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doi:10.15199/48.2025.03.50

An approach to measurements of radiofrequency conducted emission of power drives

Abstract. Measurement of radiofrequency conducted emissions is a very important part of testing electromagnetic compatibility. Different emission levels are established depending on the environment in which the equipment operates (domestic, industrial). The article presents a research stand used for didactic purposes according to the standard PN-EN 55011, which specifies the frequency range between 150 kHz and 30 MHz. The tested object is a one-phase power drive system in which, alternatively, one of two asynchronous motors can be chosen. The disturbance level depends on the motor cable's length and the cable shield's contact. The setup enables measurement with different cable lengths and grounded/floating shields. In addition, the stand is also intended to select and verify filter components.

Streszczenie. *Pomiar emisji przewodzonych częstotliwości radiowych jest bardzo ważną częścią badań kompatybilności elektromagnetycznej. W zależności od środowiska (domowe, przemysłowe), w którym pracuje określone urządzenie, ustalone są różne dopuszczalne poziomy emisji zaburzeń elektromagnetycznych. W artykule przedstawione jest stanowisko badawcze wykorzystywane w celach dydaktycznych. Pomiary dokonywane są zgodnie z normą PN-EN 55011, która określa zakres częstotliwości od 150 kHz do 30 MHz. Przedstawionym w artykule badanym obiektem jest jednofazowy falownik napędzający silnik asynchroniczny. Wpływ na generowany poziom zakłóceń wpływa m.in. długości przewodu oraz podłączenie jego ekranu do lokalnej masy odniesienia. Zaprezentowany układ umożliwia pomiar dla różnych długości przewodów oraz uziemionych lub nie ich ekranach. Ponadto stanowisko posiada również możliwość doboru i weryfikacji gotowych filtrów lub elementów filtrujących.* (**Pomiary radioelektrycznej emisji przewodzonej napędów falownikowych**)

Keywords: conducted emissions, power drive system, common and differential mode disturbance, RF suppression filter
Słowa kluczowe: zaburzenia przewodzone, układ napędowy, zaburzenia asymetryczne i symetryczne, filtry RF

Introduction

Laboratory tests performed in order to fulfil requirements of the according's rules in the relevant standards [1, 13] allow measurements to be carried out comparably, minimizing the number of factors that may affect the measurement result. This is particularly important in measurements related to electromagnetic compatibility (EMC). Depending on the tested device, the standards for EMC contain specific requirements for the work performed, and in particular, in the light of this study, this concerns the permissible level of radio frequency interference, test methods and equipment used [5].

According to the EMC definition, a device should not interfere with other devices' operation and should be immune to electromagnetic interference (EMI) [2-4]. Measurement of disturbances emission is one of the fundamental issues of EMC [1, 13]. Different interference levels are permissible depending on the electromagnetic environment in which a given device operates, as the relevant regulations specify. The emission test is aimed at verification whether the EM field intensity generated by the device does not exceed the permissible levels defined by the appropriate standards. This is even more important in an industrial environment [6, 7].

In EMC, the frequency range of the considered interference disturbances is of crucial importance, as it is closely related to the method of propagation and has impact on the operation of the exposed device or installation. In most standards, the measurement of conducted radio disturbances is specified in the 150 kHz – 30 MHz frequency range. However, for example, for special-purpose devices, the required measurement may be 9 kHz – 30 MHz [8].

EM disturbances are divided into conducted and radiated groups. Conducted disturbances arise as a result of current flowing in wires and connectors, while radiated disturbances propagate thru the air [10].

Due to the growing number of electrical and electronic devices and the importance of their functions, ensuring an appropriate level of EMF will play an increasingly important role.

The presented measurement setup and procedure is used in EMC laboratory at the WUT for the 1st level of graduate studies.

Measurement method and test setup

The measurements were made in the band B (150 kHz – 30 MHz frequency range) according to the standard [1, 13]. The diagram of the measuring setup is shown in Fig. 1. It consisted of a disturbance meter, the tested device EUT (Equipment Under Test), and a Artificial Mains Network (AMN/LISN - Line Impedance Stabilization Network). AMN has to connected with ground reference plate (GRP). Our EUT is power drive system composed of frequency inverter (FI), motor cable and asynchronous motor. EUT has to be situated above the GRP and isolated from it. The FI and motor are situated on the two different local reference grounds.

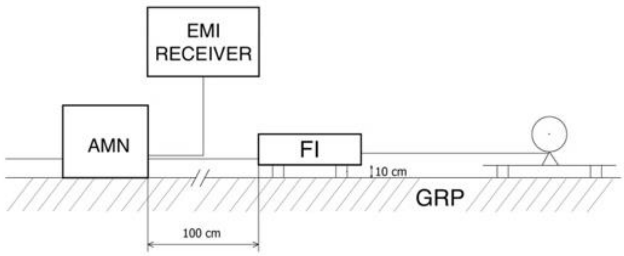


Fig. 1. Schematic of the test stand

The measurement setup is shown in Fig. 2. It consists of an AMN Schwarzbeck NSLK 8127 RC (1.) by which the RF port is connected with EMI receiver Gauss Instruments TDEMI X located on another table via coaxial 50 Ω cable. The main cord is plugged to the EUT port of AMN (3.). In the main cord the segment with removed outer isolation is inserted. It will be used for measurement common and disturbance mode of disturbances.

The EUT is a power drive system composed of frequency inverter - FI (4.), motor cable (2.) and asynchronous motor (5.). The inverter has a constant switching frequency. The inverter can be connected via cables of different lengths and type (2.).

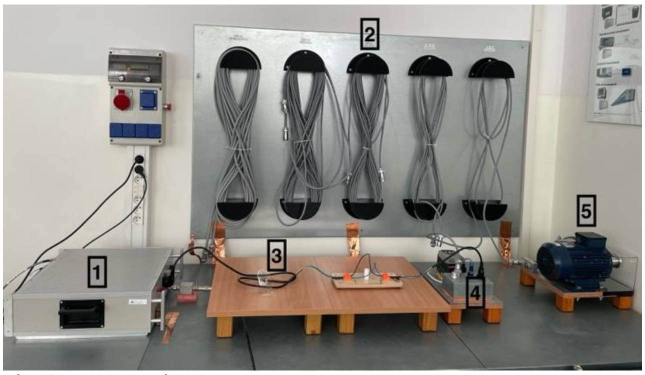


Fig. 2. Test stand

The cables (2.) were at the appropriate height from the reference ground and were intentionally wound in a "figure eight" to avoid a coil effect. This article aims to show how important factor is the cable length between the motor and the inverter. The cable shield can be connected to or be disconnected from the local ground reference on both sides of the EUT, i.e. on the motor side or FI side.

EMI was measured using the Time Domain method, which is much faster than the traditional method [11]. It it equipped with MaxPeak, Quasi-Peak Average, RMS, CISPR-AVG and CISPR-RMS detector.

The measurements were performed by frequency filter IF-Bandwidth of 9 kHz using a quasi-peak (QP) and the CISPR-AVG average detectors. EMI receiver has ability to choose the line or N in the AMN.

The disturbance level measurement was performed successively for the line and neutral wires. Carrying out measurements with it requires configuring the elements of the measurement path. The measuring path consisted of a 3 m coaxial cable with a 20 dB Schwarzbeck pulse limiter (Fig. 3) connected to the RF output of the mains stabilizer.

Fig. 3. Pulse Limiter

The differential and common modes disturbances were measured using the Fischer Custom Communications RF Current Probe (Fig. 4).

Fig. 4. Current Probe

Measurement procedure

The background measurements were first carried out before starting the main part of the measurements. This way, the level of disturbances that existed inside the laboratory environment reaching the tested system were determined. This is the reference level of disturbances. Its level is presented in Fig 5. Norm requirements is that the background noise must be at least 6 dB below the used limits. The Fig. 5 show confirms that laboratory setup fill fills requirements standards.

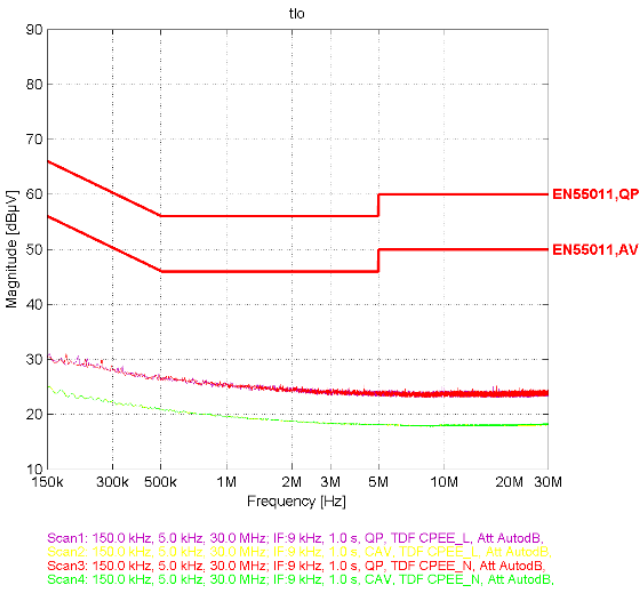


Fig. 5. Measurement of the background

The power drive system was set to an operating frequency of 50 Hz for measurements. LiYCY 4*1.5 cables with lengths of 5 m, 10 m, 20 m, and 30 m were tested, the shielding of which were connected to the local reference ground at both ends.

The measurement results for the 5 m cable length are presented in Fig. 6 and for 30 m cable length is shown in Fig. 7.

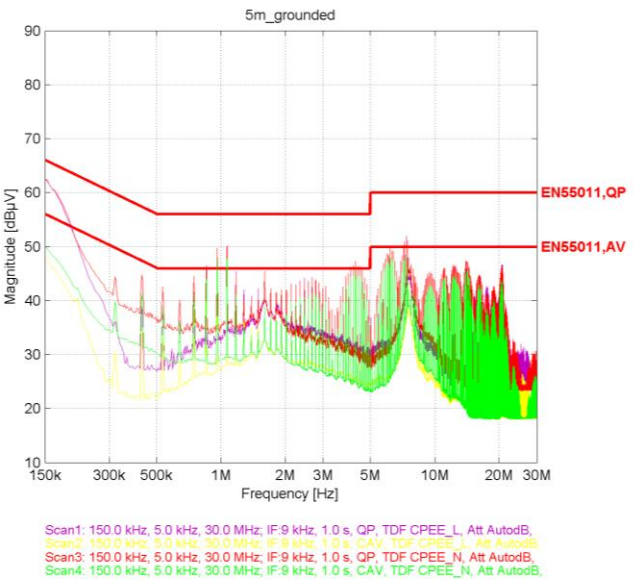


Fig. 6. Measurement of the 5 m cable shield connected to the local ground on both sides

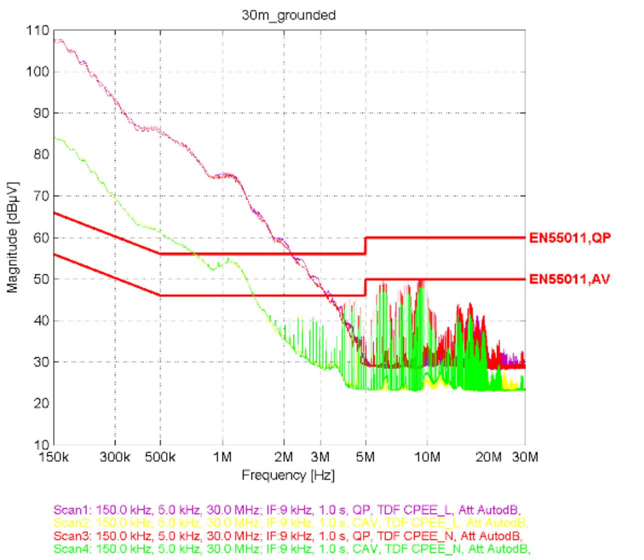


Fig. 7. Measurement of the 30 m cable shield connected to the local ground on both sides

With the increased cable length, the low and medium frequency range disturbances increased significantly. The greatest difference was recorded in the low-frequency ranges, significantly exceeding the applied permissible levels of disturbances.

Next, for the lengths of 5 m and 30 m, measurements were made with the shield disconnected from the local reference ground on the inverter side and at both ends.

The waveforms for a 30 m long cable with the shield disconnected from the inverter side are shown in Fig 8. The variant with the screen disconnected at both ends is shown in Fig. 9.

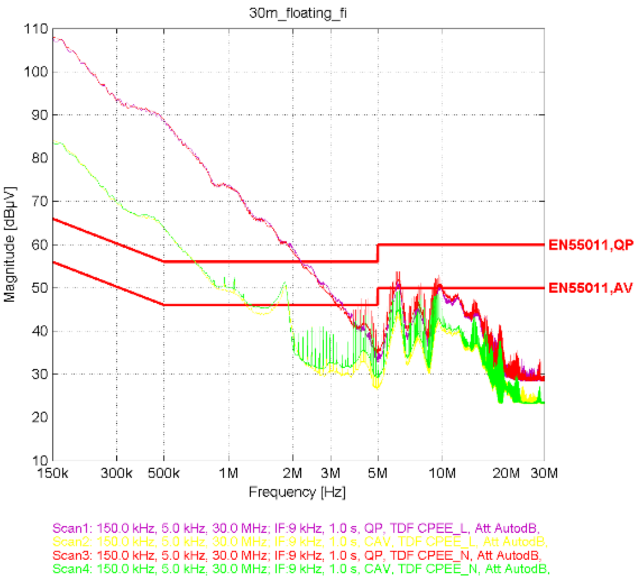


Fig. 8. Measurement of the 30 m cable shield floating on FI side

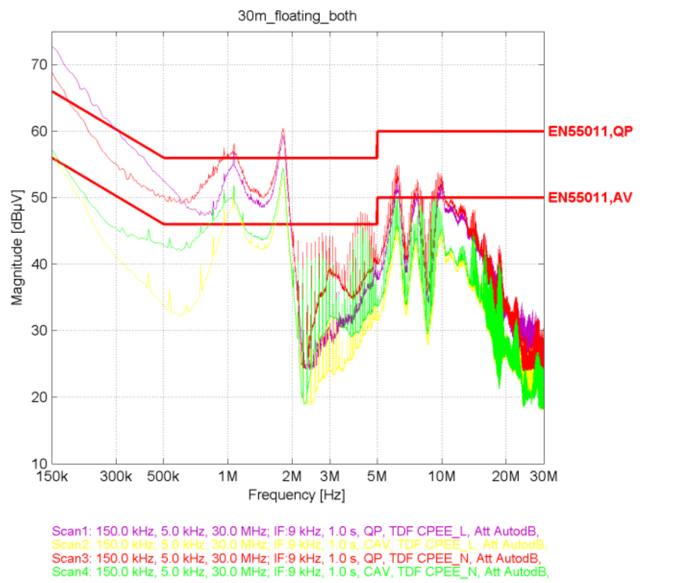


Fig. 9. Measurement of the 30 m cable floating on both sides

Disconnecting the screens significantly increased the level of disturbances, especially in the high-frequency range and, to a lesser extent, in the medium range. It is worth noting that when the screen was disconnected at both ends, the disturbances in the low-frequency range decreased.

The standard [15] requires the cable shield to be connected to the local ground reference on FI and motor sides.

These measurements were intended to determine the worst case. Before starting to suppress the recorded disturbances, measurements of the differential mode (DM) and common mode (CM) components were measured [14]. The DM and CM schema is shown in Fig. 10.

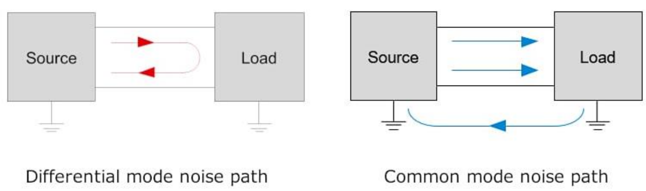


Fig. 10. Illustration of the DM and CM disturbances in two conductors line with ground reference.

The level of common mode (CM) disturbances (Fig. 11) was higher than differential mode (DM) disturbances (Fig.12).

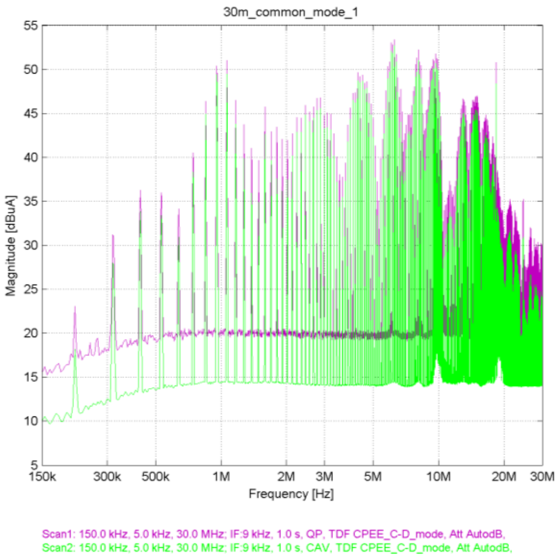


Fig. 11. Common mode disturbances for 30 m cable

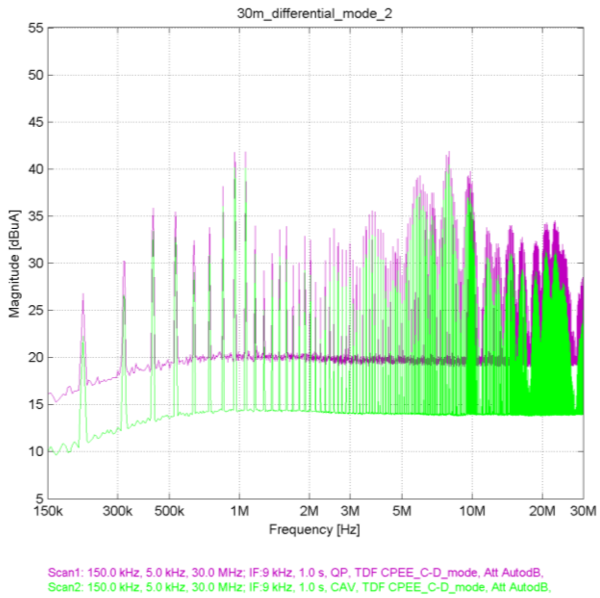


Fig. 12. Differential mode disturbances for 30 m cable

The next step was to compare three ready-made Schaffner filters shown in Fig. 13 (A: FN2010, B: FN2030, C: FN2090).

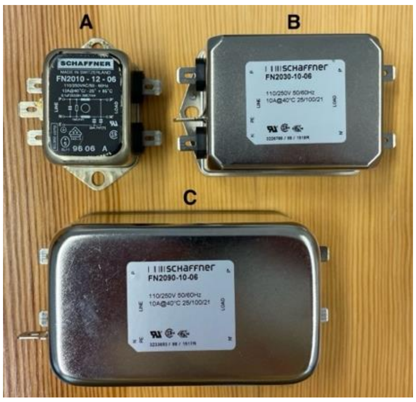
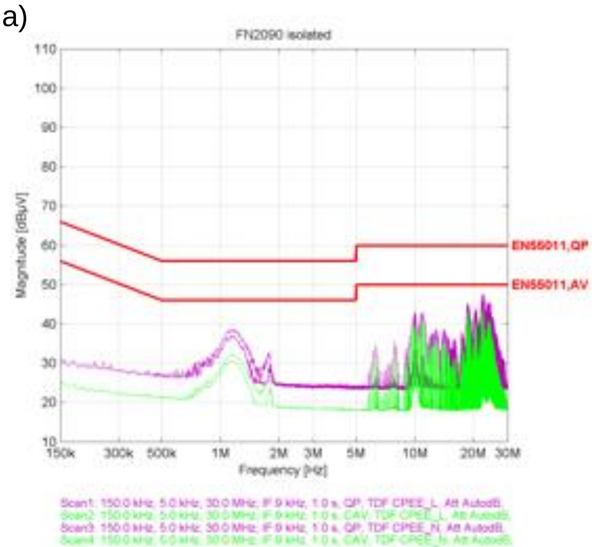


Fig. 13. Schaffner filters

Each of them, for comparison, was tested with correct assembly - connection of the filter housing to the local reference ground and incorrectly, where the filter housing was isolated from the reference local ground. Correct assembly significantly affected the disturbances in the high-frequency range. The measurements results for the FN2090 filter are shown in Fig. 14 (a - incorrectly mounted, b - correctly mounted). For the FN2030 filter measurement result shown in Fig. 15 (a - incorrectly mounted, b - correctly mounted).

a)



b)

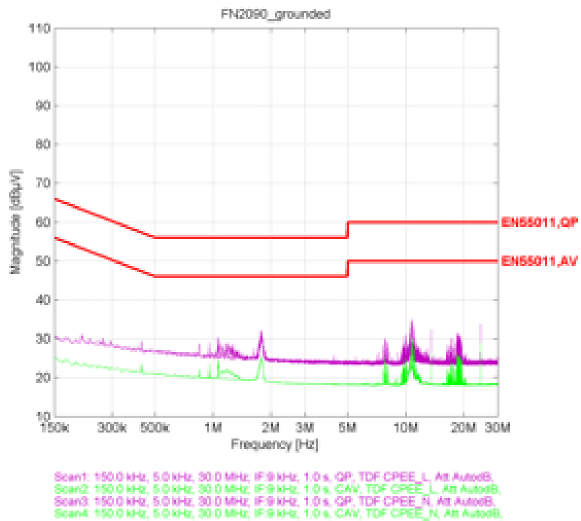


Fig. 14. Measurement of Schaffner FN2090 filter
a) Filter isolated from the local reference ground
b) Filter grounded to the local reference ground

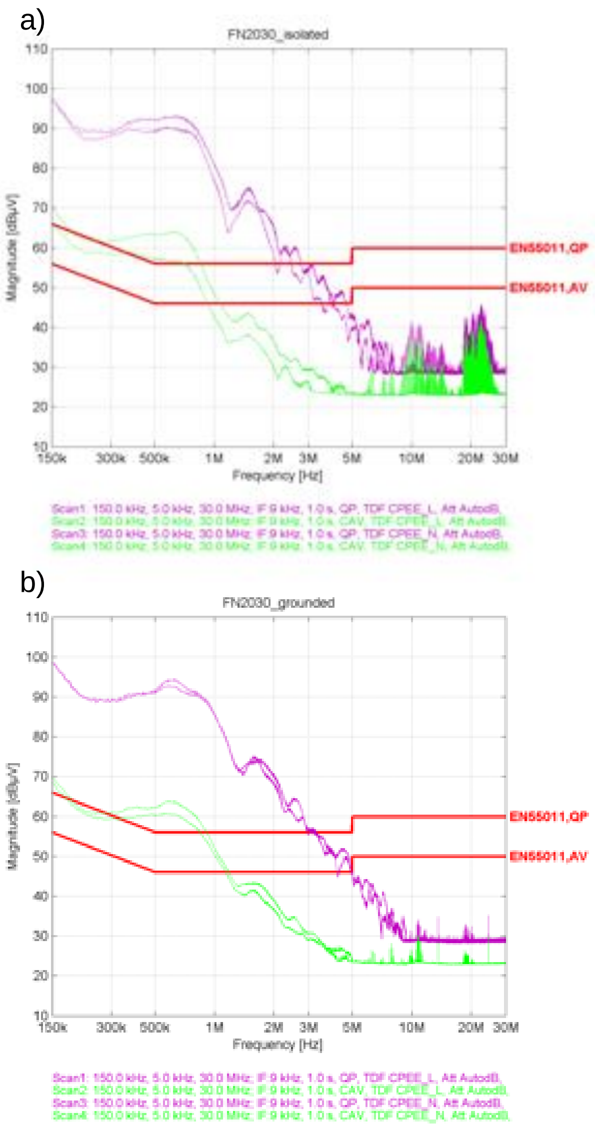


Fig. 15. Measurement of Schaffner FN2030 filter
a) Filter isolated from the local reference ground
b) Filter grounded to the local reference ground

The FN 2090 filter proved to be the most effective. The efficiency of the FN 2010 and FN 2030 filters were comparable. Only the FN 2090 filter ensures the meeting of requirements specified in the standard [1].

At the end, a self-made filter was tested, the topology of it was shown in Fig. 16. Its efficiency was measured for isolated and with the Cy capacitors connected to the PE wire.

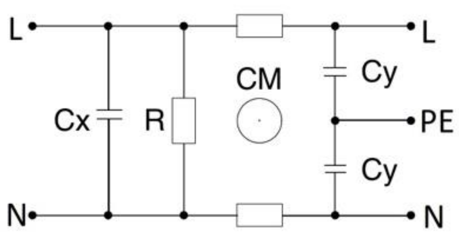


Fig. 16. Topology of self-made filter

The filter efficiency with correct assembly was shown in Fig 17.

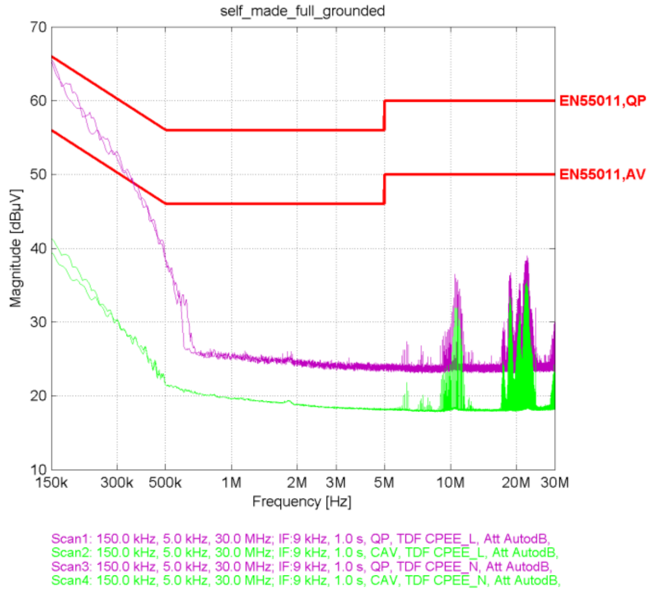


Fig. 17. Measurement of the self-made filter

Connecting C capacitors to PE significantly reduced the disturbances in the mid-frequency range.

For didactic purposes the filter topology was reduced to Cx and CM choke (Fig. 18). The achieved disturbance level was comparable to the self-made filter isolated case.

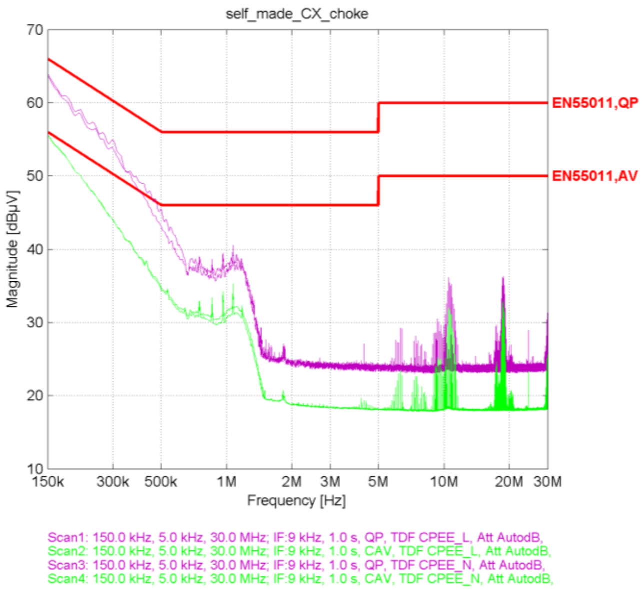


Fig. 18. Measurement of the self-made filter – Cx capacitor and CM choke

Finally, the filter topology was reduced to CM choke only. The measurement result is shown in Fig. 19.

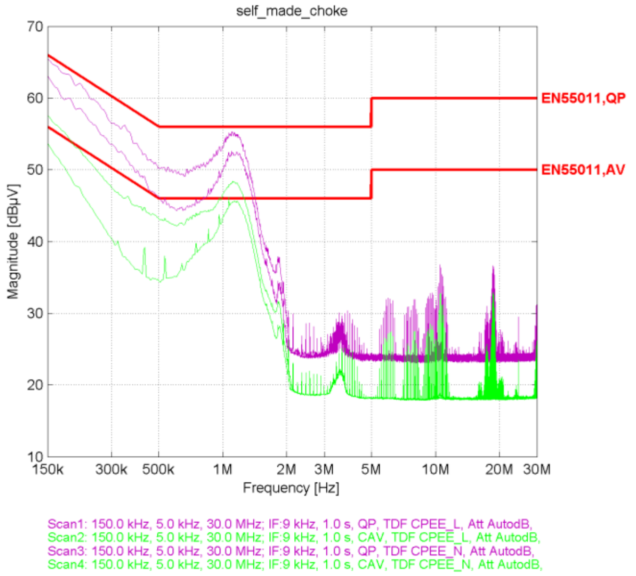


Fig. 19. Measurement of the self-made filter – choke

In Cx and CM choke solution disturbance level is lover in the low and middle frequency range than by using only CM choke.

Summary

The presented research setup allows the students to become familiar with the phenomenon of conducted electromagnetic disturbances and methods of their suppression.

The presented measurements showed an increase in the level of disturbances with increased cable length. This was particularly true for the low and medium frequency ranges. After disconnecting the cable shield from the inverter side, bigger disturbances were observed in the high frequency ranges (5-30 MHz). After disconnecting the shield at both ends of the cable, the disturbances in the low-frequency (150kHz-1MHz) ranges decreased.

Correct filter installation significantly reduces the disturbances' level, especially in the high-frequency range.

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