Technical Notes from Laplace Instruments Ltd

EMC Conducted Emissions measurement.

By David Mawdsley

The author
David Mawdsley is Technical Director of Laplace Instruments Ltd of the UK. He has been instrumental in the development of low cost, high integrity solutions for the measurement of EMC emissions, both conducted and radiated. In particular, David was responsible for the introduction of the ERS (Emissions Reference Source) now widely used to improve the accuracy of measurements on non calibrated sites. Laplace analysers and accessories provide a complete integrated system to check compliance of products to all common EN standards. He has several papers and delivered lectures on the subject of EMC for small businesses as far afield as Australia and the USA.

Detectors... what, why and when?

The EN standards for EMC emissions compliance specify the maximum allowable level (the LIMIT) of conducted interference from a product in units of dBuV as measured by a ‘Quasi-Peak’ and an ‘Average’ detector. These limit levels are generally shown as two separate columns in the standard. Any product (DUT) must be shown to be below both limits in order to be compliant.
Example of typical limit data (from EN55011, class A, Group 1)

Frequency Band MHz	Quasi-peak dBuV	Average dBuV
0.15 - 0.50	79	66
0.50 - 5	73	60
....	......	....

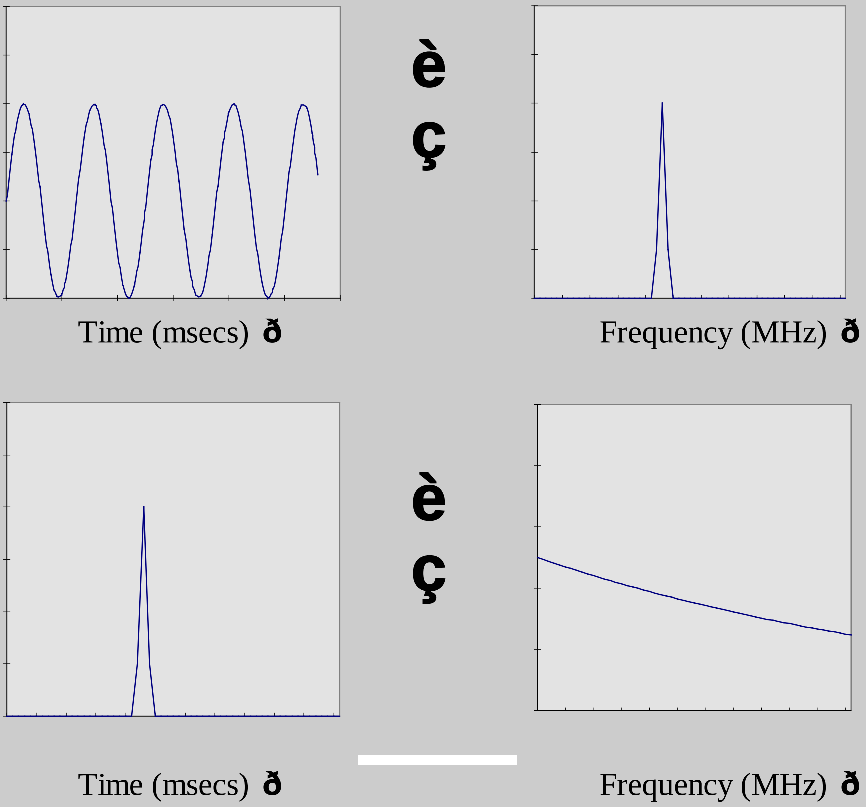
To understand why these different detectors are specified, we need to understand the nature of typical signals we can expect to encounter when testing for conducted emissions.
Signals generally are either:

- Continuous, steady state, as can be expected from electronic devices which include for example, an oscillator or clock or a switched mode power supply. These produce a nice ‘clean’ narrowband peak in the frequency spectrum.
- Pulsed signals such as typically caused by any phase angle control circuit. These create a transient pulse every time the switching device turns on. For example, a light dimmer will produce such transient pulses at a 100Hz rate corresponding to every half cycle on 50Hz mains. These produce a generally flat broadband spectrum that may extend from KHz to many MHz.

- Discontinuous noise as would be created, for example, by a commutator motor due to random low level arcing at the commutator. If the signal were viewed on an oscilloscope it would have the appearance of totally random noise. These produce a ‘messy’ broadband spectrum with erratic characteristics.

Fourier analysis of signals shows that the time domain (what you see on a scope) and the frequency domain (what you see on a spectrum analyser) work in inverse. For example, a steady time signal (continuous sine wave) produces a single peak in the frequency domain.
A single peak (a pulse) in the time domain produces a flat broadband characteristic in the frequency domain. With this knowledge, it becomes easy to deduce from the spectrum what the nature of the signal is in the time domain

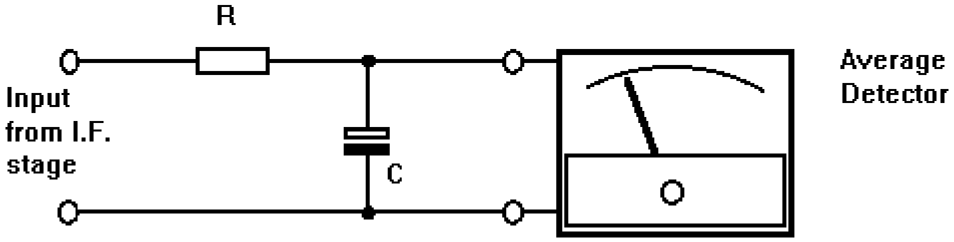
Fig 1 Relationships between time and frequency domains.



We need to find a measurement technique that will cope with this wide range of signal types and give a result that is a meaningful representation of the ‘interference’ level. For convenience, we can quantify the actual interference ‘value’ of a signal as the ‘**interference rating’**. This rating includes a subjective element. For instance, a persistent low level buzz on a hi-fi system is perceived as having a higher (worse) rating than an intermittent click, even though the click may be a much stronger signal. If we use a conventional analyser detector, which is effectively an ‘instantaneous’ detector, the results when fed with ‘discontinuous’ noise (assuming that there are significant components within the signal with a repetition rate lower than 9KHz) would be completely random fluctuations....not very useful!

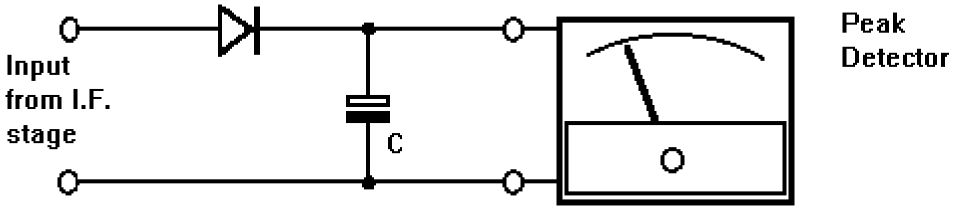
One factor to be aware of is the I.F. bandwidth of the analyser. This is specified by CISPR16 for conducted emissions measurement to be 9KHz. That means that any pulsed or discontinuous signal with a repetition frequency above 9Khz will appear as a continuous signal whilst 'slower' pulsed signals will appear as discrete peaks.

The obvious solution is to average the result by using an averaging detector, simply take the output from the I.F. filter and take it through a simple RC filter to provide averaging. This indeed is what CISPR16 specifies for the 'average' detector.



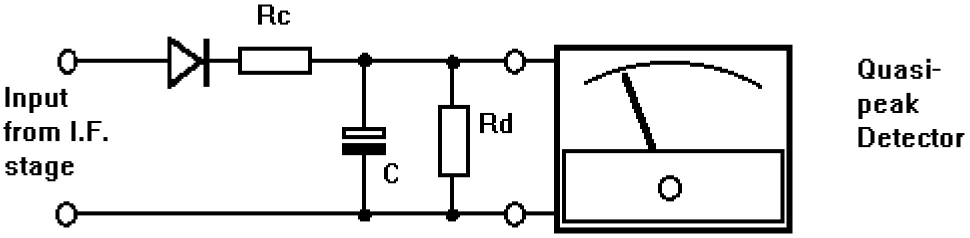
The result is an average of the noise level. The problem with this is that for many pulsed emission sources, the pulses have an extremely low duty cycle, i.e. they are very short (typically a few microseconds) compared with a repetition period which is relatively long, 10 milliseconds for a 100Hz repetition rate. This gives a duty cycle of around 0.1% and averaging this will always give a very low result, even if the interference rating was high.

On option would be to use a peak detector. This would obviously produce an output corresponding to the magnitude of the pulses, regardless of repetition rate. However, what happens if these pulses occurred only once every 5 seconds. Even if the pulses had a large amplitude, giving a high peak detector output, the interference rating should be relatively low, whilst another product may produce a lower pulse amplitude, but at a very irritating 100Hz repetition rate. This would give a lower peak detector output, but the interference rating should be higher.



Clearly peak detection is not the answer.

The compromise that provides results that are generally equivalent to the interference rating is a 'Quasi-Peak' detector. This is really a fudge that happens to give about the right answers. In hardware terms it is a cross between and averaging and a peak hold circuit.



The input is passed through a 'leaky' peak hold circuit. The charge and discharge time constants are set by Rc and Rd to match CISPR16 specifications. A typical rise time is 1msec and discharge time is 160msec. This produces the waveform as shown in figs 2a and 2b. In the old days, the output from this leaky peak hold was then taken to a critically damped moving coil meter to provide the reading. The meter effectively worked as an averaging system and in modern analysers, this function is performed by an electronic averaging circuit.

Fig 2a: High repetition rate

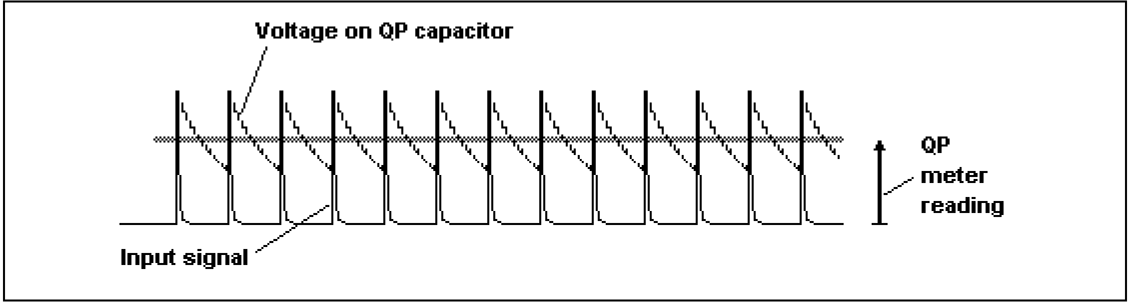
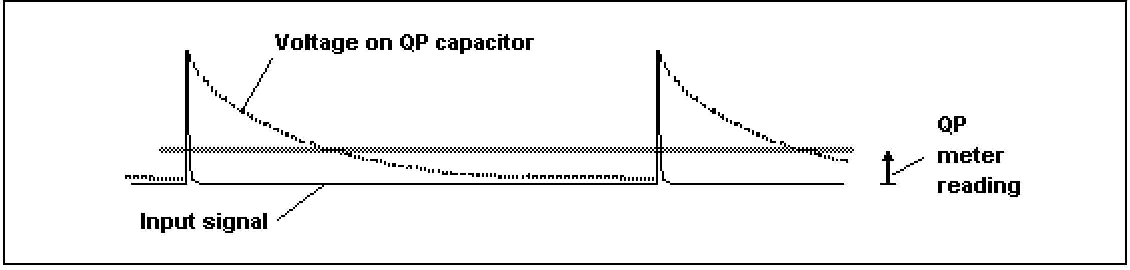


Fig 2b: Low repetition rate

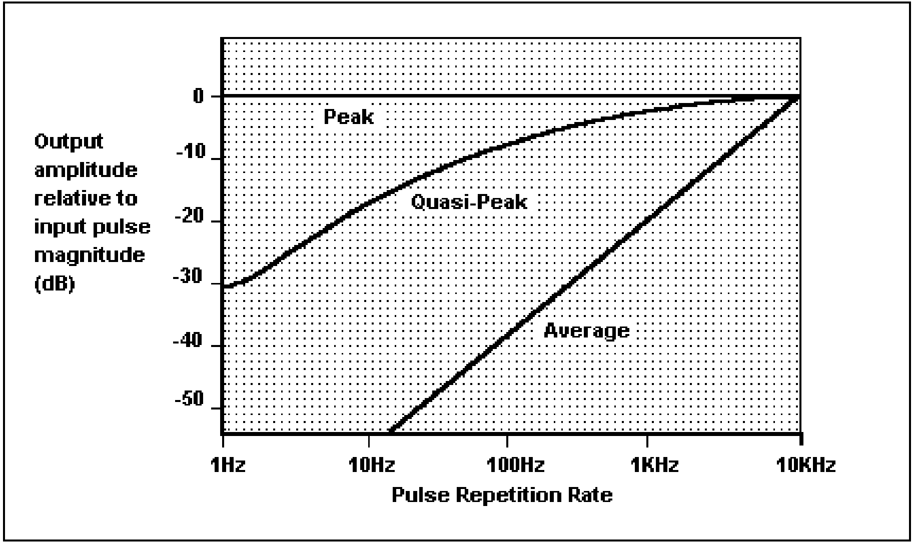


The result of this QP detector is that the output is dependant on both the peak amplitude of the pulses and the duration of the pulse (effectively the total energy in the pulse) and the pulse repetition rate.

Both the Average and QP detectors involve time constants whilst the peak detector is essentially instantaneous. This means that when scanning a signal with a spectrum analyser or receiver, the peak detector produces a far faster result. QP and Average scanning can be quite slow given that the analyser must dwell at each frequency increment for a period that is long compared with the time constants.

The relationship between PRR and QP output is shown in fig 3. Note that the average detector response to pulses is also shown.

Fig 3. Effect of pulse repetition rate



Points to note:

1. If the signal is continuous, or has a repetition rate above the IF filter bandwidth (9KHz), all detectors produce the same result. When performing radiated emissions tests, it often makes sense to use only the peak detector because generally radiated signals tend to be continuous or to have a repetition rate well above 10KHz.
2. As the repetition rate is reduced, the average detector output drops rapidly and the QP detector less rapidly. In all cases, the peak detector gives the highest (worse case) reading. Because the Peak detector always gives the worst case reading and gives the fastest sweep, it is standard practice to use the peak detector first, and compare the result with the average limit line. If the results are all below this limit, then the product must be compliant and no further testing is required. Only if the result shows peaks above this limit must further testing be done with the average and QP detectors.
3. Comparing the results of the different detectors at any given frequency can provide details of the nature of the signal. For instance, if the peak, QP and average levels are similar, the signal must be effectively continuous. If they differ by the amounts shown in Fig 3, then the signal is very impulsive. In between these two extremes a sliding scale rule-of-thumb can be applied.

Real results!

Fig 4 is taken from an actual result from a table lamp. (Although CE marked, the lamp proved to be non compliant!) The photograph shows the testing in progress. For those clever clogs who can find the deliberate fault with this test setup....yes, we know it's all wrong but please don't bother to write in, the editor is having a hard time as it is.
The measurements were obtained with a Laplace SA1000 analyser, using the peak detector, with a Pre-selector and LISN.
The limit line is EN55015, as specified for luminaires.

Fig 4a Table lamp emissions (off)

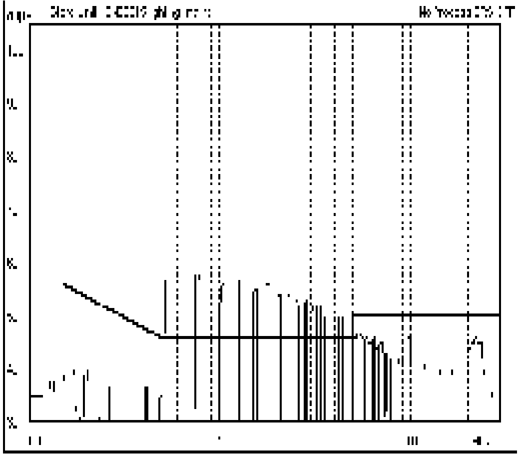


Fig 4b Lamp switched on

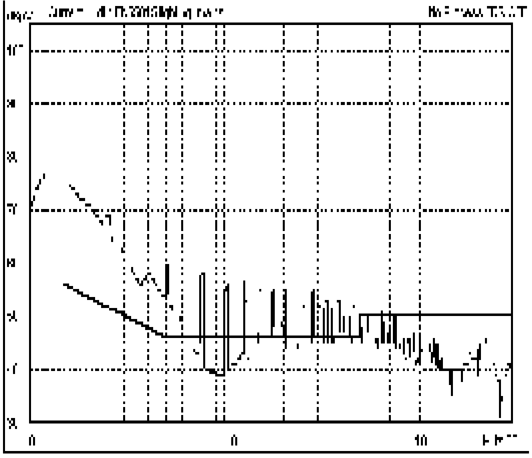


Fig 4a was obtained with the lamp switched off. There is a clear series of narrow band harmonics, suggesting an oscillator or clock signal with a fundamental of about 250KHz. The clean narrow band nature of the spectrum suggests a continuous signal and this is confirmed by the fact that the average and QP results gave very similar levels to the peak detector.

Fig 4b was obtained with the lamp switched on at a dimmed level. Now there is a classic broadband spectrum overlaid on the harmonic series noted above. Checking with the other detectors showed that this broadband level was some 10dB lower on QP and 30dB lower on average. These levels roughly correspond to a pulse repetition rate of 100Hz, implying a phase angle control system to vary the power to the bulb.

All this information obtained without resort to the oscilloscope!

If this is how a simple table lamp behaves, just how bad do you think your product is?