Identifying noise levels of individual rail pass by events

Matthew Ottley[1], Alex Stoker[1], Stephen Dobson[2] and Nicholas Lynar[1]

[1] Marshall Day Acoustics,

4/46 Balfour Street, Chippendale, NSW, Australia

Tel: +612 9282 9422, E-mail: sydney@marshallday.com

[2] Marshall Day Acoustics,

6 Gipps Street, Melbourne, VIC, Australia

Tel: +613 9416 1855, E-mail: melbourne@marshallday.com

Summary

Technology associated with acoustic data capture has advanced significantly, with commercially available Sound Level Meters allowing engineers and consultants to capture masses of multi-channel data relating to train noise. Whilst this extended dataset can provide vital information, manually scrutinizing masses of data to isolate individual train pass-bys can be time consuming and problematic.

This paper investigates the implementation of automated, remote (un-manned) systems that can be installed on-site, allowing train pass-by noise levels to be recorded with minimal user guidance. The efficacy of acoustic and ground vibration sensors to accurately identify train noise levels and train direction is investigated.

1 Introduction

The technology available for noise measurement and analysis has progressed rapidly over the last decade. The quantity of data available has increased dramatically with the advent of large solid state storage and remote connectivity of devices. It is now common to record spectral levels every second and continual high quality audio for weeks on end. Previously, noise data loggers were generally only capable of recording average noise levels over predefined periods (e.g. day and night times). New generation devices are capable of recording individual train pass-bys and there are generally two measurement and analysis options.

One option is to construct customised, dedicated measurement solutions tailored to rail noise measurements, such as the Transport for NSW Wayside Noise and Vibration Monitoring System [1]. These systems are typically installed inside the rail corridor and operated by (or on behalf of) the infrastructure owners. The advantage of such systems is that they can be designed to capture very detailed data for specific applications. Their disadvantage is that they lack flexibility and may be unattractive for consultants as their single application nature means they can be difficult to justify (in terms of upfront investment) unless continuous monitoring work is likely. Also the systems generally need to be installed within the rail corridor, requiring co-ordination and co-operation from the network operator, involving a level of bureaucracy as well as the inherent risks of working within an operating rail corridor.

An alternative option to a dedicated measurement system is to use commonly available measurement equipment, such as an advanced noise logger (logging noise parameters every second and recording continuous audio). The advantage of more general purpose equipment is that it can be deployed on other sites when not in use for rail projects. The limitation of advanced noise loggers is that it can be difficult to extract train pass-by information from the large data set collected.

Where the noise logger is located close to the train line and the ambient acoustic environment is relatively free of other extraneous noise simple software triggering (based on level and duration of noise events) can be used to identify rail pass-bys. Unfortunately sites are more often affected by a range of other extraneous ambient noise (such as nearby roads or aircraft overflights) that can interfere with simple noise triggers, leading to either extraneous noise falsely identified as trains or train pass-bys being missed.

This paper examines the potential to use general purpose measurement equipment to be deployed in such a way as to deliver robust noise level results, minimize data analysis time (i.e. reduce man hours required to sort data) and identify key data related to train pass-bys. The focus is on the tools available to quantify the following for individual pass-bys:

- Time of pass-by
- Duration of pass-by
- L_{AE} / SEL of pass-by
- L_{Amax} of pass-by
- Type of train (passenger vs freight)
- Train direction

On previous projects data acquisition has utilized two advanced noise loggers separated by at least 50m along the rail corridor. Simple threshold triggers, based on threshold noise levels and duration, are used to identify pass-bys. The time difference between the pass-by at each logger is used to determine train direction. For locations further away from the track the triggers on the logger(s) close to the track can used to create a time window for pass-bys at loggers located more remotely from the track. This system works well in many instances but has limitations where the site is subject to significant ambient noise that may activate the threshold triggers (particularly if near roads or subject to aircraft overflights). The other disadvantage to this approach is that multiple advanced noise loggers are required in order to determine train direction or to create trigger windows for sites located some distance from the rail line.

2 Methodology

2.1 System design

This paper explores the use of ground vibration sensors to generate trigger windows to capture train pass-by noise. Train passage generates a unique ground vibration event which can be used to identify pass-bys. Two vibration sensors are typically set on ground, close to the rail corridor boundary with a sufficient separation to generate leading and lagging vibration events. The vibration output is used to generate trigger periods to automatically extract noise data from a noise logger typically located at a more remote distance from the tracks. For this study, the equipment comprised a 01dB Duo Smart Noise Monitor and an 8 Channel Instantel Minimate III Plus with external geophones.

The Duo is an advanced IEC Class 1 noise monitoring platform with 1/3 octave capability, discrete time period acquisition as low as 100ms, high quality signal recording, advanced trigger coding and utility functions for high capacity memory storage and remote connectivity. The post processing software used for the Duo data is dBTrait.

The Minimate III Plus, now practically a legacy vibration monitoring platform, is primarily used for blast and construction monitoring. It was utilized for this study as it is robust and relatively inexpensive system although the minimum histogram discrete time period of two seconds is less than ideal and for this deployment, requiring a 90m separation between the geophones to obtain sufficient definition of the leading and lagging vibration events. The post processing software used for the Minimate data is Blastware.

The noise logger was installed just outside the rail corridor, between the vibration sensors.

2.2 Data processing and Analysis

The data processing procedure from each monitoring device is set out below.

Step 1: Process vibration data to identify each rail pass-by

Vibration data was first exported from Blastware as an ASCII file for import to 01dB dBTrait software. Threshold coding was then applied in dBTrait to establish the time and duration of each vibration event above ambient levels.

Each of the two vibration channels was analyzed individually. The two data sets were then compared to find overlapping events, with non-correlated events excluded. The time difference (leading and lagging) between the first sample of each pass-by on the two sensors was then used to determine the direction of the train (with the leading event indicating direction the train was coming from).

The duration of the coded event can be used to classify the train as either passenger or freight. The exact duration threshold for classification of trains will vary from site to site but in Sydney passenger train sets tend to vary from approximately 80-160m [2], suggesting a passing period of 5-10seconds at 60km/h. Based on site observations passenger trains tend to be less than 20 seconds duration on the Sydney network.

Step 2: Transfer event coding sequence to noise histogram

Within dBTrait the coded event sequence was then applied to the noise data, with the software outputting the L_{AE} and L_{Amax} parameters for each event.

3 Results

3.1 Test location 1

A location for initial system testing was found in St Peters, Sydney. The location was on the southern side of the rail corridor, with four rail lines adjacent, ranging from 8 to 30m from the measurement locations. The site was within a park with relatively low ambient noise levels from street level, but was exposed to regular aircraft overflights. The site location is shown in Figure 1 below.

Figure 1 Site 1 showing vibration sensor (V) and noise logger (N) locations

The measurements were carried out over approximately 40 minutes whilst an operator was in attendance in order to identify each individual pass-by manually, for comparison with derived results.

For comparison with the vibration encoding, the noise data was passed through a simple threshold coding for events greater than 70dB, resulting in 28 events being identified.

A more refined noise coding was also used to exclude any noise events that exceeded 70dB for less than 5 seconds, resulting in 11 events being identified. All processing is shown in Figures 2 to 6.

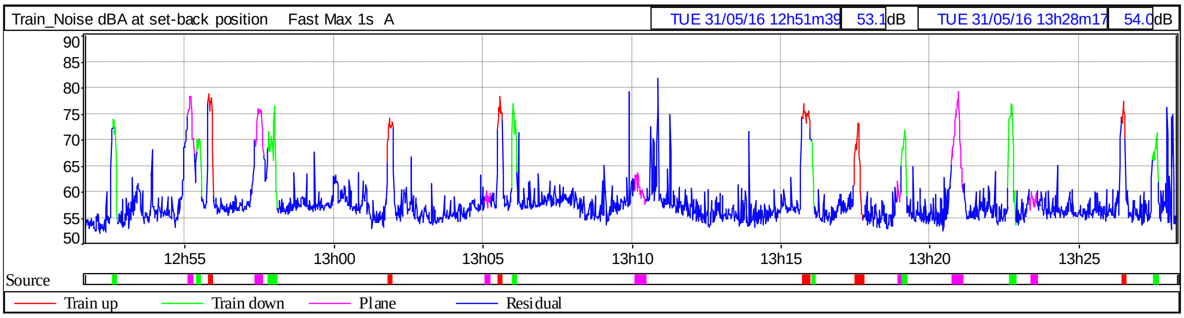

Figure 2 shows events manually encoded by the survey attendee during survey

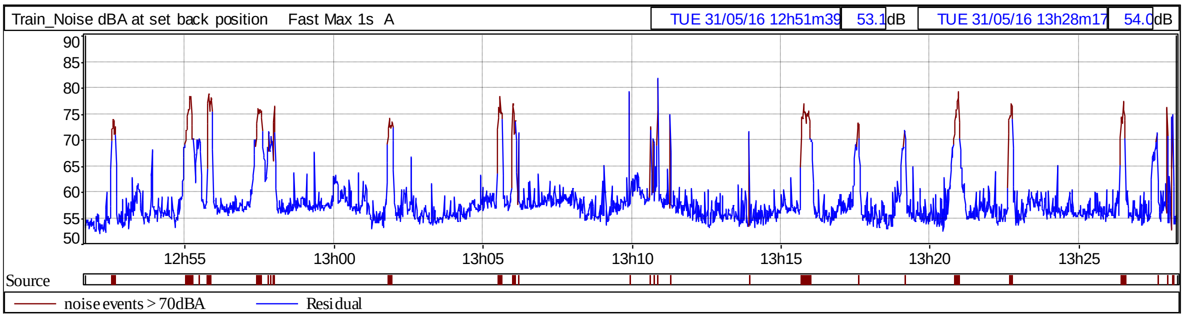

Figure 3 shows post processed events simply exceeding 70dB

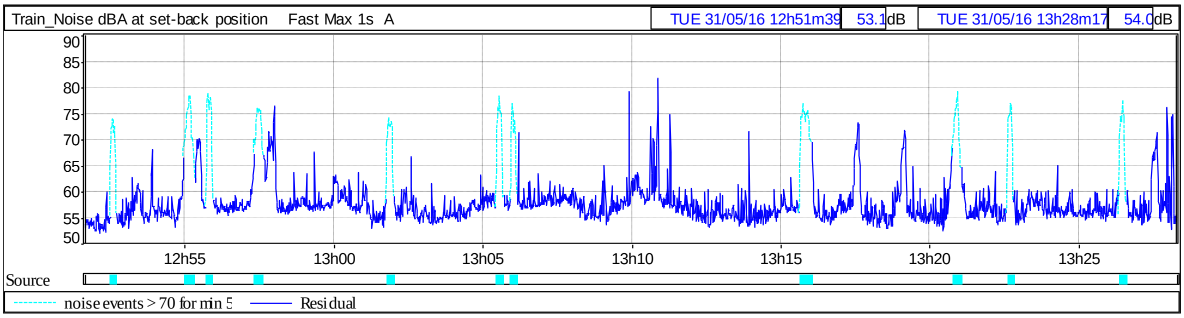

Figure 4 shows post processed events exceeding 70dB for a minimum of 5 seconds

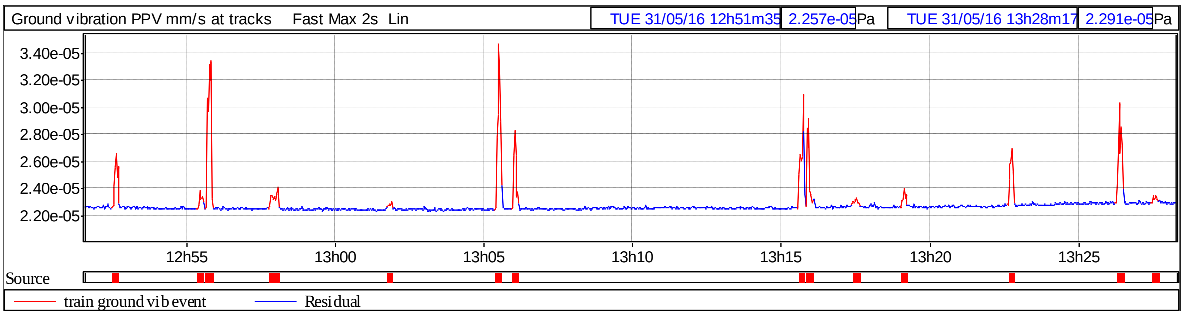

Figure 5 shows post processed vibration triggered events

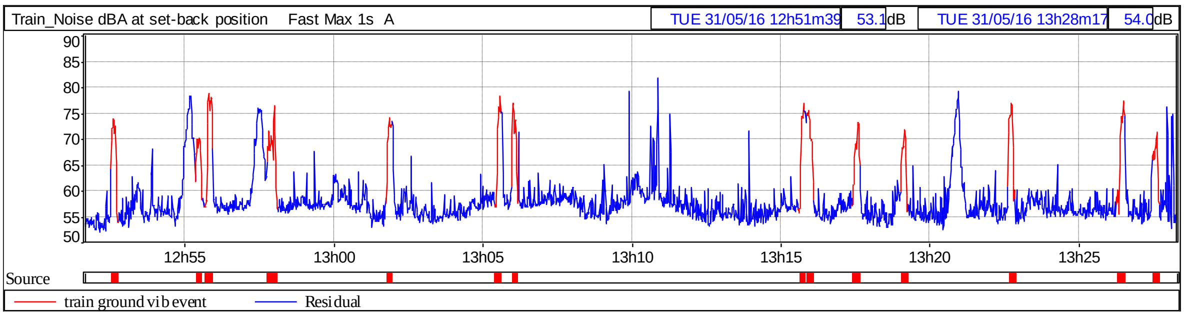

Figure 6 shows post processed vibration triggered events applied to the noise histogram

The results of the different analysis methods are summarised in Table 1 below. Note that the $L_{eq(37min)}$ column provides the L_{eq} contribution over the entire measurement period from only the identified events. The L_{AE} total column provides the sum of all L_{AE} levels from individual events.

Table 1 Summary of processed results from Site 1

Event coding	Number of events	L_{AE} Range (dB)	L_{Amax} range (dB)	L_{AE} total (dB)	$L_{eq(37min)}$ (dB)	Highest L_{Amax} (dB)
Noise threshold coding: >70dB	28	63 - 86	70 - 82	95	62	82
Noise threshold coding: >70dB AND >5sec duration	11	80 - 86	74 - 80	95	62	80
Vibration coding	13	77 - 86	70 - 79	94	61	79
Attended coding (operator observed)	14	70 - 86	69 - 79	93	60	79

Note that whilst the vibration auto-coding only identified 13 of the 14 observed events there was one observed event that included the simultaneous passing of two trains in opposite directions. A review of the histogram from the second vibration sensor showed two events, confirming two trains passing simultaneously in opposite directions.

The simple noise threshold coding identified twice as many noise events than there were train pass-bys. The noise threshold coding with minimum duration excluded most of the spurious events but also failed to identify some rail passbys (which were just below 70dB) whilst not rejecting all aircraft overflights.

From Figures 4 and 5 and Table 1 the vibration coding method identifies levels from all train passbys and excludes extraneous airborne noise sources (in this case predominantly from aircraft overflights). The method accurately identifies L_{AE} and L_{Amax} levels for individual passbys. Importantly the overall L_{AE}/L_{Aeq} levels for the period and highest L_{Amax} levels for the period are more accurately identified, and are lower than the levels taken from noise threshold coding.

3.2 Test location 2

To expand on the results from Test location 1, as well as to capture freight movements, which were not experienced during the measurement period at Test location 1, a second survey was carried out. The site for the second survey was at Asquith, on the northern edge of Sydney. The equipment was deployed for a 24 hour period in order to capture overnight freight operations. The monitor locations were between 12-18m from the two adjacent rail lines. A sub-arterial road was located approximately 4-6m from the monitor locations. The site location is shown in Figure 7 below.

Figure 7 Site 2 showing vibration sensor (V) and noise logger (N) locations

On analysis of the vibration results it was discovered that the vibration levels due to train pass-bys were not sufficiently above the ambient vibration levels to confidently identify the trains. The noise floor of the vibration logger was in the order of 0.3mm/s and at the measurement locations the vibration levels from rail passbys were less than 1mm/s in most instances, giving an insufficient signal to noise ratio.

4 Recommendations

The work at location 2 was important as it showed that the proposed method of using standard vibration loggers deigned for construction work would not be sufficient to confidently deploy the system without carrying out initial baseline monitoring of several pass-bys to ensure sufficient signal to noise. One option to improve the system would be to use higher sensitivity geophones, still measuring PPV. A second option, which would allow much clearer identification of trains, and allow rejection of other ambient vibration sources, would be to monitor vibration in 1/3 octaves and identify trains based on their signature vibration levels in the 30-60Hz range [3].

Identification of train type (passenger verses freight) from vibration levels is another possibility that could be examined with further work, particularly if more sensitive vibration logging equipment was used.

There were some difficulties encountered on site with running 90m of vibration cable, and this would preclude the use of the system on many sites. Use of suitable wireless ground vibration sensors would be beneficial. Use of vibration equipment with a finer sampling resolution (<2 seconds) would also reduce the distance required between vibration sensors in order to identify the lead/lag time between sensors, required to determine train direction.

An added benefit of the vibration sensing system examined in this paper is that it can provide a robust trigger for automated photographic snapshots (or video) of train pass-bys. These could be used to confirm train type, locomotive type/number etc. Several software options exist that could be tailored to automatically extract text (such as locomotive numbers) from the photographs. A further extension of this work could include the use of a video device triggered from each vibration sensor, with the sensors separated by a known distance, for calculation of speed between the two points.

One limitation that does exist in the method described is that the system does not discern if an extraneous noisy event occurs simultaneously with a train pass-by. For example if an aircraft passes at the same time as a train the recorded event will include noise from both the train and the aircraft. Such events may give rise to statistically outlying noise levels in the dataset. If required these outlying data points could be identified and the audio recordings manually reviewed to exclude data points if appropriate.

5 Conclusion

Investigations were undertaken to examine the possibility of using commonly available measurement equipment in order to measure and identify individual rail pass-bys with a high degree of certainty using a highly automated analysis system. The system included an advanced noise logger and a multi-channel vibration logger with two sensors located some distance apart. Vibration data from each site was processed first and threshold coding applied to establish the time and duration of each vibration event. Each of the two vibration channels was analyzed individually and the time difference (leading or lagging) between the first sample of each pass-by on the two sensors was then used to determine the direction of the train. The coded event sequence was then applied to the noise data, with the software outputting the L_{AE} and L_{Amax} parameters for each event.

Provided the vibration recordings had sufficient signal to noise the vibration coding method accurately identified all train passbys and excluded extraneous airborne noise sources (except for extraneous noise that occurred simultaneous to a train pass-by). The method identified L_{AE} and L_{Amax} levels for individual passbys more accurately than threshold coding directly on the noise histogram. Importantly the overall L_{AE}/L_{eq} levels for the period and highest L_{Amax} levels for the period are more accurately identified, and are lower than the levels taken from direct threshold coding of the noise histogram.

References

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2. Sydney Trains. Our Fleet. http://www.sydneytrains.info/about/fleet/ (2016). Accessed 1 June 2016.
3. Nelson, P.M. et al: Transportation Noise Reference Book. Butterworths (1987).