# The practicality of using a smart phone 'App' as an SLM and personal noise exposure meter (SoundLog)

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## ABSTRACT
When technical users realised that the modern 'smart' phone was in fact a sophisticated, pocket-computer, applications rapidly developed for uses other than the simple telephone phone call. Applications (apps) range from simple games to sophisticated scientific purposes. With the inclusion of an inbuilt microphone and an easily readable display one of the possible uses as a sound level meter was obvious. This can easily extended into personal noise dosimetry. But how practical and useful is smart 'phone app as a dosimeter? The National Acoustic Laboratories (NAL) has addressed this in a practical way by developing a noise dosimeter App. This paper focusses on establishing its utility by verifying dosimetry results for precision and accuracy, and for use as a hearing health education tool.

## 1. INTRODUCTION
With the introduction of numerous sound level meter Apps for the smart 'phones available for direct use by consumers NAL made a deliberate decision to develop their own dedicated App rather than attempt to review and evaluate existing Apps as many other organizations have done previously (Keen et al: 2013; Kardos & Shaw: 2014; Nast et al: 2014; Staab: 2016). No apology is made for this. Rather as NAL was interested in developing a research and educational tool it was considered to be more practical to develop, in-house, a combined sound level meter (SLM) – personal sound exposure meter (PSEM)/dosimeter App for which the parameters were clearly known and defined as required by recognized measurement procedures and standards (Standards Australia 2005; NOHSC: 2000). Hence there is no attempt here to evaluate or otherwise review and critique existing Apps.

## 2. TEST METHODS

### 2.1 Platform selection
The first decision was to choose an appropriate platform on which to develop the tool. An informal survey of smart 'phones available around the NAL premises revealed roughly an equal mix of both Android and iPhone (Apple®) devices. A practical discrimination task was arranged where the comparative performance of the respective microphones mounted within the devices could be undertaken. On each of the 'phones a recording was made using the recording application 'PCM Recorder Lite' which has both Android and Apple® versions. The recorded output RMS voltage levels were then compared from their respective WAV files for precision and consistency. At this stage 'trueness' was not considered as this could be accounted for through a future calibration process.

The Apple® devices were found to match the criteria with much less variation than the Android devices. The Apple® devices were adopted for the development platform.

### 2.2 Platform development
The software for the SLM/dosimeter App was developed by the second author (DZ) proceeding through a number of iterative development stages before the verification process described below.

### 2.3 Platform verification - Laboratory based
Initial testing comprised the parallel use of the App, installed in an iPhone 5 (OS 7.1.1) in a laboratory setting with low background noise (< 30 dB) positioned before a good quality, Tanoy V8, loud speaker. Testing consisted of the comparison of the indicated output level ($L_{Aeq}$) on the iPhone to an adjacent, calibrated, precision, integrating B&K model 2250 SLM, which conforms with IEC61672-1:2013 Class 1 and was under current calibration.

### 2.4 Platform verification – Field based

In field testing the aim was to simulate measurements that would be normally carried out by someone such as an Occupational Hygienist or other similar Workplace Health and Safety (WHS) professional. These measurements would normally be carried out using an SLM or, for longer term measurements, a PSEM or dosimeter. Both the SLM and dosimeter will provide the $L_{Aeq}$ calculated over the sample time. In the case of the dosimeter the $L_{Aeq}$ in combination with the sample time would be used to calculate the noise exposure ($L_{Aeq,8h}$). For the exercise undertaken here the $L_{Aeq}$ values were compared directly.

In the field it could be expected that both an SLM or dosimeter could be used and, for the purposes of WHS, these would be considered to be equally valid. In the current context when undertaking field based comparisons of long durations (up to around 7 h 30 min) a dosimeter was used while for shorter duration measurements (up to about 30 min) the SLM was used. Long duration field measurements were carried out at a variety of mining operations, both underground and open cut, in New South Wales, Central Queensland and Northern Territory, on an iPhone 6s and dosimeter in close proximity. As a result all non-iPhone measurements are treated equally and are plotted on graphs as such.

## 3. RESULTS AND DISCUSSION

### 3.1 Laboratory verification

Figure 1 shows the distribution of output signal WAV files recorded on the sampled smart 'phones. As can be seen Apple® iPhones model 4 and 5 provide much more consistent distributions compared to various Android counterparts (HTC Desire, Samsung S3, Google Nexus S, Samsung GT-19100T, Samsung Google Nexus, Sony Xperia). An important feature of good measurement are accuracy and trueness. The better grouping of the Apple® device microphones demonstrates they have a much more consistent performance and repeatability between microphones, implying better accuracy. The second feature, trueness, can be accounted for during a calibration process.

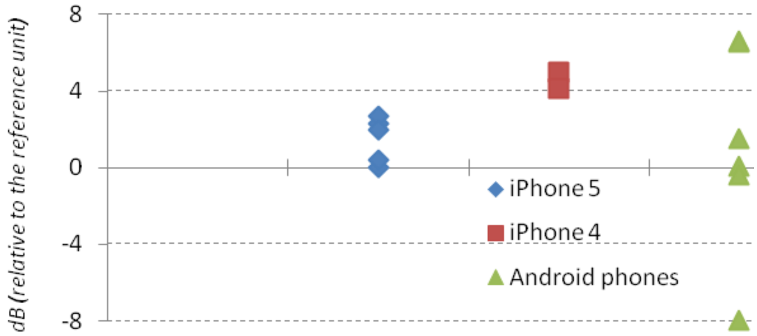



Figure 1: Comparative distribution of WAV file output $L_{Aeq}$ for various smartphone platforms.

Figure 2 graphs the measured $L_{Aeq}$ from the App compared to the B&K 2250 SLM over a range of 40 to 120 dB for a 1 kHz pure tone sine wave signal. The curve of 'best fit' shows there is an excellent linear relationship between the B&K 2250 SLM and the App response ($R^2$ = 0.99).

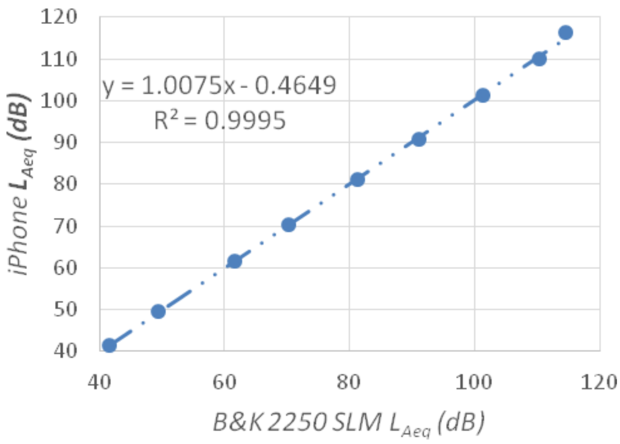



Figure 2: Relation of $L_{Aeq}$ measured on App compared to B&K 2250 for a 1 kHz signal over the range 40 to 120 dB.

As the ‘speech region’, around 4 kHz, of the acoustic spectrum is considered to be an important area when considering noise and its relation to human effects, the response of the App microphone with respect to a 4 kHz signal was checked. The outcome is presented in Figure 3. This shows a satisfactory linear correlation over the main range of interest of 80 to 120 dB.

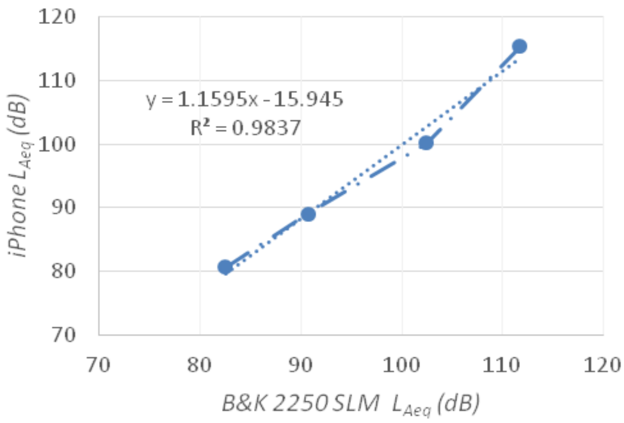



Figure 3: Relation of $L_{Aeq}$ measured on App compared to B&K 2250 for a 4 kHz signal over the range 80 to 120 dB.

Figure 4 compares $L_{Aeq}$ results for a pink noise test signal. Again there is a satisfactory correlation of $R^2$ = 0.98 over the range 40 to 120 dB.

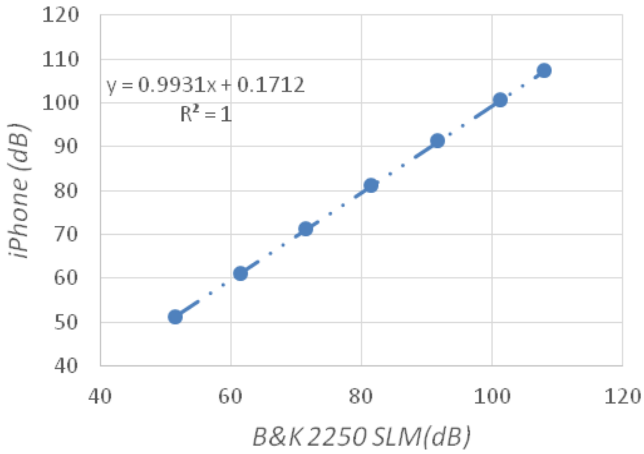



Figure 4: Relation of $L_{Aeq}$ measured on App compared to B&K 2250 for a pink noise signal over the range 40 to 120 dB.

### 3.2 Field verification

The 72 field measurements of $L_{Aeq}$ taken from the App output are compared to the combined results from the B&K 2250 SLM used for short time sample measurements and the two CEL model 350 and 35X dosimeters used for the longer term, dosimetry oriented measurements. The resulting correlation is good at $R^2 = 0.97$.

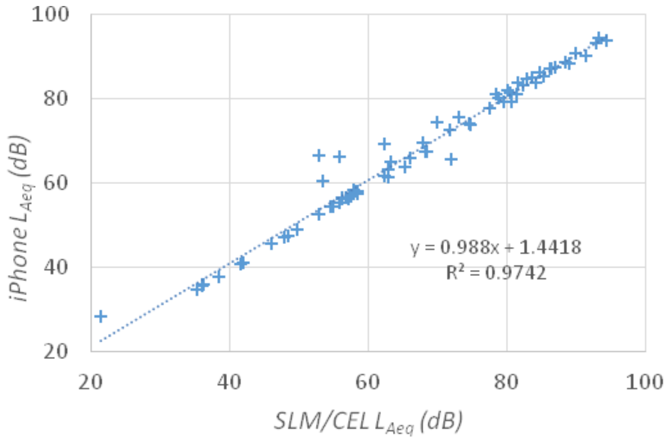



Figure 5: Comparison of field $L_{Aeq}$ measurements from App and a combination of B&K 2250 and CEL model 350 and 35X dosimeters from 20 to 100 dB.

On detailed examination of the 'outlying' data points provide reasons for their departure from the 'line of best fit'. The low $L_{Aeq}$ data point (21.3, 28.3) was taken in a low noise, anechoic room where the Apple® microphone would no normally be expected to operate as its primary function is to operate at or above conversation voice levels. Other measurements in the 60 to 70 dB range lying away from the line were taken in locations where there was wind noise that affected microphone performance resulting in a bias in the direction of the data point(s) reflected in the direction of the outliers above the line of best fit. Such areas were external building balconies, walkways, and road traffic and rail station area. Overall the correlation is very good. The SLM/CEL microphones were protected by a microphone wind-shield as routine best practice.

Figure 6 presents results for $L_{Cpeak}$ measurements between those from the {B&K 2250 SLM and two CEL model 350 and 35X dosimeters} and the equivalent iPhone results. It is readily observable that the Apple® microphone appears to exhibit a saturation effect as demonstrated by a second degree curve of best fit ($R^2 = 0.91$). The linear best fit, while having a higher correlation ($R^2 = 0.94$) does not seem to intuitively be a better representation of reality unlike the $L_{Aeq}$ results presented above, where linear correlation in the range up to 120 dB (A-weighted) was very good.

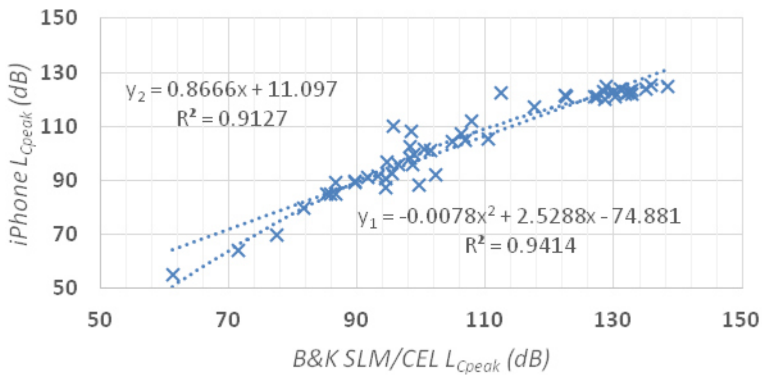
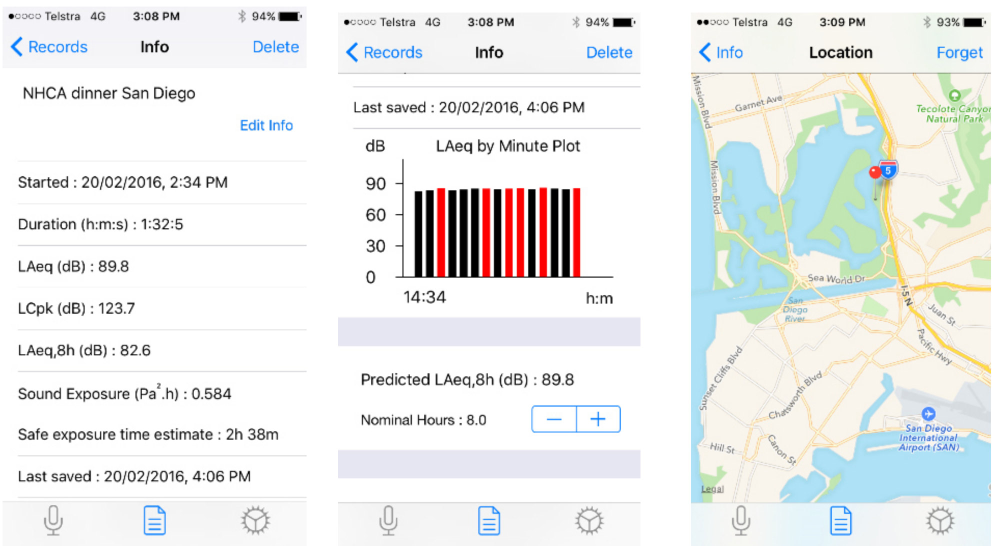



Figure 6: Comparison of field $L_{Cpeak}$ measurements from App and a combination of B&K 2250 and CEL model 350 and 35X dosimeters from 50 to 150 dB.

A closer examination of peak measurement responses could be carried out. However, in the wider context where the aim is to produce an App suitable for application to continuous noise exposure situations to which users may typically be exposed, it does not currently seem productive. Peak values must be considered unreliable and indicative only. They may require further investigation.

Practically the App output is illustrated by the photos in Figure 1 – taken in 'screen shot' mode. The output provides the measurement start, in real time, and sample time duration. A graph provides a series of the one minute $L_{Aeq}$ values for the entire recording period, in 'red' if the value is greater than or equal to 85 dB and black if less than 85 dB. Included are the maximum peak value ($L_{Cpeak}$) measured during the sampling period; the calculated exposure $L_{Aeq,8h}$ in dB and in Pascal squared hours ($Pa^2h$); and of the "Safe exposure time estimate" under the assumption that this was a measurement of the typical exposure. Also included as a retainable option is a map with the location of the measurement site, if the measurement site was fixed, such as a fixed work site, or if the measurement site is mobile, the location of the last one minute measurement interval. Options are also available for measurement details and any appropriate comments.




Picture 1: Screen shots of the App output, measurements, graph and location.

## 4. GENERAL DISCUSSION

Under laboratory conditions with continuous noise there was excellent agreement between measurements taken with the App and those carried out in parallel with a Class 1 integrating SLM. For field measurements the significant discrepancies occurred when there was opportunity for 'wind noise' to cause disturbance with the microphone function at locations with road or rail traffic movement. Smart 'phone platforms are not necessarily required to operate precisely under these conditions without a wind-screen as would be normally used as standard practice on an SLM.

For impulse noise measurement the results show obvious limitations in the performance of the App. Mobile 'phone microphones are not expected to be able to accommodate sudden transients in normal use. In fact it is possible that the phone's hardware/software combination may be specifically designed to smooth out such peaks and irregularities. As a general comment using dosimeters for measuring peak results can be uncertain as 'bumping or fooling around with the microphone' can never be excluded with an unattended instrument. Occupational hygienists and others using dosimetry will regularly check peak levels with an SLM. However, the correlation ($R^2$ = 0.94) with the measurement microphone appears reasonable until a saturation effect begins above 110 dB. As the App was intended to consider continuous noise this is not a significant limit to its use.

As a noise exposure risk management tool, the App provides sufficient information for the user to judge the relative level of risk by supplying noise level ($L_{Aeq}$) in dB, exposure in both dB ($L_{Aeq,8h}$) and a linear measure ($E_{A,T}$) in $Pa^2h$. It is indeed fortunate that the accepted daily Exposure Standard of 85 dB is 1.01 $Pa^2h$. Thus $E_{A,T}$ is easily interpreted as a level of 1 $Pa^2h$ being 'acceptable' for daily exposure to within 1% accuracy. An exposure greater than 1 $Pa^2h$ can be interpreted as requiring preventative action in relation as to how much greater the exposure is. The App provides an estimate of the recommended exposure time required to remain at less than the Standard on the assumption that the nature of the exposure does not significantly change.

There are obvious limitations in the use of this App as a replacement for the regulatory requirements of various WHS jurisdictions. However, there is no doubt that what accuracy is lost through the use of a smartphone App is gained through the convenience of use applied to personal situations and as a noise exposure risk management/assessment tool. It is a true 'personal' noise exposure meter and its use can not only assist with the management of noise exposure but also as an awareness raising tool.

More importantly perhaps, is that this SoundLog App provides non-technical persons access to a reliable means of assessing noise exposure risk without having to resort to specialist assistance. For small businesses the effort and cost of accessing professional WHS assistance is a significant deterrent. For the individual who may be aware that exposure to loud noise may pose a risk to their future hearing health the App functions as an awareness raising and discrete assessment tool.

Related follow-up information is provided through NAL's 'Know Your Noise' website (http://knowyournoise.nal.gov.au/), the NOISE (http://noisedb.nal.gov.au/) database (Beach et al: 2013) and the Apple® App Store (Sound Log).

## 5. CONCLUSIONS

For 'General' and 'Preliminary assessments', as described by the Australian/New Zealand Standard (Standards Australia: 2005), this App should be able to perform as a satisfactory assessment tool within the acceptable limits of accuracy of risk management practice as applicable for WHS. While it cannot replace a 'Detailed assessment' it can act as a personal exposure assessment tool and as an educational and awareness raising opportunity. It is also a useful tool for individual use in assessing possible hazardous listening environments.

## REFERENCES

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