# Wordt of is 2kHz – 150 kHz emissie een nieuw (EMC / Power Quality?) probleem in installaties?

**Arthur M. Hartsuiker | C.N.Rood**

de Nederlandse EMC-ESD Vereniging
EMC-ESD Event 2019

NH Conference Centre Koningshof
Veldhoven

woensdag 20 november

# 2kHz-150kHz Emissions

1. Technical background – 2kHz – 150kHz emissions
2. The “perfect storm”: Why this problem is suddenly getting worse
3. New IEC 61000-4-30 Ed. 3 (2015) “Power Quality Measurement Methods”
4. 2kHz-150kHz emissions – real world examples

EMC-ESD Event 2019

# 2kHz-150kHz Emissions Technical background

a. How these 2kHz-150kHz emissions move through the grid
   1) Overhead lines, underground cables, building wiring
   2) High-efficiency Power Transformers
   3) Power factor correction capacitors
   4) Power Line Carrier couplers

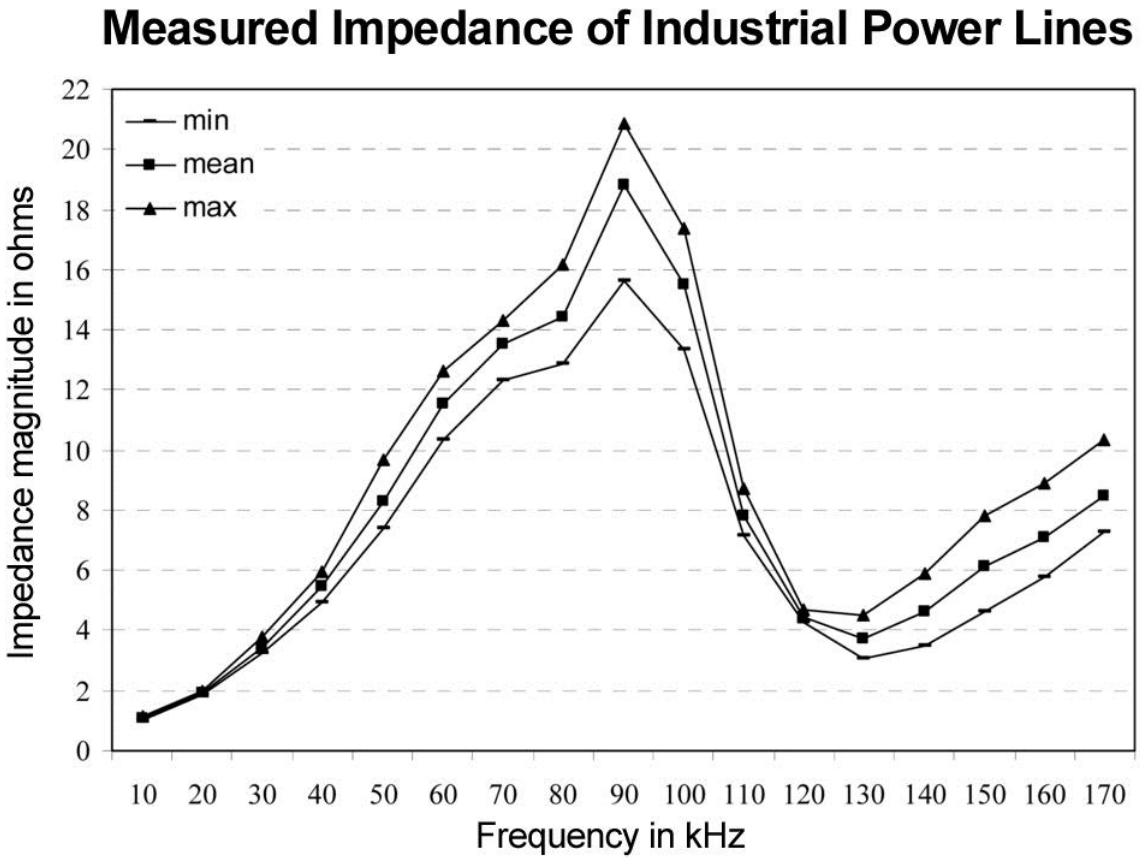
b. Sources of 2kHz-150kHz
   1) Leakage
   2) Forced emissions
   3) Intentional

c. Problems caused by these 2kHz-150kHz emissions

**d. Why this problem is suddenly getting worse**

# How 2kHz-150kHz emissions move through the grid:

## Grid is designed for 50/60 Hz, but can carry conducted energy up to about 150 kHz.




Karadeniz, E. Determining of Impedance and Attenuation on Power Line Communication System. MSc Thesis, Karadeniz Technical University, Trabzon, Turkey, 2006

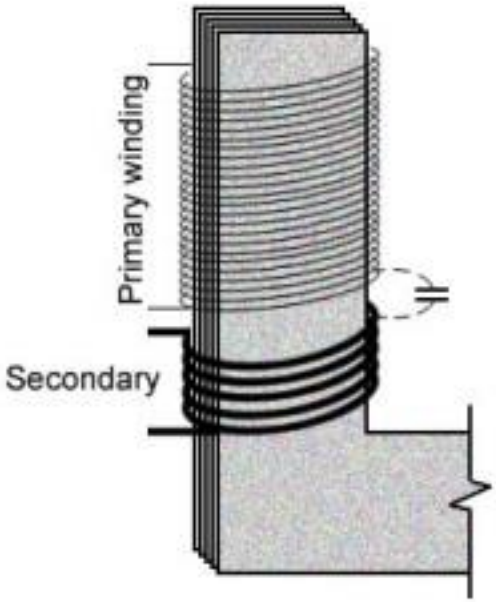
Peak impedance around 100kHz .

Impedance converts current emissions to voltage emissions...

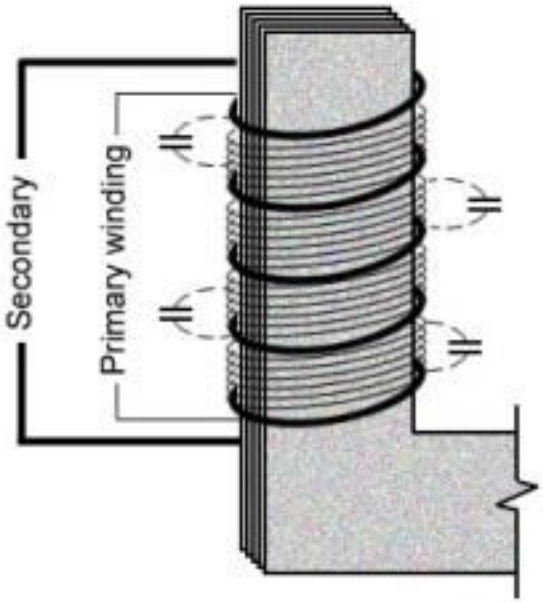
EMC-ESD Event 2019

# How 2kHz-150kHz emissions move through the grid:

## High-efficiency transformers have larger inter-winding capacitance.




Traditional transformer winding – Excellent isolation, poor efficiency.
**Mostly blocks 2kHz-150kHz**

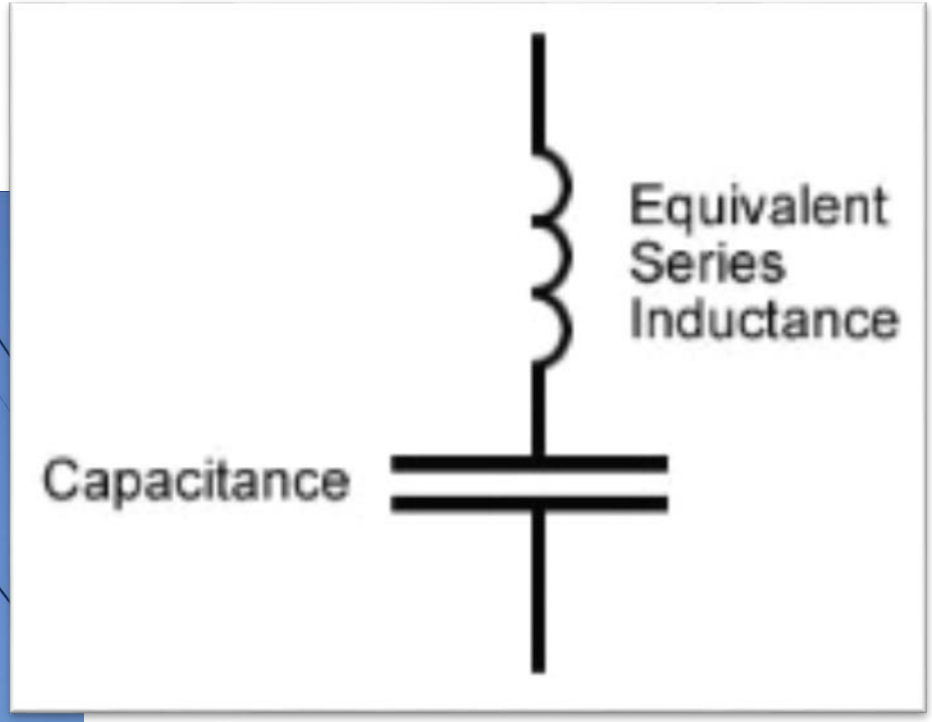



High Efficiency Transformer winding – Poor isolation, excellent efficiency.
**2kHz-150kHz leaks through**

EMC-ESD Event 2019

# How 2kHz-150kHz emissions move through the grid:

**Power factor correction capacitors don't trap these emissions.**


EMC-ESD Event 2019

How 2kHz-150kHz emissions move through the grid:

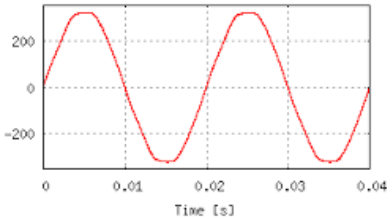
**Power Line Carrier (PLC) coupling caps provide a low-impedance path for these emissions.**


EMC-ESD Event 2019

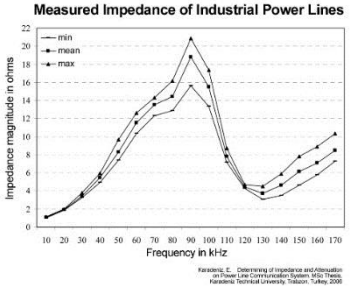
How 2kHz-150kHz emissions move through the grid:

## Summary

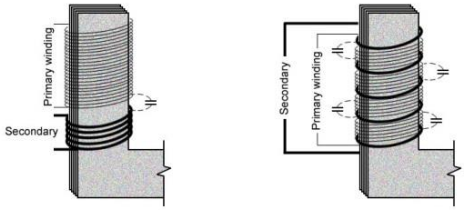
The grid is designed to carry 50/60 Hz power from one location to another.




By accident, it also carries 2kHz-150kHz fairly efficiently.




And it's getting <u>better</u> at carrying 2kHz-150kHz – **and that is bad news**.




EMC-ESD Event 2019

# Next: where do 2kHz-150kHz emissions come from?

**Leakage, forced emissions, and intentional emissions.**

Why is the ground wet?

Leakage

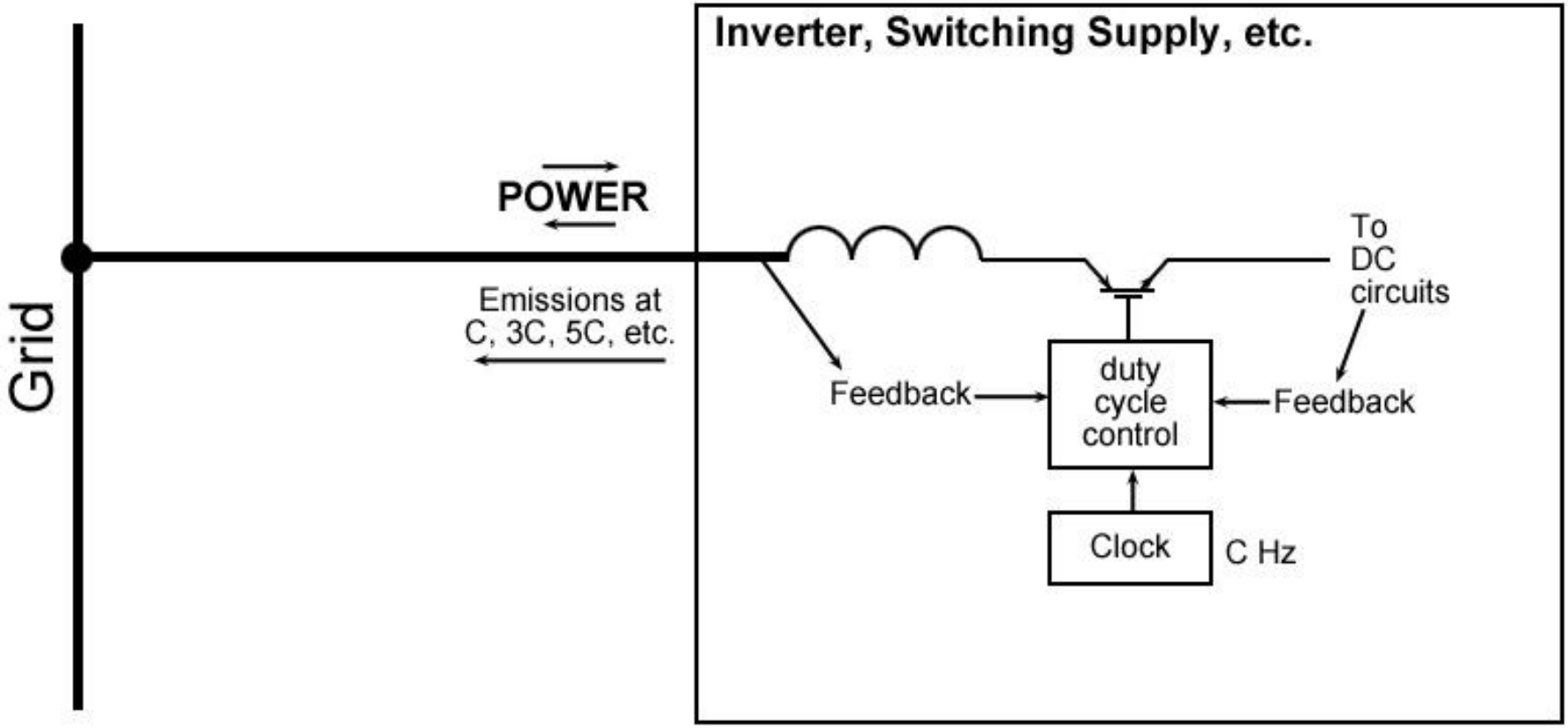
Forced emissions

Intentional…

EMC-ESD Event 2019

# Sources of 2kHz-150kHz emissions

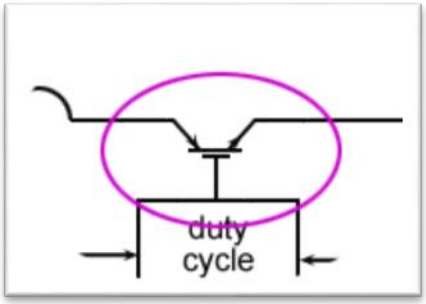
## Semiconductor switching… why?




EMC-ESD Event 2019

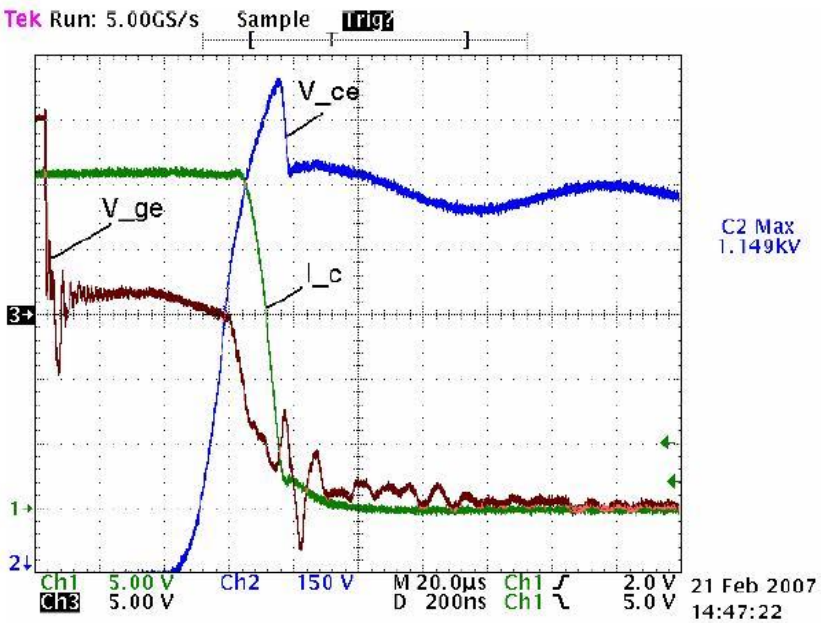
# Sources of 2kHz-150kHz emissions

## Semiconductor switching… but why? (1)

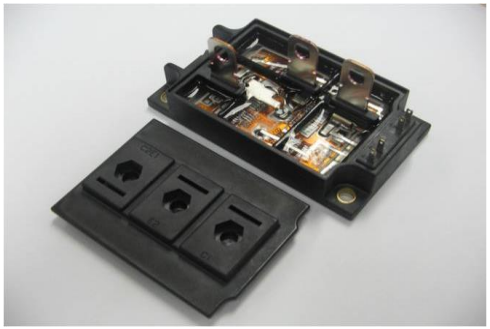


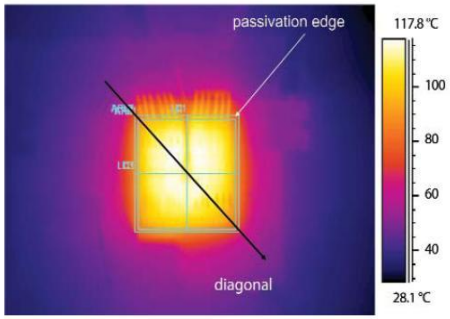

IGBT "off" – voltage, but no current
IGBT "on" – current, but no voltage
**IGBT in transition: voltage and current, so big power**

The bigger the IGBT, the slower the transition.



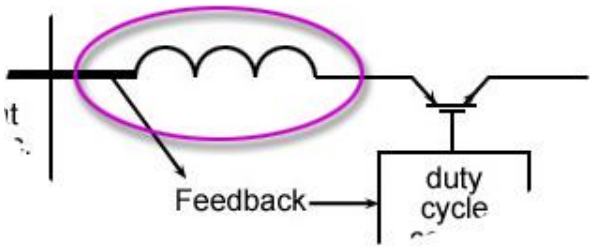

**Conclusion: for IGBT efficiency, switching frequency as <u>low</u> as possible…**






EMC-ESD Event 2019

# Semiconductor switching… but why? (2)




Between switching events,
energy is stored in magnetic core of inductor.

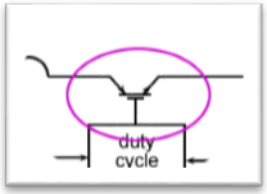
The physical size of the core (and material) determines the maximum energy storage.

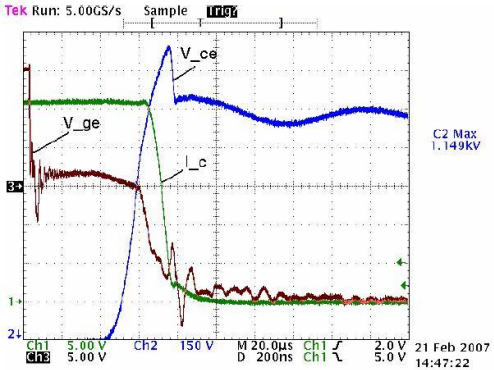
Inductors are large and expensive.

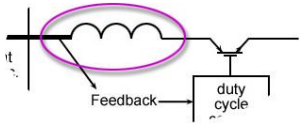
**Conclusion: for inductor efficiency, switching frequency as <u>high</u> as possible…**

# Sources of 2kHz-150kHz emissions

## Semiconductor switching… but why? (3)




**For IGBT efficiency, switching frequency as <u>low</u> as possible… For inductor efficiency, switching frequency as <u>high</u> as possible…**

**<u>So it is an ECONOMIC compromise.</u>**

**In 2015, for power greater than ~100kW, economic optimum frequency is in 9kHz-20kHz range.**

**In 2015, for power 1kW~100kW, economic optimum frequency is in 20kHz-100kHz range.**

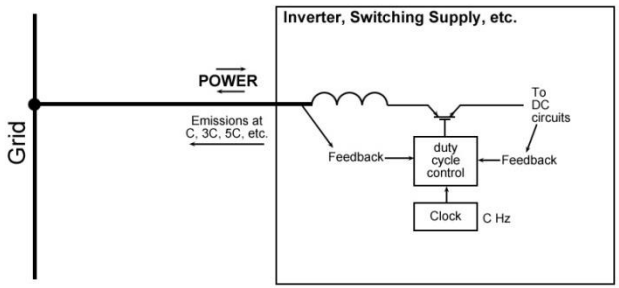
**In 2015, for power < 1kW, economic optimum frequency is in 80kHz-1MHz range.**

**OUCH!**
**All in 2kHz-150kHz range…**

EMC-ESD Event 2019

# Sources of 2kHz-150kHz emissions

## Semiconductor switching… but why? (4)




### Leakage

**Traditional problem. Power supplies, variable frequency drives, and all other AC-to-DC switching, <u>leakage</u> emissions of 2kHz-150kHz. Microwatts or milliwatts.**

### Forced emissions

**New problem. Photovoltaic inverters, fuel cells, some wind turbines, and all other DC-to-AC switching, <u>forced emissions</u> of 2kHz-150kHz. Hundreds of watts to hundreds of kilowatts**

EMC-ESD Event 2019

# Sources of 2kHz-150kHz emissions

## Intentional – power line carrier (PLC)

PLC is used for meter reading, and geographically dispersed control

Some PLC systems use fixed-frequency

Some PLC systems use spread-spectrum

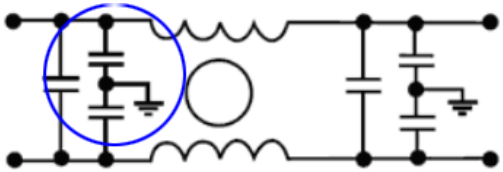
**All PLC transmitters make intentional (small) emissions in 2kHz-150kHz**

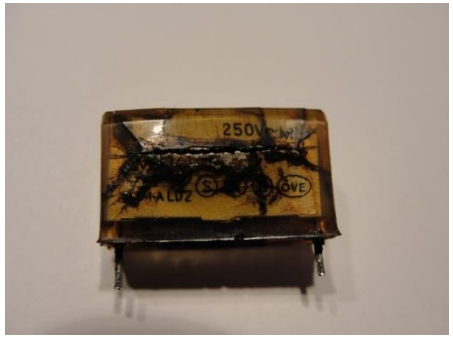
**Many PLC systems provide coupling across barriers for 2kHz-150kHz.**

EMC-ESD Event 2019

Next: Problems caused by 2kHz-150kHz emissions

# 1. Excessive **Capacitor currents**





**Capacitor (filter) from power grid conductor to earth.**

**Capacitor designed, for example, for 0,5 mA of current to Earth at 230V, 50 Hz.**

**Capacitor impedance =** $\frac{1}{2\pi F C}$

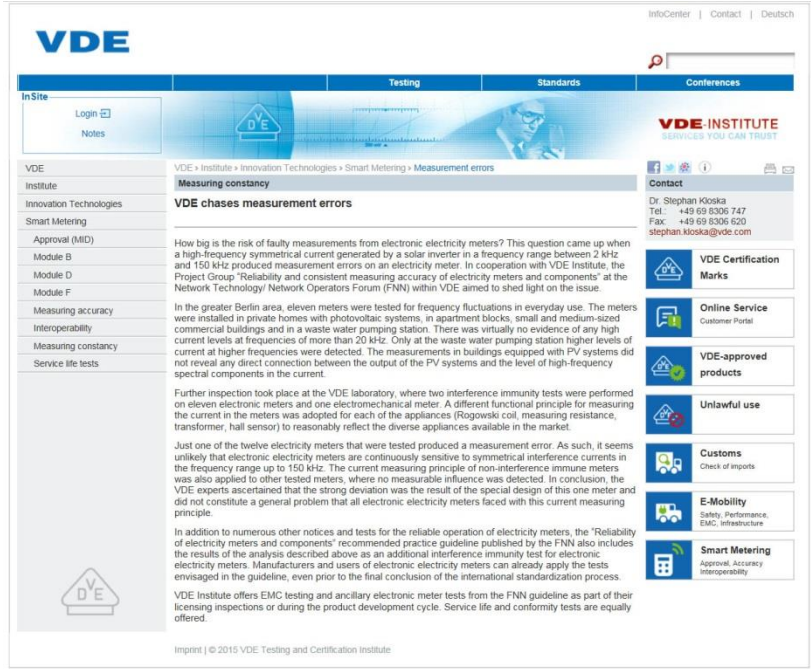
**Just 2.3V at 50 kHz increases capacitor current by a factor of 10!**

**Increased current destroys capacitors, and increases Earth current (causing protection problems, and possible safety issues).**

EMC-ESD Event 2019

Problems caused by 2kHz-150kHz emissions

# **Smart Meter measurement errors** (?)

VDE

InfoCenter | Contact | Deutsch

Testing | Standards | Conferences

InSite

Login

Notes

VDE-INSTITUTE

SERVICES YOU CAN TRUST

VDE
Institute
Innovation Technologies
Smart Metering
Approval (MID)
Module B
Module D
Module F
Measuring accuracy
Interoperability
Measuring constancy
Service life tests

VDE › Institute › Innovation Technologies › Smart Metering › Measurement errors

Measuring constancy

## VDE chases measurement errors

How big is the risk of faulty measurements from electronic electricity meters? This question came up when a high-frequency symmetrical current generated by a solar inverter in a frequency range between 2 kHz and 150 kHz produced measurement errors on an electricity meter. In cooperation with VDE Institute, the Project Group "Reliability and consistent measuring accuracy of electricity meters and components" at the Network Technology/ Network Operators Forum (FNN) within VDE aimed to shed light on the issue.

In the greater Berlin area, eleven meters were tested for frequency fluctuations in everyday use. The meters were installed in private homes with photovoltaic systems, in apartment blocks, small and medium-sized commercial buildings and in a waste water pumping station. There was virtually no evidence of any high current levels at frequencies of more than 20 kHz. Only at the waste water pumping station higher levels of current at higher frequencies were detected. The measurements in buildings equipped with PV systems did not reveal any direct connection between the output of the PV systems and the level of high-frequency spectral components in the current.

Further inspection took place at the VDE laboratory, where two interference immunity tests were performed on eleven electronic meters and one electromechanical meter. A different functional principle for measuring the current in the meters was adopted for each of the appliances (Rogowski coil, measuring resistance, transformer, hall sensor) to reasonably reflect the diverse appliances available in the market.

Just one of the twelve electricity meters that were tested produced a measurement error. As such, it seems unlikely that electronic electricity meters are continuously sensitive to symmetrical interference currents in the frequency range up to 150 kHz. The current measuring principle of non-interference immune meters was also applied to other tested meters, where no measurable influence was detected. In conclusion, the VDE experts ascertained that the strong deviation was the result of the special design of this one meter and did not constitute a general problem that all electronic electricity meters faced with this current measuring principle.

In addition to numerous other notices and tests for the reliable operation of electricity meters, the "Reliability of electricity meters and components" recommended practice guideline published by the FNN also includes the results of the analysis described above as an additional interference immunity test for electronic electricity meters. Manufacturers and users of electronic electricity meters can already apply the tests envisaged in the guideline, even prior to the final conclusion of the international standardization process.

VDE Institute offers EMC testing and ancillary electronic meter tests from the FNN guideline as part of their licensing inspections or during the product development cycle. Service life and conformity tests are equally offered.

Contact

Dr. Stephan Kloska
Tel.: +49 69 8306 747
Fax: +49 69 8306 620
stephan.kloska@vde.com

VDE Certification Marks

Online Service
Customer Portal

VDE-approved products

Unlawful use

Customs
Check of imports

E-Mobility
Safety, Performance, EMC, Infrastructure

Smart Metering
Approval, Accuracy Interoperability

Imprint | © 2015 VDE Testing and Certification Institute

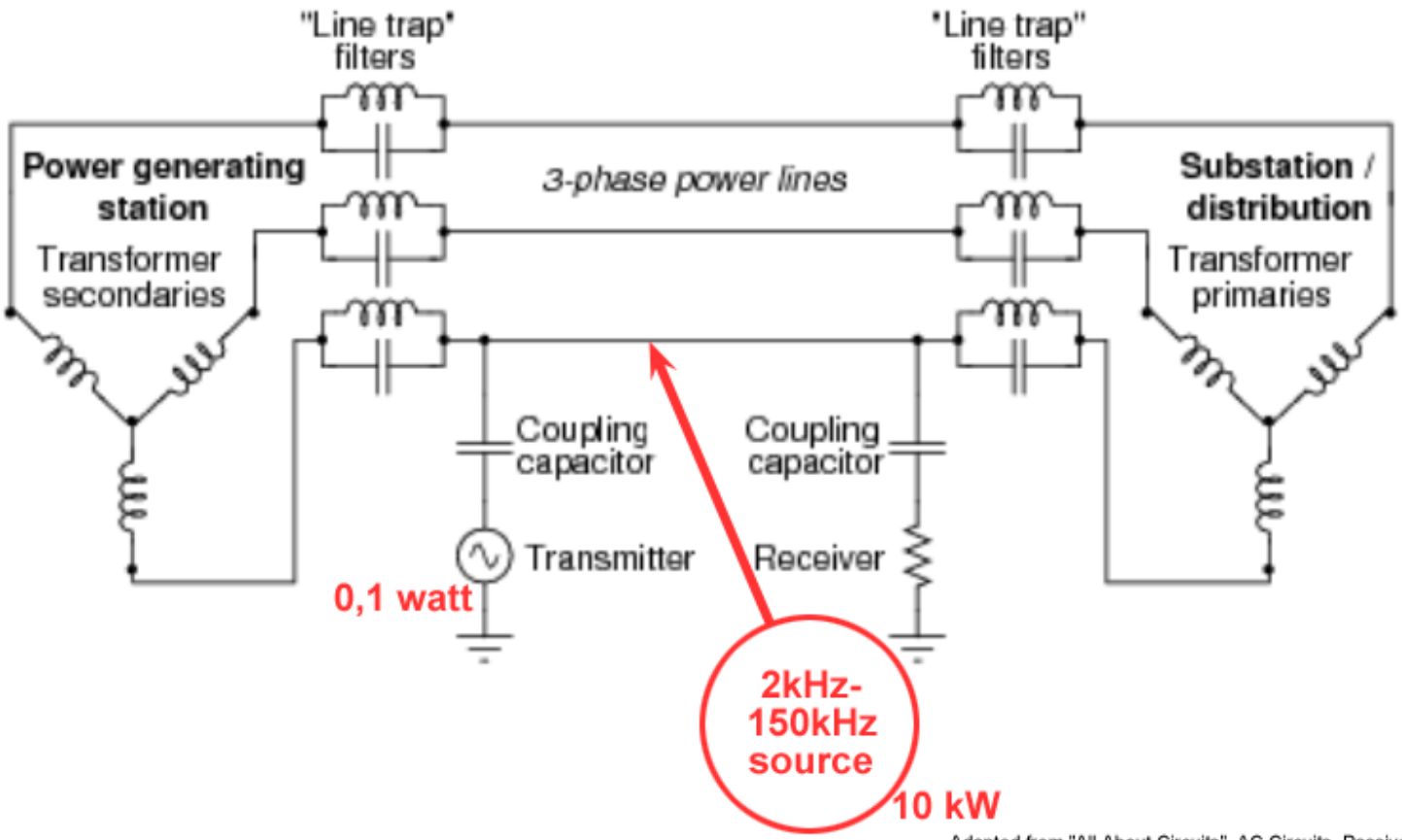
Errors in kWh readings as high as 35% have been reported...

EMC-ESD Event 2019

# Touch-controls, and dimmers, for lamps

Problems caused by 2kHz-150kHz emissions

# PLC interference – blocks meter readings




Adapted from "All About Circuits", AC Circuits, Passive filters

EMC-ESD Event 2019

# Why 2kHz-150kHz emissions problems are suddenly getting worse.

1. Big increase in powerful inverters – increased emission sources. PV inverters, battery storage, fuel cell, etc.
2. Increase in variable frequency motor drives, power supplies, and other smaller sources.
3. Increase in high-efficiency transformers – increased emission conduction.
4. Increase in high-frequency filters (high tech equipment) – increased emission sensitivity and risk of damage.
5. Increase in reliance on PLC for meter readings – increased emission sensitivity.

**The 2kHz-150kHz problem is rapidly getting worse.**

EMC-ESD Event 2019

# What can be done about 2kHz-150kHz problems?

50 Hz – 2kHz – Harmonics regulations and standards
150 kHz and higher – EMC regulations and standards
Until recently, 2kHz-150kHz – Wild West – no rules!

**1. New standards will help.**

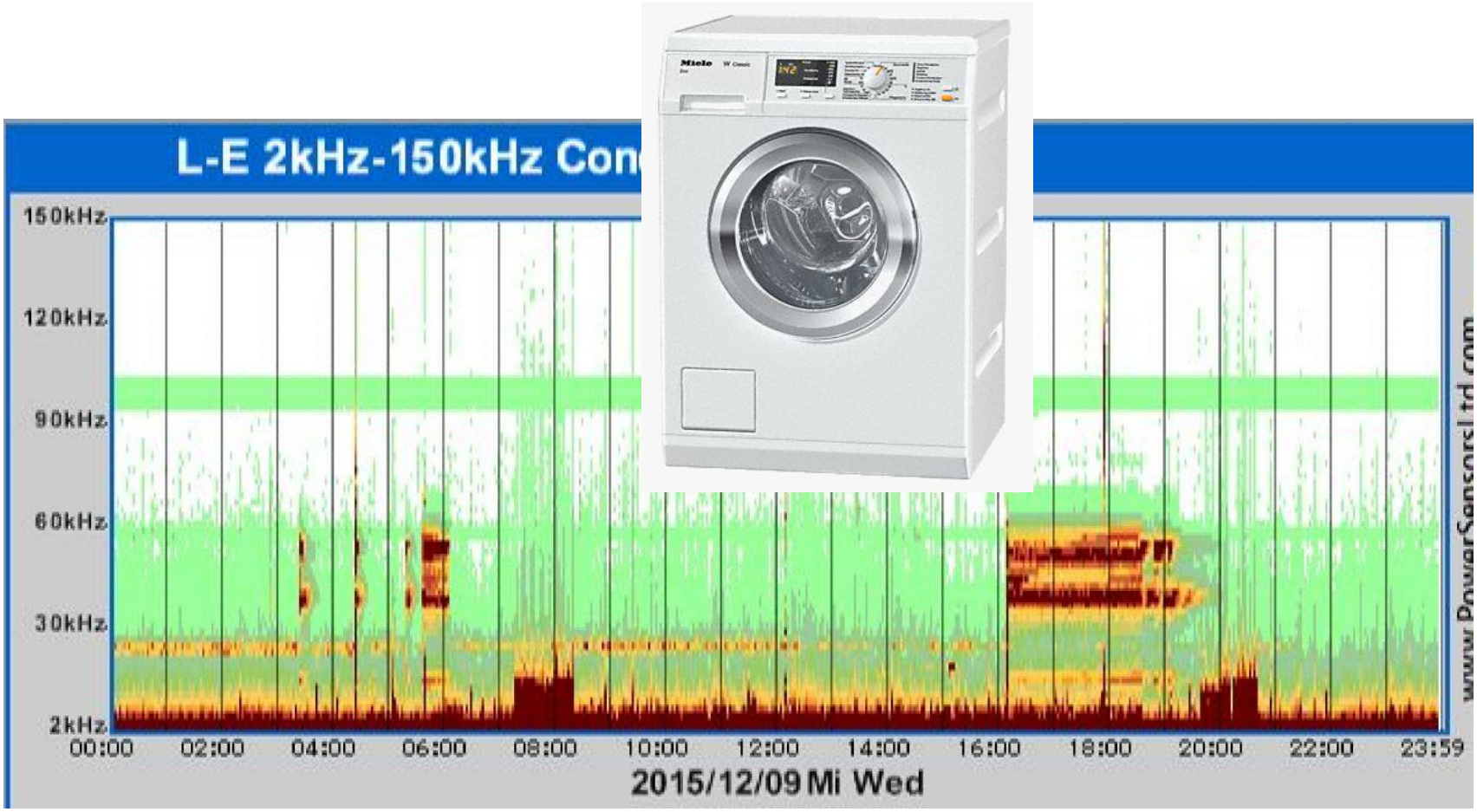
| Regulatory Agency | Conducted Limits for Electronic (RF) Lighting Devices |
|---|---|
| FCC Part 18 | Frequency (MHz) / Maximum RF line voltage measured with a 50μH/50 ohm LISN (μV)<br>Non-consumer equipment:<br>0.45 to 1.6 ..... 1000<br>1.6 to 30 ..... 3000<br>Consumer equipment:<br>0.45 to 30 ..... 250<br>(1000 μV = 60 dBμV; 3000 μV = 69.54 dBμV) |
| CISPR 15 | Frequency range / Limits dBμV/V: Quasi-peak / Average<br>9 kHz to 50 kHz** : 110 / –<br>50 kHz to 150 kHz** : 90 to 80*** / –<br>150 kHz to 0,5 MHz : 66 to 56*** / 56 to 46***<br>0,5 MHz to 2,51 MHz : 56 / 46<br>2,51 MHz to 3,0 MHz : 73 / 63<br>3,0 MHz to 5,0 MHz : 56 / 46<br>5 MHz to 30 MHz : 60 / 50<br>* At the transition frequency, the lower limit applies.<br>** The limit values in the frequency range 9 kHz to 150 kHz are considered to be "provisional limits" which may be modified after some years of experience.<br>*** The limit decreases linearly with the logarithm of the frequency in the ranges 50 kHz to 150 kHz and 150 kHz to 0,5 MHz.<br>NOTE In Japan, the limits in the frequency range 9 kHz to 150 kHz are not applicable. Moreover, the limits 56 dBμV/ quasi-peak and 46 dBμV) average apply between 2,51 MHz and 3 MHz. |

IEC 61000-4-19 – testing revenue meters for immunity

**IEC 61000-4-30 - in-situ measurements of 2kHz-150kHz emissions**

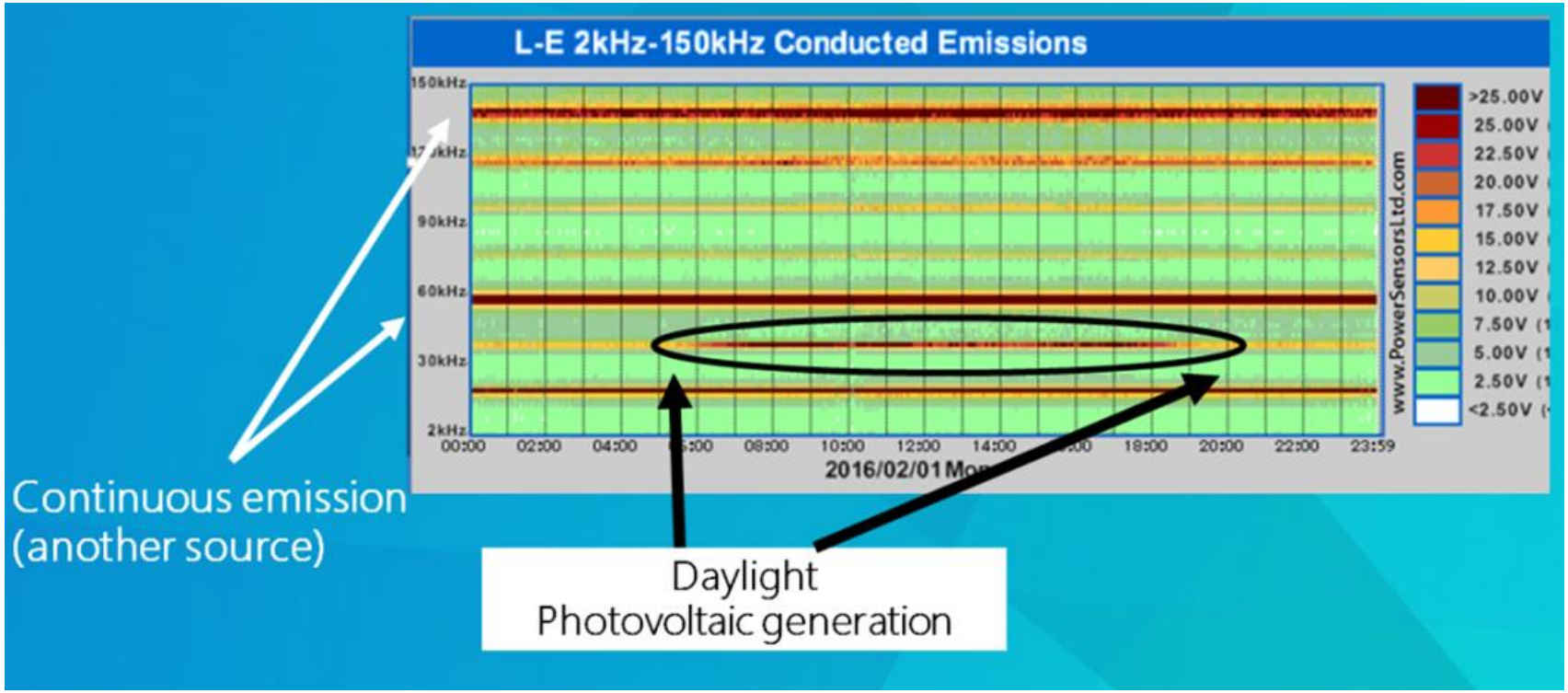
EMC-ESD Event 2019

# 2kHz-150kHz emissions – real world examples



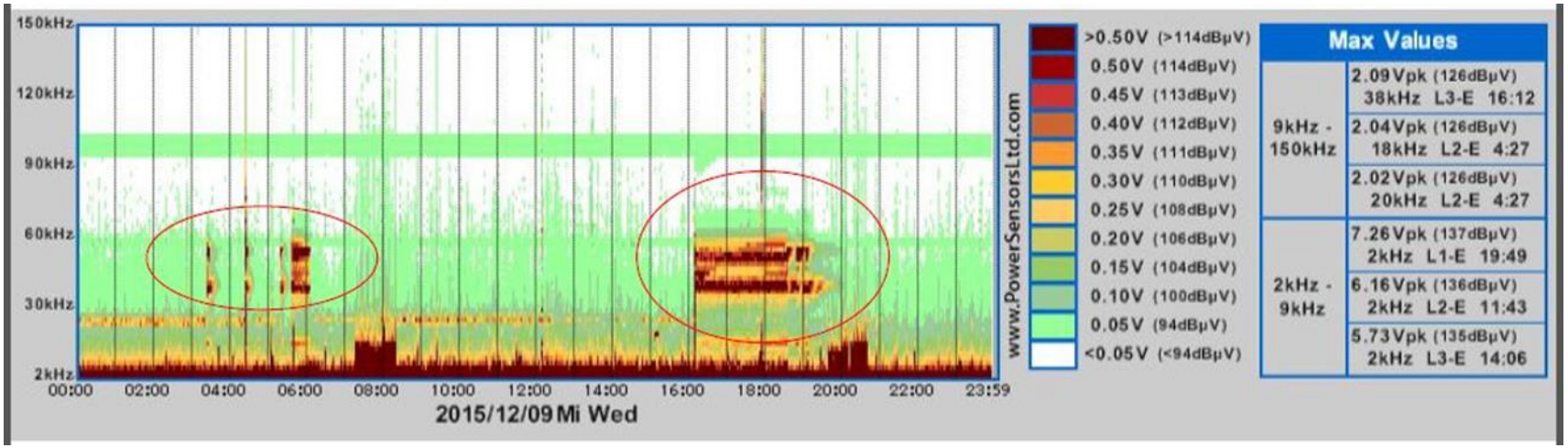

EMC-ESD Event 2019

# 2kHz-150kHz emissions – real world examples




EMC-ESD Event 2019

# 2kHz-150kHz emissions – real world examples

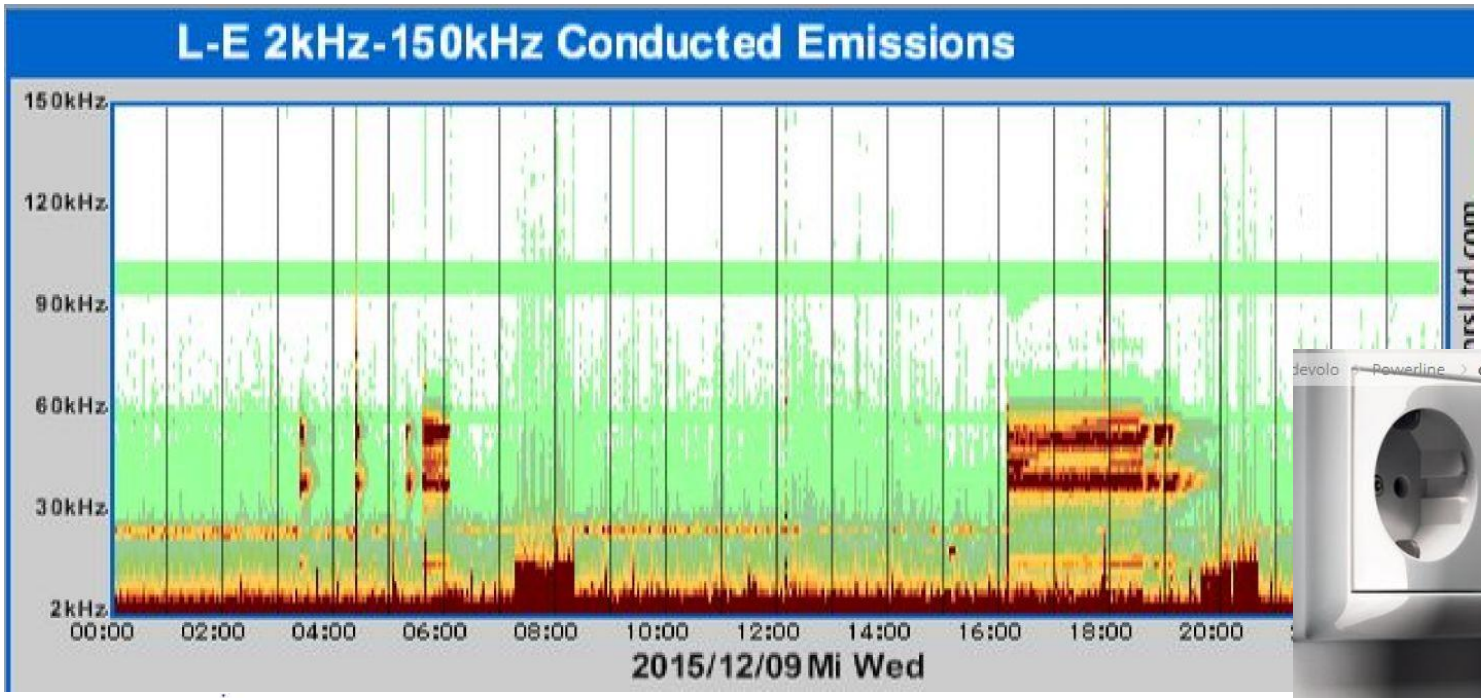




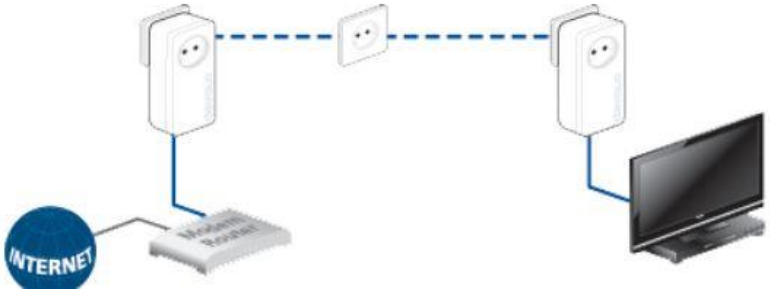
Car Charger

EMC-ESD Event 2019

# 2kHz-150kHz emissions – real world examples

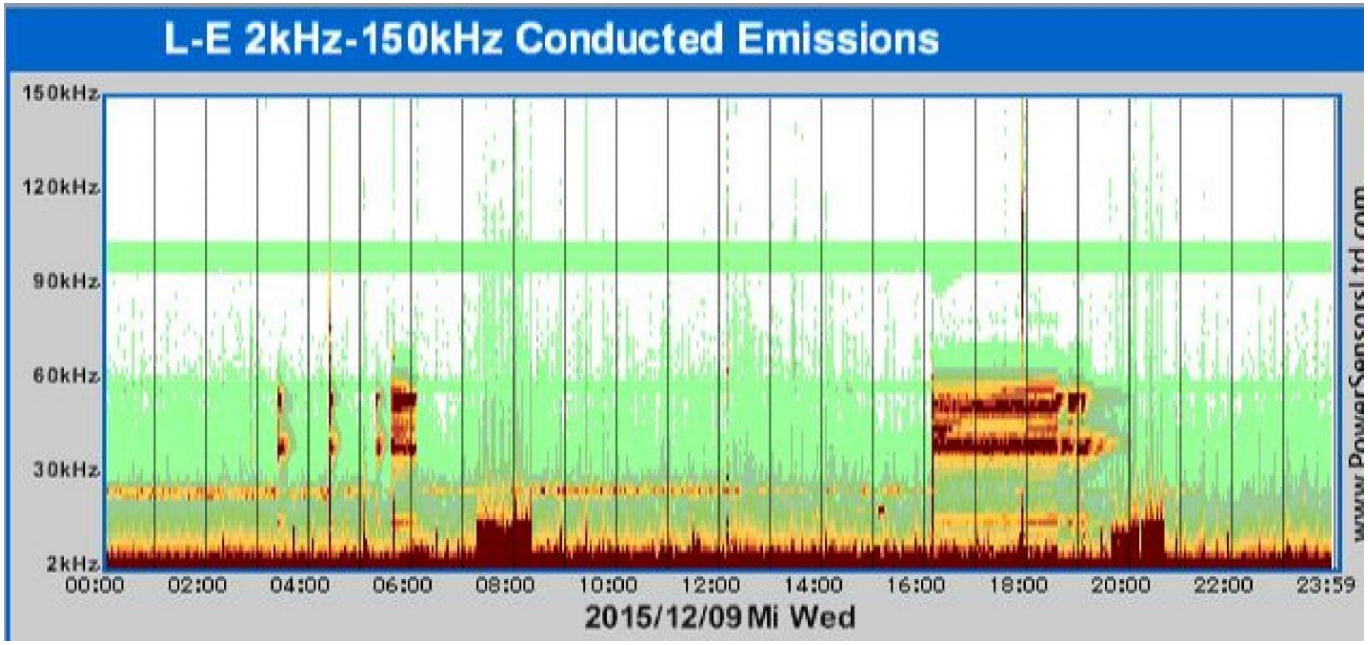






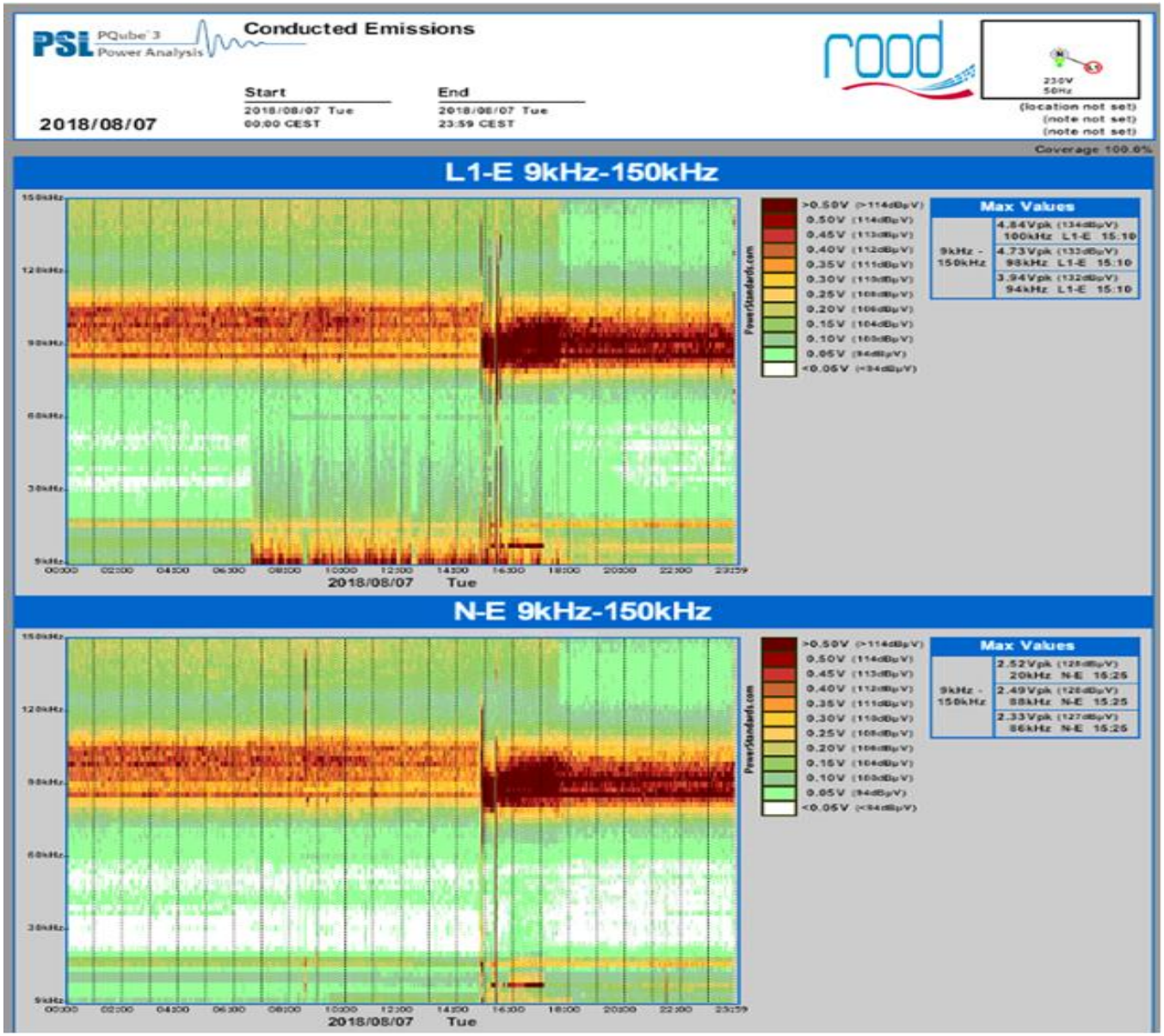

EMC-ESD Event 2019

# 2kHz-150kHz emissions – real world examples




EMC-ESD Event 2019

# 2kHz-150kHz emissions – real world examples

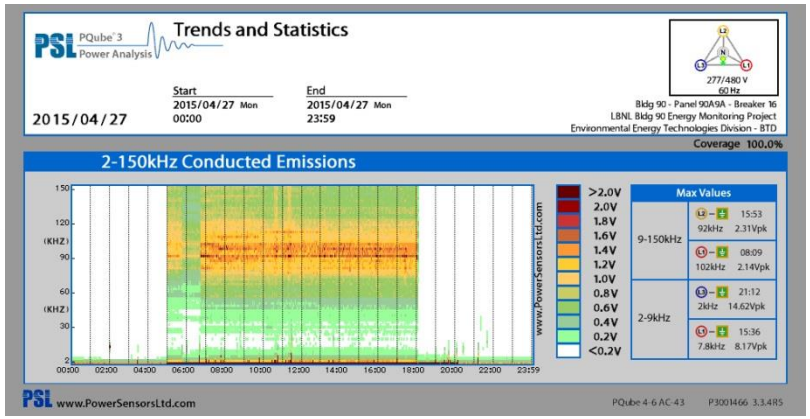



Installation Airco installation - Office C.N.Rood, Zellik (BE)

EMC-ESD Event 2019

# Conclusions: 2kHz-150kHz emissions

1. They're getting worse.
    a. More sources, and stronger sources.
    b. Better coupling through the grid.
    c. More sensitive loads.
2. Standards are coming.
3. Start by measuring and understanding.




EMC-ESD Event 2019

# Contact gegevens

Nederland:

C.N.Rood BV
Arthur Hartsuiker
Blauwroodlaan 280
2718 SK Zoetermeer
Email: ahartsuiker@cnrood.com
Tel.: + 31 (0) 79 36 00 018

België:

C.N.Rood NV/SA
Rudy de Winter
Z.1 Researchpark 40
1731 Zellik
Email: rdewinter@cnrood.com
Tel: +32 (0) 2 467 03 50

EMC-ESD Event 2019