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OBSI MEASUREMENTS FOR THE PURPOSE OF CALIBRATING ROAD SURFACE CORRECTIONS FOR CORTN BASED ROAD MODELS

Tom Cockings[1], Dominic Sburlati[2] and Matthew Harrison[3]

[1]SLR Consulting Australia Pty Ltd
2 Lincoln Street, Lane Cove NSW 2066, Australia
Email: tcockings@slrconsulting.com

[2]SLR Consulting Australia Pty Ltd
2 Lincoln Street, Lane Cove NSW 2066, Australia
Email: dsburlati@slrconsulting.com

[3]SLR Consulting Australia Pty Ltd
2 Lincoln Street, Lane Cove NSW 2066, Australia
Email: mharrison@slrconsulting.com

Abstract

In Australia, road traffic noise models are calibrated against noise measurements made simultaneously with the measurement of meteorological conditions and traffic volume and composition. Road traffic noise influencing factors, such as vehicle speed and traffic composition, are measured in order to remove as much systematic error from the calculation method prior to applying an overall calibration factor to the predictions to account for the difference between the measured and predicted traffic noise level results. Although a road surface correction is generally applied to the predictions to account for quiet road surface treatments, such as Stone Mastic Asphalt (SMA), it is not yet common practice for acoustic consultants to directly quantify one of the key road traffic noise influencing variables: road surface correction. Without direct measurement of the road surface correction, it is often difficult to accurately calibrate road traffic noise models for long alignments, or different carriageways, with different surface types.

SLR Consulting has developed an innovative and practical method whereby acoustic consultants can construct, calibrate, and operate a low-cost road surface correction measurement system using standard acoustic measurement equipment and low-cost 3D printed parts. The proliferation of road surface correction measurement systems will hopefully lead to the standardisation of road surface correction validation, leading to more accurate computer noise modelling across Australia. The ability to accurately measure the road surface correction will minimise one of the largest remaining sources of systematic error in our road noise modelling methodology. This will result in reduced variation between the "calibrated" model and the measured noise level at individual monitoring locations (minimising the standard deviation between predicted and measured noise levels).

1. Introduction

The On-Board Sound Intensity (OBSI) method measures tire-pavement noise at the source using microphones in a sound intensity probe configuration mounted to the outside of a vehicle, near the tire-pavement interface. Measurements are performed while the test vehicle drives along the pavement of interest.

Unlike standard sound pressure level measurements, sound intensity measurements provide both amplitude and an associated direction. Intensity measurements directly quantify acoustic power per unit area (units of Watts/m²). A common technique to measure intensity is to use a probe consisting of two microphones spaced apart by specified distance. Measuring both the amplitude and phase of the sound at the two microphones simultaneously provides directional characteristics of the noise source.

2. Advantages of the OBSI Method

There are many advantages to using intensity measurements over those obtained by sound pressure level measurement. Firstly, since sound intensity measurements directly quantify the sound power of the source, it is better suited to avoiding contamination from other vehicle noise such as exhaust and engine noise. Secondly, sound intensity measurements are less affected by "random" noise such as aerodynamic noise generated by the moving vehicle. Thirdly and most importantly, when compared to alternate methods of measuring tire-pavement noise at source, such as the so called Close Proximity method (CPX) commonly used in Europe in the past, the OBSI method provides better correlation to results obtained by Controlled Passby Measurements (CPM) of a test vehicle equipped with tyres of different designs measured over a variety of test surfaces. Although both methods correlate relatively well with each other generally, some research has shown that the CPX results produces some distortion in the 1/3 octave band spectra in comparison to both the passby and OBSI results [1]. This effect is demonstrated graphically in Figure 1.

Another distinct advantage of the OBSI test methodology is the relative lower equipment expense associated with the OBSI rig compared to that related to the construction of the enclosed trailer required for the CPX measurements. Additionally there are technical issues related to wind noise, test vehicle reflections and noise, and operations in traffic that could lead to undesirable inconsistencies between users and measurement test programs.

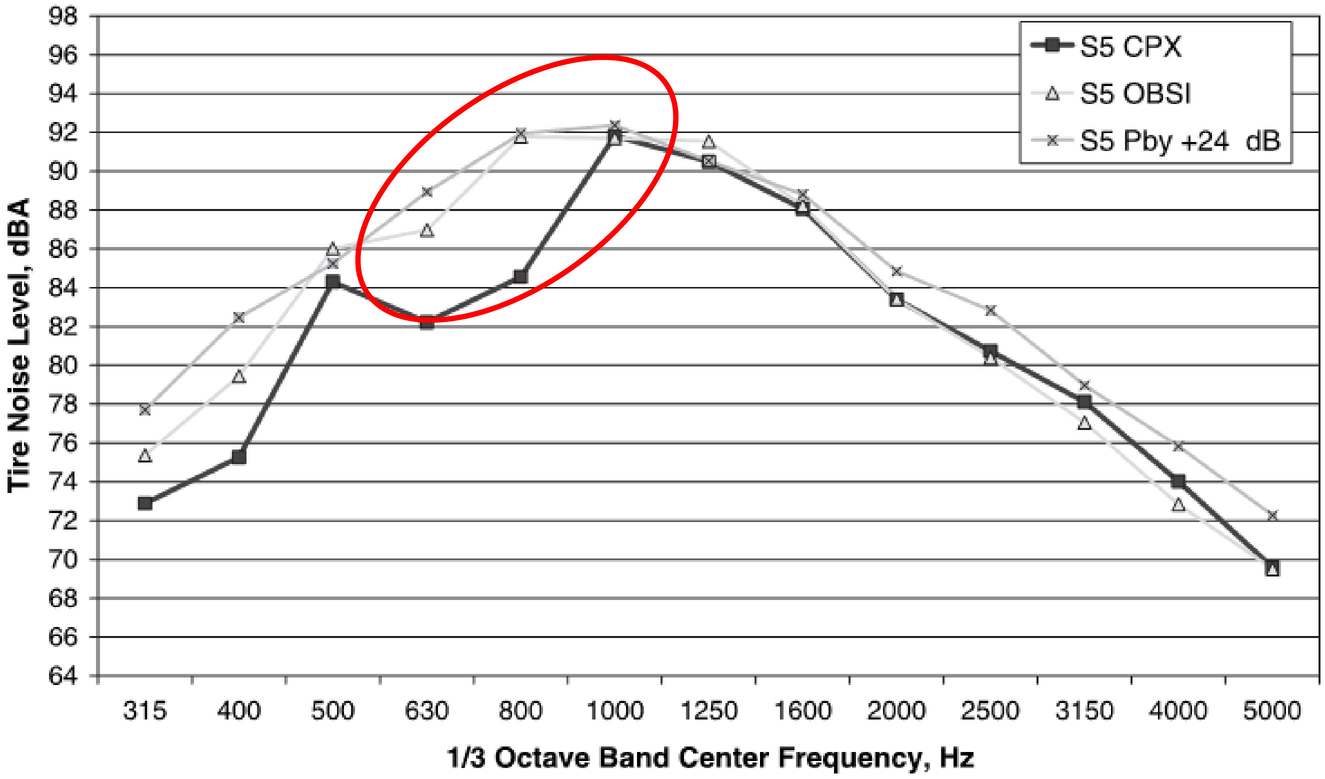

Figure 1. Comparison of spectra for CPX, OBSI and passby levels

3. The Need for Measuring Tire-Pavement Noise

With the recent increase of road infrastructure spending in NSW, communities across the state will be particularly aware of the potential noise impacts associated with road widening and capacity improvement works on their homes. Providing the community with detailed and transparent noise predictions during the EA and community consultation stage of a project will assist in assuring the community that a rigorous and scientific approach to potential noise impacts and mitigation options is being implemented.

Furthermore, tyre/road noise dominates during almost all types of driving for cars, and down to approximately 40 km/h for trucks (vehicles meeting EU requirements) [2]. In order to reliably quantify this noise source, an accurate road surface correction is required. Using accurate road surface corrections, consultants can assure the community that they have specified noise mitigation solutions using a detailed understanding of all applicable variables.

A better understanding of the modelling variables will also provide more reliable predictions, and subsequent noise mitigation specifications. Increased accuracy in noise mitigation specification may reduce the risk associated with noise mitigation specifications, or the risk allowance (safety factor), potentially reducing the cost of the noise mitigation associated with the project.

4. What is the OBSI Method and How Is It Implemented

The OBSI method most commonly used today has principally been developed in the USA by the automotive industry and researched by various road and pavement associations. The standard method uses a dual probe fixture configuration and a Standard Reference Test Tire (in the USA this is described in ASTM F2493) [3]. The National Cooperative Highway Research Program (NCHRP) project 1-44 documents the more critical aspects of the OBSI test protocol. The results of this work were published as NCHRP Report 630 [1]. The OBSI method was first standardized by the American Association of State Highway and Transportation Officials (AASHTO) in 2008. This Standard has undergone annual updates as provisional standard TP 76, “Standard Method of Test for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method.”

The measurement setup used by this Standard specifies that the probes be located close to the leading and trailing edge of the contact patch near the tyre-pavement interface (4″ horizontally from the tire sidewall, 3″ vertically above the pavement and 4.125″ in front and behind the axle centreline). Research has shown that the tire-pavement noise, measured by passby measurements, can be well described by direct measurements made at these two locations. The measurement test setup employed by this Standard is shown in in Figure 2 [4].

5. Factors that need to be Controlled during OBSI Testing

Several factors must be controlled during an OBSI test. The more significant are:

- the test tyre
- vehicle speed (for small variations in speed (i.e. +/- 5 km/hr) a correction factor can be applied during the processing
- vehicle noises (the vehicle must not make any extraneous noises that might contaminate the tire-pavement noise measurements – wheel bearing noise, suspension squeak, brake noise and foreign matter in the tyre tread are the main source of extraneous noise to be carefully avoided).
- Temperature effects (measurements should be conducted in a small temperature window (say +/- 2 degrees C)
- If the air temperature does vary, a correction factor of -0.027 dB/°C for asphalt pavements can be applied to the overall OBSI results [5].

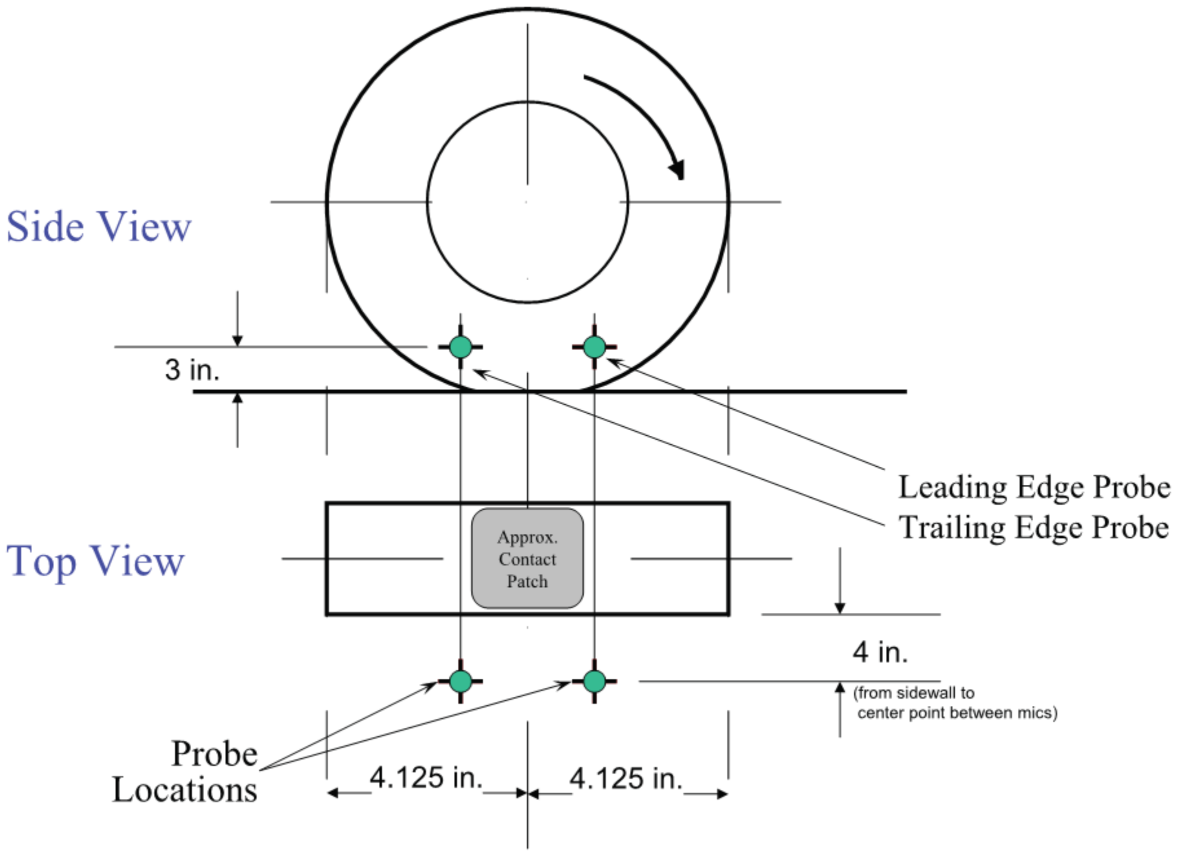

Figure 2. Sound intensity probe positions with respect to the tire-pavement interface

6. SLR OBSI Test Rig and General Measurement Set-up

SLR's approach to road surface correction measurement is an innovative rethink of the OBSI measurement method. The popularisation of the OBSI measurement methodology for the assessment of pavement noise performance has facilitated access to road surface acoustic performance data for universities and other research bodies globally. However, the costs associated with the development and manufacture of these systems leaves it out of the reach of most Australian acoustic consultancies. Using parametric CAD modelling software and low cost 3D printing, SLR Consulting has designed, manufactured and tested prototype OBSI components. Some of the prototype models are shown in Figure 3.

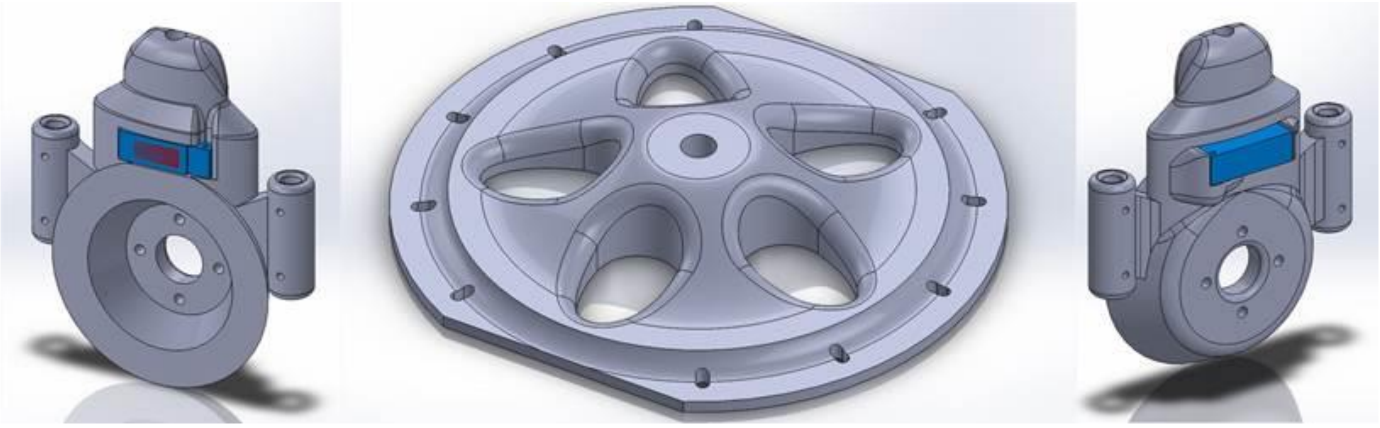

Figure 3. 3-D model of SLR OBSI test componentry

The SLR system exceeds the basic features of a typical OBSI rig. It includes additional sensors and systems, making the measured data far more valuable than a simple intensity probe including:

- High accuracy real time GPS and recording
- High accuracy speed measurement and recording
- Heads up display of high accuracy real time speed data to allow driver to better monitor speed during testing

The images in Figure 4 illustrate at test vehicle which has been fitted with the SLR OBSI system.

Figure 4. Images of a test vehicle fitted with the SLR OBSI system

7. Geo-Referenced OBSI Measurements

The heart of the SLR system uses a side-by-side phase matched microphone pair coupled to a high quality data capture system (any high quality system can be used). The dual microphone data is post processed and combined with the simultaneously captured GPS and speed data via a bespoke computer algorithm. This unique combination of data allows georeferenced mapping of road surface intensity in one thirds octaves (if necessary) along an entire test route.

Figure 5 illustrates a small section of the M4 in Sydney, NSW which has been mapped in this way. The figure shows octave band intensity when the test vehicle travelled at 80 km/h travelling on the eastern carriageway towards Sydney. The intensity information is presented in 1 second averages for each octave between 125 Hz and 4000 Hz to provide a geo-referenced road intensity sonogram.

The broadband intensity time trace is compared to the geo-referenced road intensity sonogram in Figure 6. The relevant section of the intensity time trace is aligned where the desired vehicle test speed (80 km/h) was achieved. The beginning part of the time trace shows where the test vehicle was accelerating to test speed and hence OBSI conditions were not satisfied. This comparison clearly shows individual peaks and longer term changes of intensity in the time trace coincide with the colour peaks / changes in the road intensity sonogram. SLR believe that the information content of this type of road surface mapping will be invaluable for validating road noise models in the near future.

8. Road Surface Corrections

The road surface intensity measurements from the OBSI system can be converted to road surface corrections in a straight forward manner by undertaking testing of a ‘standard’ test surface (typically DGA). These measurements can then be used as a reference intensity level from which to compare all other road surfaces and thereby correction factors.

A test site with a DGA road surface (assumed) was selected at Erskine Park industrial park. A number of controlled drive-bys were undertaken at the test site. The average of this data set was then used to establish a reference intensity level for DGA road surface types. Using this reference level the intensity data from the M4 mapping (from above) was converted to road surface corrections. Figure 7 illustrates mapping of the geo-referenced road surface corrections for the same section of the M4.

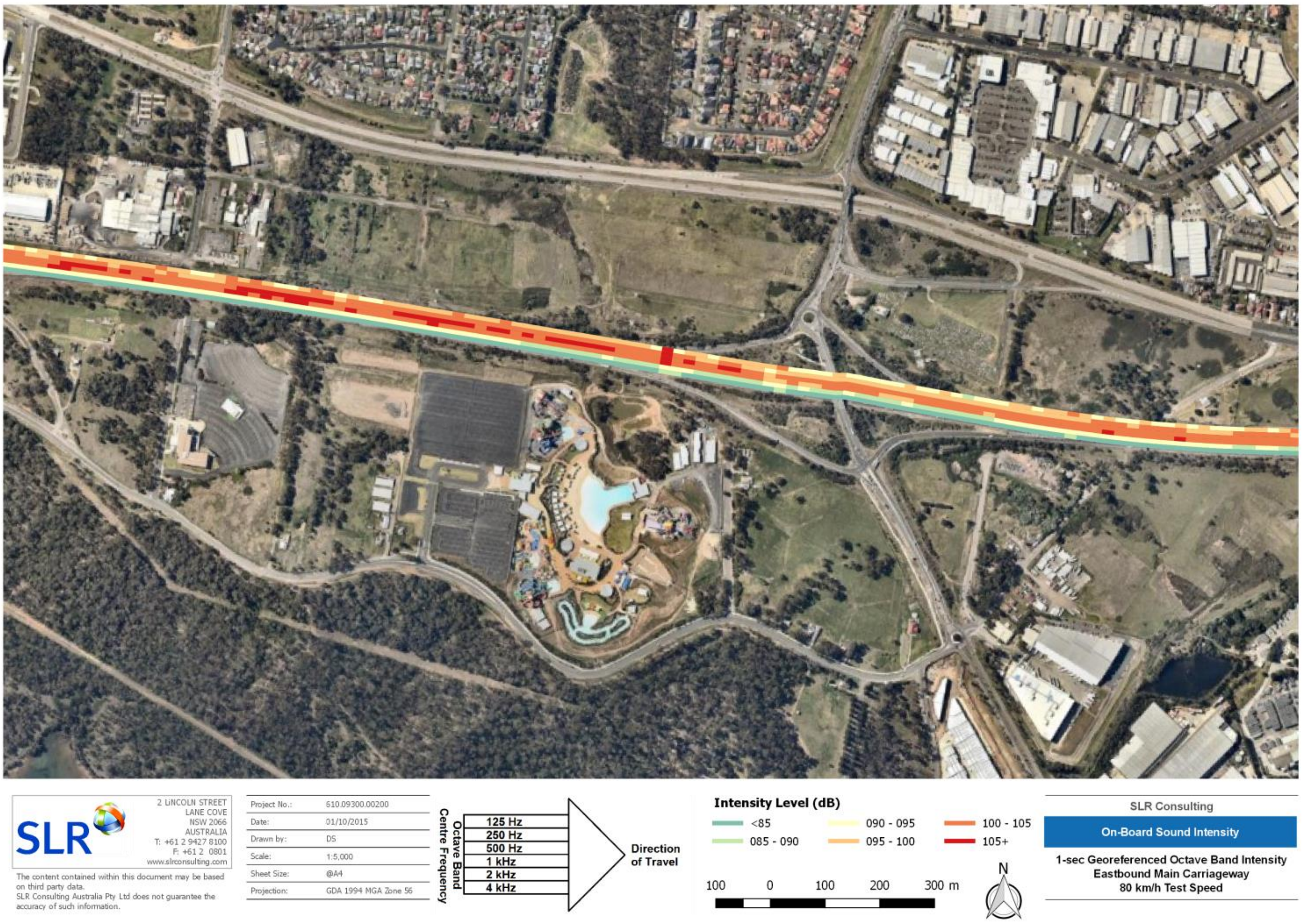

Figure 5. Geo-referenced road intensity sonogram for a small section of the M4, Sydney

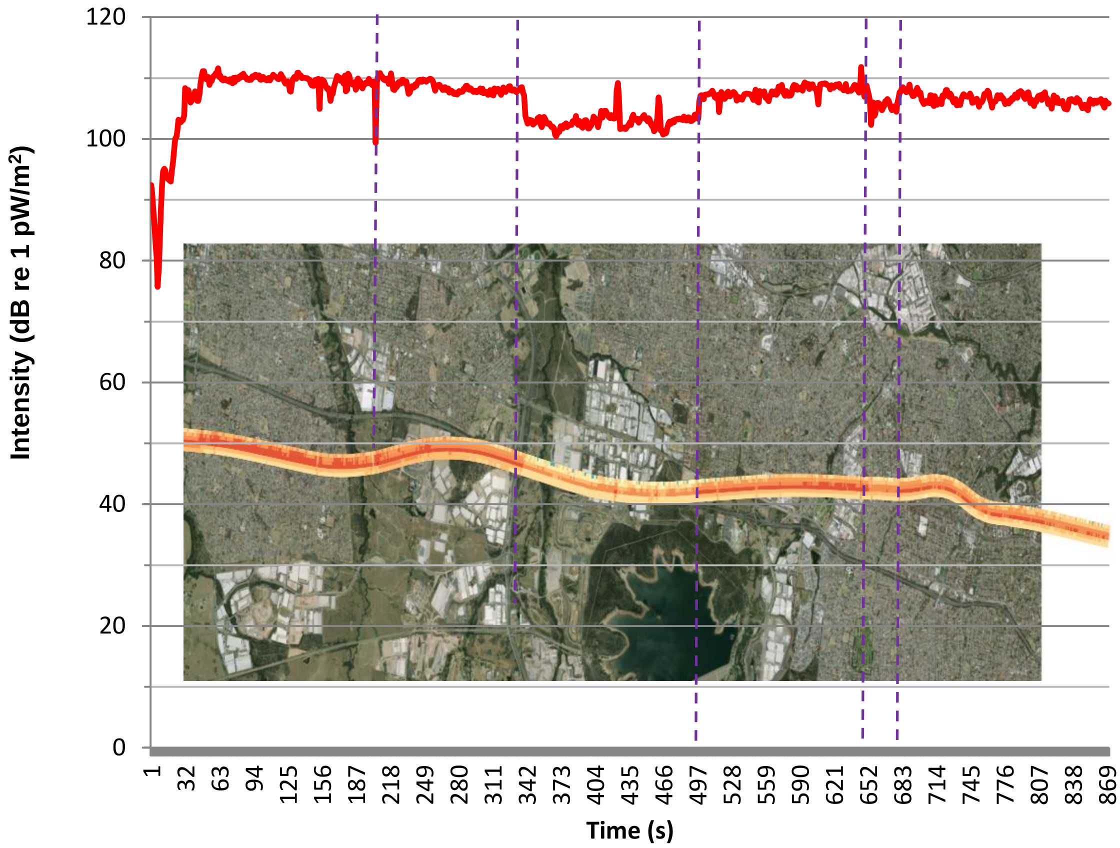

Figure 6. Comparison of the broadband intensity trace against the georeferenced road intensity sonogram for a section of the M4, Sydney

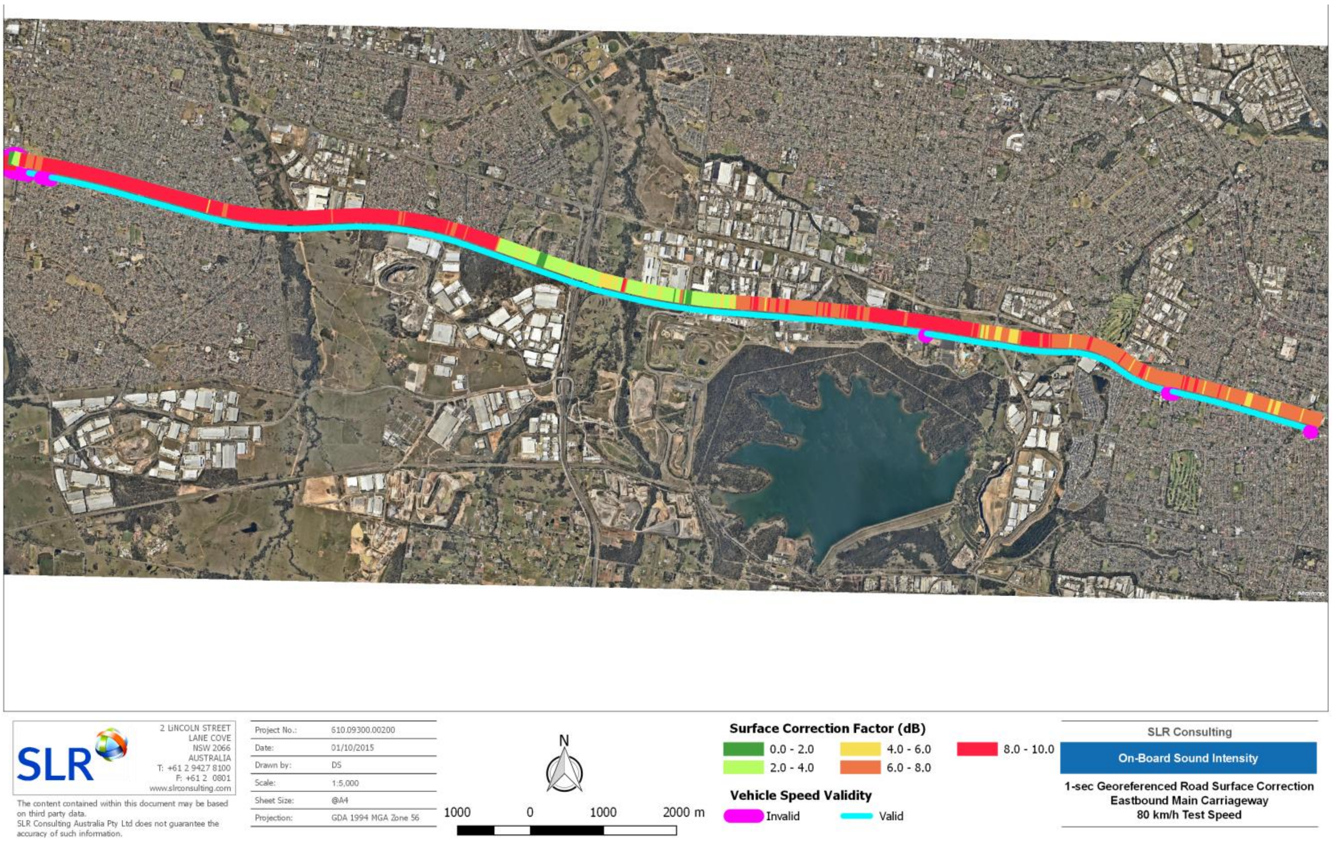

Figure 7. Geo-referenced road surface corrections for a section of the M4, Sydney

For large parts of this map road surface corrections of between 0 to +4 dB are observed. In some cases the road surface corrections are observed to exceed 8 dB relative to the reference surface. This is likely due to this particular section of the M4 having road surface in poor condition with lots of tar joints, broken surface conditions and scars from road works. The reference surface may also have provided a lower DGA correction than is typical (ie less than 0 dB). A more statistically averaged reference level from differing installation examples of DGA would largely correct for this potential source of error.

After more detailed calibration and precise definition of the DGA reference level the output from this system is likely to provide unprecedented levels of detail for the surface corrections which can be used directly in 3D noise models or for reference by road authorities to determine which sections of road need repair due to degraded acoustic properties of the surface.

9. Conclusions

The information presented in this paper for the SLR OBSI system was intended as a proof of concept for the low cost, 3D printed, OBSI mechanical design and in-house software to measure and process sensors for intensity, GPS and speed. Based on this proof of concept we have been able to show that detailed road surface intensity sonograms for large sections of road can be generated. This information can then be converted to road surface corrections with the use of a reference level for a specified road surface – nominally DGA with a road surface correction of 0 dB. Based on this proof of concept the following future steps are envisioned:

- Refine the algorithms for real-time processing with heads-up display
- Undertake OBSI measurements on a statistically relevant sample of DGA surface types in conjunction with the RMS Controlled pass-by methodology to define the reference intensity level - from which all road surface corrections can be derived.
- Existing road validation - Undertake road surface correction mapping on an existing, completed road project which already has a 3D noise model. Compare the noise level predictions from the 3D noise model, created with the traditional road surface corrections, to a model which has the directly measured OBSI surface corrections. These models should then be compared to actual noise measurements to identify the differences between the models and the measurements.
- Undertake road surface correction measurements for 100s or 1000s of kms of road and compare them against the age and nominal surface correction for that road type to provide a compelling statistically relevant data set for use in future road noise models and as an additional tool for planning road maintenance.

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