PORTRAYING THE VARIABILITY OF THE UNDERWATER SOUND FIELD ASSOCIATED WITH RENEWABLES TO THE NON-EXPERT USER

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1 INTRODUCTION

Acoustic site characterisation has often consisted of monitoring ambient noise for a highly variable amount of time and then processing the data to produce a mean linear or third octave spectrum. More advanced studies have produced mean spectra for different known conditions such as weather or shipping conditions. Such methods do convey useful information but do not contain sufficient information to fully characterise the site.

In the renewables field such measurements are usually commissioned by either developers or government agencies as part of the licensing process and may involve measurements before and during construction and again when the installed system is operating. The measurements are usually carried out by specialist contractors who have the necessary equipment and expertise. One significant problem has been the portrayal of the acoustic measurements to customers who may well be engineers or scientists, but are unlikely to have an understanding of underwater acoustics. Without a good understanding of the significance of the acoustic measurements important aspects may be overlooked or ignored.

The information from acoustic measurements is needed to assess the likely acoustic impact of the installation on the marine environment. The noise field into which the installation is to be placed may be highly variable due to factors such as weather and passing shipping. Understanding the impact involves knowing a number of factors including:

- Mean spectrum
- Variability of levels
- The presence of transients/impulses
- Identification of the dominant components of the noise field

These measurements should be made before installation starts, during the installation phase and again once the installation is operational.

This paper will concentrate on variability and how it may be portrayed in a manner that makes it easier to be understood by non-acousticians.

2 PORTRAYING VARIABILITY

Variability can be portrayed in a number of ways. Multiple averaged spectra is perhaps the simplest method. Spectra are averaged during specific periods such as very quiet weather, storm conditions or passing shipping and the resulting spectra presented to illustrate the range of spectra that may be encountered at the site. This type of presentation gives no information on the statistics of the various levels that can occur.
Percentile plots can give more information on variability if sufficient percentiles are plotted. These plots show the spectrum which exceeds a percentage of all the measured values. However, these plots still under-sample the available data.

A more recent option is the variability plot, also referred to as the Spectral Probability Density. This method was previously described in Harland, 2010, Harland, 2011 and Merchant et al 2013. The plot is named the variability plot as it is more descriptive of its purpose to the non-expert than Spectral Probability Density. The variability plot is formed by averaging the spectra over a short period, typically 1-30 seconds. This is repeated over the data collection period which may be hours, days or months. The number of occurrences of each frequency/amplitude point is counted and the resulting counts plotted as colour or intensity on frequency-amplitude axes. A typical example is shown in figure 1.

![Figure 1. Typical variability plot](image.png)

For very large datasets the counts may exceed $10^7$ so the dynamic range is well beyond normal display media such as printers or VDU's. By using the logarithm of the count rather than the count the dynamic range is reduced to a useable level. Figure 2 illustrates the effect of dynamic range compression on a variability plot. It can be seen that much of the data in the linear plot has been lost because of the poor dynamic range of the display.
Figure 2. Variability plotted with linear count (top) and logarithmic count (bottom)

Figure 3 shows a plot that demonstrates a number of aspects of this type of data display. A number of spurious internal signals in the recorder are present and show as the spikes along the bottom of the plot at 5, 8, 15.5 and 24 kHz. The spikes result because at these frequencies the level never drops below the level of the spurious signals. The peaks in the 0-5 kHz region are caused by persistent external signals. These may be ships that pass often (e.g. a ferry) with a particular tonal originating from its propulsion, or from resonant structures such as jingling chains. Outliers, such as those seen at higher levels in figures 1 & 2, are generally caused by passing ships.

It can be seen that the distribution in figure 3 is multimodal with several distinct groupings. This can be caused by the weather, e.g. a short calm interval occurs during a stormy period, or by other noise sources that persist for a significant fraction of the monitoring period.

The dip in level at 2 kHz seen in figure 2 is probably caused by an interaction between the hydrophone and its mounting arrangement.

Vol. 35. Pt.1 2013
Figure 3. Example variability plot showing spurious signals

The effect of the choice of averaging period was investigated and the results shown in figure 4 below. These plots use a 1024 point FFT with Hanning weighting.

Figure 4. Effect of changing averaging time. 0.3 sec (top left), 1 sec (top right), 5 sec (bottom left), 30 sec (bottom right)
Choosing the best averaging time will depend on the specific application. With short averaging time the effect of transients will be seen more clearly while longer averaging times will show longer term effects more clearly. A good compromise appears to be 5 seconds which picks up the highest speed passing boats.

The effect of changing the frequency resolution was also investigated. FFT sizes of 256, 1024 and 4096 were tried as was the effect of using 1024 point FFT decimated to 256 point. The results suggest that the plot appearance is not sensitive to frequency resolution with 1024 or 4096 point FFT's suitable.

3 RESULTS

A dataset was available from a fixed hydrophone deployed in the Fleet, Dorset. This data is processed for each day and figures 5-7 show three days from April 2013.

![Figure 5. Variability plot for the 4th April 2013](image)

All of these plots use a 512 point FFT with Hanning weighting. The data is then decimated by 8 to give 64 frequency bins on the plots. The 4th April, shown in figure 5, was a windy day with no rain and no boat traffic. The range of variation is low. The spurious signal at 22 kHz is due to an internal signal from a switch-mode power supply which fluctuates in level and frequency.

The 6th April was a calm day and being Saturday there was a lot of small boat traffic. The bright band at low level corresponds to the quiet conditions while the elevated noise levels are due to passing boats. Twenty two boat passes were identified.

The 9th of April was a windy day with many heavy showers and just two passing boats. The two passing boats show as the outliers at high level. The bright band is now much expanded compared with the 4th April because of the variable wind speed and rain rate.

Vol. 35, Pt.1 2013
Figure 6. Variability plot for the 6th April 2013

Figure 7. Variability plot for the 9th April 2013

Vol. 35, Pt.1 2013
4 USING VARIABILITY PLOTS

These plots can be used during the preparation of environmental impact assessments. There is sufficient information to carry out a more informed assessment of any potential impact. If plots are obtained before and during any noisy events then the differences can be highlighted and this information can be used in the assessment. It should be possible to automatically process the variability plot(s) to produce an ‘acoustic impact factor’ and this will be the focus of the next stage of this work. If this process can be formally-defined then it should allow comparisons between sites to be more meaningful.

5 CONCLUSIONS

Variability plots show the probability of a frequency/amplitude point being measured during the assessment period. They can show the ‘most likely’ spectrum to be measured at the site and they can show how the spectrum level varies during the assessment period.

Variability plots can also reveal limitations in the measurements such as spurious internal signals, internal noise limitations and spectral nulls that may arise from interference patterns around the measurement equipment.

The variability plot conveys more information than mean spectra and can be used to provide more meaningful impact assessments of renewable generators and other noise-generating systems.

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7 REFERENCES
