dBWav: A software tool for analysing and viewing long-duration hydrophone measurements

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Abstract

Underwater noise surveys using passive acoustic monitoring (PAM) typically involve deploying one or more hydrophones to measure underwater noise levels over periods ranging from several days to multiple weeks. The audio data obtained can often be several terabytes in size, particularly if the measurements contain high-frequency content. A common challenge is analysing and viewing this data quickly and efficiently. To address this issue, a software tool (dBWav) has been developed that pre-processes the raw audio and stores the key information in a much smaller data file, which can then be displayed and analysed in a simple interface. This software is intended to be a screening tool, allowing the user to locate periods/events of interest and export the necessary information in full resolution for reporting or further processing with other software.

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1. Introduction

Passive acoustic monitoring (PAM) is commonly used to understand the existing underwater noise environment in a given area. The information captured is often used as baseline data for environmental effects assessments as well as for research purposes.

There is currently no standard or widely available software for the production of calibrated PAM measurements [1]. Analysis using existing tools can be highly time consuming due to the large amounts of data obtained, and generally requires expensive software suites such as Matlab and expertise in coding.

This paper presents the software tool dBWav, which was developed by Marshall Day Acoustics as an efficient and user-friendly tool for analysis of long-duration measurements using the SoundTraps hydrophones produced by Ocean Instruments.

2. Background

Many marine species use sound for ecologically important functions including communication, navigation, finding prey, avoiding predators and locating mates and offspring. High levels of underwater noise can adversely impact these species, with effects ranging from reduced communication distances and avoidance of areas to disorientation and temporary/permanent hearing loss [2].

Ambient underwater noise surveys are an important part of understanding the impact of noise on marine species in a given area. Noise levels underwater can vary spatially, temporarily and in frequency content. To understand the environment therefore requires multiple measurement positions, sufficiently long-duration measurement periods, and for levels to be measured over a wide frequency range [3].

Once this data has been obtained, it must be analysed. The primary method of analysis is using visual tools such as time and frequency plots, statistical values, or a combination format such as a spectrogram (change in frequency spectrum over time).

3. The problem

PAM measurements capture significant amounts of data. For example, a survey involving three hydrophones with sample rates of up to 576 ksp (necessary to capture data in the hearing range some marine mammals), produces over 2 gigabytes per hour of audio data. It is not uncommon to deploy many more hydrophones in a survey, particularly for research purposes.

It can be very time consuming to process and view this data using available methods. Many software tools do not provide the level of detail, accuracy or speed necessary for consulting or research purposes. The most common approach is to use Matlab to run modifications of publicly available routines to produce the outputs. This requires a license of Matlab as well as programming expertise.

For many consultants and researchers in the field of underwater noise, these are significant time and cost hurdles to overcome with data analysis for ambient underwater surveys. A need was therefore identified for a simple software tool that can quickly process large amounts of raw audio data with an intuitive interface to view the results.

4. dBWav software tool

Marshall Day Acoustics has developed the software tool 'dBWav' as a solution to this problem. It is intended to be used for high-level analysis of hydrophone measurement data, suitable for most consulting and research applications. For more detailed and specialised applications (e.g. click detection or analysis of impulsive sources), dBWav is intended to be used as a screening tool to identify periods of interest and export the relevant data for further processing in other software tools.

The key element of dBWav is the pre-processing of the raw audio files and storing the relevant information in a much smaller data files called an LVX, which allow the data to be quickly displayed in dBWav's interface for real- time analysis.

5. Features of dBWav

dBWav is divided into two main components: pre-processing of the raw data, then viewing and analysing the results. The flow chart in Figure 1 below illustrates this process.

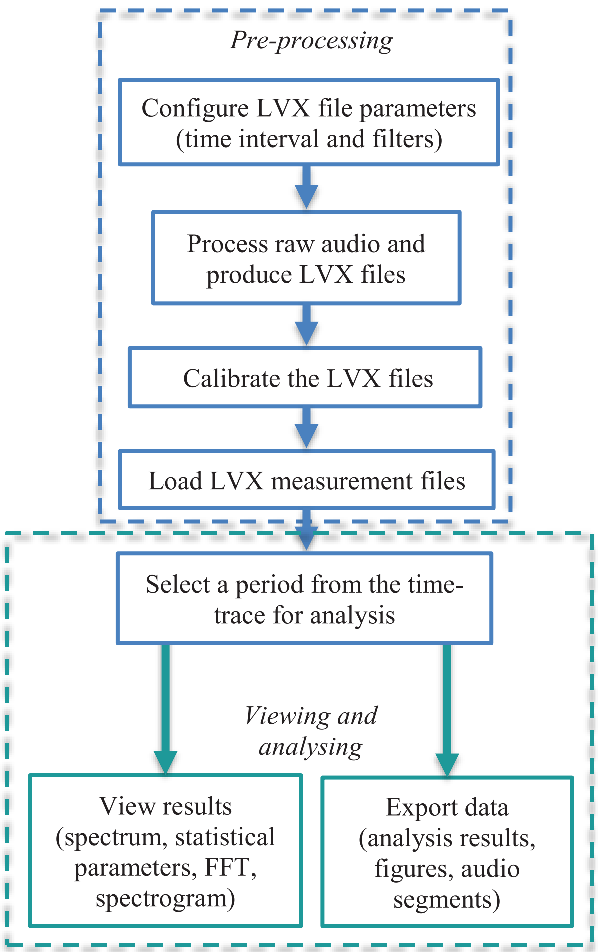

Figure 1: Figure 1. dBWav analysis process

To allow real-time analysis of data obtained from long duration surveys, dBWav pre-processes the raw audio data and stores the key results in much smaller LVX files. This means that the time consuming and computationally intensive processing of raw audio data is carried out in bulk prior to analysis, which significantly increases the speed at which the data can be accessed.

An LVX file is comprised of a table, with each row containing the levels at one-third octave bands averaged over the chosen time interval, and the relevant time stamp for that entry.

At the highest resolution (using a time interval of 1 second), the LVX files are approximately 400 times smaller than the corresponding raw audio file. Using larger time intervals further reduces the LVX file size and increases the corresponding speed at which the data can be displayed.

Not all data necessary for analysis is stored in the LVX files. To minimise the LVX file size and therefore maximise the speed of dBWav's real-time analysis, actions such as Fast Fourier Transforms (FFTs) and audio playback are carried out by selecting the period of interest in dBWav's interface and calling the relevant section of the audio file for processing. These periods can be tagged and saved with comments to the LVX file for subsequent reference and recall.

5.1 Calibration

Two methods of calibration are available in dBWav:

1. Using a recorded calibration signal at a known level
2. Using factory calibration data from the manufacturer

Method 1: pistonphone calibration

The first and primary method involves recording a tone (usually with a pistonphone at 250 Hz) at a known level on the hydrophone. The level can be determined using a sound level meter connected to the pistonphone to any hydrophone using a coupler, as illustrated in Figure 2.

Figure 2. Calibration using a pistonphone

Figure 3 shows the recorded calibration tone in dBWav. The user selects the period with the calibration tone and enters in the level recorded on the sound level meter, correcting for the difference in reference pressure between air and water. The calibration value is automatically stored in a file which is referenced when the LVX files are loaded.

This method is typically used for applications where precision is necessary for the absolute level, which requires calibration to be carried out before and after measurements, such as for effects assessments.

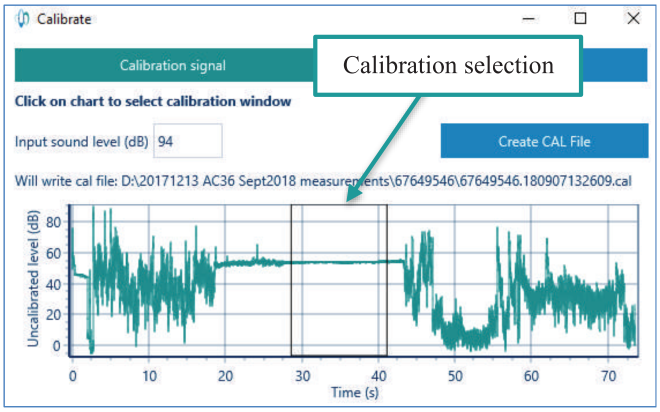

Figure 3: Viewing the calibration audio in dBWav

Method 2: factory calibration

The second method involves using the manufactures factory calibration data. This method is slightly less precise than method 1 as the sensitivity of the hydrophones can change over time. However, it is suitable for applications where absolute level precision is not necessary, such as comparing the change in noise level over the survey period.

6. Description of interface

It was the intention that dBWav's interface was dynamic and intuitive. A dynamic interface would allow almost all of the functions and results to be contained within the same window while not appearing overly busy. This was achieved by allowing the various elements in the interface to be resizable and able to be turned on/off. The interface also needed to be intuitive so that dBWav was easy to learn and use.

Figure 4 shows the interface with the LVX files from two hydrophones loaded. The top left section of the interface contains the pre- processing functions.

These are as follows:

Set Up: Set up the properties of the LVX files (filtering and time interval).

Process: Select the hydrophone audio files for processing.

Calibrate: Select calibration method and produce the calibration file that the LVX files will reference.

Open LVXs: Load the relevant LVX files. Measurements from multiple hydrophone can be loaded.

Clear LVXs: Remove the selected LVX files

The middle of the interface shows the variation in level over time for the survey period. The time trace is used for navigation to identify periods of interest. dBWav allows for multiple hydrophone time-traces to be displayed simultaneously.

When a period of interest has been identified, the user clicks-and-drags to select that period for calculation. dBWav then calls the relevant data from the LVX files to calculate overall levels, spectral content and statistical parameters for the selected period.

The calculated results can be viewed as overall levels, as a spectrum, or as a table using the analysis tabs in the lower portion of the interface. These features are described further overleaf. The calculated results can be displayed as linear levels or with marine weightings in accordance with the NOAA technical guidance [4].

Specific functions can be carried out for the time selection using buttons in the top right section of the interface. These functions are as follows:

Play: Plays the audio for the time selection

FFT Calculate the Fast Fourier Transform

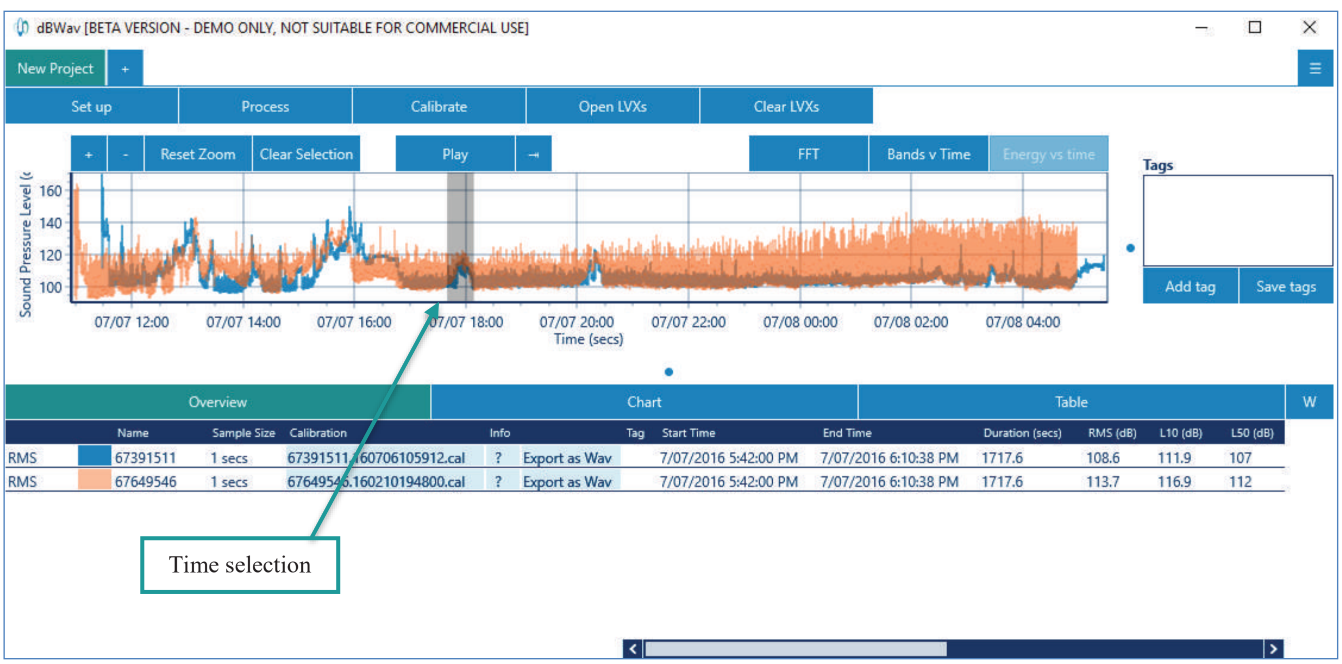

Figure 4: dBWav interface

(FFT) and corresponding spectrogram using the full resolution audio data (discussed further overleaf).

Add Tags: The user has the option to add tags to the selected period to name and describe the event. Clicking on the tag in the list will reselect that time window, and recalculate the results.

Bands vs. Time: Produce a spectrogram using the data in the LVX files. (discussed further overleaf). This is significantly faster than the FFT method.

Energy vs. Time This function will produce power spectral density plots. It is still under development.

7.1 Overall levels, spectral data and exporting

The overall levels and spectral data is updated when the user selects a period of interest. This data can be accessed by clicking on the following tab headings:

Overview: This tab shows the key overall information such as overall level, duration of selection, data and time, and statistical parameters.

Chart: The chart tab displays the average and statistical levels for each frequency band over the selected period.

Table: This tab shows the spectral data in a table. This data can be exported to the clipboard, or into a text file. It is also possible to export the raw table data from the LVX file.

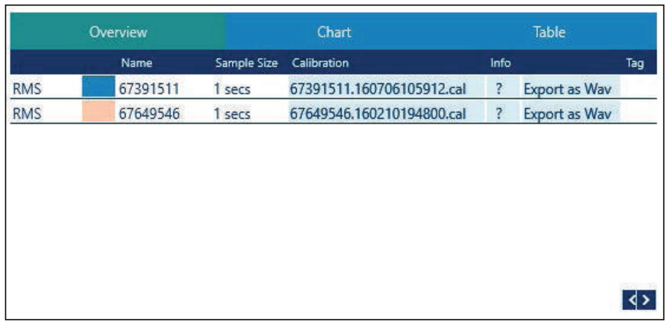

Figure 5a: Overview tab

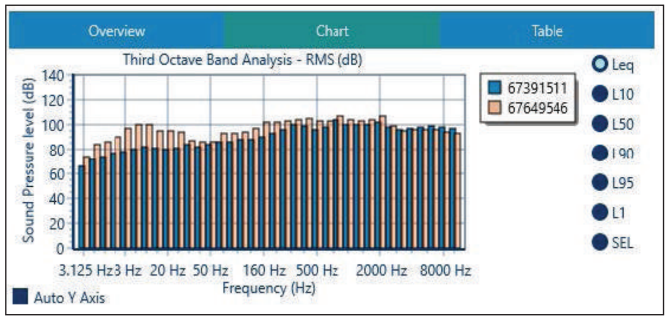

Figure 5b: Chart tab

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Changes to Brüel & Kjær's representation in New Zealand

Following a review of Brüel & Kjær representation in New Zealand, as of February 2019, Wellington based Nichecom will no longer be representing Brüel & Kjær.

Brüel & Kjær has served New Zealand customers for over 30 years by providing leading Sound & Vibration solutions and services and we value continuing this tradition for many more years to come.

To ensure we strengthen our sales and technical support to New Zealand customers we are in the process of identifying a new local partner. While we work through a new arrangement, Brüel & Kjær Australia will take care of all sales and technical enquiries directly during this period. You can reach us by phone or email:

Brüel & Kjær Australia (Sydney): +61 2 9889 8888

Brüel & Kjær Email: nzinfo@bksv.com

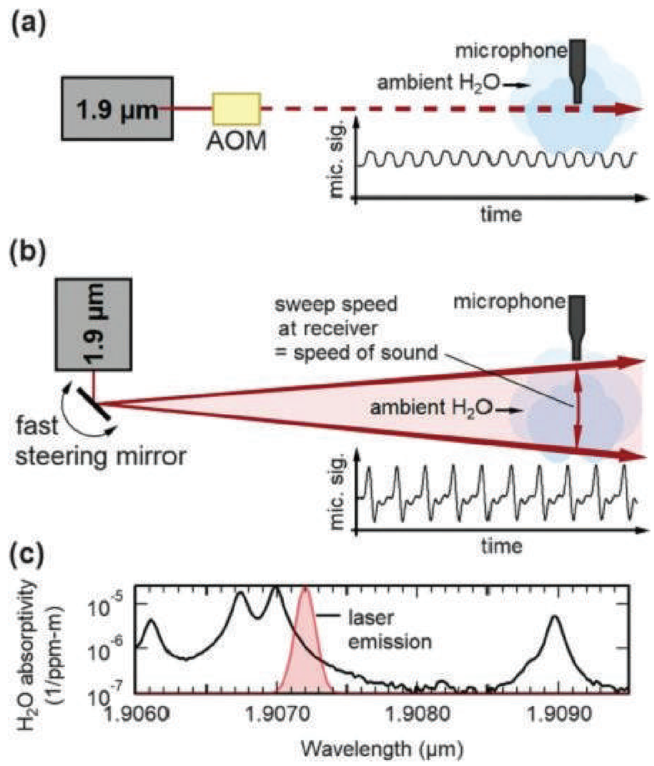
Kind regards, Maurizio Demontis
General Manager - Brüel & Kjær Australia

Now hear this: Photoacoustic communications via lasers

Modern choices of conveying information range from smartphones to computers to texts and emails. These data transmission modalities require both the sender and the recipient to be similarly equipped, but what if the intended receiver lacks the appropriate electronic devices?

Photoacoustics might be able to support communications needs in this case. MIT researchers have demonstrated two laser-based techniques that can transmit an audible message to a person without any type of receiver equipment.

Experiments demonstrated the use of a 1.9 μm thulium laser to produce photoacoustic signals from ambient atmospheric water vapour at 50% relative humidity with sound pressure levels well into the audible realm. The method generates continuous wave audible signals near the receiver via the absorption of light by water vapour.



Delivery of audible messages via photoacoustics. (a) Traditional photoacoustic configuration: 1907.2 nm laser light is absorbed by ambient water vapour. (b) Dynamic photoacoustic communication amplifies the audible signal. (c) Water absorptivity near 1.9 μm, with an overlay of the laser emission from the thulium fibre laser. Source: MIT

A fast-steering mirror was also used to sweep the laser beam, spurring the laser spot at the speed of sound over some arch adjacent to the receiver. The process amplifies the acoustic signal and produces pulsed acoustic emission without the need for a resonant chamber. Commercially available equipment applied to this technique can transmit sound to a person more than 2.5 m away at 60 decibels.

These methods for sending highly targeted audio signals over the air could be used to communicate across noisy rooms or warn individuals of dangerous or emergency situations. The researchers next plan to demonstrate the technology outdoors at longer ranges.

The study results are published in Optics Letters (https://doi.org/10.1364/OL.44.000622)

Scientists gave alligators Ketamine and headphones to understand dinosaur hearing

An experiment involving 40 drugged alligators reveals how dinosaurs might have located sounds in their environment. Scientists dosed alligators with Ketamine and had them listen to sounds through earbuds to better understand the auditory abilities of dinosaurs.

The experiment, described in a paper published Monday in The Journal of Neuroscience [Vol. 39, Issue 20, 15 May 2019), was designed to study the "*neural maps*"—brain passageways that carry information about soundwaves—that alligators generate to locate noises in their habitats. These maps are vital for many vertebrates, and are especially developed in nocturnal predators such as barn owls because they rely heavily on sound to locate prey.

See www.vice.com/en_us/article/a3b9kj/scientists-gave-alligators-ketamine-and-headphones-to-understand-dinosaur-hearing for more information.

Can we design a structure that can block noise but preserve air passage?

"*Today's sound barriers are literally thick heavy walls*," says Reza Ghaffarivardavagh, a mechanical engineer at Boston University. Although noise-mitigating barricades, called sound baffles, can help drown out the whoosh of rush hour traffic or contain the symphony of music within concert hall walls, they remain a clunky approach not well suited to situations where airflow is also critical.

Imagine barricading a jet engine's exhaust vent—the plane would never leave the ground. Instead, workers on the tarmac wear earplugs to protect their hearing from the deafening roar.

An alluring question enticed the researchers: "*Can we design a structure that can block noise but preserve air passage?*"

Leaning on their mathematical prowess and the technology of 3D printing, it turns out they can. The research appears in Physical Review (Vol 99, Issue 2, January 2019). The mathematically designed, 3D-printed acoustic metamaterial is shaped in such a way that it sends incoming sounds back to where they came from, Ghaffarivardavagh and Zhang say. Inside the outer ring, a helical pattern interferes with sounds, blocking them from transmitting through the open centre while preserving air's ability to flow through. (Credit: Cydney Scott/Boston U.)

Ghaffarivardavagh and Zhang let mathematics—a shared passion that has buoyed both of their engineering careers and made them well-suited research partners—guide them toward a workable design for what the acoustic metamaterial would look like.

"*Sound is made by very tiny disturbances in the air. So, our goal is to silence those tiny vibrations,*" Ghaffarivardavagh and Zhang say. "*If we want the inside of a structure to be open air, then we have to keep in mind that this will be the pathway through which sound travels.*"

They calculated the dimensions and specifications that the metamaterial would need to have in order to interfere with the transmitted sound waves, preventing sound—but not air—from being radiated through the open structure. The basic premise is that the metamaterial needs to be shaped in such a way that it sends incoming sounds back to where they came from, they say.

As a test case, they decided to create a structure that could silence sound from a loudspeaker. Based on their calculations, they modelled the physical dimensions that would most effectively silence noises. Bringing those models to life, they used 3D printing to materialize an open, noise-cancelling structure made of plastic

Sounding the alarm on aquatic noise

A collaborative team led by University of Victoria (Canada) doctoral student and Hakai Scholar Kieran Cox and fish ecologist Francis Juanes has found that human-caused noise is changing the ability of fish to forage, reproduce and avoid predation. The team analysed

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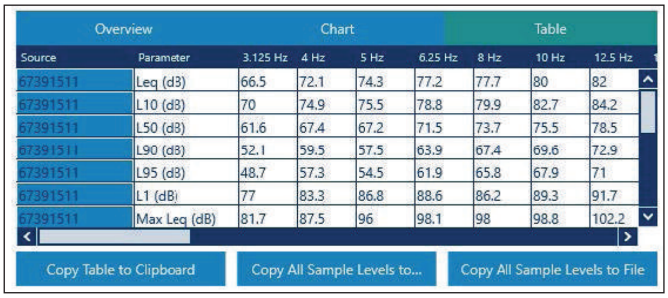
Figure 5 (a-c) shows a series of screen shots from each of the tabs.



Source	Parameter	3.125 Hz	4 Hz	5 Hz	6.25 Hz	8 Hz	10 Hz	12.5 Hz
67391511	Leq (dB)	66.5	72.1	74.3	77.2	77.7	80	82
67391511	L10 (dB)	70	74.9	75.5	78.8	79.9	82.7	84.2
67391511	L50 (dB)	61.6	67.4	67.2	71.5	73.7	75.5	78.5
67391511	L90 (dB)	52.1	59.5	57.5	63.9	67.4	69.6	72.9
67391511	L95 (dB)	48.7	57.3	54.5	61.9	65.8	67.9	71
67391511	L1 (dB)	77	83.3	86.8	88.6	86.2	89.3	91.7
67391511	Max Leq (dB)	81.7	87.5	96	98.1	98	98.8	102.2

Figure 5c: Table tab

7.2 FFT

The user can choose to calculate the FFT over the time selection. The FFT function utilises the full resolution of the raw data by calling the relevant section from the audio file and processing it. The results can be displayed quickly for short time selections; however, longer selections can be time consuming to process.

Once that FFT has been calculated, a spectrum will be displayed as shown in Figure 6. A range of standard window lengths and types can be chosen from the drop-down menus. The levels shown for the FFT are relative levels, not absolute calibrated levels.

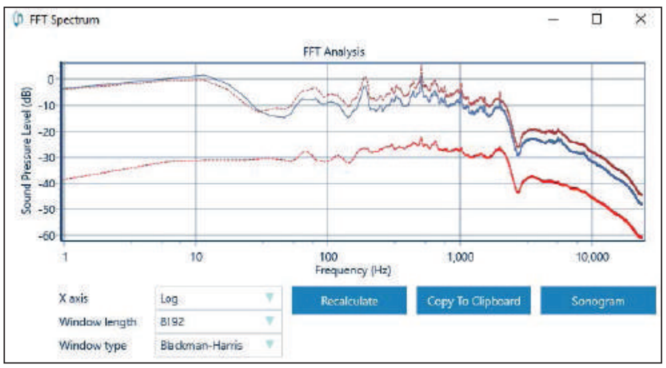


Figure 6: FFT example

A spectrogram can also be produced from the FFT by clicking on the 'Sonogram' button. An example is shown below in Figure 7. These levels are also relative.

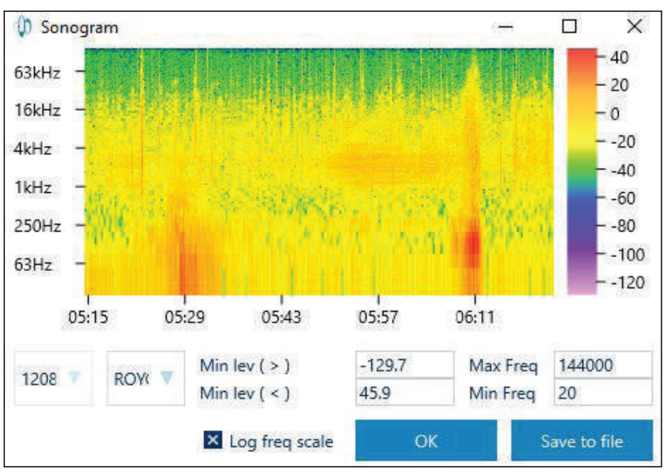


Figure 7: Sonogram example

7.2 Bands versus Time

The Bands versus Time function can also produce a spectrogram. This method is significantly faster than the FFT as it uses the data in the LVX file instead of calculating from the raw audio. The Bands versus Time levels are calibrated.

An example of the Bands versus Time output is shown in Figure 8 below.

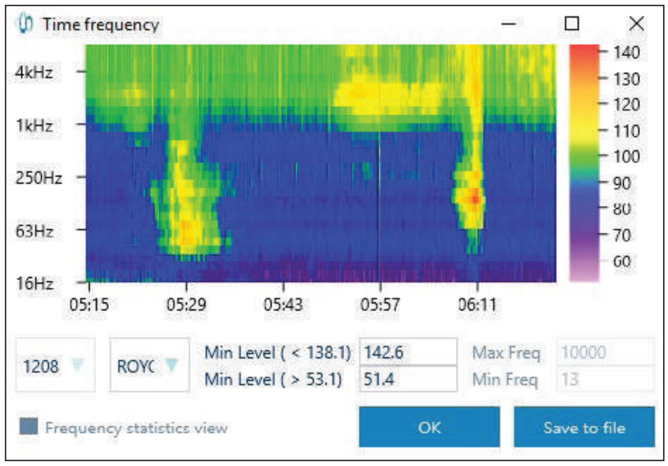


Figure 8: Bands versus Time example (1/3 octave spectrogram)

8. Conclusions

A need for an efficient and easy to use software tool for analysing long-duration hydrophone measurements has been identified.

Marshall Day Acoustics has developed the software tool dBWav to meet this need. This tool allows for real-time analysis of the measurement data by pre-processing the raw audio data and storing the relevant information in a much smaller data file, which can be quickly accessed to display information in dBWav's interface.

dBWav is able to produce many of the results necessary for use as a high-level analysis tool for both consulting and research purposes. It contains exporting features for further analysis using other software tools as required.

9. Future work

This paper has described version 1.0 of dBWav. Features that are in progress for the next version are:

- Produce power spectral density and empirical probability density plots
- Underlay the spectrogram in the main time-trace navigation window. Periods of interest can be identified more easily using a spectrogram as it contains frequency information as well as level.
- Allow calibration with electrical values as well as pistonphone and factory calibration
- Increase upper frequency limit