# In-situ measurements on HFPQ

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## *ABSTRACT*

*Emission problems in the frequency range 2 to 150 kHz gain interest, as more problems are noticed in both domestic environments and light industrial environments. The most appropriate commercially available measurement probe to perform in situ measurements in this frequency range is discussed. Two real life problems analysed with this method are described.*

## INTRODUCTION

The low voltage distribution networks experience a large shift in consumer topology. This new topologies and applications change the emission and immunity behavior on the low voltage grid. Most household appliances contain SMPS (switched mode power supplies), which are sources of high frequency disturbances. Also, the increased use of decentralized energy sources, using grid connected inverters to inject the generated power into the grid, causes higher frequency harmonics to pollute the grid voltage. These emitted PCH (Power Conversion Harmonics) range from 2 kHz to several MHz and are related to the PWM switching behavior.

The emission and immunity in the 2 kHz to 150 kHz range is a fast evolving area. Standards are still under consideration. For measurements, test engineers are nowadays designated to measurement methods used in adjacent frequency ranges, meaning 0 to 2 kHz (harmonics) and 150 kHz – 30 MHz (conducted emission). The only partially related standard is the EN 50065 on low voltage network signaling (power line communication). In the latter, specific artificial mains networks (AMN) are described. The search for an appropriate measurement method under laboratory conditions is discussed in [1].

Besides the laboratory measurement probes giving accurate and reproducible measurements, test engineers need also measuring tools for troubleshooting purposes. This paper discusses the demands for and choice of an appropriate in situ test probe. The paper is arranged as follows. The first chapter discusses the measuring devices suitable for the considered frequency range. The second chapter discusses two normally used devices for in situ EMI measurements and which of these are preferred for in situ HFPQ measurements. The third chapter discusses two real life emission problems in the HFPQ range.

## MEASUREMENTS BETWEEN 2 AND 150 KHZ

In this section the most common measurement probes in the range 2 and 150 kHz, mentioned in the standards are discussed in this section. To be valuable for a wide range of field engineers, low and medium cost probes are selected.

### Artificial mains networks between 2 and 150 kHz

In CISPR16-1 [2], several types of AMN (Artificial Mains Networks) are defined. The topology of all AMN is similar, but the values of the used components are different. This makes the AMN suitable for frequencies between 9 kHz and 100 MHz. For the lower frequency range, the standard EN 50065 [3] mentions a modified AMN suitable between 3 kHz and 9 kHz (Fig. 1). This standard is similar to IEC 61000-3-8 [4].

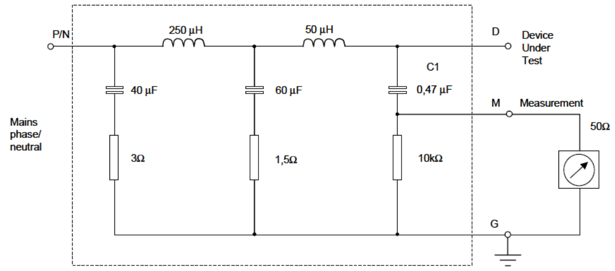


**Fig. 1: AMN 3 kHz – 9 kHz [4]**

### Current probe

Current probes can be divided in types using Hall-sensors and current transformers. They benefit from the ability to be clamped on a cable or wire. Fig. 2 shows a probe ranging from 20 Hz - 100 MHz. The sensitivity can be a problem for this type of probe in the considered range. Current probes are specially made to have a flat response in the high frequency range, but have a sharp roll-off in the low frequency range.

**Fig. 2: Current Probe R&S EZ-17**

Current probes based on Hall-sensors start from DC and commercially available probes give a flat response up to

30 MHz or more. The lowest current capability for commercially available probes is typically some hundreds of µA, in combination with a limited dynamic range. An example of a probe based on the Hall- principle is given in Fig. 3.

**Fig. 3: Current probe Tektronix TCPA300**

Rogowski coils are air-cored coils. The sensor is made of a helical coil, with starts and ends at the same side. This gives the possibility to open the coil to be put around a conductor. Another advantage of this setup is that interference will be cancelled out. Large diameters of coils are available on the market. In this way, large conductors and even common mode currents in shafts can be measured. The air coil results in a low inductance, making a high frequency response possible. Also due to the air coil, there is no saturation and the sensor is highly linear, even for large currents. The coils have a large dynamic range, but a limited sensitivity. For this reason, a dedicated Rogowski coil made for measuring currents below 100 µA will be of a homemade type. Rogowski coils can be used from the mHz-range up to some tens of MHz.

## Voltage probes

The 50/1500 Ω voltage probe is mentioned in CISPR16-1 [2] and proposed as an alternative for measurements where no AMN can be used in CISPR 11 [5] (fig. 4). This probe is based on a capacitive resistive voltage division.

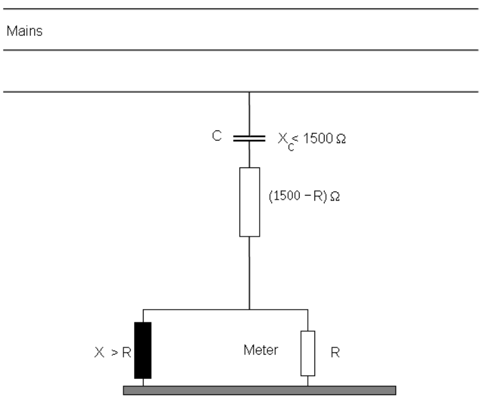


**Fig. 4: Voltage probe**

Capacitive probes are based on a capacitive voltage division. The capacitive voltage probe (CVP) (fig. 5) is allowed by CISPR 22 [6] as an alternative for ISN's (impedance stabilization network). These networks are similar to AMN's, but are specific for data cables, e.g. coax or UTP (unshielded twisted pair). The CVP is intended to measure between 150 kHz and 30 MHz. Commercially available CVP's show a linear behavior down to 10 kHz, which make the probe suitable in the considered range.

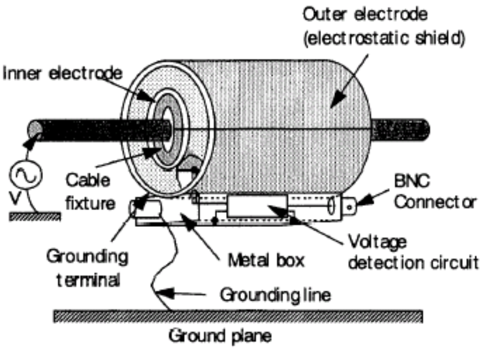


**Fig. 5: Capacitive Voltage Probe [6]**

## IN SITU MEASUREMENTS

Laboratory measurements and in situ measurements demand totally different properties of the measuring devices. For laboratory measurements, several conditions have to be met, in order to have a high reproducibility and accuracy. First of all, the measurement devices need sufficiently high accuracy. This asks for a calibration of the recording device (spectrum analyser, EMI-receiver or oscilloscope) and all used probes and for a first and second level control. Secondly the environmental conditions are under control and not influencing the measurements. For reproducible measurements, requirements on the power supply are stated in the standards. This means that the voltage range and voltage distortion have to be monitored during the measurements. For most standards, the grid impedance is defined. Also temperature and humidity can be an issue.

Thirdly, the DUT (device under test) has a finite but non negligible settling time. For lighting products this can be half an hour. Additionally, some DUTs needs aging before testing. Finally, it is obvious that one device at a time is tested.

For in situ measurements, most requirements mentioned above cannot be met. As the main purpose is to find the source of the problem, these are of minor importance. As opposed to laboratory measurements, high accuracy and calibration are less important. Troubleshooting asks mainly comparative measurements. This means that the absolute level of the emission should not be known with a high accuracy. A certain accuracy is of course needed, for the experienced engineer, to see if the measured emission is at an unexpected high level. A simplified first level control is necessary for all measurements, both in laboratories and in situ. The impedance is not under control, but is also less important as comparative measurements are used. Finally, the largest problem in situ is caused by the background noise. Nevertheless, the case studies will point out that problems give a really distinct spectrum.

Up to this point, it is shown that in situ measurements are less demanding for the measurement apparatus than laboratory measurements. On the other hand, in situ measurements have specific needs. First, the field engineer should be equipped with a simple plug and play device for analysing. This means that the electrical circuits should not be interrupted for diagnosing. The AMN is for this reason not usable. Additionally, the high leakage current of an AMN is in most practical cases a problem. A clamp on device will be necessary. Secondly, the probe itself should not be heavy and voluminous, eliminating the capacitive voltage probe. Thirdly, due to the background distortion, the sensitivity should be sufficiently high. Commercially available Rogowski coils are for this reason not used [1]. For other current probes, the maximum measurable cable diameter can be important.

The field engineer normally uses two devices for solving EMI problems above 150 kHz, i.e. the current probe (EZ-17 or similar), due to its high frequency range (20 Hz – 100 MHz) and the large cable diameter that can be measured, and the voltage probe (PLIP or similar). Fig. 6 shows the result of the measurement with the current probe. Fig. 7 shows the same measurement with the voltage probe.

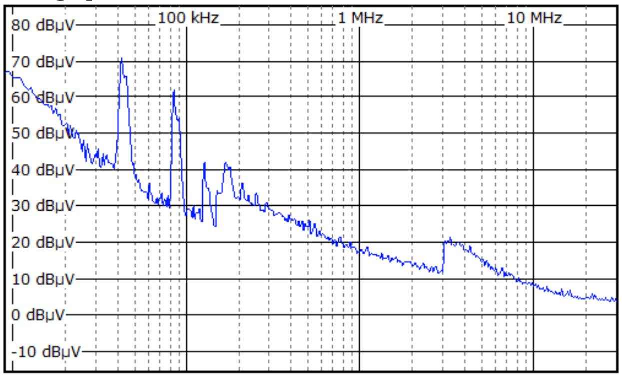


**Fig. 6. Measurement on CFL with current probe EZ-17**

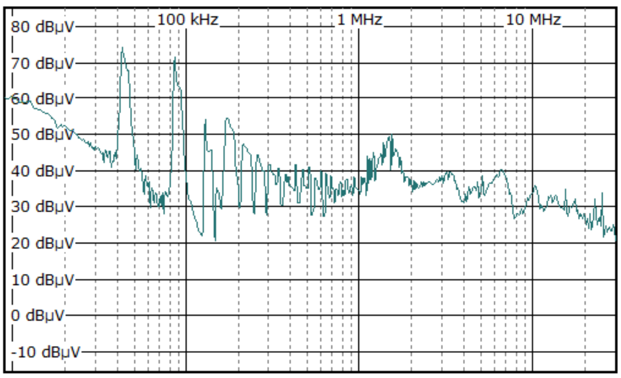


**Fig. 7. Measurement on CFL with voltage probe**

It is obvious that the voltage probe is much more sensitive and gives much more detailed measurements. The current probe suffers from the large attenuation at lower frequencies. The main parameter to consider is the transfer impedance. This impedance $z_t$ gives the relation between the measured voltage $v$ by the receiver and current $i$ in the wire. The datasheets normally mention the transfer impedance as a logarithmic value:

$$i_{db\mu A} = v_{dB\mu V} - z_{t\_dB\Omega}$$

(fig. 8). More sensitive current probes can be useful for these measurements.

To solve frequency problems in the range 9 – 150 kHz, the voltage probe can be used. The voltage probe has the advantage that the full range from 9 kHz up to 30 MHz can be measured, meaning that both HFPQ problems and EMI problems can be detected with the same setup. This is a large benefit, as initially it is not known what the real problem is. The voltage probe has a nearly flat attenuation characteristic of 30 dB (fig. 9), which is in practice compensated with a linear amplifier with 30 dB gain.

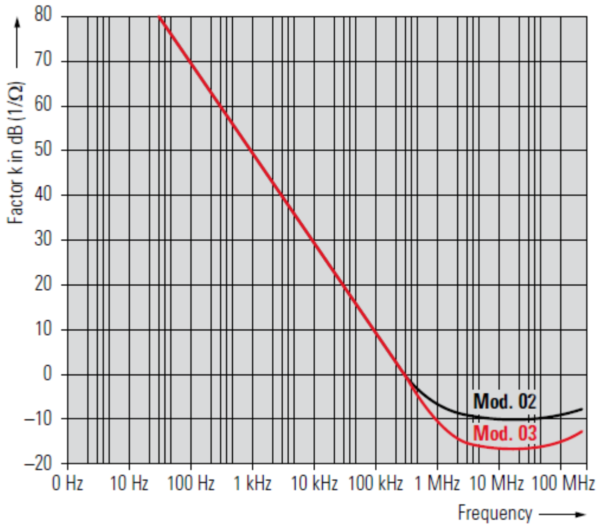


**Fig. 8. Transducer factor of the current probe (datasheet)**

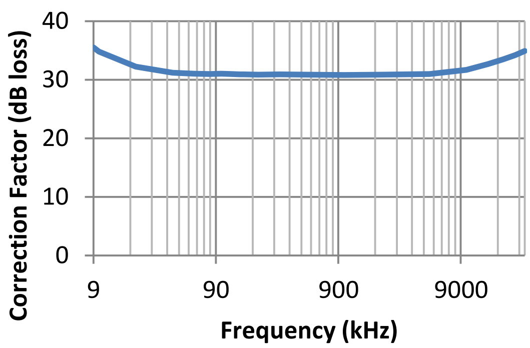


**Fig. 9. Attenuation factor of the voltage probe (calibration data)**

## CASE STUDIES

### Case 1 : Exterior lighting disturbing home automation system

The first problem analysed in the range 2 – 150 kHz was a disturbance of a home automation system. More precisely, the communication between the master and an outdoor unit was disturbed. Experiences of the residents showed that the exterior lighting caused the problem. The voltage probe was placed at the electrical distribution point of the house. Measurements with the voltage probe (fig. 10) showed a high level of emission around 40 to 47 kHz. Particular frequencies can be seen, as the 12 lights did not switch at the same frequency. With a binary searching method, it was found that only the lights switching at 41,52 kHz caused a problem. The problem was solved by replacing these lights.

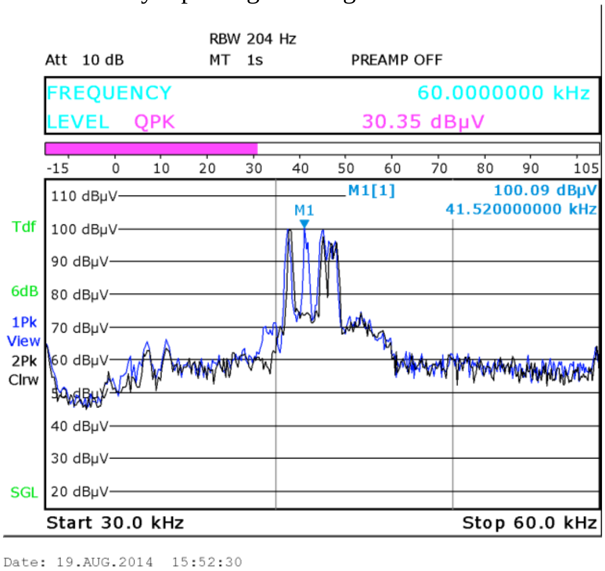


**Fig. 10. In situ measurement case 1**

### Indoor lighting disturbing touchscreen of a smartphone

The second problem involved a SME programming games on smartphones. When entering their new building, several employees had problems with the touchscreens of their smartphones, making it impossible to work.

Measurements were done on the low voltage grid on an arbitrary socket with the voltage probe. The voltage probe has the benefit that no free wires to clamp the probe on have to be found, any socket suffice. Due to the propagation of the lower frequencies, emission can be found in the full grid at every socket. The emission was extremely large in this case (fig. 11), with a level over 130 dBµV. A binary search method identified that the lighting caused the problem. The search was impeded because the emission only increased after the lights were switched on for 10 minutes, due to the heating of the armature. After searching it was found that the emission was caused by the HF ballast of one light, which had a failure in the EMI-filter.

The additional benefit that the device measures up to 30 MHz can be seen here. The switching harmonics are high, but the full emission is extremely high.

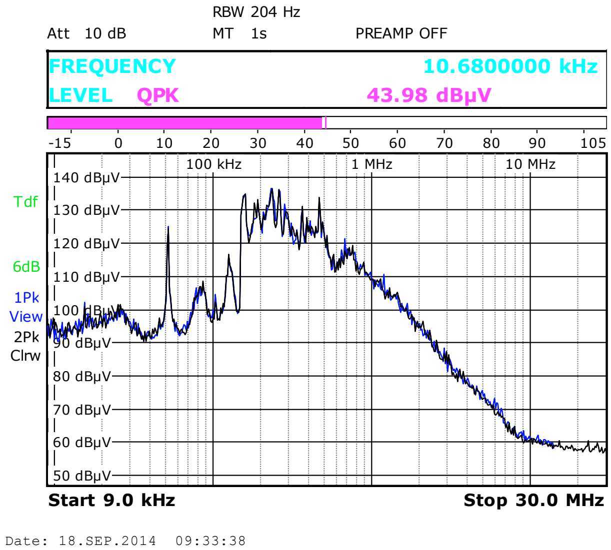


**Fig. 11. In situ measurement case 2**

## CONCLUSION

In this paper the search for a valuable tool for in situ measurements on HFPQ is discussed. The search is limited to commercially available devices. It is shown by arguments that the voltage probe, as described in CISPR16-2, has the largest benefits. Two real life cases proof that problems can be analysed in a very efficient way.

## REFERENCES

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