INVESTIGATION OF THE WINDSOR HUM

Windsor, Ontario

Final Report

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EXECUTIVE SUMMARY

Since early 2011, residents of the City of Windsor and nearby communities have reported an intermittent low frequency noise, which has been labeled as the Windsor Hum. A previous study confirmed the existence of the low frequency excitation and estimated the source to be in the vicinity of Zug Island; a highly industrialized island located on the US side of the Detroit River.

A subsequent investigation by the University of Western Ontario (UWO) and the University of Windsor was supported by the Canadian Department of Foreign Affairs and International Trade (DFAIT) to try to locate the source of the Hum. The research conducted by the University of Windsor's NVH-SQ Research Group was comprised of two phases. The first phase was to identify and characterize the acoustic signature of the Hum using noise monitoring equipment deployed throughout the Windsor-Essex community. Once the Hum was measured and characterized, the second phase was to determine the exact source of the noise using noise source identification (NSI) hardware and software using a beamforming algorithm.

This report includes an in-depth discussion of possible sources capable of producing the reported Hum sound. The results of the literature study compared the potential sources to the characterised sounds measured in the first phase of the project. For the duration of the project, the Hum manifested on only a handful of days, which made the identification of the source difficult. Good data representative of the Hum was measured using the stationed noise monitors. Conclusive evidence of the source was not achieved using the NSI system since the Hum was not present on those days that this equipment was deployed on the river.

The conclusion of the research is that the Windsor Hum does exist and has both qualitative and quantitative characteristics that surmise the likely source of the Hum to be from the blast furnace operations on Zug Island. It is recommended that community noise monitoring be continued and that efforts be given to allow NSI measurements to be made on Zug Island lands during the periods that the monitors identify occurrence of the Hum sound

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APPENDICIES

1. INTRODUCTION

The University of Windsor was retained by the Department of Foreign Affairs and International Trade (DFAIT) to perform a noise source investigation study in Windsor, Ontario. The purpose of the study was to investigate an unknown noise, first documented when the Ontario Ministry of the Environment began receiving complaints in early 2011. Residents of the areas of West and South Windsor, as well as the Town of LaSalle, started hearing an unnatural hum, or drone sensation in their homes. The media eventually named the sound the Windsor Hum. Often perceived in certain geographical areas, the hum sensation has been reported to appear intermittently at all hours of the day, but has been most prominent during the late evening and early morning hours.

The City of Windsor is located at the southwestern tip of Ontario and is at the international border between Canada and the USA, separated by the Detroit River. Windsor is a highly industrialized city with many industries directly related to, or in support of the automotive industry. The Ambassador Bridge, located on the city's west side, is also the busiest border crossing between the two countries in terms of trade volume.

1.1 The Hum Worldwide

Since the early 1970's, similar hums have been reported throughout the world. Reports of hum, howl, and rumble have appeared in the news in communities including, but not limited to the following, (in chronological order of first known reported occurrence):

- Sydney, Australia (1970);
- Largs, Scotland (1989);
- Taos, New Mexico (1991);
- Hueytown, Alabama (1992);
- Peterborough, England (1994);
- Auckland, New Zealand (2006);
- Liverpool, England (2008);
- Leeds, England (2009);
- Bristol, England (2009);
- Vancouver, British Columbia (2010);
- Woodland, Durham (2011);
- Herbrandston, Wales (2013);

In each of these cases, local newspapers have told stories of residents being kept awake at all hours of the night, subject to the intermittent hum noise in their own homes and disrupting their lives. Some describe the noise as similar to an idling diesel engine or industrial machines in the distance. While not everyone in these communities has heard the hum, for those that do, the hum sensation is a constant annoyance, which they do not become accustomed to. With each report also comes a wide range of potential sources. Predictions vary from mechanical sources (submarine activity, generators, worn industrial machines), sonar systems, radio towers, and environmental features (rock faults and coastal shifts), to human physiological traits such as psychological problems and tinnitus.

1.2 Impact on Residents

While not all residence within an affected community hear the Hum, some of those who do report hearing it also describe side effects including loss of sleep and insomnia, nausea, muscle spasms, chronic stress, difficulty concentrating, fatigue, heart palpitations, headaches, increased tension, eye strain, pins and needles, irritable ear pressure, personality changes and occasionally thoughts of suicide. Not all of the self-proclaimed ‘hummers’, suffer from side effects but for many of the reported cases it is reported that the quality of life for these individual may be lessened with negative impacts on relationships and careers.

Similar to those reports mentioned above, the Windsor Hum has been described by some who have experienced it as an intolerable disturbance. Some people within the Windsor area communities have also reported adverse health impacts including loss of sleep, headaches, increased stress and depression. These reports have come from the media and direct communications by those affected.

1.3 The Windsor Hum

When reports of the Windsor Hum began appearing in 2011, the Ministry of the Environment of Ontario (MOE) launched an investigation that considered several local industries but could not identify the source. It was concluded there were too many potential noise sources in the area for a simple investigation. This was partially due to the number of industry and the geographic extent of the documented complaints. As a heavy industrialized border city, the ambient noise levels in the affected area are generally high as a result of high road and rail traffic volumes, dense industrial operations and its close proximity to the international shipping channel and

Detroit, Michigan; a city which also has heavy industrialization along the Detroit River, west of the international bridge crossing.

1.3.1 NRCan Investigation

Following the initial MOE investigation, a second study of the Windsor Hum was conducted by National Resources Canada (NRCan) during the summer of 2011. NRCan installed several Seismograph vibration monitors at various locations within the City of Windsor. A study of ground vibrations was deemed an appropriate approach given that initial reports suggested that the Hum was the result of ground-borne vibrations. Monitoring locations were selected within the affected communities to locate the source of the Hum disturbance. Several conclusions were made by the researchers following several months of data collection: (i) the long duration of the excitations were not consistent with earthquake or other seismic activities, (ii) the prominent frequency of the excitation was approximately 35 Hz, and (iii) due to the speed of the propagating energy, the excitation was an air-borne noise source and not a ground vibration. Samples of the results from the investigation are provided in **Appendix A**. By examining the gap in time in the measured data between each of the various measurements locations, NRCan was able to triangulate the data to approximate that the source was located in the general area of Zug Island. Given that the NRCan report concluded that the Hum was the result of an air-borne excitation, the next step to locate the source should be an acoustical study, (Bent and Woodgold 2011).

1.3.2 University Research

A press conference was held in January 2013 at the University of Windsor to announce a federal government funded research project to locate the source of the Windsor Hum as a process to protect the quality of life for citizens of Windsor. To facilitate this research, the Department of Foreign Affairs and International Trade (DFAIT) contracted the University of Western Ontario (UWO) and the University of Windsor into a joint research study to investigate the source of the Windsor Hum phenomenon.

As part of the DFAIT contract, UWO deployed monitoring equipment in the area of LaSalle in March of 2013. The equipment is capable of collecting low frequency data in the frequency range from 0.1 Hz to 200 Hz. Most sounds having frequencies above 20 Hz are considered audible to an average human listener when presented at sufficient amplitudes. The frequency capabilities of the equipment assured that the previously observed 35 Hz tone was within the measurement range of the UWO equipment.

A dedicated email address was established for local residents to report perceived events of the Hum to aid the researchers in their subsequent analysis of the measured data. Both universities had access to this information to allow them to refine the search parameters and to assess the measured data in correlation to the residential feedback.

The preliminary results of the UWO study did not make any definite conclusions. Dominant frequencies were found to be 15-20 Hz, 30 Hz, 42 Hz, and 60 Hz. It was further determined that this entire frequency range of data originated from the direction of Detroit, including the area of Zug Island.

2. RESEARCH APPROACH AND METHODOLOGY – UNIVERSITY OF WINDSOR

The research conducted by the University of Windsor was separated into two phases, (i) validate the existence and characterize the noise for the Hum phenomenon, and (ii) upon confirming the source characteristic, use noise source identification (NSI) technology to pin point the source emitter; the only methodology available to the research team without having direct access to the Zug Island lands.

2.1 Phase 1 – Part 1: Long Term Noise Monitoring

The objective of Phase 1 was to continuously monitor and log the noise data of the affected areas. To accomplish this, two outdoor noise monitoring terminals (NMT), Brüel & Kjær (B&K) Type 3639 NMTs, were deployed. These units are designed for permanent, mobile, and portable monitoring where unattended outdoor noise (and/or vibration) measurements are required. The NMT hardware meets the IEC 61672 Class 1 standard for noise measurement, as well as several other standards including DIN 45657 and ANSI S1.4. The B&K product and service information, product data sheets and general information relative to this project is provided in **Appendix B**. The analyzer inside the weather tight NMT enclosure is a Type 2250 Sound Level Meter having a broadband, linear frequency range from 3 Hz to 20 kHz which is a good range for this project's requirements. The microphone is a Type 4952 Outdoor Microphone, capable of withstanding harsh climate conditions, and has a frequency response from 8 Hz to 12.5 kHz.

The first NMT was a permanent installation located approximately 100 meters from the Detroit River shoreline, directly across from Zug Island. A photo of the permanent NMT installation is given in **Figure 1**. The second NMT was a mobile unit that was installed and relocated within different residential areas. The chosen locations were based on areas where heavy concentrations of Hum complaints have been noted. Photographs of the portable NMT system are given in **Appendix C**. The intent of monitoring at the residential locations was to be able to correlate reported Hum incidences with collected noise data.

The NMTs are equipped with a 3G cellular modem, which allow remote access to the real time noise data using a personal computer having Internet access. Day and nighttime noise threshold trigger levels were used to identify and record the noise when the preset sound pressure level was exceeded. The intent of having the recorded sound is to capture, identify and distinguish the sound of the Hum from other generated exceedances. For each trigger, a 30-second recording is made and included in a detailed daily noise report, which is received by the researchers each morning. Other metrics logged by the NMTs include a rolling equivalent energy level (Leq) averaged over 5-minute intervals for each 24-hour period, statistical exceedance levels as well as logged maximum and minimum levels and third octave frequency spectra. Results of the logged data were subsequently automatically summarized into Excel spreadsheets and included in the daily reports for review by the researchers. Samples of the Excel data sheets are provided in **Appendix C.**

Figure 1: Permanent NMT Setup

2.2 Phase 1 – Part 2: High Resolution Data Collection

While the NMTs provided recordings for triggered events with audio playback, as well as other environmental noise metrics, the data was limited in terms of frequency resolution. For this reason, a secondary measurement was used to better quantify the hum frequency signature and consisted of a B&K Module LAN-XI Type 3056 acquisition system which has a frequency range from 0 Hz to 51.2 kHz. A Type 4189 free-field microphone having a low-frequency cut-off of 6.3 Hz was also used. Using a specialized firmware application (BZ-7848) loaded on the acquisition module, the LAN-XI system was used as a stand-alone recorder, thus eliminating the need for a PC to be connected during data collection. The system has the advantage of recording data at a higher sampling rate and in a format optimized for later post-processing of the acquired data. This secondary unit was located adjacent to the permanent NMT as shown in **Figure 2**.

Figure 2: PULSE Acquisition System Setup at NMT

The secondary measurement system was deployed during a period when the Hum was active from the evening on Friday July 5th until late in the morning on Saturday July 6th. From these measurements, detailed frequency spectra, which characterized the low frequency nature of the

Hum, was acquired. The data, given in **Appendix D**, along with the sound recordings provided confirmation of the Windsor Hum.

2.3 Phase 2: Noise Source Identification using Beamforming

With the Hum sound recorded and characterized, the next phase of the research was to locate the source of the disturbance. During the study period, it was noted that optimum identification of the Hum was during the late evening and nighttime. These are also times of lowest ambient environmental background noise levels. Due to access restrictions to the island, a research vessel owned by the University of Windsor's Great Lakes Institute for Environmental Research was used to get within close proximity of the Zug Island shore to facilitate the acquisition of NSI data. **Figure 3** is an aerial view of the Detroit River and Zug Island. The red circle in **Figure 3** also indicates the target measurement zone for the NSI exercise.

Figure 3: Aerial Photo of Zug Island with Distance from Island to be Measured Marked in Red

A pentangular array Type WA-1676-W-02 (comprising of thirty Type 4959 microphones) was used as the NSI microphone array. Both qualitative and quantitative data was collected of the Zug Island site to locate potential noise sources for the Hum. The array is capable of outputting acoustical colour maps, similar to thermal imaging techniques, to identify and quantify sources of noise over a large target area using an acoustic beamforming algorithm. Product data and information sheets describing the system are given in **Appendix B**. Acoustic beamforming is a method of mapping noise sources using a microphone array that discerns the direction from which the sound originates. This is accomplished by employing a time delay approach as the source passes over the array of microphones. Using this approach, and knowing the target frequencies identified in Phase 1 of the research, the aim was to identify the Hum signature within the measurement target zone. A photograph of the pentangular array mounted on the research vessel is shown in **Figure 4**. Bruel & Kjaer PULSE Labshop software was used to acquire the noise data, which allows for real-time data acquisition and performed fundamental real time and post processed analysis of the data. A 36-channel B&K LAN-XI acquisition system was used as the data collection front end.

Figure 4: Setup of the Pentangular Array on Research Vessel

3. RESULTS

The following section details the observations and conclusion resulting from the data collection and analysis exercises. Discussion of the results from the subjective and objective metrics is also given.

3.1 Phase 1 – Part 1: Long Term Noise Monitoring Results

Continuous noise data was collected by the NMTs over a period of approximately six months for which the data reports and sound files were examined on a daily basis by the researchers using both objective and subjective metrics. Regular visits were also made by the researchers to the permanent NMT site to maintain the equipment and to qualitatively monitor the noise levels and sounds. It was not until the first week of July that the Windsor Hum was detected using the NMT recordings. It was then that the secondary measurement system was deployed and an analysis of the data confirmed both the prominent low frequency spectra of the noise source as well as the irregular intervals. The researchers also observed a specific nighttime operation, described as a bright blue flame from several exhaust stacks located on Zug Island, which coincided with observation of the Hum sound. The blue flames were easily visible from the Canadian shoreline, nearly one kilometer away. While there are many factors involved, a blue flame is typically an indication of high levels of oxygen during the combustion process, required in high temperature industrial operations. While no solid relation can be made by these qualitative observations between the acquired noise data and the specific nighttime operations at the Island, it is important to note the correlation. A photograph illustrating the flames is given in **Figure 5**.

Figure 5: Photograph of Zug Island and identified Nighttime Operations Exhaust

3.2 Phase 1 – Part 2: Results of High Resolution Data Collection

As discussed previously, a secondary equipment deployment and analysis was carried out once the Hum was identified to measure the sound with equipment capable of higher frequency resolution analysis. For this, a standalone B&K PULSE acquisition system was installed for a short duration at the permanent NMT site near the Detroit River.

The data collected during the overnight period on July 5/6 was extensively assessed against multiple criteria. The Windsor Hum signature was most dominant during the early morning hours, specifically between 3 AM and 4 AM. Three short term recordings were selected and post-processed using PULSE Reflex software using; (i) Fast Fourier Transformation (FFT), (ii) overall time analysis, and (iii) waterfall frequency spectrum (three-dimensional FFT). The FFT metric is an algorithm to transform the time domain data into the frequency domain. The overall time analysis computes the sound pressure level (SPL) with respect to the recorded time domain. The waterfall plot is a three-dimensional graph of the SPL versus the frequency and time domains. The complete assessment of the collected and processed data is provided in **Appendix D**. This includes both linear and A-weighting data analysis for each metric. This data confirmed the presence of a significant and prominent low frequency component of the measured noise located at 63 Hz. A sample portion of the data analyzed is provided in **Figure's 6, 7**, and **8** below. These results are similar to those observed by NRCan and UWO.

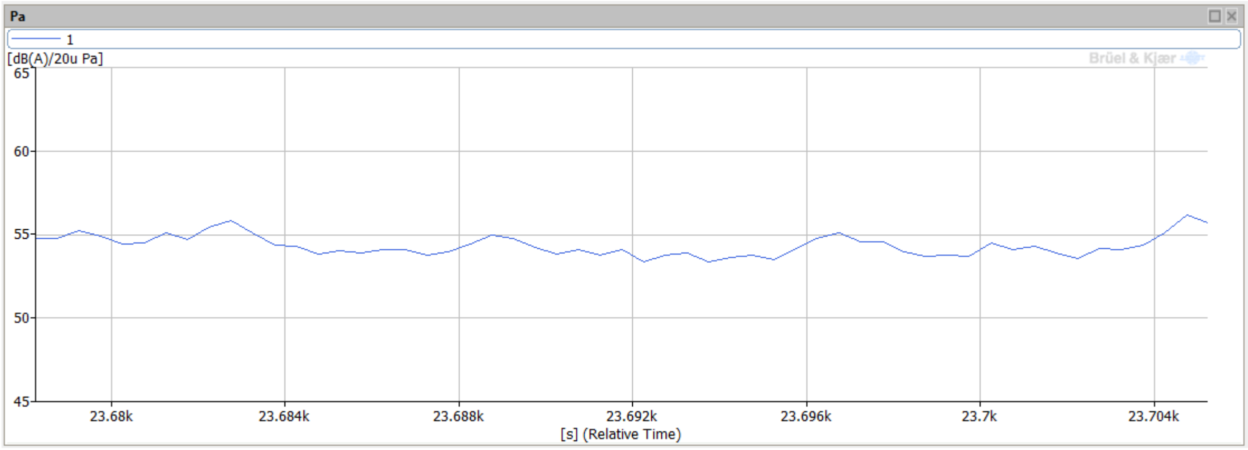

Figure 6: Plot of A-weighted Overall SPL vs. Time for Time Period 1

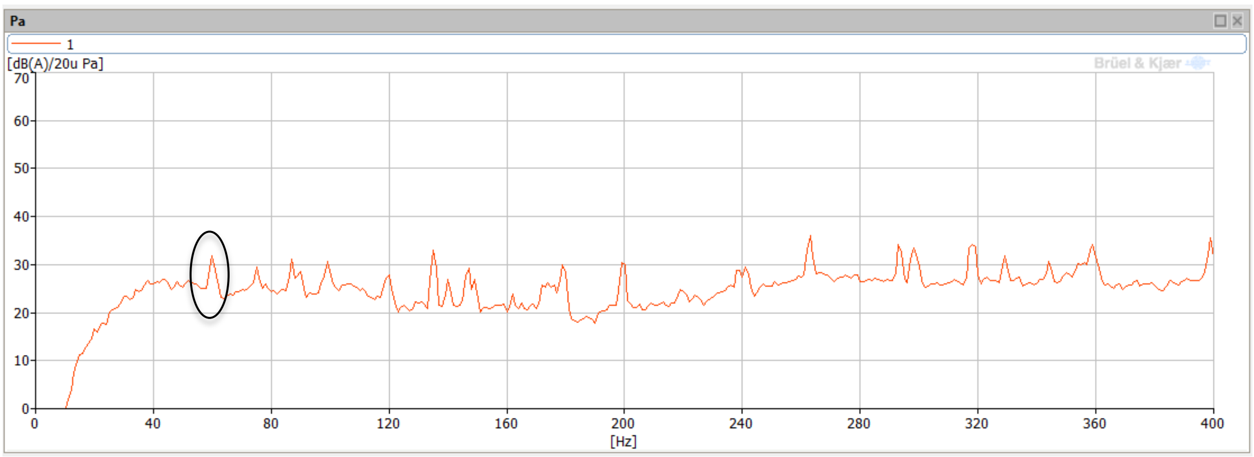

Figure 7: Plot of A-weighted Overall SPL vs. Frequency for Time Period 1

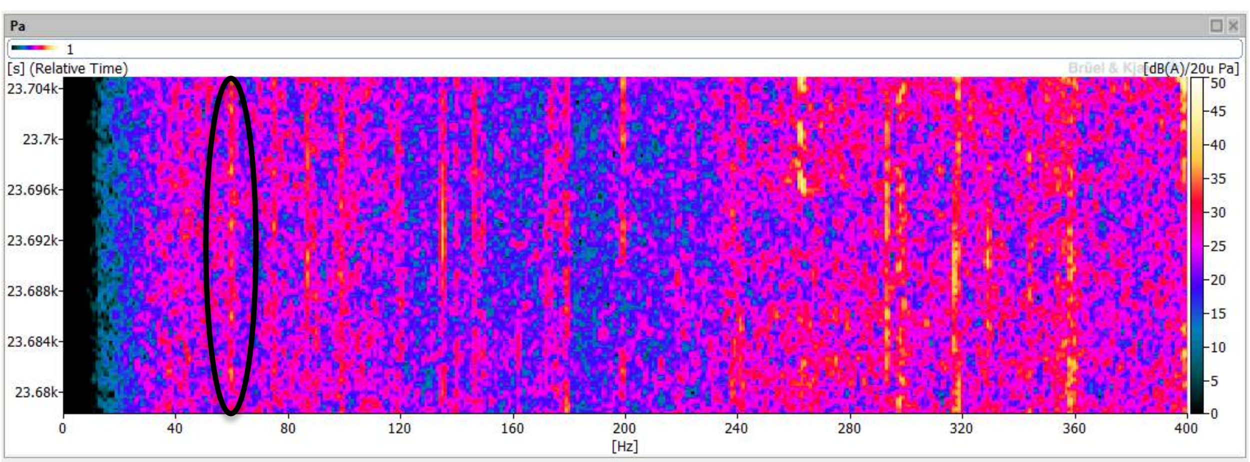

Figure 8: Waterfall plot of A-weighted SPL vs. Frequency and Time for Time Period 1

3.3 Phase 2: Results of Noise Source Identification Measurements

Following the first NMT measurements of the Hum noise, deployment of the NSI system was not possible until the early morning hours on August 22, 2013, due to availability of the research boat. It became evident to the researchers that the specific nighttime industrial operations, identified previously and illustrated in Figure 4, were not active at Zug Island during this day. As a result, the Windsor Hum signature was not captured. The researchers closely monitored for the Hum sound and were not able to identify it again before the close of the acquisition time line of the study. However, given that the NSI acquisition equipment was installed, calibrated and ready on-board, acquisition of NSI data was made to further identify and characterize the other various noise sources on the island. The collected data was subsequently post-processed using the B&K array acoustics post-processing software suite. A sample analysis output is provided in the noise contour plot given in **Figure 9**. The corresponding analysis of the sound power 1/3 octave frequency response is shown in **Figure 10**. For reference, an octave is the interval between two points where the frequency at the second point is twice the frequency of the first.

The Zug Island region is isolated and shown in red for both the contour and frequency response figures. Analysis of the data shows that the major contributor to the overall sound power level from the region of Zug Island is from the low-frequency noise content. This observation is given even in the absence of the Hum and previously identified nighttime operations. It should be noted that due to the wave and drifting motion of the boat during the data acquisition, some error resulting from sound coming from, and reflecting off of the water, was detected. While this does result in some loss of spatial determination of the noise sources, it does not remove the fact of the presence of significant measured low frequency noise.

Figure 9: Contour Plot over Image from Pentangular Array – Measurement 1

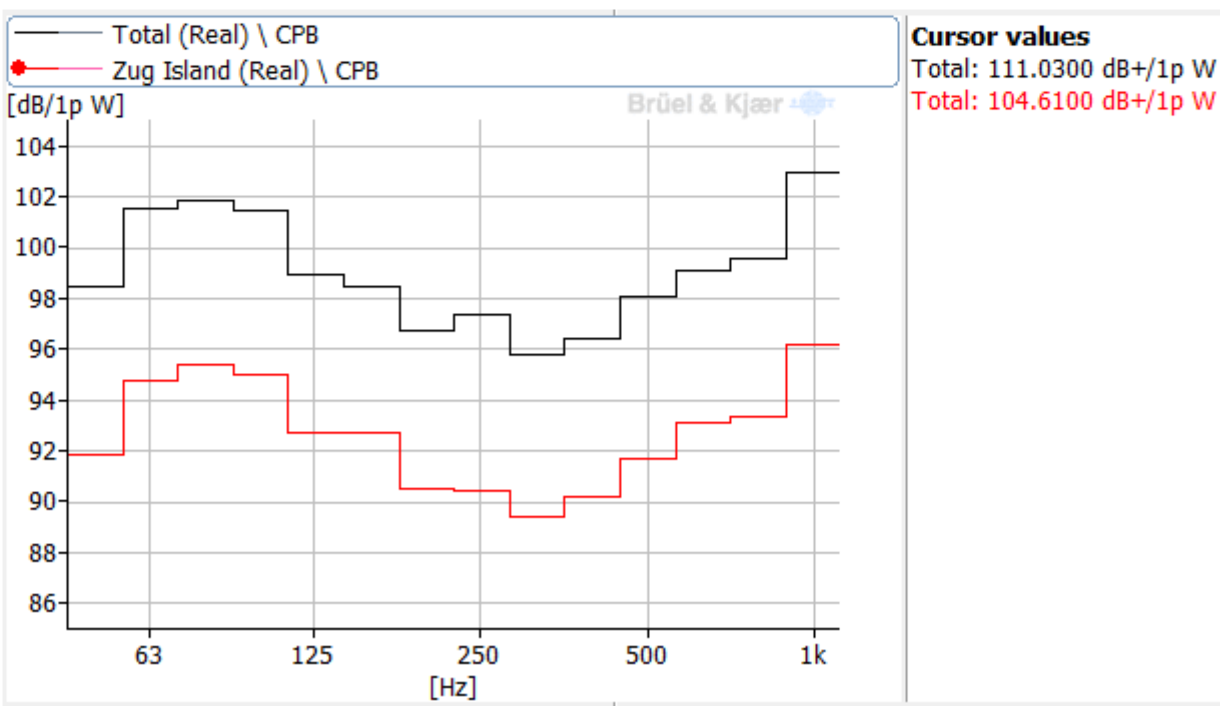

Figure 10: Sound Power Level Frequency Spectral Analysis – Measurement 1

At the conclusion of the first boat trip, the primary focus was aimed to examine the data to determine if the methodology undertaken was successful, even though Hum phenomenon did not occur that night. Once the data was examined, the method and testing procedure was refined to make it the most accurate and reduce possible sources of error during future trips. It is worth noting that during the measurement acquisition, a dominant noise source was detected during measurements 7 through 12. This noise source was identified to be high-pressure steam exhaust operation (possibly part of a maintenance or equipment testing process) and was not observed previously by the research group.

To avoid unnecessary measurements, the decision was made to not attempt another nighttime trip with the NSI equipment until the characteristic Hum was again positively identified. Continued noise monitoring of the NMT data was the focus of the research from this point forward. Unfortunately, the Hum did not manifest itself again before the NMT monitors were decommissioned in early October. In fact, the researchers did not become aware of any further Hum activity until January 2014, just prior to the completion of this report.

4. DISCUSSION

Results obtained have shown that the Windsor Hum does exist and is also a quantifiable sound. While direct access to Zug Island have restricted any conclusions to qualified guesses, the ground vibration data measured by NRCan and array data obtained by the Western University of Ontario team support the conclusions of this report that the Windsor Hum phenomenon most likely originates from the Zug Island area. If anything, there has been no data to date, which suggests that the source is from anywhere else, especially given the heavy industrialization of the surrounding area on both sides of the Detroit River. Further, the observed operations at Zug Island are also consistent and coincide with the time periods of Hum activity. To further the discussion and strengthen the hypothesis, the following discussions identify potential noise sources on the island and the most likely to cause the observed characteristic sounds and frequencies.

4.1 Zug Island Description

Zug Island is an industrial island located on the south-eastern edge of Detroit, Michigan and fronts onto over one kilometer of waterfront property. The island is a prominent area feature and can be easily seen from the Canadian side of the border. Transportation on and off the island is available three ways; (i) a land bridge which services the island for employee traffic and shipping operations via large trucks; (ii) a rail bridge which is located on either side of the island to facilitate the export of steel and raw materials; and (iii) large shipping docks which allow tankers and other large ships to load and unload materials at the waterfront. Operations on the island include two large blast furnace facilities and a petroleum coke (petcoke) baking process. While vehicle traffic and railway horns can be heard clearly at the Windsor waterfront, the most audible sounds are characteristic of the blast furnace operations and associated high temperature exhaust towers.

4.2 Blast Furnace Operation – Overview

The high capacity blast furnace, similar in appearance to those used on Zug Island, is a popular design used for the production of pig iron as the unique shape allows for a high production rate while also maintaining a high level of thermal efficiency. While an in-depth detail of the entire blast furnace process is not applicable to this research, the brief overview that follows is focused on a discussion of the characteristics of the airflow (including the temperature) into the furnace, as well as the general geometry of the stack. These parameters are the principal features related to the noise emission levels. The described processes associated with the blast furnace operation are taken directly from Steel Works: The Online Resource for Steel (last accessed in December 2013) and are outlined below.

The blast furnace is essentially a large cylindrical oven, which is used to convert mineral ore into usable steel for manufacturing. Capable of producing 12,000 tonnes per day, a blast furnace can run continuously for up to 10 years with only short periods of downtime to perform scheduled maintenance (American Iron and Steel Institute 2013). Often standing over 20 metres in height, the stack is the most prominent feature of the furnace. Acting as a funnel, the brick lined oven channels raw materials through the superheated flame; chemically reducing and physically converting iron oxides into liquid iron. A conveyor feeds the tower with varying proportions of iron ore, limestone, and petcoke which steadily pour into the top of the furnace. Typically the raw materials require 6 to 8 hours to descend to the bottom (this is dependent on several of the processes parameters, such as temperature, air flow, etc.). At the same time, preheated as air is force-blown into the bottom of the furnace, which ascends to the top of the stacks in approximately 6 to 8 seconds and triggers numerous chemical reactions. The superheated air is forced into the bottom of the tower, providing the necessary oxygen for combustion. It enters at both high volume and velocity through a series of water-cooled ports known as tuyeres; this process is further described below. Air enters the blast zone of the furnace igniting the petcoke and converting the mineral ore and petcoke mix into a molten mixture of slag and pig iron.

The rate of pig-iron production in any given blast furnace is proportional to the rate at which oxygen, as air or air plus pure O_2 is blown into the furnace. Typical operational blast rates in the furnace are 40-50 Nm^3/min of blast air per square metre of hearth area. It is worth noting that a blast furnace can operate down to about 70% of its normal capacity without any deleterious effects; below this rate, the charge begins to react unevenly. Blast temperatures in modern installations are typically from 1000°C to 1300°C (Peacey and Davenport 1981).

The high burning temperature increases the efficiency of the furnace. To achieve this, hot dirty exhaust gas is collected at the top of the furnace and fed through a series of gas cleaning processes to recirculate the effluent. The exhaust gas is re-burnt as fuel in hot ovens, which generates steam. This process is used to convert the thermal energy from the effluent gas into mechanical energy for a turbo blower, compressing the large amount of air required in the smelting process (American Iron and Steel Institute, 2013). The turbo blower is the first step in generating the superheated air outside of the furnace with flow-rates between 37 m^3/s and 108 m^3/s. The blown air flows through the "cold blast main" up to the hot stoves exterior of the plant. This cold blast enters the stove, which has been previously heated by dirty exhaust gas from the stack. The heat stored in the stove's refractory brick is then transferred to convert the cold air to a "hot blast" form. The moving air temperature at this stage can be from 870°C to 1260°C depending on the design and conditions of the stove. As the superheated air exits the stove it enters the "hot blast main" which runs up to the intake at the bottom of the furnace. There is a "mixer line" connecting the cold and hot blast mains equipped with a value to control the blast temperature to keep it constant. The hot blast main enters into a doughnut shaped pipe that encircles the furnace, named the "bustle pipe". The circular tube distributes the air around the furnace through equally spaced nozzles, called "tuyeres" around the circumference of the furnace. The number of nozzles may vary from fourteen on a small blast furnace to forty on a large blast furnace. These tuyeres are made of copper and are water cooled since the temperature directly in front of them may between 1980°C and 2300°C. Oil, tar, natural gas, powdered coal and oxygen can also be injected into the furnace at the tuyere level to combine with the coke to release additional energy. This may be necessary to increase productivity. The molten iron and slag drip past the tuyeres on the way to the furnace hearth, which starts immediately below tuyere level.

4.3 Potential Noise Sources

Outlined above is the typical blast furnace process for converting petcoke and iron ore into commercial grade steel. Unfortunately, as the investigators did not have access to the Zug Island facility, they can only speculate the specific processes involved at this facility and the associated potential sources of noise associated with them. From the above described process, noise sources may include but are not limited to: (i) the high velocity air travelling through air ducts and the tuyeres which ignites while entering the blast zone; (ii) the discharge of compressed air fluctuations into the atmosphere; (iii) the effluent gas exiting the waste stack continuously being burnt off; and (iv) the intermittent release of large amounts of steam. Secondary noise sources may come from other processes on the island, most notably from the screening process to sort the baked coke piles and raw materials after their crushed.

4.3.1 Blast Mains and Ducts, and Tuyeres

As Zug Island is assumed to be a high volume facility, it necessarily follows that the equipment involved would be of a large industrial scale, capable of emitting a proportional amount of noise. The airflow requirements alone to run such a plant are massive and can produce a large amount of associated duct noise. The formula below, taken from (Crocker 2007), is used to aid in the prediction of air duct noise sound power level (L_w), based on the flow velocity (v) and cross-sectional area (A).

$$L_w = constant + 10*\log(A) + 60*\log(v)$$

The constant is dependent on the type of fitting used in the air duct. As an example, assigning a value of zero to the constant and approximating the values of flow velocity and cross-sectional area based on previously provided information, sound power levels exceeding 150 dB are predicted. While this value is not directly applicable to blast furnace noise, but serves as a reference for the level of energy generated by a system of this magnitude.

For a larger furnace, a greater number of tuyeres are required to provide constant heat throughout the blast zone. According to Klyacho and Shigorin (1975), the most intense period of this operation is at the start of the melting process as the largest amount of minerals are ignited simultaneously. In order to increase the heat of a flame, it requires a greater airflow. The Windsor Hum signature is unique in the sense that the noise experienced is likely to be mostly contained in the low frequency dynamics (LFD), ranging from 0 to 70 Hz. This range is also subject to both the audible as well as the inaudible, or feel sensation. Furnace operations contain instabilities caused primarily by temperature fluctuations, with factors such as modifications in the material volumes, changes in the airflow, etc. can also have an impact (Crocker 2007). These instabilities result in pressure changes, and it is shown below in **Figure 11,** the largest spike in pressure amplitude occurs in the LFD. It is important to note that **Figure 11** is only a typical spectrum depicting the changes in pressure caused by thermo-acoustic instabilities (Crocker

2007); with this in mind, it is shown that the principle spike in the LFD is estimated to be in the 60 to 80 Hz frequency range, which is within the same range that the Windsor Hum signature was characterized by the Windsor research team.

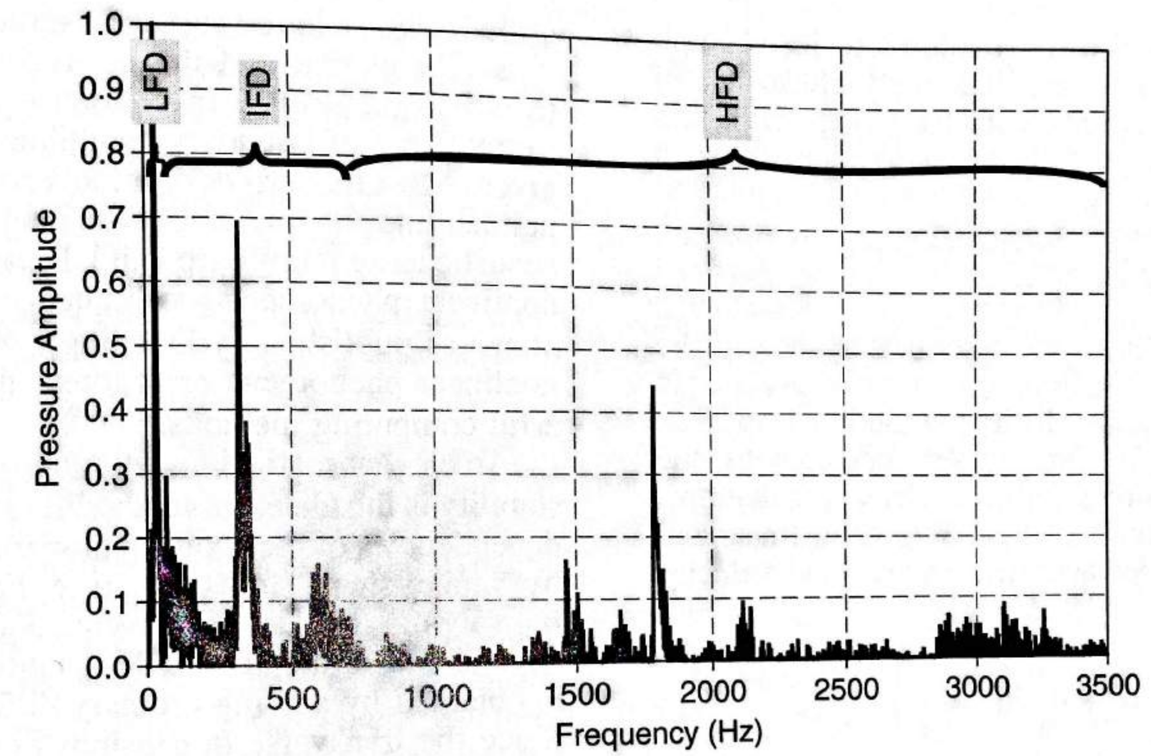

Figure 4 Typical spectrum of thermoacoustically induced pressure oscillations.

Figure 11: Typical Frequency Spectrum of Thermo-acoustically Induced Pressure Oscillations (Crocker 2007)

4.3.2 Air Discharge Valves (Snort Valves)

As the Windsor Hum is characterized by an intermittent time signature which can last hours at a time, it is unlikely that air-discharge valves are the primary cause of the disturbance. With that in mind, it is still important to account for all primary noise sources in a blast furnace environment.

Snort valves allow for the exhaust of excess pressure fluctuations into the atmosphere in case of emergency. This typically occurs when pockets of air and fuel ignite in the blast furnace and a large pressure burst results. When the snort valve is released, it is accompanied by a proportional blast of noise, which unless properly silenced, can propagate large distances from the facility.

Fortunately, successful attenuating measures have been found for effectively reducing snort valve noise. Each snort valve may be outfitted with perforated steel tube lined with steel wool as a sound absorbing-material. With a large enough silencer in place, the installation allows for effective attenuation with little impact on the capacity of the air-discharge valve, (Klyachko and Shigorin 1975).

4.3.3 Effluent Stack Burn Off from Hot-Blast Stove

As was shown in Figure 5 of this report, a large blue flame is an indication of a high temperature combustion process taking place. A flame of this type is capable of producing a large amount of turbulence and aerodynamic discharge noise which can be easily heard on the Canadian side of the Detroit River. The flame will typically have medium and high frequency components as opposed to the low-frequency spectra of the Windsor Hum. Due to the size of the stack and flame, attenuating this noise source is quite difficult. Smaller exhaust stacks require sound insulating covers which absorb the acoustic energy from the reaction. However, the high level of heat and fast flow-rate render this form of attenuation largely ineffective. Rerouting the exhaust or finding another means of dispersing the effluent may be necessary.

4.3.4 Boiler Facility Release

Once used, the steam from the boiler house is discarded, resulting in a violent gas expansion, see **Figure 12** below. During this release, noise levels can reach dangerous levels for workers nearby, while the high humidity levels make conventional attenuation methods inappropriate.

Figure 12: Photograph of Periodic Steam Release from Zug Island

4.3.5 Raw Material Screening Process

Screening operations produce large amounts of low frequency noise and vibrations as a result of centrifugal loading forces on the filter screens. This force is most often caused by an off-balanced rotation which if not properly absorbed will transfer into the bearing assembly and can propagate into the device mounts. (Klyachko and Shigorin 1975). Unwanted vibrations are commonly known to produce either ground borne noise and vibration, mechanical noise, or a combination of the two.

Decreasing the operating speed of the unbalanced force or isolating the machine from the surroundings can often effectively reduce these levels.

5. CONCLUSIONS AND RECOMMENDATIONS

The conclusion of the research is that the Windsor Hum does exist and has both qualitative and quantitative characteristics that surmise the likely source of the Hum to be from the blast furnace operations on Zug Island. It is further concluded that the Hum is audible by a concentrated portion of Windsor's west end community and other nearby residential areas. These conclusions are reinforced by the periodical nature of the Hum noise, which has been observed and measured by the researchers and coincides with the observed irregular operations associated with the steel making operations on Zug Island.

It is recommended that additional noise measurements be made in closer proximity of the target sources using the same techniques used in this study. Such an assessment should focus on nighttime operating conditions with acquired data coinciding with reports of the Hum on the Windsor side of the Detroit River. This however, will require access to the Zug Island if a meaningful outcome is expected.

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6. BIBLIOGRAPHY

American Iron and Steel Institute. *SteelWorks - The online resource for steel.* 2013. http://www.steel.org/ (accessed 12 06, 2013).

Bent, A.L., and C.R.D. Woodgold. *Seismic Investigation of the "Rumblings" in Windsor Ontario.* Geological Survey of Canada, Open File 6999, 2011.

Biswas, A.K. *Principles of Blast Furnace Ironmaking.* Brisbane: Cootha Publishing House, 1981.

Crocker, M. J. *Handbook of Noise and Vibration Control.* Hoboken: John Wiley & Sons Inc., 2007.

IHSA. "Construction Health & Safety Manual - Section 34 Steel Mills." *Infrastructure Health & Safety Association.* 2013. http://www.ihsa.ca/resources/health_safety_manual.cfm (accessed 12 06, 2013).

Klyachko, L.N., and P.I. Shigorin. "Reducing the Noise Level in Steel-Melting and Blast-Furnace Departments." *Metallurgy* 7 (July 1975): 40-42.

Peacey, J. G., and W. G. Davenport. *Principles of Blast Furnace Ironmaking: Theory and Practice.* Cootha, 1981.

Reeve, D. A., J. T. Price, and J. F. Gransden. *High Temperature Behaviour of Blast Furnace Coke – A Review*. Goverment Document, Canada Centre for Mineral and Energy Technology (CANMET), 1977.

Silber, E.A., and P.G. Brown. *Scientific Research to Characterize and Localize the Windsor Hum: Preliminary Report.* Department of Physics and Astronomy, University of Western Ontario, 2013.

Steel Works: The Online Resource for Steel. *How a Blast Furnace Works.* n.d. http://www.steel.org/Making%20Steel/How%20Its%20Made/Processes/How%20A%20 Blast%20Furnace%20Works%20larry%20says%20to%20delete.aspx (accessed October 2013).

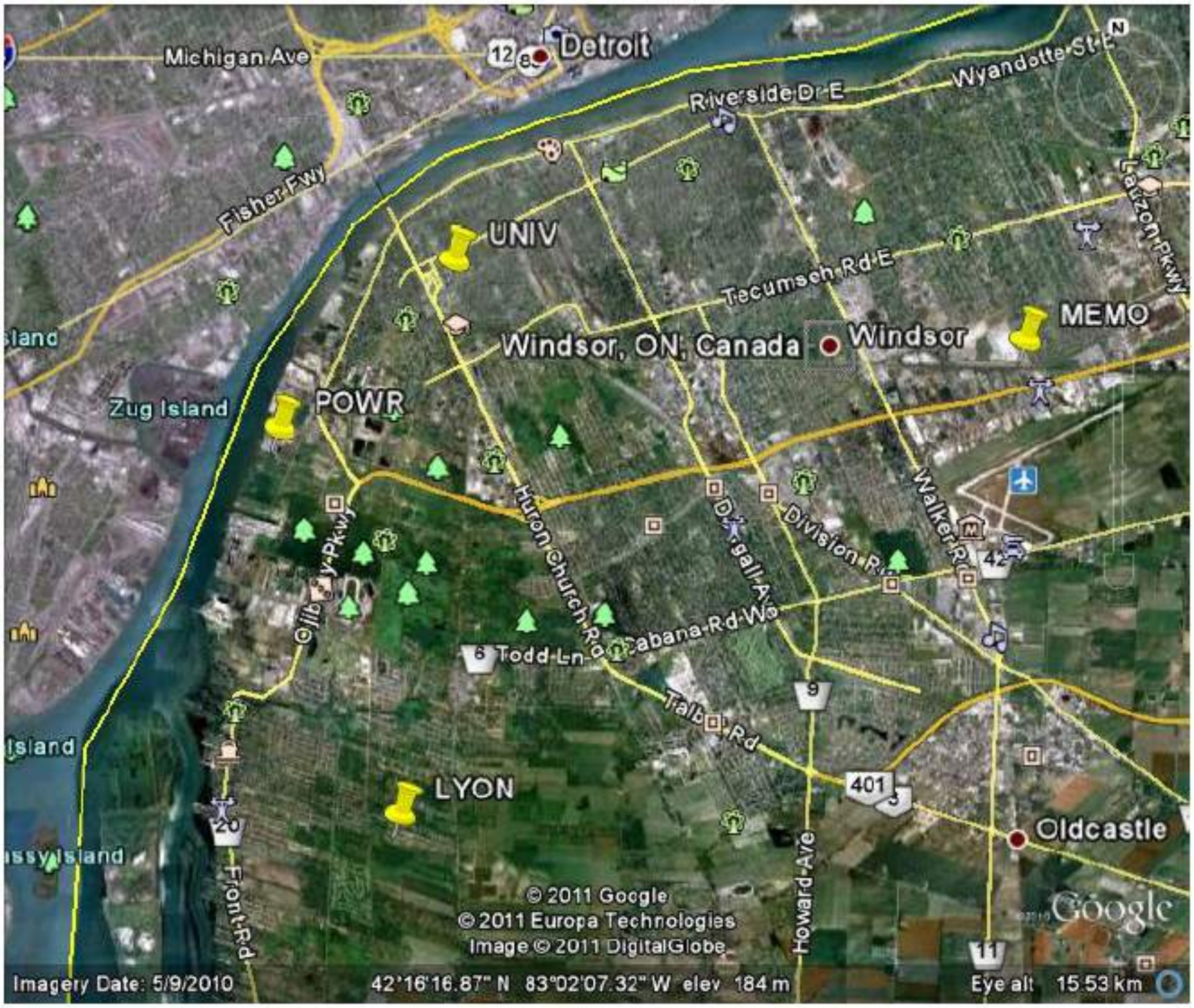
Szekely, J. *Blast Furnace Technology: Science and Practice.* New York: Marcel Dekker, 1972.

APPENDIX A
NRCan & UWO Data

Contents

NRCan Ground-borne Vibration Data
University of Western Ontario (UWO) Data

NRCan Ground-borne Vibration Data



A 1: Ariel View of NRCan Installations (Bent and Woodgold 2011)

<u>Station Identifiers:</u>

MEMO – Ministry of the Environment
UNIV – University of Windsor
POWR – Brighton Bean Power Station
LYON – Private Residence on Lyoness Avenue

Figure 15. Map showing locations of seismograph stations and best estimate (red region) for the location of the recorded signal discussed in the text. The red box indicates the region where the 95% confidence intervals of the data from stations LYON (yellow lines) and POWR (blue lines) overlap.

A 2: NRCan Source Estimation with 95% Confidence Interval (Bent and Woodgold 2011)

University of Western Ontario (UWO) Data

Figure 1: Map showing the locations of two infrasonic arrays deployed in Windsor. Array 2 is located ESE from Zug Island (top), while Array 1 as stationed further south (bottom).

A 3: UWO Monitoring Equipment Locations (Silber and Brown 2013)

Figure 3: Picture showing the array2 installation (Centre Element) at the TC site

A 4: Photograph of UWO Equipment (Centre Element) Installation (Silber and Brown 2013)

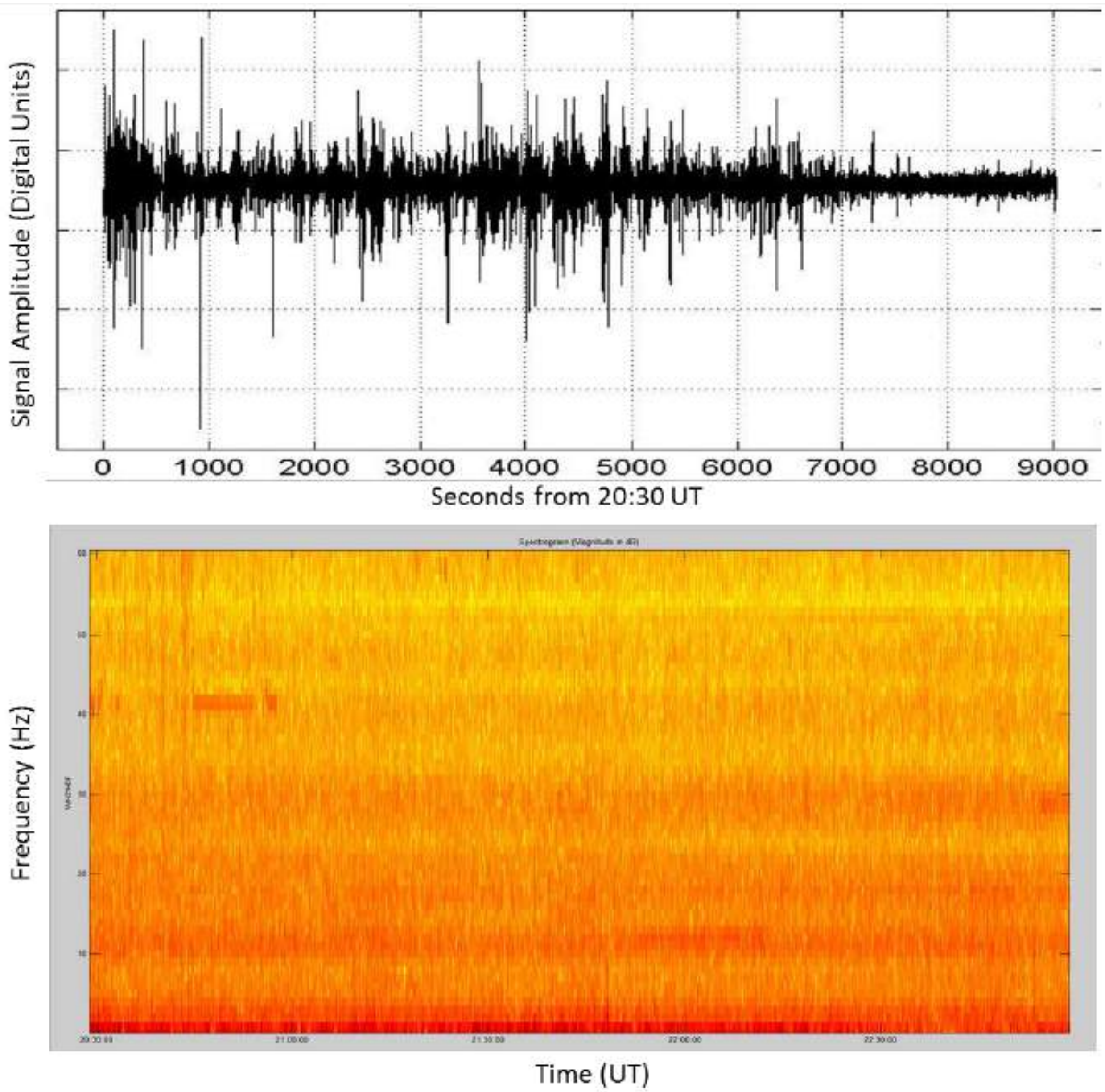


Figure 9: Waveform (above) showing total pressure amplitude as a function of time and spectrogram (below) of the signals received on March 18, 2013 starting at 20:30 UT at Array 2 (channel 1).

A 5: UWO Waveform and Spectrogram Plots (Silber and Brown 2013)

APPENDIX B
Brüel & Kjær Product Data Sheets

Contents

http://www.bksv.com

Noise Monitoring Terminal Type 3639-A

PRODUCT DATA

Noise Monitoring Terminals Types 3639 and 3655

The Brüel & Kjær family of Noise Monitoring Terminals (NMTs) is ideal for anyone who needs to continuously monitor noise levels in order to demonstrate compliance with regulations, manage their activities, limit noise impact or measure to improve their noise maps. Each NMT provides noise information you can trust, enabling you to make real-time decisions to avoid breaching noise restrictions. Unlike other instruments that are not specifically designed for continuous unattended outdoor monitoring, Brüel & Kjær NMTs accurately and reliably capture data. Each unit runs with little user attention, which reduces your total monitoring cost and reduces the demands on your valuable time.

The family of Noise Monitoring Terminals (NMTs) is made up of intelligent units designed to work unattended as part of an environmental noise monitoring system for permanent, mobile or portable monitoring. Using Brüel & Kjær noise management software, the NMTs can be controlled by a remote PC enabling them to measure, record, process, store and transmit noise information.

Uses and Features

Uses

- Permanent, mobile and portable monitoring of any application requiring unattended outdoor noise measurement

Features

- Specifically designed for permanent, continuous outdoor monitoring
- A wide range of solutions for all applications, needs and budgets
- Type approved to IEC 61672 Class 1 specifications; uniquely, including windscreen effects
- 120 dB dynamic range
- Self-monitoring capabilities for increased uptime
- Built-in facilities to minimise gaps in data
- Charge Injection Calibration (CIC) or a built in actuator for remote verification of the entire measurement chain
- Safe and reliable live data streaming
- LAN, WLAN, 3G and CDMA communication capabilities for remote operation
- Industry-standard Internet and security protocols for safe and reliable data transfer
- Wide range of integrated peripherals for communications, powering, mounting, weather, GPS, camera, etc.

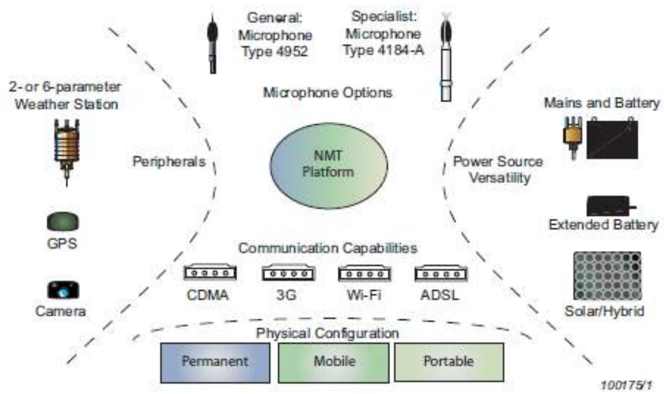
Brüel & Kjær

B 1: Noise Monitoring Terminals Types 3639 and 3655 – Uses and Features

Physical Configurations

The NMTs are modular both in hardware and software, making them suitable for a wide range of applications, needs and budgets. They come in a wide range of standard and customised configurations and with a wide range of accessories, peripherals and services, so whatever professional noise monitoring solution you need, Brüel & Kjær can deliver a solution. NMTs are available in permanent, mobile and portable variants with two microphone options for either general or specialist use. A wide range of peripherals covering communications, integrated weather monitoring, power, physical mounting and additional inputs such as GPS modules, cameras, etc., are available.

Fig. 1
Overview of the Noise Monitoring Terminal and its accessories



Permanent Noise Monitoring

Fig. 2
Permanent NMT mounted on a pole (microphone on top of pole not visible)

Suitable for permanent continuous monitoring at the same location for periods of several months to several years, Brüel & Kjær's Permanent NMTs (Fig. 2) have been specifically designed to operate unattended in harsh environments, protecting the contents from weather, tampering, vandalism, theft, etc. The durable, weatherproof cabinet includes a mounting kit for fastening the cabinet to a wall or pole. The cabinet is well protected by a weatherproof locking mechanism, and padlocks can be mounted. Protection is also provided for the cabling to reduce the risk of tampering or accidental damage. Permanent NMTs send a signal to the remote PC when the door is open, allowing unauthorised intrusion to be detected and recorded. The NMTs work according to specifications even in winter conditions, operating on mains down to –30°C. If required, a low-temperature protection kit is available for continuous operation under even more extreme weather conditions. Contact your local Brüel & Kjær representative for more information.

Permanent NMTs can be battery operated so that they can function when there is no usable local power source or mains power has been disrupted. They can be powered from a variety of sources, such as solar panels, through the DC supply input.

A 10 m microphone cable is included to ensure that the outdoor microphone can be positioned in the correct acoustical position while the cabinet is conveniently and securely mounted. It is easy to add new accessories, like a GPS unit or weather station, to the NMT even after the installation of the NMT on a wall or a pole, easing installation and configuration.

B 2: Noise Monitoring Terminals Types 3639 and 3655 – Physical Configurations

Different Microphones for Different Needs

Two different standard microphones, for either general use, appropriate for use in all applications, or for specialist use. The general-purpose Outdoor Microphone Type 4952 is a handy, robust outdoor microphone offering easy mounting, maintenance and calibration. The specialist Weatherproof Microphone Type 4184-A is an extremely robust microphone for demanding situations. Both ensure that the NMTs fulfil the strictest measurement standards (IEC 61672 Class 1) and give you results you can trust.

General Use: Outdoor Microphone Type 4952 (for General-purpose NMTs)

Fig. 5
Outdoor Microphone Type 4952 with integrated coupling for easy fitting onto the top of a water pipe

NMTs fitted with Outdoor Microphone Type 4952 are general purpose, suitable for all applications and for long periods of unattended outdoor use. The basic design principle is ease of use. The outdoor microphone is light, small and comes with integrated coupling for simple fitting on top of standard, widely available, 1" water pipe. The microphone's exterior housing is made of a chemical-resistant polymer that provides extremely high protection against corrosion. The microphone's long-term stability guarantees unattended outdoor use for up to a year without any significant change in sensitivity (after which period, the microphone should be checked and recalibrated). The windscreen and bird spike can be removed in seconds, enabling easy acoustical calibration of the microphone using Sound Calibrator Type 4231, which gives a fixed calibration signal, independent of atmospheric conditions. Frequency response is precisely controlled such that, with the appropriate linearization, IEC 61672 Class 1 requirements are fulfilled, with either 0 or 90° reference direction. Outdoor Microphone Type 4952 can be safely placed inside the NMT cabinet during transportation.

Specialist Use: Weatherproof Microphone Type 4184-A (for Specialist NMTs)

Fig. 6
Weatherproof Microphone Type 4184-A with adaptor for easy fitting onto the top of a standard water pipe

NMTs fitted with the Weatherproof Microphone Type 4184-A become suitable for specialist use where monitoring in a high-humidity or corrosive environment or where you wish to use an electrostatic actuator for remote calibration checks.

The Weatherproof Microphone is extremely robust and has become the global reference to which all other outdoor microphones are compared. The unit can be used in most humid and corrosive atmospheres because the casing is made completely of stainless steel and has a built-in protection system against humidity. The microphone's unique probe design ensures not only an extremely high level of protection within the casing, affording rain protection according to IEC 529 IP44 and operation all the way up to 100% RH, but also maintains measurement accuracy complying with the most strict measurement standards (IEC 61672 Class 1). The microphone has both CIC function and a built-in actuator for remote verification of system integrity and correct operation. Being extremely robust and with a high level of system integrity built in, the microphone requires little maintenance and offers high uptime and extreme long life, even after accredited calibrations and periodic verification due to the use of greasing to reseal the microphone unit.

B 3: Noise Monitoring Terminals Types 3639 and 3655 – Microphone Options

Noise Monitoring and Analysis

For all configurations, noise monitoring and analysis is performed by the included analyzer protected inside the cabinet. The analyzer measures data coming from the outdoor microphone and logs it onto its removeable memory, including broadband and spectral Leqs or SPLs[*] with one or two frequency weightings, continuously at half- or one-second intervals. The NMT can also identify, record and analyse noise events. Analyses produced include:

- **Hourly reports:** Information each whole hour including Total L_{eq} and statistical distribution. Total, Background and Noise Event L_{eq} and Effective Perceived Noise Level (EPN) of all events according to ICAO Annex 16
- **Short reports:** Information during a period of time between 1 and 30 minutes, calculating minimum, maximum, L_{eq} and five user-defined L_N values. Short reports can include sound recordings[†]
- **Calibration Check reports:** Results of the Charge Injection Calibration or Actuator tests, which can be performed automatically four times a day
- **Noise events:** Information on noise events detected based on hourly varying trigger and duration values. For each event, SPL or L_{eq} values, spectra, Perceived Noise Level (PNL), and Perceived Noise Level Tone Corrected (PNLT) values according to ICAO Annex 16, are stored at half- or one-second intervals. Sound recordings of events can also be stored
- **Instrument Health reports:** Information on the NMTs internal temperature, battery voltage, mains voltage and external voltage

Fig. 7
View the results and status of the NMT remotely from a web browser

Data can be streamed over LAN-based communication or via 3G, with a maximum deviation of two seconds from the NMT to the central control server with Brüel & Kjær noise management solutions. Once on the server, Brüel & Kjær's central control software client can access and analyse the data.

In addition, the NMT's user interface can be viewed directly in a web browser allowing simple remote access to data and the status of the NMT from any PC.[‡]

The NMT can be upgraded through its software licensing to interface to third party software for remote noise monitoring with batch data transfer.

Alarms[**]

Permanent NMTs have a number of alarms that are triggered as soon as the related condition is detected so users can quickly respond to issues. Alarms cover:

- Door Open/ Close
- Mains Power Off/On
- Battery Low/OK
- Temperature High/OK
- Communications power off/on

Setup and Calibration

The analyzer's display and interface eases initial setup and servicing. Initial calibration of the NMT is done using Sound Calibrator Type 4231 or Pistonphone Type 4228 – depending on microphone. In addition, the NMT has built-in CIC, a patented technique used for remotely monitoring the entire measurement setup including the microphone, preamplifier and connecting cable. With specialist NMTs, calibration check using an actuator is also possible. The NMT can initiate up to four automatic, routine system checks per day at user-specified times, storing results for later download and investigation.

[*] Two frequency weightings are not available with Types 3639-E and -G
[†] Sound recording quality, duration and level is user-defined. Recording low-quality files reduces the time and bandwidth required to download the files from the NMT, often reducing operating costs. High-quality files enable post-processing, for example, tone analysis to determine noise limit compliance based on rating levels, using Brüel & Kjær's PULSE Multi-analyzer system or other application.
[‡] Currently not available for Types 3639-E and -G
[**] Not all alarms are available for Type 3655 portable noise monitoring units

B 4: Noise Monitoring Terminals Types 3639 and 3655 – Noise Monitoring and Analysis

Power

Fig. 9
Add solar panels to the NMT to reduce power consumption or even allow 24/7 battery operation

Permanent NMTs are delivered with one battery so that the NMT can function if mains power has been disrupted. With two batteries mounted in the cabinet, the NMT can operate for 90 hours on battery power, thus fulfilling a range of specific legislation, standards and de facto good practice that demand significant battery back-up. With Battery Box UA-2141, the NMT can operate for 180 hours (more than seven days) on battery power for even more demanding remote monitoring locations.

The batteries are charged whenever external AC or sufficient DC power is applied to the NMT. Additionally, the NMT can be powered from a variety of sources connected through the DC supply input. Thus, solar panels can be added to the NMT, which enables lower power use or even permanent 24/7 operation. Additional batteries are used to provide sufficient backup for operation in overcast conditions, even during winter months.*

Note: The use of the peripheral devices described above may increase power consumption and reduce the back-up power duration.

Permanent Mounting

Permanent NMTs come complete with a mounting kit for fastening the cabinet to a wall or pole. This mounting kit allows of the use of small, low-cost, standard size water pipes to protect the cables for the microphone and weather station. For compliance with specific legislation, standards and de facto good practice, the microphone must be placed at, for example, 4 or 6 m height and at some distance from large reflecting surfaces. Brüel & Kjær can supply a range of alternative masts for permanent or temporary mounting of the cabinet and correct positioning of the microphone. These include ground-mounted, wall-mounted and telescopic masts. For more information, contact your local Brüel & Kjær representative.

Service and Support

Brüel & Kjær offers a wide range of support and services to ensure efficient and problem-free operation. These include a range of calibration services (accredited and traceable), repairs, conformance tests, warranty extensions, installation, training, a help line and equipment rental. These services can be performed on site, locally or at the factory. For example, Traceable Calibration is available both as an on-site service and as a more rigorous calibration at the factory in Denmark. Annual and long-term service packs for NMTs and for entire environmental noise management or noise monitoring systems are also available. In addition, NMTs may be operated from systems hosted by Brüel & Kjær, such as WebTrak for airports and Noise Sentinel for urban and industrial applications.

* For more information, see case study: Solar/Wind Power for Noise Monitoring Terminals (BN-0619) or contact your local Brüel & Kjær representative.

B 5: Noise Monitoring Terminals Types 3639 and 3655 – Power Options

Compliance with Standards

CE C-Tick	CE-mark indicates compliance with: EMC Directive and Low Voltage Directive. C-Tick mark indicates compliance with the EMC requirements of Australia and New Zealand.
Safety	EN/IEC 61010–1 and ANSI/UL 61010–1*: Safety requirements for electrical equipment for measurement, control and laboratory use. UL 61010B–1: Standard for Safety – Electrical measuring and test equipment.
EMC Emission	EN/IEC 61000–6–3: Generic emission standard for residential, commercial and light industrial environments. EN/IEC 61000–6–4: Generic emission standard for industrial environments.* CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits. FCC Rules, Part 15: Complies with the limits for a Class B digital device. IEC 61672–1, IEC 61260, IEC 60651 and IEC 60804: Instrumentation standards.
EMC Immunity	EN/IEC 61000–6–1: Generic standards – Immunity for residential, commercial and light industrial environments.* EN/IEC 61000–6–2: Generic standards – Immunity for industrial environments. EN/IEC61326: Electrical equipment for measurement, control and laboratory use – EMC requirements. IEC 61672–1, IEC 61260, IEC 60651 and IEC 60804: Instrumentation standards.

* Specifically referring to Type 3655-C

Note: The above is only guaranteed using accessories listed in this document

Conforms with the following National and International Sound Level Meter Standards:

- IEC 61672–1 (2002-05) Class 1
- IEC 60651 (1979) plus Amendment 1 (1993–02) and Amendment 2 (2000–10), Type 1
- IEC 60804 (2000–10), Type 1
- DIN 45657 (1997–07)
- ANSI S1.4–1983 plus ANSI S1.4 A–1985, Amendment, Type 1
- ANSI S1.43–1997, Type 1

Conforms to the following National and International Frequency Analysis Standards:

- IEC 61260 (1995–07) plus Amendment 1 (2001–09), 1/3-octave Bands Class 0
- ANSI S1.11–1986, 1/3-octave Bands, Order 3, Type 0–C
- ANSI S1.11–2004, 1/3-octave Bands, Class 0

Note: The International IEC Standards are adopted as European standards by CENELEC. When this happens, the letters IEC are replaced with EN and the number is retained. The analyzers also conform to these EN Standards

Specifications for Noise Monitoring Terminal Type 3639-A

All specifications are valid with Noise Monitoring Software BZ-7232 version 4.1.1.

General-purpose Permanent Noise Monitoring Terminal Type 3639-A is supplied with Outdoor Microphone Type 4952, which includes Microphone Preamplifier ZC-0034. The microphone can only be connected to the analyzer through a microphone extension cable

MICROPHONE
Type: Prepolarized Outdoor Microphone
Nominal Open Circuit Sensitivity: 31.6 mV/Pa, (corresponding to −30 dB re 1 V/Pa) ±2 dB
Capacitance: 12 pF (at 250 Hz)
Reference Direction: Selectable between 0° (Top) and 90° (Side)

MICROPHONE PREAMPLIFIER ZC-0034
Nominal Preamplifier Attenuation: 0.3 dB
Extension Cable between Microphone Preamplifier ZC-0034 and Analyzer: Up to 100 m without degradation of the specifications

MEASURING RANGES (BROADBAND)
Dynamic Range: From typical noise floor to max. level for a 1 kHz pure tone signal, A-weighted: 20.0 – 141 dB
Linear Operating Range: In accordance with IEC 61672, A-weighted: 1 kHz: 31.1 – 141 dB
Primary Indicator Range: In accordance with IEC 60651, A-weighted: 29.8 – 124 dB
Linearity Range: In accordance with IEC 60804, A-weighted: 27.7 – 141dB

MEASURING RANGES (1/3 OCTAVE)
Dynamic Range: From typical noise floor to max. level for a pure tone signal at 1 kHz 1/3-octave: 2.9 – 141 dB
Linear Operating Range: In accordance with IEC 61260: ≤29.5 – 139.3 dB

SELF-GENERATED NOISE LEVEL
Typical values at 23°C for nominal microphone open-circuit sensitivity:

Weighting	Microphone	Electrical	Total
A	14.0 dB	18.7 dB	20.0 dB
B	12.9 dB	17.5 dB	18.8 dB
C	13.0 dB	18.7 dB	19.7 dB
Z (5Hz – 20 kHz)	14.4 dB	24.8 dB	25.2 dB

B 6: Noise Monitoring Terminals Types 3639 and 3655 – Compliance with Standards and Specifications

Specifications for Noise Monitoring Terminal Type 3639-C

All specifications are valid with Noise Monitoring Software BZ-7232 version 4.1.1.

Specialist Permanent Noise Monitoring Terminal Type 3639-C is supplied with Weatherproof Microphone Type 4184-A, which includes Microphone Preamplifier ZE-0773. The microphone can only be connected to the analyzer with a microphone extension cable

MICROPHONE
Type: Weatherproof Microphone
Nominal Open Circuit Sensitivity: 10.9 mV/Pa, (corresponding to −39.25 dB re 1 V/Pa) ±1.5 dB
Capacitance: 18 pF (at 250 Hz)
Reference Direction: Selectable between 0° (Top) and 90° (Side)

MICROPHONE PREAMPLIFIER ZE-0773
Nominal Preamplifier Attenuation: 0.2 dB
Extension Cable between Microphone Preamplifier ZE-0773 and the Analyzer: Up to 100 m without degradation of the specifications

MEASURING RANGES (BROADBAND)
Dynamic Range: From typical noise floor to max. level for a 1 kHz pure tone signal, A-weighted: 28.8 – 149.7 dB
Linear Operating Range: In accordance with IEC 61672, A-weighted: 1 kHz: 40.2 – 149.7 dB
Primary Indicator Range: In accordance with IEC 60651, A-weighted: 38.9 – 132.7 dB
Linearity Range: In accordance with IEC 60804, A-weighted: 36.8 – 149.7 dB

MEASURING RANGES (1/3-OCTAVE)
Dynamic Range: From typical noise floor to max. level for a pure tone signal at 1 kHz 1/3-octave: 11.1 – 149.7 dB
Linear Operating Range: In accordance with IEC 61260: ≤37.0 – 149.7 dB

SELF-GENERATED NOISE LEVEL
Typical values at 23°C for nominal microphone open-circuit sensitivity:

Weighting	Microphone	Electrical	Total
A	21.1 dB	28.2 dB	28.8 dB
B	18.7 dB	26.8 dB	27.4 dB
C	18.7 dB	27.3 dB	27.9 dB
Z (5Hz – 20 kHz)	22.7 dB	32.5 dB	32.9 dB

Common Specifications for Types 3639-A and 3639-C

All specifications are valid with Noise Monitoring Software BZ-7232 version 4.1.1.

TRANSDUCERS
Transducers are described in a transducer database with information on Serial Number, Nominal Sensitivity, Polarization Voltage, Free-field Type, CCLD required, Capacitance and additional information.
The analog hardware is set up automatically in accordance with the selected transducer

CORRECTION FILTERS
For Microphone Types 4952 and 4184-A, Noise Monitoring Software BZ-7232 is able to correct the frequency response to compensate for sound field and accessories
Sound Field: Free-field or Diffuse-field. Two Free-field reference directions: 0° (Top) and 90° (Side)

MICROPHONE POLARIZATION VOLTAGE
Selectable between 0 V and 200 V

CALIBRATION
Initial calibration is stored for comparison with later calibrations
Acoustic calibration:
- NMT 3639-A and 3655-C: Using Sound Calibrator Type 4231 , the calibration process automatically detects the calibration level
- NMT 3639-C: Using Pistonphone Type 4228

Automatic checks: Performed up to 4 times per day
- NMT 3639-A: Charge Injection Calibration (CIC)
- NMT 3639-C: CIC or Actuator Calibration

Calibration History: Up to 20 of the latest calibrations made are listed. Can only be viewed on the analyzer

FREQUENCY ANALYSIS
1/1- or 1/3-octave band analysis (availability depending on the system management software used)
1/1-oct. Band Centre Frequencies: 16 Hz – 16 kHz
1/3-oct. Band Centre Frequencies: 12.5 Hz – 20 kHz

INPUT SOCKET
Connector: Triaxial LEMO
Input Impedance: ≥1 MΩ
Direct Input: Max. input voltage: ±14.14 Vpeak
CCLD Input: Max. input voltage: ±7.07 Vpeak
CCLD Current/Voltage: 4 mA/25 V

POWER CONSUMPTION

Operational Mode	Typical Power Draw at 12 V DC or Mains AC (W)	Comments
LAN (Analyzer and Utility Unit only)	4.5	
Router (operational)	3 (extra)	
Weather station	0.05 (extra)	For operation down to +3°C ambient temperature
	11 (extra)	For lower temperatures (**Note:** Between –2 and +3°C, the additional power needed is 5.5 W)
Heater (activated below 5°C)	18 (extra)	
Recharging internal batteries	7.5 (extra)	
Low-temperature Protection Kit	30 (extra)	Operate only on AC

POWER SUPPLY
The measuring part of Type 3639-A/C is powered from the analyzer's internal battery pack. The battery pack is charged from the external AC supply, External DC supply or the NMT Batteries. The NMT Batteries are charged from either the External AC supply or sufficient External DC supply. Typical Operating Times are given at room temperature. At low temperatures it will be reduced

Analyzer Battery Pack:
- Type: Rechargeable Li-Ion
- Typical Operating Time: 8 hours

NMT Batteries:
- Type: One or two 12 V rechargeable, valve regulated, lead acid
- Typical Operating Time: One battery, 45 hours; two batteries, 90 hours; four batteries, 180 hours*. With Cellular Router installed, 25/50/100 hours

* Requires Battery Box for Permanent NMTs UA-2141

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B 7: Noise Monitoring Terminals Types 3639 and 3655 – Common Specifications

External DC Power Supply:
- Voltage: 12 – 24 V DC

External AC Power Supply:
- Voltage: 90 – 132 and 180 – 264 V_{RMS}, Autoranging
- Frequency: 47 – 66 Hz

CLOCK
Back-up battery powered clock. Drift <0.45 seconds per 24-hour period

WARM-UP TIME
From Power Off: <2 minutes
From Standby: <10 seconds with prepolarized microphones

TEMPERATURE
IEC 60068–2–1 & IEC 60068–2–2: Environmental Testing. Cold and Dry Heat
Operating Temperature: –30 to +55°C (–22 to 131°F), <0.1 dB
Storage Temperature: –25 to +70°C (–13 to 158°F)

HUMIDITY
IEC 60068–2–78: Damp Heat: 90% RH (non-condensing at 40°C (104°F))
Effect of Humidity: <0.1 dB for 0% <RH <90% (at 40°C (104°F) and 1 kHz)

SOUND POWER EMITTED FROM TYPE 3639-A/C
Sound Power Level: <36 dB (A) L_W

MECHANICAL
Environmental Protection: IP 55 (without external cables), IP 44 (with external cables)
Non-operating:
- IEC 60068–2–6: Vibration: 0.3 mm, 20 m/s^2, 10 – 500Hz
- IEC 60068–2–27: Shock: 1000 m/s^2
- IEC 60068–2–29: Bump: 4000 bumps at 400 m/s^2

DIMENSIONS AND WEIGHTS
NMT Cabinet:
- Height: 610 mm (24 in)
- Width: 390 mm (15.4 in)
- Depth: 120 mm lb(4.7 in)
- Weight: 10.14 kg (22.4 lb) with no NMT battery; 16.1 kg (35.5 lb) with one battery; 22.4 kg (49.4 lb) with two NMT batteries

Mounting Kit: 7.5 kg (16.5 lb)

SOFTWARE
Measurement Partner Suite BZ-5503: Update of software and licenses for the analyzer. BZ-5503 is supplied on DVD BZ-5298

COMPUTER REQUIREMENTS (FOR BZ-5503)
Operating System: Windows® 7 or XP (32- or 64-bit versions)
Recommended PC:
- Intel® Core™ 2 Duo
- 2 GB RAM
- SVGA graphics display/adaptor
- Sound card
- DVD drive
- Mouse
- USB
- Windows® 7
- Microsoft®.NET 4.0

Specifications for Software Controlled via Remote PC

All specifications are valid with Noise Monitoring Software BZ-7232 version 4.1.1.

Noise Monitoring Terminal Type 3639-A/C can be remote controlled from a PC running Environmental Noise Management System Software Type 7843, ANOMS or Noise Sentinel Type 7871. The specifications that can be fulfilled is dependent on the system software used. In some cases, the relevant system software is specified

BASIC MEASUREMENTS
Logging Rate: ½ or 1 s
Detectors: Parallel detectors on every measurement:
A- or B-weighted (switchable): Broadband detector channel with one exponential time weighting (Fast, Slow, Impulse), one linearly averaging detector and one peak detector
C- or Z-weighted (switchable): As for A- or B-weighted
Overload Detector: Monitors the overload outputs of all the frequency weighted channels
Measurements:
X = frequency weightings A or B
Y = frequency weightings C or Z
V = frequency weightings A, B, C or Z
U = time weightings F,S or I

LXeq	LYeq	LXE	LYE	LCeq – LAeqk
LXUmax	LYUmax			
LXUmin	LYUmin			
LXIeq	LYIeq	LAIeq – LAeq		
Lvpeak				

EVENT DETECTION
Settings: Individual setting for each hour in a 24-hour period
Event Start Trigger: L_{eq} or $L_{(SPL)}$ with minimum threshold exceeding duration
Event Stop Trigger: L_{eq} or $L_{(SPL)}$ with minimum threshold exceeding duration

REPORTS*†
Short Reports:
- **Period:** User-defined 1 to 30 minutes, whole number of reports each hour
- **Data:** Start time; Stop time; Minimum of $L_{(SPL)}$ over the period; Maximum of $L_{(SPL)}$ over the period; Total L_{eq} over the period; Total L_{Ieq} over the period; 5 L_N Values with user-defined percentile levels; Standard deviation; Wind speed and wind direction (Noise Sentinel only)

One Hour Reports:
- **Data:** Start time; Stop time; Level distribution (per mil ‰ for L (instantaneous)) in 110 1 dB classes, plus an Overload class and a Below class; One hour minimum of $L_{(SPL)}$; One hour maximum of $L_{(SPL)}$; One hour total L_{eq}; One hour minimum of L_{eq}; One hour maximum of L_{eq}; L_{eq} Event value (total L_{eq} for all the events during the one-hour period); L_{eq} Background value (total L_{eq} for all the periods between events during the one-hour period); Persistent overload for the one-hour period; Standard deviation

Event Reports:
- **Data Compression:** Event data for ENM/Noise Sentinel are compressed. The event data samples are L_{eq} values if the trigger is set to L_{eq} and $L_{(SPL)}$ values if the trigger is set to SPL. The maximum number of samples is 101 (always one sample before trigger). If the event period exceeds 100 samples, the samples are compressed with a factor 2, 4, 8 ...
- **Data:** Based on ½ or 1 s logging. Start time; Stop time; Event data; T10 Duration (T10 is the time within the event where the level is below 10 dB of the maximum level); $L_{E(T10)}$ calculated over the T10 period; L_{eq} Spectrum (total L_{eq} spectrum over the event period); EPNL over the event period; Total L_{eq} over the event period; L_E calculated over the event period; Maximum of L_{eq} over the event period; Time of maximum of L_{eq}; Maximum of $L_{(SPL)}$ over the event period; Time of maximum of $L_{(SPL)}$; 120 PNL and PNLT, where each value is a 0.5 s PNL/PNLT value (dB 10); $L_{eq2} – L_{eq1}$
- **Additional Data for ANOMS:** Wind speed at time of maximum L_{eq}; Wind direction at time of maximum L_{eq}; Humidity; Temperature; Event spectra; Number of event spectra

* Which data is available is dependent on the central system management software the NMT is used with. For more information, see the relevant central system management software's Product Datasheet.
† All trigger levels, L_{eq} values and SPL values can be with one or two frequency weightings

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B 8: Noise Monitoring Terminals Types 3639 and 3655 – Common Specifications (Continued)

Sound Level Meter Type 2250

PRODUCT DATA

Hand-held Analyzer Types 2250 and 2270

with Sound Level Meter Software BZ-7222, Frequency Analysis Software BZ-7223, Logging Software BZ-7224, Enhanced Logging Software BZ-7225, Signal Recording Option BZ-7226 and Tone Assessment Option BZ-7231

Type 2250 and Type 2270 are the innovative, 4th generation hand-held analyzers from Brüel & Kjær. The analyzers' easy, safe and clever design philosophy is based on extensive research. Type 2250 has been awarded several prizes for its combination of excellent ergonomics and attractive design.

Both analyzers can host a number of applications, including frequency analysis, logging (profiling) and signal recording, but in addition, Type 2270 adds dual-channel capabilities such as sound intensity/sound power measurements and dual-channel building acoustics applications. Applications are available separately at any time – or you can order a fully pre-configured instrument from the factory.

The combination of application modules and innovative hardware makes these instruments into dedicated solutions for performing high-precision measurement tasks in environmental, occupational and industrial application areas. As a result, Brüel & Kjær delivers the functionality you need now, plus the capability to add more functionality later – this is a very secure investment.

Uses and Features

Uses

- Environmental noise assessment
- Occupational noise evaluation
- Reverberation Time measurements*
- Selection of hearing protection
- Noise reduction
- Product quality control
- Class 1 sound measurements to the latest international standards
- Real-time analysis of sound in 1/1- and 1/3-octave bands
- Tone assessment using 1/3-octave methods
- Loudness and noise rating measurements
- Analysis of time histories for broadband parameters and spectra (Logging)
- Documentation of measurements using text, voice and metadata annotations
- Documentation of measurements through recording of measured signals
- Logging up to 10 broadband parameters and 3 spectral parameters

Features

- Dual-channel measurement capability†
- Large, high-resolution, touch-sensitive color screen
- Data storage on high-capacity plug-in memory cards
- Communication via USB, LAN, or GPRS/3G modems
- Dynamic range in excess of 120 dB
- 3 Hz – 20 kHz broadband linear frequency range
- 24- or 16-bit recording during all or parts of a measurement (optional)
- Personalized measurement, display and job setup
- Integral digital camera for documentation and reference†
- "Smiley" quality indicators with hints and warnings
- Timers for automatic start of measurement
- PC software included for archiving, previewing and exporting data; software maintenance and remote online display
- Automatic detection of and correction for windscreen
- GPS coordinates stored with measurement data
- Simultaneous measurement of acoustic and weather parameter data
- Robust and environmentally protected (IP44)

* For more information, please refer to the relevant product data sheet.

† Type 2270 only.

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B 9: Hand-held Analyzer Types 2250 and 2270 – Uses and Features

Applications and Hardware

Introduction

Types 2250 and 2270 have generous hardware and software specifications. They deliver an extremely flexible instrument that can cover your current and future measurement and analysis needs – from the traditional uses in assessing environmental and workplace noise to industrial quality control and development. These analyzers offer a technological platform for performing measurement applications in a compact and robust hand-held instrument.

This data sheet describes different combinations of software modules (applications) available for Type 2250 and Type 2270. All instruments come with the Sound Level Meter Software BZ-7222 enabled. This makes them modern Class 1 Sound Level Meters (SLMs) and fulfil the requirements of the latest standard, IEC 61672–1, as well as earlier standards (see the specifications section for detailed compliance information). Even in their most basic configuration, these analyzers are delivered with a number of pre-defined measurement and display setups tailored to suit specific requirements.

Optional Applications

Additional applications that can be used in any combination can be purchased when needed and are delivered as easily installed licenses. Your hand-held analyzer investment is securely protected because when your need for measurements and analyses expands, these analyzers can accommodate your needs. Brüel & Kjær is committed to maintaining an ever-growing range of applications on these platforms.

The optional applications described in this data sheet are:

- **Frequency Analysis Software BZ-7223** – analyse in real-time the 1/1- and 1/3-octave filter bands over a wide frequency range with a dynamic range from the noise floor in each individual band to 140 dB
- **Logging Software BZ-7224** – freely select parameters to log at periods from 1 s to 24 h. Running together with SLM Software, all broadband parameters can be logged. If Frequency Analysis Software is also enabled, spectra can be logged at the same rates. Logging (or noise profiling) is used to develop time histories for use in environmental noise as well as workplace noise assessment
- **Enhanced Logging Software BZ-7225** – continuously monitor and log periodic reports in addition to the features of Logging Software. Parameters such as L_{dn} and L_{den} are calculated
- **Signal Recording Option BZ-7226** – attach actual samples of the measured signal to your measurements. This option works with all other applications. The recording uses the measurement transducer, while voice annotations (standard) use a separate commentary microphone
- **Tone Assessment Option BZ-7231** – identify any 1/3-octave bands with audible tones above a set limit

Information regarding the following applications can be found in their respective Product Data sheets:

- **Reverberation Time Software BZ-7227** – start a basic measurement by clapping your hands. The 'traffic light' shows measurement status at a glance, and the resulting reverberation time (RT) spectrum is shown as well as the average RT for the room. For assessing the acoustic quality of auditoria, halls, public spaces and workplaces. (Product Data BP 2152)
- **Building Acoustics Software BZ-7228 and Dual-channel Building Acoustics Software BZ-7229** – assess sound insulation in buildings and of building elements. Airborne as well as impact sound insulation can be measured, and final results shown on the spot to international (ISO) and 12 national standards. The required sound sources and PC reporting software are available, as well as complete building acoustics systems. (Product Data BP 2190)
- **FFT Analysis Software BZ-7230** – analyse frequency using the Fast Fourier Transform (FFT) algorithm, the tool of choice for measurement and diagnostics of machinery noise and vibration. The frequency 'profile' of a machine is its fingerprint, revealing sources of noise and vibration and their paths to the measurement position. Useful in product development, troubleshooting, quality control and environmental noise measurements.
  With Tone Assessment Option BZ-7231, FFT Analysis offers objective indication of tonal noise audibility and annoyance (Product Data BP 2183)
- **Sound Intensity Software BZ-7233 (Type 2270 only)** – make sound intensity measurements from beginning to end. A single user can make complete intensity measurements for total sound power and noise source location. You can use the built-in camera to take a photo to aid in probe placement during measurement and for use as a background for a map of the results (Product Data BP 2341)

Long-term and Continuous Noise Monitoring

For long-term and continuous noise monitoring, Brüel & Kjær offers a wide range of Noise Monitoring Terminal (NMT) and Noise Sentinel solutions that will meet and evolve with your needs. For more information, please consult Product Data BP 2379 for NMT solutions and Product Data BP 2389 for Noise Sentinel solutions.

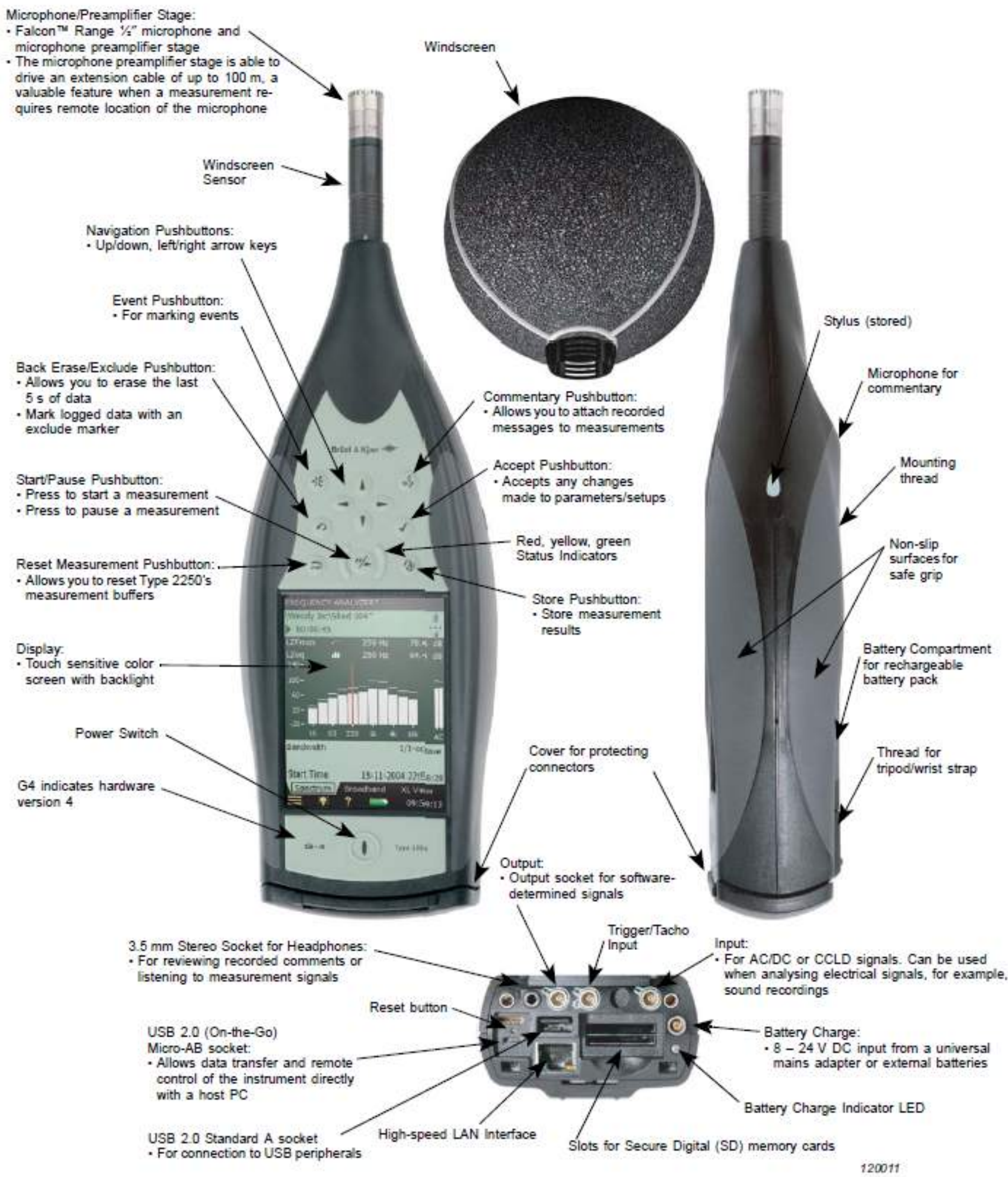
B 10: Hand-held Analyzer Types 2250 and 2270 – Applications and Hardware

Using the Platform

Great care has been taken to ensure that the hardware is ergonomically optimal in field use. Similarly, the software design has focused not only on making valid measurements but also on making field use efficient, convenient and intuitive.

All user choices for setups (what to measure) and preferences (how to display it) are controlled using easy to understand lists, that can be expanded and collapsed. No more cluttered displays, choose only the parameters you want to see.

Fig. 2 Key features of Hand-held Analyzer Type 2250



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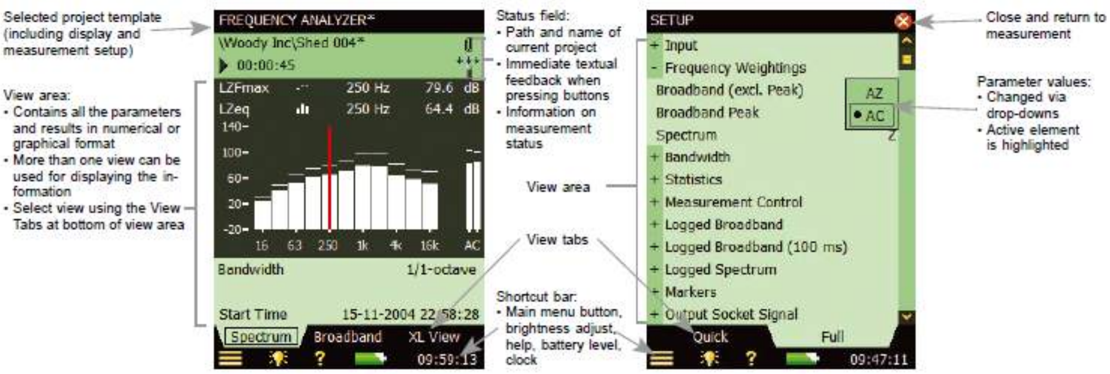
B 11: Hand-held Analyzer Types 2250 and 2270 – Using the Platform: Key Features

Display Capabilities

As a user, you have several ways of tailoring the display to suit your specific needs. However, standard display elements are used to ensure uniformity, not only across different applications, but also across different users, setups and preferences. Once you have set up your measurement and display parameters the way you wish, you can save the setup in user-defined templates.

Fig. 5 Typical display when (Left) measuring and (Right) modifying/updating the measurement setup.



Appearance

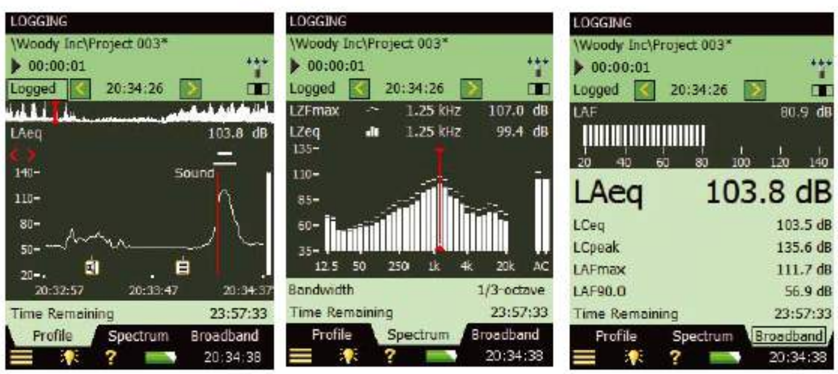
Fig. 6
Alternative display colour schemes – the left-hand display shows the maximum-contrast bright sunlight display. The right-hand display shows the night time display, which is optimised to take into account the physiology of human vision, allowing you to read the display without ruining your night vision.

The analyzer applies a default color scheme for the display, as seen in most examples in this data sheet. However, you can adjust color schemes to suit your needs – for example, for very bright light (where maximum contrast is needed) or for night-time use (where no interference with night-vision is wanted).

Data Display

The analyzers make a distinction between the measurement made and how it is displayed. The analyzers measure all quantities in parallel; however, you can choose to view any measured quantity during or after measurement without affecting your measured data.

Fig. 7
Logging Software BZ-7224 displays (from left to right): Profile with online sound marker, spoken commentary and note; current spectrum; and current broadband values.
Select freely between these displays at any time



For example, if logging broadband values and spectra, you can observe the profile, time history, overall or current spectrum, or overall or current broadband values. The display choice has no influence on what is measured or stored.

B 12: Hand-held Analyzer Types 2250 and 2270 – Display Capabilities

Compliance with Standards

CE ✓	CE-mark indicates compliance with the EMC Directive and Low Voltage Directive. C-Tick mark indicates compliance with the EMC requirements of Australia and New Zealand.
Safety	EN/IEC 61010–1, ANSI/UL 61010–1 and CSA C22.2 No.1010.1: Safety requirements for electrical equipment for measurement, control and laboratory use.
EMC Emission	EN/IEC 61000–6–3: Generic emission standard for residential, commercial and light industrial environments. CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits. FCC Rules, Part 15: Complies with the limits for a Class B digital device. IEC 61672–1, IEC 61260, IEC 60651 and IEC 60804: Instrumentation standards. Complies with Canadian standard ICES–001
EMC Immunity	EN/IEC 61000–6–2: Generic standard – Immunity for industrial environments. EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements. IEC 61672–1, IEC 61260, IEC 60651 and IEC 60804: Instrumentation standards

Specifications – Hand-held Analyzer Type 2250/2270 Platform

Specifications apply to Type 2250/2270 fitted with Microphone Type 4189 and Microphone Preamplifier ZC-0032

Microphone

SUPPLIED MICROPHONE
Type 4189: Prepolarized Free-field ½″ Microphone
or
Type 4190: Free-field ½″ Microphone
Nominal Open-circuit Sensitivity: 50 mV/Pa (corresponding to –26 dB re 1 V/Pa) ± 1.5 dB
Capacitance: 14 pF (at 250 Hz)

MICROPHONE PREAMPLIFIER ZC-0032
Nominal Preamplifier Attenuation: 0.25 dB
Connector: 10-pin LEMO
Extension Cables: Up to 100 m in length between the microphone preamplifier and Type 2250/2270, without degradation of the specifications
Accessory Detection: Windscreen UA-1650 can be automatically detected when fitted over ZC-0032

MICROPHONE POLARIZATION VOLTAGE
Selectable between 0 V and 200 V

SELF-GENERATED NOISE LEVEL
Typical values at 23°C for nominal microphone open-circuit sensitivity:

Weighting	Microphone	Electrical	Total
"A"	14.6 dB	12.4 dB	16.6 dB
"B"	13.4 dB	11.5 dB	15.6 dB
"C"	13.5 dB	12.9 dB	16.2 dB
"Z" 5 Hz–20 kHz	15.3 dB	18.3 dB	20.1 dB
"Z" 3 Hz–20 kHz	15.3 dB	25.5 dB	25.9 dB

Interface

KEYBOARD
Pushbuttons: 11 keys with backlight, optimised for measurement control and screen navigation

ON-OFF BUTTON
Function: Press 1 s to turn on; press 1 s to enter standby; press for more than 5 s to switch off

STATUS INDICATORS
LEDs: Red, amber and green

DISPLAY
Type: Transflective back-lit colour touch screen
240 × 320 dot matrix
Colour Schemes: Five different – optimised for different usage scenarios (day, night, etc.)
Backlight: Adjustable level and on-time

USER INTERFACE
Measurement Control: Using pushbuttons on keyboard
Setup and Display of Results: Using stylus on touch screen or pushbuttons on keyboard
Lock: Keyboard and touch screen can be locked and unlocked

USB INTERFACE
USB 2.0 OTG Micro AB and USB 2.0 Standard A sockets

MODEM INTERFACE
Connection to Internet through GPRS/EDGE/HSPA modem connected through the USB Standard A Socket
Supports DynDNS for automatic update of IP address of host name

PRINTER INTERFACE
PCL printers, Mobile Pro Spectrum thermal printer or Seiko DPU S245/S445 thermal printers can be connected to USB socket

MICROPHONE FOR COMMENTARY
Microphone, which utilises Automatic Gain Control (AGC), is incorporated in underside of analyzer. Used to create voice annotations for attaching to measurements

CAMERA (TYPE 2270 ONLY)
Camera with fixed focus and automatic exposure is incorporated in underside of analyzer.
Used to create image annotations for attaching to measurements
Image Size: 2048 x 1536 pixels
Viewfinder Size: 212 x 160 pixels
Format: JPG with exif information

Inputs/Outputs

SECURE DIGITAL SOCKET
2 × SD sockets
Connect SD and SDHC memory cards

LAN INTERFACE SOCKET
- Connector: RJ45 Auto-MDIX
- Speed: 100 Mbps
- Protocol: TCP/IP

B 13: Hand-held Analyzer Types 2250 and 2270 – Compliance with Standards and Specifications

INPUT SOCKET (2 - TYPE 2270 ONLY)
Connector: Triaxial LEMO
Input Impedance: ≥ 1 MΩ
Direct Input: Max. input voltage: ± 14.14 V_{peak}
CCLD Input: Max. input voltage: ± 7.07 V_{peak}
CCLD Current/voltage: 4 mA/25 V

TRIGGER SOCKET
Connector: Triaxial LEMO
Max. Input Voltage: ± 20 V_{peak}
Input Impedance: > 47 kΩ
Precision: ± 0.1 V

OUTPUT SOCKET
Connector: Triaxial LEMO
Max. Peak Output Level: ± 4.46 V
Output Impedance: 50 Ω

HEADPHONE SOCKET
Connector: 3.5 mm Minijack stereo socket
Max. Peak Output Level: ± 1.4 V
Output Impedance: 32 Ω in each channel

Power

EXTERNAL DC POWER SUPPLY REQUIREMENTS
Used to charge the battery pack in the analyzer
Voltage: 8 – 24 V DC, ripple voltage < 20 mV
Current Requirement: min. 1.5 A
Power Consumption: < 2.5 W, without battery charging, < 10 W when charging
Cable Connector: LEMO Type FFA.00, positive at centre pin

EXTERNAL AC MAIN SUPPLY ADAPTOR
Part No.: ZG-0426
Supply Voltage: 100 – 120/200 – 240 VAC; 47 – 63 Hz
Connector: 2-pin IEC 320

BATTERY PACK
Part No.: QB-0061 Rechargeable Li-Ion battery
Voltage: 3.7 V
Capacity: 5200 mAh nominal
Typical Operating Time:

- Single-channel: >11 h (screen backlight dimmed); >8.5 h (full screen backlight)
- Dual-channel: >7.5 h (full screen backlight)

Use of external interfaces (LAN, USB, WLAN) will decrease battery operating time
Battery Cycle Life: > 500 complete charge/discharge cycles
Battery Aging: Approximately 20% loss in capacity per year
Battery Indicator: Remaining battery capacity and expected working time may be read out in % and in time
Battery Fuel Gauge: The battery is equipped with a built-in fuel gauge, which continuously measures and stores the actual battery capacity in the battery unit
Charge Time: In analyzer, typically 10 hours from empty at ambient temperatures below 30°C. To protect the battery, charging will be terminated completely at ambient temperatures above 40°C. At 30 to 40°C charging time will be prolonged. With External Charger ZG-0444 (optional accessory), typically 5 hours
Note: It is not recommended to charge the battery at temperatures below 0°C (32°F) or over 50°C (122°F). Doing this will reduce battery lifetime

CLOCK
Back-up battery powered clock. Drift < 0.45 s per 24 hour period

Storage

INTERNAL FLASH-RAM (NON-VOLATILE)
For user setups and measurement data: 512 MB

EXTERNAL SECURE DIGITAL MEMORY CARD
SD and SDHC Card: For store/recall of measurement data

USB MEMORY STICK
For store/recall of measurement data

Environmental

WARM-UP TIME
From Power Off: < 2 minutes
From Standby: < 10 seconds for prepolarized microphones

TEMPERATURE
IEC 60068–2–1 & IEC 60068–2–2: Environmental Testing. Cold and Dry Heat.
Operating Temperature: –10 to + 50°C (14 to 122°F), < 0.1 dB
Storage Temperature: –25 to +70°C (–13 to +158°F)

HUMIDITY
IEC 60068–2–78: Damp Heat: 90% RH (non-condensing at 40°C (104°F)).
Effect of Humidity: < 0.1 dB for 0% < RH < 90% (at 40°C (104°F) and 1 kHz)

MECHANICAL
Environmental Protection: IP44
Non-operating:
IEC 60068–2–6: Vibration: 0.3 mm, 20 m/s^2, 10 – 500 Hz
IEC 60068–2–27: Shock: 1000 m/s^2
IEC 60068–2–29: Bump: 4000 bumps at 400 m/s^2

WEIGHT AND DIMENSIONS
650 g (23 oz.) including rechargeable battery
300 × 93 × 50 mm (11.8 × 3.7 × 1.9″) including preamplifier and microphone

User Interface

USERS
Multi-user concept with login. Users can have their own settings with jobs and projects totally independent of other users

PREFERENCES
Date, Time and Number formats can be specified per user

LANGUAGE
User Interface in Catalan, Chinese (People's Republic of China), Chinese (Taiwan), Croatian, Czech, Danish, English, Flemish, French, German, Hungarian, Japanese, Italian, Korean, Polish, Portuguese, Romanian, Russian, Serbian, Slovenian, Spanish, Swedish and Turkish

HELP
Concise context-sensitive help in English, French, German, Italian, Japanese, Korean, Polish, Portuguese, Romanian, Serbian, Slovenian and Spanish

UPDATE OF SOFTWARE
Update to any version using BZ-5503 through USB or update via Internet:

- any version from 4.0 and up

REMOTE ACCESS
Connect to the analyzer using Measurement Partner Suite BZ-5503, using the 2250/2270 SDK (Software Development kit) or using an Internet browser supporting Java Script. The connection is password protected
Two levels of protection:

- Guest level: for viewing only
- Administrator level: for viewing and full control of the analyzer

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B 14: Hand-held Analyzer Types 2250 and 2270 – Specification (Continued)

Outdoor Microphone Type 4952

PRODUCT DATA

Outdoor Microphones — Types 4952 and 4952-A

Outdoor Microphones Types 4952 and 4952-A are suitable for long periods of unattended outdoor use. Their exterior housing is made of a chemical resistant polymer that provides extremely high protection against corrosion.

The microphones' long-term stability guarantees unattended outdoor use for up to a year without any significant change in sensitivity.

Frequency response is precisely controlled, such that, with the appropriate linearization, IEC 61672 Class 1 requirements are fulfilled.

The windscreen upper part and bird spike can be removed in seconds, enabling easy acoustical calibration of the microphone.

Low weight makes this an ideal choice for portable use.

USES AND FEATURES

USES

- Unattended outdoor installations
- Measurements in all weather conditions
- Microphone for noise monitoring systems
- IEC 61672 Class 1 compliant outdoor sound measurement
- Complaint investigations

FEATURES

- Easy 'click-on' and 'click-off' assembly and disassembly
- Easy and true acoustical calibration
- CIC for on-site verification
- Measurement to EN/IEC 61672 Class 1 and ANSI S 1.40 – 1984
- Sensitivity 31,6 mV/Pa
- Wide dynamic range
- Built-in preamplifier with TEDS – IEEE P1451.4
- Protected against the effects of wind, rain and perching birds
- Useable for both 0° and 90° angle of incidence

Brüel & Kjær

B 15: Product Data: Outdoor Microphones – Type 4952 – Uses and Features

Description

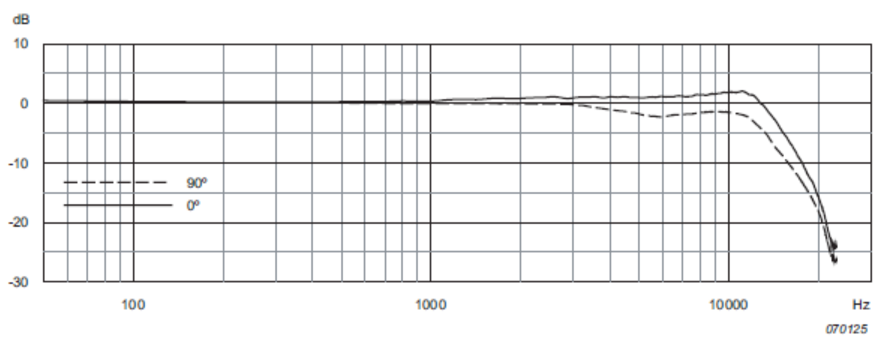
The exterior housing of Outdoor Microphones Types 4952 and 4952-A is made of a chemical resistant polymer that provides extremely high protection against corrosion. This and the microphones' excellent long-term stability guarantee unattended outdoor use for at least a year with no significant change in sensitivity.

Many outdoor microphone systems provide durability at the expense of microphone accessibility, which makes acoustical calibration difficult. With Types 4952 and 4952-A, the windscreen can be removed in seconds, enabling easy true acoustical calibration of the microphone.

The Brüel & Kjær patented Charge Injection Calibration (CIC) feature allows precise verification of the microphone (including preamplifier and cabling) at remote sites.

Frequency response is precisely controlled, such that, with the appropriate linearization (as available with Brüel & Kjær's Noise Monitoring Terminal Type 3639-E), EN/IEC 61672 Class 1 requirements are fulfilled up to 20 kHz. Typical frequency response without linearization is shown in Fig. 1.

Fig. 1 Type 4952 – Typical frequency response



Directivity Response

The complete microphone unit including wind and rain protection has been carefully designed in order to obtain true omnidirectional characteristics. With the appropriate filtering (as available in recommended Brüel & Kjær instrumentation), the requirements of the IEC 61672 paragraph 5.3 (table 1) and ANSI S1.4–1983 can be met with the same Outdoor Microphone, both for 0° and 90° reference direction, thus increasing the number of possible applications for Outdoor Microphones Types 4952 and 4952-A.

Windscreen and Rain Protection

A carefully designed windscreen keeps the airflow away from the microphone, thereby avoiding influence on the diaphragm from flow-borne pressure fluctuations. The windscreen also protects the microphone and preamplifier from the direct airflow, eliminating flow noise caused by von Karman vortices.

Additionally, the windscreen provides rain protection, but even if water should enter behind the windscreen, acoustically designed fine-mesh water protection will lead the water away, providing double rain protection for the microphone cartridge.

The upper part ends in a bird spike, which prevents birds from perching on the microphone. The end of the bird spike is rounded in order to reduce the risk of eye injury.

B 16: Product Data: Outdoor Microphones – Type 4952 – Description

Finally the windscreen can be replaced easily, and spare windscreens are available in sets of six in order to reduce the cost of lifetime ownership.

Mounting
This Outdoor Microphone is available in two variants: Types 4952 and 4952-A. Type 4952 fits onto a pole with 1″ thread according to ISO 228 BSP (British Standard Pipe). Type 4952-A includes Tripod Adaptor UA-1707 for tripod mounting.

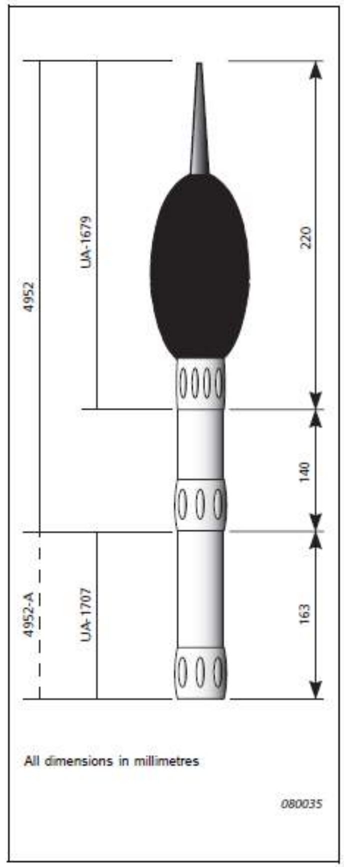
For both variants, the output socket is located under the pole coupling so that the connector and cable are well protected.

Long Lasting
The units provide excellent long-term mechanical stability. Replacement upper parts with windscreen are available.

Microphone Cartridge
Types 4952 and 4952-A feature a highly stable, prepolarized, free-field, ½″ type 1 microphone cartridge with a stainless steel diaphragm.

Integral Preamplifier
The integrated preamplifier operates over a wide range of temperatures, humidity levels and other environmental conditions. It combines an extremely wide frequency and dynamic range with low noise and is capable of driving very long cables.

Calibration Chart Included
A calibration chart, showing the frequency response for 0° as well as 90° angle of incidence, is included with the Outdoor Microphone.



Compliance with Standards

CE C-Tick	CE-mark indicates compliance with: EMC Directive and Low Voltage Directive. C-Tick mark indicates compliance with the EMC requirements of Australia and New Zealand.
Safety	EN/IEC 61010–1 and ANSI/UL 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use.
EMC Emission	EN/IEC 61000–6–3: Generic emission standard for residential, commercial and light industrial environments. EN/IEC 61000–6–4: Generic emission standard for industrial environments. CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits. FCC Rules, Part 15: Complies with the limits for a Class B digital device.
EMC Immunity	EN/IEC 61000–6–1: Generic standards – Immunity for residential, commercial and light industrial environments. EN/IEC 61000–6–2: Generic standards – Immunity for industrial environments. EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements. **Note:** The above is only guaranteed using accessories listed in this Product Data sheet.
Mechanical	Non-operating: IEC 60068–2–6: Vibration: 0.3 mm, 20 m/s^2, 10–500 Hz IEC 60068–2–27: Shock: 1000 m/s^2 IEC 60068–2–29: Bump: 1000 bumps at 400 m/s^2
Enclosure	IEC 60529: Protection provided by enclosures: IP 44.

3

B 17: Product Data: Outdoor Microphones – Type 4952 – Description (Continued) and Compliance with Standards

Specifications – Outdoor Microphones Types 4952 and 4952-A

Guaranteed Specifications[a]

SENSITIVITY (at 250 Hz)
31.6 mV/Pa corresponding to – 30 dB re 1 V/Pa ±3 dB

General Specifications

FREQUENCY RESPONSE
Calibration Chart with typical frequency response for both 0° and 90° angle of incidence, see Fig. 1

SUPPLY VOLTAGE
±14 to ±60 V
or 28 to 120 V

MICROPHONE POLARIZATION VOLTAGE
0 V

INHERENT NOISE
<16 dB SPL (A-weighted)

MAX SPL
>130 dB

MAX. OUTPUT VOLTAGE
V_{supply} –10 V

OUTPUT IMPEDANCE
<25 Ω

MAX. OUTPUT CURRENT
20 mA peak

OUTPUT SLEW RATE
2 V/µs

a. Guaranteed specifications are valid at 23°C (73.4°F).

PREAMPLIFIER CONNECTOR
LEMO Type FWG.IB.307

MOUNTING THREAD
Standard 1" thread according to ISO 228 ("water pipe thread")

Environmental

OPERATING TEMPERATURE RANGE
–30 to +60°C (–22 to +140°F)

STORAGE TEMPERATURE
– 30 to +70°C (–22 to +158°F)

TEMPERATURE COEFFICIENT (at 250 Hz)
–10 to +50°C 0.005 dB/K

OPERATING HUMIDITY RANGE
0% – 100% RH without condensation

INFLUENCE OF HUMIDITY
< 0.1 dB in the absence of condensation

PRESSURE COEFFICIENT (at 250 Hz)
–0.021 dB/kPa

VIBRATION SENSITIVITY (< 1 kHz)
63.5 dB equivalent SPL for 1 m/s² axial acceleration

MAGNETIC FIELD SENSITIVITY
7 dB SPL for 80 A/m, 50 Hz field

DIMENSIONS
Max. Diameter: 75 mm (2.59")

4952	**Max. Length:**	360 mm (14.2")
	Weight:	230 g (8.12 oz.)
4952-A	**Max. Length:**	523 mm (20.6")
	Weight:	430 g (15.17 oz.)

Ordering Information

Optional Accessories

CABLES[b]

AO-0414	Microphone extension cable for Type 3639-E, LEMO 1B to LEMO 1B
AO-0645	Microphone extension cable for 2250, LEMO 1B female to 10-pin LEMO 1B male

OTHER

UA-1700	Windscreen for Type 4952
UA-1701	Windscreens for Type 4952, set of 6
UA-1679	Upper part, complete with windscreen
UA-1251	Lightweight tripod

b. Cables are available in customer specified lengths

OPTIONAL ACCESSORIES (4952 only)

UA-1707	Tripod adaptor for Type 4952

Services

4952-CAF	Accredited Calibration of Outdoor Microphone, Replacement of Windscreen Included
4952-CTF	Traceable Calibration of Outdoor Microphone, Replacement of Windscreen Included

For annual preventive maintenance, including recalibration, please consult your local Brüel & Kjær representative

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Local representatives and service organisations worldwide

Brüel & Kjær

BP 2099 – 12 2008-03 Rosendahls Bogtrykkeri

B 18: Product Data: Outdoor Microphones – Type 4952 – Specifications

A Heritage of Excellence

Brüel & Kjær has more than 70 years of proven committment to continuous product improvement and groundbreaking new innovations in measurement transducers.

Milestones in Brüel & Kjær Microphone History

Generation	Year	Type	Milestone
First Generation	1956	Type 4131	World's first volume-produced measurement microphones, Types 4131 (free-field) and 4132 (pressure-field), developed, amongst others, by Dr. Per V. Brüel
	1967	Type 4138	World's first 1/8" measuring microphone. Due to on-going product improvements, this type is still available
	1975	Type 4160	Brüel & Kjær is requested to produce a replacement for the Western Electric WE 640 AA Reference Microphone. As a result, Type 4160 and later the ½" Type 4180 were introduced (still the world de facto acoustical standards)
	1980	Type 4155	Brüel & Kjær launches the world's first high-stability, measurement grade, electret microphones
	1984	Type 4179	Using advanced modelling and clever design, this microphone has a noise floor of –2.5 dB(A), still unbeaten after nearly 30 years!
Falcon Range	1987	Type 4182	Brüel & Kjær introduces probe microphone for measurement in extremely confined spaces and up to more than 600ºC
	1993	Type 4188*	Falcon series is introduced. Featuring stainless steel, press-fitted diaphragms, these microphones result in a step change in microphone technology
	1994	Type 4189	Falcon series at peak performance. Type 4189 is probably the world's most popular ½" free-field microphone
	2000	Type 4297	The world's only one-unit Sound Intensity Calibrator enables calibration without dismantling the probe
Titanium Generation	2003	Type 4948*	Surface Microphone – a Brüel & Kjær first: an "all titanium" sensor originally developed for aerospace applications
	2004	Type 4949*	Surface Microphones now also find their way into the automotive industry, where they break new frontiers in wind-tunnel testing
	2005	Type 4952*	World's first outdoor microphone where all parts exposed to the weather are made from polymer materials
	2006	Type 4955*	Continuing the "All Titanium" concept, this TEDS microphone has 1.1V/Pa sensitivity and a typical noise floor of 5.5dB
	2009	Type 4961	Multi-field Microphone – world's first ¼" measurement microphone that guarantees accurate and error-free measurements in both free and diffuse fields and at any angle
	2012	Type 1706	World's first microphone preamplifier that can handle temperatures up to +125°C/+257°F

Pictures are not to scale

* Utilising one or more Brüel & Kjær patented principles

060229/1

6 Brüel & Kjær Transducers www.bksv.com/transducers

B 19: Transducers and Conditioning – Microphone History

Outdoor Microphones

Brüel & Kjær's outdoor microphones are intended for permanent or semi-permanent outdoor use. In addition to the obvious weather protection, other features can be found with all Brüel & Kjær outdoor microphones, including calibration facilities, on-site remote verification (CIC), and conformance with standards of special importance such as IEC 61672, Electroacoustics – Sound Level Meters. This particular standard defines the requirements to the directivity response of the microphone and is often overlooked or misinterpreted.

- **Weatherproof Microphone Unit Type 4184** is for permanent, semi-permanent and portable noise monitoring. It features a probe type microphone for optimal protection and directivity response plus both CIC facility and a built-in acoustic sound source for verification
- **Outdoor Microphone Type 4198** is for semi-permanent noise monitoring. Depending on circumstances, this well protected microphone can sustain several months of unattended use. Features CIC, a Falcon range microphone and Outdoor Microphone Kit UA-1404
- **Outdoor Microphone Type 4952** has outer parts constructed of carefully selected polymer materials making it suitable for longer periods of unattended outdoor use (at least one year service intervals). This microphone also features CIC. The use of separate equalization filters enables Type 4952 to fulfil the requirements of IEC 61672 both for 0° and 90° of incidence
- **Outdoor Microphone Kit UA-1404** is for the protection of your existing Type 4188, 4189, or 4190 microphones

All outdoor microphones are supported by a broad range of accessories. Please refer to the Microphone Accessories for an overview.

Type No.		4184	4198	4952
Diameter	inch	Probe	1/2	1/2
Optimized		Outdoor	Outdoor	Outdoor
Standards		I, K	I, K	I, K
Nominal Open-circuit Sensitivity	mV/Pa	12.5	50	31.6
Polarization Voltage*	V	200	0	0
Optimized Frequency Response ±2 dB	Hz	20 to 8000	6.3 to 16000	8 to 12.5 k
Dynamic Range with Preamplifier	dB(A) to dB	25 to 140	15.2 to 146	15.8 to 146
Inherent Noise	dB (A)	25	15.2	< 16
Venting		Yes	Rear	Rear
Lower Limiting Frequency (–3 dB)	Hz	< 20	2 to 4	1 to 5
Operating Temperature Range	°C	–40 to 55	–25 to 60	–30 to 60
Temperature Coefficient	dB/°C	–0.005	–0.001	0.005
Pressure Coefficient	dB/kPa	–0.006	–0.01	–0.021
Preamplifier Included		Yes	Yes	Yes
Connector		B&K 7-pin	LEMO 1B	LEMO 1B

* 0 V = Prepolarized microphone

B 20: Transducers and Conditioning – Outdoor Microphone Comparison

PRODUCT DATA

LAN-XI Data Acquisition Hardware for PULSE™ and Test for I-deas™

From 2 to 1000+ channels in the same system

LAN-XI Data Acquisition Hardware is a versatile system of modular hardware that can be used as a stand-alone, single-module front-end, as part of a distributed module setup, or collected in 5- or 11-module frames. The hardware works with both PULSE and Test for I-deas.

The individual modules have a very rugged industrial design, perfect for use in the field, and, at the same time, are plug and play modules that you can easily reconfigure in different setups. Running on AC, DC, battery or Power over Ethernet (PoE) and with interchangeable front-panel connectors, LAN-XI hardware provides an extremely flexible system: scalable from 2 to more than 1000 channels with a frequency range of 25.6, 51.2, 102.4 or 204.8 kHz and unlimited data transfer capacity.

Uses and Features

Uses

- Real-time, multichannel sound and vibration data acquisition system: scalable from 2 to 1000+ measurement channels, all phase- and sampling-synchronous (IEEE 1588 Precision Time Protocol):
  - Stand-alone, single-module front-end for small setups: up to 12 input channels or 4 input/2 output channels
  - Distributed, multichannel system setups with multiple single-module front-ends located close to each measurement point
  - Multichannel systems comprising any number of front-end frames in combination with any number of single-module front-ends
- Laboratory and field measurements using the same AC, DC, battery or PoE powered system
- Multipurpose conditioning of transducers: same input channel can condition all sound and vibration transducers

Features

- Frequency range of 25.6, 51.2, 102.4 or 204.8 kHz depending on module
- Low-frequency auxiliary channels (Type 3056 only)
- High-speed tacho inputs (Type 3056 only)
- Dyn-X technology input channels, 160 dB input range (except Type 3053)
- Interchangeable front panels (BNC, LEMO or multi-pin connectors) – use your preferred cabling
- Display on each module's front panel:
  - Simplifies system configuration and reduces the time for setting up a measurement system
  - Provides module status information on self-test and error conditions
- Full overload detection including out-of-band overload and generator overload
- Indication of incorrect/defective conditioning on each channel connector
- LAN interface allows the front-end to be close to the test object and reduces the number of signal cables and transducer cable length
- Powered by mains, DC, battery or, for stand-alone modules, PoE (IEEE 802.3af)
- Rugged and light modules cast in magnesium
- Silent operation
- Fully compatible with PULSE IDA[e] hardware
- Fully compatible with all PULSE applications
- Automatic detection of hardware and transducers:
  - Supports IEEE 1451.4-capable TEDS transducers

Brüel & Kjær

B 21: LAN-XI Data Acquisition Hardware – Uses and Features

System Overview

LAN-XI data acquisition hardware covers a range of input/output modules that can be used stand-alone, in a distributed network or in frames holding up to 11-modules. Compatible with PULSE IDA[e] hardware, LAN-XI hardware is extremely flexible and can be easily reconfigured, as requirements demand, into 2- to more than 1000-channel systems. Applications include:

- Noise source identification using an acoustic array
- Operating deflection shape
- Modal analysis
- Satellite qualification tests
- High-frequency beamforming
- Other high-channel count measurements in sound and vibration

The modules work equally well as single-module systems, or as part of a large LAN-XI measurement system, making them some of the most flexible data acquisitions modules on the market. In addition, interchangeable front panels give you the flexibility to use a wide range of transducers.

4/6-ch. Input Module LAN-XI 51.2 kHz Type 3050

The core of the LAN-XI range, these modules are designed to cover as many sound and vibration measurement applications as possible.

Type 3050 comes in two basic variants, offering the choice between four and six high-precision input channels with an input range from DC to 51.2 kHz

120510

3-ch. Input Module LAN-XI 102.4 kHz Type 3052

Specifically designed to measure high frequency (>50 kHz) sound and vibration signals, Type 3052 has three input channels with a frequency range from DC to 102.4 kHz. Combined with a dynamic range of 160 dB, this ensures that demanding measurement needs can be met.

120511

12-ch Input Module LAN-XI 25.6 kHz Type 3053

A 12-channel input module that delivers a compact and cost-efficient solution for high channel count applications. Standing alone, Type 3053 is the world's smallest 12-channel sound and vibration analyzer.

120512

4-ch. Input/HS-Tacho + 8-ch. Aux. Module LAN-XI 51.2 kHz Type 3056

This module aims at applications where monitoring low-frequency voltage signals along with the sound and vibration signals is required. The module offers a combination of four 51.2 kHz input channels with eight simultaneously sampled low-frequency auxiliary channels. Unique to Type 3056 is the support of high-speed tacho signals on input channels 1 – 4 which lets you record the signals needed to perform angle domain analysis using PULSE Reflex Type 8740.

Type 3056 features four DC outputs that can be controlled as a function of tolerance curves result and level meter results. This is used for simple On/Off control of third-party equipment in production test Pass/Fail, etc.

120513

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B 22: LAN-XI Data Acquisition Hardware – System Overview

Generator, Input/Output Module LAN-XI 51.2 kHz Type 3160

A combination of inputs and generator outputs make a complete stand-alone analyzer test system. The module is ideal for applications where system excitation is required such as audio and electroacoustic test applications.

Type 3160 comes in two basic variants, offering the choice between 2 inputs/2 outputs and 4 inputs/2 outputs. All input and output channels have a frequency range of DC to 51.2 kHz. The combination of inputs and output channels makes it one of the most versatile data acquisition modules available.

120514

1 ch. Input + 1 ch. Output Module LAN-XI 204.8 kHz Type 3161

Specifically aimed at high-frequency applications such as transducer calibration and underwater defence applications, Type 3161 offers a combination of one input channel and one generator output channel. Both input and output channels have a frequency range of DC to 204.8 kHz. The combination of input connectors – Direct/CCLD, 200 V and Charge – on the front panel allows connection to virtually any microphone and accelerometer, including direct connection to Hydrophones Type 8103, 8104, 8105 and 8106.

130488

Frames and Other Modules

See also:

- LAN-XI Front-end Frames: Type 3660-C (5-module) and 3660-D (11-module) on page 13
- 1-module Wireless LAN Frame Type 3660-A-200 on page 14
- Notar™ BZ-7848-A (LAN-XI stand-alone recorder license) on page 15
- Battery Module Type 2831-A on page 13

Table 1 LAN-XI front-end modules

Input Type*	Product Name	Type Number	Input Channels	Generator Output Channels	Frequency Range	Front-panel Connectors Included
Direct, CCLD†, Mic. Preamp. (0 or 200 V Polarization Voltage) Charge‡	6-ch. Input Module LAN-XI 51.2 kHz (Mic, CCLD, V)	3050-A-060	6	–	0 to 51.2 kHz	BNC: UA-2100-060
	4-ch. Input Module LAN-XI 51.2 kHz (Mic, CCLD, V)	3050-A-040	4	–		BNC: UA-2100-040
	4-ch. Input Module/HS Tacho + 8 ch. LAN-XI 51.2 kHz (Mic, CCLD, V, HS Tacho, Aux)	3056-A-040	4 + 8	–		BNC: UA-2111-040
	Generator, 4/2-ch. Input/Output Module LAN-XI 51.2 kHz (Mic, CCLD, V)	3160-A-042	4	2		BNC: UA-2100-060
	Generator, 2/2-ch. Input/Output Module LAN-XI 51.2 kHz (Mic, CCLD, V)	3160-A-022	2	2		BNC: UA-2100-022
	3-ch. Input Module LAN-XI 102.4 kHz (Mic, CCLD, V)	3052-A-030	3	–	0 to 102.4 kHz	BNC: UA-2100-030
	1 ch. Input + 1 ch. Output Module LAN-XI 204.8 kHz (Mic, CCLD, V)	3161-A-011	1	1	0 to 204.8 kHz	BNC/LEMO/ TNC: UA-2117-011
Direct, CCLD†, Charge‡	12-ch. Input Module LAN-XI 25.6 kHz (CCLD, V)	3053-B-120	12	–	0 to 25.6 kHz	SMB: UA-2107-120
Battery Module						
–	Battery Module	2831-A	–	–	–	UA-2106

* Supply for older MM-0012 and MM-0024 photoelectric tachometers not available. Compatible with CCLD Laser Tacho Probe Type 2981. RS–232 connector for remote control not available

† Constant Current Line Drive: also known as DeltaTron, ICP®, IEPE accelerometers and microphone preamplifiers

‡ Via CCLD Converter Type 2646 or the range of Charge to CCLD Converters Type 2647

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B 23: LAN-XI Data Acquisition Hardware – System Overview (Continued)

Fig. 13
View showing connectors of Type 3660-A-200

To access the micro-SD card (with mini-SD adaptor) in your LAN-XI module you need to remove Type 3660-A-200, Fig. 13.

Note: A Japanese version of this Wireless LAN Frame, Type 3660-A-201 is also available. See the separate Product Data (BP 2487).

Notar™ BZ-7848-A (LAN-XI stand-alone recorder license)

Uses

- Record time data to a memory card (wav files): no need for PC
- Remotely access the recorder over wired LAN (standard) or wireless LAN or 3G network (requires wireless access point or 3G modem)
- Use as a modular, real-time analyzer by connecting the same LAN-XI hardware to a computer

Features

- Small and rugged solid state memory card has no shock-sensitive moving parts like tape recorders or PC hard drives
- Simple start and stop control on the module
- Available memory and overload displayed on the module's built-in LCD screen
- Built-in home page allows any PC, PDA or smartphone with web browser to be used as remote (may require wireless access point or 3G modem)
- Data can be transferred over LAN connection, or the memory card can be removed and inserted in a PC card reader
- Extremely long operating time: >7 hours when used together with LAN-XI Battery Module Type 2831-A

Expanding on the LAN-XI platform, LAN-XI Notar BZ-7848-A allows you to record time data from a single LAN-XI module to an internal memory card. This means that the LAN-XI module is the entire measurement system, a very small and rugged data recorder.

BZ-7848-A works with all LAN-XI modules, although auxiliary and high-speed tacho signals from Type 3056 are **not** supported. It includes a 16 GB micro-SD card with mini-SD and SD adaptors, UL-1018. Stored data can be either transferred by placing the memory card in a PC card reader or downloading over the LAN connection.

The recorder is set up (for example, bandwidth, number of channels, signal conditioning, etc.) through the module's home page. This means that any PC, PDA or SmartPhone with browser can be used (may require wireless access point or 3G modem).

Once the recorder is set up, the PC, PDA or smartphone web browser can control recording and display feedback. The LAN-XI module's button and LCD screen can also be used for control and feedback. Since there is no need to change channel input ranges, control is much simpler than with previous recorders.

The included 16 GB card allows nearly 4 hours of recording with 6 channels at 25.6 kHz bandwidth (51.2 kHz sampling frequency). Micro-SD cards with greater capacity will become available allowing even longer recording sessions. Since the memory card is removable, it is simple to upgrade the memory or use multiple cards. Multiple cards allows analysis to begin on recordings while new recordings are made on another.

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B 24: LAN-XI Data Acquisition Hardware – Notar BZ-7848-A

Compliance with Standards

(For environmental specifications and compliance with standards for PCs, see the specifications given by their respective manufacturers)

11-MODULE LAN-XI FRONT-END FRAME TYPE 3660-D, 5-MODULE LAN-XI FRONT-END FRAME TYPE 3660-C,1-MODULE WIRELESS LAN FRAME TYPE 3660-A-200, INPUT/OUTPUT MODULES TYPE 3050, 3052, 3053, 3056, 3160 AND 3161, BATTERY MODULE TYPE 2831-A

	CE-mark indicates compliance with: EMC Directive and Low Voltage Directive RCM mark indicates compliance with applicable ACMA technical standards – that is, for telecommunications, radiocommunications, EMC and EME China RoHS mark indicates compliance with administrative measures on the control of pollution caused by electronic information products according to the Ministry of Information Industries of the People's Republic of China WEEE mark indicates compliance with the EU WEEE Directive
Safety	EN/IEC 61010–1 and ANSI/UL 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use
EMC Emission	**Frames** EN/IEC 61000–6–4: Generic emission standard for industrial environments CISPR 22: Radio disturbance characteristics of information technology equipment. Class A Limits
	Modules EN/IEC 61000–6–3: Generic emission standard for residential, commercial, and light-industrial environments CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits
EMC Immunity	EN/IEC 61000–6–1: Generic standards – Immunity for residential, commercial and light industrial environments EN/IEC 61000–6–2: Generic standards – Immunity for industrial environments EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements **Note:** The frames and modules fulfil the immunity standards, except **Type** 3660-C meets EN 61000–4–2 at ±4 kV air discharge and EN 61000–4–5 surge 1.5 kV line-earth , and **Type** 3660-D meets EN 61000–4–2 at ±1 kV air and conduct discharge and EN 61000–4–5 surge ±1.5 kV line-earth **Note:** The above is only guaranteed using accessories listed in this Product Data
Temperature	IEC 60068–2–1 & IEC 60068–2–2: Environmental Testing. Cold and Dry Heat Ambient Operating Temperature: –10 to +55°C (14 to 131°F) Storage Temperature: –25 to +70°C (–13 to +158°F)
Humidity	IEC 60068–2–78: Damp Heat: 93% RH (non-condensing at 40°C (104°F))
Mechanical (non-operating)	**Frames** IEC 60068–2–6: Vibration: 0.3 mm, 2 g, 10 – 500 Hz IEC 60068–2–27: Shock: **3660-C:** 100 g; **3660-D:** 50 g IEC 60068–2–29: Bump: **3660-C:** 1000 bumps at: 25 g empty, 15 g loaded with modules; **3660-D:** 25 g loaded with modules
	Modules IEC 60068–2–6: Vibration: 0.3 mm, 2 g, 10 – 500 Hz IEC 60068–2–27: Shock: 100 g IEC 60068–2–29: Bump: 1000 bumps at: 25 g
Enclosure	IEC 60529: Protection provided by enclosures: 3660-C, 3660-D: IP 20; **3050, 3052, 3053, 3160, 3161, 2831-A:** IP 31

EFFECT OF RADIATED AND CONDUCTED RF, MAGNETIC FIELD AND VIBRATION

Radiated RF: 80 – 2700 MHz, 80% AM 1 kHz, 10 V/m
Conducted RF: 0.15 – 80 MHz, 80% AM 1 kHz, 10 V
Magnetic Field: 30 A/m, 50 Hz
Vibration: 5 – 500 Hz, 12.7 mm, 15 m/s^2

Input measured with shorted input. All values are RMS. Conducted RF immunity on all channels is only guaranteed using an external connection from measuring ground to chassis terminal

Input/Output	Radiated RF	Conducted RF	Magnetic Field	Vibration
Direct/CCLD	<250 µV	<300 µV	<4 µV	<80 µV
Preamplifier*	<250 µV	<50 µV	<8 µV	<80 µV
Charge (1 nF transducer)†	<10 pC	<3 pC	<0.3 pC	<3 pC
Generator	<250 µV	<50 µV	<2 µV	<5 µV

* Not applicable for Type 3053 †Valid for Type 3161-A-011

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B 25: LAN-XI Data Acquisition Hardware – Compliance with Standards

INPUT CHANNELS (CONTINUED)

Absolute Max. Common Mode Voltage		±5 V_{peak} without damage
		±3 V_{peak} without clipping
		If common mode voltage exceeds the max. value, care must be taken to limit the signal ground current in order to prevent damage. Maximum is 100 mA. The instrument will limit the voltage to the stated max. "without damage" common mode value
Anti-aliasing Filter At least 90 dB attenuation of those frequencies which can cause aliasing	Filter Type	3rd order Butterworth
	−0.1 dB @	25.6 kHz
	−3 dB @	64 kHz
	Slope	−18 dB/octave
Supply for Microphone Preamplifiers		Not available
Supply for Microphone Polarization		Not available
Supply for CCLD		3.6 mA from 24 V source
		If any CCLD-coupled channel is paralleled with another channel, this must also be CCLD-coupled. Otherwise the signal might be clipped by the paralleled channel
Tacho Supply		CCLD for Type 2981 (Power supply for legacy types MM-0012 and MM-0024 not available)
Analog Special Functions		**Transducers:** Supports IEEE 1451.4 capable transducers with standardised TEDS
Overload Detection		**Signal overload:** Detection level in 1 V range: ±1 V_{peak} in 10 V range: ±10 V_{peak}. (in CCLD mode ±7 V_{peak}) **CCLD overload:** Detection of cable break or short-circuit + detection of CCLD transducer working point fault. Detection level: +2 V / 20 V **Common mode voltage overload** Detection level: ±3 V **Protection:** If signal input level exceeds the measuring range significantly, the input will go into protection mode until the signal goes beyond the detection level again – but at least for 0.5 second. While in protection mode the input is partly switched off and the input impedance is strongly increased. (The measured value will be strongly attenuated but still detectable) **Detection level:** Direct mode: ±33 V_{peak}. CCLD mode: +27/ −2 V_{peak}

POWER REQUIREMENTS
DC Input: 10 – 32 V DC
Connector: LEMO coax., FFA.00.113, ground on shield
Power Consumption:
DC Input: <15 W
Typical Operating Time on Battery Type 2831-A:
>7 hours with single module
>40 minutes in Type 3660-D frame (up to two batteries in Type 3660-D)
Supply via PoE: According to IEEE 802.3af, Max. cable length 50 m (164 ft)

Temperature Protection:
Temperature sensor limits module's internal temperature to 80°C (176°F). If temperature exceeds limit, system will automatically enable fan in LAN-XI frame or shut down module outside frame

LAN
Connector type RJ 45

DIMENSIONS AND WEIGHT
Height: 132.6 mm (5.22″)
Width: 27.5 mm (1.08″)
Depth: 250 mm (9.84″)
Weight: 750 g (1.65 lb)

Specifications – Type 3056

HIGH-SPEED TACHOMETER CHANNELS
Available on channels 1 to 4:

	PULSE LabShop	PULSE Time Data Recorder Type 7708
Ch. 1	High-speed tacho signal or normal input	High-speed tacho signal or normal input
Ch. 2	High-speed tacho ref or normal input	High-speed tacho ref or normal input
Ch. 3	High-speed tacho signal or normal input	Normal input
Ch. 4	High-speed tacho ref or normal input	Normal input

Analog Bandwidth: >1 MHz @ 5 V_{peak} (TTL level)
Tacho Resolution: 15 ns
Max. Tacho Input Voltage: 10 V_{peak}
Absolute Max. Input Voltage: ±60 V_{peak}
Trigger Level: 0.2 V to 7 V
Default Trigger Level: 1.5 V

Triggering on rising or falling edge

Upper RPM Limit	Max. Pulses/Revolution	Angular Resolution (°)
1000	60000	0.0000025
6000	10000	0.000015
20000	3000	0.00005
150000	400	0.00375

AUXILIARY INPUT CHANNELS (simultaneously sampled)
Number of Channels: 8 DC channels in 2 × 10-pole LEMO connectors
Input Connector: 2 × 10-pole LEMO
Sampling Rate: 16 Hz
Input Connection: Single-ended
Input Voltage Range: ±10 V in one range
Input Protection: 50 V
Input Impedance: 1 MΩ || 300pF
Precision: ±0.1% of reading ±1 mV offset (after warm up time)
Noise: <3 µV (10 mHz – 8 Hz) measured without temperature drift and DC offset
Noise-free Dynamic Range: 120 dB (typical)
Noise-free Resolution: 19 to 20 bits (typical)
Temperature Coefficient: <15 µV/°C (typical)

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B 26: LAN-XI Data Acquisition Hardware – Specifications

Distortion: 90 dB @1 Hz 10 V_{peak} (typical)
Programmable DC Output Channels: 4 open-drain outputs (2 per connector) able to sink 100 mA from an external supply of typically 24 V, which allow simple relay control (on/off, pass/fail, etc.) via OLE2 automation interface

DC Output without External Supply: 5 V, max. 50 mA
DC Output Protection: 40 V
DC Out Supply: 5 V out, max. 100 mA total for module

INPUT CHANNELS (DYN-X)

Frequency Range		DC to 51.2 kHz Lower frequency range can be set in PULSE software
Sampling Rate		131 ksamples/s
A/D Conversion		2 × 24 bit
Data Transfer		24 bit
Input Voltage Range		10 V_{peak} Extended range: 31.6 V_{peak}
Input Signal Coupling	**Differential**	Signal ground is "floating" (1 MΩ re: chassis)
	Single-Ended	Signal ground is connected to chassis ("Grounded")
Input Impedance		Direct, Microphone: 1 MΩ || <300 pF
		CCLD: >100 kΩ || <300 pF
Absolute Maximum Input		±60 V_{peak} without damage

High-pass Filters		**– 0.1 dB ***	**–10% @ ****	**–3 dB @ ****	**Slope**
* Defined as the lower frequency, f_L, for guaranteed fulfilment of –0.1 dB accuracy in 10 V_{peak} range ** Defined as the nominal –10%/3 dB filter frequency	0.1 Hz –10% analog high-pass filter 0.7 Hz –0.1 dB digital high-pass filter	0.5 Hz 0.7 Hz	0.1 Hz 0.15 Hz	0.05 Hz 0.073 Hz	–20 dB/dec.
	1 Hz –10% digital high-pass filter 7 Hz –0.1 dB digital high-pass filter	5 Hz 7 Hz	1.0 Hz 1.45 Hz	0.5 Hz 0.707 Hz	–20 dB/dec.
	22.4 Hz –0.1 dB analog high-pass filter	22.4 Hz	15.8 Hz	12.5Hz	–60 dB/dec.
	Intensity filter (analog)	115 Hz	23.00 Hz	11.5 Hz	–20 dB/dec.

Absolute Amplitude Precision, 1 kHz, 1 V_{Input}		±0.05 dB, typ. ±0.01 dB
Amplitude Linearity (linearity in one range)	0 to 80 dB below full scale	±0.05 dB, typ. ±0.01 dB
	80 to 100 dB below full scale	±0.2 dB, typ. ±0.02 dB
	100 to 120 dB below full scale	typ. ±0.02 dB
	120 to 140 dB below full scale	typ. ±0.02 dB
	140 to 160 dB below full scale	typ. ±1 dB
Overall Frequency Response **re 1 kHz, from lower limit f_L to upper limit f_U** f_L is defined as the lower frequency for guaranteed fulfilment of –0.1 dB accuracy in 10 V_{peak} range (see under High-pass Filters) f_U is defined as the chosen frequency span. DC (f_L = 0)		±0.1 dB ±0.3 dB in 31.6 V range

Noise		**Input Range**	**Guaranteed**		**Typical**	
			Lin*	**1 kHz**	**Lin***	**1 kHz**
* Measured lin. 10 Hz to 25.6 kHz or lin. 10 Hz to 51.2 kHz:	**Signal level <316 mV_{peak}** 10 Hz to 25.6 kHz 10 Hz to 51.2 kHz	10 V_{peak}	<4 µV_{rms} <13 µV_{rms}	<25 nV_{rms}/√Hz	<3 µV_{rms} <10 µV_{rms}	<19 nV_{rms}/√Hz
(Input terminated by 50 Ω or less)	**Signal level >316 mV_{peak}** 10 Hz to 25.6 kHz 10 Hz to 51.2 kHz	10 V_{peak}	<60 µV_{rms} <350 µV_{rms}	<375 nV_{rms}/√Hz	<50 µV_{rms} <250 µV_{rms}	<313 nV_{rms}/√Hz
	Signal level <1 V_{peak} 10 Hz to 25.6 kHz 10 Hz to 51.2 kHz	31.6 V_{peak}	<20 µV_{rms} <45 µV_{rms}	<125 nV_{rms}/√Hz	<15 µV_{rms} <35 µV_{rms}	<95 nV_{rms}/√Hz
	Signal level >1V_{peak} 10 Hz to 25.6 kHz 10 Hz to 51.2 kHz	31.6 V_{peak}	<200 µV_{rms} <1200 µV_{rms}	<1250 nV_{rms}/√Hz	<150 µV_{rms} <800 µV_{rms}	<950 nV_{rms}/√Hz

Spurious-free Dynamic Range re Full-scale Input (Input terminated by 50 Ω or less) Spurious-free Dynamic Range is defined as the ratio of the rms full-scale amplitude to the rms value of the largest spurious spectral component (non-harmonic)	**Input Range**	**Typical**
	10 V_{peak}	160 dB
	31.6 V_{peak}	140 dB

DC Offset re Full Scale Measured after automatic DC compensation at current temperature when changing from AC to DC coupling or changing input range when DC coupled	**Guaranteed**	**Typical**
	<–90 dB	–100 dB

Harmonic Distortion (all harmonics)	**Guaranteed**	**Typical**
	–80 dB (–60 dB in 31.6 V range)	–100 dB @ 1 kHz (–80 dB @ 1 kHz in 31.6 V range)

Crosstalk: Between any two channels of a module or between any two channels in different modules	**Frequency Range**	**Guaranteed**	**Typical**
	0 to 51.2 kHz	–100 dB	–140 dB

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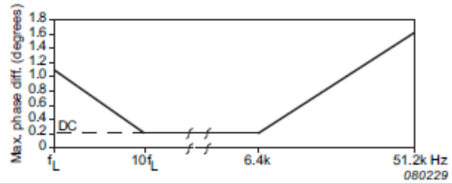
B 27: LAN-XI Data Acquisition Hardware – Specifications (Continued)

INPUT CHANNELS (DYN-X) (CONTINUED)

Channel-to-Channel Match		Guaranteed	Typical
(10 V_{peak} input range)	Maximum Gain Difference f_L is defined as the –0.1 dB frequency of the high-pass filter	0.2 dB from lower frequency limit, f_L, to 51.2 kHz (0.4 dB at –10% filter frequency)	±0.05 dB
	Maximum Phase Difference (within one frame) f_L is defined as the –0.1 dB frequency of the high-pass filter		
	Additional PTP sync. error (phase difference) between modules/frames (using a single standard gigabit switch)	**Typical:** <200 ns (approx. ±0.07° @ 1 kHz, ±2° @ 25.6 kHz)	
Channel-to-Channel Match **(31.6 V_{peak} input range)**	Maximum Gain Difference	0.6 dB from lower frequency limit, f_L, to 51.2 kHz (1 dB at –10% filter frequency)	
	Maximum Phase Difference (within one frame)	4° from lower frequency limit, f_L, to 51.2 kHz	
Sound Intensity Phase Match	**Frequency Range**	**Guaranteed Phase Match**	**Typical Phase Match**
(only for using intensity filter and in 10 V_{peak} input range)	50 to 250 Hz	±0.017°	±0.005°
	250 Hz to 2.5 kHz	0.017° × (f/250)	±0.005°
All channels matched	2.5 to 6.4 kHz	±0.17°	±0.08°
Common Mode Rejection in 10 V_{peak} input range		**Guaranteed**	**Typical**
Values for 31.6 V_{peak} range are 10 dB lower.	0 to 120 Hz	70 dB	80 dB
	120 Hz to 1 kHz	55 dB	60 dB
	1 to 51.2 kHz	30 dB	40 dB
Absolute Max. Common Mode Voltage		±5 V_{peak} without damage	
		±4 V_{peak} without clipping	
		If common mode voltage exceeds the max. value, care must be taken to limit the signal ground current in order to prevent damage. Max. is 100 mA. The instrument will limit the voltage to the stated max. "without damage" common mode value	
Anti-aliasing Filter At least 90 dB attenuation of those frequencies which can cause aliasing	Filter Type	3rd order Butterworth	
	–0.1 dB @	51.2 kHz	
	–3 dB @	128 kHz	
	Slope	–18 dB/octave	
Supply for Microphone Preamplifiers		±14.0 V, max. 100 mA per channel (max. 100 mA total/module)	
Supply for Microphone Polarization		200 V ±1 V, or 0 V (Set per channel)	
Supply for CCLD		4 to 5 mA from 24 V source, option to DC-couple CCLD power supply	
Tacho Supply		CCLD for Type 2981 (Power supply for legacy Types MM-0012 and MM-0024 not available)	
Analog Special Functions	**Microphone Charge Injection Calibration:** All modules with 7-pin LEMO support CIC via dedicated application software and OLE interface **Transducers:** Supports IEEE 1451.4-capable transducers with standardised TEDS (up to 100 m (328 ft) cable length)		
Overload Detection	**Signal Overload:** Adjustable detection level ±1 V_{peak} to ±10 V_{peak}. Default level ±10 V_{peak} (CCLD mode ±7 V_{peak}) (31.6 V range: ±31.6 V) can be set in PULSE Transducer Database **CCLD Overload:** Detection of cable break or short-circuit + detection of CCLD transducer working point fault. Detection level: +2 V/20 V **Microphone Preamplifier Overload:** Detection of microphone preamplifier current consumption too high or too low. Detection level default 10 mA/1 mA Adjustable detection level 1 to 20 mA or 100 mA if disabled **Common Mode Voltage Overload:** Detection level: ±3.0 V		
Protection	If signal input level exceeds the measuring range significantly, the input will go into protection mode until the signal goes below the detection level again for at least 0.5 s. While in protection mode, the input is partly switched off and the input impedance is greatly increased. (The measured value will be strongly attenuated but still detectable) In DC mode – 10 V_{peak} range, the detection limit is ±12 V. In all other measuring modes (except CCLD) the limit is ±50 V_{peak} including DC component or ±12 V_{peak} AC In CCLD mode the limit is +50/–2 V_{peak} including DC component or ±12 V_{peak} AC In the 31.6 V range, the limit is ±50 V_{peak}		

POWER REQUIREMENTS
DC Input: 10 to 32 V DC
Connector: LEMO coax., FFA.00.113, ground on shield
Power Consumption:
DC Input: <15 W

Supply via PoE: According to IEEE 802.3af, Max. cable length 50 m (164 ft)
Temperature Protection:
Temperature sensor limits module's internal temperature to 80°C (176°F). If temperature exceeds limit, system will automatically enable fan in LAN-XI frame or shut down module outside frame

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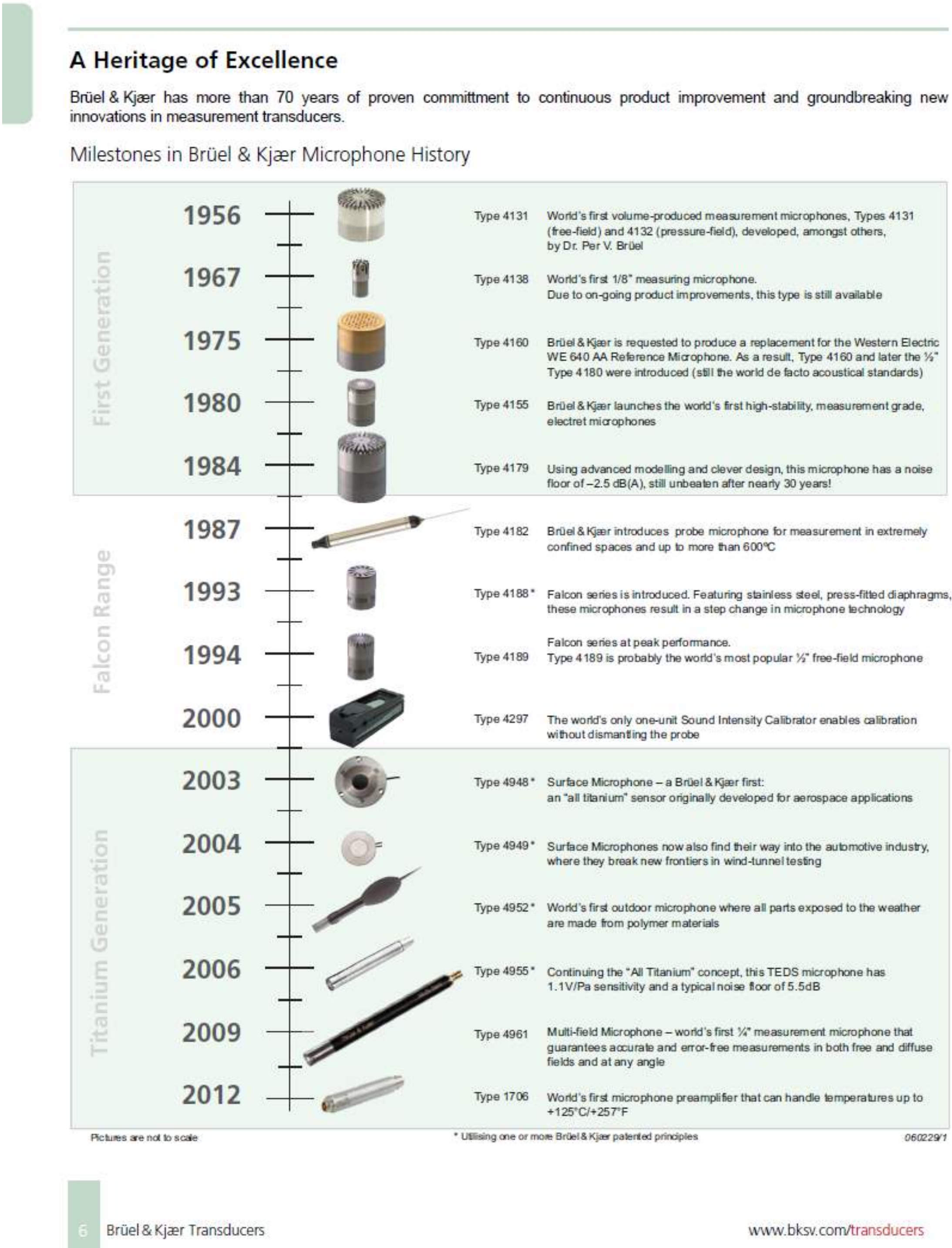
B 28: LAN-XI Data Acquisition Hardware – Specifications (Continued)

1/2” Free Field Microphone Type 4189



A Heritage of Excellence

Brüel & Kjær has more than 70 years of proven committment to continuous product improvement and groundbreaking new innovations in measurement transducers.

Milestones in Brüel & Kjær Microphone History

	Year	Type	Milestone
First Generation	1956	Type 4131	World's first volume-produced measurement microphones, Types 4131 (free-field) and 4132 (pressure-field), developed, amongst others, by Dr. Per V. Brüel
	1967	Type 4138	World's first 1/8" measuring microphone. Due to on-going product improvements, this type is still available
	1975	Type 4160	Brüel & Kjær is requested to produce a replacement for the Western Electric WE 640 AA Reference Microphone. As a result, Type 4160 and later the ½" Type 4180 were introduced (still the world de facto acoustical standards)
	1980	Type 4155	Brüel & Kjær launches the world's first high-stability, measurement grade, electret microphones
	1984	Type 4179	Using advanced modelling and clever design, this microphone has a noise floor of –2.5 dB(A), still unbeaten after nearly 30 years!
Falcon Range	1987	Type 4182	Brüel & Kjær introduces probe microphone for measurement in extremely confined spaces and up to more than 600°C
	1993	Type 4188*	Falcon series is introduced. Featuring stainless steel, press-fitted diaphragms, these microphones result in a step change in microphone technology
	1994	Type 4189	Falcon series at peak performance. Type 4189 is probably the world's most popular ½" free-field microphone
	2000	Type 4297	The world's only one-unit Sound Intensity Calibrator enables calibration without dismantling the probe
Titanium Generation	2003	Type 4948*	Surface Microphone – a Brüel & Kjær first: an "all titanium" sensor originally developed for aerospace applications
	2004	Type 4949*	Surface Microphones now also find their way into the automotive industry, where they break new frontiers in wind-tunnel testing
	2005	Type 4952*	World's first outdoor microphone where all parts exposed to the weather are made from polymer materials
	2006	Type 4955*	Continuing the "All Titanium" concept, this TEDS microphone has 1.1V/Pa sensitivity and a typical noise floor of 5.5dB
	2009	Type 4961	Multi-field Microphone – world's first ¼" measurement microphone that guarantees accurate and error-free measurements in both free and diffuse fields and at any angle
	2012	Type 1706	World's first microphone preamplifier that can handle temperatures up to +125°C/+257°F

Pictures are not to scale

* Utilising one or more Brüel & Kjær patented principles

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6 Brüel & Kjær Transducers www.bksv.com/transducers

B 29: Transducers and Conditioning – Microphone History

SELECTING THE RIGHT MICROPHONE

Brüel & Kjær offers a broad spectrum of solutions that respond to varying needs and applications. This adaptability is evident in the range of transducers designed for specific environments, industries, tasks and conditions, as well as general purpose instruments that provide a wide operational range.

Selecting the best transducer for a given measurement task can be understandably overwhelming. Our interactive transducer selection guide on www.bksv.com can be a big help to quickly narrow your choices. Alternatively, you can use the Microphone Matrix below to help you select the right microphone to fit your needs.

Condenser microphones:
- are either externally polarized or prepolarized
- come in different sizes: 1-inch, 1/2-inch, 1/4-inch, or 1/8-inch
- are optimised for either free-, pressure-, or diffuse-field

For a quick overview, product types are listed according to these classifications. Microphones that do not directly match one of these classes are denoted as "Special Microphones".

1/8-inch microphones are pressure types. Due to their small size, the free-field and pressure response are approximately the same up to quite high frequencies (for example, the free-field correction is less than 1 dB at 15 kHz).

Mapping Brüel & Kjær measurement microphones in the Microphone Matrix is now a simple task.

The Microphone Matrix

Type of Microphone		Type 1/8-inch	1/4-inch	1/2-inch	1-inch	Polarization
	Free-field		4954	4137 4176 4188 4189 4950		Prepolarized
			4939	4190 4191	4145	Externally polarized
	Pressure-field		4944	4947 4948 4949 4953		Prepolarized
		4138	4938 4941	4192	4144	Externally polarized
	Diffuse-field			4942		Prepolarized
				4943		Externally polarized
	Special		4961 4958	4948 4949		Prepolarized
			4187, 4957 4938-WH-1418 4938-W-001	4180 4193 4955	4160 4179	Externally polarized

For Selection Consider the Following

Which kind of input module – classical or CCLD?
CCLD (including DeltaTron and IEPE) can only work with prepolarized types; classical input works with both prepolarized and externally polarized cartridges. For more information about CCLD and classical input see the preamplifier section. For portable instruments and where high humidity is present, prepolarized microphones are preferred. For more general use in the laboratory or where high temperature is present, the use of external polarised microphones is recommended.

Does the microphone have to fulfill any specific standard?
If this is the case, see Microphone Standards in the appendix.

Frequency range and maximum sound pressure level (SPL) will often determine which microphone size to use.

Generally a smaller microphone has a broader frequency range and a lower sensitivity. For more details, see Maximum Limits and Dynamic Range.

For which sound field should the microphone be optimised*?
For measurements made away from reflecting surfaces, for example, when making outdoor measurements, or in acoustically well-damped indoor environments, a free-field microphone is best. But for measurements made in small closed couplers, or close to hard surfaces, a pressure-field microphone is best. For measurements in enclosed areas where reverberation is likely, microphones optimised for diffuse-field (random-incidence) response are best. In some cases, pressure type microphones can also be found to have sufficiently flat random incidence response. This is because the random

* Optimised means that the microphone has a flat frequency response in the specified frequency range of the particular sound field

B 30: Transducers and Conditioning – Microphone Matrix

Definition of Given Microphone Standards

The following abbreviations for standards are used in the tables.

	IEC 61094		IEC 61672		ANSI
A	IEC 61094–4 WS1F	**I**	IEC 61672 Class 1	**K**	ANSI S1.4 Type 1
B	IEC 61094–4 WS2F	**J**	IEC 61672 Class 2	**L**	ANSI S1.4 Type 2
C	IEC 61094–4 WS3F			**M**	ANSI S1.12 Type M
D	IEC 61094–4 WS1P				
E	IEC 61094–4 WS2P				
F	IEC 61094–4 WS3P				
G	IEC 61094–1 LS1P				
H	IEC 61094–1 LS2P				

Free-field Microphones

Free-field microphones are particularly suitable for performing measurements away from reflecting surfaces, for example, when making outdoor measurements with a sound level meter, or in an acoustically well-damped indoor environment such as an office with natural acoustic damping.

Type No.		4939	4954	4137*	4176	4188	4189
Diameter	inch	1/4	1/4	1/2	1/2	1/2	1/2
Optimised		Free-field	Free-field	Free-field	Free-field	Free-field	Free-field
Standards		C	C	J, L	I, K	I, K	B, I, L
Nominal Open-circuit Sensitivity	mV/Pa	4	3.16	31.6	50	31.6	50
Polarization Voltage**	V	200	0	0	0	0	0
Optimised Frequency Response ±2 dB	Hz	4 to 100000	4 to 80000	8 to 12500	7 to 12500	8 to 12500	6.3 to 20000
Dynamic Range with Preamplifier (Preamplifier type number)	dB(A) to dB	35 to 164 (2670)	35 to 164 (2670)	15.8 to 146 (2669)	14 to 142 (2669)	15.8 to 146 (2669)	15.2 to 146 (2669)
Inherent Noise	dB (A)	28	<35	14.2	13.5	14.2	14.6
Capacitance	pF	6.1	5.1	12	12.5	12	13
Venting		Side	Side	Rear	Rear	Rear	Rear
Lower Limiting Frequency (–3 dB)	Hz	0.3 to 3	0.3 to 3	1 to 5	0.5 to 5	1 to 5	2 to 4
Operating Temperature Range	°C	−40 to 150	−40 to 150	−30 to 125	−30 to 100	−30 to 125	−30 to 150
Temperature Coefficient	dB/°C	+0.003	+0.009	+0.005	−0.004	+0.005	−0.001
Pressure Coefficient	dB/kPa	−0.007	−0.007	−0.021	−0.02	−0.021	−0.01

* Class 2 microphone for Type 2237 ** 0 V = Prepolarized microphone

B 31: Transducers and Conditioning – Free Field Microphones

05/12/2013 Stand-alone recorder - LAN-XI Notar™ - Brüel & Kjær

Brüel & Kjær
creating sustainable value

Stand-alone recorder - LAN-XI Notar™ - BZ-7848

Firmware that transforms any LAN-XI module into a stand-alone recorder with up to 12-channels. Battery power and solid-state memory gives a rugged and versatile recorder.

Uses

- Record time-data to a memory card without a fragile or bulky PC
- Remote access to the recorder over wired LAN (standard)
- As a modular, real-time analyzer (standard LAN-XI configuration)

Features

- No input ranging necessary with each channel's input range covering 160 dB
- Interchangeable front panels (BNC, LEMO or Charge) to adapt to preferred transducer cabling
- Small and rugged solid-state memory card with no shock-sensitive moving parts
- Simple start-and-stop control on the module
- Available memory and overload displays on the built-in LCD screen
- Built-in home page allows remote use with any PC, PDA or SmartPhone (may require wireless access point or 3G modem)
- Data transfer over LAN connection or memory card
- Power with mains, external DC, Power over Ethernet (PoE) or battery
- Long life battery >7 hours can be swapped in the field

www.bksv.com/Products/analysis-software/data-acquisition/data-recording/Lanxi-stand-alone-recorder 1/1

B 32: Stand-alone Recorder – LAN-XI Notar – BZ-7848 – Uses and Features

PULSE Reflex Core Post-processing Software

Brüel & Kjær

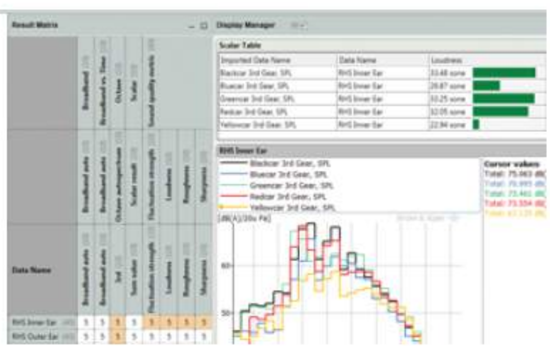
creating sustainable value

PULSE Reflex Core

Our post-processing software platform for fast and efficient analysis, viewing and reporting of sound and vibration data. Analysis capabilities include: FFT analysis, CPB Nth octave analysis (to IEC, DIN and ANSI standards), order analysis (including tracked resampling), and calculation of a wide range of sound quality metrics.

> Overview of PULSE Reflex modules

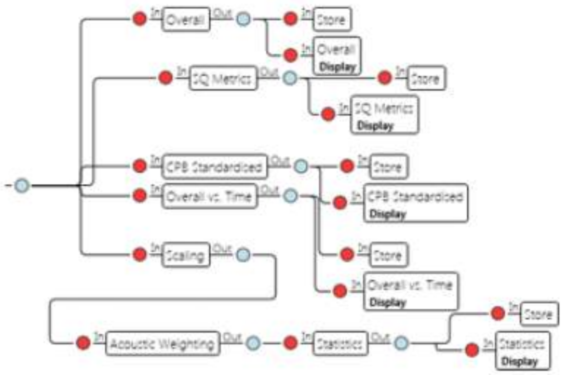
At the heart of the system is a relational database for managing test projects and their associated sound and vibration data. User-defined meta-data fields are easy to set up and are used throughout the system for data searches, data filtering/sorting, display annotation and reporting.



Simple and intuitive

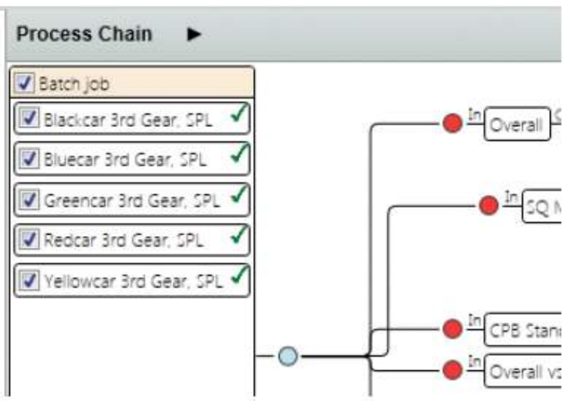
An innovative GUI delivers genuine ease-of-use through a workflow concept that is easy to learn and consistent across applications. Reflex Core deals with both repetitive (test bench) procedures and ad hoc troubleshooting by including automation in the workflow without constraining the user to a pre-defined sequence of operations.

B 33: PULSE Reflex Core – Overview



Powerful analysis capabilities

Multiple parallel analyses can be performed simultaneously, including stationary and non-stationary spectral analysis, order analysis, statistics, and sound quality metrics. Results are automatically sorted for easy post-processing.



High productivity

Batch processing is included as standard in Reflex Core, enabling many recordings to be processed in a single batch operation. No matter how many tests or data types, the results from any number of tests are automatically sorted for quick comparison and reporting.

Flexible data management

Test data and processed results can either be entirely managed inside the Reflex Core database or stored in external files. Meta-data is used throughout the workflow for easy data searching, display annotation and automated report generation.

B 34: PULSE Reflex Core – Overview (Continued)

Pentangular Array Type WA-1676-W-002 (30 x 4959 Microphones)

PRODUCT DATA

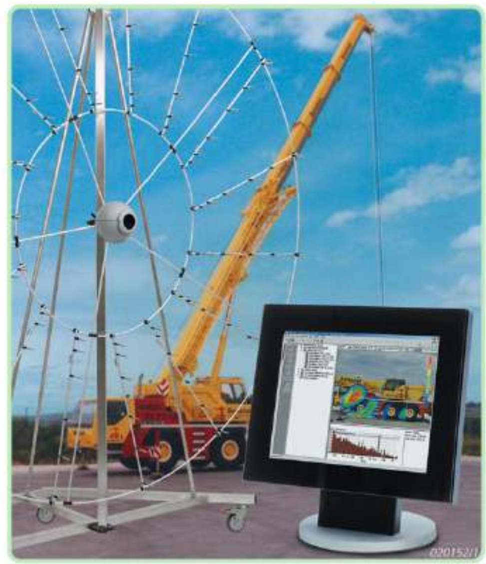
PULSE™ Array-based Noise Source Identification Solutions: Beamforming Type 8608, Acoustic Holography Type 8607 and Spherical Beamforming Type 8606

Noise Source Identification (NSI) is an important method for optimising the noise emission from a wide range of products from vehicles, white goods, power tools and heavy machinery to components like engines, tyres, gear-boxes, exhausts, etc.

The goal of NSI is to identify the most important sub-sources on an object in terms of position, frequency content and sound power radiation. Ranking of sub-sources can be used to identify where design changes will most effectively improve the overall noise radiation.

Array-based methods provide both the fastest measurement process and the highest quality of the results. The combination of acoustical holography with phased array methods gives accurate, high-resolution maps in the full audible frequency range.

Time-domain methods can be used to study transients like impacts and run-ups or to get detailed understanding of stationary sources, for example, noise radiation versus crank angle on engines. For large, stationary sources, an automated microphone positioning system (robot) can be used to measure automatically.



Hardware and Software

Software

- Spherical Beamforming Type 8606, providing a full 360 degree sound field map without making any assumptions about the sound field
- Acoustic Holography Type 8607, a method for mathematically describing the sound field based on a set of measurements
- Beamforming Type 8608, a method of mapping noise sources by differentiating sound levels based on the direction from which they originate
- All applications can post-process data
- Options available for all applications: Conformal; Transient; Quasi-stationary and Sound Quality Metrics Calculations
- Refined Beamforming Calculations for improved spatial resolution available as an option for Beamforming
- Road Vehicle and Rail Vehicle options for Beamforming
- Panel Contribution (patented method), Intensity Component Analysis and In Situ Absorption options for Acoustic Holography

Arrays

- Grid arrays for scanned and general purpose measurements
- Patented arm wheel arrays, numerically optimised for acoustical performance in relation with beamforming
- Slice wheel arrays, numerically optimised for acoustical performance in relation to Beamforming and Acoustical Holography
- Hand-held array for real-time holography mapping, patch holography and conformal mapping using Statistically Optimised Near-field Acoustical Holography (SONAH, patent pending) and Equivalent Source Method (ESM)
- Spherical array for Beamforming even in confined environments
- Single signal cable system for connecting up to 132 channels via one socket

Brüel & Kjær

B 35: PULSE Array-based Noise Source Identification Solutions – Hardware and Software

Selection of Arrays and Robots

Table 1 A selection of Brüel & Kjær's arrays and robots for fixed, path and scanned measurements

Spherical Array	Wheel Array (incl. camera)	Half-wheel Array	Grid Array
			
Applications: Vehicle and aircraft interior, building and industrial plants	**Applications:** General purpose (90-channel array typically used in automotive component applications)	**Applications:** Road vehicle and rail vehicle moving source beamforming including wind-tunnel and pass-by testing	**Applications:** General purpose, non-moving noise sources
NSI Method: Spherical Beamforming	**NSI Method:** Beamforming	**NSI Method:** Beamforming	**NSI Method:** Acoustic Holography and Transient Calculations
No. of Channels: 36 or 50	**No. of Channels:** 42 and over	**No. of Channels:** 42 and over	**No. of Channels:** 6 and over
Size: 20 cm diameter	**Size:** 0.65 m to 4.0 m diameter	**Size:** 1.5 m to 4.0 m diameter	**Size:** 0.125 m × 0.125 m and over (various spacing available)
Maximum Frequency: 12 kHz	**Maximum Frequency:** 20 kHz	**Maximum Frequency:** 10 kHz	**Maximum Frequency:** 6 kHz
Accessories: Tripod WQ-2691	**Accessories:** Tripod WQ-2691	**Accessories:** Carriage WA-0893	**Accessories:** Support Stand WA-0810 or Array Positioning System

Slice Wheel Array	Hand-held Array (single or double-layer)	2D Robot	Pentangular Array
			
Applications: General purpose, engines, automotive components/ interior, etc.	**Applications:** Components, interiors, etc.	**Applications:** From large, stationary noise sources, such as vehicles and engines, down to hearing aids and dentist drills	**Applications:** Outdoor noise sources, wind turbines, factories
NSI Method: Beamforming and Acoustic Holography	**NSI Method:** Real-time Holography, Patch Mapping and Conformal Calculations	**NSI Method:** Acoustic Holography	**NSI Method:** Beamforming, extraneous noise suppression
No. of Channels: 18, 36, 60 or 84	**No. of Channels:** min. 6 × 6 × 1, max. 8 × 8 × 2	**No. of Channels:** 2 to 96	**No. of Channels:** 30
Size: 0.35 m to 2.0 m diameter	**Spacing:** 25, 30, 35, 40 and 50 mm (size dependent on channel count and spacing)	**Size:** 1 m × 1 m up to 10 m × 3 m	**Size:** 3.5 m diameter
Maximum Frequency: – Beamforming 36-ch.: 6.0 kHz; 60-ch.: 8.0 kHz – Acoustic Holography 36-ch.: 1.5 kHz; 60-ch.: 1.2 kHz	**Maximum Frequency:** 6 kHz	**Maximum Frequency:** 12 kHz	**Maximum Frequency:** 5 kHz **Minimum Frequency:** 100 Hz
Accessories: Tripod WQ-2691	**Accessories:** 3D Creator Optical Sensor Positioning System WU-0695-W-001	**Accessories:** Integral Connection Array WA-0806, Flexible Connection Array WA-0807 and Robot Controller WB-1477	**Accessories:** Tripod WQ-2691

2

B 36: PULSE Array-based Noise Source Identification Solutions – Arrays

Noise Source Identification using Array-based Measurement Methods

To improve overall noise levels, it is necessary to locate, quantify and rank the individual noise sources coming from a machine. This starts by identifying 'hotspots' – areas where the local sound radiation is significantly greater than that of the surrounding area. Knowing these hotspots, the dominating frequencies and relative sound power contributions enable the cause of the noise to be identified and its contribution to the overall noise level to be assessed.

Traditionally, this has been done by mapping the sound intensity directly at a number of points across the source measured with an intensity probe. With array-based techniques, this process can be significantly improved as many points are acquired simultaneously, making measurements much faster. Brüel & Kjær provides a wide selection of arrays to cover most practical situations. The measurement types can be classified as:

- Fixed: The array is set-up and not moved during the measurements, for example, a pentangular array used to measure a wind turbine
- Patch: A grid array is moved from one position to another either manually or with a robot, for example, a hand-held array used for conformal mapping of a vehicle dashboard
- Scanned: A single, a row, or a full grid of microphones is scanned over a source by means of a robot, for example, used for measurements on stationary noise sources such as transformers or dentists' drills

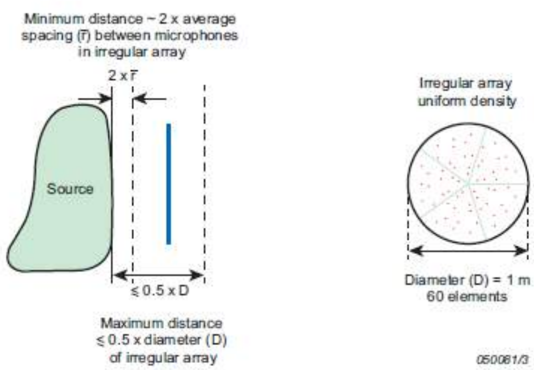
Array Acoustics Post-processing to Optimise the Return on Measurement Data

The calculation, display and reporting of the measurement is done by the suite of products known as Array Acoustics, which includes Post-processing. The three main applications are Beamforming, Spherical Beamforming and Near-field Acoustical Holography (NAH). The applicability can be increased by adding one or more of the general options such as; Transient, Quasi-stationary, Conformal or Sound Quality Metrics Calculations. A number of options are specifically designed for use with a particular application, for example, Moving Source Options for Beamforming, and Panel Contribution for NAH.

Furthermore, in the calculations themselves, you can select from a range of algorithms to optimise this process, for example, NNLS and DAMAS2 for Refined Beamforming; SONAH and ESM for NAH.

Acoustic holography methods such as Statistically Optimized Near-field Acoustic Holography (SONAH) and Equivalent Source Method (ESM) are restricted in use to arrays with less than half wavelength average inter-element spacing. For a given array, this restriction defines an upper limit on the supported frequency range. To extend the frequency range, irregular "Combo Array" geometries are used for SONAH at low frequencies and for beamforming above the previously mentioned upper limiting frequency. A major drawback is the need for two methods to cover the full frequency range: a low-frequency measurement at close range for SONAH and a high-frequency measurement at longer distance for beamforming. The patented Wide Band Holography (WBH) method can cover the combined frequency ranges of SONAH and beamforming based on a single measurement at an intermediate distance (Fig. 1).

Fig. 1
The Wideband Holography patented method used to cover the combined frequency ranges of SONAH and beamforming, based on a single measurement at an intermediate distance



Near-field Acoustic Holography, NAH

NAH builds a mathematical model describing the sound field based on a set of sound pressure measurements typically taken in a plane fairly close to the source. From this description the parameters of the sound field, sound pressure, sound intensity, particle velocity, etc., can be derived in target planes parallel to the measurement plane.

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The model can also be used to calculate far-field responses, estimating the sound pressure distribution along a line in the far-field based on the Helmholtz Integral Equation (HIE). Further potential noise reduction schemes can be applied to evaluate the impact of various source reduction possibilities. Two algorithms are available: Statistically Optimised Near-field Acoustic Holography (SONAH) and Equivalent Source Method (ESM).

The SONAH calculation method overcomes the limitations that traditional NAH calculation methods have, namely:

- The measurement area must cover the full noise source plus some additional area to avoid spatial window effects
- The measurement grid must be regular rectangular to support spatial FFT calculations

SONAH can operate with irregular arrays and allows for measurements with arrays smaller than the source, without severe spatial windowing effects.

The Equivalent Source Method (ESM) calculation can be used to deal with very curved surfaces, in that it can remove artefacts which SONAH can produce on non-plane surfaces. ESM is, therefore, implemented in Acoustical Holography when using Conformal calculations for the options Panel Contribution, Intensity Component Analysis and In Situ Absorption.

Measurement and Analysis

Stationary NAH measurements are typically made using a limited size grid array that is scanned over the source using a robot positioning system. To maintain an absolute phase reference between scan positions, a set of reference signals is simultaneously acquired. Transient measurements are typically performed using large fixed arrays, as all measurement positions must be acquired simultaneously.

Performance

- **Resolution:** The resolution, defined as the shortest distance at which two point sources can be separated, is approximately equal to:
  $R = \min(L, \lambda/2)$
  where L is the distance from array to source and λ is the wavelength
- **Frequency Range:** The frequency range is determined by:
  $f_{max} = c/2dx$ and $f_{min} = c/8D$
  where c is the speed of sound, dx is the average spacing between measurement points and D is the diameter of the array

The use of NAH is, therefore, limited at high frequencies by the spacing between measurement points. Typically NAH can be used from 50 Hz to 3000 Hz.

Features and Benefits

- Easy, high-resolution mapping at low and mid frequencies
- Very low f_{min} using SONAH or ESM
- Fully automated data acquisition including robot control using PULSE Acoustic Test Consultant Type 7761

Typical Applications

- Contribution analysis
- Engines and powertrains
- Components
- Door seal leakage
- Office machinery
- White goods
- Heavy machinery

Application Examples

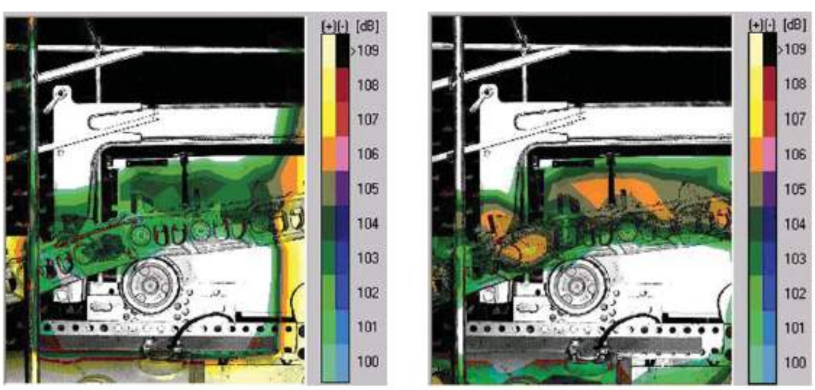
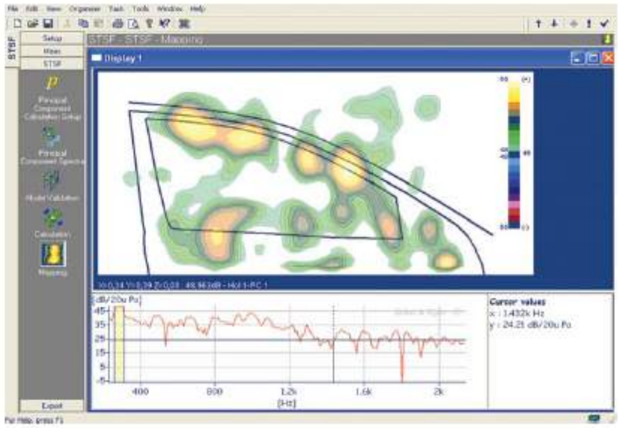


Fig. 2
Averaged particle velocity maps for the 1/12-octave bands 205 – 1454 Hz, A-weighted.
***Left:** NAH*
***Right:** SONAH. Note how SONAH reduces the edge effects*

B 38: PULSE Array-based Noise Source Identification Solutions – Measurement Methods (Continued)

Fig. 3
Map of door seal leakage.
Acoustical Holography calculations provide high-resolution mapping by calculating results in a plane close to the source surface



Planar Beamforming

Beamforming is a method of mapping noise sources by differentiating sound levels based on the direction from which they originate. The method is very quick, allowing a full map to be calculated from a single-shot measurement. It also works at high frequencies. Innovative Brüel & Kjær wheel arrays can be used with PULSE Beamforming to produce acoustically optimal results while maintaining maximum ease of use and handling.

Compared to other source location methods, the beamforming method is quick since all channels are measured simultaneously. This optimises the use of expensive measuring facilities such as anechoic chambers and wind tunnels, and takes away the tediousness and repetitiveness of many traditional methods.

Where the object under test can be considered to be composed of non-coherent sources, the Refined Beamforming algorithms based on deconvolution can be used to improve the spatial resolution of the noise maps by a factor of three or more.

Measurement and Analysis

The sound field radiating from the test object is measured at a number of microphone positions at some distance from the object. The microphones are arranged in a planar array facing towards the centre of the object.

By introducing a specific delay on each microphone signal and adding the result, it is possible to computationally create an acoustical antenna equivalent to a parabolic reflector with a main lobe of high sensitivity along a certain angle of incidence. By repeating the calculation process on the same set of measured data for a large number of angles, a full map of the relative sound pressure contribution at the observation point can be generated. With Beamforming, results can be calculated to within an angle of up to 30° away from the centre axis so that even small arrays can map large objects. It is, for example, possible to map a full vehicle from just one measurement position.

Array Design

The dynamic range (also known as the Maximum Side Lobe (MSL) level) of the maps will typically be between 8 and 15 dB depending on the design of the array. In general, irregular arrays outperform traditional regular array designs, but even irregular arrays with the same number of microphones may have very different performance depending on the exact position of the microphones. Brüel & Kjær uses a patented numerical optimisation method to design arrays with optimal performance for the frequency range and number of microphones.

The special sliced wheel array design is optimised to perform with both Beamforming and Acoustical Holography and can, therefore, be used with a combination of the methods to provide mapping of the full audible frequency range.

Performance

- **Resolution:** Defined as the shortest distance at which two point sources can be separated, is approximately equal to:
  $R = L/D * \lambda$
  where: L is the distance from array to source, D is the size of the array, and λ is the wavelength

The use of Beamforming is, therefore, limited at low frequencies by resolution. Typically Beamforming can be used from 500 Hz to 20 kHz.

For large sound sources outdoors, such as wind turbines and factories, a pentangular array is recommended. This funnel shaped array enables extraneous noise from the rear of the array to be suppressed up to 10 dB (depending on the frequency).

For road and rail vehicles, the dedicated Moving Source Beamforming Option has been developed.

Features and Benefits

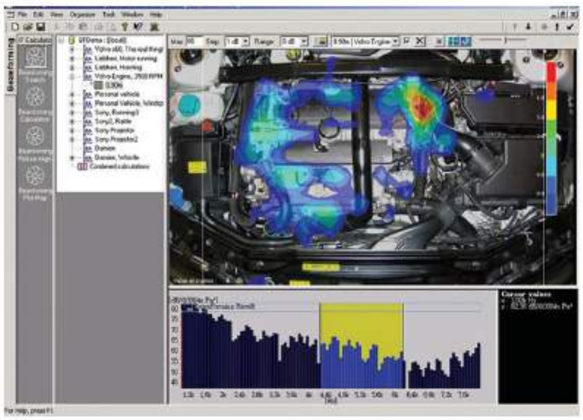
- Quick snapshot measurements
- Ideal for mid and high frequencies
- Covers large objects
- May, in combination with SONAH, cover the full audible frequency range

Typical Applications

- Contribution analysis
- Machinery
- Construction equipment
- Wind tunnels
- Engines and powertrains
- Components
- Seals
- Vehicle interiors

Application Example

Fig. 4
Beamforming result on a car engine



Conformal Mapping

A completely conformal map can be created based on a set of patch measurements at known positions and object geometry. The object geometry can either be imported from a number of standard formats or detected using the position detection system integrated in the hand-held array.

Object Geometry

Replacing the microphone array with a pointer, the positioning system in the hand-held array's handle registers the 3D coordinates of the most significant points of the geometry. Meshing tools can then be used to refine the object geometry to a suitable granularity depending on the resolution required. Alternatively, the object geometry can be imported from existing CAD or CAE models, in which case a reduction of the model is usually required in order to minimise the number of elements, and thereby the number of measurement points. CAD surface models can be imported via the IGES file format (file extension .igs) or surface mesh models via the Universal File Formats 2411 and 2412 (file extension .unv).

In general, IGES file format types 143 and 144, as well as the 500 series (also called B-Rep) can be imported. STL and UFF files can also be imported.

Measurement and Analysis

Measurements with the hand-held array are made at the most accessible places around the object, with 36 to 128 points typically measured simultaneously. Based on the integrated positioning system, the software keeps track of the positions measured. Typically the number of measurement points should correspond to the maximum frequency.

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B 40: PULSE Array-based Noise Source Identification Solutions – Planar Beamforming (Continued)

Fig. 10
Typical Pentangular Array system

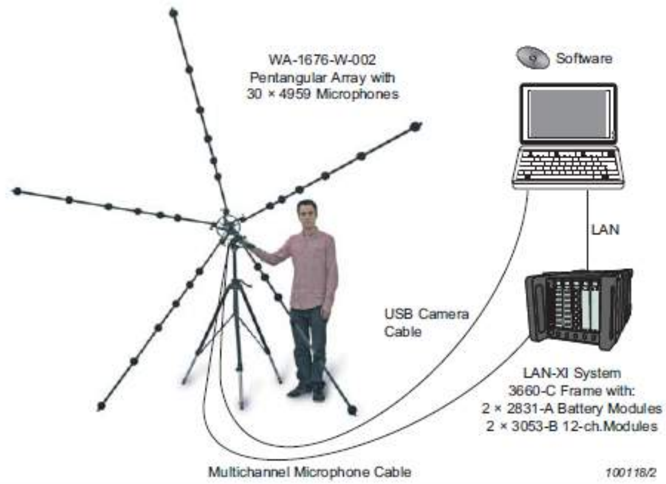
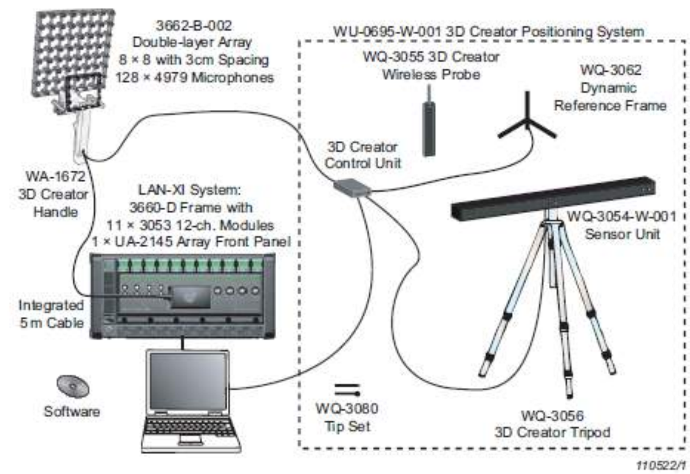


Fig. 11
Typical Hand-held Double-layer Array system with Array Front Panel UA-2145 with single cable for all acoustic signals



Hand-held Arrays – Frequency Ranges

Hand-held Array Type	Layer	Configuration	Grid Spacing (mm)	Mics. Required	Array Length (m)	Typical Min. Frequency (Hz)	Typical Max. Frequency (Hz)
Type 3662-A-001	Single	8 × 8 × 1	25	64	0.175	245	6174
Type 3662-A-002	Double	8 × 8 × 2	25	128	0.175	245	4979
Type 3662-A-003	Single	6 × 6 × 1	25	36	0.125	343	6174
Type 3662-A-004	Double	6 × 6 × 2	25	72	0.125	343	4979
Type 3662-B-001	Single	8 × 8 × 1	30	64	0.210	204	5145
Type 3662-B-002	Double	8 × 8 × 2	30	128	0.210	204	4979
Type 3662-B-003	Single	6 × 6 × 1	30	36	0.150	286	5145
Type 3662-B-004	Double	6 × 6 × 2	30	72	0.150	286	4979
Type 3662-C-001	Single	8 × 8 × 1	35	64	0.245	175	4410
Type 3662-C-002	Double	8 × 8 × 2	35	128	0.245	175	4410
Type 3662-C-003	Single	6 × 6 × 1	35	36	0.175	245	4410
Type 3662-C-004	Double	6 × 6 × 2	35	72	0.175	245	4410
Type 3662-D-001	Single	8 × 8 × 1	40	64	0.280	153	3859
Type 3662-D-002	Double	8 × 8 × 2	40	128	0.280	153	3859
Type 3662-D-003	Single	6 × 6 × 1	40	36	0.200	214	3859
Type 3662-D-004	Double	6 × 6 × 2	40	72	0.200	214	3859

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B 41: PULSE Array-based Noise Source Identification Solutions – Pentangular Array System

Specifications – Types 8606, 8607 and 8608

Configuration

OPERATING SYSTEM REQUIREMENTS
Microsoft® Windows® 8 Pro (x64), Windows® 7 SP1 (x32 and x64) or Windows® XP Professional (SP3)

OTHER SOFTWARE REQUIREMENTS
Microsoft® Office 2007 (SP2), Office 2010 (SP2) x32, or Office 2013 (x32)
Microsoft® SQL Server® 2008 R2 Express Edition (SP 1), included with PULSE)

COMPUTER CONFIGURATION/DATA ACQUISITION FRONT-ENDS
As for PULSE

PREREQUISITES
- PULSE 7700, 7770, or 7771
- PULSE Acoustic Test Consultant Type 7761

One of:
- PULSE LAN-XI and IDA®/IDA Multiple Module Front-end Driver Type 3099-A-X*
- PULSE LAN-XI Single Module and IDA®/IDA Systems any size Front-end Driver Type 3099-A-X1*
- PULSE LAN-XI Dual Module and IDA®/IDA Systems any size Front-end Driver Type 3099-A-X2*

* X = the license model, either N: Node Locked or F: Floating

	Acoustic Holography Type 8607	Beamforming Type 8608	Spherical Beamforming Type 8606
Measurement			
Monitor view	Yes	Yes	Yes (for single camera)
Data	Time or Spectral	Time	Time
Process	Single, Patch or Scanned	Single	Single
Optical picture	N/A	Take or reuse	Take or reuse
Automatic processing	Store automatically, Calculate automatically, Selectable calculation	Store automatically, Calculate automatically, Selectable calculation	Store automatically, Calculate automatically, Selectable calculation
Data Management			
Databases	Multiple simultaneous	Multiple simultaneous	Multiple simultaneous
Inspect metadata	Yes	Yes	Yes
Search on metadata	Yes	Yes	Yes
Change metadata	Yes	Yes	Yes
Calculation			
Multi core support	Yes	Yes	Yes
Target mesh type	Planar, Conformal	Planar, Conformal	Spherical, Conformal
References	Physical and Virtual	Physical	Physical
Methods	NAH, SONAH, ESM	Delay and Sum, Refined NNLS, DAMAS 2	SHARP, FAS
Filtering	Frequency, Order	Frequency, Order	Frequency, Order
Domains	Stationary, Quasi-stationary, Transient	Stationary, Quasi-stationary, Transient	Stationary, Quasi-stationary, Transient
Function	Pressure, Intensity, Reactive Intensity, Particle Velocity, Front Source Intensity, Rear Source Intensity, Scattered Intensity, Radiated Intensity, Absorption Coefficient	Pressure Contribution, Pressure, Intensity	Pressure Contribution, Pressure, Intensity
Index dimensions	Time, RPM, Angle	Time, RPM, Angle	Time, RPM, Angle
User Interface			
User levels	Basic and Advanced User defined	Basic and Advanced User defined	Basic and Advanced User defined
Defaults	User defined	User defined	User defined
Contribution Analysis			
Sound Power	Area, Component	Area, Component	Area, Component
Map Displays			
Number of displays	1 × 1 to 4 × 4	1 × 1 to 4 × 4	1 × 1 to 4 × 4
Alignment of displays	Camera Position, Data, Frequency, Index, Colour scale	Camera Position, Data, Frequency, Index, Colour scale	Camera Position, Data, Frequency, Index, Colour scale
Playback	Calculated Points	Calculated Points	Calculated Points
Reporting			
Cut and Paste	One view, All views	One view, All views	One view, All views
Movie file generation	Animation driven Audio driven	Animation driven Audio driven	Animation driven Audio driven
Microsoft® Word report generator	Across frequencies Across indices	Across frequencies Across indices	Across frequencies Across indices
Capacity			
Calculation*	Stationary (frequency based): • 2000 measurement points • 2000 target points • 6 references • 400 line FFT Stationary (time based): As Type 8608	Stationary (time based): • 300 s at 12.8 kHz • 60 measurement points • 8000 target points • 800 line FFT (or equivalent)	Stationary (time based): • 300 s at 6.4 kHz • 800 lines FFT • 2592 target points (spacing 5° in azimuth and elevation)

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B 42: PULSE Array-based Noise Source Identification Solutions – Specifications

	Acoustic Holography Type 8607	Beamforming Type 8608	Spherical Beamforming Type 8606
Calculation*	Transient: • 300 s at 12.8 kHz • 60 measurement points • 400 target points • 300 frames • 800 line FFT (or equivalent)†	Transient: • 300 s at 12.8 kHz • 60 measurement points • 400 target points • 300 frames • 800 line FFT (or equivalent)†	Transient: • 300 s at 12.8 kHz • 50 measurement points • 400 target points • 300 frames • 800 line FFT (or equivalent)
Measurement	Frequency Data: • Set by PULSE FFT analyzer (Type 3560-B/C/D/E with Type 7700 or 7770) • 2000 measurement points • 6 references • 400 line FFT Time Data: As Types 8606 and 8608	Time Data: • 300 s at 12.8 kHz • Set by data recorder (Data Recorder Type 7701 or Time Data Recorder Type 7708)	Time Data: • 300 s at 12.8 kHz • Set by data recorder (Data Recorder Type 7701 or Time Data Recorder Type 7708)

* For one parameter at a time (for example, sound pressure, sound intensity)
† Full compliance with specification with Windows® 64-bit. With Windows® 32-bit, the specification is halved

Ordering Information

Type/Part No.	Name	Acoustic Holography Type 8607	Beamforming Type 8608	Spherical Beamforming Type 8606
8606-X*	PULSE Array Acoustics Spherical Beamforming	–	–	Required
8607-X*	PULSE Array Acoustics Acoustic Holography	Required	–	–
8608-X*	PULSE Array Acoustics Beamforming	–	Required	–
BZ-5644-X*	PULSE Array Acoustics Wideband Holography	–	Option	–
BZ-5635-X*	PULSE Array Acoustics Quasi-stationary Calculations	Option	Option	Option
BZ-5636-X*	PULSE Array Acoustics Transient Calculations	Option	Option	Option
BZ-5637-X*	PULSE Array Acoustics Conformal Calculations	Option	Option	Option
BZ-5638-X*	PULSE Array Acoustics Sound Quality Metrics	Option	Option	Option
BZ-5639-X*	PULSE Array Acoustics Refined Beamforming Calculations	–	Option	–
BZ-5943-X*	PULSE Array Acoustics Road Vehicles Moving Source Beamforming	–	Option	–
BZ-5939-X*	PULSE Array Acoustics Rail Vehicles Moving Source Beamforming	–	Option	–
BZ-5941-X*	PULSE Array Acoustics Wind Turbines Moving Source Beamforming	–	Option	–
BZ-5640	PULSE Panel Contribution	Option†	–	–
BZ-5641	PULSE Intensity Component Analysis	Option†	–	–
BZ-5642	PULSE In Situ Absorption	Option†	–	–
BZ-5370	PULSE ATC Robot Option	Option	–	–
BZ-5611	PULSE ATC Positioning Option	Option	–	–
7761-X*	PULSE Acoustic Test Consultant	Prerequisite	Prerequisite	Prerequisite
7700/7770/7771-Xy*,‡	PULSE FFT & CPB/FFT/CPB	Prerequisite	Prerequisite	Prerequisite
3099-A-X/X1/X2**	Front-end Driver	Prerequisite	Prerequisite	Prerequisite

* X = license model either N for node-locked or F for floating
† requires PULSE Array Acoustics Conformal Calculations BZ-5637-X
‡ y = optional channel count, from 1 (single) to 7. No number denotes unlimited channels (channel-independent)
** See PREREQUISITES on page 11

ACCESSORIES

Type 9665	Array Positioning System (Robot)
UA-2145	Array Front Panel for LAN-XI 11 modules
WA-0810	Support Stand for Grid Array
WA-0806	Integral Connection Array
WA-0807	Flexible Connection Array
WB-1477	Robot Controller
WU-0695-W-001	3D Creator Optical Sensor Positioning System
WA-1565-W-003	Spherical Array for 36 Channels
WA-1565-W-004	Spherical Array for 50 Channels
WA-1647-W-001	Car Seat Fixture for Spherical Array
WA-0728-W-004	Single-channel Pistonphone Adaptor, stethoscope, for Spherical Array with Microphones Type 4959
WA-0728-W-005	Single Channel Pistonphone Adaptor, stethoscope version for foldable array with Type 4959
WA-0890	Full wheel/Half-wheel Beamforming Array
WA-1558	Slice Wheel Array
WQ-2691	Tripod
WA-0893	Carriage for Half-wheel Array
Type 3662-X-yyy*	Hand-held Array (see Table 1)
Type 4957	10 kHz Array Microphone
Type 4958	20 kHz Precision Array Microphone
Type 4959	10 kHz Very Short Array Microphone

* X = A, B, C or D, which is standard spacing at 25, 30, 35 or 40 mm; yyy = 001, 002, 003 or 004, which are channel counts at 8×8×1, 8×8×2, 6×6×1 or 6×6×2

TRADEMARKS
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BP 2144–20 2013-08

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Local representatives and service organisations worldwide

Brüel & Kjær

B 43: PULSE Array-based Noise Source Identification Solutions – Specifications (Continued)

Brüel & Kjær

creating sustainable value

Beamforming

Beamforming is a method of mapping noise sources using an acoustical array. Beamforming discerns the direction from which the sound originates by means of the time delays that occur as the sound passes over an array of microphones. The method is very quick, allowing a full map to be calculated from a single-shot measurement. It is mainly used from one to a few wavelength's distance from the source under test and is chiefly of interest for medium to high frequencies.

Applications are found indoors, outdoors (Moving Source Beamforming), underwater and in windtunnels.

B 44: Beamforming

PRODUCT DATA

Short 20 kHz Array Microphone — Type 4959

Array Microphone Type 4959 is a ¼" prepolarized microphone specially designed for use in Brüel & Kjær's hand-held and foldable arrays.

Uses
- In Brüel & Kjær hand-held and foldable arrays

Features
- Sensitivity: 11.2 mV/Pa (–39 dB re 1 V/Pa)
- Frequency Range: 50 Hz – 20 kHz
- Dynamic Range: 32 – 134 dB
- Built-in DeltaTron® preamplifier with TEDS (IEEE 1451.4 V.1.0)
- Specified phase-matching
- Transfer function described in TEDS
- Dimensions: 13 mm long, 7 mm diameter
- Temperature Range: –10 to +55°C (+14 to +131°F)

070157

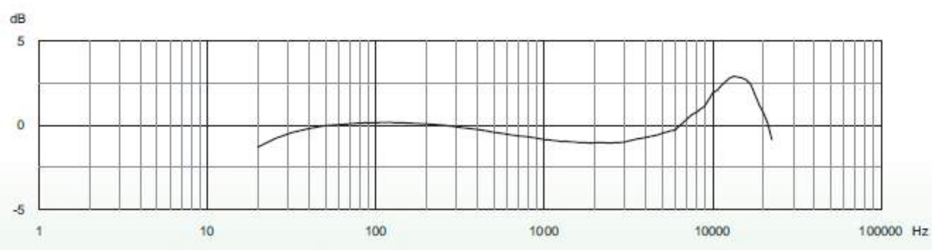
Description
Type 4959 microphones have good, stable amplitude and phase-matching over wide ranges of temperature and humidity. Their frequency response is optimised for a flat response in a pressure field.

Each microphone's built-in TEDS (Transducer Electronic Data Sheet) contains information about the complex transfer function, enabling applications to use data for individual transducers, resulting in more precise measurements.

The preamplifier is an industry standard DeltaTron (constant current line drive) type, allowing the use of the same coaxial cable for signal, power supply and TEDS.

A rugged protection grid provides an integrated heat shield. The microphone is front-vented for pressure equalization.

Fig. 1 Typical pressure-field response



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Brüel & Kjær

B 45: 20 kHz Array Microphone – Type 4959 – Uses and Features and Description

Specifications – Type 4959

Specifications	Value
Guaranteed Specifications*	
Sensitivity	−39 dB re 1 V/Pa ±3 dB
	11.2 mV/Pa (@ 250 Hz)
Pressure-field Frequency Response (re 250 Hz)	±2 dB, 100 Hz to 5 kHz ±3 dB, 50 Hz to 10 kHz +5/−3 dB, 10 kHz to 20 kHz
Inherent Noise (without RF field)	<32 dB SPL (A-weighted)
Upper Limit of Dynamic Range	134 dB (THD <3%)
Phase Matching relative to a factory reference	<±5°, 100 to 3 kHz <±10°, 3 kHz to10 kHz
General Specifications†	
Inherent Noise (A-weighted)	32 dB (−10 to +40°C, +14 to +104°F) 37 dB (−10 to +55°C, +14 to +131°F)
Output Impedance	<150 Ω
Output Voltage Voltage Swing DC Bias	 $>5\ V_{pp}$ 12 V ± 4 V
Output Socket	Dedicated Brüel & Kjær Hand-held Array socket
Polarization Voltage	Prepolarized
TEDS	IEEE 1451.4 V.1.0 Template I27-0-0-1U
Environmental	
Operating Temperature Range	−10 to +55°C (+14 to +131°F)
Storage Temperature	−25 to +70°C (−13 to +158°F)
Operating Humidity Range	0% to 90% RH without condensation
Vibration Sensitivity (20 to 1000 Hz)	Approx. 50 dB equivalent SPL for 1 m/s^2 axial acceleration
Magnetic Field Sensitivity	40 dB SPL for 80 A/m, 50 Hz field
Physical	
Diameter	7 mm (~1/4″)
Length	13 mm (1.34″)
Weight	3 g (0.9 oz.)

* Valid at +23°C (+73.4°F) with 4.5 mA current drive with a compliance voltage of 28 V
† General specifications are typical values

Ordering Information

Type 4959 Short 20 kHz Array Microphone
Type 4959 is delivered in an ESD safe plastic bag

Optional Accessories	
Type 4228	Pistonphone
WA-0728	6-microphone Adaptor for Pistonphone Type 4228
Traceable Calibration	
4959-CFF	Factory Standard Calibration – includes TEDS update (included with delivery)

CE Compliance with EMC Directive and Low Voltage Directive of the European Community
Compliance with EMC Requirements of Australia and New Zealand

Safety: EN/IEC 61010−1: Safety requirements for electrical equipment for measurement, control and laboratory use
EMC Emission: ENIEC 61000−6−3: Generic emission standard for residential, commercial and light industrial environments
EMC Immunity: EN/IEC 61000−6−2: Generic standards – Immunity for industrial environments.

BP 2202−12 2011-02

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Local representatives and service organisations worldwide

Brüel & Kjær

B 46: 20 kHz Array Microphone – Type 4959 – Specifications

PULSE LabShop

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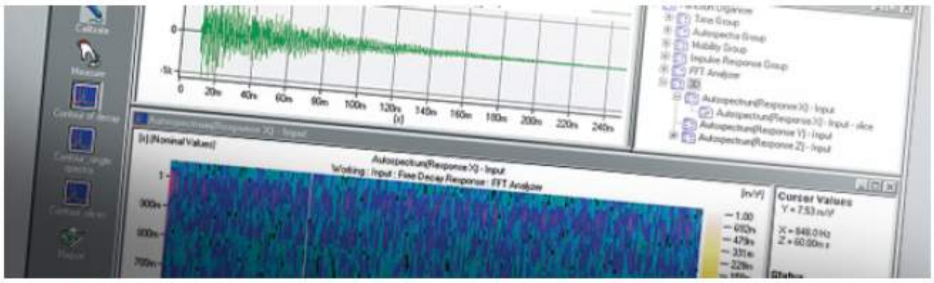
creating sustainable value

PULSE LabShop



Our well-established flagship for real-time data acquisition from 2 - 1000+ channels. Equipped to perform fundamental analysis software tasks as standard, it is limited only by the computer running it.

Standard PULSE LabShop tools:

- FFT analysis
- CPB real-time 1/n octave analysis
- Order analysis
- Envelope analysis
- Cepstrum analysis
- SSR analysis

> Overview of PULSE LabShop modules

Powerful analysis capabilities

Standard PULSE LabShop analysis tools are:

- FFT analysis
- CPB real-time 1/n octave analysis
- Order tracking analysis
- Envelope analysis
- Cepstrum analysis
- Steady state response (SSR) analysis
- Time-capture analysis
- In addition you can record your time data with the Time Data Recorder option

B 47: PULSE LabShop – Overview

Multi-analysis

Since most tests can only be run once with the same conditions, its multi-analysis capability means you can capture test data and run it through LabShop's multiple analyzers in parallel - making this capability a great strength of PULSE LabShop.

It allows you to combine any kind of analysis and recording tools to analyse your data simultaneously - based on the same raw time-data samples. Displaying consistent results in real-time, it saves a great deal of time and gives immediate confidence in the achieved test results.

Best-in-class real-time performance

Running on Microsoft® Windows 7 and 8 operating systems, PULSE LabShop continuously keeps pace with advances in computing power, adapting to get most out of your PC's performance. Standard PCs can currently run PULSE LabShop and analyse 160 FFT signals or 80 CPB signals up to 25kHz, giving the possibility to use standard office PCs for measurement tests. Extremely high real-time performance is achieved with high-end PCs and LAN switches.

We recently configured a 320-channel satellite test system analysing data up to a 50kHz bandwidth / 131kHz sampling frequency. See a video about the satellite test system.

B 48: PULSE LabShop – Analysis and Performance

Customisation and programmability

Versatile and highly customisable, LabShop can be tailored to your needs. The built-in 'Smart Start' concept eases the setup of new analyses and automatically presents the results on screen, and stores often-used setup and result views for recall at the push of a button.

For integration with test cells and third-party solutions, PULSE LabShop includes an extensive programmable interface, allowing you to integrate it with your application. A built-in VBA (Visual Basic® for Applications) allows easy customisation, and PULSE LabShop software is delivered with a library of demo examples for coding in Microsoft Visual Studio environment (C++, C# /.Net, Visual Basic etc.) as well as Matlab.

Modular LAN-XI data acquisition hardware

LAN-XI is a versatile system of modular units that can be combined in frames. Every module can be used individually as a small system front-end of up to 12 channels, or become part of a distributed-module setup connected via LAN. All modules include a standard frequency range of 0 - 51.2 kHz, with a single measuring range of 160 dB that eliminates the need for input ranging.

Specialised modules are available such as the high frequency 102.4 kHz input module, and modules with full generator functionality from 0 to 51.2 kHz.

> LAN-XI data acquisition hardware

B 49: PULSE LabShop – Customization and Programmability and Hardware

Noise Source Identification using Array-based Measurement Methods

To improve overall noise levels, it is necessary to locate, quantify and rank the individual noise sources coming from a machine. This starts by identifying 'hotspots' – areas where the local sound radiation is significantly greater than that of the surrounding area. Knowing these hotspots, the dominating frequencies and relative sound power contributions enable the cause of the noise to be identified and its contribution to the overall noise level to be assessed.

Traditionally, this has been done by mapping the sound intensity directly at a number of points across the source measured with an intensity probe. With array-based techniques, this process can be significantly improved as many points are acquired simultaneously, making measurements much faster. Brüel & Kjær provides a wide selection of arrays to cover most practical situations. The measurement types can be classified as:

- Fixed: The array is set-up and not moved during the measurements, for example, a pentangular array used to measure a wind turbine
- Patch: A grid array is moved from one position to another either manually or with a robot, for example, a hand-held array used for conformal mapping of a vehicle dashboard
- Scanned: A single, a row, or a full grid of microphones is scanned over a source by means of a robot, for example, used for measurements on stationary noise sources such as transformers or dentists' drills

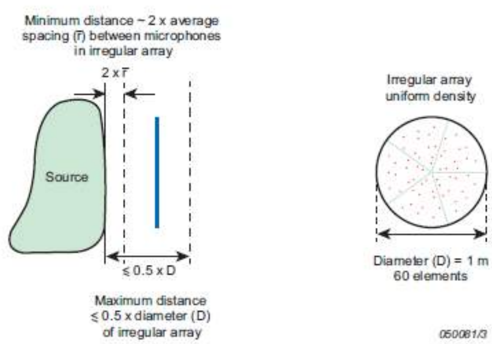
Array Acoustics Post-processing to Optimise the Return on Measurement Data

The calculation, display and reporting of the measurement is done by the suite of products known as Array Acoustics, which includes Post-processing. The three main applications are Beamforming, Spherical Beamforming and Near-field Acoustical Holography (NAH). The applicability can be increased by adding one or more of the general options such as; Transient, Quasi-stationary, Conformal or Sound Quality Metrics Calculations. A number of options are specifically designed for use with a particular application, for example, Moving Source Options for Beamforming, and Panel Contribution for NAH.

Furthermore, in the calculations themselves, you can select from a range of algorithms to optimise this process, for example, NNLS and DAMAS2 for Refined Beamforming; SONAH and ESM for NAH.

Acoustic holography methods such as Statistically Optimized Near-field Acoustic Holography (SONAH) and Equivalent Source Method (ESM) are restricted in use to arrays with less than half wavelength average inter-element spacing. For a given array, this restriction defines an upper limit on the supported frequency range. To extend the frequency range, irregular "Combo Array" geometries are used for SONAH at low frequencies and for beamforming above the previously mentioned upper limiting frequency. A major drawback is the need for two methods to cover the full frequency range: a low-frequency measurement at close range for SONAH and a high-frequency measurement at longer distance for beamforming. The patented Wide Band Holography (WBH) method can cover the combined frequency ranges of SONAH and beamforming based on a single measurement at an intermediate distance (Fig. 1).

Fig. 1
The Wideband Holography patented method used to cover the combined frequency ranges of SONAH and beamforming, based on a single measurement at an intermediate distance



Near-field Acoustic Holography, NAH

NAH builds a mathematical model describing the sound field based on a set of sound pressure measurements typically taken in a plane fairly close to the source. From this description the parameters of the sound field, sound pressure, sound intensity, particle velocity, etc., can be derived in target planes parallel to the measurement plane.

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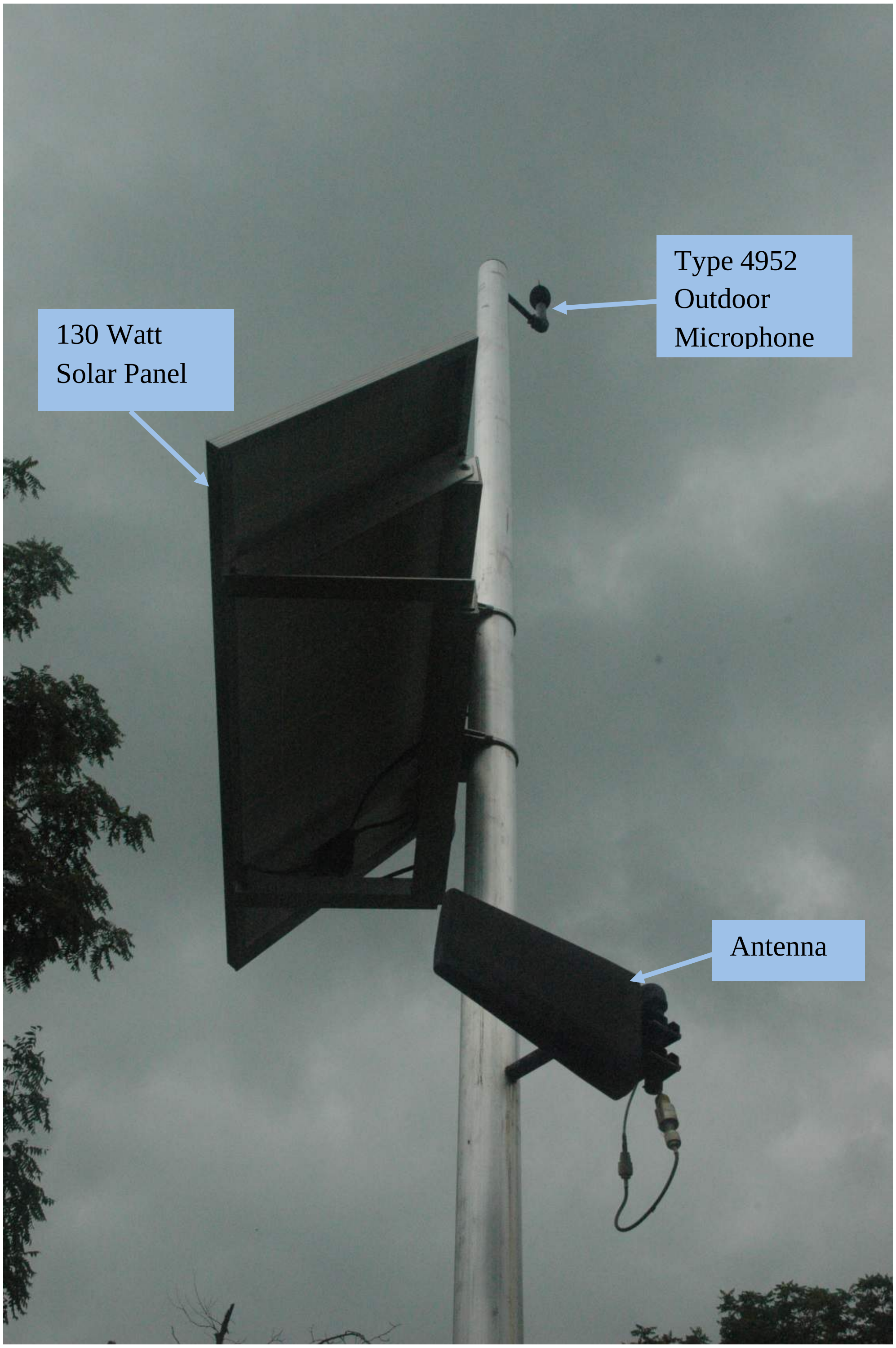
B 50: PULSE Array-based Noise Source Identification Solutions – Array Acoustics Pose-processing Suite

APPENDIX C
Phase 1 – Part 1

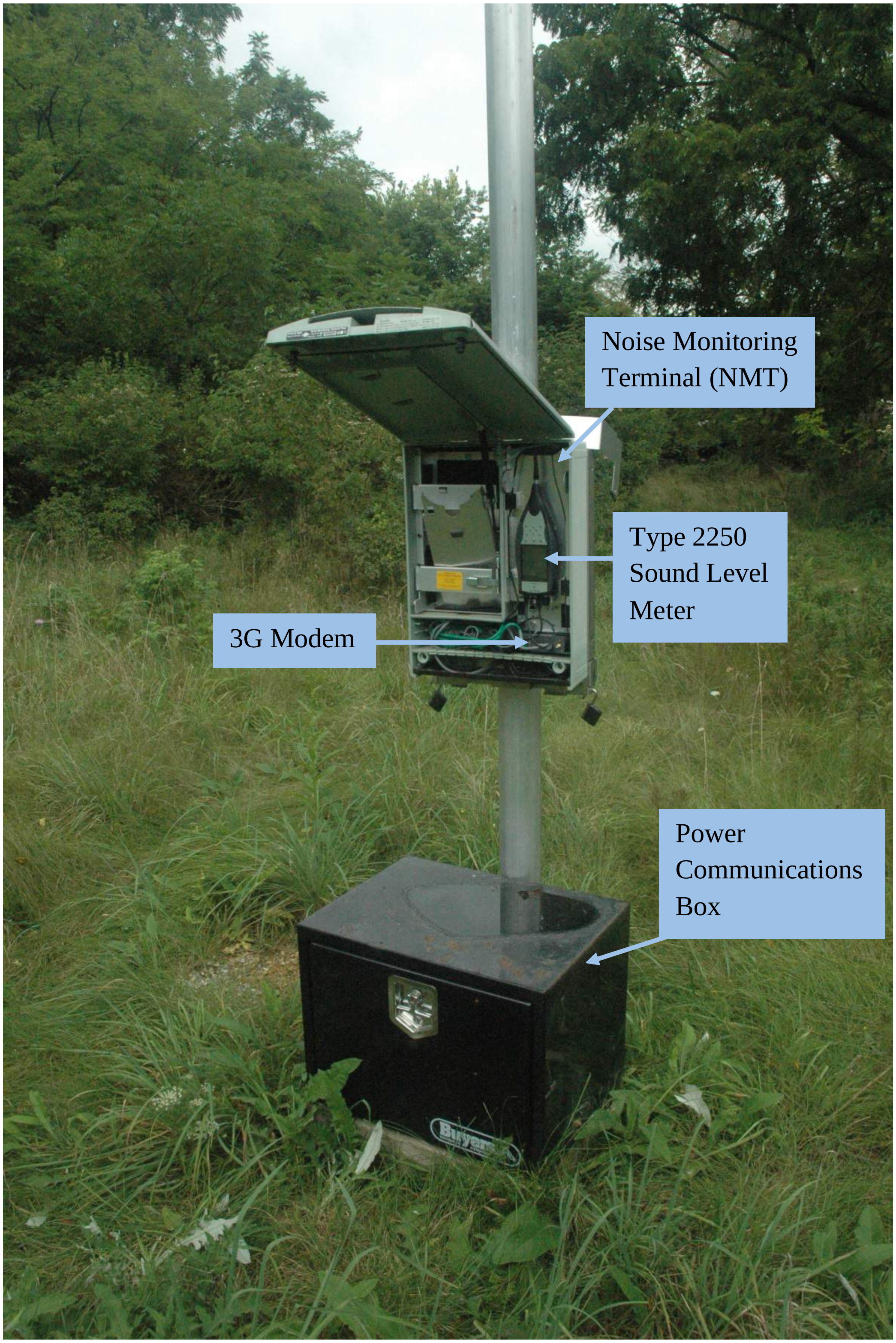
Contents

Phase 1 – Part 1 Installation Photographs

C 1: Complete Installation of Permanent Noise Sentinel Site – Complete View



C 2: Installation of Permanent Noise Sentinel Site – Higher Portion

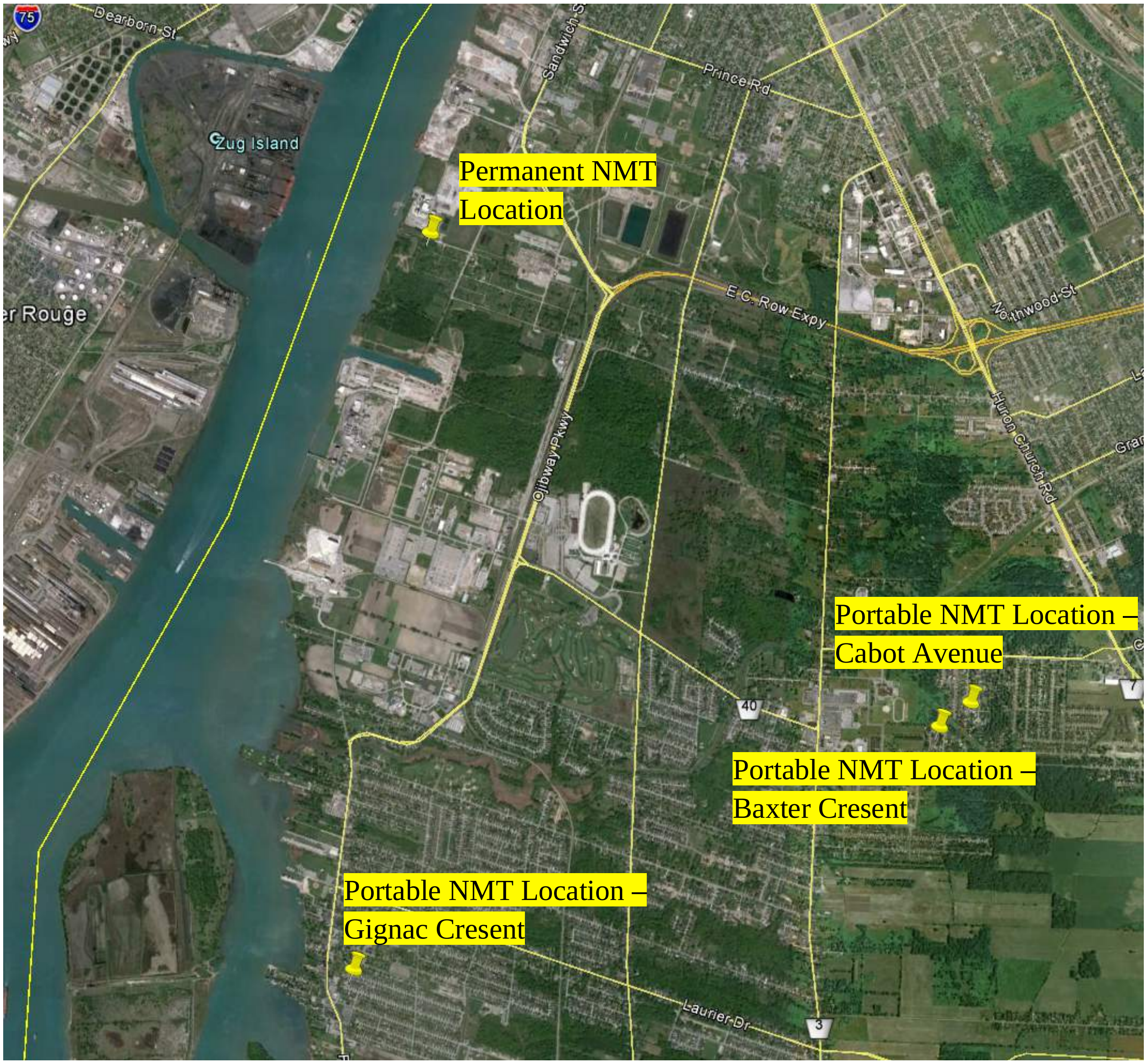


C 3: Installation of Permanent Noise Sentinel Site – Lower Portion

C 4: Installation of Portable Noise Sentinel at Local Residence – NMT

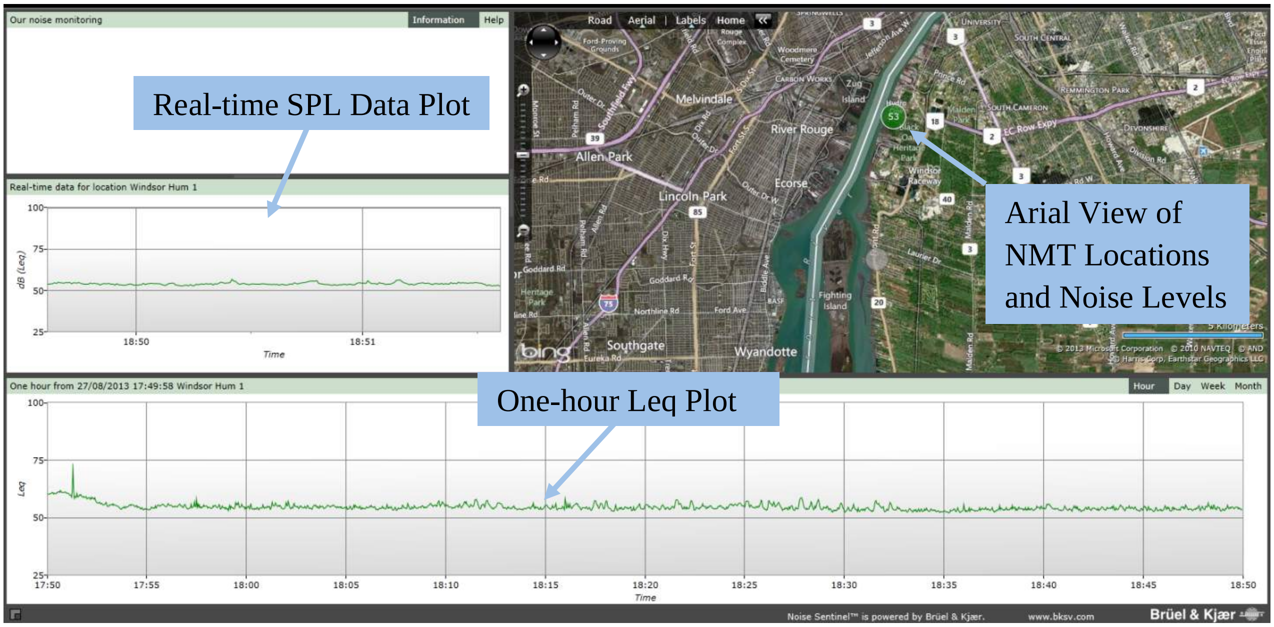
C 5: Installation of Portable Noise Sentinel at Local Residence – Microphone

Phase 1 – Part 1 Measurement Locations



C 6: Noise Sentinel Monitoring Locations

Phase 1 – Part 1 Measurement Data

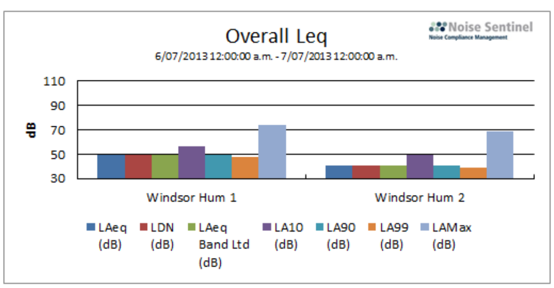


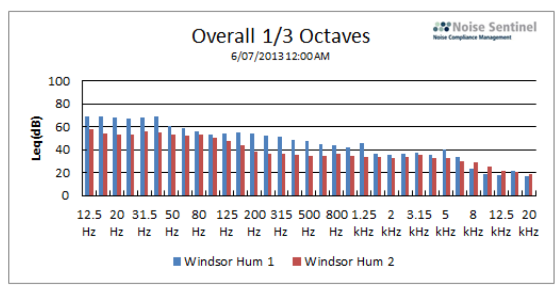
C 7: Noise Sentinel Live Web Monitoring

Long Period

Windsor Hum (6/07/2013 12:00 AM - 7/07/2013 12:00 AM)

Brüel & Kjær





Overall Data

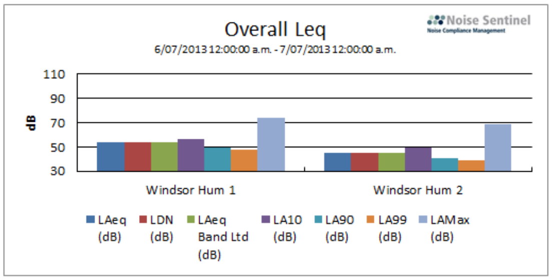
Location	Start Time	End Time	Activity	LDN (dB)	L_{Aeq} (dB)	L_{leq} (dB)	L_{eq} ⅓ Octave Band Spectra	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz
Windsor Hum 1	6/07 12:00:00 AM	8/07 12:00:00 PM	30%	49.5	49.5			69.1	69.3	68.0	67.0	67.9	69.4	60.9	59.2	55.7	53.5	53.9	54.8	54.2	52.3
Windsor Hum 2	6/07 12:00:00 AM	8/07 12:00:00 PM	30%	41.0	41.0			57.5	54.1	52.9	53.7	56.1	55.4	53.6	52.5	53.4	50.5	47.3	44.0	38.7	36.9

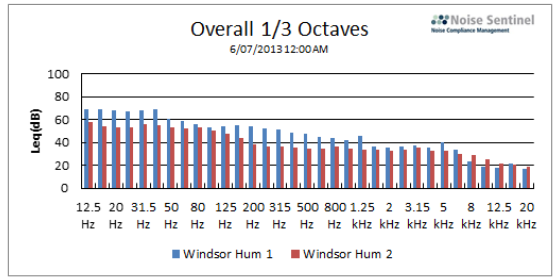
C 8: Sample Section of Noise Sentinel Daily Report – Long Period

Short Period

Windsor Hum (6/07/2013 12:00 AM - 7/07/2013 12:00 AM)

Brüel & Kjær

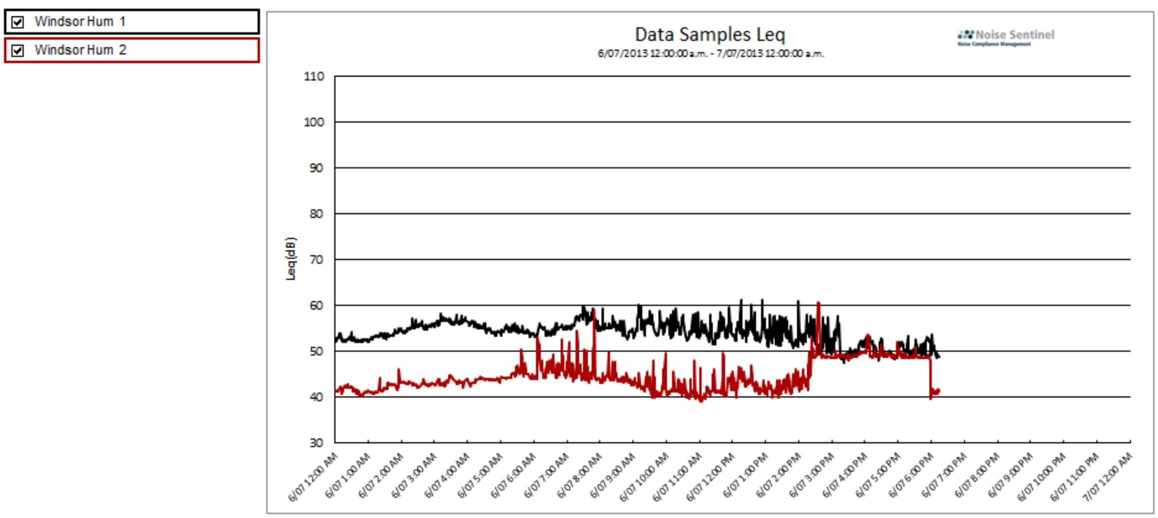




Overall Data

Location	Start Time	End Time	Activity	LDN (dB)	L_{Aeq} (dB)	L_{leq} (dB)	L_{eq} ⅓ Octave Band Spectra	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz
Windsor Hum 1	6/07 12:00:00 AM	7/07 12:00:00 AM	76%	53.5	53.5			69.1	69.3	68.0	67.0	67.9	69.4	60.9	59.2	55.7	53.5	53.9	54.8	54.2	52.3
Windsor Hum 2	6/07 12:00:00 AM	7/07 12:00:00 AM	76%	45.0	45.0			57.5	54.1	52.9	53.7	56.1	55.4	53.6	52.5	53.4	50.5	47.3	44.0	38.7	36.9

C 9: Sample Section of Noise Sentinel Daily Report – Short Period (Part 1)



Data Samples - Resolution 1 min(s)

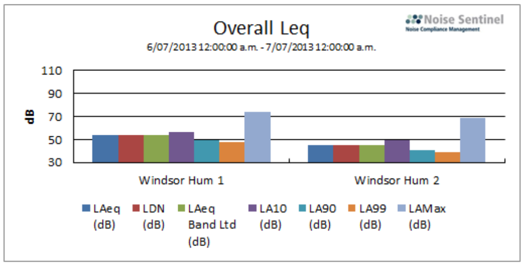
Location	Start Time	End Time	Activity	LDN (dB)	L_{Aeq} (dB)	L_{leq} (dB)	L_{eq} ⅓ Octave Band Spectra	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz
Windsor Hum 1	6/07 12:00:00 AM	6/07 12:01:00 AM	85%	52.1	52.1			69.2	68.6	66.8	66.7	67.8	69.0	58.8	55.6	51.6	51.9	54.9	55.5	54.9	51.2
Windsor Hum 2	6/07 12:00:00 AM	6/07 12:01:00 AM	75%	41.7	41.7			56.0	53.6	51.8	51.0	51.5	50.2	51.2	50.0	51.9	45.5	44.5	38.4	33.7	32.6
Windsor Hum 2	6/07 12:01:00 AM	6/07 12:02:00 AM	100%	41.2	41.2			54.7	51.6	50.0	50.7	49.9	49.7	50.8	50.0	51.8	45.4	44.1	37.4	32.7	32.1
Windsor Hum 2	6/07 12:02:00 AM	6/07 12:03:00 AM	100%	41.2	41.2			52.8	50.0	50.0	49.2	49.1	49.6	50.3	50.0	52.2	45.5	44.6	37.7	32.0	31.3
Windsor Hum 2	6/07 12:03:00 AM	6/07 12:04:00 AM	100%	41.2	41.2			51.2	49.1	49.2	49.5	49.4	48.4	49.4	49.7	52.3	45.1	43.3	37.4	32.3	31.4
Windsor Hum 2	6/07 12:04:00 AM	6/07 12:05:00 AM	100%	41.4	41.4			51.5	49.1	48.8	49.6	49.0	48.7	49.6	50.0	52.5	45.3	44.1	39.4	32.8	31.4
Windsor Hum 2	6/07 12:05:00 AM	6/07 12:06:00 AM	100%	41.4	41.4			49.2	47.5	49.6	50.8	50.6	50.0	50.6	50.3	52.2	45.8	43.7	38.6	33.2	31.8

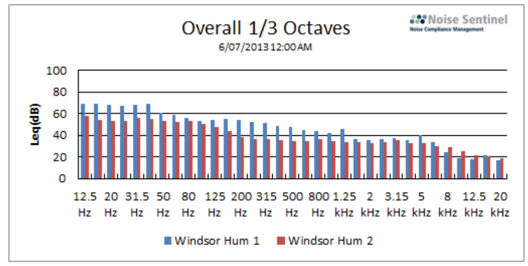
C 10: Sample Section of Noise Sentinel Daily Report – Short Period (Part 2)

Logged Data

Windsor Hum (6/07/2013 12:00 AM - 7/07/2013 12:00 AM)

Brüel & Kjær

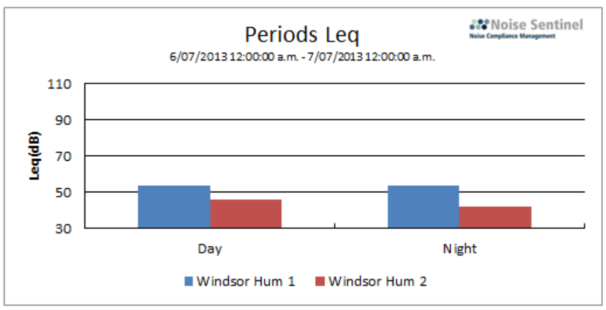




Overall Data

Location	Start Time	End Time	Activity	LDN (dB)	L_{Aeq} (dB)	L_{eq} ⅓ octaves Band Spectra	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz
Windsor Hum 1	6/07 12:00:00 AM	7/07 12:00:00 AM	76%	53.5	53.5		69.1	69.3	68.0	67.0	67.9	69.4	60.9	59.2	55.7	53.5	53.9	54.8	54.2	52.3
Windsor Hum 2	6/07 12:00:00 AM	7/07 12:00:00 AM	76%	45.0	45.0		57.6	54.1	52.9	53.7	56.1	55.4	53.6	52.5	53.4	50.5	47.3	44.0	38.7	37.0

C 11: Sample Section of Noise Sentinel Daily Report – Logged Data (Part 1)



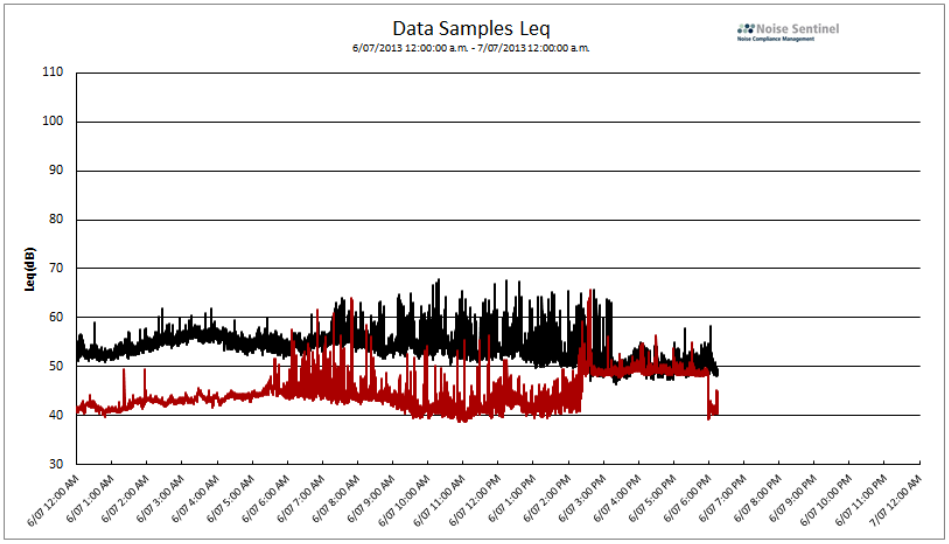
Periods Data

Location	Start Time	End Time	Activity	LDN (dB)	L_{Aeq} (dB)	L_{eq} ⅓ octaves Band Spectra	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz
Windsor Hum 1 (Day)	6/07 6:00:00 AM	6/07 10:00:00 PM	76%	53.4	53.4		68.5	68.7	67.6	66.3	67.3	68.7	61.1	59.9	56.6	52.8
Windsor Hum 1 (Night)	6/07 12:00:00 AM	7/07 12:00:00 AM	75%	53.6	53.6		70.2	70.3	68.9	68.2	69.1	70.5	60.5	57.0	53.1	54.6
Windsor Hum 2 (Day)	6/07 6:00:00 AM	6/07 10:00:00 PM	76%	46.0	46.0		55.6	51.7	50.9	52.1	54.6	54.1	52.8	52.2	52.7	51.1
Windsor Hum 2 (Night)	6/07 12:00:00 AM	7/07 12:00:00 AM	75%	42.2	42.2		59.9	56.9	55.3	55.8	58.1	57.3	54.8	53.1	54.4	49.1

C 12: Sample Section of Noise Sentinel Daily Report – Logged Data (Part 2)

☑ Windsor Hum 1

☑ Windsor Hum 2



Data Samples - Resolution 5 sec(s)

Location	Start Time	End Time	Activity	LDN (dB)	L_{Aeq} (dB)	L_{eq} ⅓ octave Band Spectra	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
Windsor Hum 1	6/07 12:00:00 AM	6/07 12:00:05 AM	100%				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Windsor Hum 2	6/07 12:00:00 AM	6/07 12:00:05 AM	100%				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Windsor Hum 2	6/07 12:00:05 AM	6/07 12:00:10 AM	100%				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

C 13: Sample Section of Noise Sentinel Daily Report – Logged Data (Part 3)

System Performance

Brüel & Kjær

Windsor Hum (6/07/2013 12:00 AM - 7/07/2013 12:00 AM)

Overall Data

Location	Start Time	End Time	Activity	Downtime
Windsor Hum 1	6/07 12:00:00 AM	7/07 12:00:00 AM	76%	05:46:00
Windsor Hum 2	6/07 12:00:00 AM	7/07 12:00:00 AM	76%	05:46:00

Periods Data

Location	Start Time	End Time	Activity	Downtime
Windsor Hum 1 (Day)	6/07 6:00:00 AM	6/07 10:00:00 PM	76%	03:46:00
Windsor Hum 1 (Night)	6/07 12:00:00 AM	7/07 12:00:00 AM	75%	02:00:00
Windsor Hum 2 (Day)	6/07 6:00:00 AM	6/07 10:00:00 PM	76%	03:46:00
Windsor Hum 2 (Night)	6/07 12:00:00 AM	7/07 12:00:00 AM	75%	02:00:00

Data Samples - Resolution 5 sec(s)

Location	Start Time	End Time	Activity	Downtime
Windsor Hum 1	6/07 12:00:00 AM	6/07 12:00:05 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:05 AM	6/07 12:00:10 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:10 AM	6/07 12:00:15 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:15 AM	6/07 12:00:20 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:20 AM	6/07 12:00:25 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:25 AM	6/07 12:00:30 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:30 AM	6/07 12:00:35 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:35 AM	6/07 12:00:40 AM	100%	00:00:00
Windsor Hum 1	6/07 12:00:40 AM	6/07 12:00:45 AM	100%	00:00:00

C 14: Sample Section of Noise Sentinel Daily Report – System Performance

Setup

Windsor Hum (6/07/2013 12:00 AM - 7/07/2013 12:00 AM)

Brüel & Kjær

Location	Start Time	End Time	Resource Name	Serial Number	Resource Type	Longitude	Latitude	CIC day	Short Report Duration (min)	Short Report Percentiles	Time Weighting	Weighting Filter
Windsor Hum 1	19/06 3:28:10 PM		NMT - 3000363	3000363	2250	-83.09474722	42.2768666	1	0	5, 10, 50, 90, 95	Slow	A-Filter
Windsor Hum 2	25/06 11:10:43 AM		NMT - 2774018	2774018	2250	-83.051712	42.246745	1	0	5, 10, 50, 90, 95	Slow	A-Filter

Periods and Penalties	Requested	Start Time	End Time	Penalty (dB)
Day	Yes	06:00:00	22:00:00	0
Night	Yes	22:00:00	06:00:00	0

Assessment Parameters	
Name	Windsor Hum Daily Data Report V2
Generate Time	6/07 6:18:23 PM
Generate Duration	00:03:11.9123073
Software	NS 5.0.2.0
Report Type	StandardExcelReporting
Night Period	Selected
Data Query Start Time	6/07 12:00:00 AM
Data Query End Time	7/07 12:00:00 AM

Assessment Selection	
Logged Data	Yes
Short Period	Yes
Long Period	Yes
Noise Events	Yes
System Performance	Yes
Alert Data	Yes

C 15: Sample Section of Noise Sentinel Daily Report – Setup

Alert Data

Windsor Hum (6/07/2013 12:00 AM - 7/07/2013 12:00 AM)

Brüel & Kjær

Alert Log

Location	Start Time	End Time	Title	Message	Activity	Threshold	Value	Unit	Severity	Sounds	Comments
Windsor Hum 1	6/07 12:00:00 AM	6/07 12:15:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 52.4dB in period 6/07/2013 12:14:00 a.m. - 6/07/2013 12:15:00 a.m..	100%	47.0	52.4	dB	Exceedance	Sound	
Windsor Hum 1	6/07 12:15:00 AM	6/07 12:30:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 54.3dB in period 6/07/2013 12:29:00 a.m. - 6/07/2013 12:30:00 a.m..	100%	47.0	54.3	dB	Exceedance	Sound	
Windsor Hum 1	6/07 12:30:00 AM	6/07 12:45:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 52.4dB in period 6/07/2013 12:44:00 a.m. - 6/07/2013 12:45:00 a.m..	100%	47.0	52.4	dB	Exceedance	Sound	
Windsor Hum 1	6/07 12:45:00 AM	6/07 1:00:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 52dB in period 6/07/2013 12:59:00 a.m. - 6/07/2013 1:00:00 a.m..	100%	47.0	52.0	dB	Exceedance	Sound	
Windsor Hum 1	6/07 1:00:00 AM	6/07 1:15:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 53.5dB in period 6/07/2013 1:14:00 a.m. - 6/07/2013 1:15:00 a.m..	100%	47.0	53.5	dB	Exceedance	Sound	
Windsor Hum 1	6/07 1:15:00 AM	6/07 1:30:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 54.1dB in period 6/07/2013 1:29:00 a.m. - 6/07/2013 1:30:00 a.m..	100%	47.0	54.1	dB	Exceedance	Sound	
Windsor Hum 1	6/07 1:30:00 AM	6/07 1:45:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 53.7dB in period 6/07/2013 1:44:00 a.m. - 6/07/2013 1:45:00 a.m..	100%	47.0	53.7	dB	Exceedance	Sound	
Windsor Hum 1	6/07 1:45:00 AM	6/07 2:00:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 55dB in period 6/07/2013 1:59:00 a.m. - 6/07/2013 2:00:00 a.m..	100%	47.0	55.0	dB	Exceedance	Sound	
Windsor Hum 1	6/07 2:00:00 AM	6/07 2:15:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 55dB in period 6/07/2013 2:14:00 a.m. - 6/07/2013 2:15:00 a.m..	100%	47.0	55.0	dB	Exceedance	Sound	
Windsor Hum 1	6/07 2:15:00 AM	6/07 2:30:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 55.3dB in period 6/07/2013 2:29:00 a.m. - 6/07/2013 2:30:00 a.m..	100%	47.0	55.3	dB	Exceedance	Sound	
Windsor Hum 1	6/07 2:30:00 AM	6/07 2:45:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 54.8dB in period 6/07/2013 2:44:00 a.m. - 6/07/2013 2:45:00 a.m..	100%	47.0	54.8	dB	Exceedance	Sound	
Windsor Hum 1	6/07 2:45:00 AM	6/07 3:00:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 56.3dB in period 6/07/2013 2:59:00 a.m. - 6/07/2013 3:00:00 a.m..	100%	47.0	56.3	dB	Exceedance	Sound	
Windsor Hum 1	6/07 3:00:00 AM	6/07 3:15:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 56.9dB in period 6/07/2013 3:14:00 a.m. - 6/07/2013 3:15:00 a.m..	100%	47.0	56.9	dB	Exceedance	Sound	
Windsor Hum 1	6/07 3:15:00 AM	6/07 3:30:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 56.2dB in period 6/07/2013 3:29:00 a.m. - 6/07/2013 3:30:00 a.m..	100%	47.0	56.2	dB	Exceedance	Sound	
Windsor Hum 1	6/07 3:30:00 AM	6/07 3:45:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 56.5dB in period 6/07/2013 3:44:00 a.m. - 6/07/2013 3:45:00 a.m..	100%	47.0	56.5	dB	Exceedance	Sound	
Windsor Hum 1	6/07 3:45:00 AM	6/07 4:00:00 AM	Noise Alert	Noise limit alert in Windsor Hum 1 of 56.6dB in period 6/07/2013 3:59:00 a.m. - 6/07/2013 4:00:00 a.m..	100%	47.0	56.6	dB	Exceedance	Sound	

C 16: Sample Section of Noise Sentinel Daily Report – Alert Data

APPENDIX D
Phase 1 – Part 2

Contents

Phase 1 – Part 2 Measurement Photographs

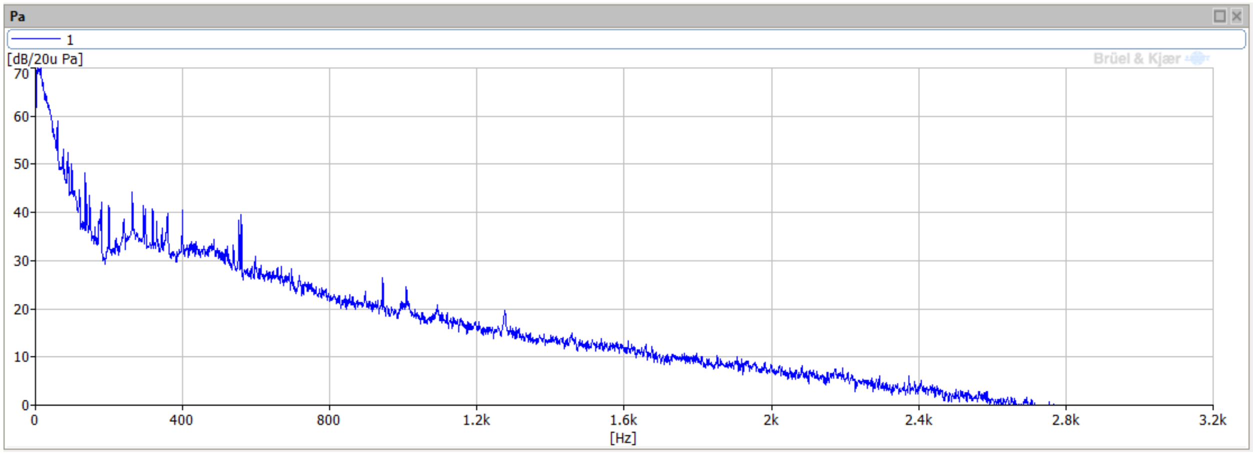
D 1: PULSE Acquisition System Setup at NMT

Phase 1 – Part 2 Measurement Location

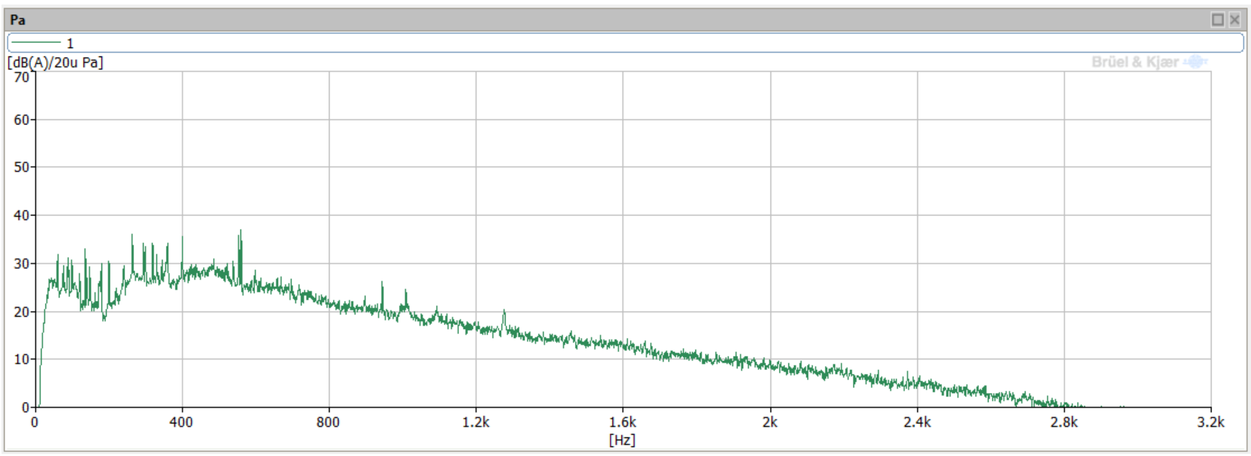
D 2: Phase 1 – Part 2 Equipment Location and Surrounding Area

D 3: Phase 1 – Part 2 Equipment Location and Surrounding Area – Zoomed-in View

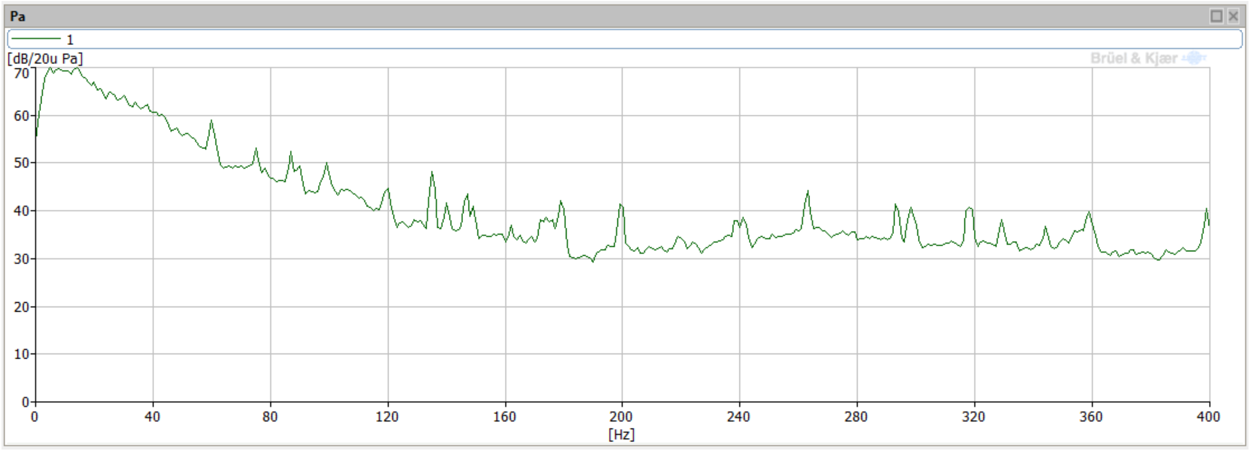
Phase 1 – Part 2 Measurement Data



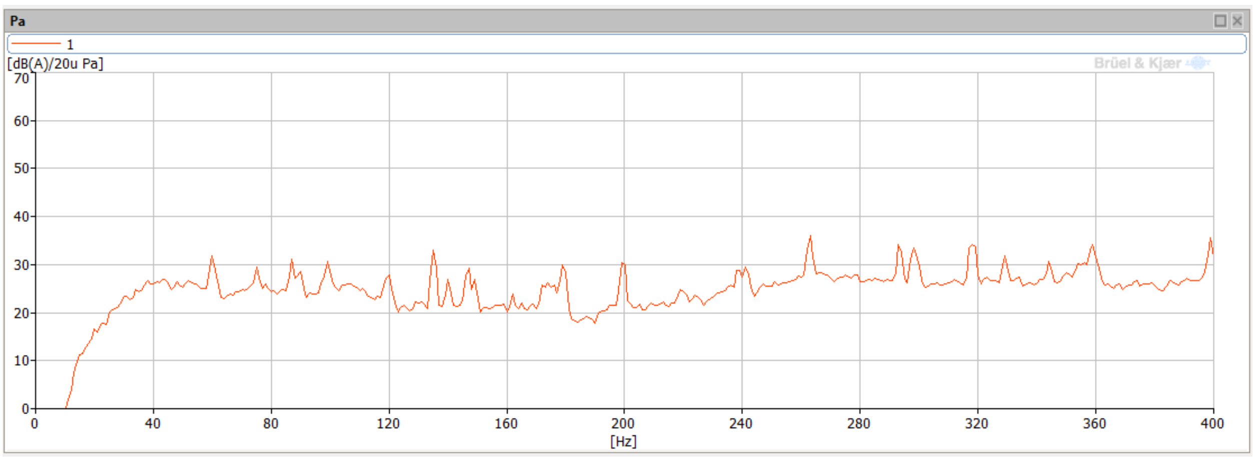
D 4: Plot of Linear Overall SPL vs. Frequency (0 – 3.2 kHz) for Time Period 1



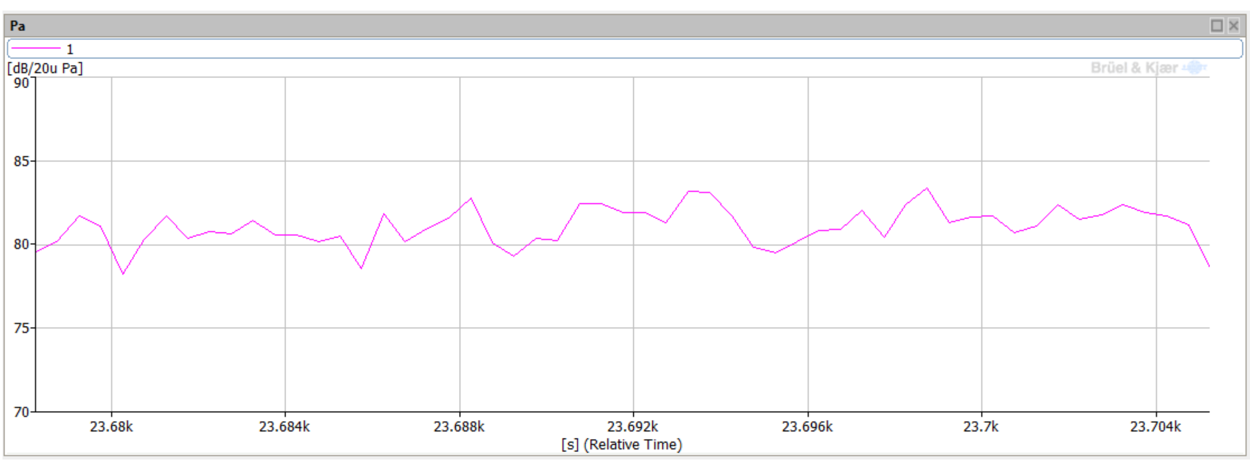
D 5: Plot of A-Weighted Overall SPL vs. Frequency (0 – 3.2 kHz) for Time Period 1



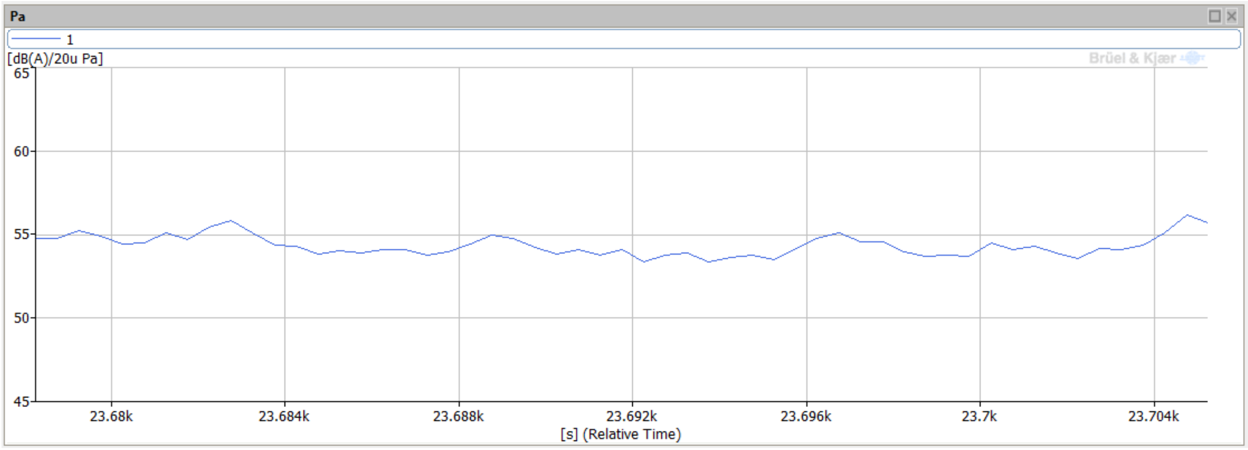
D 6: Plot of Linear Overall SPL vs. Frequency (0 – 400 Hz) for Time Period 1



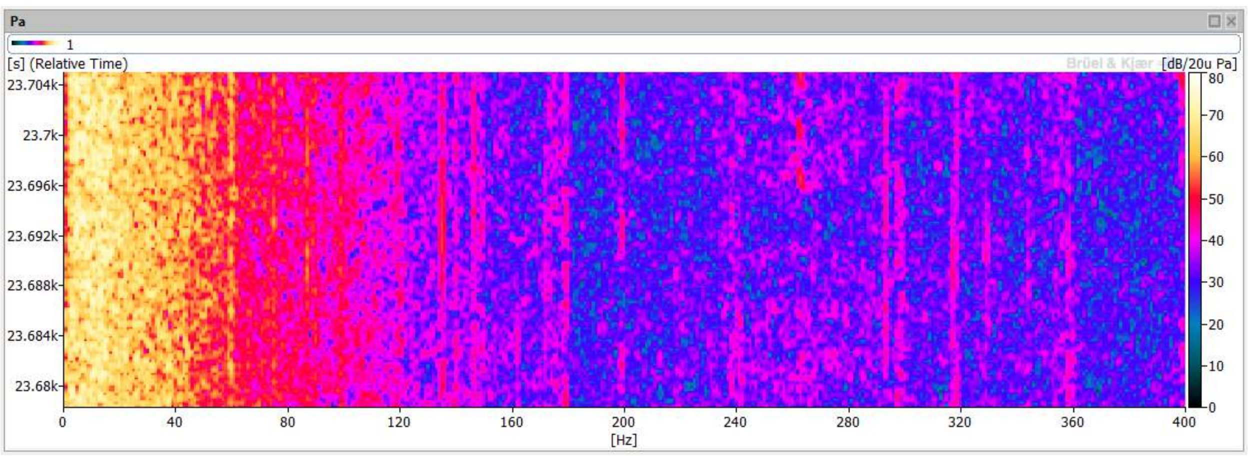
D 7: Plot of A-Weighted Overall SPL vs. Frequency (0 – 400 Hz) for Time Period 1



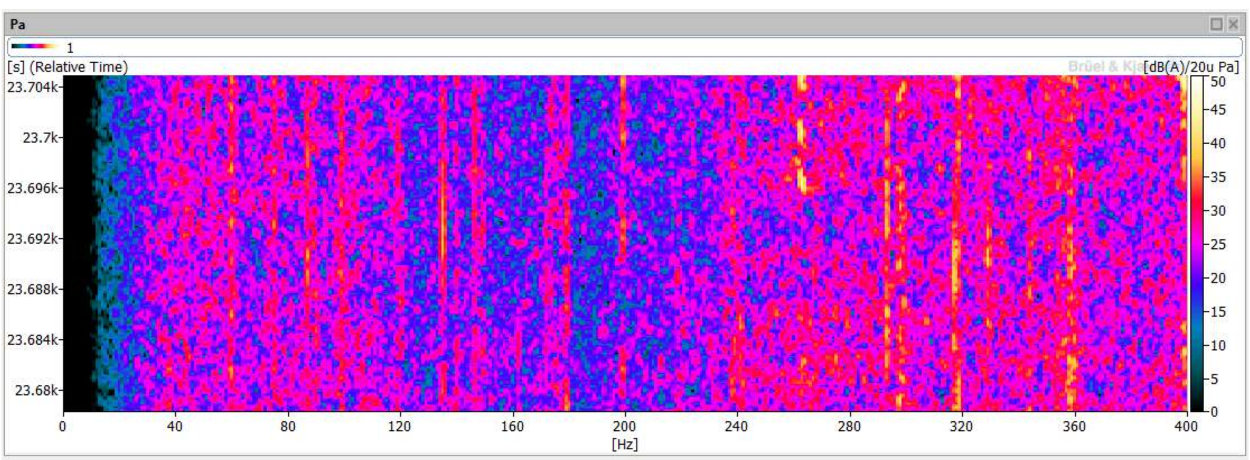
D 8: Plot of Linear Overall SPL vs. Time for Time Period 1



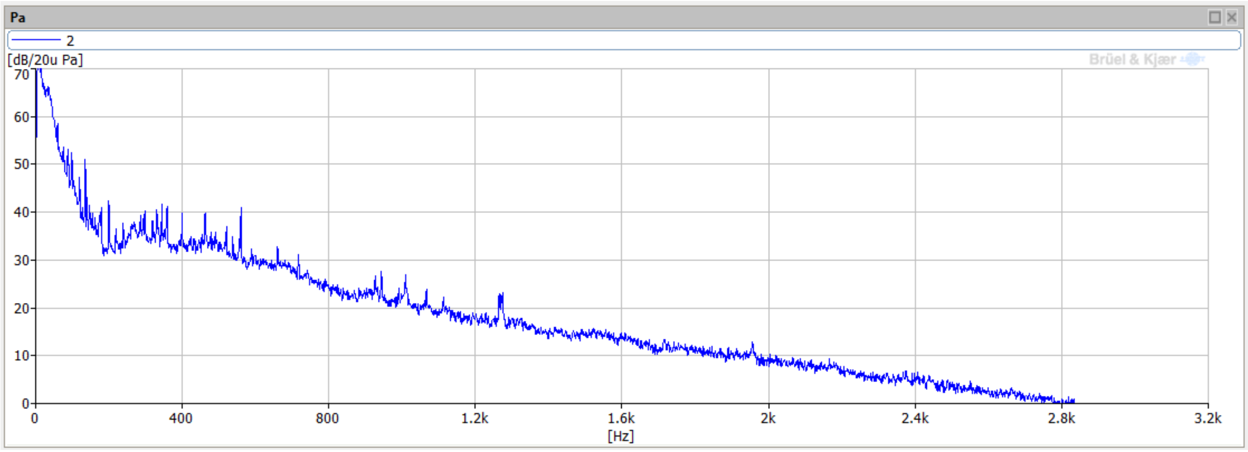
D 9: Plot of A-Weighted Overall SPL vs. Time for Time Period 1



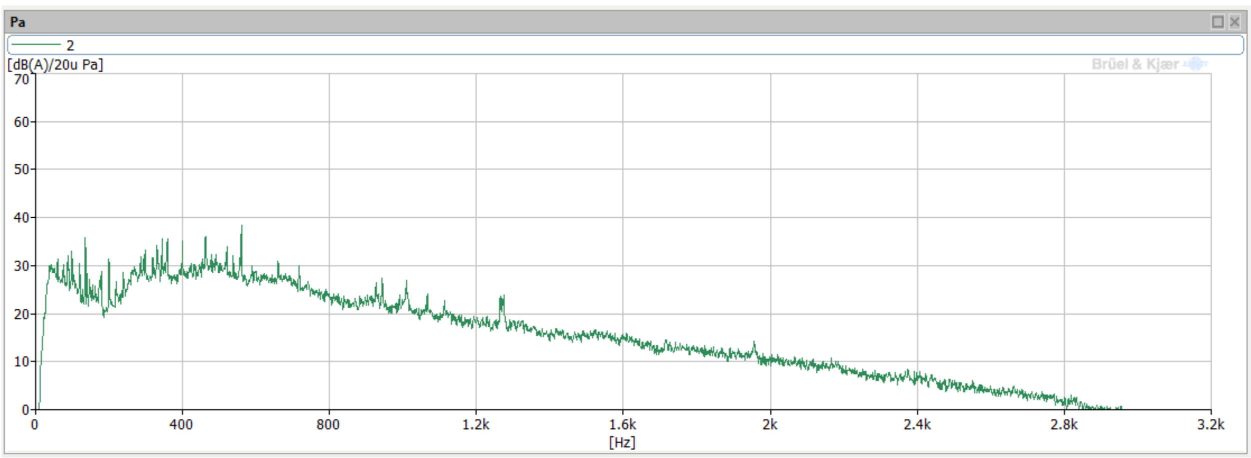
D 10: Waterfall Plot of Linear SPL vs. Frequency and Time for Time Period 1



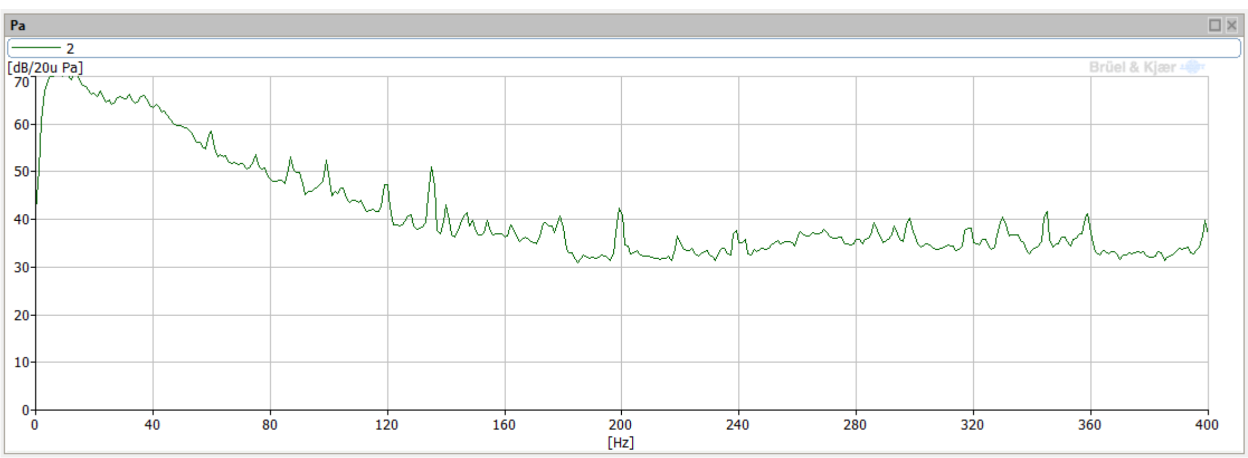
D 11: Waterfall Plot of A-weighted SPL vs. Frequency and Time for Time Period 1



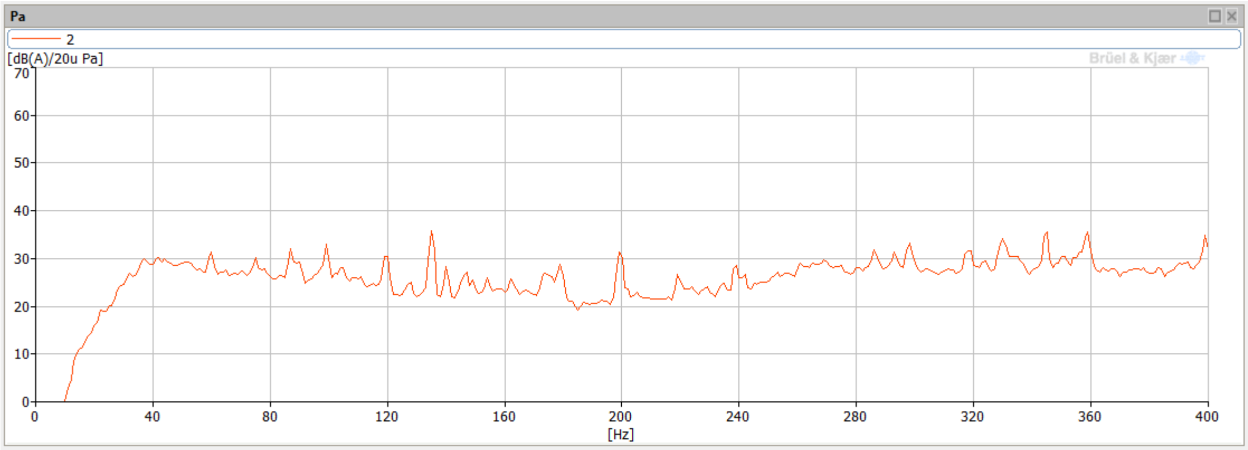
D 12: Plot of Linear Overall SPL vs. Frequency (0 – 3.2 kHz) for Time Period 2



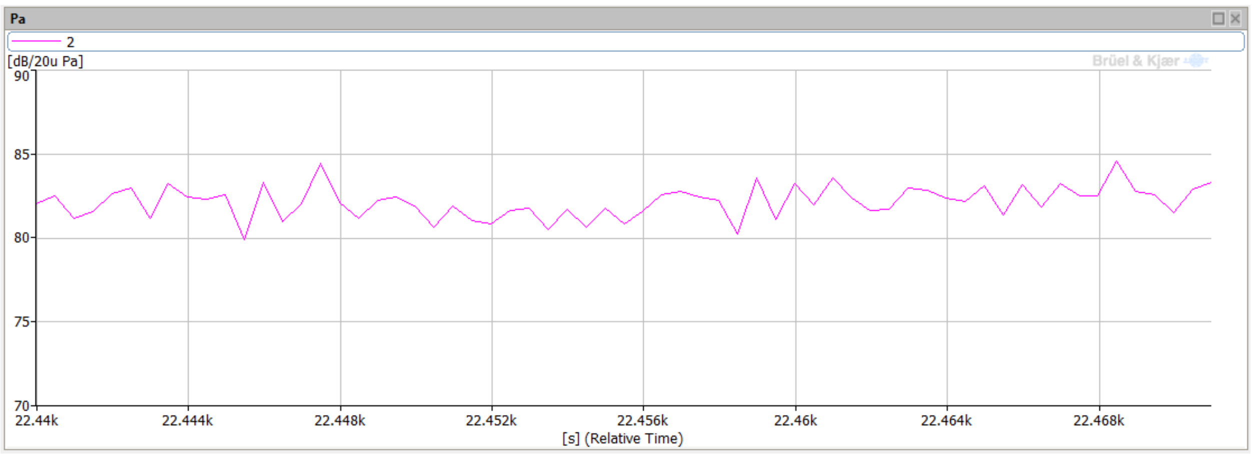
D 13: Plot of A-Weighted Overall SPL vs. Frequency (0 – 3.2 kHz) for Time Period 2



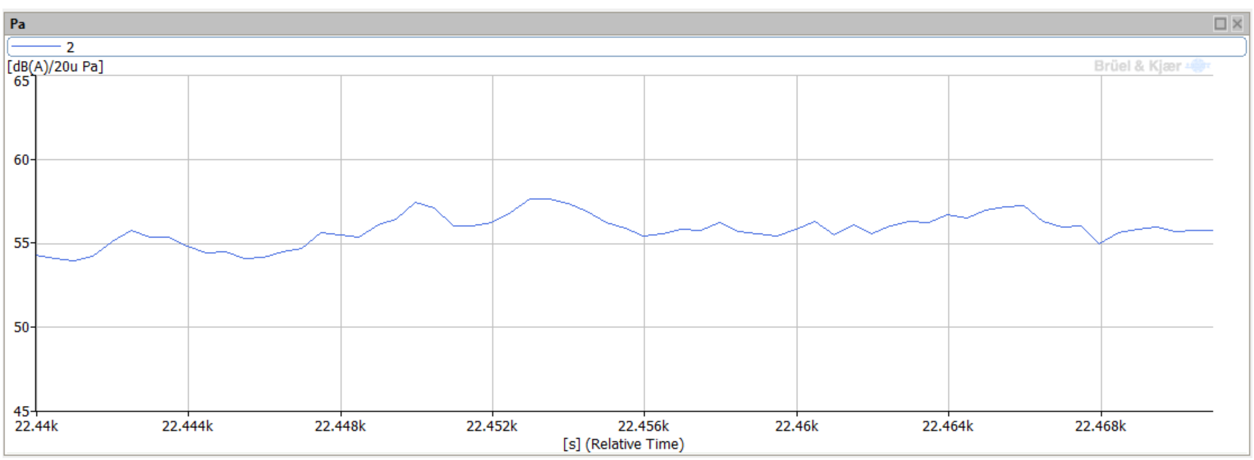
D 14: Plot of Linear Overall SPL vs. Frequency (0 – 400 Hz) for Time Period 2



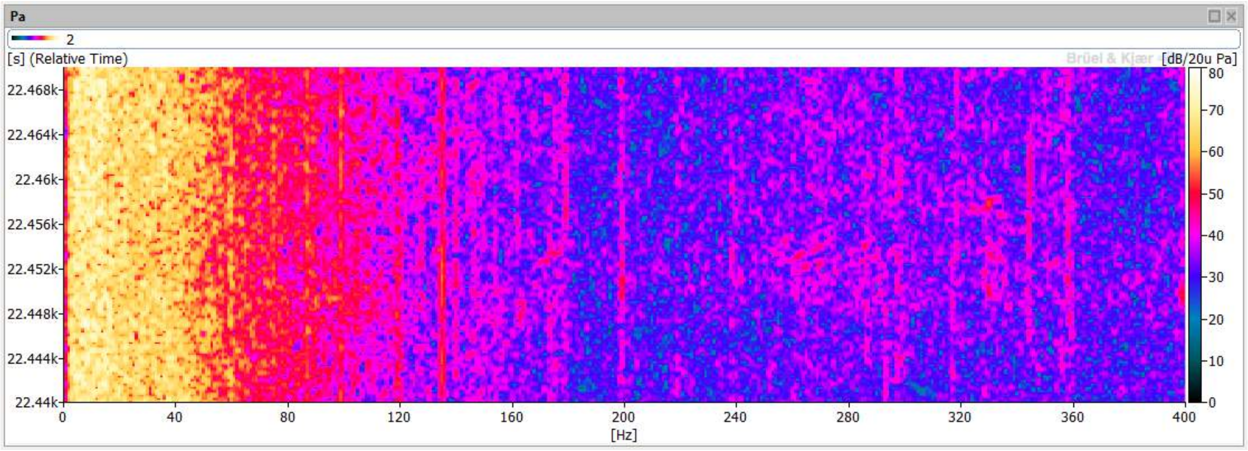
D 15: Plot of A-Weighted Overall SPL vs. Frequency (0 – 400 Hz) for Time Period 2



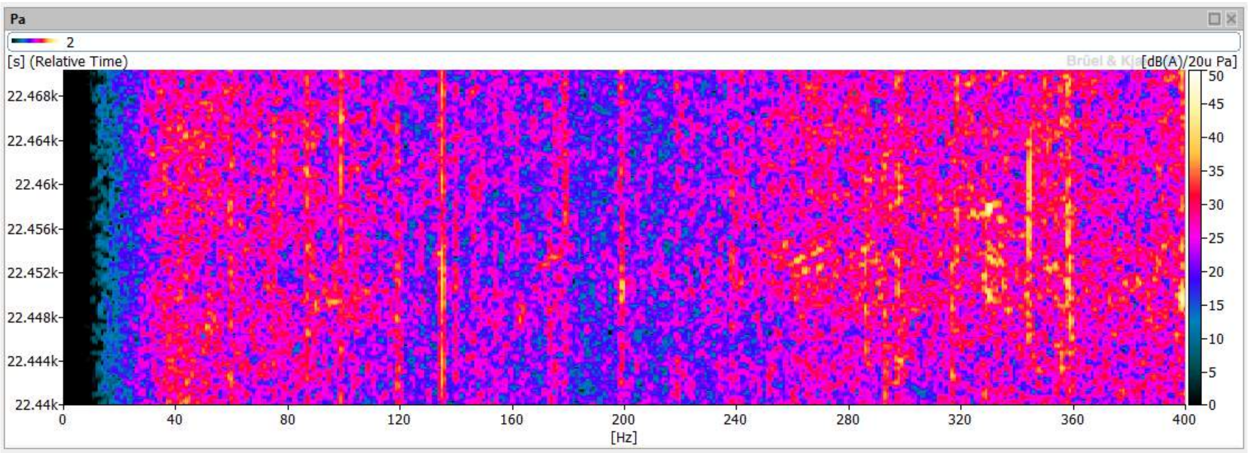
D 16: Plot of Linear Overall SPL vs. Time for Time Period 2



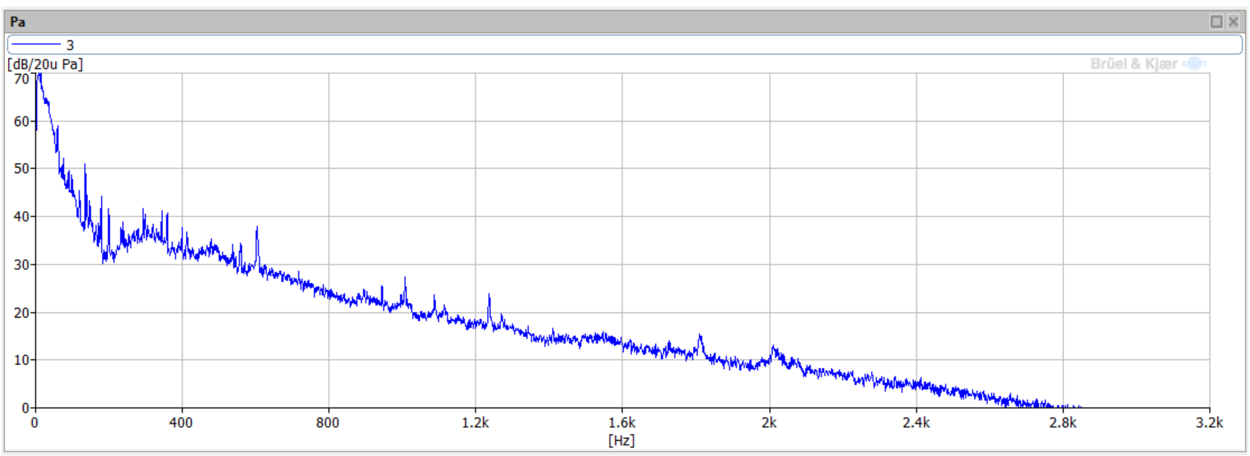
D 17: Plot of A-Weighted Overall SPL vs. Time for Time Period 2



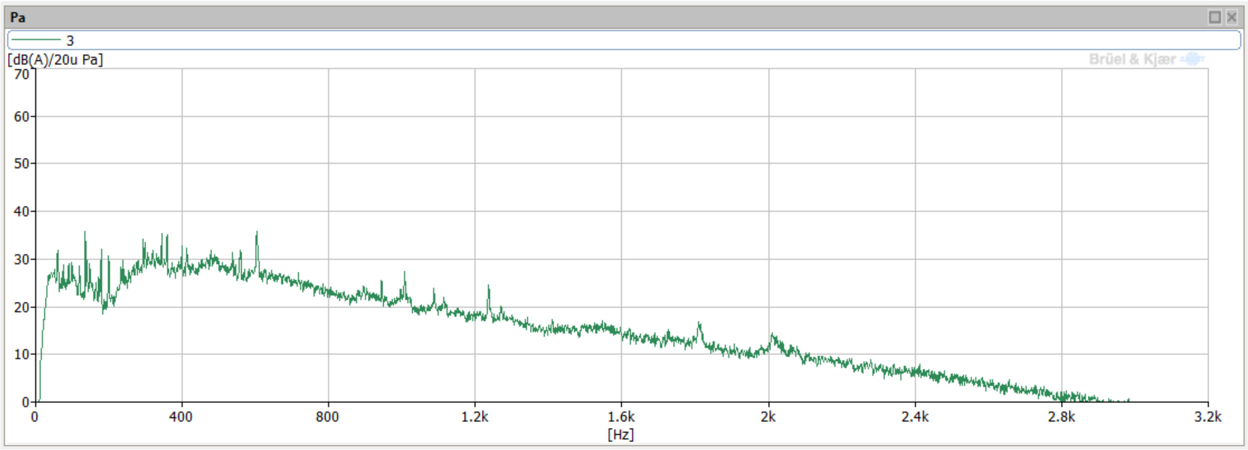
D 18: Waterfall Plot of Linear SPL vs. Frequency and Time for Time Period 2



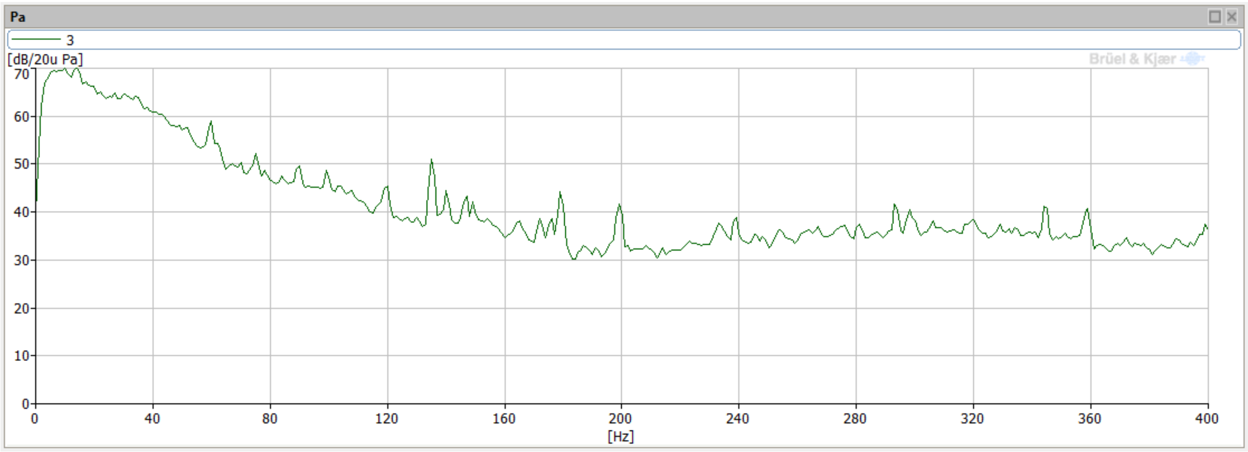
D 19: Waterfall Plot of A-weighted SPL vs. Frequency and Time for Time Period 2



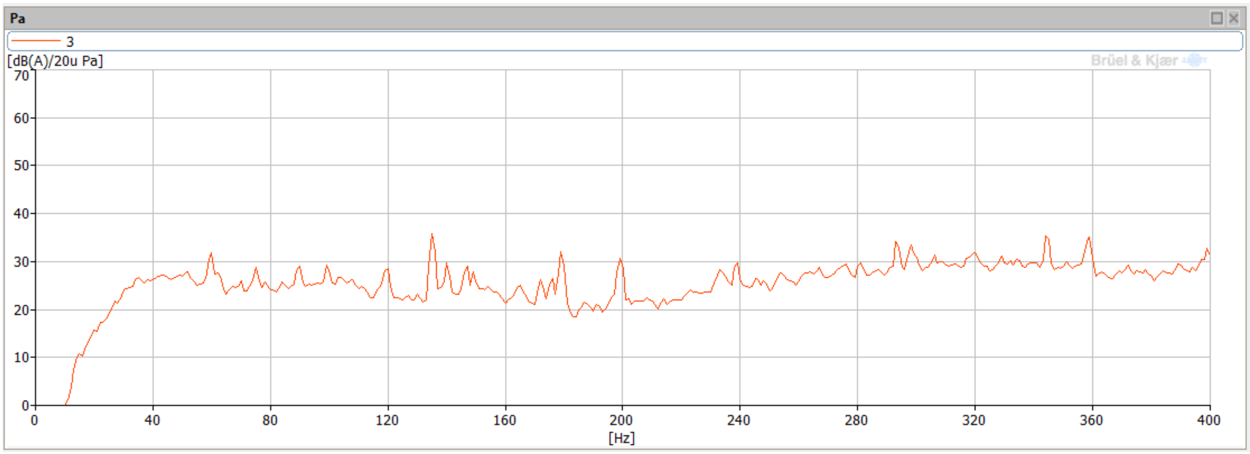
D 20: Plot of Linear Overall SPL vs. Frequency (0 – 3.2 kHz) for Time Period 3



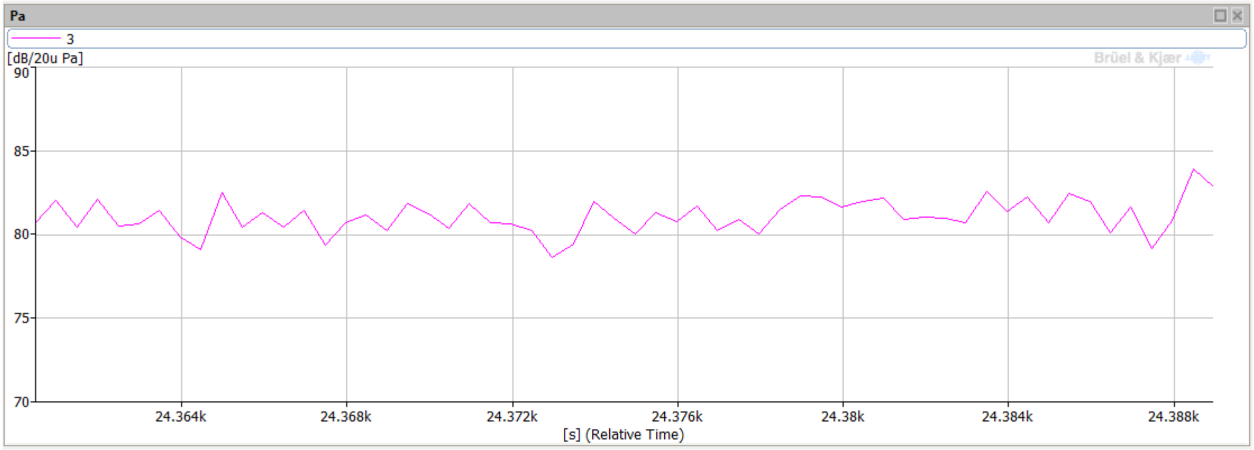
D 21: Plot of A-Weighted Overall SPL vs. Frequency (0 – 3.2 kHz) for Time Period 3



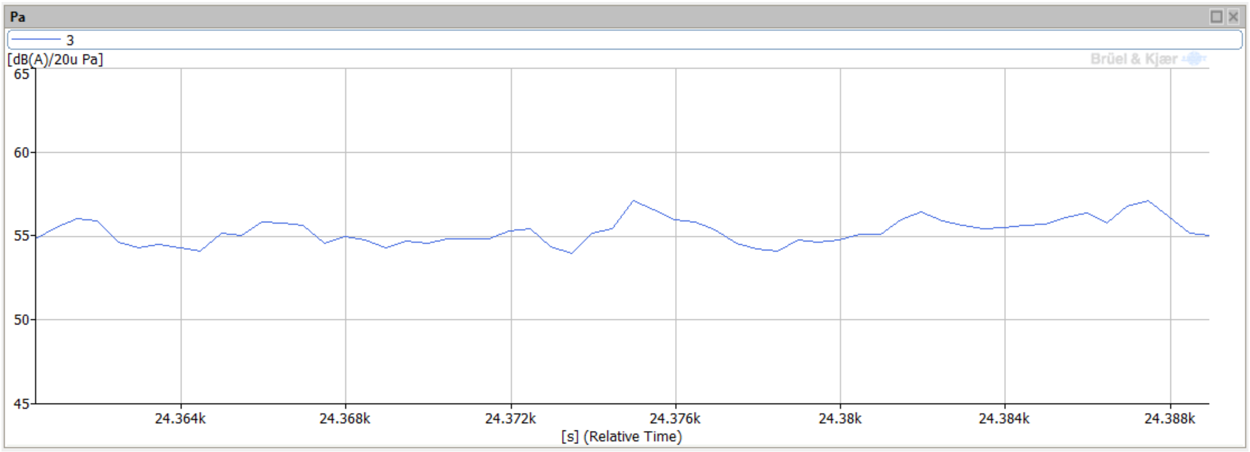
D 22: Plot of Linear Overall SPL vs. Frequency (0 – 400 Hz) for Time Period 3



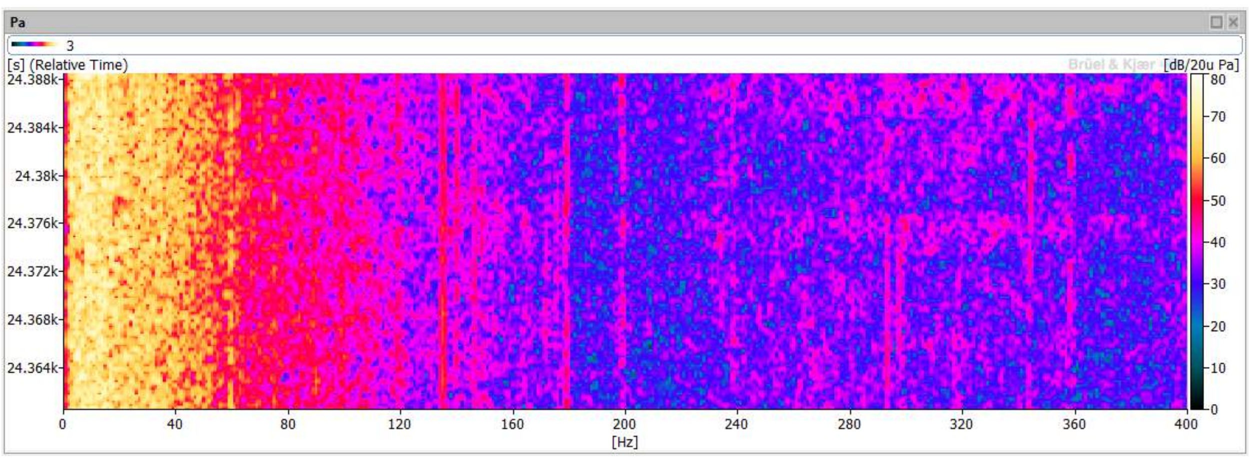
D 23: Plot of A-Weighted Overall SPL vs. Frequency (0 – 400 Hz) for Time Period 3



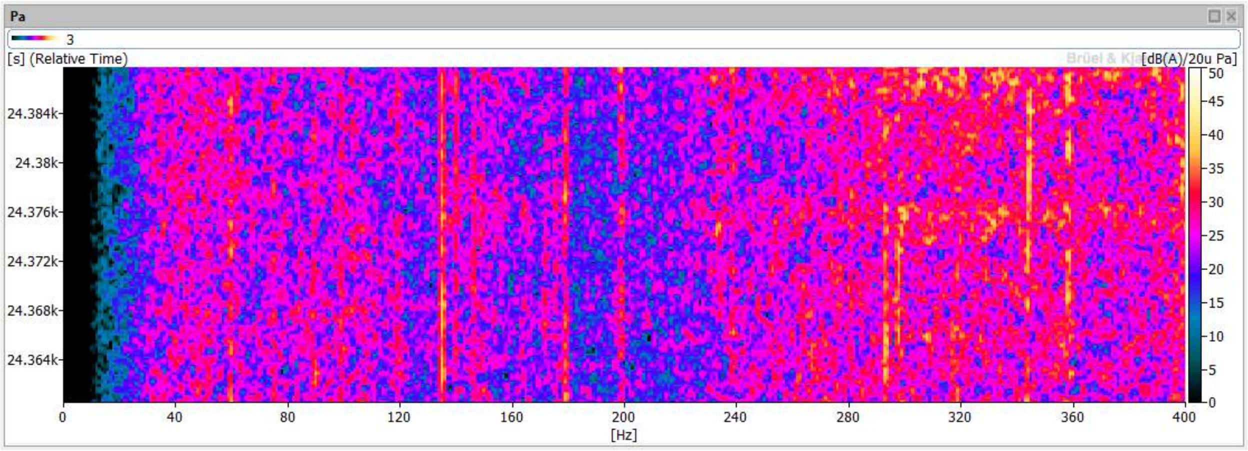
D 24: Plot of Linear Overall SPL vs. Time for Time Period 3



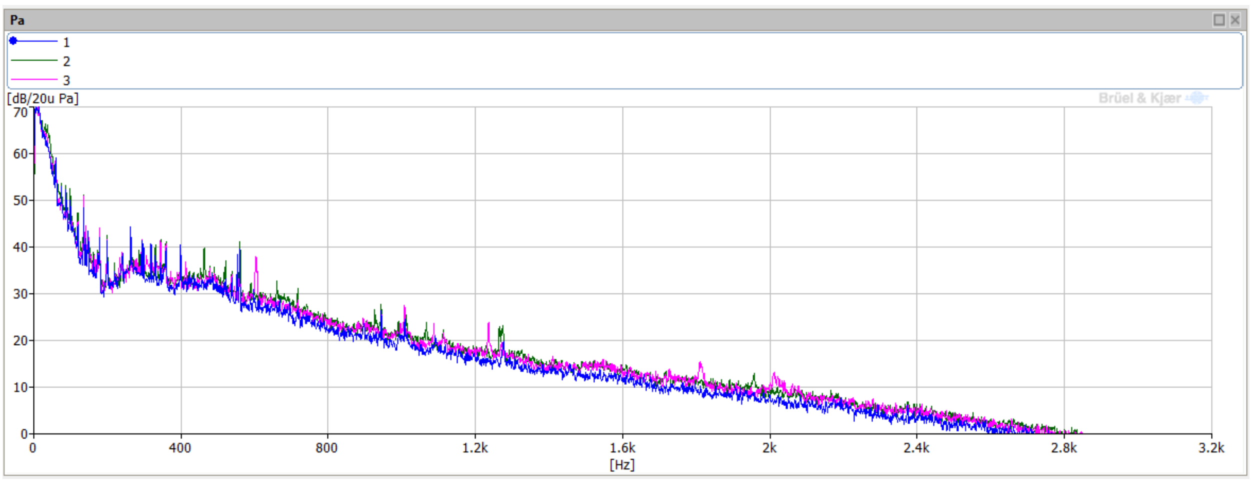
D 25: Plot of A-Weighted Overall SPL vs. Time for Time Period 3



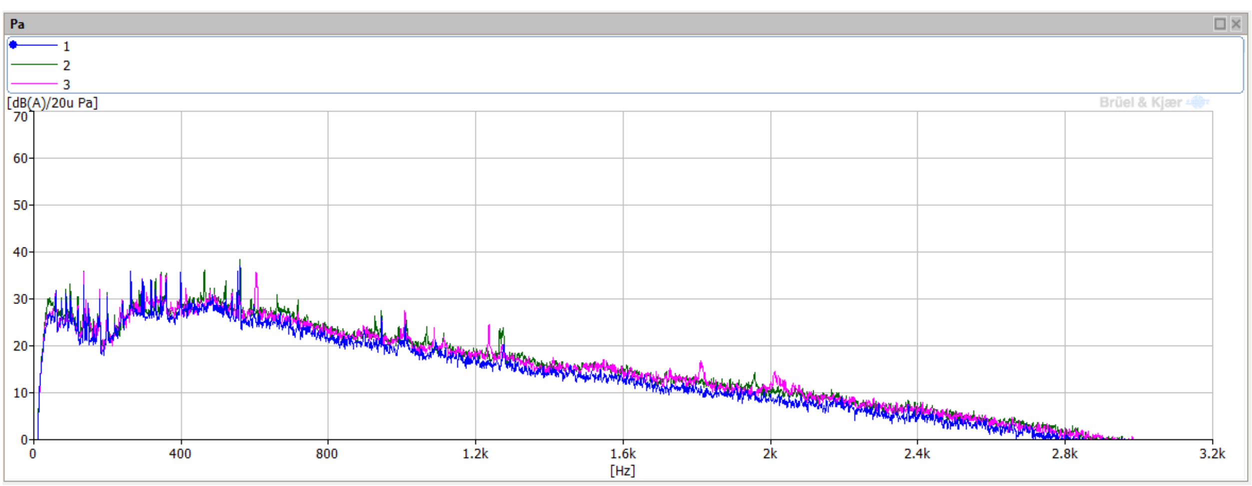
D 26: Waterfall Plot of Linear SPL vs. Frequency and Time for Time Period 3



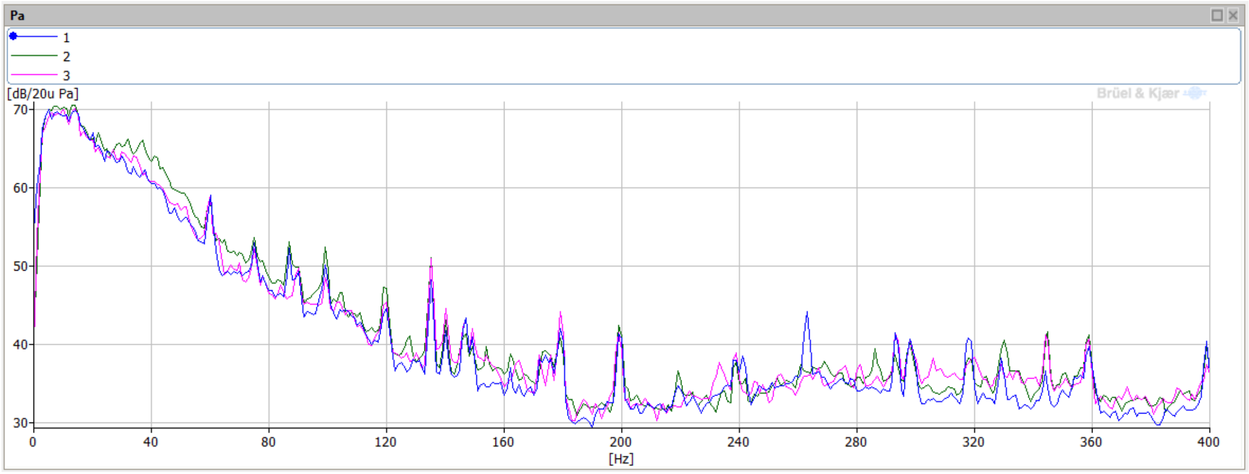
D 27: Waterfall Plot of A-weighted SPL vs. Frequency and Time for Time Period 3



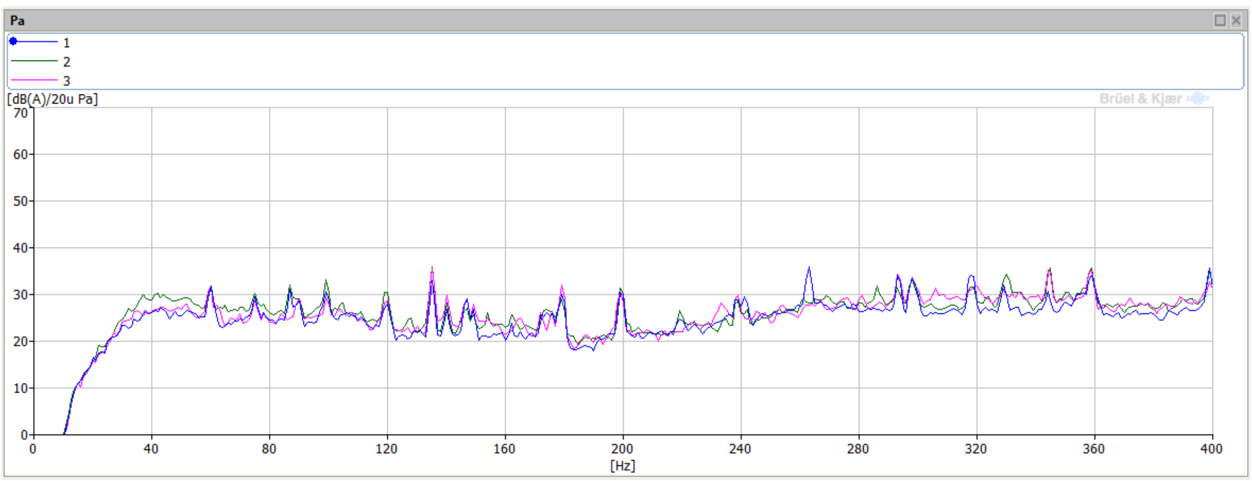
D 28: Plot of Linear Overall SPL vs. Frequency (0 – 3.2 kHz) for All 3 Time Periods



D 29: Plot of A-weighted Overall SPL vs. Frequency (0 – 3.2 kHz) for All 3 Time Periods



D 30: Plot of Linear Overall SPL vs. Frequency (0 – 400 Hz) for All 3 Time Periods



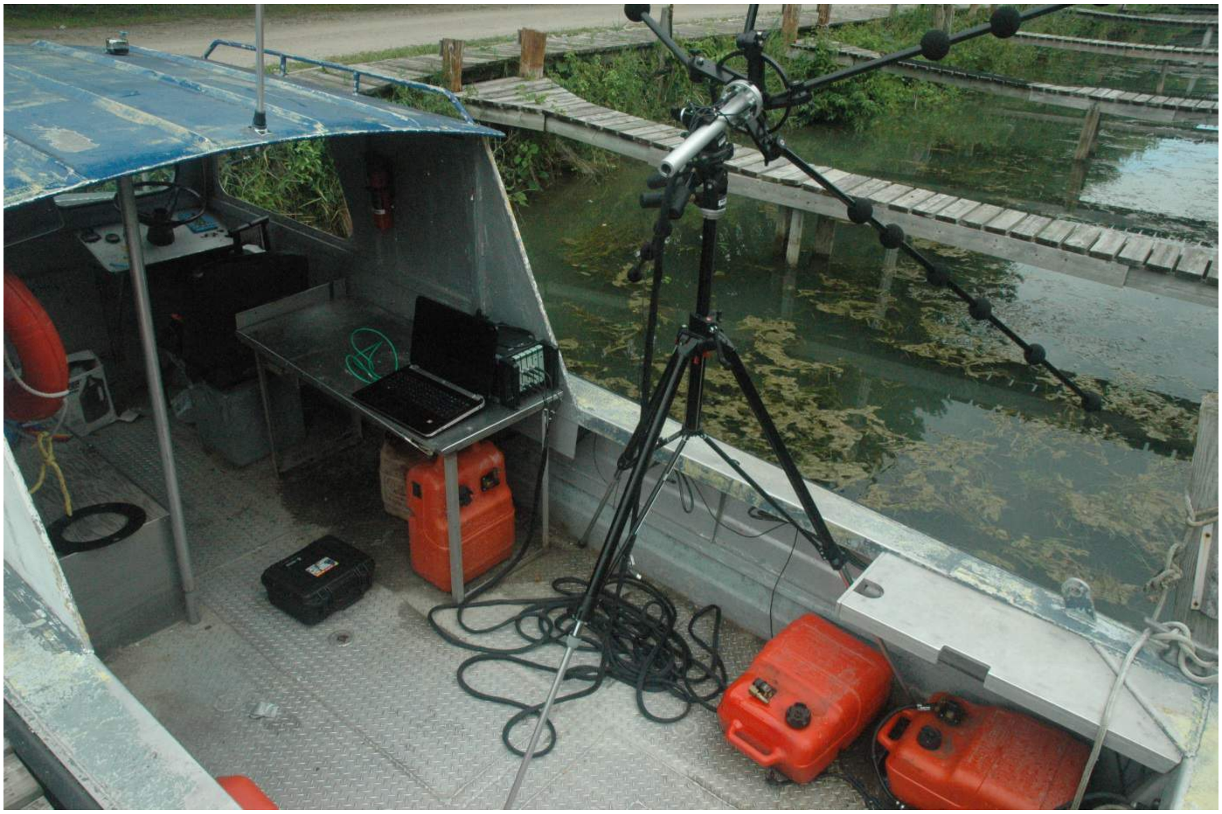
D 31: Plot of A-weighted Overall SPL vs. Frequency (0 – 400 Hz) for All 3 Time Periods

APPENDIX E
Phase 2

Contents

Phase 2 Measurement Photographs

E 1: Pentangular Array Setup



E 2: Pentangular Array and Data Acquisition Equipment Setup

E 3: Zug Island during Phase 2 Measurement Period – Photograph 1

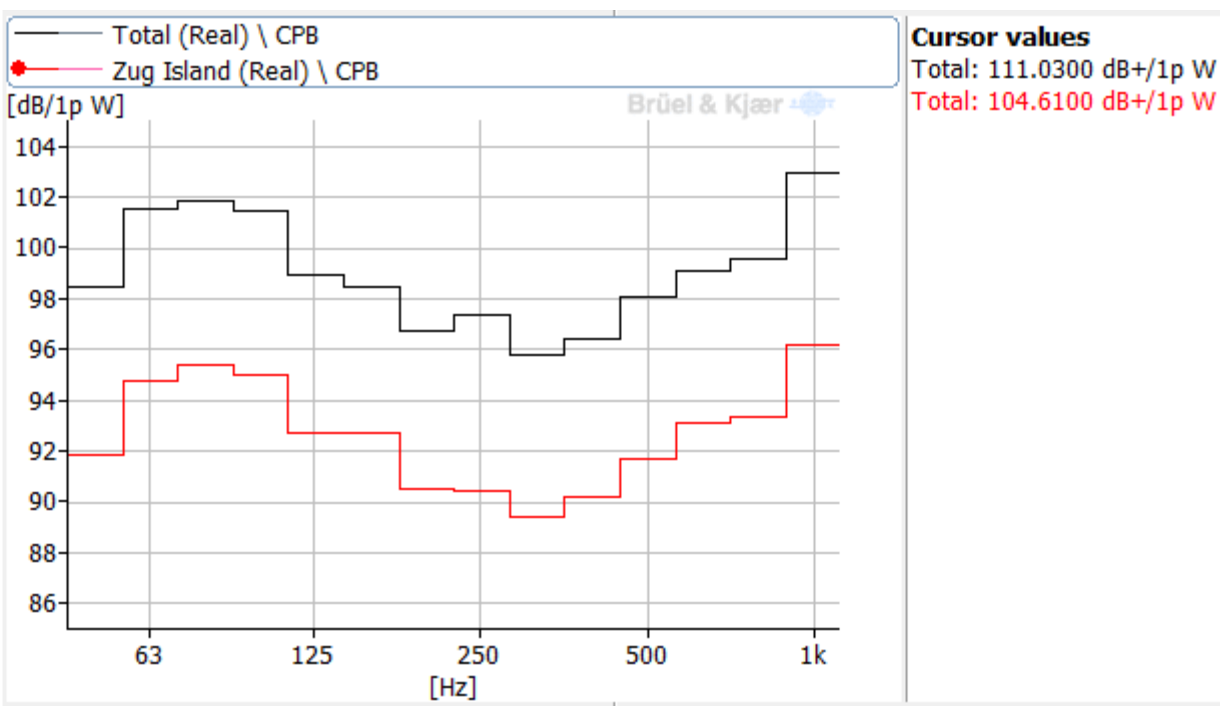
E 4: Zug Island during Phase 2 Measurement Period – Photograph 2

Phase 2 Measurement Location

E 5: Aerial Photo of Zug Island with Distance from Island to be Measured Marked in Red

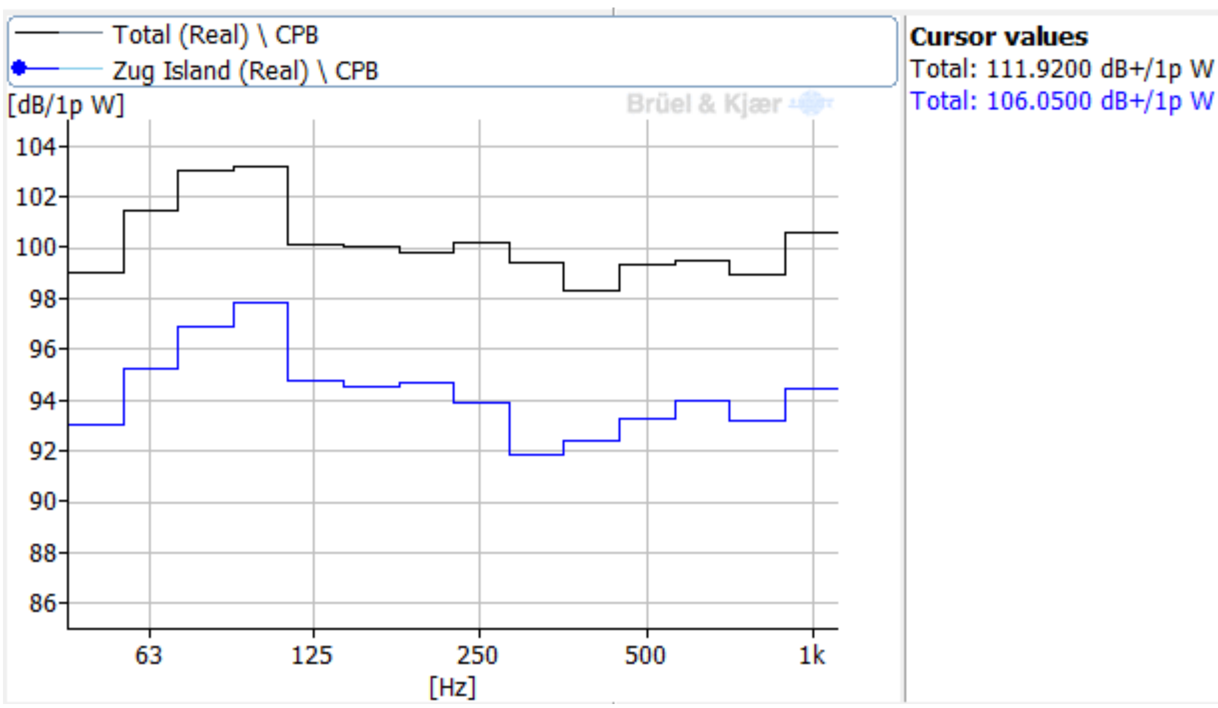
Phase 2 Measurement Data

E 6: Contour Plot over Image from Pentangular Array – Measurement 1

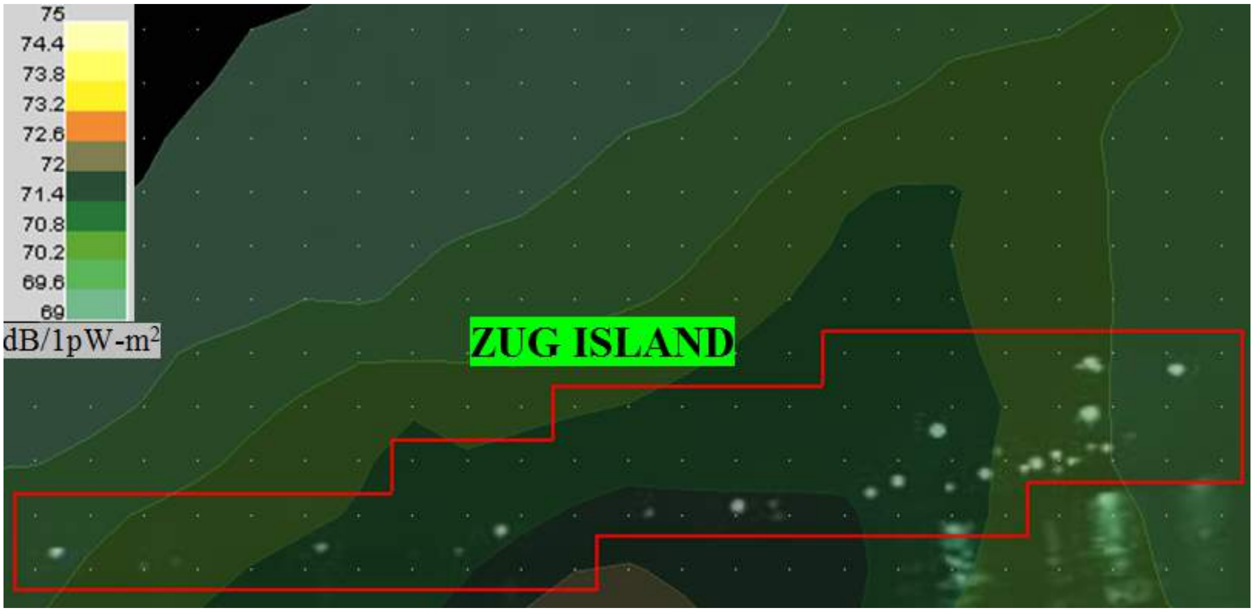


E 7: Sound Power Level Frequency Spectral Analysis – Measurement 1

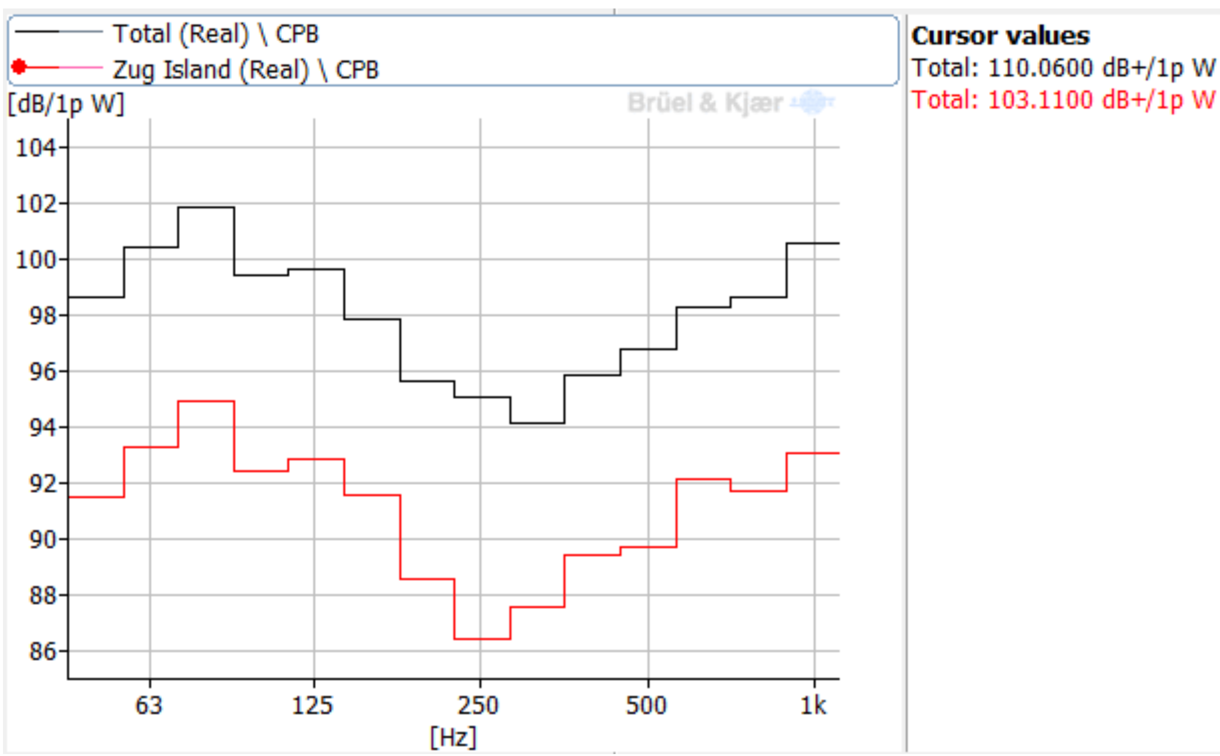
E 8: Contour Plot over Image from Pentangular Array – Measurement 2



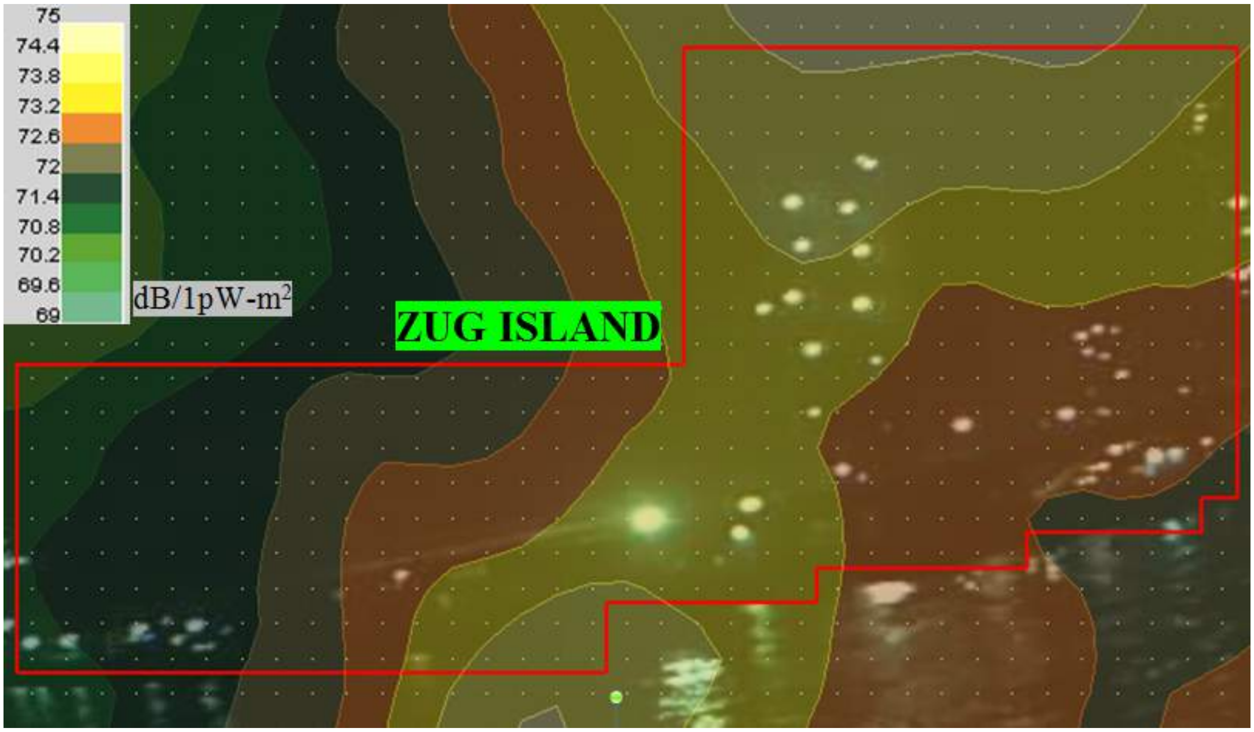
E 9: Sound Power Level Frequency Spectral Analysis – Measurement 2



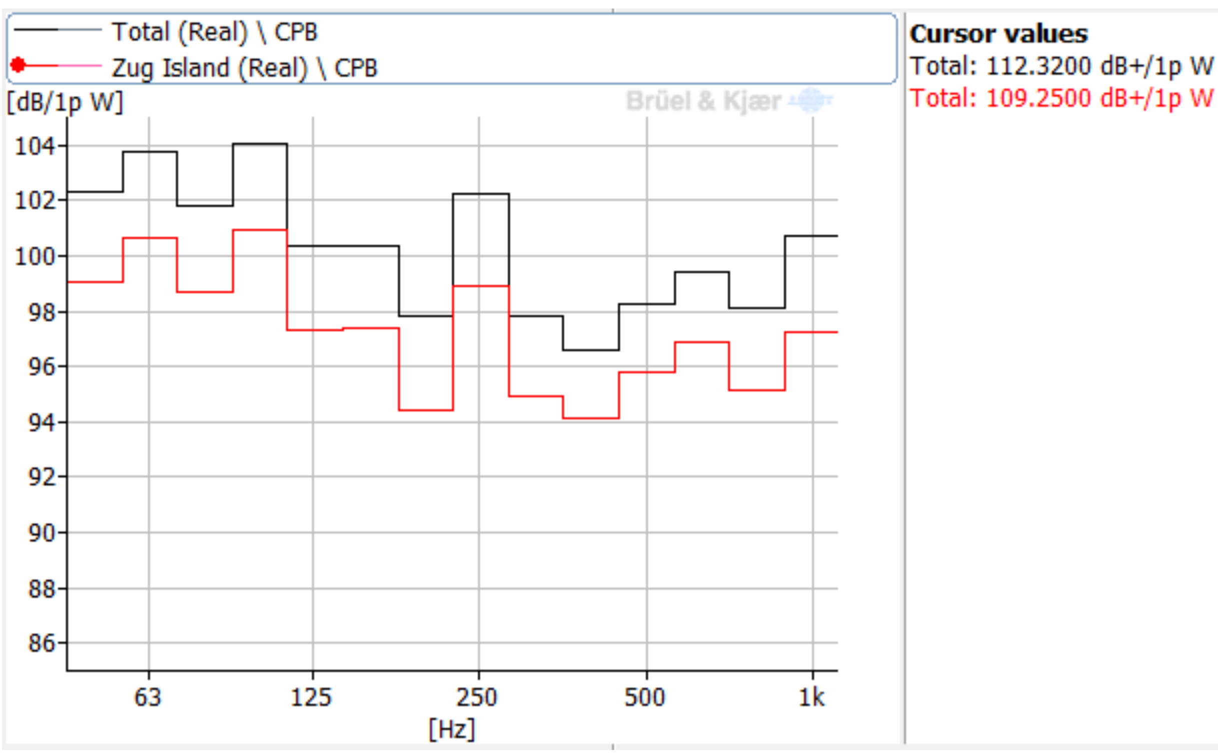
E 10: Contour Plot over Image from Pentangular Array – Measurement 3



E 11: Sound Power Level Frequency Spectral Analysis – Measurement 3

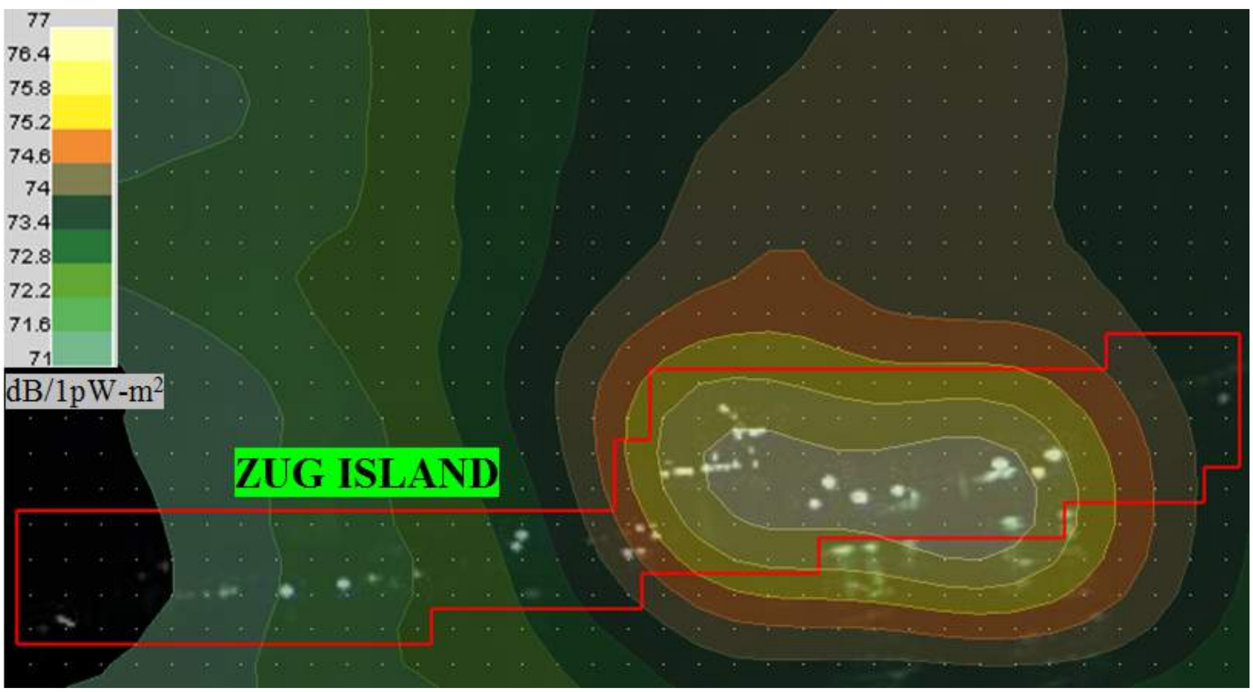


E 12: Contour Plot over Image from Pentangular Array – Measurement 4

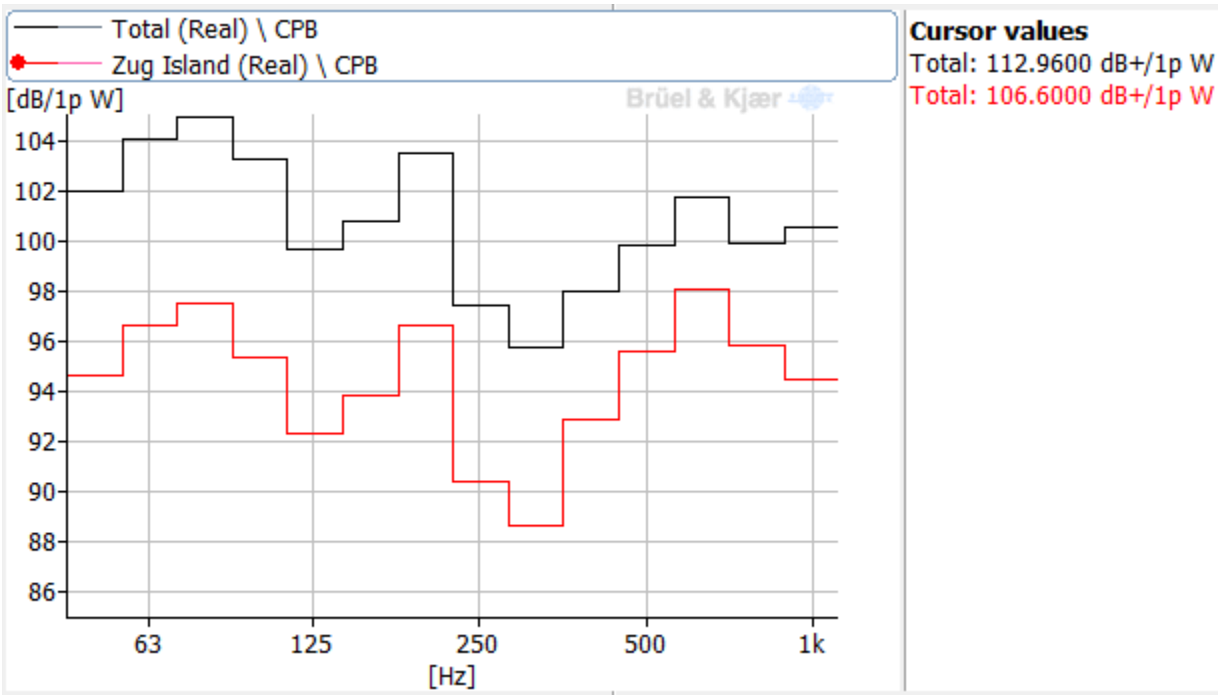


E 13: Sound Power Level Frequency Spectral Analysis – Measurement 4

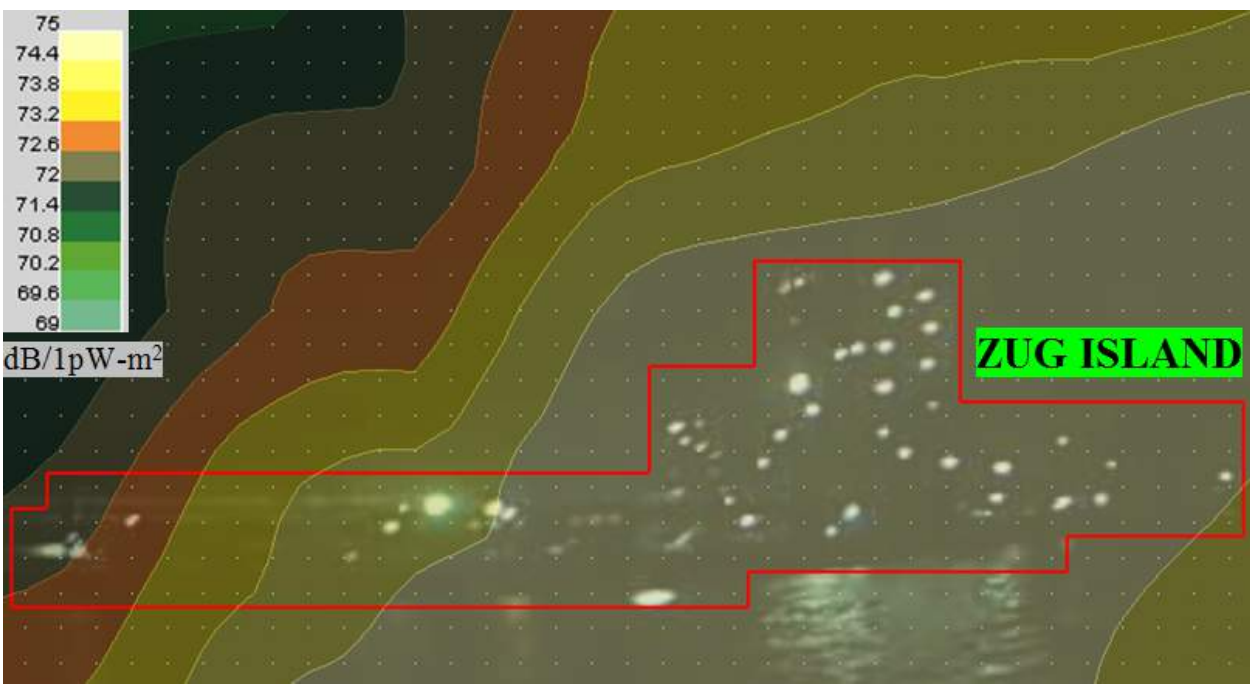
E 14: Contour Plot over Image from Pentangular Array – Measurement 5



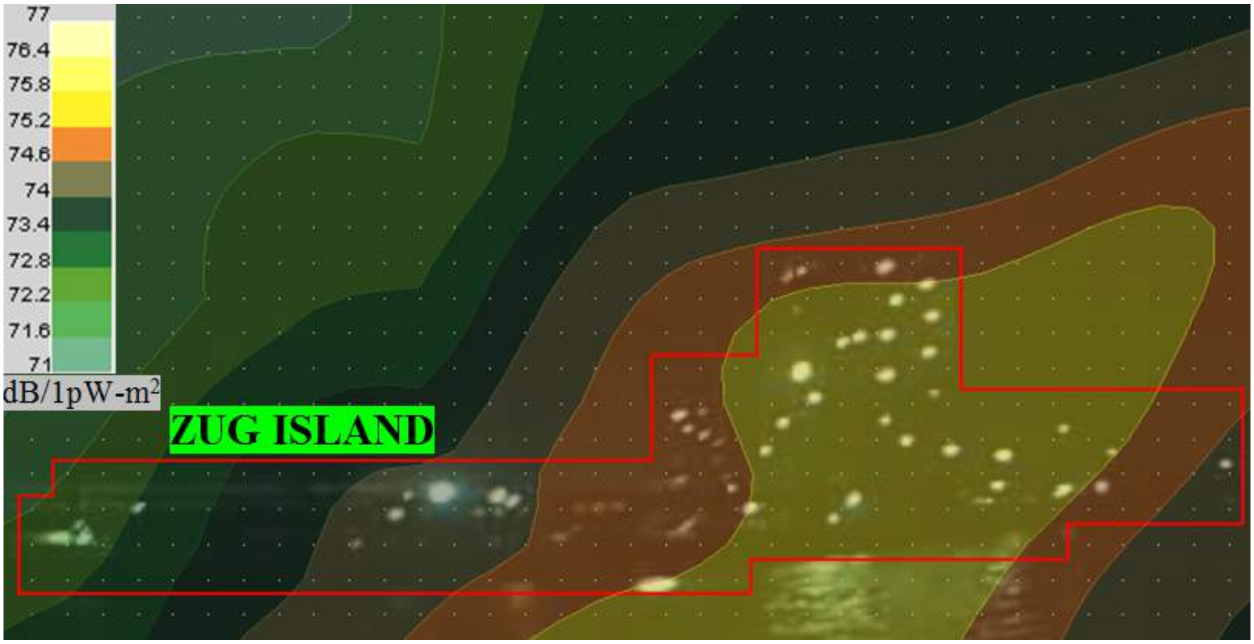
E 15: Modified Contour Plot over Image from Pentangular Array – Measurement 5



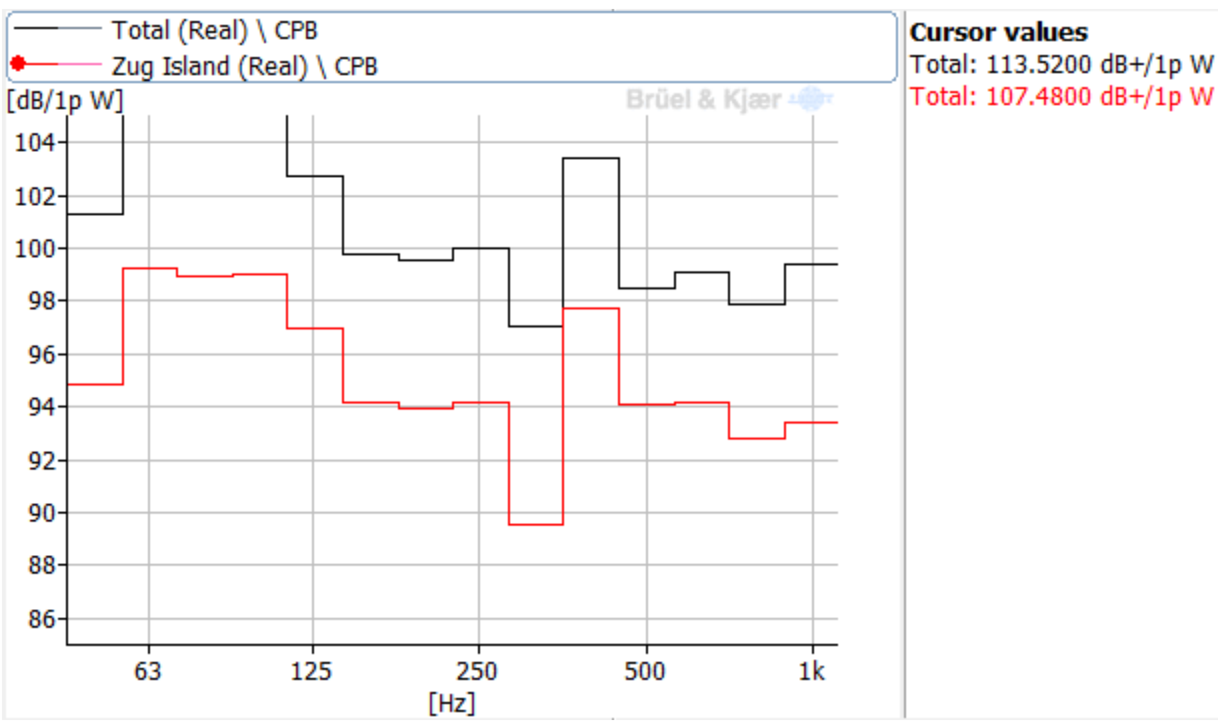
E 16: Sound Power Level Frequency Spectral Analysis – Measurement 5



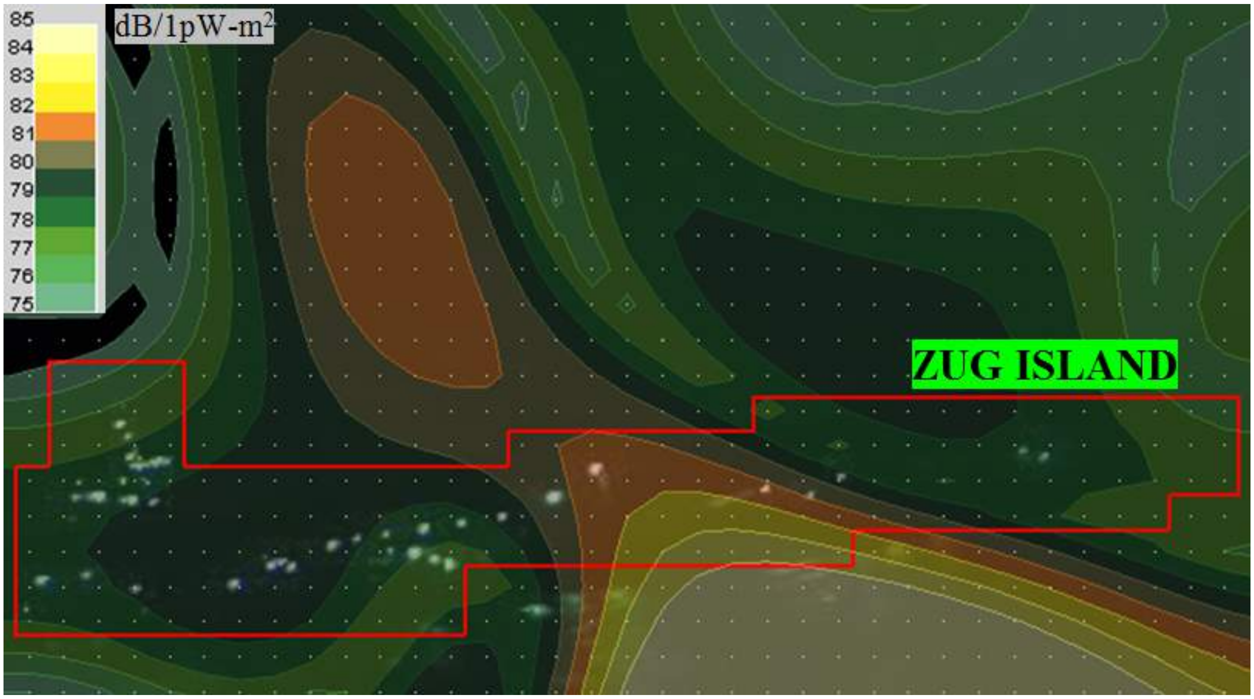
E 17: Contour Plot over Image from Pentangular Array – Measurement 6



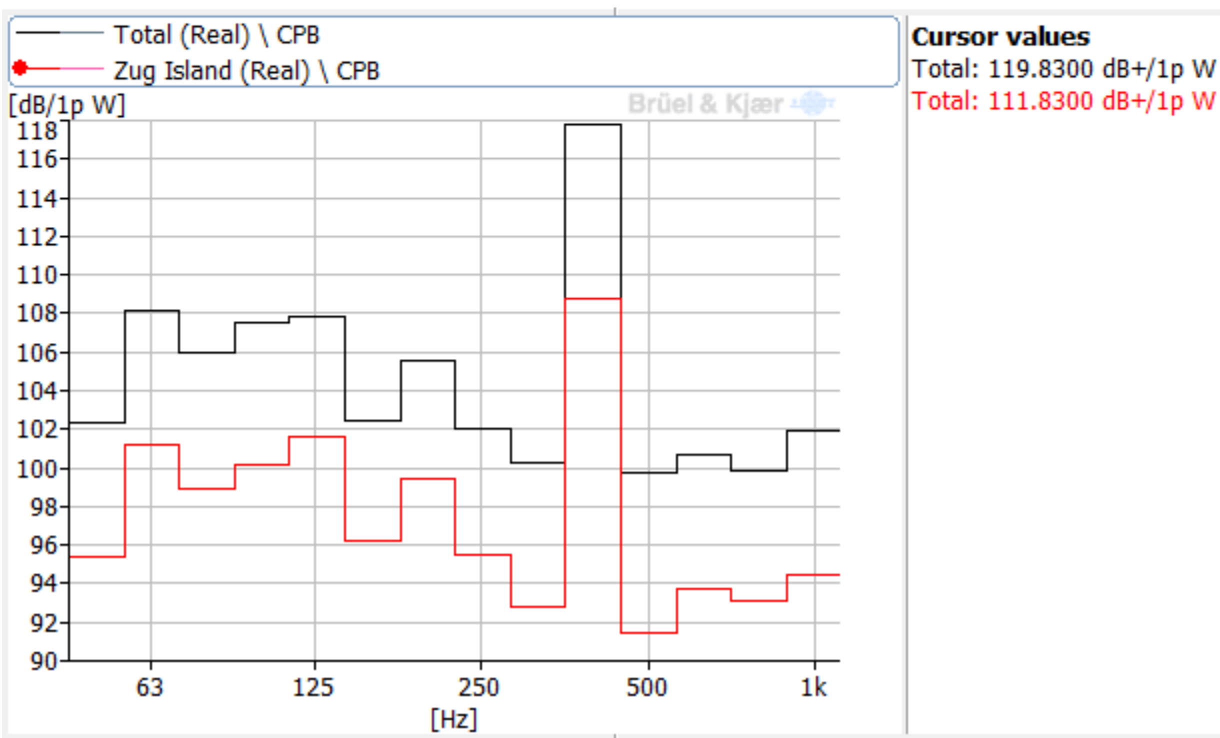
E 18: Modified Contour Plot over Image from Pentangular Array – Measurement 6



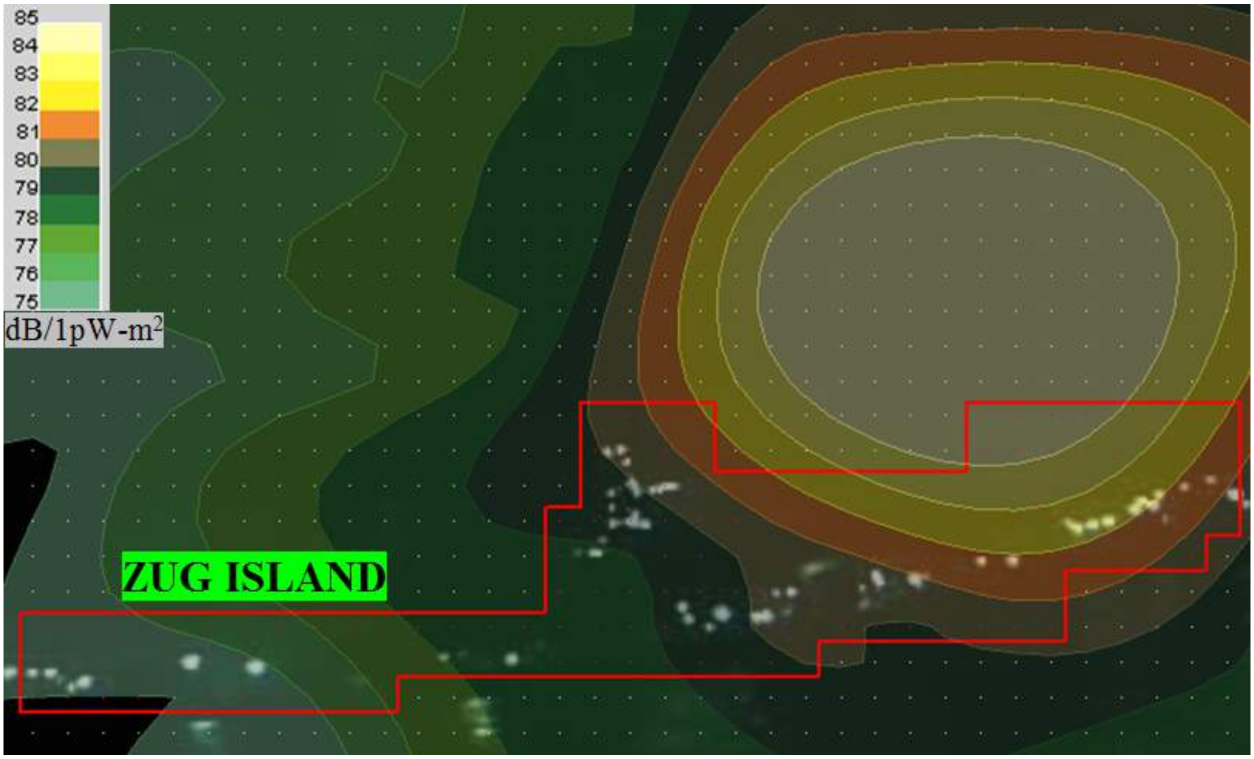
E 19: Sound Power Level Frequency Spectral Analysis – Measurement 6



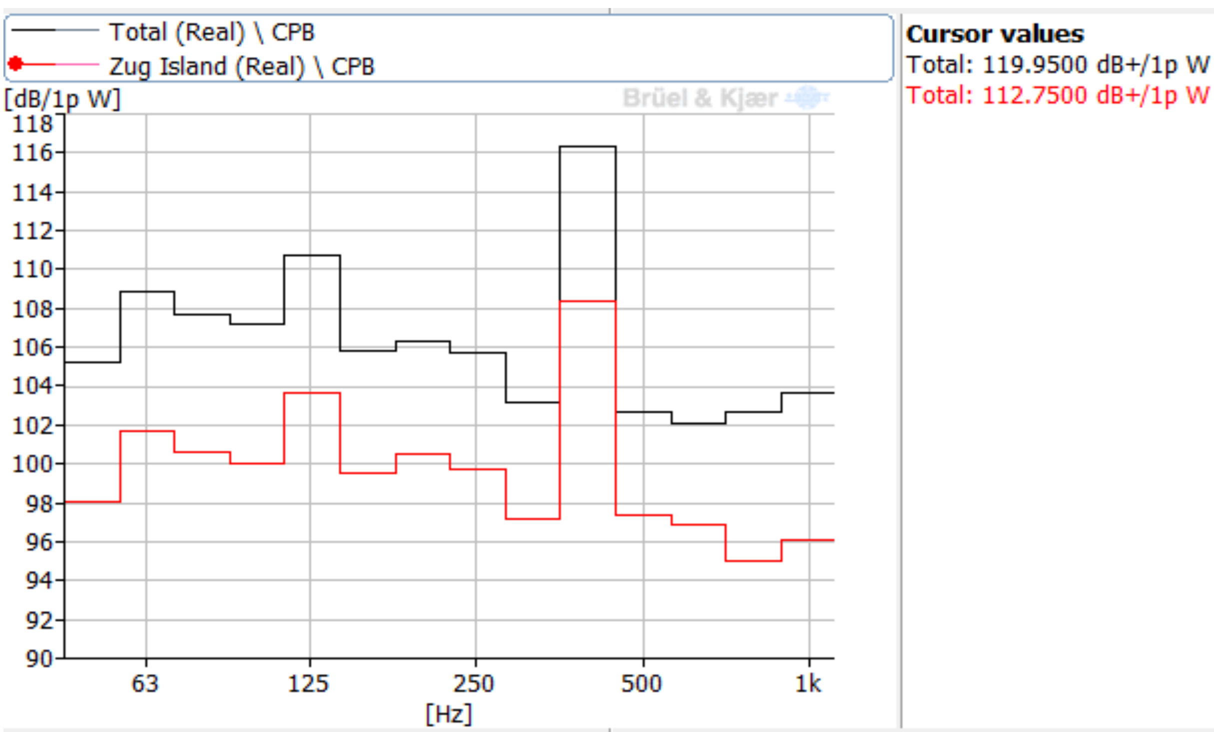
E 20: Contour Plot over Image from Pentangular Array – Measurement 7



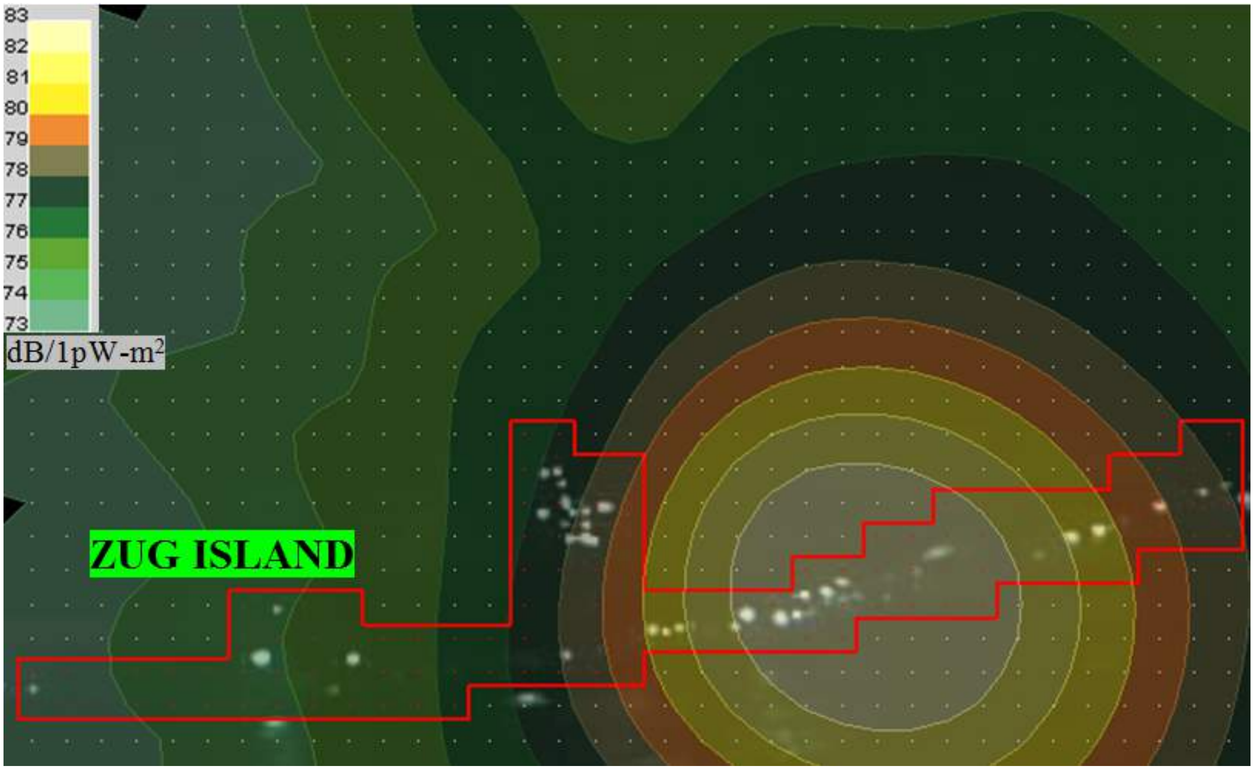
E 21: Sound Power Level Frequency Spectral Analysis – Measurement 7



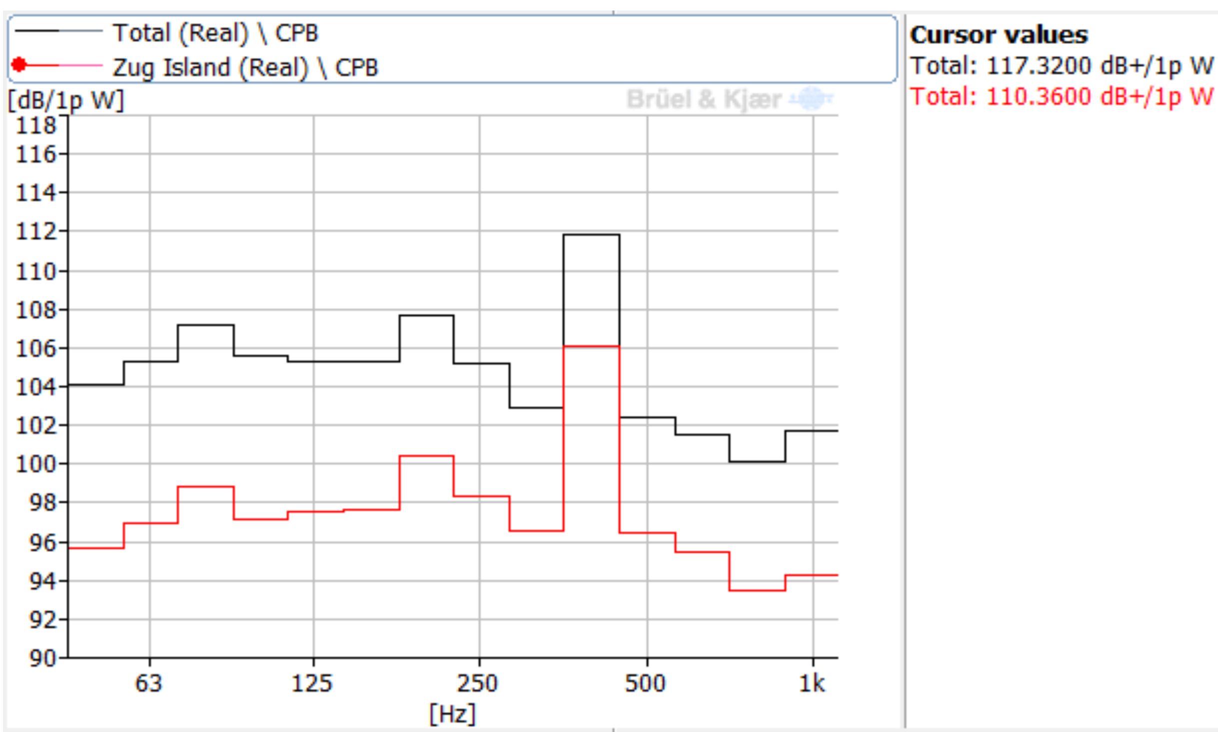
E 22: Contour Plot over Image from Pentangular Array – Measurement 8



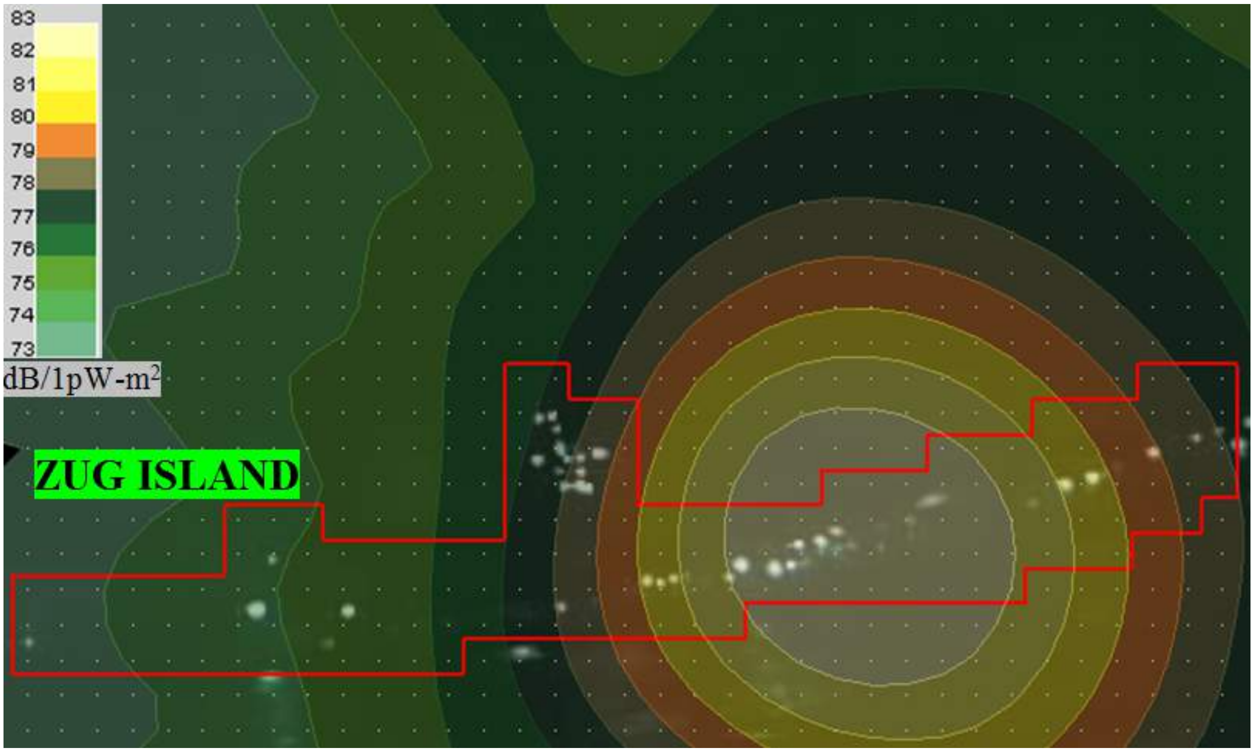
E 23: Sound Power Level Frequency Spectral Analysis – Measurement 8



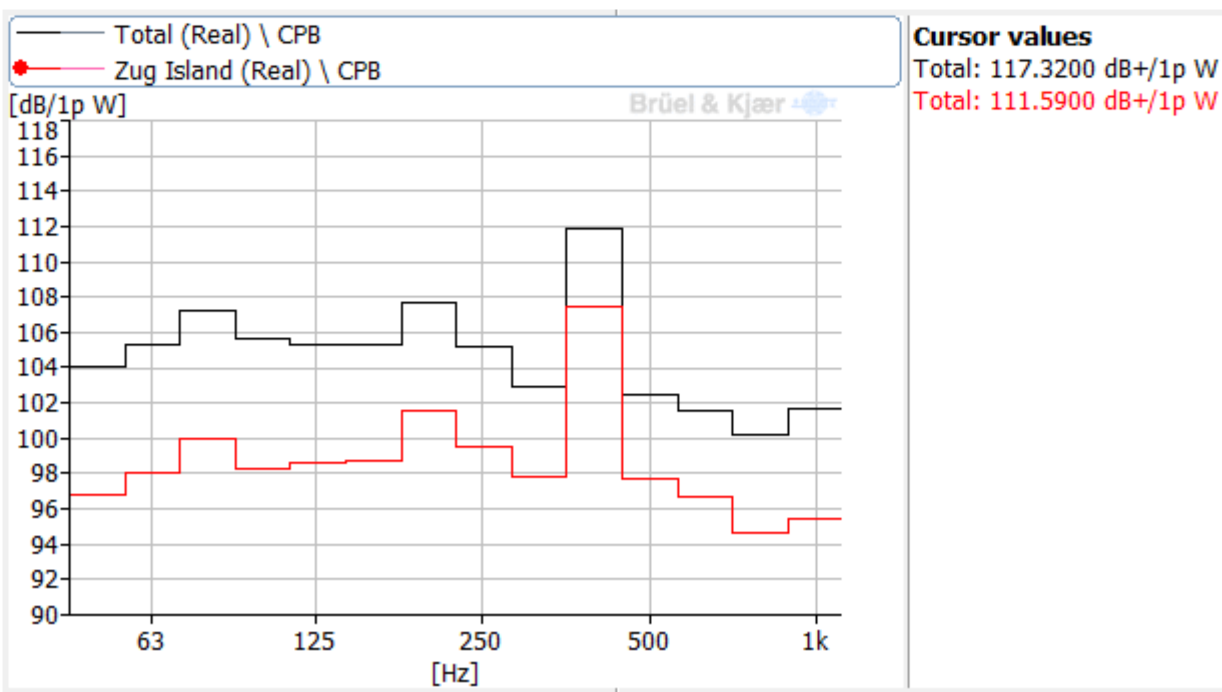
E 24: Contour Plot over Image from Pentangular Array – Measurement 9



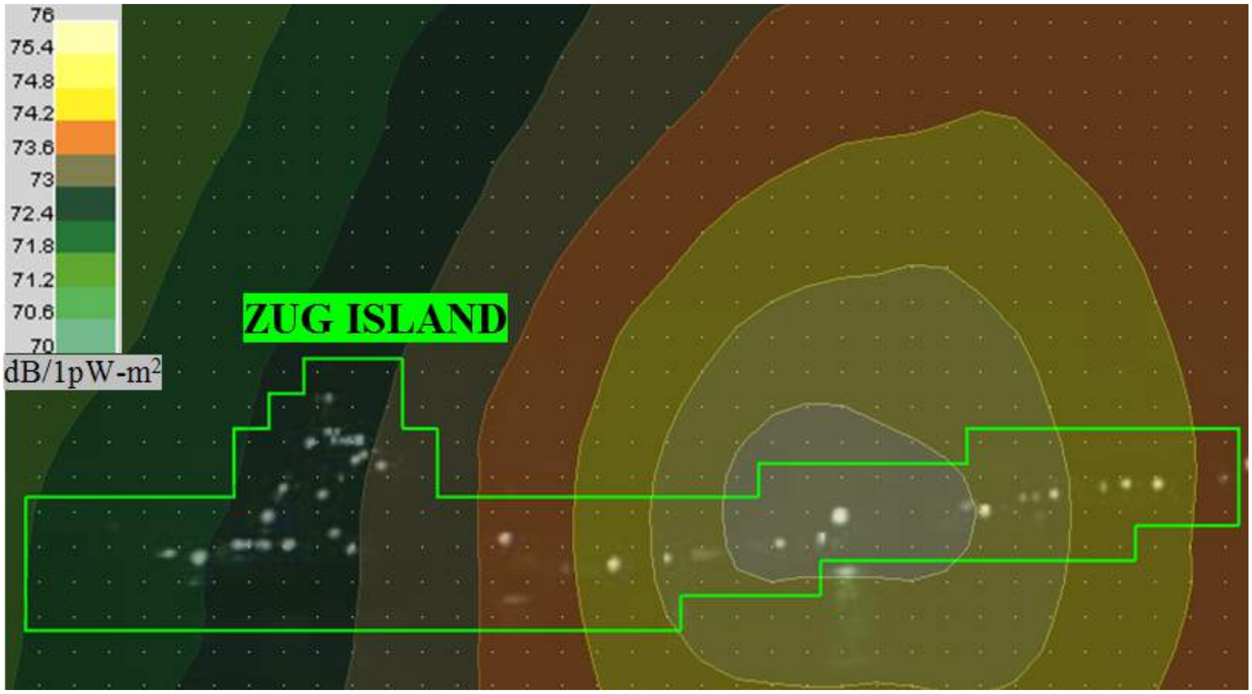
E 25: Sound Power Level Frequency Spectral Analysis – Measurement 9



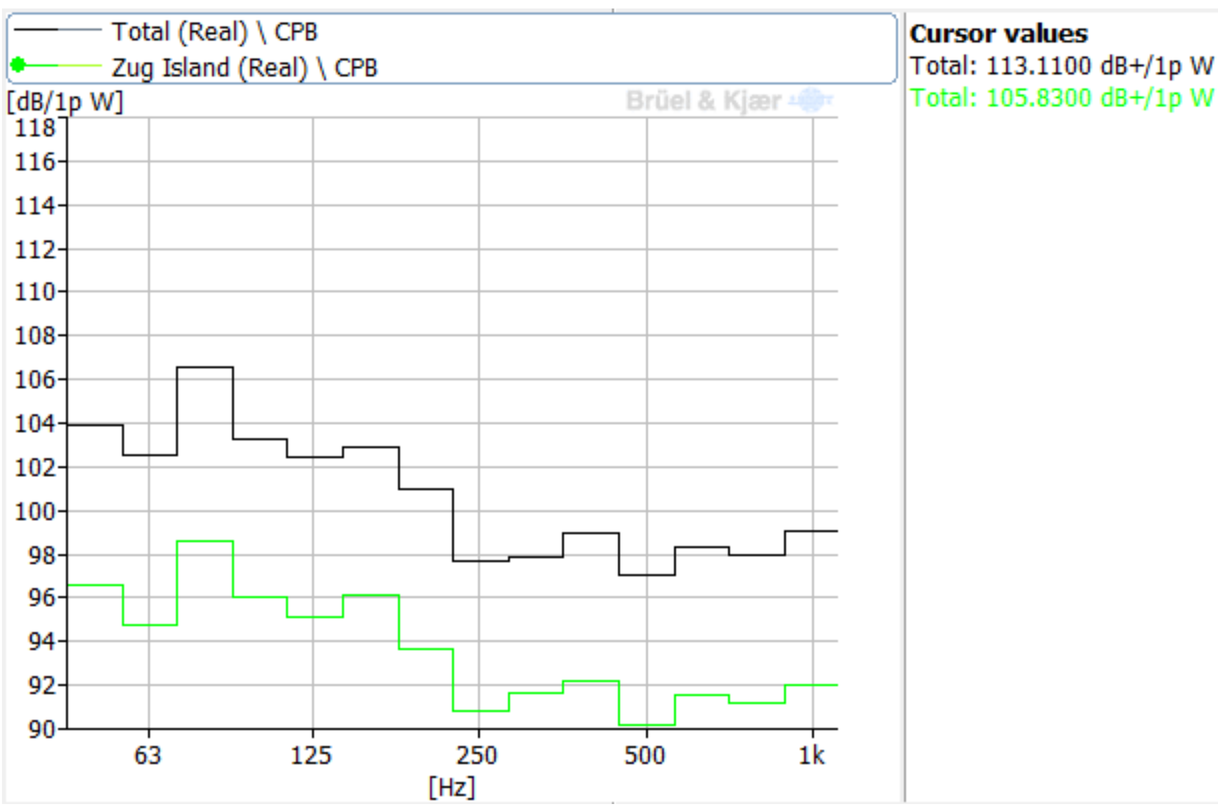
E 26: Contour Plot over Image from Pentangular Array – Measurement 10



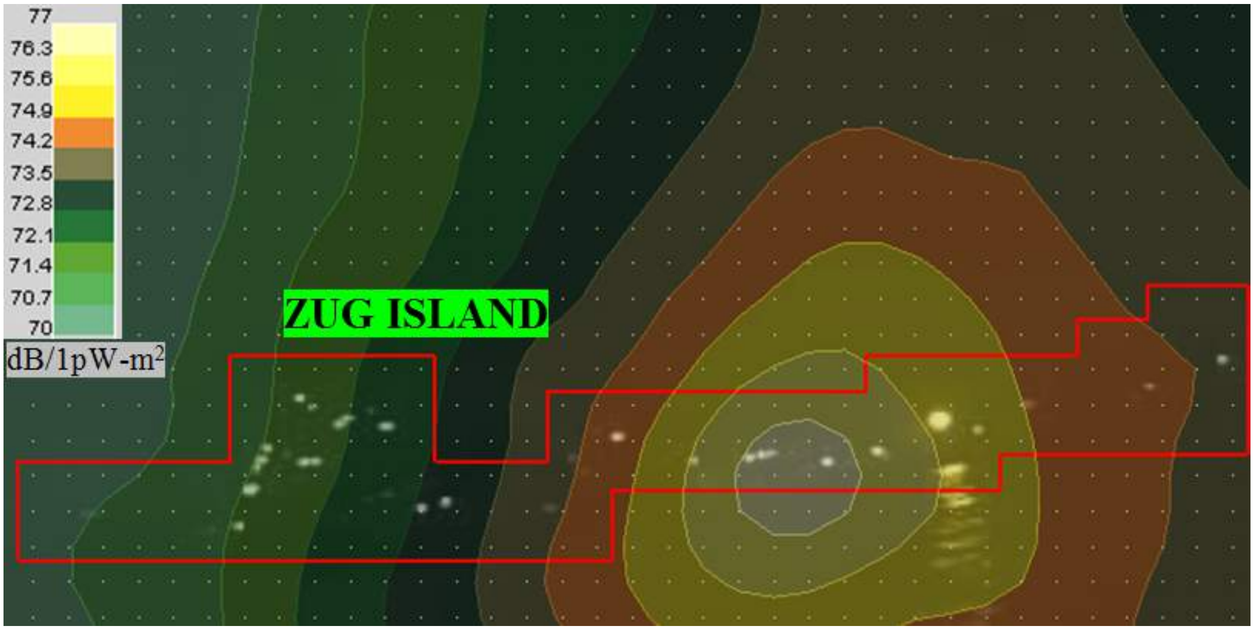
E 27: Sound Power Level Frequency Spectral Analysis – Measurement 10



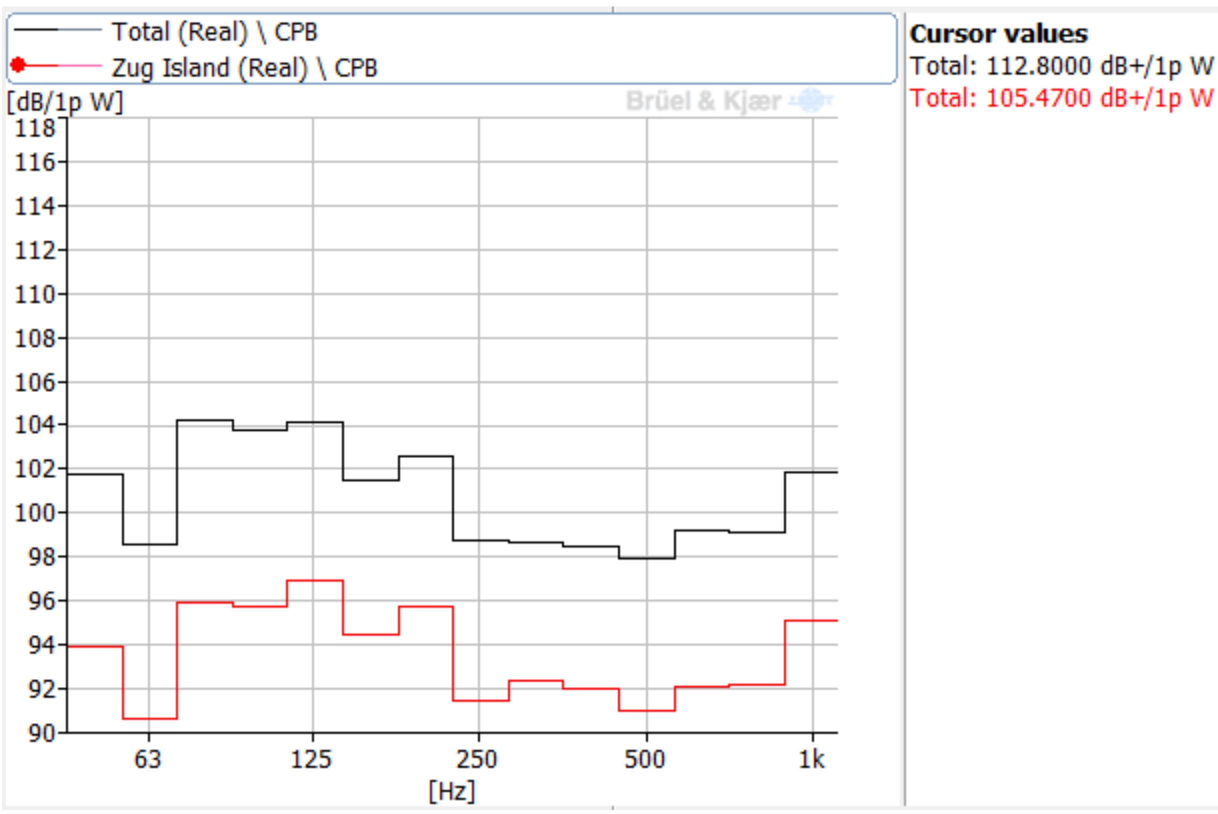
E 28: Contour Plot over Image from Pentangular Array – Measurement 11



E 29: Sound Power Level Frequency Spectral Analysis – Measurement 11



E 30: Contour Plot over Image from Pentangular Array – Measurement 12



E 31: Sound Power Level Frequency Spectral Analysis – Measurement 12

E 32: Pentangular Array Measurement Information and Notes

Measurement #	Measurement Time (s)	Notes/Comments
1	2	Steady noise levels during measurement acquisition
2	2	
3	2	
4	5	
5	5	
6	10	
7	2	Significant background noise observed from Zug Island, determined by researchers to be some sort of steam-related process
8	2	
9	2	
10	2	
11	1	
12	2	

APPENDIX F
List of Known Hum Reports

Auckland, New Zealand

2006-10-22 **NPR Radio Show**

The buzz behind Auckland's hum

Robert Siegel, Host

Tom Moir – Engineering Professor at Massey University was brought in to study it.

2011-06-14 **ONE News**

Auckland Hum

Pippa Wetzell (with Tom Moir)

2013-08-20 **North Shore Times**

40-year mystery

Liz Willis

Bristol, United Kingdom

2009-05-18 **BBC Online**

The Bristol Hum: Your Viewpoints

2013-07-29 **Bristol Post Online**

Have you ever heard the Bristol Hum? Scientists "baffled" by noise

Herbrandston, Wales, United Kingdom

2013-05-18 **Western Telegraph**

Herbrandston residents 'tortured' by mystery low frequency noise

Hueytown, Alabama

Started January 1992

Coal mining town of 15000 people

1992-04-14 **The New York Times**

Hueytown Journal; Humming Along and Howling Mad

Ronald Smothers

Largs, Scotland, United Kingdom

Started in 1989 - Ongoing

Detected a frequency between 50Hz and 60Hz.

1990-01-06 **The Herald Scotland**

"Hum adds unwelcome buzz to Largs Nightlife"

Ian Sutherland

2001-10-18 **The Guardian**

"What's that noise? It's a constant, irritating hum that makes life miserable for all who hear it – but nobody knows what it is. Laura Barton Investigates."

Laura Barton

Accessed 2013-07-06

Leeds, United Kingdom

2009-05-19 **BBC News**

Have you heard 'the Hum'?

James Alexander

Liverpool, England

Started in 2006

2008-10-04 **Daily Post**

Mystery hum makes us glum; Residents suffer years of baffling noise

Eryl Crump

Peterborough, England, United Kingdom

1994-06-22 **The Independent**

“What’s that terrible noise?: All over the country people are plagued by a strange hum. Are their ears playing up or is it something sinister? Emma Brooker Investigates”

Emma Brooker

Sydney, Australia

Started in 1970

2007-10-04 **Stuff.co.nz**

Mysterious North Shore hum remains elusive

Taos, New Mexico

Started in 1991

Video Uploaded 2006-09-06

Thomaston

Started in 1998

2006-05-26 **Foothills Media Group**

Residents irritated by ‘hum’

Samantha M. Friedrich

Vancouver, British Columbia

2010-06-02 CTV Environment Reporter

Mysterious ‘Hum’ Harasses Vancouver Residents

Mark Stevenson

Windsor, Ontario

2013-08-01 **CBC News**

Windsor's Mysterious Hum is Real, Says Researcher

Wellington, New Zealand

2012-10-11 **3News**

Singapore's frigate 'Stalwart' source of Wellington hum?

Lloyd Burr

2012-10-11 **3News**

Wellington 'hum' becomes nationwide obsession

Lloyd Burr

http://www.3news.co.nz/Wellington-hum-becomes-nationwide-obsession/tabid/423/articleID/272369/Default.aspx

2012-10-14 **3News**

Mysterious Low Hum Noise Baffles Wellington, New Zealand Residents: low hum noise baffles Wellington residents

2012-10-16 **3News**

Wellington hum ***disappears***

Lloyd Burr

Woodland, Durham

2011-06-09 **Telegraph**

Tiny village is latest victim of the 'The Hum'

Richard Alleyne

Worldwide News

2013-07-27 **Huffington Post**

Hum Heard Around World Impacts 2 Percent Of People In Hum-Prone Areas, Study Suggests

Marc Lallanilla