HDM® Technical Document

This document provides all the information you need on LimitEar's Hearing Dose Management® (HDM®) technology: from the regulations and importance of noise measurement, to integration with other devices and our algorithm.

The Law

The European Physical Agents (Noise) Directive, which applies to all 27 member states of the EU, was implemented as The Control of Noise at Work Regulations 2005 in the UK. The aim is to ensure that all workers' hearing is protected from excessive noise at their place of work. Most of the world follows similar legislation. However, in the USA things are done a little differently, with the Occupational Noise Exposure Standard – a regulation from the Occupational Health and Safety Administration (OHSA). Throughout this document we will refer to the European regulations, although most of the principles are the same the world over.

Noise Measurement

Noise intensity is the amount of sound energy being transmitted to the ear by vibrating air particles. It is measured in decibels (dB) for both average and peak noise values at work. As you might imagine, hearing loss is more likely at some frequencies than others. When measuring noise at work, emphasis is normally given to mid-high range frequencies using an 'A' weighted scale referred to as dB(A). For peak noise levels a different 'C' weighted scale is used, referred to as dB(C); this reflects the different mechanism of hearing loss from instantaneous events. The law specifies two Exposure Action Values (EAVs) at which action is necessary and Exposure Limit Values (ELVs) which must not be exceeded. All levels relate to an average exposure over an eight-hour period.

- The first action level of 80dBA gives employees the right to ask for hearing protection, which the employer must provide. Employers must assess noise levels and provide adequate information and training.
- The second action level of 85dBA requires employers to provide hearing protection, which the employee must use (87dBA is the level which should not be exceeded when the hearing protection is in use).
- There are also three levels for peak exposure. The first and second action levels are 135dBC and 137dBC respectively. The maximum peak level that must not be exceeded is 140dBC. Exposures above these levels will almost certainly result in hearing loss.

According to the Health and Safety Executive, examples of typical noise levels include:

- Normal conversation 50–60 dB(A)
- A loud radio 65–75 dB(A)
- Noise that is intrusive but conversation is possible 80dB(A)
- Need to shout to converse with someone 2m away 85dB(A)
- Need to shout to converse with someone 1m away 90dB(A)
- A heavy lorry about seven metres away 95–100 dB(A)
- A jet aircraft taking off 25 metres away 140 dB(A)

While the first three examples are clearly not hazardous, the next three could become so if the individual is exposed for a prolonged period of time. Of course, the final example is highly hazardous.

A small increase in the decibel scale corresponds to a large increase in intensity. A rise of 10dB is a tenfold increase in sound intensity; an increase of 3dB is a doubling of intensity. However, because of the way we perceive sound intensity, 3dB increase is subjectively only slightly louder. Although 83dB may only seem to be slightly louder then 80dB it is in fact twice as intense and potentially much more damaging. For the same noise exposure level, the exposure period needs to be halved. Under OHSA regulations, the defined relationship between Permissible Exposure Limit (PEL) and exposure period is known as the exchange rate; although elsewhere it is a 3dB increase in level that requires a halving of exposure time, under OHSA the exchange rate is 5dB.

Noise Peaks and Averages

Noise levels cover a vast range of intensity, 90dB from the HSE examples but in extreme 140dB (10-million-fold) between the lowest threshold of hearing and highest regulatory peak limit. Noise exposure regulations recognise this and allow for a mix of high and low-level exposure within the overall exposure limit.

Diagram 1 (below) shows sound intensities (below) and 3 different averages (above) for a short period at the start of a BBC Radio 4 news broadcast. The pips can be clearly recognised here. What is significant is the relationship between instantaneous peaks in the lower trace (yellow) which the ear is being exposed to, and the averages taken over different time periods. Light blue represents the average over a period of 1 second; it is clearly less than the peak intensity, but still follows the short-term signal fluctuations. Dark blue uses a 10 second average, features lower levels than the shorter average and still shows some following of the general signal level. Green has a 60 second average; this takes time to build up and is relatively insensitive to short-term fluctuations.

The significance for hearing dose management is that damage and the regulated limits are for long periods of time, such as 8 hours in a day. Normal fluctuations over periods of a few seconds have very little effect on the daily dose. High short-term levels can be safely experienced As long as the averaged dose is effectively managed. This is where HDM Pro® pushes back the boundaries of what can be achieved with other so-called solutions.

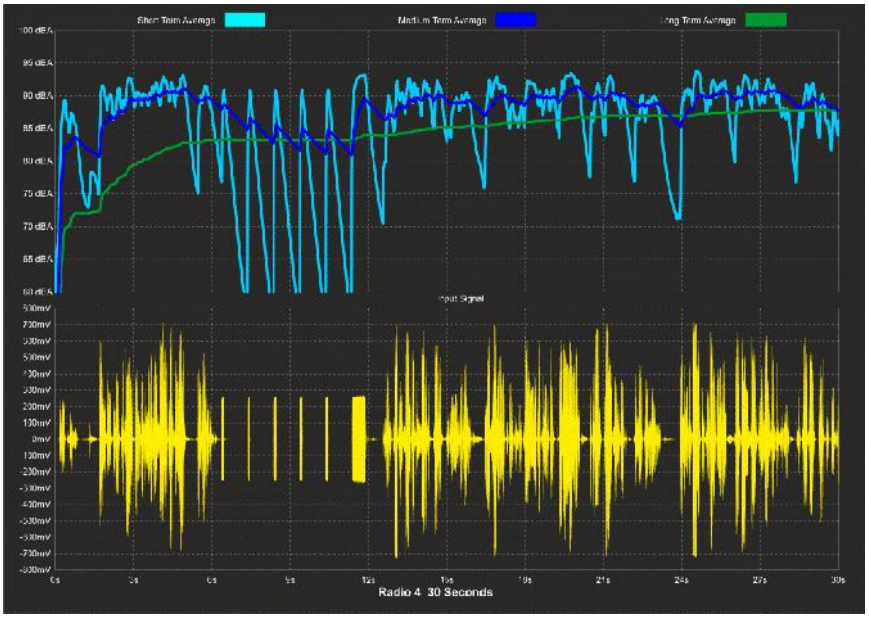


Diagram 2 (below) shows the situation with programme content which has a highly constrained (compressed) dynamic range. A very different picture, but HDM Pro® accurately takes account of what is actually happening at all times. (Radio 1 mix speech and music).

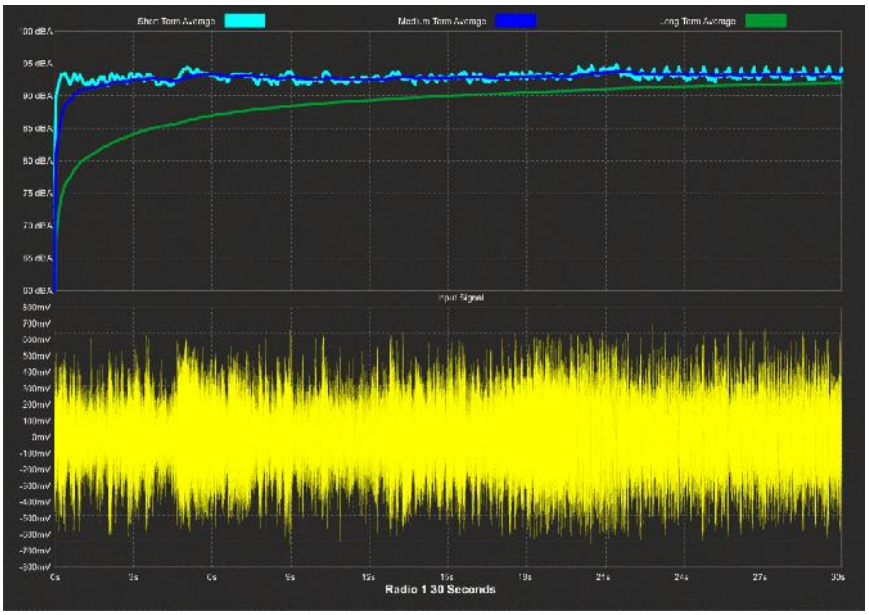
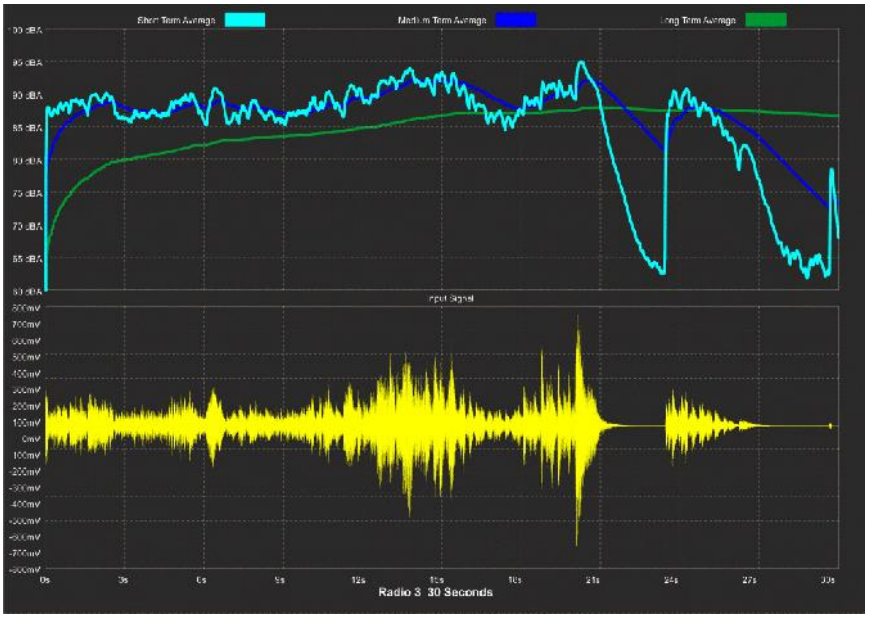


Diagram 3 (below) shows higher quality musical programme content (piano, Radio 3) having a highly variable intensity and wide dynamic range. HDM Pro® has no problem with any amount of channel switching!



Practical Compliance

Workplace noise is commonly measured by sound level meters (hand-held instruments). To measure the noise exposure of an individual over the course of a working day, dosimeters (personally-worn exposure meters) are used. These instruments use

microphones and with suitable processing can derive a number of noise parameters (e.g. average noise level, 'Leq') which can be compared to legislation.

Such measurement is much more difficult for employees wearing headphones. The reproduced sound delivered by the headphone speakers is usually greater than the ambient noise contributions, which are to an extent attenuated by the headphones. One technique for headset hearing dose monitoring utilises miniature (and expensive) microphones inserted into the ear space. However, as it is so easy to significantly change the reproduced sound level, occasional monitoring can become ineffective.

An alternative is to continually monitor or control the electrical input to the headphone speakers. For this to be accurate several parameters have to be used to relate electrical input to sound output such as earpiece sensitivity, impedance and frequency response. This is in addition to parameters relating to the nature of the programme content.

HDM® Technology

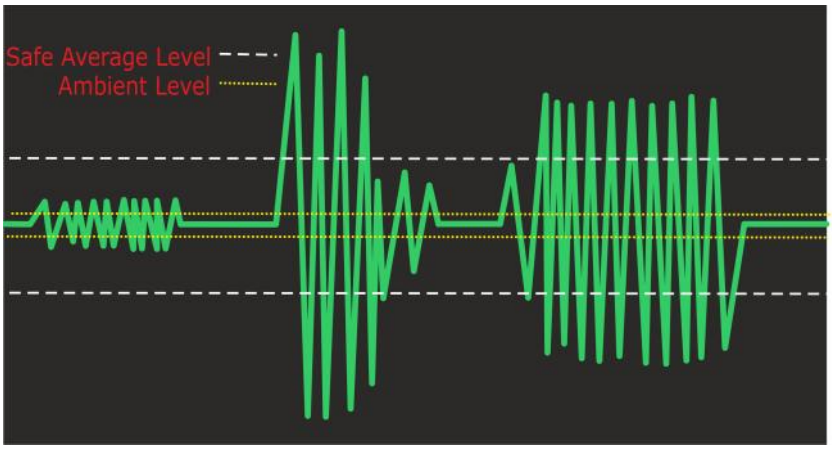
HDM® technology continually monitors the electrical signals entering the earpieces. It then computes the resulting average noise dose contributions. It also assesses the likelihood of exceeding the level appropriate for safe hearing. As long as safe levels are not likely to be exceeded, then sound is permitted untouched. The only time HDM® has to step in is if safe levels are likely to be exceeded. HDM Pro® intervenes as little as possible within these guidelines as most of us want the reproduced sound that reaches our ears via headphones or earpieces to be as natural as possible. HDM Pro® is a low intrusion solution, if ever there was one.

It does this through a combination of advanced electronics and software utilising hybrid circuitry and a microcontroller. Powered by a small internal battery, HDM Pro® devices can be recharged through micro USB chargers – standard with most of today's mobile phones.

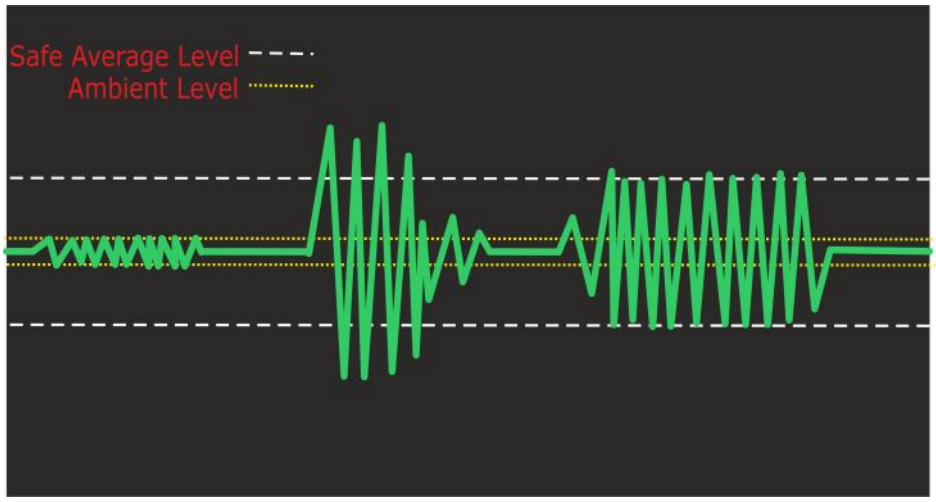
Key to its success is accurate determination of the signal content entering the earpieces, careful estimation of the consequent noise exposure, and intelligent evaluation of the limits and flexibility offered by regulation.

Benefits Compared to Traditional Techniques

Traditional methods designed to protect the hearing of people wearing earpieces have severe limitations illustrated here. What is not covered here is the most obvious method, turning the volume down – simple attenuation!

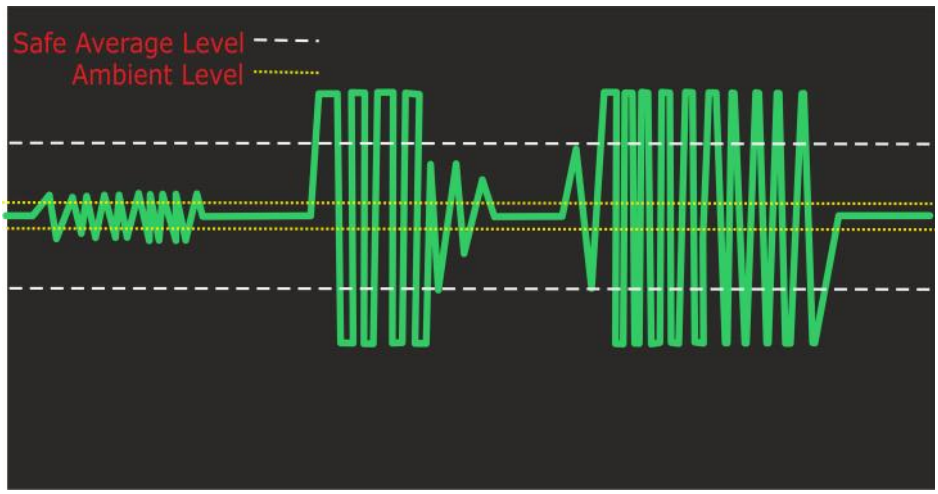


Fixed Attenuation: This method simply adds a resistance to the electronic circuit that reduces the whole signal. It indiscriminately cuts the sound down by a percentage which means that the loud bits do get quieter but so do the quiet bits as well. The only way for this method to protect the user and to ensure that they comply with the regulations is to take the absolute maximum noise down to the allowable average level. This could mean a reduction of between 20 to 30 dB. At this attenuation the quiet bits can become virtually inaudible so it doesn't really work. If it only takes out 10dB then the user could quite easily be subjected to noise levels way above the legal level.



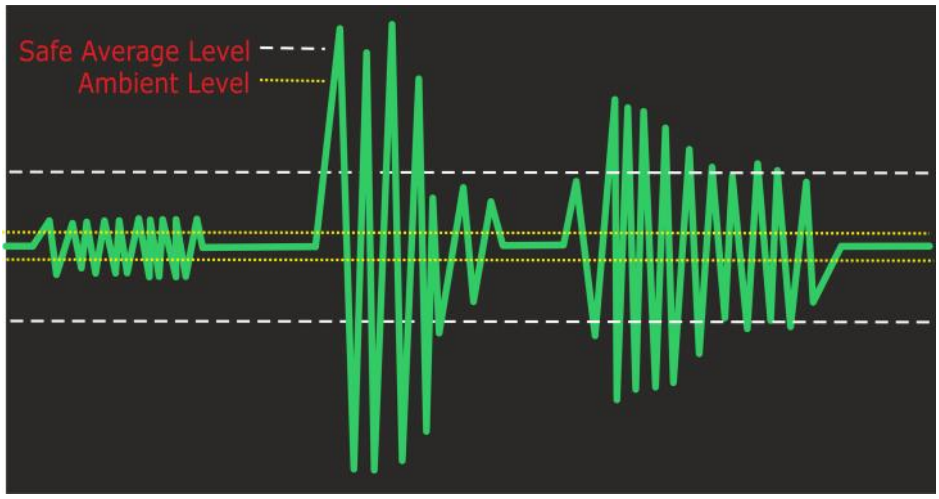
The significant disadvantage (apart from the above guesswork) is that quiet sounds can become inaudible amongst the general ambient sound level, as indicated by the low levels in diagram 5 (above).

Level Clipping: Perhaps a rather a crude approach. Peak chopping allows lower sound levels through but limits noise peaks above a certain level. By making assumptions about the programme content, this can go some way to protecting the user. However, it introduces distortion and cannot be relied on unless the threshold is set very low with correspondingly greater distortion.



Its significant disadvantage is severe distortion and the relatively poor ability to constrain dose levels, as illustrated by the clipping shown by uniform peaks in diagram 6 (above).

Short-Term Limiting: More intelligent than level clipping in that it takes a short-term average of the signal and uses this to introduce a degree of attenuation. Again, with assumptions about programme content and the daily hearing dose pattern, this does offer some degree of protection.



The disadvantages with such solutions are that they can introduce distortion and pumping due to the fluctuations in programme content. This is signified by the falling off of the relatively short right-hand clip in diagram 7 (above). They typically have a limited range of attenuation and do not control the levels with precision. To better protect users, it is necessary to have relatively low operating thresholds, which restricts usability in some situations. This contributes to the perception of such devices as "getting in the way of me doing my work".

Hearing Dose Management® (HDM®): HDM Pro® overcomes the drawbacks of traditional methods. It lets through quieter sounds untouched and can permit sound levels way over the limits imposed by other devices for short periods of time. It only reduces the sound levels as it needs to, making full use of the Noise at Work dose limits and long-term averages. This ensures that the user receives the most audible safe listening experience and is not exposed to a noise dose above the legal limits over the whole period.

HDM® compared with current low cost solutions:

Allowing Noise to Exceed Average

Here is the basic maths regarding the measurement of noise increase and decrease – some of which might surprise you…

- An increase of 10dB increases the sound level by a factor of 10
- An increase of 3dB doubles the sound level
- A decrease of 3dB reduces the sound level by half

Imagine you have a factory machine that gives out a noise level of 75dB. If you get a second machine and place it next to the first the noise level goes up by 3dB to 78dB. However, (and this is where the concept gets a little trickier) to go up to 81dB (a further increase of 3dB) you would need to add a further two machines as you need to double the sound level.

So, moving on to what comes through your earpieces. The regulations say you can be exposed to a Leq of 85dB (the second action level) for an eight-hour period. If you're

only working a four hour shift then you can be exposed to twice that level (88dB) and for two hours it can be 91dB. This means that simply clamping the signal to 85dB just doesn't make sense.

With HDM® the sound allowed through is continuously monitored. If the user's average is a long way below the 85dB action level, then sound is passed through untouched. As the noise dose gets closer to the action level, LimitEar starts to reduce the sound to protect the user – it really is that simple!

Integration into Other Devices

HDM Pro® technology is a digital/analogue hybrid circuit that can be incorporated into many different devices. It's specific to the type of headphones or earpieces being used. This means it needs to be paired with them rather than the source of the sound. So that means that if you have a walkie talkie and a detachable set of headphones then the HDM Pro® would be built into the headphones, rather than the walkie talkie.

The electronics to deliver the HDM Pro® functionality are built into a small ergonomically designed puck which is installed into the headphone cable, please see the images below.

Find out more by contacting information@limitear.com or calling us on 0845 643 4055.