# Instrumentation corner

## John Shelton. Statistics in third octaves: La Belle $L_n$?

In the May/June issue of Acoustics Bulletin, Martin Williams wrote a nice summary article on the calculation and possible pitfalls of statistical values of noise levels, otherwise known as $L_n$'s.

The vast majority of statistical calculations refer to the A-weighted sound pressure levels, and the use of $L_{A90}$ as a descriptor of background noise level is almost universal and is written into several standard and codes of practice.

However, in recent years, the concept of spectral $L_n$'s has emerged, either through a genuine desire to calculate them, of simply because sound level meter manufacturers find a new think to calculate, hence differentiating their products from the competition — the jury is still out on which! Indeed, I remember this calculation possibility finding its was into one of our newsletters as long ago as 1994, but it is only recently that it has become a feature of modern sound analysers.

So what is a spectral $L_n$? Well, it is to be hoped that we are all familiar with what is meant by $L_{A90}$ - the A-weighted sound pressure level exceeded for 90% of the time. If we now consider our real-time spectrum analyser as a series of band-limited sound level meter (31 of them from 20Hz to 20kHz!) eacj calculating a value of Ln, for each third-octave band, we can now think in terms of an $L_n$ spectrum. An obvious extrapolation from equating $L_{A90}$ with background noise level would therefore be to equate an $L_{90}$ spectrum to the background spectrum.

So is this a reasonable assumption? After all, I have regularly seen statements to that effect in environmental noise reports. Apart from the issues highlighted in Martin's article, which still apply to spectral data, we first have to understand what is actually being calculated.

An example of an $L_n$ spectrum is shown in Figure 1. This is ordinary office noise, and shows a typical $L_{eq}$ spectrum and the associated $L_{90}$ spectrum, measured with a modern sound level meter capable of doing this kind of measurement with a couple of button pushes.

Logically, you can see that the $L_{90}$ is lower than the $L_{eq}$ and intuitively

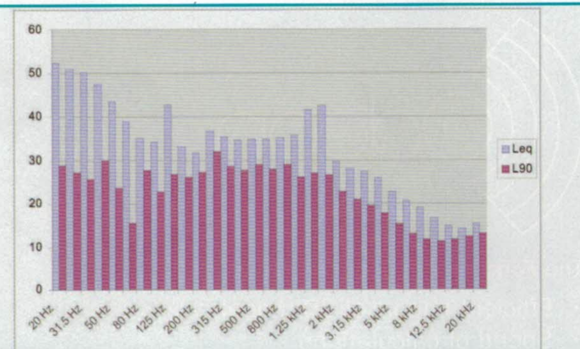


Figure 1

*$L_n$ spectrum for office noise*

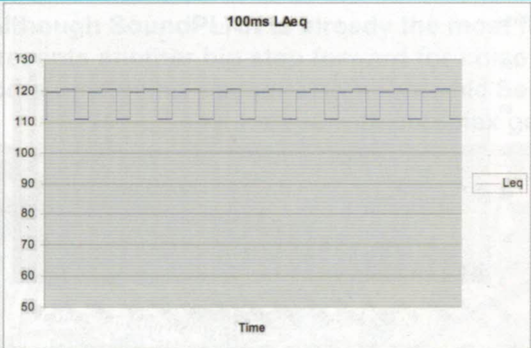


Figure 2

*Three bursts of sine wave repeated over 30 minutes*

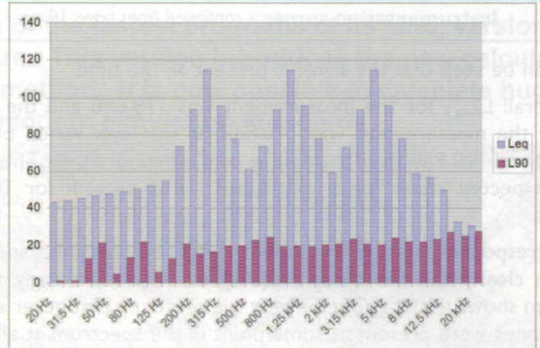


Figure 3

*'Spectra' for the measurements in Figure 2*

it seems reasonable to think of the $L_{90}$ spectrum as the spectrum exceed for 90% of the time - the 'background spectrum'. So what is the problem? If we look at the true $L_{A90}$ as displayed on the sound level meter, we see a value of 36.9dB, and if we add up the energy in the $L_{90}$ spectrum, we get a total $L_{A90}$ of 36.3dB, which is certainly within the realms of calculation error, and the shape of the spectrum looks credible for the type of environment.

But the interesting thing about this $L_n$ spectrum is that it is actually a spectrum which *never existed*! The spectrum that is displayed is simply a construct from the Ln calculated in each of the 31 individual band-limited sound level meters. Each third-octave value is completely independent of the next.

To illustrate the dangers in the 'background spectrum' assumption, two signals were constructed to see what kind of error is possible in this type of measurement. Running these signals through a sound level analyser yields some interesting results. Both signals would be extremely unpleasant to listen to, but in neither case did the 'background spectrum' express this.

The first signal was three bursts of a sine wave, at frequencies of 250Hz, 1kHz and 4kHz. Each frequency lasted one minute before switching to the next frequency, a duty cycle of 33%. The time history of $L_{Aeq,100ms}$ over a 30-minute period is shown in Figure 2. The level of each frequency changes slightly as a function of the A-weighting curve,

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but it can be seen that the signal is present all the time.

The overall $L_{Aeq,T}$ for the measurement was 118.6dB and the overall $L_{A90}$ for the measurement was 110.8dB, as the level varied between 119.6dB and 110.9dB over the course of the measurement. This would be an expected result for a continuous signal, present for 100% of the time.

The corresponding spectra are shown in Figure 3. In the $L_{eq}$ spectrum, you can clearly see the three frequencies, but interestingly, the $L_{90}$ spectrum shows nothing. Of course, it is a spectrum that never existed, as the tones were present at some point in the spectrum at all times, but there was only signal in each of the third octave bands for 33% of the time.

Although this scenario is artificial, imagine if someone was installing a fan with a strong tonal component, and a noise limit was applied in terms of an $L_{90}$ spectrum. All they would have to do would be to make sure that the frequency of the tonal component changed regularly with time, and the tone would not show up at all!

Another example uses a broad-band noise signal consisting of two signals, both pink noise, one high-pass filtered at 1kHz, and the other low-pass filtered at 1kHz, as shown in Figure 4. A signal was present at all times, each noise with a duty cycle of 50%. The $L_{Aeq,T}$ for the measurement was 107dB and the $L_{A90}$ was 101.1dB, again not surprising for a continuous signal. The resulting spectra for $L_{eq}$ and $L_{90}$ are shown in Figure 5.

As expected, the $L_{eq}$ spectrum is flat, as it consists of an average of both the high-pass and low-pass filtered signal. The $L_{90}$ spectrum however is completely different, even implying a tonal component in the 'background' noise with a peak at 1kHz. Again, it is a spectrum which never existed. In this case, the value of $L_{A90}$ calculated from the spectral values is closer to reality, with a level of 92.7dB, but it is still lower than the true value.

So what are we to learn from this? By taking two different signals, we can fool our statistical spectrum analyser into giving very misleading results. Although the signals used are unlikely to be experienced in environmental noise (we hope!) they should make us think about what we are really measuring or calculating, and to treat spectral Ln values with caution.

Two simple rules of thumb emerge.

1 Never calculate an overall A-weighted $L_n$ from the $L_n$ spectrum

2 Never assume an $L_{90}$ spectrum has any relation to a 'background noise' spectrum unless you know quite a bit about the type of signal you are measuring.

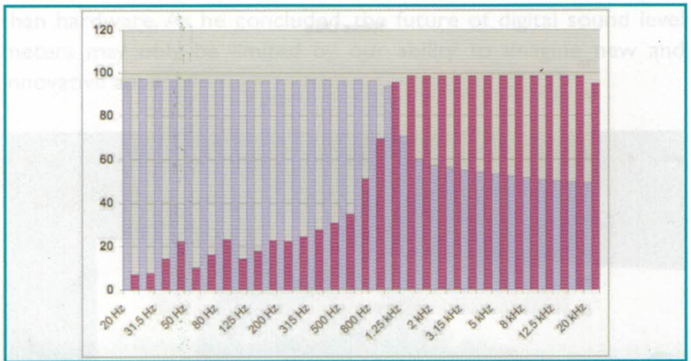


**Figure 4**

*Two pink noise signals, 1kHz high-pass and 1kHz low-pass filtered*

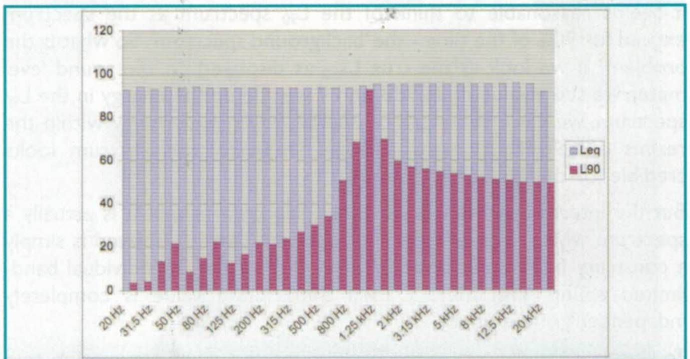


**Figure 5**

*Figure 3: 'Spectra' for the measurements in Figure 4*

It could be useful, for example, to get an idea of an underlying spectrum when your measurements are polluted by occasional noises - such as birdsong, the bane of A-weighted $L_{eq}$ measurement.

So, next time you see a new feature in your new sound level meter, always remember the golden rule: don't measure and report a result just because you can!

These and other issues are regularly discussed in the IOA's Measurement and Instrumentation group, at our one-day meetings held over the year.