

Conducted emissions in the 2kHz -150kHz band Supra-harmonics

PQube® 3 Application Note v3.0



Introduction

A new threat to grid operators: 2kHz-150kHz emissions, or “Supra-harmonics”, can burn capacitors, knock out communications and even foul up revenue meters.

The biggest single source? Emissions from photovoltaic inverters. Some wind turbines, fuel cells, battery chargers can also be significant sources.

Supra-harmonics also affect street lighting controls, household dimmers, semiconductor manufacturing equipment, medical scanners, security systems and transportation controls.



Figure 1 Wrong meter readings caused by 2kHz-150kHz



Figure 2 capacitor burned by 2kHz-150kHz emissions

As we move towards greener energy supplies, this problem will get worse. Today, the only way to track it is with the new PQube 3 instrument.

PQube 3 instruments all include special high frequency spectrum hardware specifically for this frequency range.

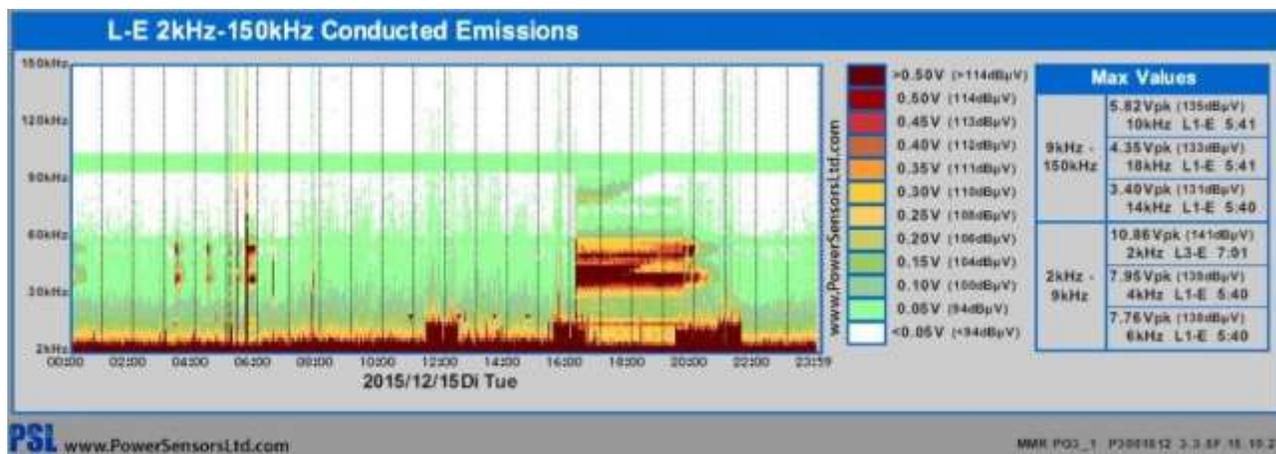


Figure 3 PQube 3 measures supra-harmonics on site 24hour a day /7 days a week.

PQube®3 is the only instrument that continuously measures and records all conducted emissions in the 2kHz to 150kHz range. And your PQube 3 automatically emails data and graphs directly to your inbox.

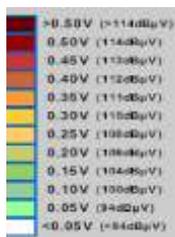
Fully Class A compliant with the new Edition 3 of IEC 61000-4-30 (Power quality measurement methods)!

Your PQube3 emails this supra-harmonic graph to you. No software required!



How do you read the supra-harmonic graph?

- the horizontal axis of the graph represents 1 day, 24 hours from midnight to midnight.
- the vertical axis of the graph represents the emission frequency spectrum from 2 kHz (bottom) to 150kHz (top).
- the color map shows the peak amplitude at a given time (1 minute interval) and at a given frequency. It is expressed in Volts and in dB μ V (units used for compatibility level assessment).



- the right side of the graph shows 2 tables:
 - the 3 highest peak values across the 9kHz-150kHz range, their respective frequencies and time of occurrence.
 - the 3 highest peak values across the 2kHz-9kHz range, their respective frequencies and time of occurrence.

Max Values	
9kHz - 150kHz	5.82Vpk (135dB μ V) 10kHz L1-E 5:41
	4.35Vpk (133dB μ V) 18kHz L1-E 5:41
	3.40Vpk (121dB μ V) 14kHz L1-E 5:40
2kHz - 9kHz	10.86Vpk (141dB μ V) 2kHz L3-E 7:01
	7.95Vpk (138dB μ V) 4kHz L1-E 5:40
	7.76Vpk (138dB μ V) 6kHz L1-E 5:40

Technical background: 2kHz-150kHz emissions

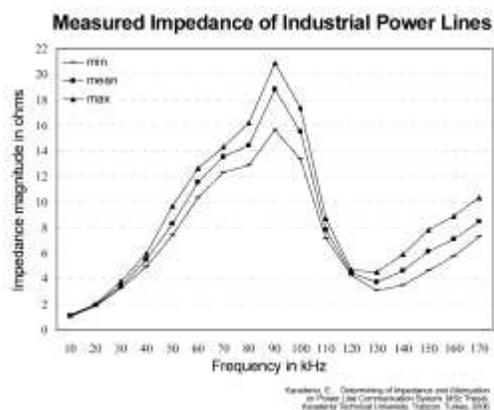
How do supra-harmonics move through the grid?

Electrical networks are designed to transfer energy at 50 or 60Hz. However, these networks can conduct at higher frequencies, up to about 150kHz.

At around 100 kHz, the network impedance typically peaks, maximizing the conversion of supra-harmonic current into voltage.



Figure 4 2kHz-150kHz emissions move through overhead and underground power lines



These conducted emissions travel through overhead lines, underground cables and building wiring. They also pass through high efficiency transformers, due to their larger-than-normal inter-winding capacitance.

Power factor correction capacitors do not trap these supra-harmonic emissions, because they are often filtered to operate only at 50 or 60Hz.

Power line carrier (PLC) couplers provide, by design, a low-impedance path for emissions in this frequency range.

In summary, the grid is designed to move power at 50/60Hz but, unfortunately, it also carries 2kHz-150kHz fairly efficiently.

What generates supra-harmonic emissions?

Equipment that generate supra-harmonics isn't doing anything wrong in regards to regulations, but can harm other equipment.

Photovoltaic inverters, fuel cells, some wind turbines, and almost all other DC to AC switching equipment generate 2kHz-150kHz forced emissions.

Power supplies, variable frequency drives and other AC to DC switching devices can produce 2kHz to 150kHz leakage emissions.

Power line carriers (PLC) generate emissions intentionally. For the purpose of data transmission, they provide coupling for 2kHz-150kHz across barriers in the network.



Figure 5 photovoltaic inverters generate 2kHz to 150kHz "forced emissions" into the grid

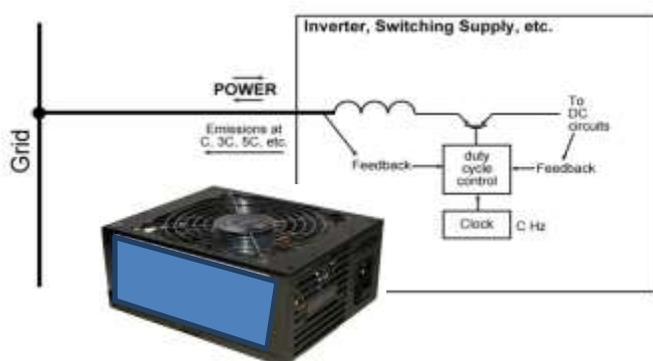


Figure 6 switching power supplies emissions

Problems caused by supra-harmonic emissions

Overheating capacitors:

Capacitors, found commonly in LC input filters, are sized for normal operation at 50/60Hz. So, for example, 1 mA current to Earth flows in the filter at 230V, 50 Hz. The capacitor impedance = $\frac{1}{2\pi F C}$ is a function of inverse of the frequency. So with just 2.3 Volts at 50 kHz, the capacitor current exceeds the normal 50Hz current by a factor of 10. This increased current destroys capacitors, trips GFI protection, and even creates safety issues.



Figure 7 capacitor damaged by excessive high frequency currents

Energy meter readings accuracy:

Supra-harmonic emissions can strongly affect the accuracy of energy meters, unless they are designed specifically for immunity against this range of frequency (good news! a new standard for meter immunity is now available: IEC 61000-4-19).

Interference in PLC communication:

These systems communicate on frequency bands from 3 kHz and up to a few hundred kilohertz. The range coincides with emissions of switching devices such as inverters. This can substantially degrade reliability or invalidate communications.

Conducted emissions are getting worse, with the rapid growth of powerful inverters, variable frequency motor drives, high-frequency filters (high tech equipment) and also the reliance on PLC for meter readings which increases emission sensitivity.

For a complete list of 2kHz-150kHz emission problems refer to the standard IEC 61000-4-19.

Emission, immunity and measurement Standards

2kHz-150kHz Standards are in development:

- CISPR- 16 - equipment and methods for measuring disturbances and immunity to them at frequencies above 9 kHz
- IEC 61000-4-19 – testing revenue meters for immunity
- IEC 61000-4-30 Ed3 - in-situ measurements of 2kHz-150kHz emissions – PQube®3 implements the measurement methods recommended for 2kHz-150kHz emissions.

The PQube3 is your best solution.

Your PQube[®]3 continuously monitors supra-harmonic emissions

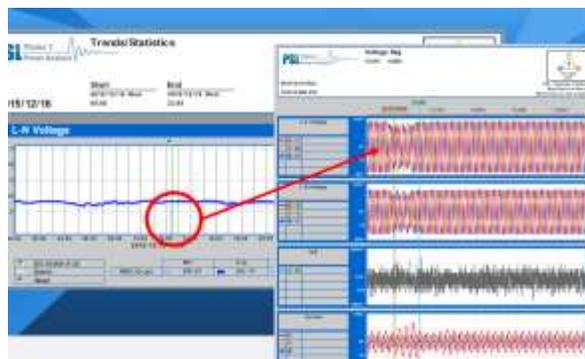
- ✓ Your PQube3 is tiny! It is the smallest high precision power quality and energy monitor available. It installs virtually anywhere you need to measure emissions. It can be installed on a DIN-rail in an electrical panel, embedded into sensitive equipment, installed in enclosure in a substation or mounted on utility poles. Your PQube3 measures voltages directly up to 830V (L-L).
- ✓ Your PQube3 records 24/7 no matter what! It powers from 24VAC, 24-48VDC, POE (Ethernet) or from 100-240VAC (option). It comes with an optional plug-in UPS battery back-up that you can



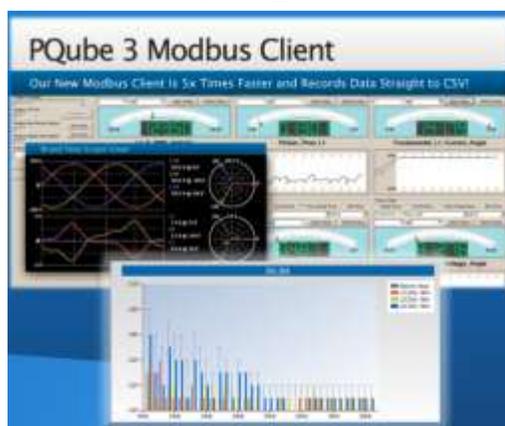
you
an
It

configure for up to 1 hour.

- ✓ Your PQube3 records, every minute, the minimum/average/peak amplitudes on each frequency band. It also reports the highest peak values reached during the day and their frequency band.
- ✓ Your PQube3 comes with 4 additional AC or DC voltage inputs, 1 digital input and up to 2 optional environment sensors (temperature, humidity, pressure, mechanical shocks...). Those are ideal for correlating supra-harmonics signatures with external parameters like solar irradiance, wind velocity, rotation speed of wind turbines...
- ✓ Your PQube3 automatically sends you a daily email with attachments: ASCII (CSV) file and with graphs (GIF), and also sends email upon occurrence of power quality disturbances...



- ✓ If you have access to a LAN connection, your PQube 3 reports supra-harmonic emissions in real time (via Modbus TCP)!
- ✓ No access to the network? You can use a USB memory stick to configure your PQube3 and download the recorded measurements (or with the extractible micro SD card). The measurements are stored for months into a 16GB internal memory.



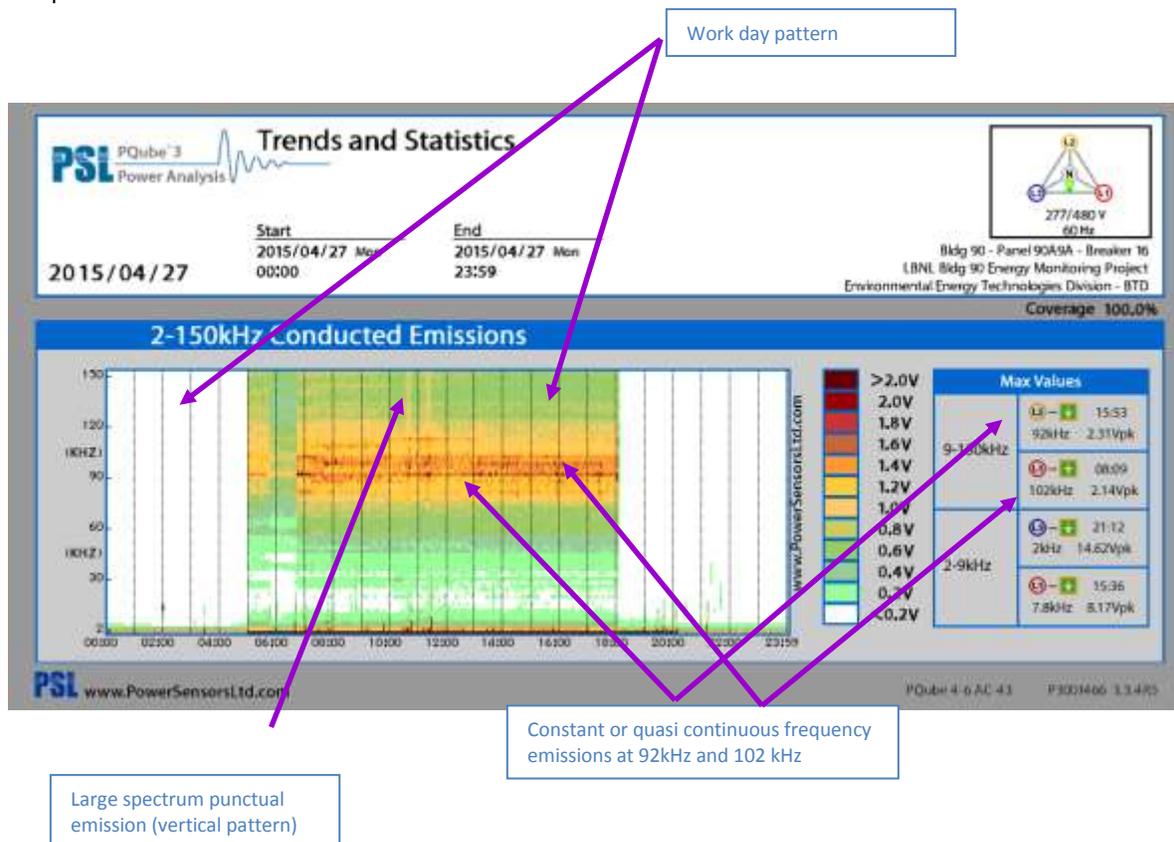
the
to

PQube 3 2kHz – 150kHz Measurement Specifications

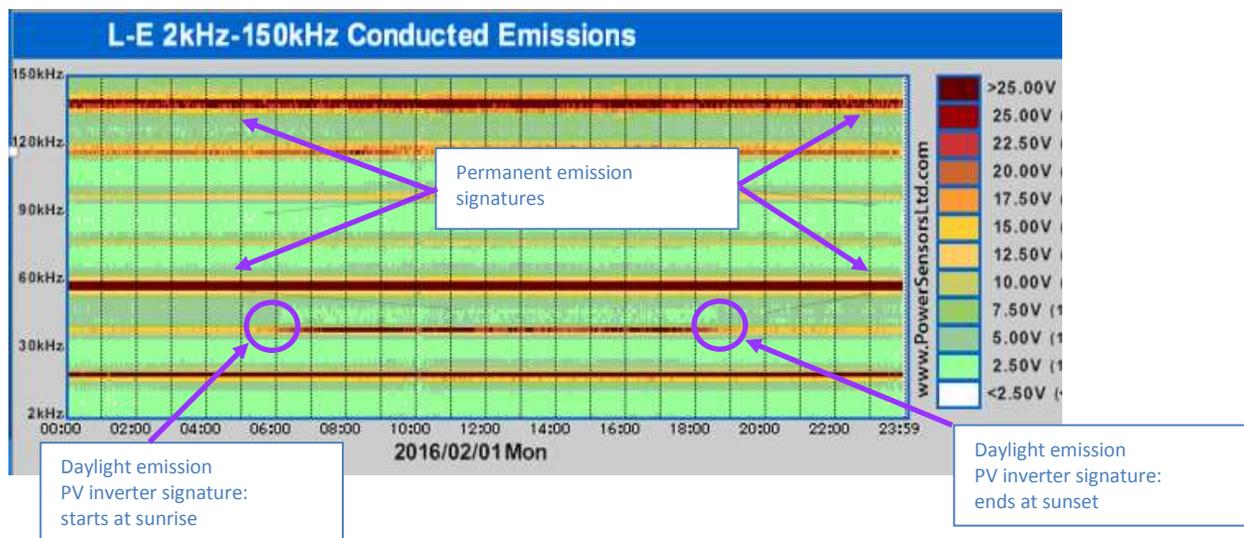
Amplitude Range	0-60Vpk
Frequency Range	2 kHz—9kHz and 8kHz to 150kHz
Measurement Method	Fully compliant and certified to IEC 61000-4-30 Ed. 3, Annex C Frequency band resolution for 2 kHz to 9 kHz range – 200Hz bins Frequency band resolution from 8 kHz to 150kHz range – 2000Hz bins Basic measurements : amplitudes for each bin, every 10/12 cycles Aggregation interval : 1min Parameters: minimum, average and maximum (peak) reached during the interval
Recordings	Daily recording as CSV file and graphical overview GIF file
Amplitude accuracy	5% typical (5% - 100%FS)

Examples of 2kHz-150kHz field measurements

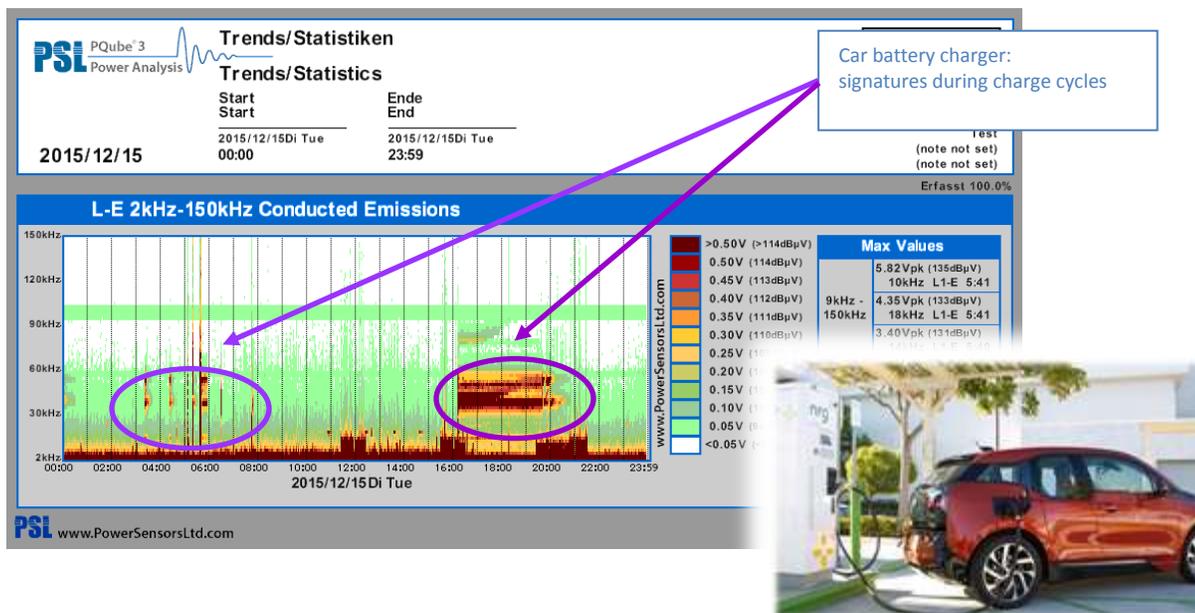
The example below is taken during week day conducted emissions at Lawrence Berkeley National Lab in Berkeley, California. There is a clear pattern with (low amplitude) emissions starting precisely at 5:00 AM local time, and stopping shortly after 6:00PM. The horizontal orange band indicates a continuous emission during the work day predominantly at 92kHz and 102kHz with an idle period between 5:50AM and 6:50AM.



The following example clearly confirms how serious emissions from PV inverters can be! This was done using a color map range of 0V to 25V. This inverter emission frequency signature is at 40kHz.



Another example of field measurement, a car battery charger connected to the Low voltage distribution grid: emissions of typical signatures during charge cycles are easily identifiable.



More information

Email: sales@powersensorsltd.com
 Web site: www.pqube3.com