarithms of the shipping measures ND^{-1}, N_1, N_2, and N_3.

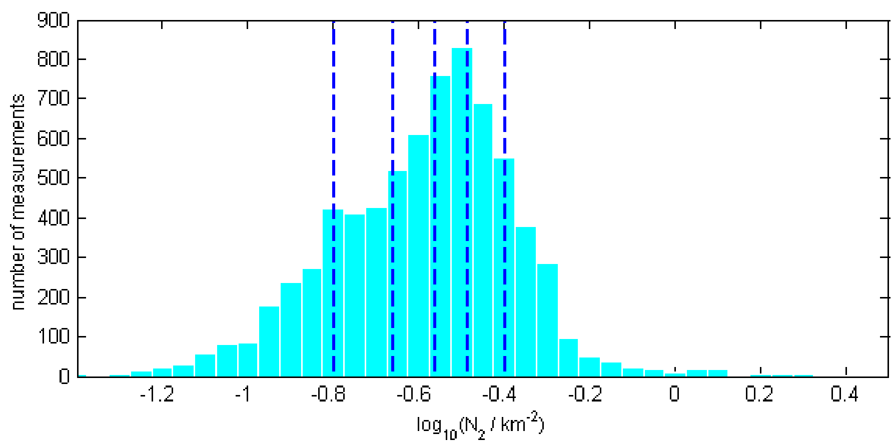

Figure 5.6 Histogram of $\log_{10}(N_2)$ values corresponding to the measurements of background noise. The dashed vertical lines separate distinct subsets each containing about 1200 measurements.

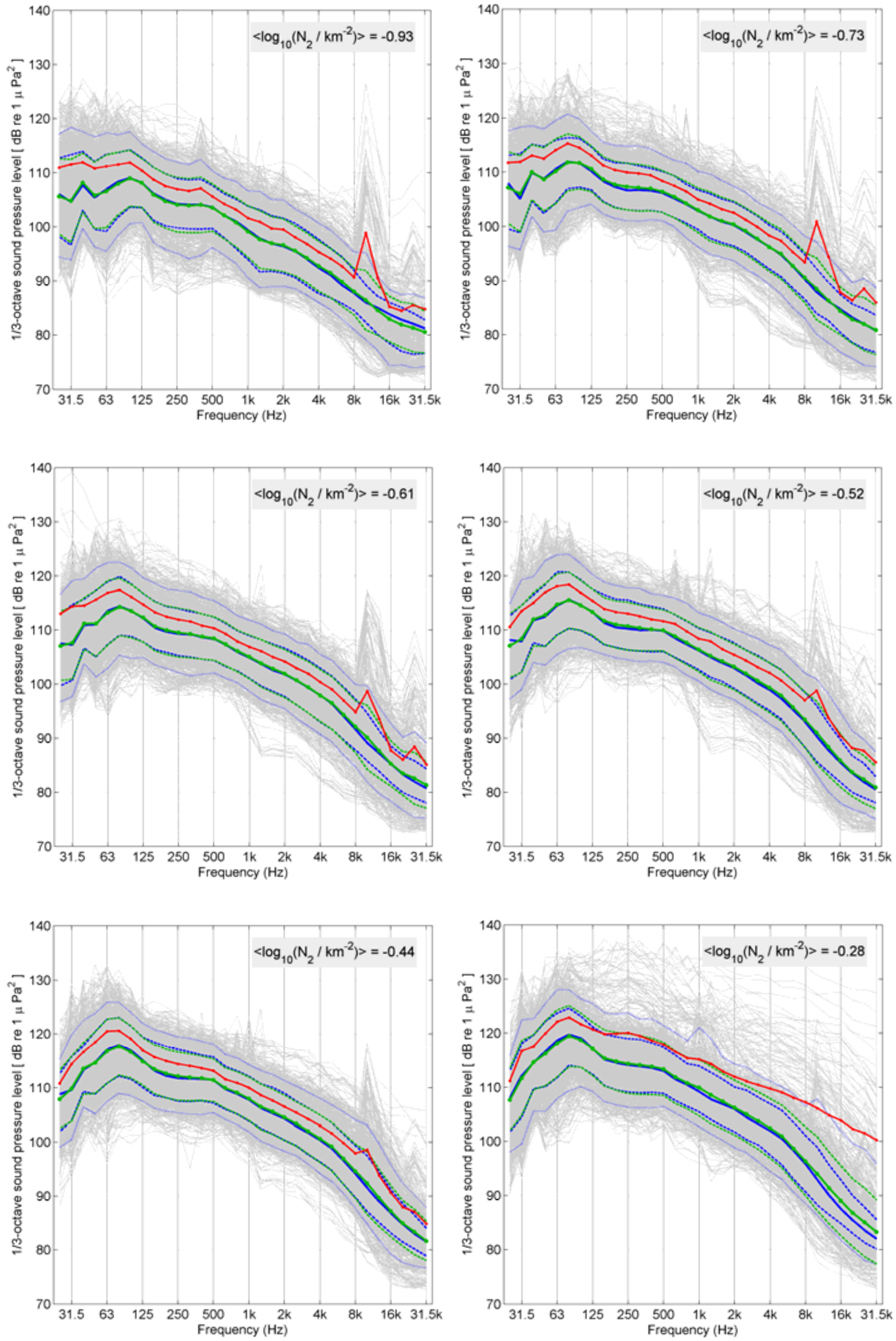

Figure 5.7 Sound pressure levels in 1/3-octave bands. The six panels display the results for distinct subsets that have been selected by imposing requirements on the value of $\log_{10}(N_2)$, which is a measure for shipping conditions. For each subset the average value of $\log_{10}(N_2)$ is indicated in the corresponding panel. The meaning of the various plotted lines in each panel is explained in the caption of Figure 5.2.

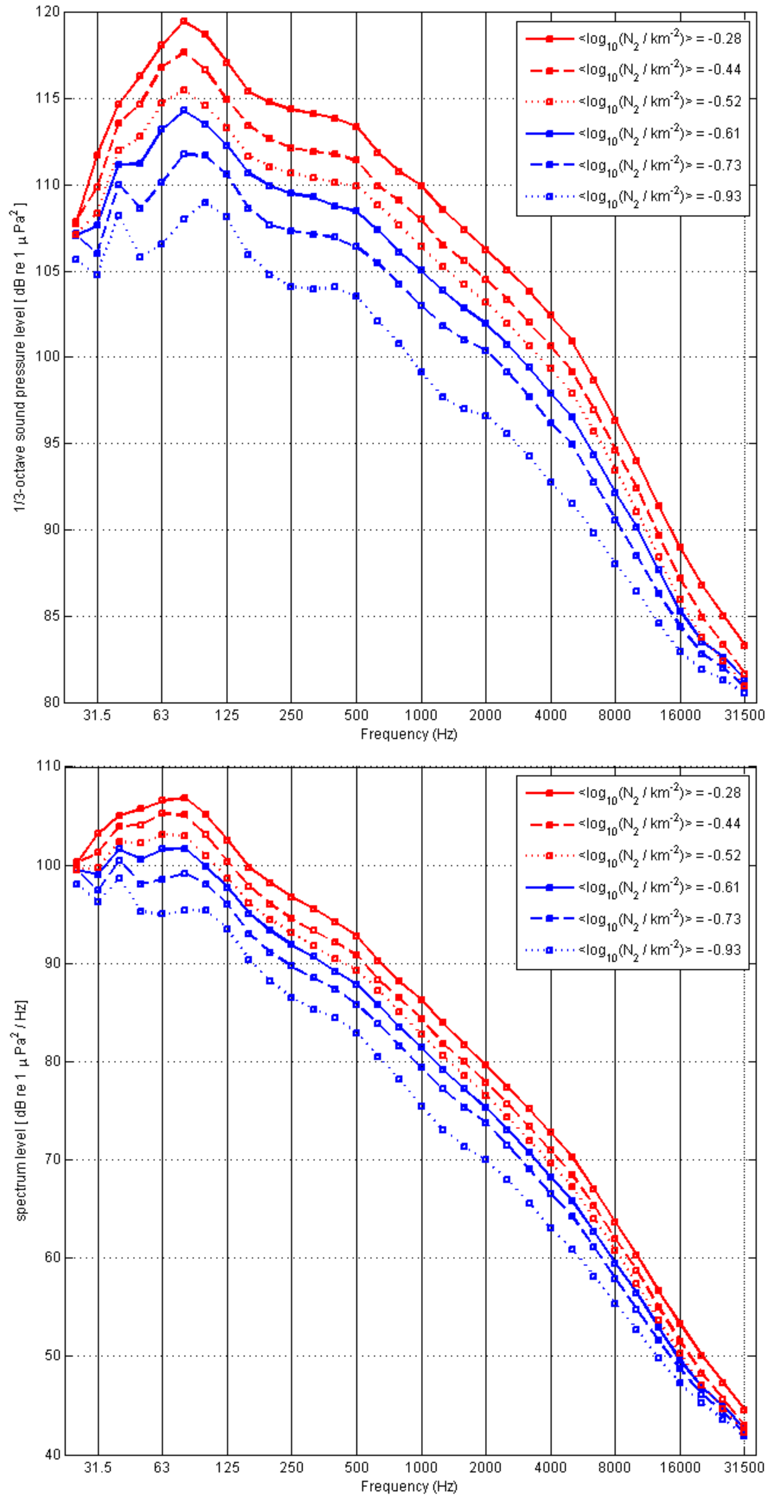

Figure 5.8 Average sound pressure levels in 1/3-octave bands (upper panel) and the corresponding average spectrum levels (lower panel). The six lines plotted in each panel represent the averages for distinct subsets, which have been selected by imposing requirements on the value of $\log_{10}(N_2)$ (an overview of the measured SPLs in these subsets are displayed in Figure 5.7). For each subset the average value of $\log_{10}(N_2)$ is indicated in the legend.

5.3 Correlations of background noise with wind speed

As discussed in section 4.4, the correlations between the hourly averages of the wind speed and the average SPLs were investigated.

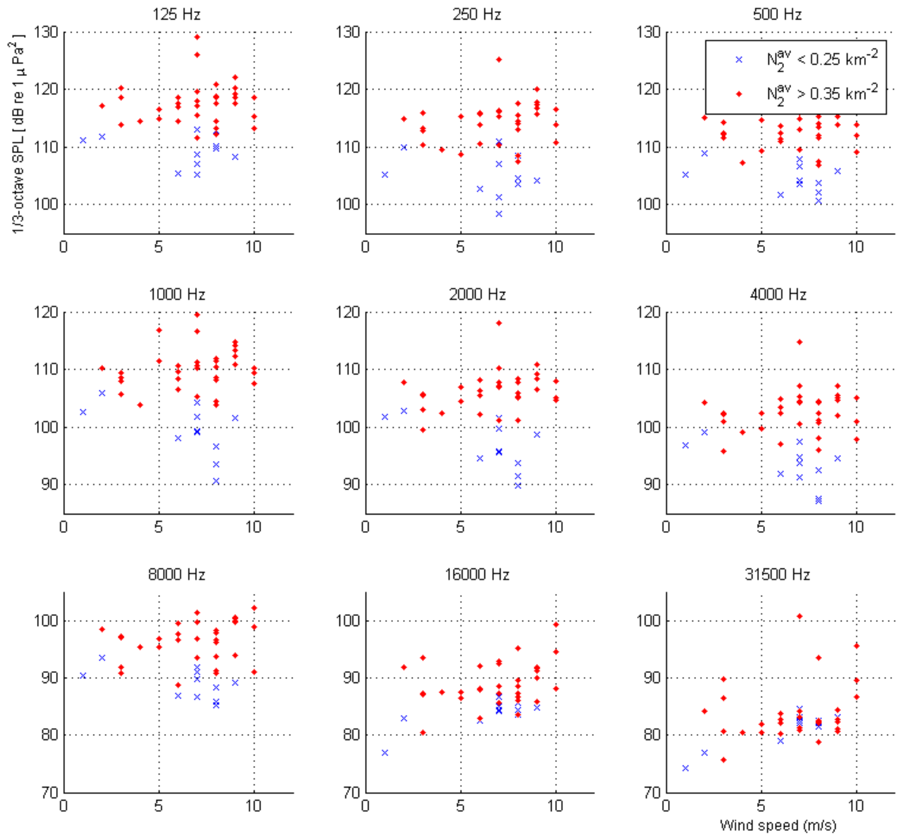

Figure 5.9 Scatter plots of the hourly averages of the sound pressure level versus those of the wind speed. The blue crosses indicate $N_2^{av} < 0.25$ km^{-2}, whereas the red circles indicate $N_2^{av} > 0.35$ km^{-2}.

Scatter plots of the mean values of the SPL versus the mean wind speed are shown in Figure 5.9 for different requirements on the average value of N_2 (from the results discussed in section 5.2 it already followed that the SPL is clearly correlated with N_2, which represents shipping conditions). The coefficients representing the correlation between the average SPL and the average wind speed were determined after imposing varying requirements on the average value of N_2 (denoted as N_2^{av}).

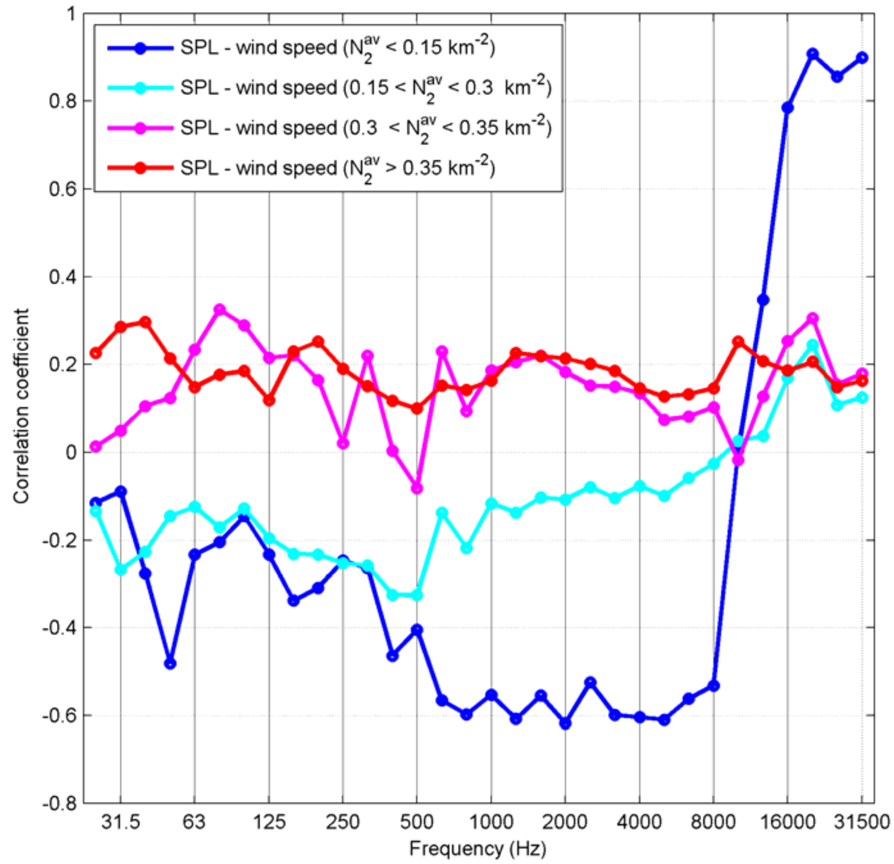

Figure 5.10 Coefficients representing the correlation between the hourly averages of the wind speed and those of the sound pressure levels in various 1/3-octave bands. The correlation coefficients for distinct requirements on the average value of the shipping measure N_2 are displayed.

The determined correlation coefficients are plotted in Figure 5.10 for the various 1/3-octave bands. As can be seen in this figure, positive and negative correlations are present. The corresponding p-values indicate that in both cases non-zero correlations are statistically significant. The correlation coefficients determined for relatively heavy shipping conditions ($0.3 < N_2^{av} < 0.35$ km^{-2}, or $N_2^{av} > 0.35$ km^{-2}), are mostly positive and between 0.1 and 0.3 over the full displayed frequency range. For less heavy shipping conditions ($N_2^{av} < 0.15$ km^{-2}, or $0.15 < N_2^{av} < 0.3$ km^{-2}), however, the correlation coefficients are negative for the frequency bands between 20 Hz and 8 kHz and turn into positive for frequency bands above about10 kHz. This behaviour is most strongly present for the requirement $N_2^{av} < 0.15$ km^{-2}.
There are several possible explanations for the behaviour of the correlation coefficients observed in Figure 5.10. An explanation for the positive correlations in the case of heavy shipping conditions may be that the amount of sound produced by ships increases with increasing wind speed. Since effects from shipping have been observed for frequencies up to about 40 kHz this may explain why the correlations were found to be positive over a comparably wide frequency range.
An explanation for the negative correlation coefficients for less heavy shipping conditions (i.e., lower values of N_2^{av}) may be that the attenuation of sound produced by ships increases with increasing wind speed, for instance, due to an increase of surface scattering. Although this effect can only be present in the presence of ships, this effect is expected to be stronger for ships that are further way, and is therefore expected to play a role for small enough values of N_2^{av}.

The effect of wind-speed dependent noise produced, for instance, by the wind generated breaking of waves is expected to lead to a positive correlation coefficient.
However, such effects are only noticeable if the background noise is not dominated by other kinds of background, such as ship-produced noise. As discussed in section 5.2 the observed shipping noise decreases with increasing frequency above a frequency of about 5 kHz, and moreover decreases with decreasing values of N_2. Therefore, the positive correlation coefficients observed for higher frequencies and lower values of N_2^{av} most likely indicate that under these conditions the wind-generated noise contributes significantly to the measured background noise.

5.4 Summary

From the measured data sound pressure levels (SPLs) for 1/3-octave bands in the frequency range between 20 Hz and 80 kHz have been determined. Typical 1/3-octave sound pressure levels determined at 100 Hz, 1 kHz, and 10 kHz are 114±6, 105±6, and 90±6 dB re 1 μPa^2, respectively (see Table 5.1). The corresponding average spectrum levels are 100±6, 82±6, and 57±6 dB re 1 μPa^2 / Hz, respectively. For each 1/3-octave band the difference between the minimum and the maximum value of the SPL was found to be up to about 50 dB. However, for a subset of 90 % of the measurements this difference was found to be up to about 20 dB.
High-frequency noise measurements (above 40 kHz) are dominated by non-acoustic effects that have most likely been caused by electric systems (see section 4.5).
For frequencies below 40 kHz the measured SPLs depend on the varying shipping conditions represented by the measures *ND*, N_0, N_1, N_2, or N_3. Significant effects of shipping conditions were observed in a broad frequency range, from 20 Hz up to 40 kHz. These effects were found to be most strongly present for frequencies between 50 Hz to 10 kHz, and to decrease in magnitude with frequency, above a frequency of about 5 kHz.
Correlations of the SPLs with wind speed were observed. Both positive and negative correlations were observed depending on the shipping conditions. Strong positive correlations with wind speed were observed for high frequencies. These observations indicate that above about 10 kHz, in the case of not too heavy shipping conditions, wind-generated noise, e.g. caused by the breaking of waves, may contribute significantly to the measured background noise.

6 Conclusions

6.1 Analysis results

- Typical 1/3-octave sound pressure levels at 100 Hz, 1 kHz, and 10 kHz were found to be 114±6, 105±6, and 90±6 dB re 1 μPa^2, respectively (the corresponding average spectrum levels are 100±6, 82±6, and 57±6 dB re 1 μPa^2 / Hz, respectively).
- Shipping noise dominates the acoustic background noise in practically the whole measured frequency range up to 40 kHz. However, for low shipping densities, as measured by N_2, the measured noise may be dominated by wind generated noise for frequencies above about 10 kHz.
- When future results of noise measurements in the presence of MV2 construction activities will be compared with the present background noise measurements, shipping conditions can be accounted for by imposing requirements on the determined shipping measures, e.g. on the measure N_2 (see Figure 5.8).
- High frequency noise measurements (above 40 kHz) are dominated by non-acoustic effects that have most likely been caused by electric systems.

6.2 Lessons learned

- AIS (Automatic Identification System) logs provide essential information for the quantitative investigation of shipping noise.
- During future measurements an improved radio frequency shielding and suppression of the used electric and electronic equipment may reduce noise caused by high-power electric systems.
- The use of a meteo station enabling measurements of wind speed and other weather parameters from a location closer to the measurements, e.g. from the measurement ship, should be considered for future background noise measurements.
- The use of cables to transfer the hydrophone outputs to the measurement ship constitutes a risk factor in particular in the case of rough weather conditions. The possibility of using an autonomous measurement station for the recording of underwater acoustics should be considered.

7 Acknowledgements

We would like to thank M. van Spellen, B. A. J. Quesson, and the crews of the ‘Mon Desir’ and the ‘Spirit’, who were involved in carrying out the measurements. Furthermore, we much appreciate the discussions concerning the data analysis with H. J. M. Heemskerk, C. A. F. de Jong, and P. A. van Walree.

8 References

[1] G. J. M. Meulepas, G. C. Duyckinck Dörner, and W. C. van der Lans, *‘Milieueffectrapport Aanleg Maasvlakte 2’*, 9P7008.A5/Milieukwaliteit/R005/GJM/Nijm.

[2] P. A. van Walree, M. A. Ainslie and W. H. M. Groen, *‘Measurement plan underwater sound Maasvlakte 2’*, Report TNO-DV 2008 C302.

[3] Offerte 96726, *‘Nulmeting onderwatergeluid Maasvlakte 2’*, August 12, 2008.

9 Signature

The Hague, May 2009

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Dr. J. Dreschler
Author

A System effects

The following kinds of system noise were found:

- Effects from a cable connector problem: from the beginning of the measurements, during a time period of about halve a day, data was recorded while noticeable differences between the voltages of CH1 and CH2 were present. After a period of about a halve day it was found that a cable connector was the cause of this. While using this cable connector high noise levels were registered in the frequency interval between 40 and 90 kHz. This was the case for both CH1 and CH2, but the noise level was clearly higher for CH1. In order to illustrate this effect the registered electrical power density as a function of the frequency is shown in Figure A.1 for both CH1 and CH2. After the repair of the cable connector (around 11:30h, September 9) the measured noise in both CH1 and CH2 had clearly decreased.

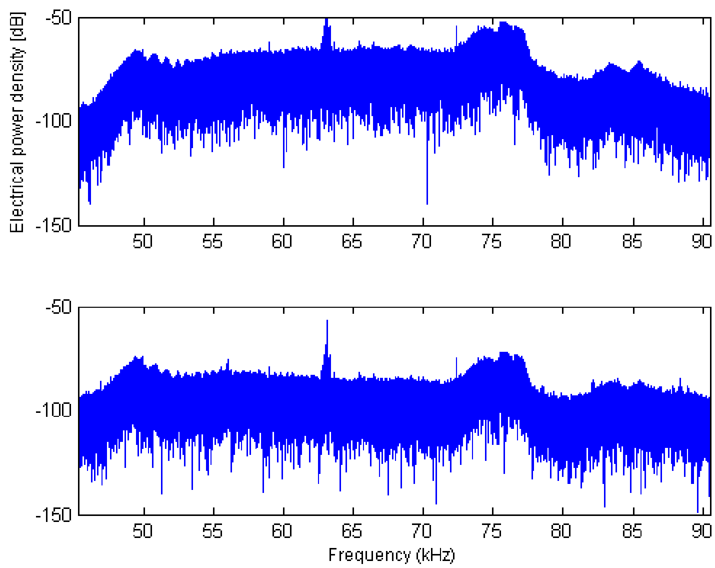

Figure A.1 Electrical power spectral density measured in the presence of a cable connector problem for CH1 (upper panel) and CH2 (lower panel). The plot covers the frequency range of the highest three 1/3-octave bands with nominal centre frequencies 50, 63, and 80 kHz.

- In the 1/3-octave band with a nominal centre frequency of 80 kHz a high noise level was present during distinct time intervals. The variations of the noise levels were small during these intervals. This effect was present for both CH1 and CH2 with a higher noise level for CH1 (see Figure A.2).

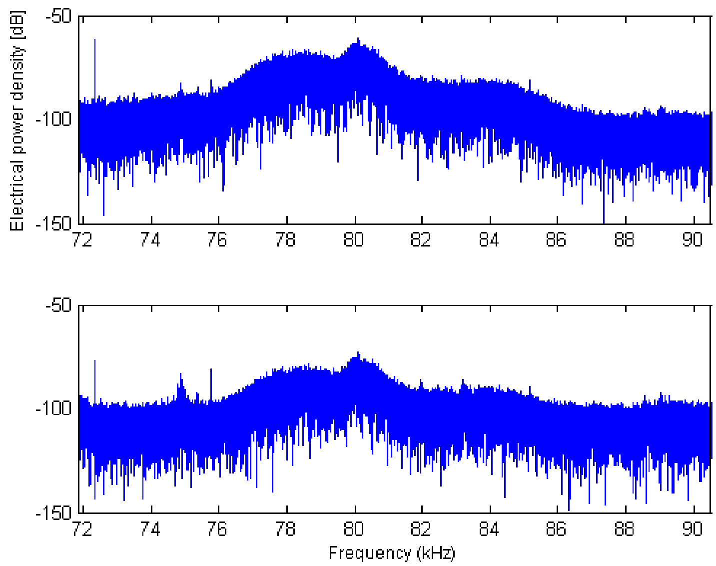

Figure A.2 Electrical power spectral density measured in the presence of a remarkably high measured level in the 1/3-octave band with a nominal centre frequency of 80 kHz for CH1 (upper panel) and CH2 (lower panel). The plots cover the full frequency range of this 1/3-octave band.

- In the 1/3-octave band with a nominal centre frequency of 63 kHz a high noise level was present during the full measurement period with remarkably small variations in time. This effect is most clearly visible for CH1, but also for CH2.
  After investigating the electrical power density in this frequency band it became clear that the higher noise levels were concentrated in the frequency interval between 62 and 65 kHz (see Figure A.3). In this frequency interval series of peaks of the electrical power density can be observed with a frequency spacing of 50 Hz (see Figure A.4). As this frequency spacing equals the AC frequency of the electronic power supply it is very likely that this effect is caused by the electronic systems itself.

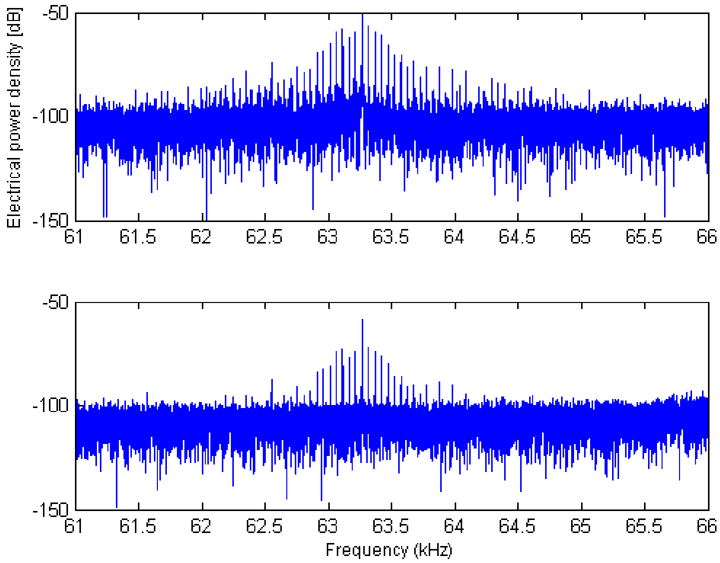

Figure A.3 Electrical power spectral density measured for CH1 (upper panel) and CH2 (lower panel). The plots cover the frequency range of the 1/3-octave band with a nominal centre frequency of 63 kHz.

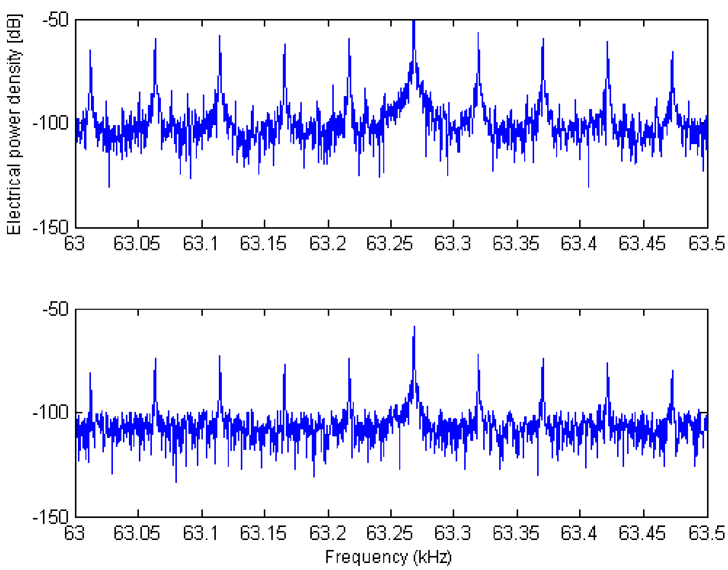

Figure A.4 Electrical power spectral density for CH1 (upper panel) and CH2 (lower panel) plotted for the frequency range between 63.0 kHz and 63.5 kHz. The plots zoom in on series of peaks having a frequency spacing of about 50 Hz.

B Logbook

B.1 Overview

Date	Start time	Stop time	Remarks
8 Sept 2008	21:20	24:00	Data recorded.
9 Sept 2008	00:00	12:45	Data recorded.
	12:50	17:15	Data recorded.
	17:15	17:30	Test performed comparing 3 generators.
	17:30	24:00	Data recorded.
10 Sept 2008	00:00	01:18	Data recorded.
	01:18	02:05	No data due to program crash.
	02:05	24:00	Data recorded.
11 Sept 2008	00:00	05:24	Data recorded.
	05:24	09:09	Data recorded.
	09:09	24:00	No data due to program crash.
12 Sept 2008	00:00	07:42	Data recorded.
	07:42	07:59	Loosening signal cables: no data recorded.
	07:59	21:11	Data recorded.
	10:00		Signal cable comes loose: signal CH2 (upper hydrophone) lost.
	21:11	21:21	No data due to program crash. Ship moves to new position.
	21:21	24:00	Data recorded.
13 Sept 2008	00:00	24:00	Data recorded.
14 Sept 2008	00:00	09:30	Data recorded.
	09:30	14:33	Hydrophone cable broken: cable repair.
	14:33	20:28	Data recorded.
	20:28		Array flows on sea surface. Measurement session ended.

B.2 Logboek Maasvlakte 2:

Tijden zijn genoteerd in lokale tijd.

Hydrofoon ‘LAAG’: B&K 8101 S/N 783889 aangesloten via 150 m B&K kabel op B&K Instrumentatieversterker, type 2610, TNO CI = 350 006 00.

Hydrofoon ‘HOOG’: B&K 8101 S/N 783882 aangesloten via 160 m B&K kabel op B&K Instrumentatieversterker, type 2610, TNO CI = 350 002 00.

De B&K hydrofoon instrumentatie versterkers (2x type 2610) bestaan elk uit:
Sectie 1: ‘Input Section Gain’ amplifier.
Sectie 2: 22.4 Hz Low pass Filter.
Sectie 3: ‘Output Section Gain’ amplifier.

Tenzij anders vermeld:
Sectie 1: ‘Input Section Gain‘ amplifier ingesteld op +40 dB.
Sectie 2: 22.4 Hz Low pass Filter.
Sectie 3: ‘Output Section Gain’ amplifier ingesteld op 0 dB.

De Gain van sectie 1 is als volgt vastgesteld:
Het signaal van Sectie 1 is via de achterzijde van de versterker naar buiten gevoerd door schakelaar “Filters Ext” op ‘On’ te zettten en dit signaal op de ingang van een scope aan te sluiten. Dit signaal moet altijd kleiner blijven dan max. 20 Vpp anders treedt clipping op. Dit is te bewerkstelligen door de gain van sectie 1 aan te passen, doch wel zo hoog mogelijk. Gelet is daarbij op de ‘swing’ van de laagfrequente DC-component in dit signaal (door toedoen van de golfbeweging op de hydrofoon).
Op de achterzijde (via ingang “from filter”) van de versterker wordt het signaal (op de ingang van de scope) ook weer de versterker binnen gevoerd.
Door Sectie 2 (22.4 Hz Low Pass Filter) wordt vervolgens de (langzaam fluctuerende) DC-component verwijderd.
Sectie 3 is gemakshalve op 0 dB gezet zodat deze sectie als niet aanwezig kan worden beschouwd (met eveneens een maximale output van 20 Vpp).

Voor het kanaal ‘hydrofoon hoog’ wordt de instelling van de instrumentatieversterker ook hetzelfde aangehouden als bij kanaal ‘hydrofoon laag’.

Na de instrumentatieversterker volgt het anti-aliasing filter (Rockland, ingesteld als Low-Pass Filter, Passband Gain = 0 dB).

Kanaal ‘hydrofoon laag’: Rockland filter (model 852) 2 secties in serie: per sectie 48 dB/octaaf, beide secties op fc = 90 kHz (dus -6 dB bij 90 kHz).

Kanaal ‘hydrofoon hoog’: Het Rockland filter (model 452) bestaat uit 2 identieke secties, per sectie een filterhelling van 24 dB/octaaf. Slechts de 2^{e} sectie gebruikt (1^{e} sectie bleek defect): 24 dB/octaaf, fc op 90 kHz (vergeten deze terug te zetten op 80 kHz, maar is voor de meting niet storend).

Maandag 1 september 2008 [week 36]:

- Opstelling opgebouwd en getest.
- Vertrokken naar zee, maar halverwege omgekeerd i.v.m. te grote golfhoogte.

Dinsdag 2 september 2008:

- Geen werkzaamheden verricht i.v.m. slechte weersvoorspellingen.

Woensdag 3 september 2008:

- Vertrokken naar zee, maar terug gekeerd i.v.m. te grote golfhoogte.

Donderdag 4 september 2008:

- Vertrokken naar zee, maar terug gekeerd i.v.m. te grote golfhoogte.

Vrijdag 5 september 2008:

- Vertrokken naar zee.
- Eerste poging is goed gegaan alleen wel kabel onderste hydrofoon beschadigd, namelijk: bij poging om gewicht te water te laten is een signaalkabel tussen bolder en gewicht gekomen.
- Reparatie uitgevoerd.
- 's Middags tijdens slechter weer 2e poging ondernomen, zee opgeruwd, toch geprobeerd, waardoor de kabels in de schroef terecht zijn gekomen. Gelukt alles uiteindelijk weer binnen te halen. 's Avonds naar het lab. gereden om alles te repareren.
- Reparatie uitgevoerd op TNO. Van 11:00 tot zaterdag 3:00 gewerkt.

Zaterdag 6 september 2008:

- Geen werkzaamheden.

Zondag 7 september 2008:

- 10:00 Naar ‘Mon Desir’ gereden. Poging ondernomen om 11:30 en op locatie geweest, maar besloten terug te gaan i.v.m. te grote golfhoogte.

Maandag 8 september 2008:

- 17:00 Vertrokken naar zee.
- 20:00 Meetopstelling in positie gebracht en getest.
- 20:55 Start generator test:
    - Bestandsnaam Prefix: zeegenerator1 ➔ generator ‘Mon Desir’ “aan”.
    - Bestandsnaam Prefix: zeegeneratoruit ➔ metingen afgebroken i.v.m. veel scheepvaart in de buurt (2 nmi).
    - Bestandsnaam Prefix: zeegeneratorborent ➔ hier ook scheepvaart op korte afstand.
    - Generator meting heeft nu dus geen zin.
- 21:30 AANVANG NULMETINGEN (Buiten is het inmiddels donker geworden).
- Windsterkte: 5 Bft.
- Rondom 22:15 – 22:30 Wim opgehaald door boot ‘Spirit’ => opgenomen in data!

Dinsdag 9 september 2008:

Mark aan boord.

- 07:30 Wind: ZZW, 3 Bft. Golfhoogte: 0,5 – 0,7 m. Luchttemperatuur: 16,8 ºC.
- 08:30 Zelfde bericht als 7:30.
- 09:35 Vissersboot op ca. 600 m Stuurboord, geen AIS.
- 10:30 Wind: ZZW, 3 Bft. Golfhoogte: 0,5 – 0,7 m. Luchttemperatuur: 19,4 ºC.
- 10:35 Relatief groot amplitude verschil op instr. amps (type 2610). (Achteraf bleek op te treden nadat Martijn de tussenkabel [haspel –amplifier] van kanaal 'hydrofoon laag' had verlegd.)
- 10:45 Kanaal 'hydrofoon laag' grotere amplitude.
- 10:55 Kanaal 'hydrofoon laag' uitgeschakeld.
- 11:15 Tussenkabel 4 polig → 7 polig gerepareerd en draait nu in test.
- 11:26 Hydrofoon 'LAAG' uitgeschakeld om gerepareerde connector in te 'tapen'.
- 11:55 Kanaal 'hydrofoon laag' werkt nu goed.
- 12:15 Geluidssnelheidprofiel met DIGIBAR bepaald tot 11 m. (Waarom maar tot 11 m?)

Depth [m]	Sound speed [m/s]
1	1157.8
2	1505.5
3	1511.3
4.0	1512.8
5.0	1512.9
6.0	1513
7	1513.2
8	1513.2
9	1513.3
10	1513.3
11	1513.4
12.0	
13.0	
14.1	
15.0	

- 12:45 Opname 'nulmeting1' gestopt. Boordaggregaat gestart.
- 12:47 Opname 'nulmeting2' gestart.
- 13:35 2 zeilboten op 1,5 nmi.

- 14:11 'Sound-speed profile' gemeten tot maximaal 17 meter diepte.

Depth [m]	Sound speed [m/s]
1	1158
2	1512
3	1513.8
4	1513.7
5	1513.5
6	1513.5
7	1513.3
8	1513.3
9	1513.3
10	1513.4
11	1513.4
12	1513.4
13	1513.4
14	1513.4
15	1513.4
16	1513.4
17	1513.4

- 14:30 Wind: ZO, 3 – 4 Bft. Golfhoogte: 0,5 m. Luchttemperatuur: 23,8 ºC.
- 16:30 Wind: ZO, 3 – 4 Bft. Golfhoogte: 0,5 m. Luchttemperatuur: 23,0 ºC.
- 17:15 Stop 'nulmeting2'.
- 17:16 Start boordgenerator.

Ch1	Ch2
-37.9	-39.4
-38.6	-40
-37.1	-39.4
-34.3	-36.1

- 17:20 Start havengenerator (generator door Martijn zo genoemd).

Ch1	Ch2
-29.9	-32.8
-30.8	-33.7
-30.7	-33.2
-29.3	-31.8

- 17:25 Start Bo-rent-generator.

Ch1	Ch2
-31.1	-34.2
-31	-33.7
-28.3	-31.2
-28.6	-31.5

- 17:35 Start 'nulmeting3' met boordgenerator.
- 19:13 'Sound-speed profile' gemeten.

Depth [m]	Sound speed [m/s]
1	1158.1
2	1158.2
3	1505.5
4	1512.8
5	1513.3
6	1513.7
7	1513.7
8	1513.7
9	1513.7
10	1513.8
11	1513.8
12	1513.8
13	1513.8
14	1513.8
15	1513.9
16	1513.9
17	1513.9

- 20:30 Wind: ZW, 4 Bft. Golfhoogte: 70 cm. Temperatuur: 20 ºC.
  Eigen positie: AIS: 51 58.064 – 3 55.083, scheeps GPS: 51 58.070 – 3 55.077.

Woensdag 10 september 2008:

- 01:58 Crash software (“OUT OF MEMORY”).
- 02:10 Restart computer – Restart software – ‘nulmeting4’ – meting is vrijwel direct gestopt.
- 02:11 Restart sofware: ‘nulmeting5’.
  Wim overgenomen:
  - $Gain_0$ type 2610: beide channels 0 dB.
  - $Gain_i$ type 2610: beide channels 40 dB.
- 09:11 Bo-rent-generator aangezet i.v.m. reparatie 24 V boordnet – opname is bij file nr. 414 van ‘nulmeting5’.
- 09:18 Golfhoogte ca. 1 m (positie?).
  Luchttemperatuur: 19,3 ºC. Watertemperatuur: 18,4 ºC (twijfel: sensor niet goed in water?).
- 09:30 Het schip ‘Oraholm’ passeert op ca. 3 km.
- 09:59 Tijdens ‘nulmeting8’: Van Martijn vernomen dat het schip ‘Grand Nigeria’ gaat ‘drainen’ of er al mee bezig is. Betekent mogelijk ‘afval lozen’. Range: ca. 2 km.
- 10:38 Golfhoogte lijkt toe te nemen: ca. 1,5 m.
- 10:47 Bo-rent-generator gaat uit / boordgenerator aan. Dit is gebeurd tijdens het opnemen van files nr. 36 en nr. 37 van ‘nulmeting9’.
- 10:58 Diepte: 18 m (= 2,2 m + 16 m).
- 12:40 AIS logging “not responding” in task manager, weet niet of AIS logging 337698 door is gegaan.
- 13:57 File nr. 2 van ‘nulmeting10’: overflow => anker.
- 14:07 File nr. 13 van ‘nulmeting10’: ‘ringel’ opgenomen (‘ringel’ is regelmatig hoorbaar) => oorzaak? Garnalen of ander dier?
- 14:15 Gemerkt dat de oranje kraan ‘klappert’. Verwacht dat dit hoorbaar is op de hydrofoons.
- 14:25 Hydroliek even gestart => meting stil gelegd.

- 14:30 Voor-ankerketting geprobeerd strakker te zetten (zie 14:07).
- 14:31 Metingen weer gestart => 'nulmeting12'.
- 14:49 Voor 'nulmeting14': Voltage range ADC op [5 V] gezet vanwege spikes op kanaal 1 ('hydrofoon laag') => mogelijk slecht contact?
  Ook op kanaal 2 ('hydrofoon hoog') zijn spikes, maar minder. Op signaal voor 22 kHz geen DC-spike gezien of in zeer mindere mate. Lijkt dus toch geen slecht contact.
  Na 14:54 lijken spikes weer afgenomen.
- 15:35 Wind: ZW, 3 Bft. Golfhoogte: ca. 0.5 m.
- 15:51 Golfhoogte: ca. 0,3 m (bijna vlak).
- 19:30 Temperatuur water: 18,8 ºC. Temperatuur lucht: 18,1 ºC.

Donderdag 11 september 2008:

- 09:00 Geconstateerd dat acquisitie PC is gestopt. Laatste file van 'nulmeting22' is opgenomen 11 sept. 5:25. De input range van de ADC was gezet op [2 V] voor de nacht.
- 09:09 Metingen weer gestart om 11 sept. 9:09.
  Opnamegat tussen 5:25 en 9:09 = 3u 43min.
  Bij analysefase: KIJK wat er voor AIS activiteit is geweest en besluit dan wat met dit 'gat' te doen.
- 09:43 Metingen 'nulmeting25' herstart met input range ADC: [0.5 V].
- 09:49 Wind: ZZO, 2 – 3 Bft. Heldere lucht, zonnig. Golfhoogte: ca. 0,5 m.
- 13:20 Temperatuur water: 19,2 ºC. Temperatuur lucht: 22,1 ºC. Wind: ZO, 4 Bft. Veel kleine golfjes van ca. 0,4 m.
- 14:10 Zeilboot nadert (geen AIS). (Tijdens het opnemen van files: nr. 78, 79 en 80 van 'nulmeting27'.)
- Overload voor files: nr. 78 en 79 (betwijfel of dit van de zeilboot zal zijn, denk ik, eventueel later uitluisteren).
- Voor files nr. 94 en 95 van 'nulmeting27': veel overload.
- Voor files nr. 1 en 2 van 'nulmeting28': overload (met input range ADC: [5V]).
- 14:30 Blijkt dat grote jongen **'Normed Amsterdam'** komt aanvaren < 500 m.
  Daardoor overloads voor 'nulmeting28' en 'nulmeting29'.
  Voor 'nulmeting30': input range ADC: [20 V]!
  Via scheepsradio waarschuwing gegeven!
- 14:43 We blijken populair: Ook 'Arklow River' is nieuwsgierig (tijdens het meten van 'nulmeting31'). Input range ADC: [10 V].
- 14:52 Start 'nulmeting32'.
- 15:03 Beide schepen blijken rondje te varen, komen weer terug maar nu aan de andere kant, houden wel meer afstand.
- 17:26 Programma gestopt om te kijken of we wat aan "OUT OF MEMORY" probleem kunnen doen.
- 17:44 Programma weer gestart.
- 18:05 'Sound-speed profile' gemeten. Dit kon niet eerder vandaag wegens teveel stroming.

Depth [m]	Sound speed [m/s]
1	1512.4
2.0	1515.1
3.1	1514.7
4.0	1514.6
5.1	1514.6
6.0	1514.5
7.1	1514.5
8.1	1514.5
9.2	1514.5
10.0	1514.6
11.0	1514.6
12.1	1514.6
13.0	1514.6
14.0	1514.6
15.0	1514.6
16.0	1514.6
17.0	1514.6

- 18:29 Donkere wolken zijn genaderd. Wind neemt nu toe: ZW, 4 Bft. Golfhoogte: 0,4 m. Temperatuur daalt.
- 19:15 Nu ongeveer laag water.
- 19:25 Ankerketting voor weer gespannen.
- 19:26 Metingen even gestopt om de kraan vast te zetten – slecht weer lijkt op komst.
- 19:29 Metingen weer gestart.
- 19:37 Luchttemperatuur: 21,1 ºC. Watertemperatuur: 20,6 ºC. Onweer is begonnen, op stuurboord.
- 19:39 Kraan anders gepositioneerd.
- 19:40 Metingen gestopt i.v.m. aantrekken ankerketting voorzijde.
- 19:50 Metingen weer gestart.
- 19:52 Klokken acquisitie PC en AIS gecontroleerd: 1 s verschil.
- 19:54 Vastgesteld dat de neus v.d. boot van noorden ca. 45 graden naar oosten is gedraaid.
- 23:35 Het vaartuig ‘RPA15’ is in de nabijheid gekomen.

Vrijdag 12 september 2008:

- Wind (317 deg): richting WNW, snelheid 7,5 m/s => 4 Bft (6 Bft incidenteel).
- Ca. 06:00 De wind is toegenomen en de golfhoogte is ca. 1 – 1,5 m (zie hiervoor).

- 07:42 Opname gestopt vanwege het verlengen en vieren v.d. hyd. signaalkabels.
- 07:49 Weer gestart.

- 08:30 ‘Jan v. Gent’ (loodsboot) vaart over bakboord redelijk dichtbij (ca. 300 m) => geen AIS (of niet op onze AIS gezien). Golfhoogte ca. 1,5 – 2 m.

- 10:00 Hyd. Signaalkabels v.d. staalkabel afgescheurd! Tie-raps (8 mm) breken af.

- 10:10 We zijn kanaal 2 ('hydrofoon hoog') kwijt! De versterker voor dit kanaal was uit tijdens het opnemen van de files: nr. 128 – 173 van 'nulmeting48'.

  Elke keer als de boot een 'roll'-beweging naar stuurboord maakt, dan spant de staalkabel (de 'snaar' spant) en is door de boot een laagfrequente trilling hoorbaar en voelbaar.

  Aan het A-frame op het achterdek hangt een staalketting die af en toe tegen de ladder op het A-frame knalt. Boot beweegt te erg => het is te gevaarlijk om deze vast te zetten!

- 11:30 Wind: WNW, 6 Bft.
- 13:13 Golfhoogte: ca. 2 – 2,5 m. Wind: NW, 6 Bft.
- 13:23 Het regent (duidelijk zichtbaar op het zeeoppervlak) dikke druppels.
- 13:32 Wind: WNW, 5 Bft (weerbericht).
- 13:53 Regen opgehouden.
- 14:30 Wind: NNW, 5 Bft. Golfhoogte: officieel 1,30 m (gemiddeld).

  Regelmatig gaan er flinke trillingen (bonken) door het schip. In hoeverre dit op de hydrofoon hoorbaar is, is moeilijk te zeggen.

  Als voorbeeld neem 14:44: gemiddeld een laag niveau maar wel spikes tot 1 V (input range ADC: [1 V]).

- 14:49 Input range ADC: [2 V], 'nulmeting50'.
- 14:52 Speaker aangezet – 'ringel' geluiden ook hoorbaar.
- 14:58 Screen saver "ALARM !!!" uitgeprobeerd. Screentijd 3 min.
- 15:06 Programma weer gestart!
- 16:00 Programma gestopt om dekkraan te verplaatsen!
- 17:30 Het weer lijkt wat rustiger te worden => Algemeen beeld: Weer is droog, bewolkt. Aan de horizon wordt het lichter. Golfhoogte nog steeds 1 – 1,5 m met uitschieters van 2 m.
- 18:24 Weer gestart. Meting was even onderbroken vanwege een ankerkettingmanoeuvre.
- 18:42 'Spirit' is aantocht. Vanaf de opname van file nr. 19 van 'nulmeting57' is het vaartuig 'in de buurt'.
- 20:08 'Spirit' vertrekt. Windkracht: 4 – 5 Bft. Windrichting: Noord. Golfhoogte: 80 cm – 1 m. Stroom: Noord → Zuid.
  Benoit Quesson heeft het overgenomen!
- 21:14 Measurements stop: software crashes AND ship changing position to be more in the stream.
- 21:21 Soft crashed again / Matlab restarted … ship in position and measurements go on – 'nulmeting64'.
- 21:34 Fishing boat passing by 1.5 nmi. The general level of noise is a bit higher. A few big waves were present a bit earlier (might be visible in data).
- 22:01 Input range ADC: [1 V], 'nulmeting65'.
- 22:18 Input range ADC: [0.5 V], 'nulmeting66'.
- 22:38 Input range ADC: [1 V], 'nulmeting67'.
- 22:58 Input range ADC: [2 V], 'nulmeting68'.

Zaterdag 13 september 2008:

- 00:50 Hydraulic generator on.
- 00:55 Hydraulic generator off.

- 08:45 Input range ADC: [1 V], ‘nulmeting69’.
  Air temperature: 17.4 ºC. Water temperature: 18.4 ºC (with multimeter so maybe 2 to 3 degrees less). It was found out that the laser thermometer on board gave another reading of the temperature about 2 to 3 degrees less than the multimeter reading. The laser seems to be trusted with ‘temperature feeling’.
- 09:11 Input range ADC: [0.5 V], ‘nulmeting70’.
- 09:27 Input range ADC: [1 V], ‘nulmeting71’.
- 09:30 Wind: 0 – 1 Bft (practically no wind). Waves: 0.5 m.
- 11:04 Input range ADC: [0.5 V], ‘nulmeting72’.
- 11:18 Input range ADC: [1 V], ‘nulmeting73’.
- 13:30 Small speed boat passing nearby and visible in data.
- Wind: N, 4 Bft. Waves: 0.7 m. Stream: North → South.
- 13:40 Sound-speed profile:

Depth [m]	Sound speed [m/s]
1	1501.8
1.5	1508.2
2.0	1508.5
2.7	1511.9
3.0	1512.2
3.5	1512.6
4.0	1512.8
4.5	1513.2
5.0	1513.4
5.5	1513.5
6.1	1513.7
6.5	1513.8
7.0	1513.8
7.6	1513.9
8.0	1513.9
8.5	1513.9
9.0	1513.9
9.5	1513.9
10.0	1513.9
10.5	1513.9
11.0	1513.9
11.5	1513.9
12.0	1513.9
12.5	1513.9
13.0	1514.0
13.5	1514.0
14.1	1514.0
14.6	1514.0
15.1	1514.0
15.5	1514.0
16	1514.0
16.6	1514.0
17.0	1514.0
17.5	1514.0

- 16:21 Input range ADC: [2 V], ‘nulmeting74’ => big ships passing by.

- 16:32 Input range ADC: [1 V]. ‘nulmeting75’.
- 17:44 Input range ADC: [0.5 V], ‘nulmeting76’.
- 18:13 Input range ADC: [1 V], ‘nulmeting77’.
- 18:50 Input range ADC: [2 V], ‘nulmeting78’ (two big ships passing).
- 19:00 Input range ADC: [1 V], ‘nulmeting79’.
- 19:54 Input range ADC: [2 V], ‘nulmeting80’.
- 20:00 Water temperature: 18.9 ºC with multimeter and 16.0 ºC with laser thermometer. The last one seems more accurate.
- 20:28 Input range ADC: [1 V], ‘nulmeting81’. Wind: N, 3 – 4 Bft.
- 22:07 Matlab crash.
- 22:08 Matlab restarted. Input range ADC: [1 V], ‘nulmeting82’.
- 23:10 Oscilloscope on/off visible for file no. 62 of ‘nulmeting82’.
- 23:27 Input range ADC: [2 V], ‘nulmeting83’ (for the night).

Zondag 14 september 2008:

- 09:35 Recording stopped – cable ‘hyd. laag’ broken: cable broke between recording of files nos. 603 and 604 in ‘nulmeting83’ corresponding to a time between 09:30 and 09:31 (PC clock). Checked in data: last valid recording is file no. 600 of ‘nulmeting83’ (09:27).

Cable is broken ‘above water’ due to too high stress on it. It is therefore possible to try to repair.

- 12:25 Contact test on broken cable, ‘nulmeting84’.
- 12:38 End of reparation: Signal ‘hyd. laag’ is back again: need to wait one hour for joints to dry but cable is already operational. Started ‘nulmeting85’ with input range ADC: [1 V].
- Water temperature 14.5 ºC (laser). Air temperature: 18.5 ºC (multimeter).
- Sound-speed profile:

Depth [m]	Sound speed [m/s]
0.5	1158.3
1.0	1158.3
1.5	1158.4
2.1	1506.4
2.5	1509.7
3.0	1509.9
3.5	1510.1
4.0	1511.4
4.5	1512.9
5.1	1513.3
5.6	1513.5
6.2	1513.6
6.5	1513.7
7.0	1513.8
7.7	1513.9
8.0	1513.9
8.6	1513.9
9.2	1513.9
9.6	1514.0
10.2	1514.0
10.6	1514.0
11.3	1514.0
11.6	1514.0
12.2	1514.0
12.6	1514.0
13.0	1514.0
13.6	1514.0
14.0	1514.0
14.5	1514.1
15.0	1514.1
15.5	1514.1
16.1	1514.1
16.5	1514.1
Probe going up	
3.0	1510.1
2.5	1509.9
2.0	1509.9
1.3	1509.9
0.9	1509.9

- 14:33 ‘nulmeting86’ with input range ADC: [2 V].
- 14:40–50 Joints are dry, finishing of the cable reparation with extra ‘chips’ shielding… cable is almost as good as new… data is stopped and amplifier switched off.
- 14:51 Installation of cable with tie raps on the steel cable.
- 15:09 Cable is ready, data recorded again with input range ADC: [2 V], ‘nulmeting87’.
- 18:06 Wind: E–NE, 4 – 5 Bft.

- 18:18 ‘nulmeting88’ with input range ADC: [1 V].
- 18:46 ‘nulmeting89’ with input range ADC: [0.5 V] (very quiet).
- 19:31 Water temperature 14.3 ºC (laser). Air temperature 17.5 ºC (multimeter). Protocol to take temperature: a bucket of water is taken from the sea and the temperature is measured in there with the laser thermometer. The multimeter is used for air temperature since the laser is more suited to give the temperature of a surface.
- 20:08 Input range ADC: [1 V], ‘nulmeting91’ (‘nulmeting90’ is empty).
  2 big ships passing by.
- 20:28 ‘Zeros’ in the data of ‘hydrofoon laag’: possibly a bad contact in the repaired cable?
  After this time more zeros in the data recorded.
  For all files recorded after file no. 20 of ‘nulmeting91’: The data is <u>invalid (because of the ‘zero’s).</u>
  The repaired section above water does not seem to be the problem since it does not give any zeros or extra noise if it is moved or twisted a bit.
- 20:56 The tie-raps (fixing the electrical cable to the steel cable) installed this afternoon are already broken!
  => The ship is moving a lot despite the normal sea (because of stream/anchor etc.) and a LOT of strength is put on the cables. Maybe the ‘zeros’ are due to stress in the electrical cable because of the broken attachments?
- 20:57 Hydraulic engine on.
- 20:59 Hydraulic engine off.
- 21:01 Hydraulic engine on for about 30 s.
- 21:20 Buoy detected drifting near the ship: attachment to the steel block at the bottom is broken and the hydrophones are only attached via the electrical cable now. Hydrophones are dragged immediately on board. End of recordings.

End of logbook

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