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Ageing Platform for EMC Testing

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As fontes de alimentação comutadas podem originar interferências eletromagnéticas devido às suas características de projeto inerentes. Os circuitos de comutação internos de uma fonte de alimentação criam emissões ricas em harmónicos e que podem criar interferência elétrica tanto internamente, por exemplo no circuito de alimentação da fonte, como externamente a equipamentos eletrónicos nas imediações.

O trabalho desta tese é avaliar como o envelhecimento afeta as emissões conduzidas de um dispositivo e se com o envelhecimento do equipamento este deixa de cumprir as normas impostas pelo Comité Internacional Especial de Perturbações Radioelétricas, o que caso aconteça torna os dipositivos não-conformes segundo a Diretiva Comunitária de Compatibilidade Eletromagnética.

Os dispositivos testados foram fontes de alimentação normalmente usadas em computadores pessoais, do tipo desktop. Para começar, foram realizados testes de forma a medir as emissões conduzidas das fontes de alimentação. Todos os testes foram executados num local apropriado e com toda a exigência que advém do seguimento das normas.

Para envelhecer os dispositivos, foi criada uma plataforma, o método selecionado para acelerar o tempo de vida dos equipamentos foi o ciclo de alimentação. A aplicação deste método provoca um envelhecimento elétrico no equipamento e basicamente consiste em ligar e desligar repetidamente a energia dos dispositivos em teste, por um determinado período de tempo. A maior vantagem é que usando esta técnica o tempo necessário para envelhecer um equipamento é largamente reduzido quando comparado com o uso normal.

No fim dos testes verificou-se uma alteração do espectro, o que indica que a plataforma desenvolvida demonstrou permitir alterar o comportamento dos dispositivos sujeitos aos ensaios. Da análise dos resultados verificou-se que o envelhecimento influência estas mesmas emissões, ainda assim não foi o suficiente para violar os limites de emissão de ruído conduzido. De acordo com os resultados obtidos foram tiradas conclusões sobre como a degradação de um dispositivo leva a um aumento das emissões conduzidas.

Palavras-chave: Compatibilidade Eletromagnética, Interferência Eletromagnética, Plataforma de Envelhecimento e CEM, Emissões Conduzidas

Abstract

Switching power supplies generate electromagnetic interference due to of their inherent design characteristics. Internal switching power supply circuits that generate undesirable emissions that are rich in harmonics can cause electrical interference both internally to the circuit in which the power supply is installed and to other electronic equipment in the vicinity of the emission source.

The work of this thesis was to evaluate how ageing could affect the conducted emissions of a device and if with the ageing of the device, the limits regarding conducted emissions, imposed by the Comité International Spécial des Perturbations Radioélectriques continue to comply, otherwise the devices will become non-compliant according to the Community Directive of EMC.

The devices tested were switching-mode power supplies, usually used in desktop computers. To start they were under tests for conducted emissions. All the test were done in a proper site and with all the standards that are inherent to such tests.

To age the devices a platform were created, the acceleration life condition selected was power cycling. The application of this method leads to an electrical ageing of the equipment and it basically consists in turn the power of the devices under test On and Off repeatedly, during certain period of time. The major advantage is that with the use of this technique the time needed to age an equipment is largely reduced when compared with a normal usage.

In the end of the test there was a modification of the spectrum, what indicates that the platform created can change the emissions of the devices under test. By analyzing the results it was verified that the ageing affect these emissions, however it was not enough to make the device non-compliant. According to the results obtained conclusions were taken about how the ageing of a device may lead to an increase in the conducted emissions.

Keywords: Electromagnetic Compatibility, Electromagnetic Interference, Ageing and EMC Platform, Conducted Emissions.

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f	Frequency	Hz
$\hat{I}n$	Peak of the neutral current	A
$\hat{I}p$	Peak of the phase current	A
v	Voltage	dBμV
$\hat{V}n$	Peak of the neutral voltage	V
$\hat{V}p$	Peak of the phase voltage	V

Acronyms

AC – Alternating Current

AVG – Average

CISPR – International Special Committee on Radio Interference

DUT – Device Under Test

EI – Environmental Interference

EMC – Electromagnetic Compatibility

EMI – Electromagnetic Interference

EMR - Electromechanical Relays

FCC – Federal Communications Commission

ITE – Information Technology Equipment

LIFA - LabVIEW Interface for Arduino

LISN – Line Impedance Stabilization Network

PSU – Power Supply Unit

QP – Quasi Peak

RFI – Radio Frequency Interference

SSR - Solid State Relay

1. INTRODUCTION

1.1. Framework

Electromagnetic interference (EMI), also called Radio Frequency Interference (RFI), is a disturbance that affects an electrical circuit due to either electromagnetic conduction or electromagnetic radiation emitted from an external source[1]. EMI problems have been increasing with the proliferation of mobile electronic systems, wireless communication systems, and computer networks. The electromagnetic energy disrupting the normal operation or function of electronic devices is known as Environmental interference (EI) [1]. The source of EI can be categorized as environmental (naturally occurring), incidental or intentional.

The electromagnetic spectrum is becoming increasingly crowded, so we need to know if electromagnetic interference varies with the ageing of the equipment.

Conducted emissions refers to the mechanism that enables electromagnetic energy to be created in an electronic device and coupled to its AC power cord. The primary reason why conducted emissions are regulated is because electromagnetic energy that is coupled to a product's power cord can find its way to the entire power distribution network and use the larger network to radiate more efficiently than the product could by itself. The frequency range where conducted emissions (150 kHz to 30 MHz) are regulated is typically lower than the frequency range where radiated emissions (30 MHz to 1 GHz) are regulated. In Europe, this regulation is imposed by the Comité Européen de Normalisation et en Électronique et en Electrotechnique (CENELEC) and by the Federal Communications Commission (FCC) in the United States. CENELEC is the recognized association by the EU for standardization in the electrotechnical engineering field. Concerning EMC standards, these are prepared by adoption of IEC/CISPR international standards through a procedure called "parallel vote" which reduces the efforts in the creation of the legal documentation while granting uniformity in the standards. The standards both in CENELEC or CISPR are the same but CENELEC is the one with authority. If a product passes all radiated emissions regulations but fails a test on conducted emissions, the product cannot be legally sold [2]. Therefore it is vital to have a better understanding of the conducted emissions.

The community directive of EMC has the general requirements that the equipment is designed and produced to ensure disturbance levels and acceptable sensitivity (Annex I of the Directive), otherwise they are considered non-compliant [3]. The main objective of this work is understand how the emissions change within their lifetime.

A platform was built with that purpose, by accelerating the ageing of devices. The Accelerated Life Tests (ALTs) were the theoretical basis to age the Device Under Test (DUT). The ageing platform designed has the ability to switch the power, on and off, of the DUTs so the acceleration factor selected was power cycling. The main objective was to apply a high level of electrical stress over a short period of time to a device assuming that there will be a change in the conducted emissions. After the ageing of the devices, conducted emission tests were made to observe how the EMC performance changed.

The devices under test in this experiment were switched-mode power supplies which are generally defined as any type of electronic circuit that converts and/or regulates voltage or current by switching circuits and energy storage elements (capacitors and inductors) [4].

The main goal of this thesis is to understand how the conducted emissions change with the ageing of a device and if they continue to comply with the limits imposed by standards and regulations when they get closer to their wear-out.

1.2. Structure of the document

This dissertation is composed of 5 chapters, including this introductory chapter. The rest of the present document is organized as follows. Chapter 2 provides a brief overview of the background addressing the following topics Electromagnetic Compatibility and its requirements, the Line Impedance Stabilization Network and Accelerated Life Tests. Chapter 3 describes the platform, which components were selected and why, shows the two set-ups used, both for EMC and ageing test, and also specifies EMC tests regulations. Chapter 4 discusses the results obtained. Chapter 5 concludes the thesis with directions for future work.

2. ELECTROMAGNETIC INTERFERENCE IN POWER SUPPLIES

In electronic devices, the two prominent types of EMI are conducted EMI and radiated EMI [5]. Comprehensive regulations and standards provide limits to both radiated and conducted EMI generated when the power supply is connect to the grid.

When comparing the modern switched-mode power supplies with those from older generations, the new switches have reduced switching times, which will cause faster rise and fall times for the voltage and current waveforms. These fast edges produce significant energy at surprisingly high frequencies, which are the root cause of mostly EMI problems in switched-mode power supplies. This high frequency energy that will be produced within the power supply may sometimes stop it from working properly or passing reliability tests essential for their good performance.

The main objective of studying EMI is to meet EMI regulations while not disturbing devices connected to the same network. Power supplies should be susceptible, which means that they should be able to tolerate a certain amount of EMI from other sources [6].

2.1. Electromagnetic Compatibility

Electromagnetic compatibility (EMC) is the ability of an electronic system to function properly in its intended electromagnetic environment, and not be a source of pollution to that environment [5]. The electromagnetic environment is made of both radiated and conducted energy. EMC therefore has two aspects, emission and susceptibility.

Susceptibility is the capacity of a device or circuit to respond to unwanted electrical energy (i.e. noise). The susceptibility level of a circuit or device is the noise environment in which the equipment can operate satisfactorily, without degradation, and with a defined margin of safety [5].

The purpose of monitoring emissions is to limit the electromagnetic energy emitted, and thereby control the electromagnetic environment in which other products must function. Regulating the emissions from one product may eliminate any interference problem detected in other products, therefore it is required to take them into account in an attempt to produce an electromagnetically compatible environment.

2.2. Electromagnetic Compatibility Requirements

The standards are produced by CENELEC, which is the European organization responsible for standardization in the electrotechnical engineering field. As said before, the CISPR standards on EMC are fully adopted by CENELEC, becoming this way mandatory to all EU countries.

The most widely used standard in Europe is EN 550022, a modified derivative of CISPR 22 and applies to information technology equipment (ITE). Basically it sets limits on the radiated and conducted emissions of ITE, similar standards are used in United States, the Code Federal Regulations, Title 45, Part 15 also known as 47 CFR 15. The limits are divided into Class A and Class B equipment [5], Class A digital devices are those that are marketed for use in a commercial, industrial, or business environment. Class B digital devices are those that are marketed for use in a residential environment. The Class B limits are more stringent that the Class A limits, because of the assumption that interference from a device in an industrial environment can be more easily corrected than in a residential environment. Further, the owner of the interfering device in a residential environment is not as likely to have the expertise of financial resources to correct the problem as would as industrial user.

In this experiment, only tests for Conducted Emissions for Class B devices were made, so the frequency range extends from 150 kHz to 30 MHz. Compliance is verified by inserting a line impedance stabilization network (LISN) into the unit's ac power cord. There are two levels to be satisfied: quasi-peak (QP) detector in the measurement receiver and average (AVG) detector. These limits can be seen in Table 2.1 and in Figure 2.1 [7].

Frequency (MHz)	Quasi Peak (dBµV)	Average (dBµV)
0.15	66	56
0.5	56	46
0.5 – 5	56	46
5 – 30	60	50

Table 2.1 - CISPR 22 Conducted Emissions Limits for Class B Digital Devices

Average detection is similar in many respects to peak detection. The output of the envelope detector is the modulation envelope. For average detection to take place, the peak detected signal must pass through a filter whose bandwidth is much less than the resolution bandwidth (9 KHz). The filter averages the higher frequency components, such as noise at the output of the envelope detector [8].

Quasi-Peak was meant to simulate human responses to noise. Humans have a slowly increasing level of aggravation or annoyance to a persistent disturbance. The signal level is effectively weighted according to the repletion frequency of the spectral components constituting the signal. So, the result of a quasi-peak measurement will always be dependent on the repetition rate. Further, because of finite charge and discharge time constants involved in quasi-peak detection, the spectrum analyzer must sweep considerably slower in this mode. Therefore, peak detection can be carried out, and this turns out to be much faster [9].

Usually, if we can meet the quasi-peak limits, we automatically meet the average limits too (using average detection and average limits). But there are cases when CISPR 22 quasi-peak limits may be complied with, but the average limit test is failed. That could be hard to fix without a major re-design of the PCB layout [9].

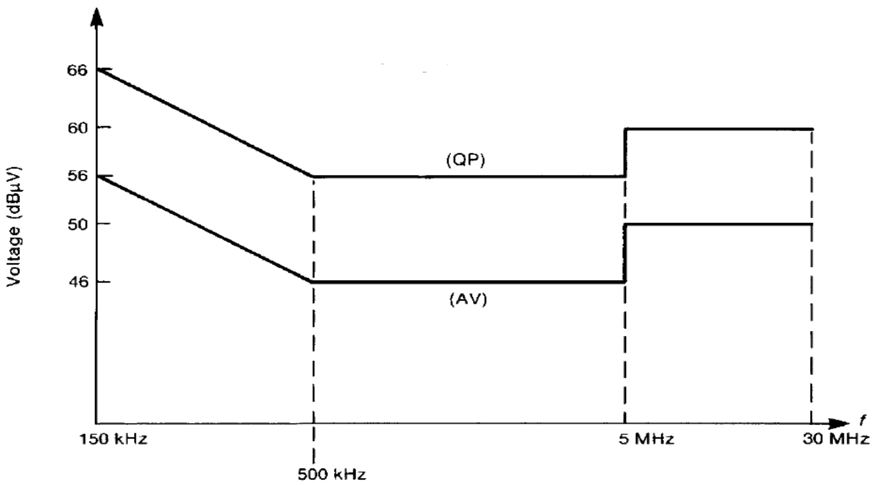

Figure 2.1 - CISPR 22 Conducted Emission Limits for Class B

2.3. Line Impedance Stabilization Network

The first objective of the Line Impedance Stabilization Network (LISN) is to present a constant impedance at the product's power cord outlet over the frequency range of the conducted emission test. The second objective is to block conducted emissions that are not due to the product being tested so that only conducted emissions of the product are measured. Thus, the two objective of the LISN are to present a constant impedance between the phase conductor and the safety wire and between the neutral conductor and the safety wire, and to prevent external conducted noise on the power system net from contaminating the measurement [7]. These objectives are to be satisfied only over the frequency range of the conducted emission test (150 kHz – 30 MHz). In Figure 2.2, a basic electric circuit of the LISN is shown, where the $\hat{I}p$ is the phase current peak, $\hat{I}n$ is the neutral current peak, $\hat{V}p$ is the phase voltage peak and $\hat{V}n$ is the neutral voltage peak.

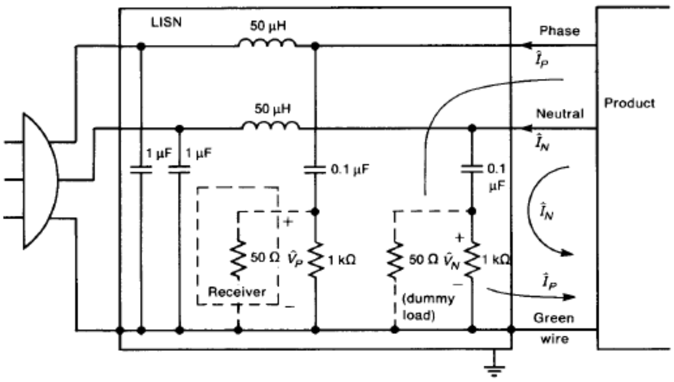

Figure 2.2 - Illustration of the LISN Circuit

2.4. **Accelerated Life Tests**

The objective of the Accelerated Life Test (ALT) is to expose the modes and mechanism of failure, to identify parametric degradation of the materials and structures under test, to reveal the physics of failure and the longer-term failure mechanisms [10]. All these tests use a severe environment to accelerate possible defects and potential failures. Accelerated life testing are frequently needed to ensure customer satisfaction, and give an indication of the actual reliability of the product and its components. When comparing the expenses associated with a field problem after the product is largely deployed, the cost of such tests is considered worth the investment.

Some of the common accelerated test conditions are:

- High Temperature (Steady-State);
- Low Temperature Storage;
- Thermal Cycling;
- Power Cycling;
- Thermal Shock;
- Mechanical Shock;

The main objective of these tests is to detect and evaluate different kinds of failures, there are some accelerated test equipment who allow to perform a combination of these tests.

However, in this thesis the accelerated life tests were not used for detecting or evaluating failures but instead to analyze how the degradation changes within the lifetime of the device.

3. ACCELERATED AGEING PLATFORM

In this chapter, the design of the platform and its components are going to be reviewed, the user interface is explained and the experimental setup, in which several power supply units were under a process of ageing, is show.

The Figure 3.1 shows a basic sketch of the implementation that was done to test the devices, in this case as we said, the Power Supply Units.

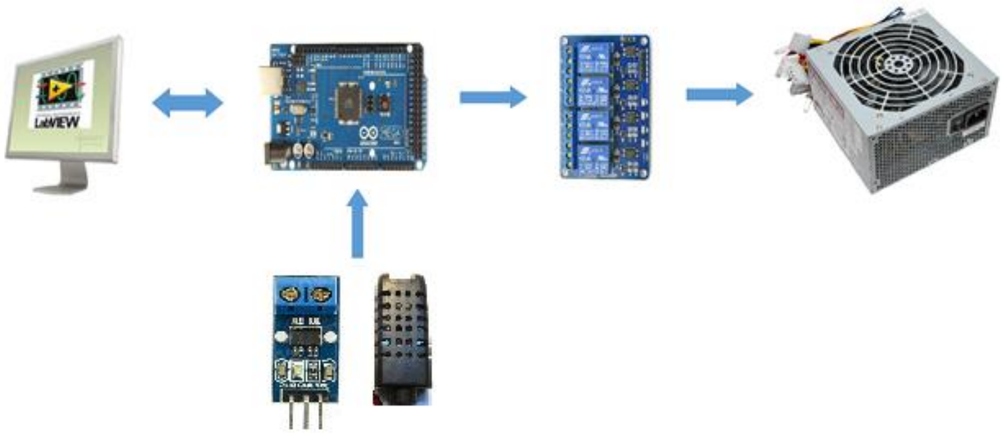

Figure 3.1 - Experiment Setup, PC Arduino, Relay, PSU and Sensors

3.1. Accelerated Ageing Platform

The platform created is a portable device intended to age equipment's, mainly electrically. That is achieved by switching the power On and Off several times. The components used to build the platform were an arduino board, relay modules, current, temperature and humidity sensors. The LabVIEW was the software utilized to control the arduino.

The platform consists in an Arduino board which will control all the relays, while reading data from sensors. The Arduino is connected to a Computer via USB and electrically to a Relay Module, Current Sensors and Temperature and Humidity Sensors. The information sent by the computer (using the LabVIEW) to the Arduino, controls the Relay Module where the socket is connected, and therefore also control the power delivered to the DUT. The sensors of humidity and temperature are used to monitor the experiment and to collect more data to analyze. In the future these sensors are planned to be used in accelerated life test which combine more than one ageing factor, as an example humidity and temperature chambers.

3.1.1. Selecting Components

To create the ageing platform various components were compared, in order to choose the more appropriate ones, the specifications of both the Arduino and the Raspberry Pi, Electromechanical Relays and Solid State Relays, different types of current, temperature and humidity sensors were compared.

The Arduino was chosen over the Raspberry Pi, because it is more appropriate when using sensors, switches, it is cheaper and easier to use. In Figure 3.2 there's a comparison between both Arduino and Raspberry Pi boards.

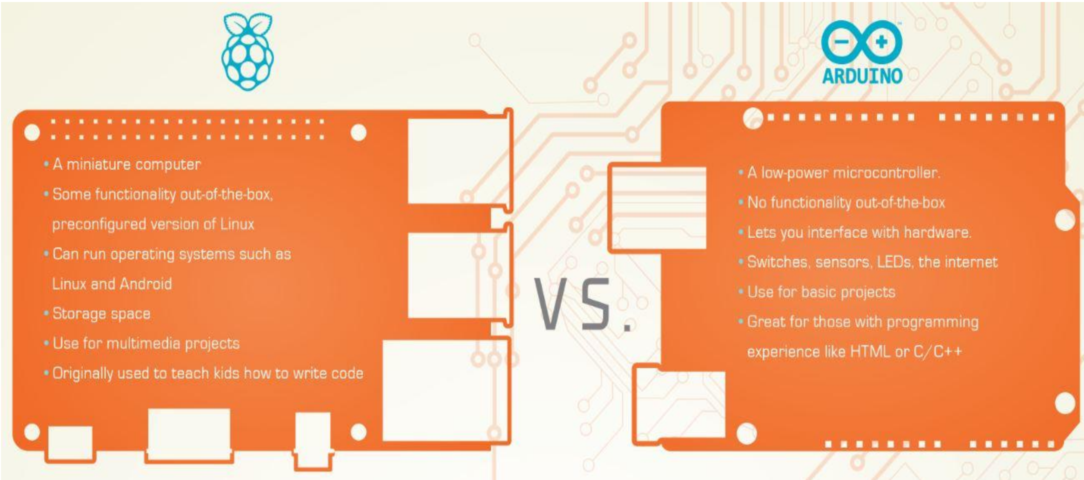

Figure 3.2 - Comparison between Arduino and Raspberry Pi [11]

There are advantages of the Solid State Relays (SSR) over Electromechanical Relays (EMR), however the price of the SSR was expensive (80€ per unit), this difference in price is related with zero-crossing, which is the ability that the SSR's have to only change the output state when the voltage is zero, creating less electromagnetic "noise" [12]. Considering that the main point is ageing the devices the zero-cross control is not desirable and taking into account the budget available and comparing all the other characteristics it was decided that EMR was the best choice for our project.

The current sensor selected, Allergo ACS712, is based on the principle of Hall-effect and provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems [13]. In Figure 3.3 there's the sensor pin outs and connections and in Table 3.1 some specifications.

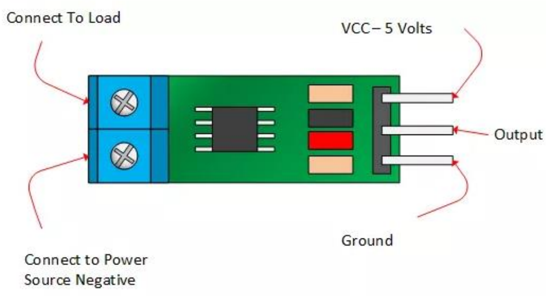

Figure 3.3 - Sensor Pin Outs and Connections

Supply Voltage (VCC)	Current Measurement Range	Voltage at 0A	Scale Factor
5 V DC	-20 to 20 A	VCC/2 (nominally 2.5V DC)	100 mV per A

Table 3.1 - Current Sensor Specifications [13]

Supply Voltage (VCC)	Temperature Measuring Range	Humidity Measuring Range	Temperature Accuracy	Humidity Accuracy
3.3 - 5V DC	-40 to 80 Celsius	0 - 100% RH	+/- 1 Celsius	+/- 5% RH

Table 3.2 - Some specification of the DHT21 [14]

The temperature and humidity sensors chosen are digital sensors, also known as Digital Humidity and Temperature (DHT21), which utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability, in Table 3.2 some specification are shown [14].

3.1.2. User Interface

The LabVIEW Interface for Arduino (LIFA) is the plugin used to make possible the communication between the Arduino and the LabVIEW. LIFA sends data packets from LabVIEW to the Arduino. The Arduino processes these packets and sends return packets. Return packets are parsed by LabVIEW to provide useful information to the end user. Each packet, shown in Figure 3.4, is 15 bytes by default and contains a header, a command byte, data bytes, and a checksum. The LIFA firmware on the Arduino processes the packets by ensuring no data has been corrupted during transmission, then checks the command byte and execute instructions with the given data bytes based on the command byte.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Header	Command Byte	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7	Data8	Data9	Data10	Data11	Checksum

Figure 3.4 - Packet used between LabVIEW and Arduino communication [15]

In the program designed in the LabVIEW, some parameters have to be selected, they are presented below.

- **Total Time or the Number of Iterations** that will define for how long the experiment will perform.
- **The On Time and Off Time** will control the output state of the relay, one relay for each socket, meaning that the user can choose how much time the relay is going to be in that same state.
- **The start button** is used to start the experiment.
- **The Stop button** when pressed will put the output of the relay in the Off state, and then if Start button is pressed, the experiment will restart, if the Continue button is pressed the experiment will continue where it stopped.
- Is also given the opportunity to the user **to turn On or Off the humidity and temperature sensors**.

Some information regarding the actual state of the test is shown in four LEDs and in a progress bar.

- The Running LED is On whenever the experiment is running,
- The Complete LED is On when the total time or iterations are reached;
- The Transition LED turns On whenever a change in the state of the relay occurs;
- The Pin State LED is On when the relay is conducting.
- The progress bar is a visual indication of the evolution of the test.

An image of the layout can be seen in Figure 3.5.

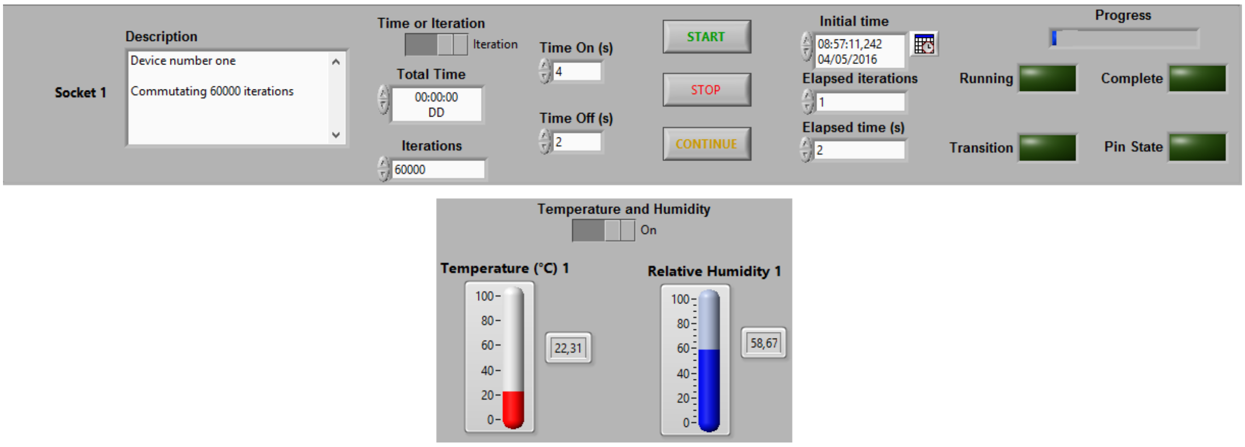

Figure 3.5 - User interface available in the PC, designed using LabVIEW

3.1.3. Hardware

The platform is a portable device, built inside a case, the upper part relates to control while the bottom part is related to power, the electrical circuits are divided in two, one on the left (labeled as “A” in Figure 3.6) and one on the right (B) sides of the case. The electrical power is supplied by two plugs (10), each one related with one side of the case. The upper part has the Arduino board (4), the current sensors (3A, 3B), the relay modules (1A, 1B) and switches (2A, 2B) for each socket, which were installed as a protecting measure. In the PCB (5) there are a Ground and Voltage (5V) bus and three 10k resistors that are used for the connection off the humidity and temperature sensors with the Arduino board. The arduino is connected with the computer by USB (7) and powered with a transformer (6).

The bottom of the case has eight triple-sockets divided in two groups (8A, 8B), three temperature and humidity sensors (8), one transformer to power the Arduino and two circuit breakers (11) one for each circuit. A socket (9) is also installed to plug a pc or other equipment. In Figure 3.6 you can see the upper, and in Figure 3.7 the bottom, parts of the case.

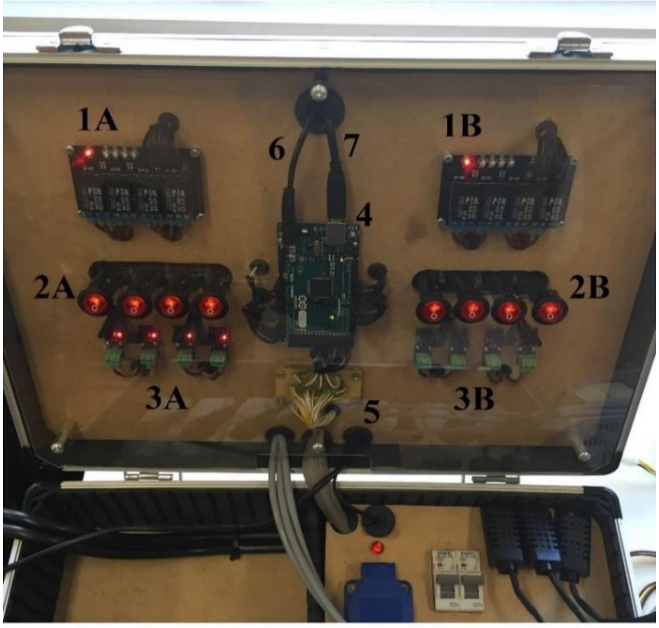

Figure 3.6 - Upper part of the case

Figure 3.7 - Bottom part of the case

3.2. Tests for Conducted Emissions Setup

In order to initiate the experiment, the power supplies had to be tested for the Conducted Emissions to get the initial reference (in both phase and neutral connections). This was done using an Electromagnetic Interference Receiver who also works as LISN (3), a ground plane (1), a computer with software for observing the conducted emissions (4), an isolation transformer (5), a power supply (6) and the device under test (2), Figure 3.8 shows the setup.

There are rules, who derive from the standards EN 55022 [16], who have to be taken into account when performing these kind of tests:

- Ground Plane

  Should measure 2 m x 2 m x 2.5 mm, the material has to be conductive and his resistance below 5Ω. The conductivity and resistance of the ground plane was tested and measured with a multimeter in different points to verify its validity;

- Table

  The table where the DUT is placed must follow the specifications of the standards and should be completely made of non-conductive material. Plastic table was selected since it offers a good price/quality ratio;

- DUT

  The DUT has to be placed 80 cm above the ground in the top of the table, at least 40 cm away from the vertical ground plane and also 1m away from the LISN.

All the cables should be the shortest as possible to increase the accuracy of the measurements.

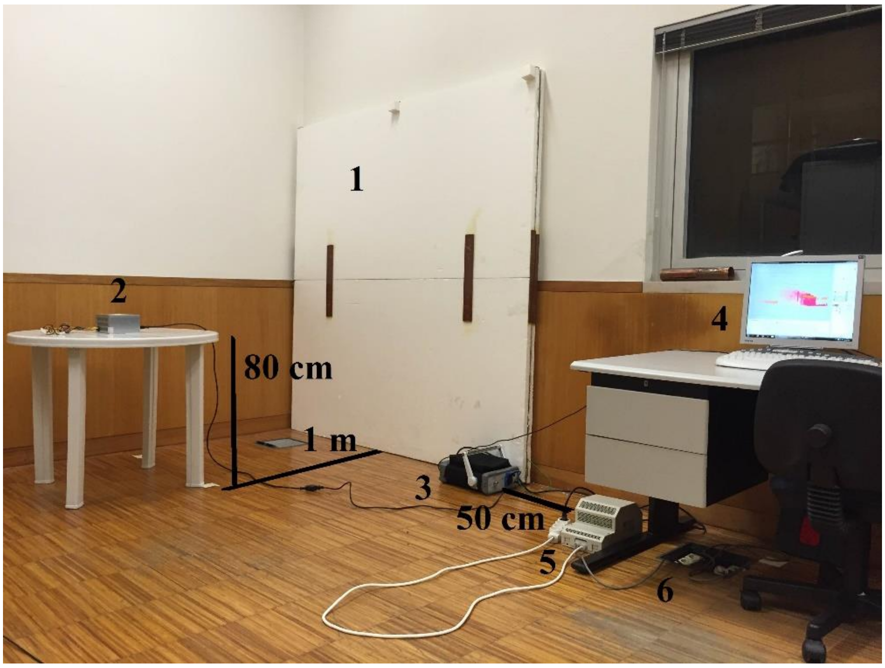

Figure 3.8 - Setup for conducted emission tests

After the previous procedure the DUTs were taken for starting the ageing process as can be seen in Figure 3.9.

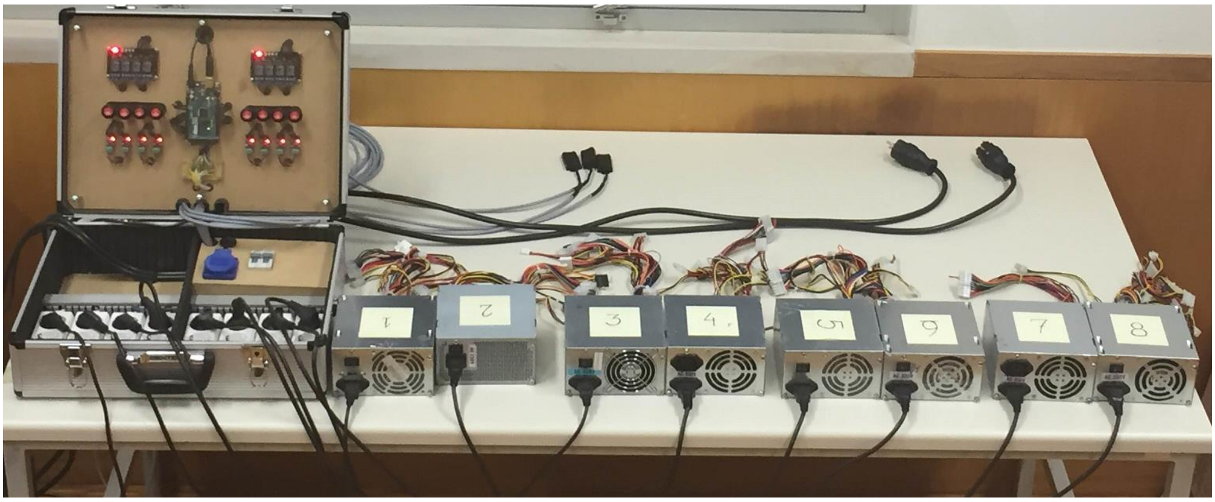

Figure 3.9 - Setup for ageing the DUTs using the platform created

4. EXPERIMENTAL RESULTS

In this chapter, the results presented relate with the ageing and EMC tests and some information regarding all the five tests done. Firstly the DUTs were tested for the conducted emissions, to get a reference, the Figure 4.1 and the Figure 4.2 show the initial reference of the DUT number 1. Then five tests were done and the results compared. In Table 4.1 it is presented how many tests and iterations were done during the experiment. The tests made provide information regarding, peak and average, in both phase and neutral connection. The quasi-peak test was only done once because it was twenty times longer when compared to the peak and the difference between them was not significant. The limits for Quasi-Peak are used in the spectrum related with the Peak measurements merely as reference, since the Peak is not imposed by standards or regulations. The limits presented are for Class B equipment. All the tests were made without any load connected to the devices the main reasons were, the difference between the power of the DUTs and also because at the time there were no loads available for all the DUTs. The number of iterations of the first test was chosen based in assumptions, and then according to the results obtained the number of iterations was adjusted.

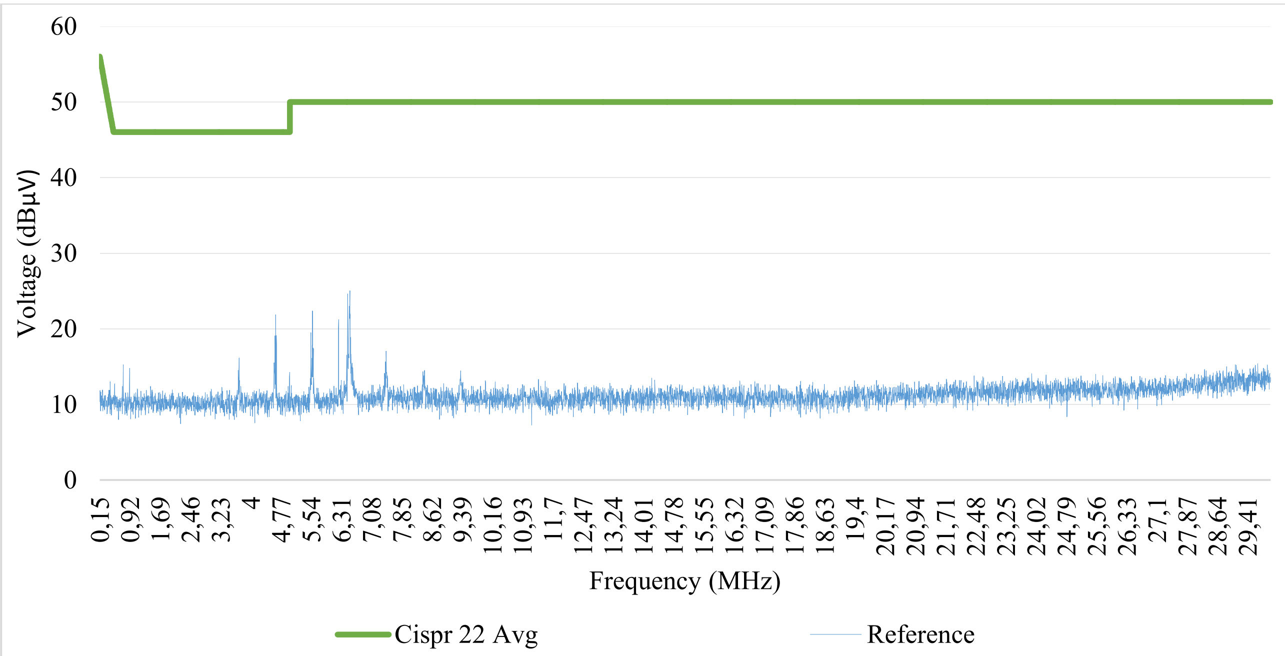

Figure 4.1 - Initial reference of the Conducted Emissions Test of DUT number 1, Average

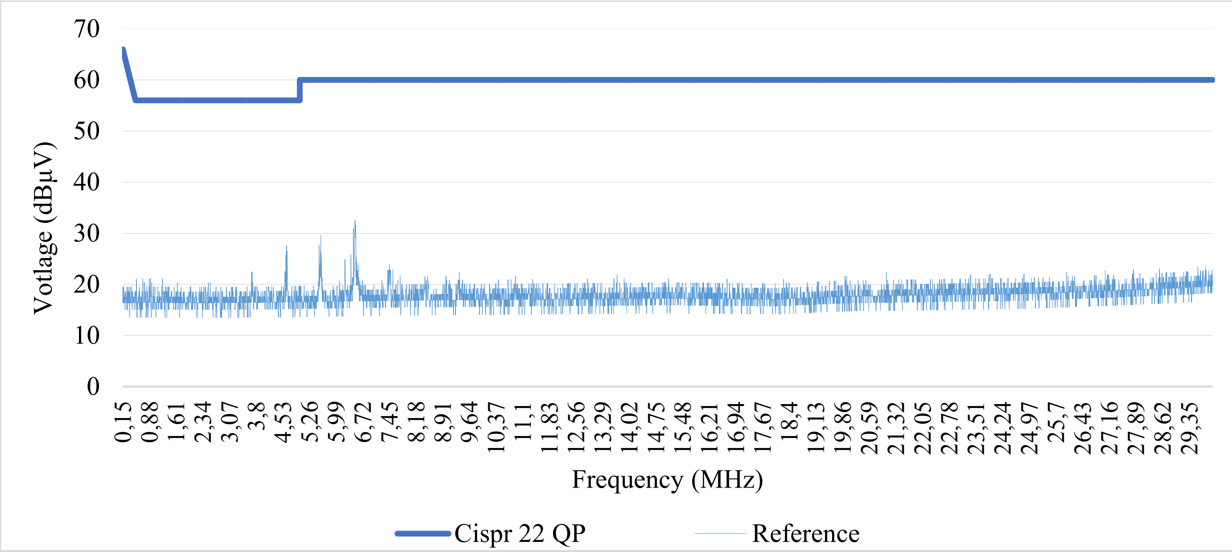

Figure 4.2 – Initial reference of the Conducted Emission Test of DUT number 1, Peak

Ageing Test Number	Number of the Device Under Test	Iterations	Commutation Time in seconds (On - Off)
1	1,2,3,4 5,6,7,8	5000	4 - 2 3 - 3
2	1,2,3,4 5,6,7,8	10000	4 - 2 3 - 3
3	1,2,3,4 5,6,7,8	15000	4 - 2 3 - 3
4	1,2,3,4 5,6,7,8	30000	4 - 2 3 - 3
5	1,2,3,4 5,6,7,8	60000	4 - 2 3 - 3

Table 4.1 - Ageing tests performed to the DUT

4.1. First ageing test

The DUTs selected were obtained from decommissioned computers used at the Department of Electrical and Computer Engineering of the University of Coimbra. As expected, these were used power supplies and no information was available about how long they were operating, how many commutations they had already done and no relationship between them as they were from different brands. As there is no information about their actual "age", it was initially chosen a small number of 5000 iterations. Once the first test was finished, the DUTs number one and five were analyzed again and by observing the conducted emissions spectrum, it was clear that the emissions did not changed much as it was expectable. So it was assumed that five thousand commutations were not enough to increase the produce perceptible degradation. Hereupon, no more DUTs were tested for conducted emissions until the next test were finished.

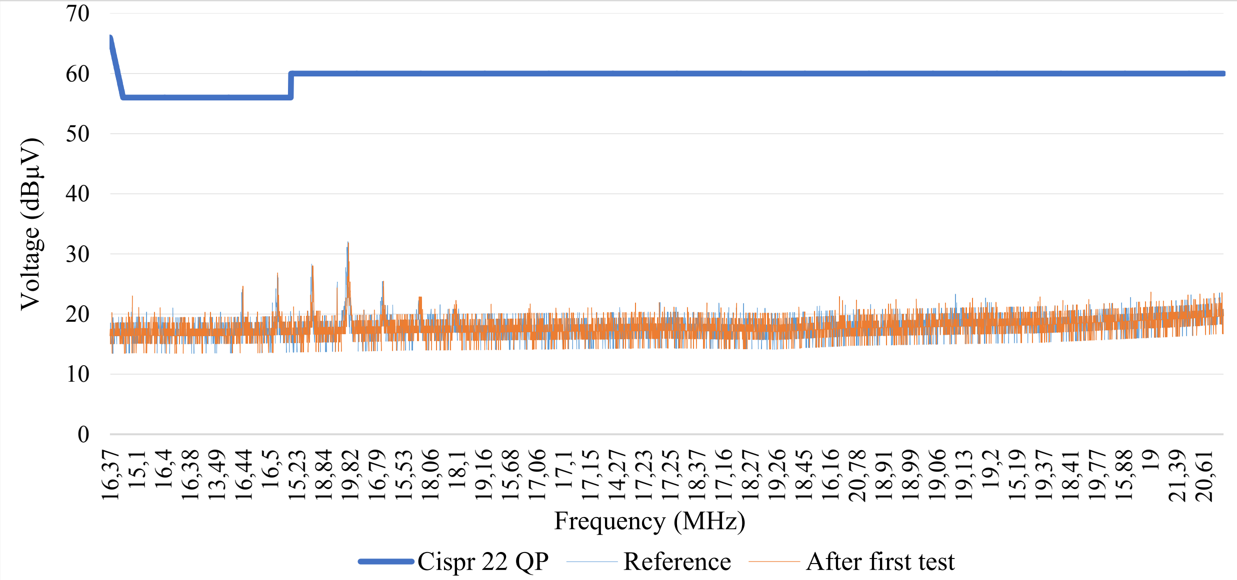

Figure 4.3 - Spectrum of the Conducted Emissions, DUT number 5, Peak, Phase

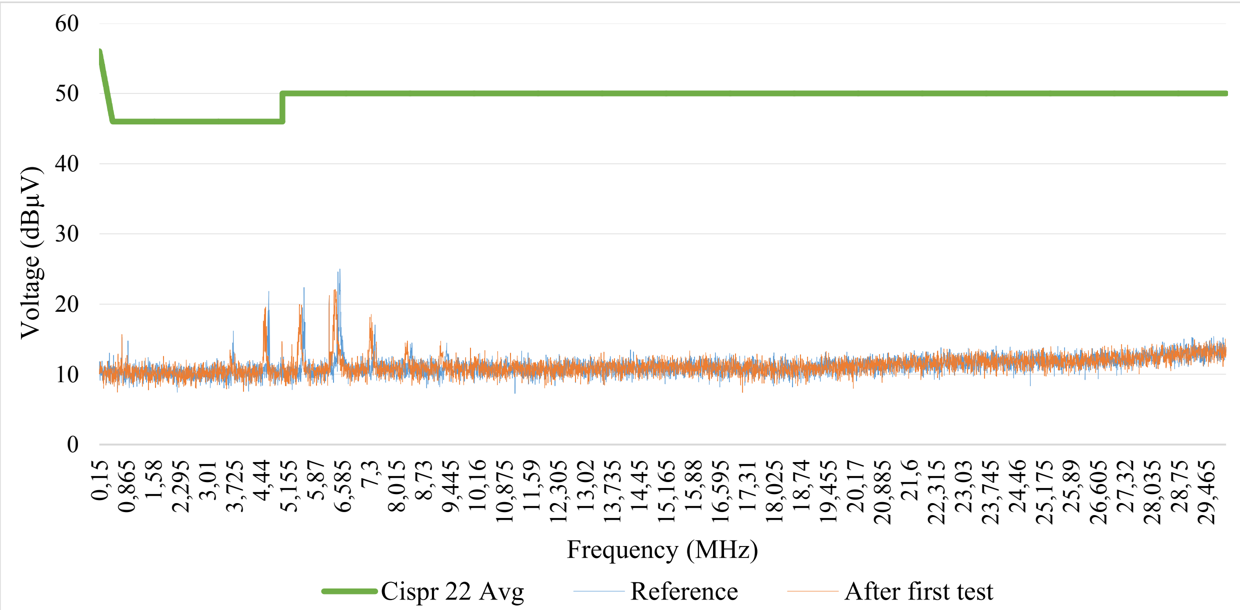

Figure 4.4 - Spectrum of the Conducted Emissions, DUT number 1, Average, Phase

4.2. Second ageing test

In the second test, ten thousand commutations were performed and afterwards the tests for conducted emissions. In some devices a slightly shift of the spectrum to the right was observed and also an increase of the peak in some specific frequencies.

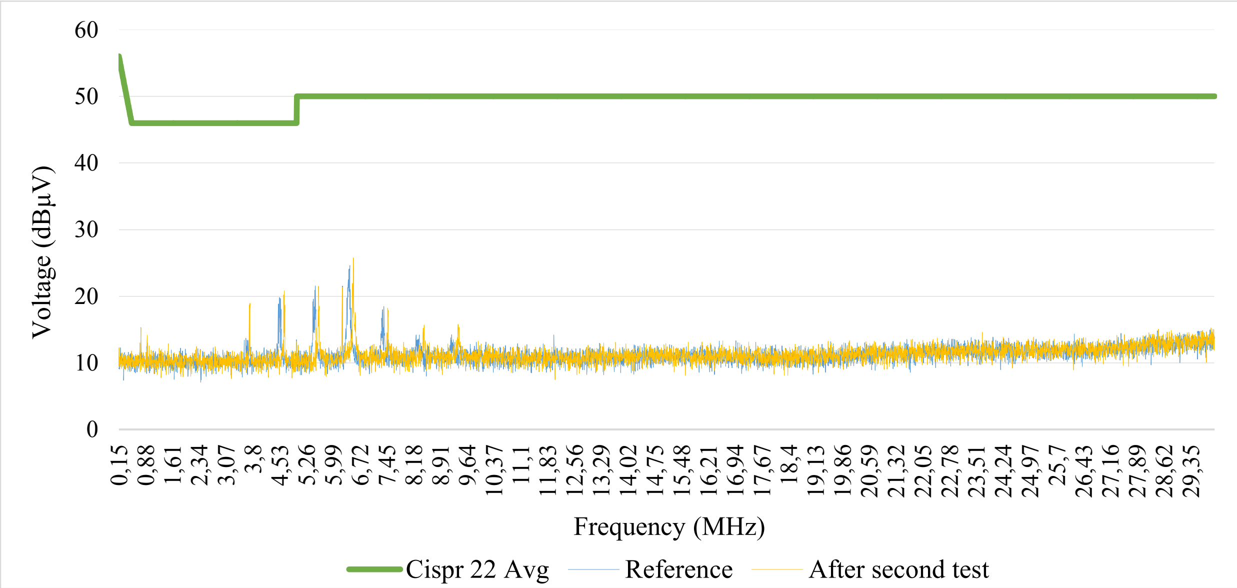

Figure 4.5 - Spectrum of the Conducted Emissions, DUT number 4, Average, Phase

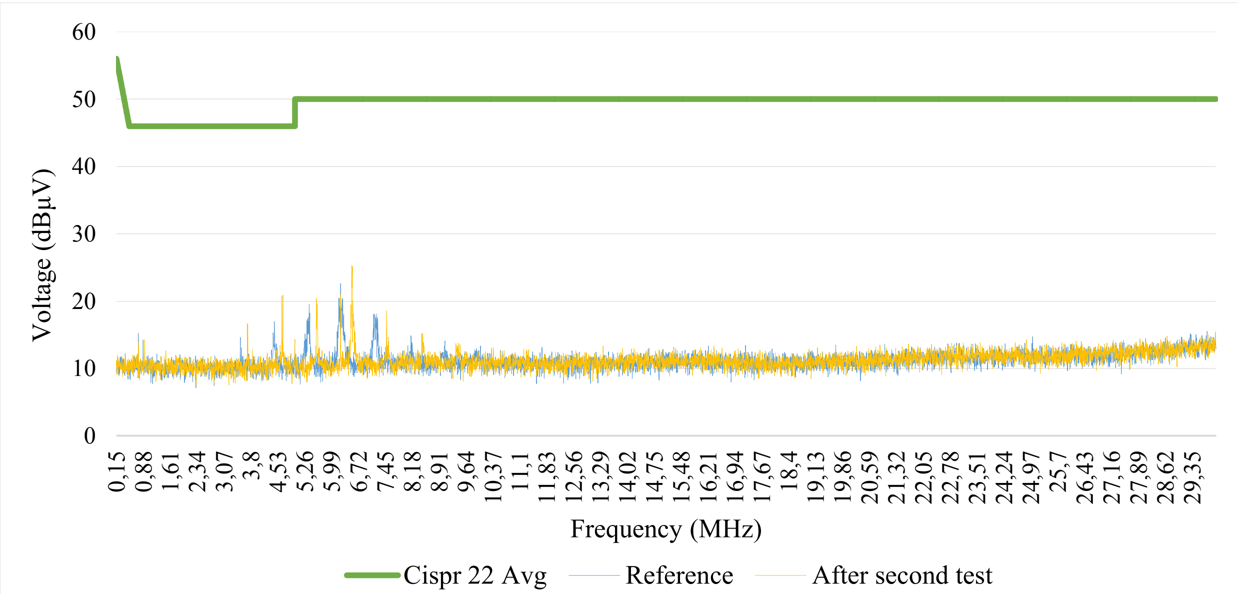

Figure 4.6 –Spectrum of the Conducted Emissions, DUT number 2, Average, Phase

4.3. Third ageing test

The third test, consisted in fifteen thousand commutations followed by the conducted emissions tests. The spectrum for the conducted emissions remained almost similar in the majority of the DUTs when compared with the second test.

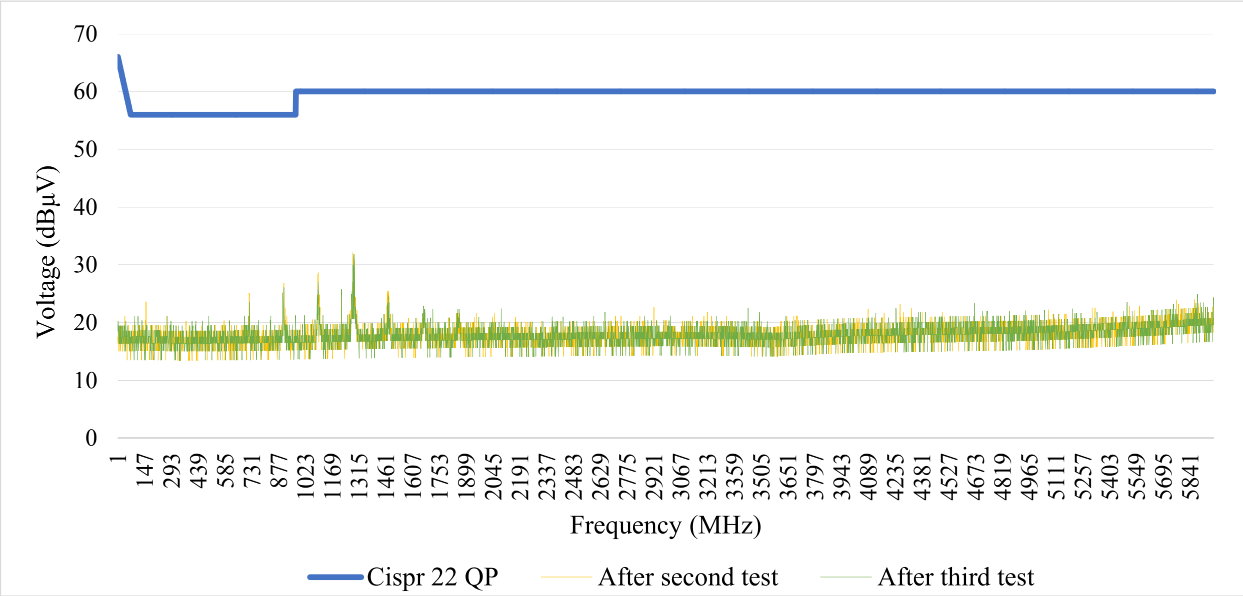

Figure 4.7 - Spectrum of the Conducted Emissions, DUT number 7, Peak, Neutral

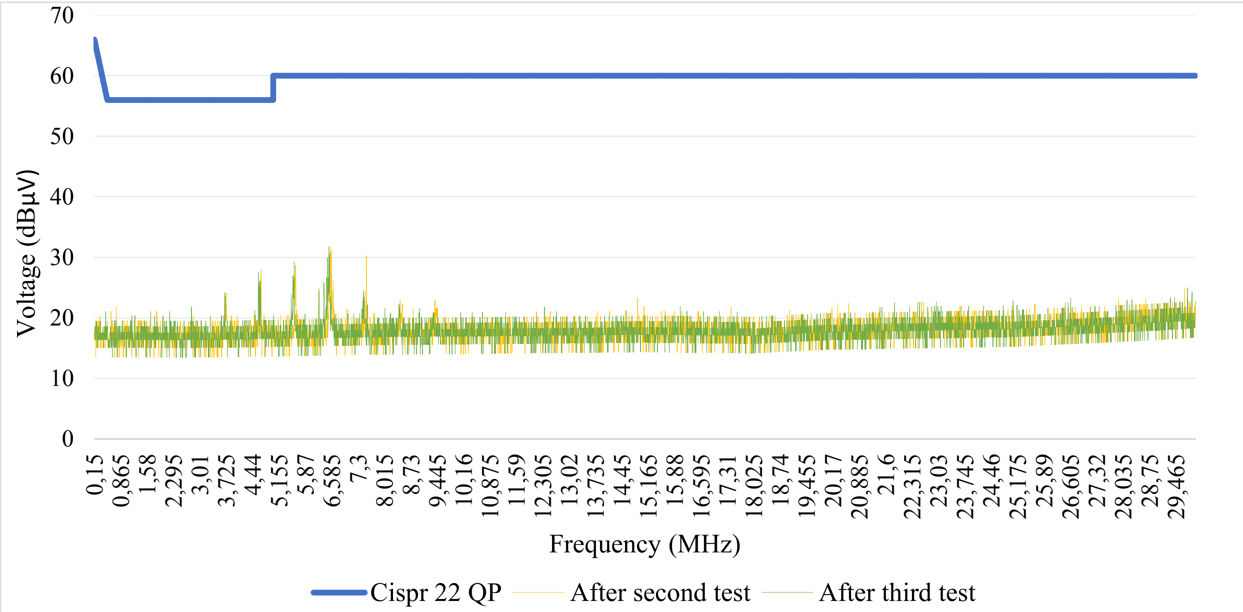

Figure 4.8 - Spectrum of the Conducted Emissions, DUT number 3, Peak, Phase

4.4. Fourth ageing test

The procedure was repeated once more, and in the fourth test, thirty thousand commutations were performed. It was noticed that the DUT number two had the spectrum shifted to the right as well as an increase in the voltage of the major peaks. Still the limits were not exceed. No more tests were done to device number four since it stopped working. In all the other devices the spectrum's changes were not too substantial.

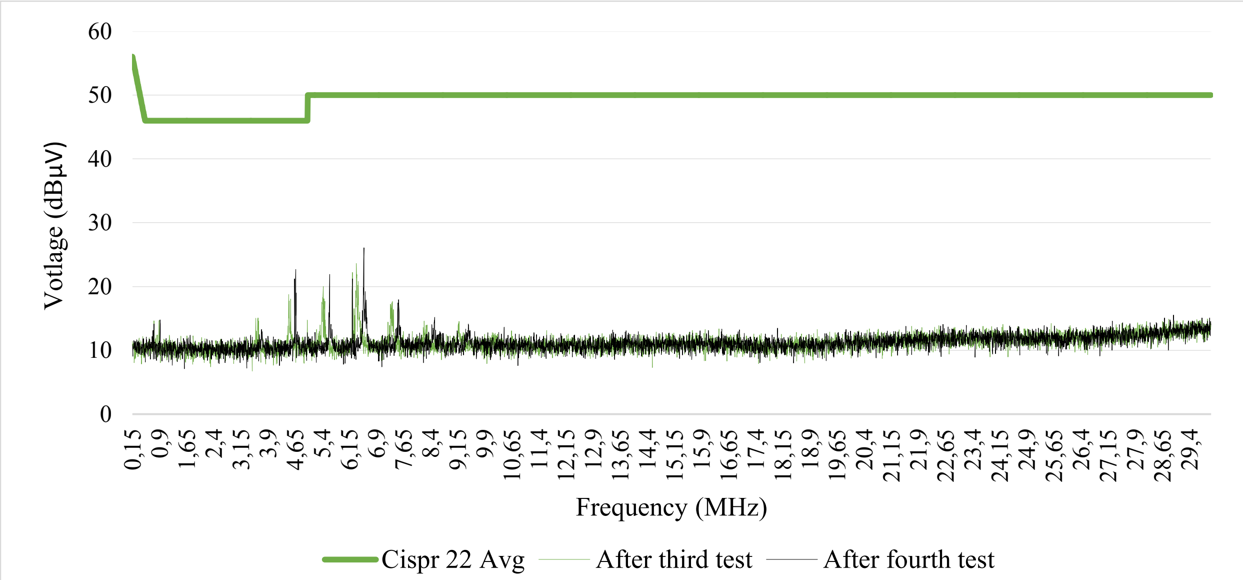

Figure 4.9 - Spectrum of the Conducted Emissions, DUT number 2, Average, Neutral

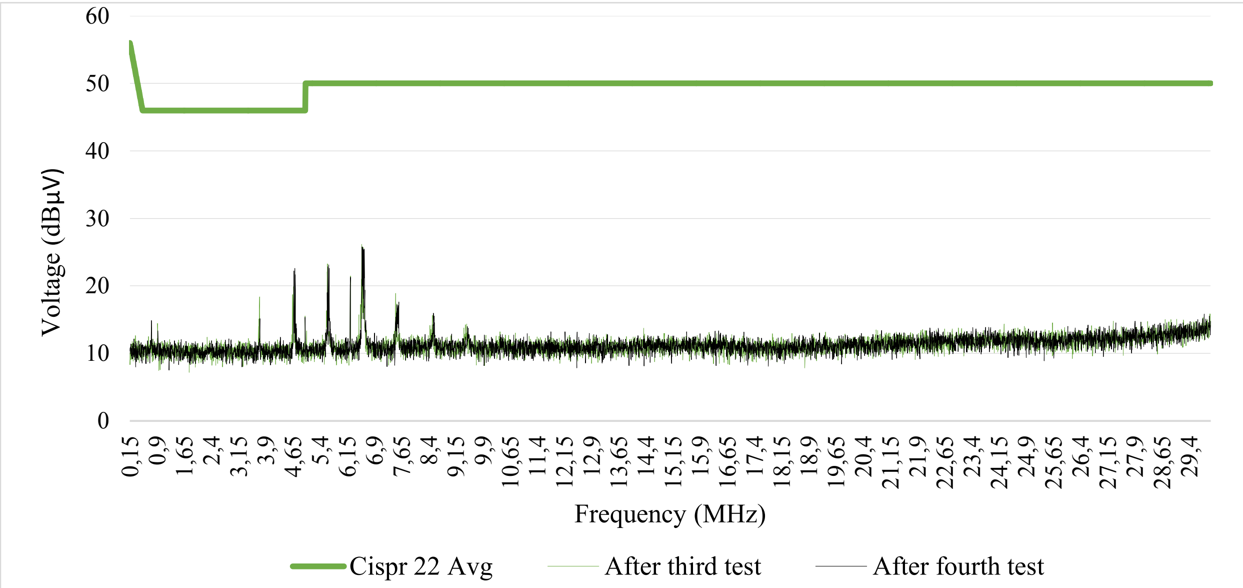

Figure 4.10 - Spectrum of the Conducted Emissions, DUT number 7, Average, Phase

4.5. Fifth ageing test

Since the degradation of the conducted emissions triggered by the commutations was not evolving quickly, it was decided to cover with tape the ventilation opening of some random selected power supplies. For this, DUTs number one, two, five and six, were selected. It was expected that, as the power supplies were not ventilating properly, the heat triggered would increase the degradation of the conducted emissions. Conducted Emissions test were made for all the power supplies.

Nevertheless, no differences were noticed possibly because they were under this condition for only one test.

Besides no limits were exceed, the last test for the conducted emissions showed that in all the tests made to the DUTs, there was a perceptible shifting of the major peaks to the right, meaning that the peaks are appearing at higher frequencies. Figure 4.11 and Figure 4.12 show the spectrum where the shifting was more visible. The Figure 4.13 shows the measurement where the shifting was less significant.

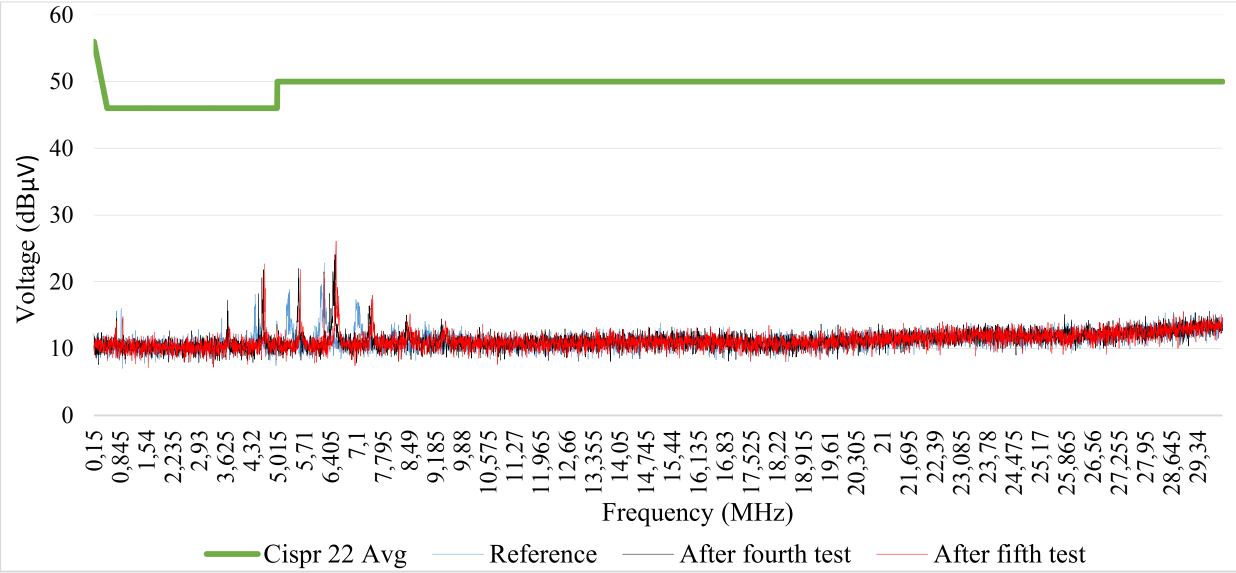

Figure 4.11 – Spectrum of the Conducted Emissions, DUT number 2, Average, Neutral

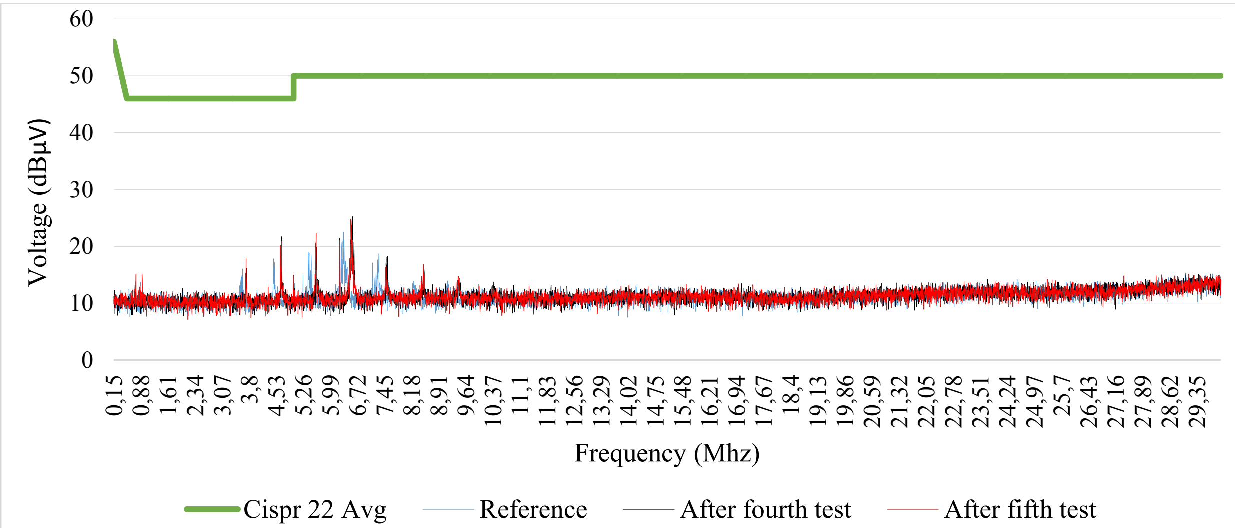

Figure 4.12 – Spectrum of the Conducted Emissions, DUT number 3, Average, Phase

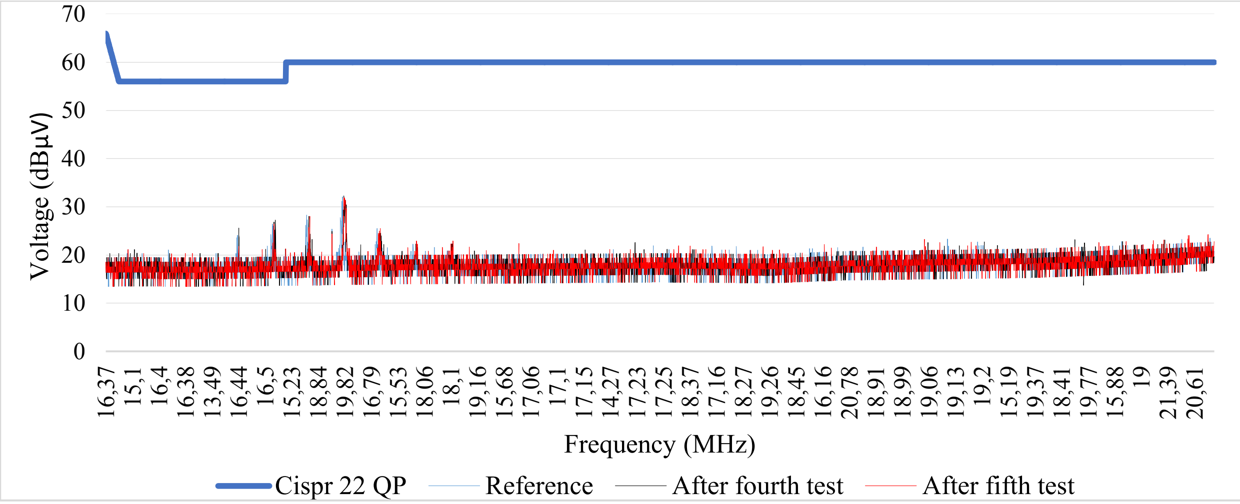

Figure 4.13 - Spectrum of the Conducted Emissions, DUT number 5, Peak, Phase

In some DUTs it was also visible that the major peaks slightly increased, Figure 4.14 shows one test where this increase was more noticeable.

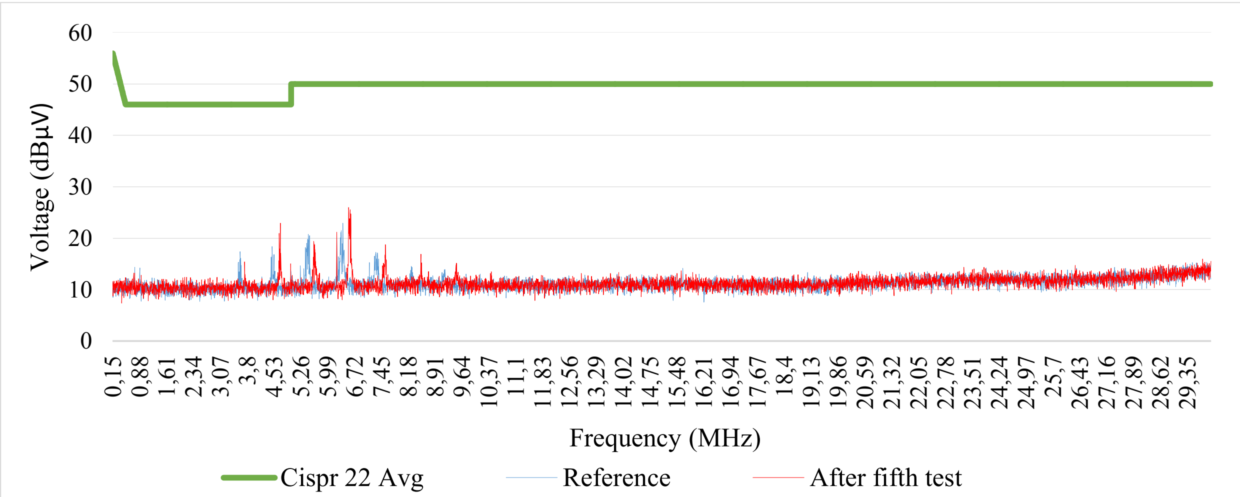

Figure 4.14 - Spectrum of the Conducted Emissions, DUT number 8, Average, Neutral

5. CONCLUSIONS

5.1. Conclusion

The presented work is focused on how the conducted emissions change with the ageing of a device, if they continue to satisfy the limits imposed with ageing. For this, it was proposed and assembled, a platform for ageing and EMC.

The technique considered for ageing the devices is called power cycling, and it is based on the fact that turning the power On and Off repeatedly will provoke a degradation of the electronic components of the device. A platform was built for that purpose and was tested, successfully. The Arduino board was the basis of the ageing platform. It had to acquire multiple signals at the same time, and when all the devices are plugged, under test, and the sensors are acquiring data, the board got a little bit slower. Despite that the Arduino still continued to execute its function properly.

The devices were under several tests and the results show that some degradation has occurred in the spectrum of all the devices. The DUTs considered for testing consisted on switched-mode power supplies obtained from decommissioned computers used at the Department of Electrical and Computer Engineering of the University of Coimbra. No information was available about how many commutations the devices performed, so it was difficult to identify if the level of degradation already existent in the devices was high or not. As the devices were commutating without load, the current absorbed was very small, what may contributed to a slower degradation. Another issue relates with the environment where the tests took place, even though all the requirements were met, there's a high probability that interference may come from different sources, such as electric cables.

One device should had been used as a device for control to ensure that the LISN kept the accuracy, still when the same device was repeatedly tested, the results acquired from the LISN were identical.

All the sensors had a good performance, but one of the relays, the one corresponding to the socket five, stopped working properly. The research done before the platform was built, appointed that a relay can usually do five hundred thousand commutations but this one failed after one hundred and twenty thousand.

After one hundred and twenty thousand commutations, the emissions still continue below the limits, however a change in the degradation of the spectrum for the conducted emissions was detected which encourages the idea that with more commutations these limits will most likely be in risk of being overtaken.

5.2. **Future work**

The work developed in this thesis it's related with an area still under a lot of investigation, some of the decisions were based in assumptions, for example the number of commutations selected. More tests have to be made to increase the knowledge of this area.

There are some changes that may improve the overall performance of both the tests and the aging, firstly the experiment should start with devices unused and from different brand to have an improved range of comparison. To increase the degradation of the conducted emissions more accelerated life conditions could be used. Similarly the use of load in all the devices under test could aggravate the conducted emissions degradation. A control device should be used to detect a possible degradation of the LISN.

Since the Arduino response rate got slower when the number of sensors and actuators increased, the use of a Raspberry Pi or even a different programming language, instead of LabVIEW, Visuino which is a software dedicated to Arduino, could stand as a solution to this issue.

The increase the robustness of the platform, solid state relays could substitute the electromechanical relays.

6. REFERENCES

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Spectrum of the conducted emissions for all the DUTs

DUT number 1

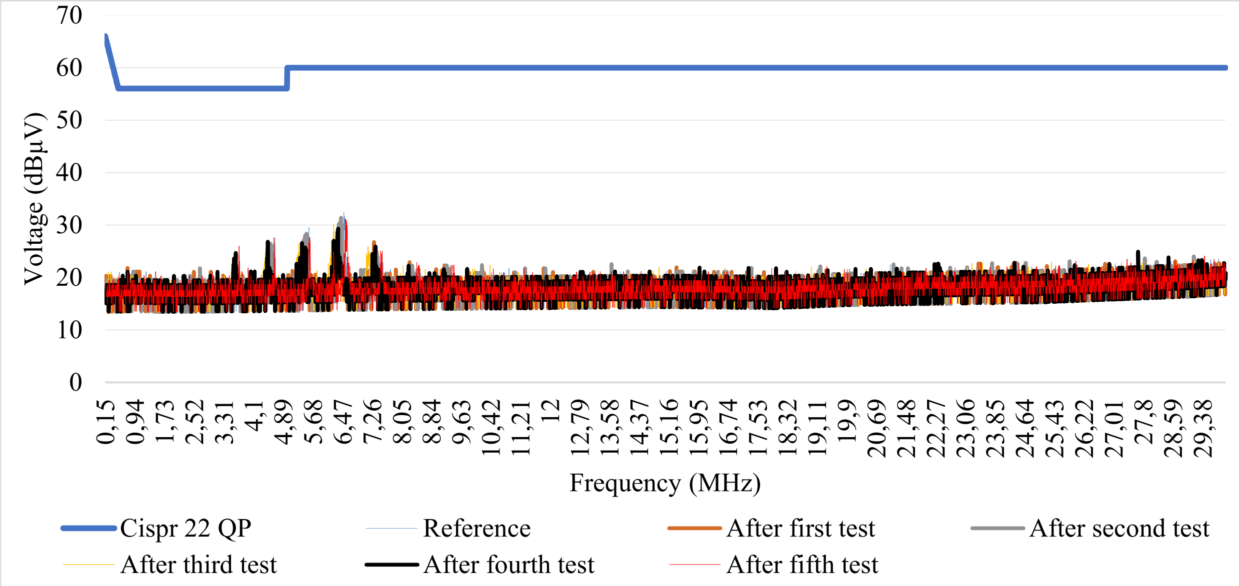

Figure A 1 – Spectrum of the conducted emissions, Peak, Phase

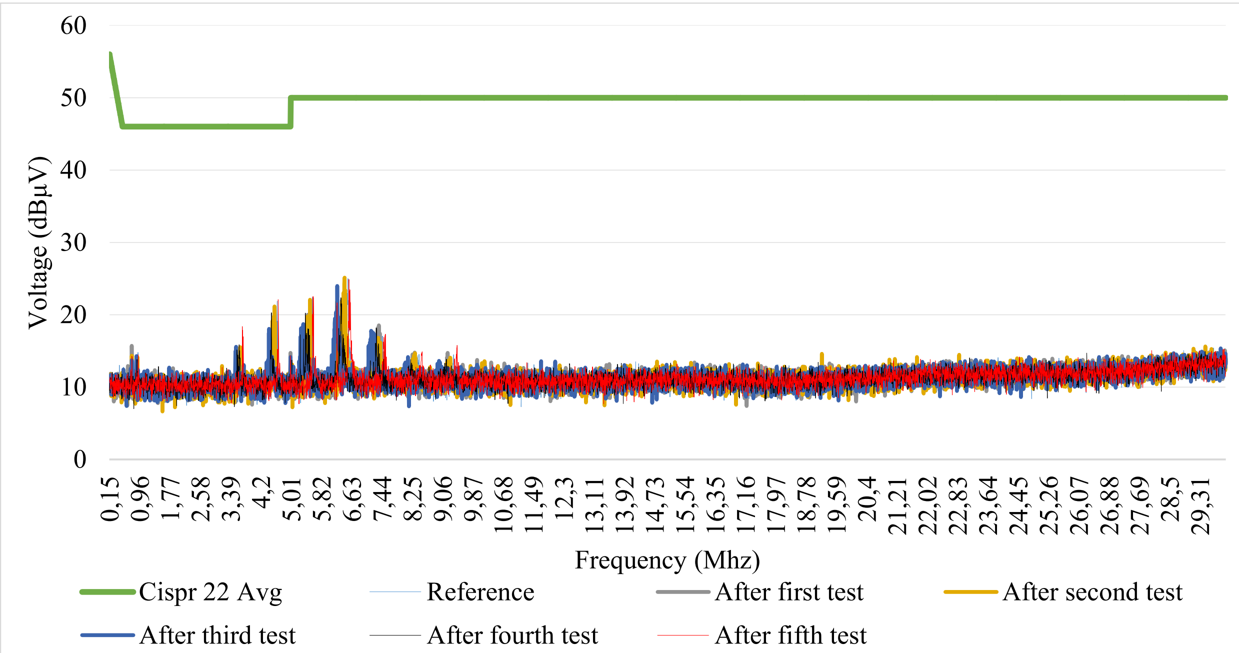

Figure A 2 – Setup for the conducted emissions, Average, Phase

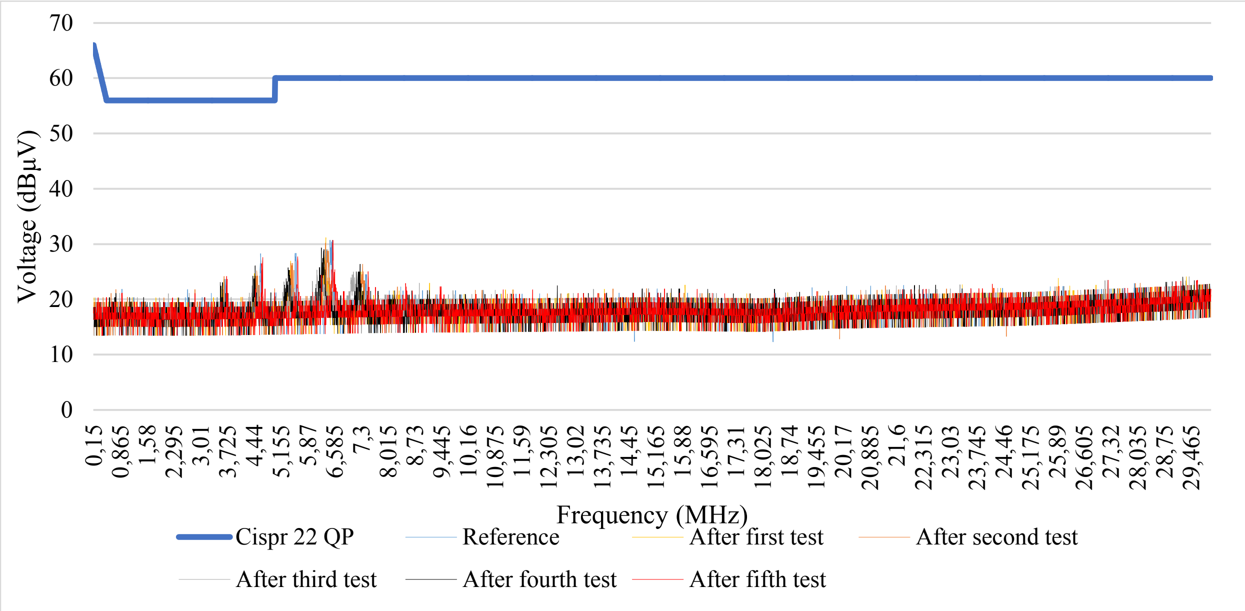

Figure A 3 - Spectrum of the conducted emissions, Peak, Neutral

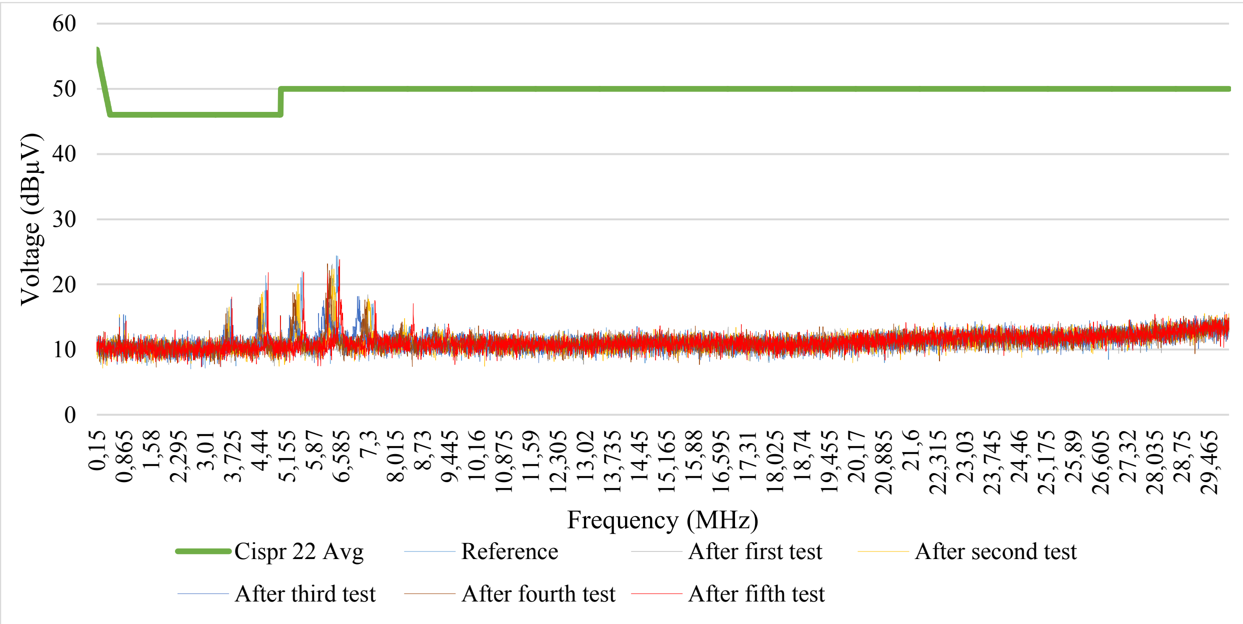

Figure A 4 – Spectrum of the conducted emissions, Average, Neutral

DUT number 2

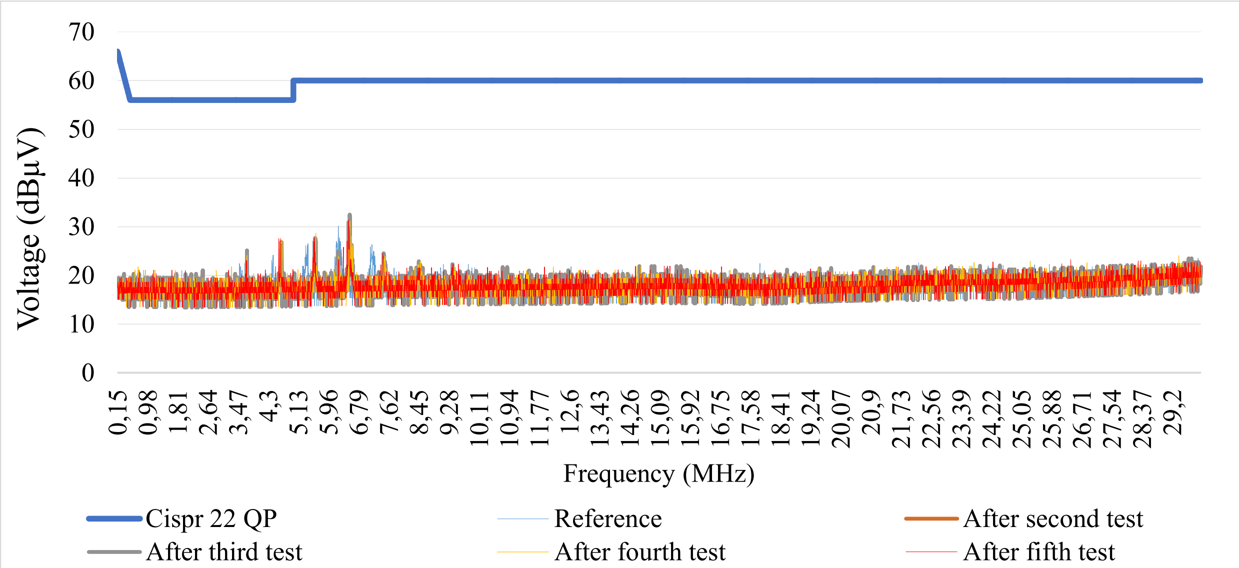

Figure A 5 - Spectrum of the conducted emissions, Peak, Phase

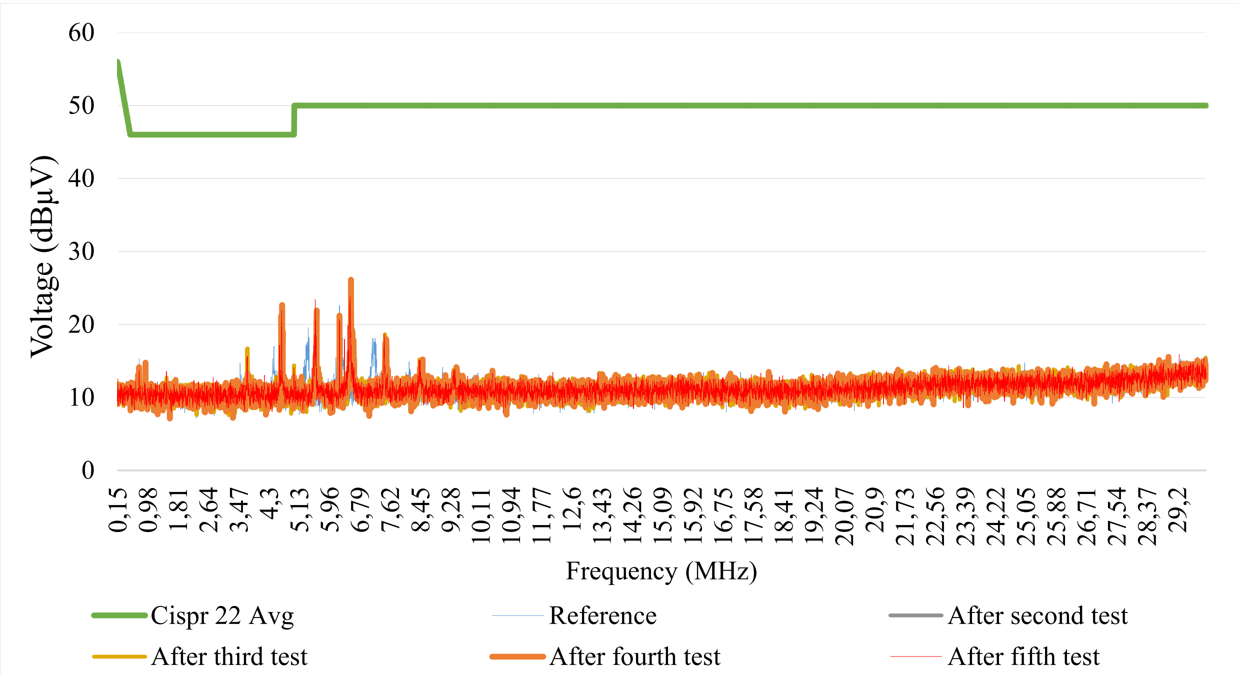

Figure A 6 - Spectrum of the conducted emissions, Average, Phase

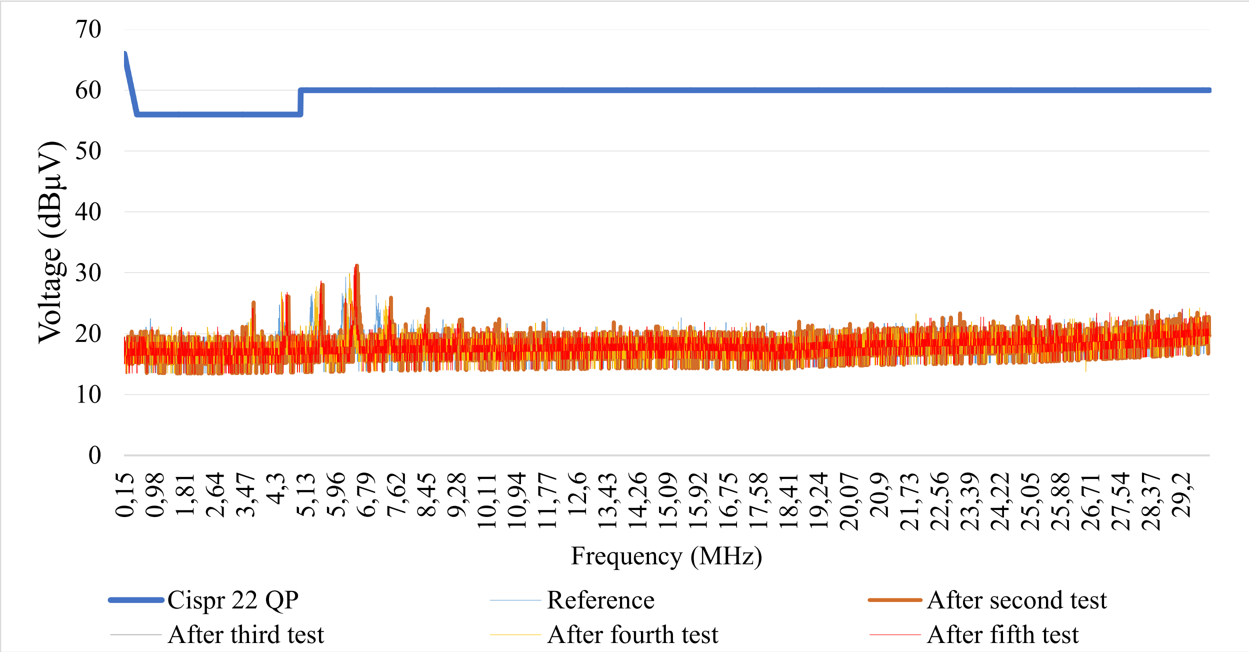

Figure A 7 - Spectrum of the conducted emissions, Peak, Neutral

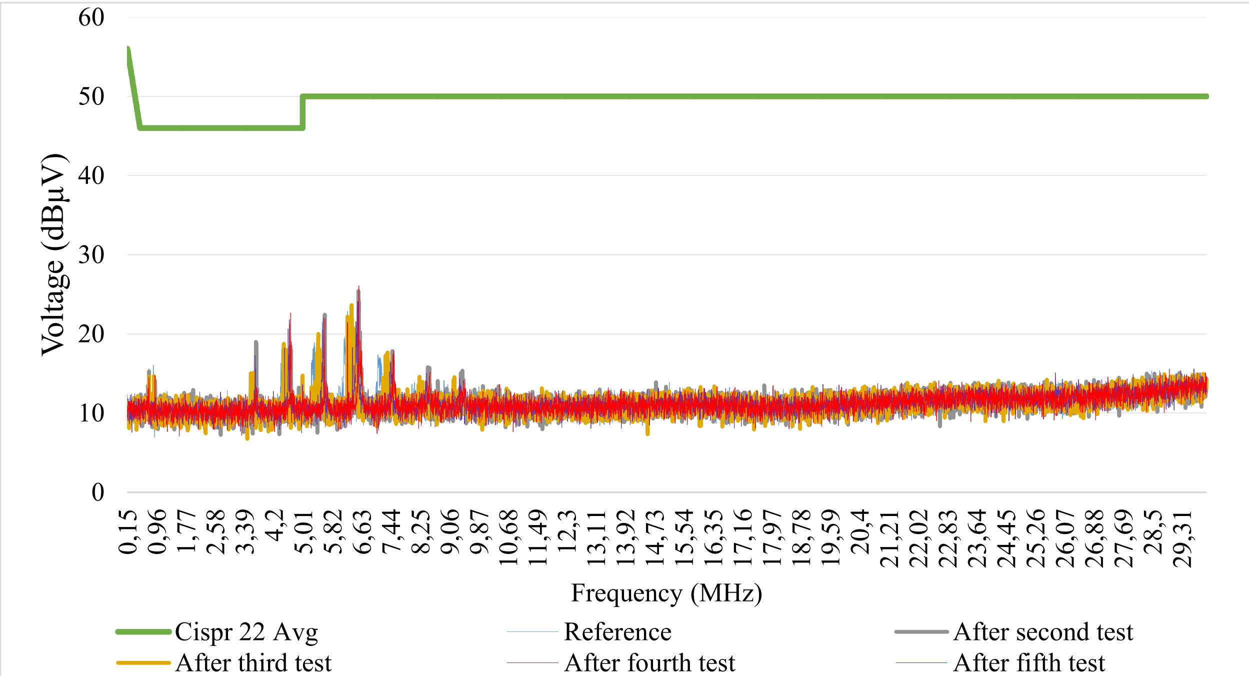

Figure A 8 - Spectrum of the conducted emissions, Average, Neutral

DUT number 3

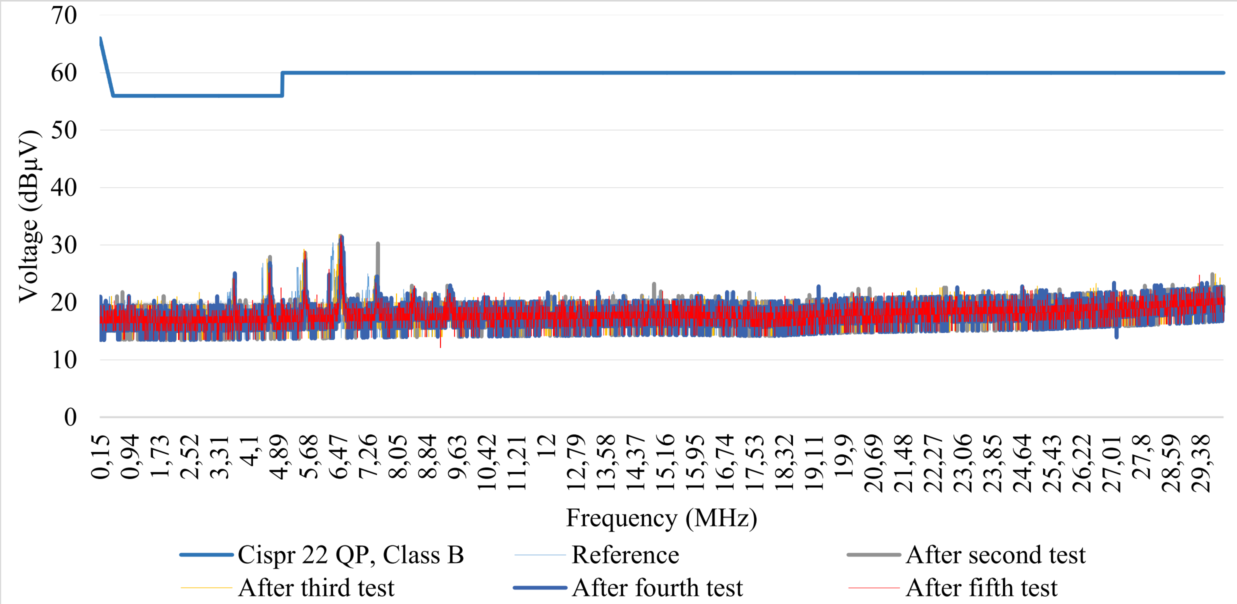

Figure A 9 - Spectrum of the conducted emissions, Peak, Phase

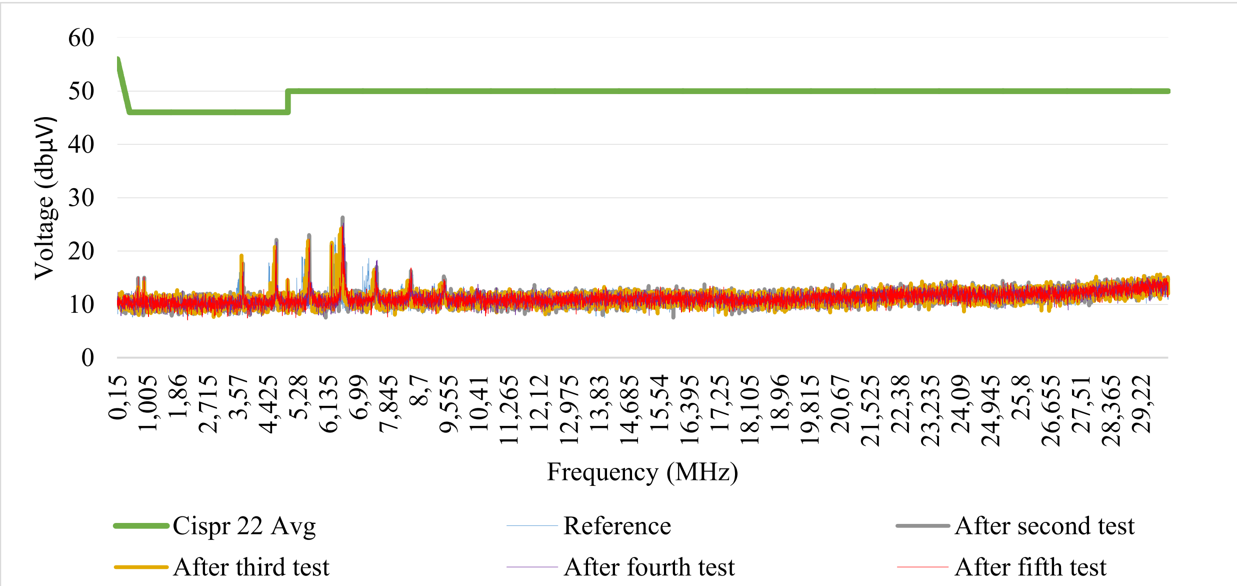

Figure A 10 - Spectrum of the conducted emissions, Average, Phase

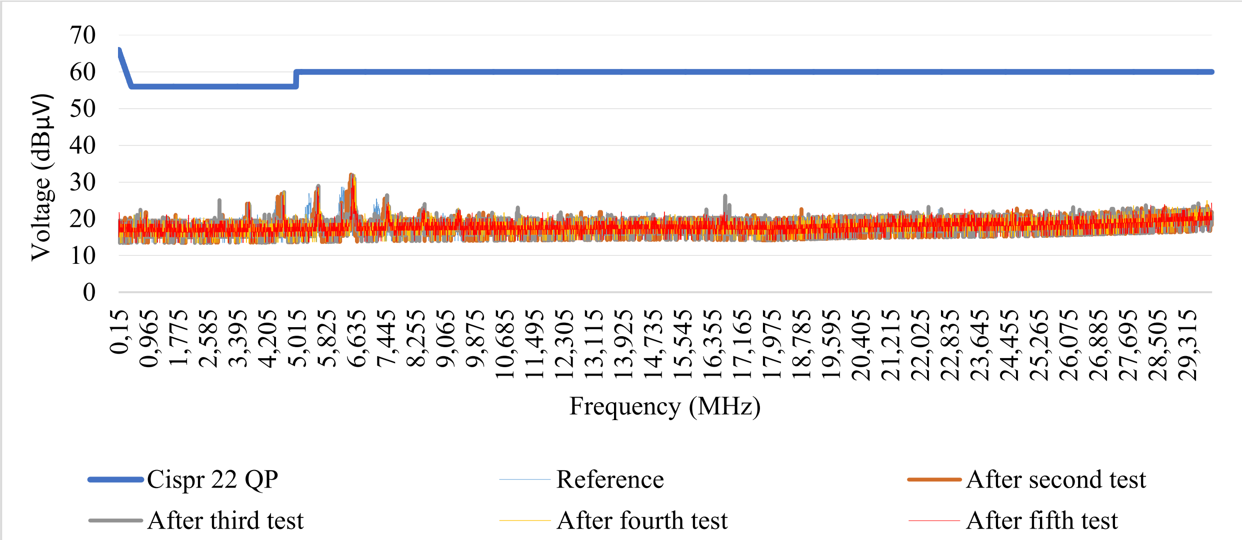

Figure A 11 - Spectrum of the conducted emissions, Peak, Neutral

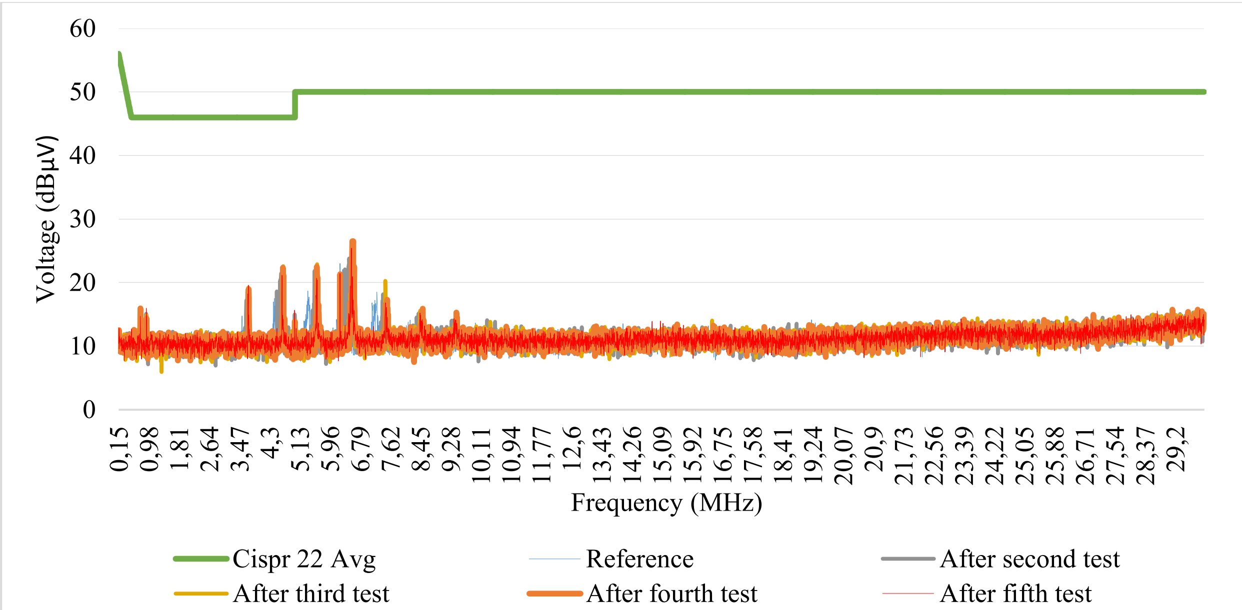

Figure A 12 - Spectrum of the conducted emissions, Average, Neutral

DUT number 4

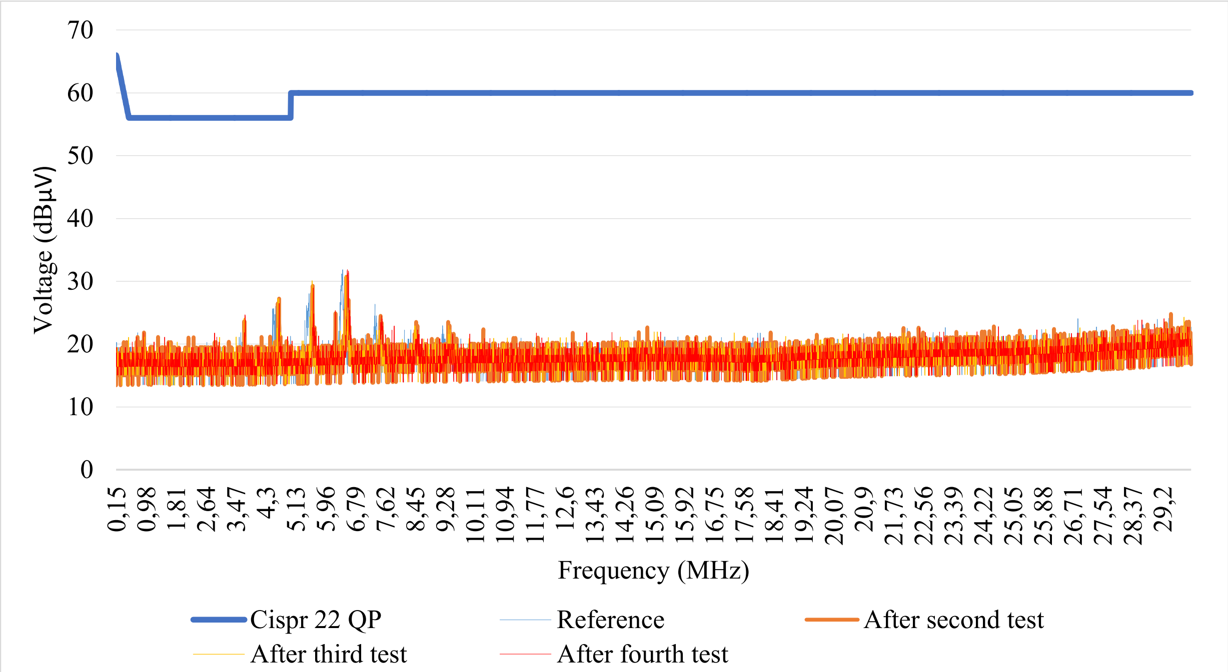

Figure A 13 - Spectrum of the conducted emissions, Peak, Phase

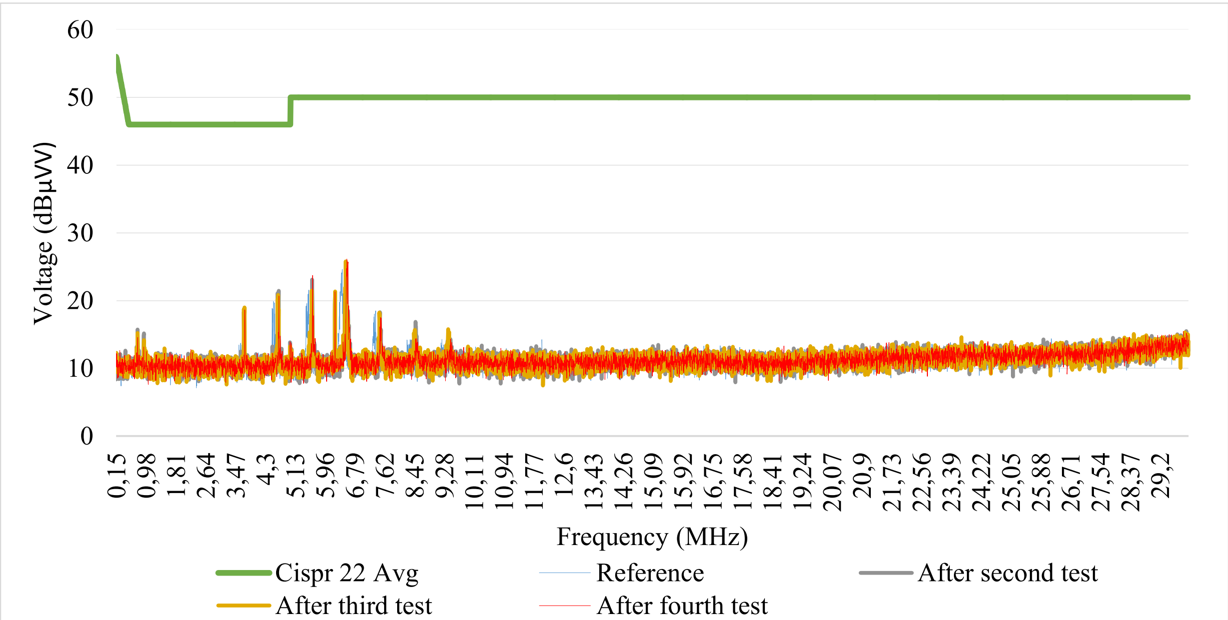

Figure A 14 - Spectrum of the conducted emissions, Average, Phase

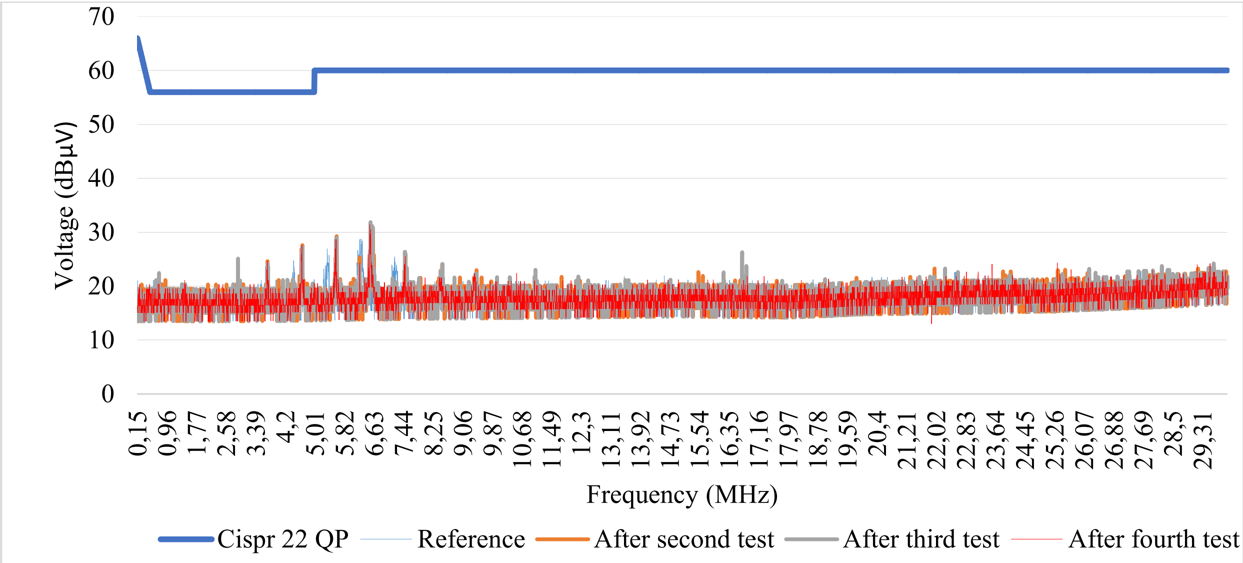

Figure A 15 - Spectrum of the conducted emissions, Peak, Neutral

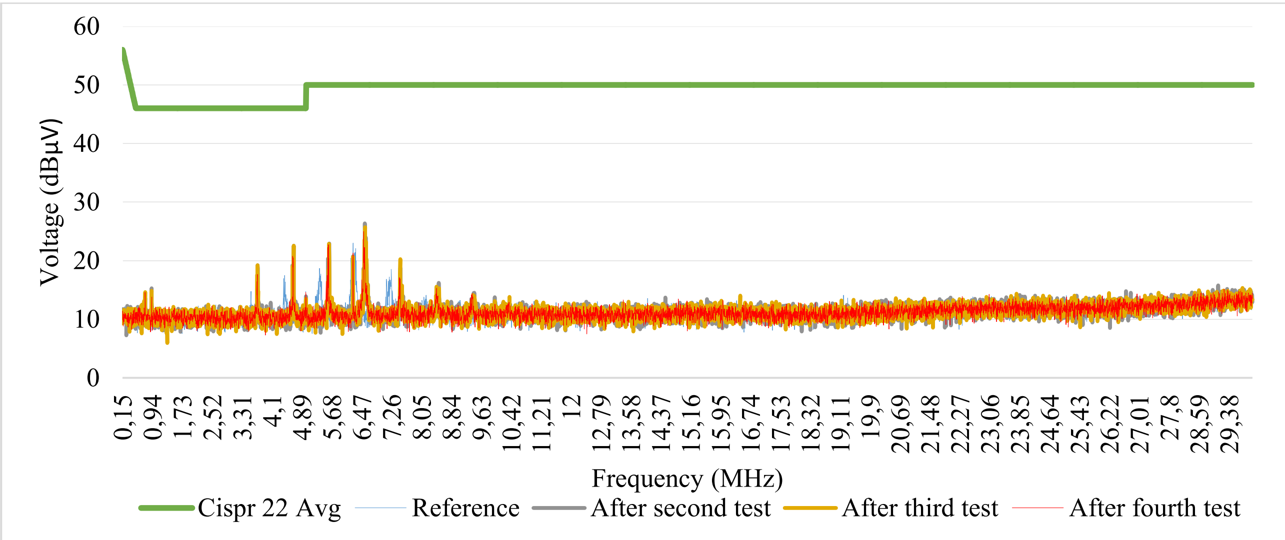

Figure A 16 - - Spectrum of the conducted emissions, Average, Neutral

DUT number 5

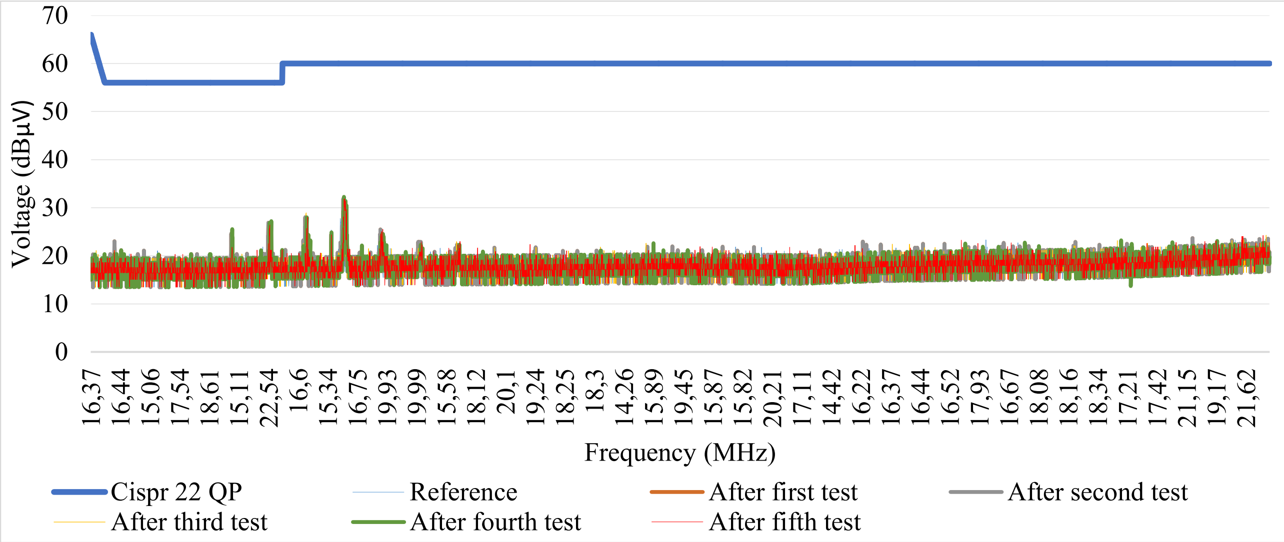

Figure A 17 - Spectrum of the conducted emissions, Peak, Phase

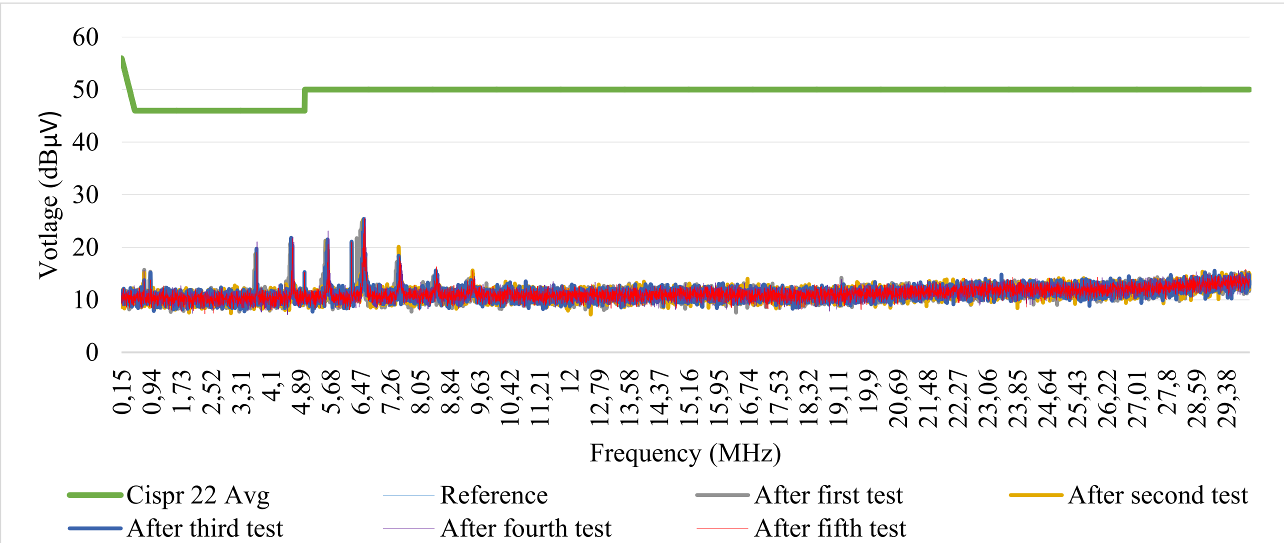

Figure A 18 - Spectrum of the conducted emissions, Average, Phase

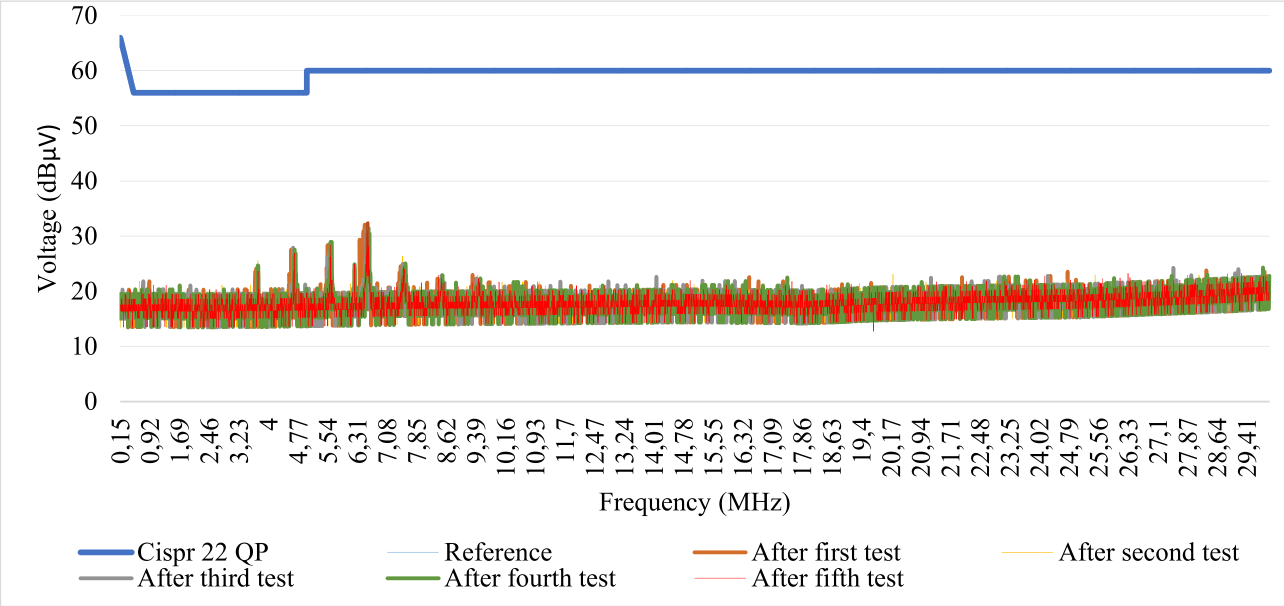

Figure A 19 - Spectrum of the conducted emissions, Peak, Neutral

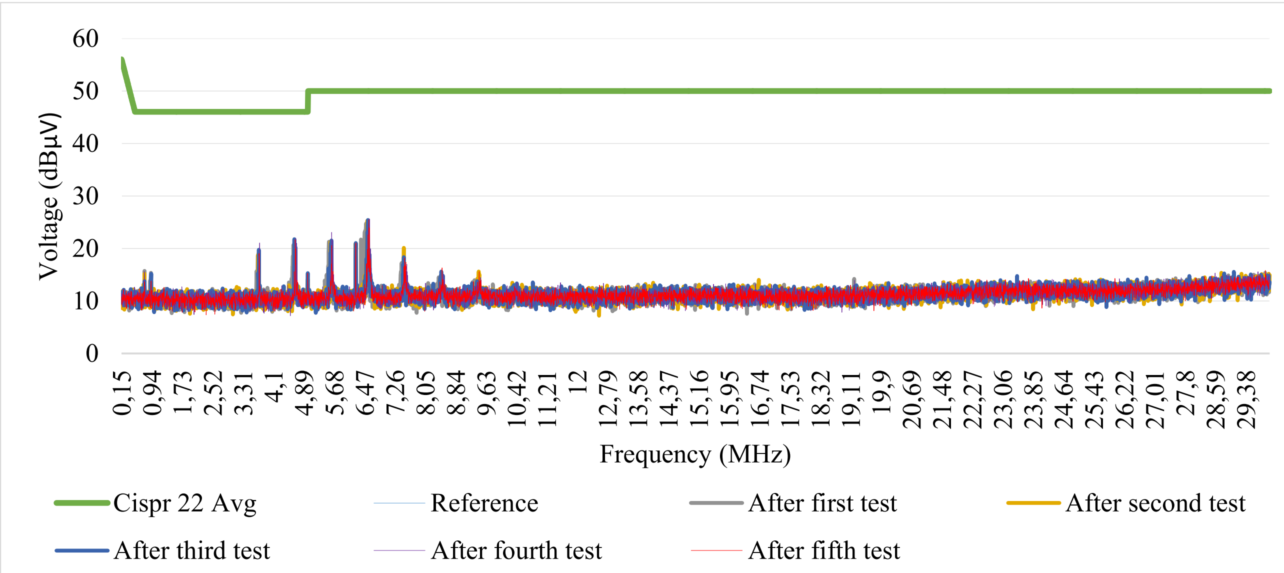

Figure A 20 - Spectrum of the conducted emissions, Average, Neutral

DUT number 6

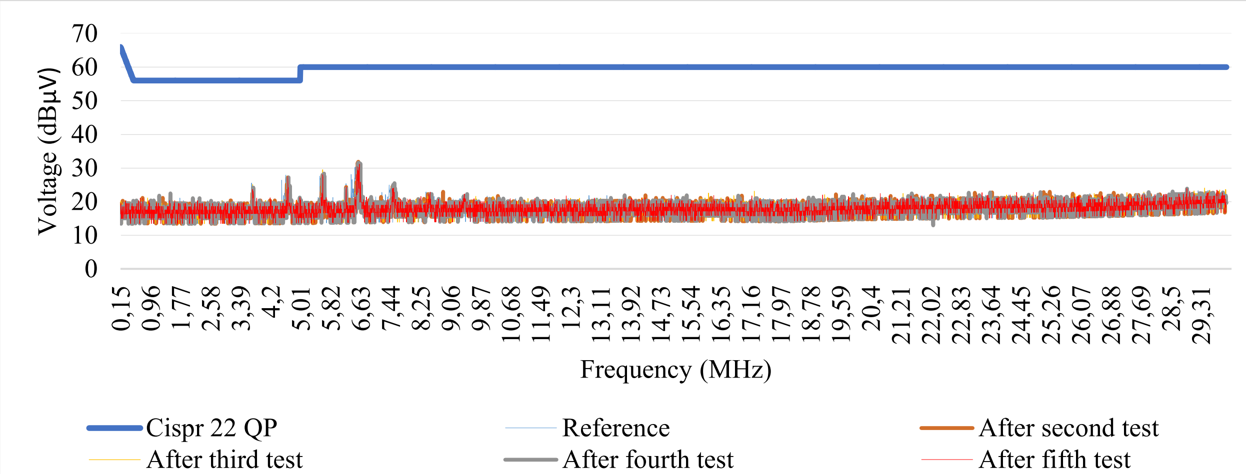

Figure A 21 - Spectrum of the conducted emissions, Peak, Phase

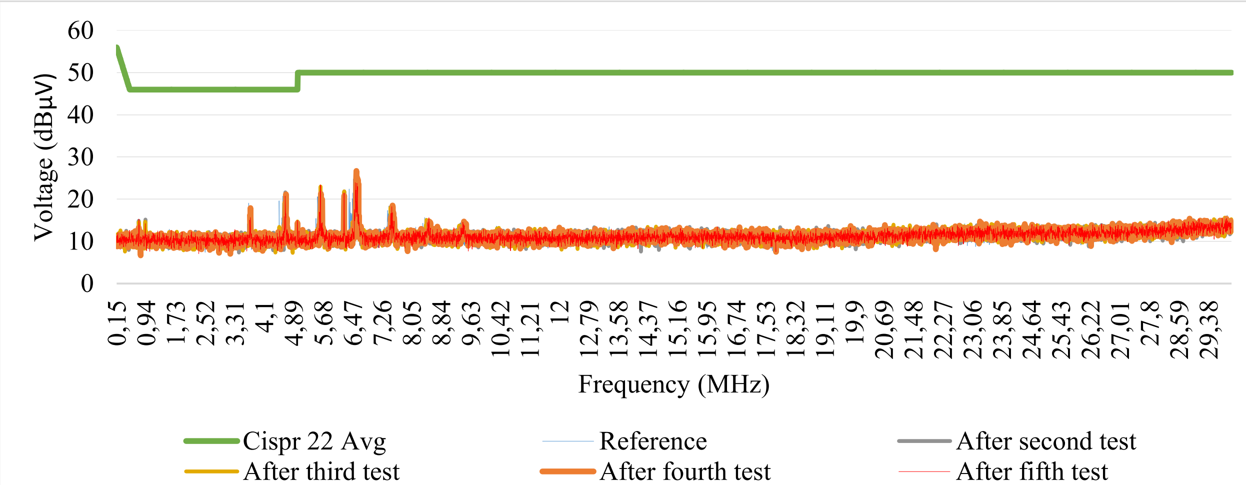

Figure A 22 - Spectrum of the conducted emissions, Average, Phase

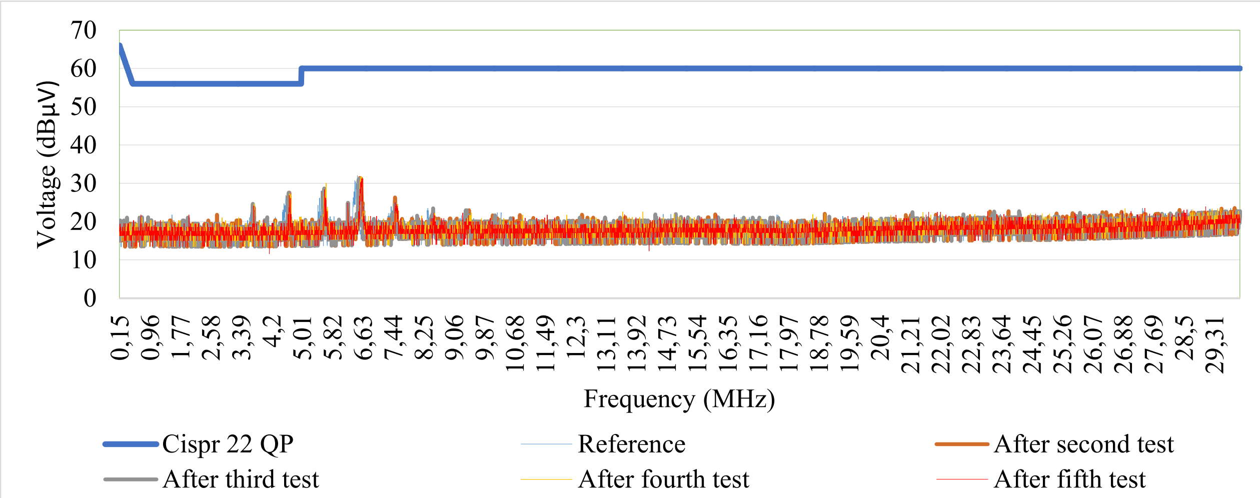

Figure A 23 - Spectrum of the conducted emissions, Peak, Neutral

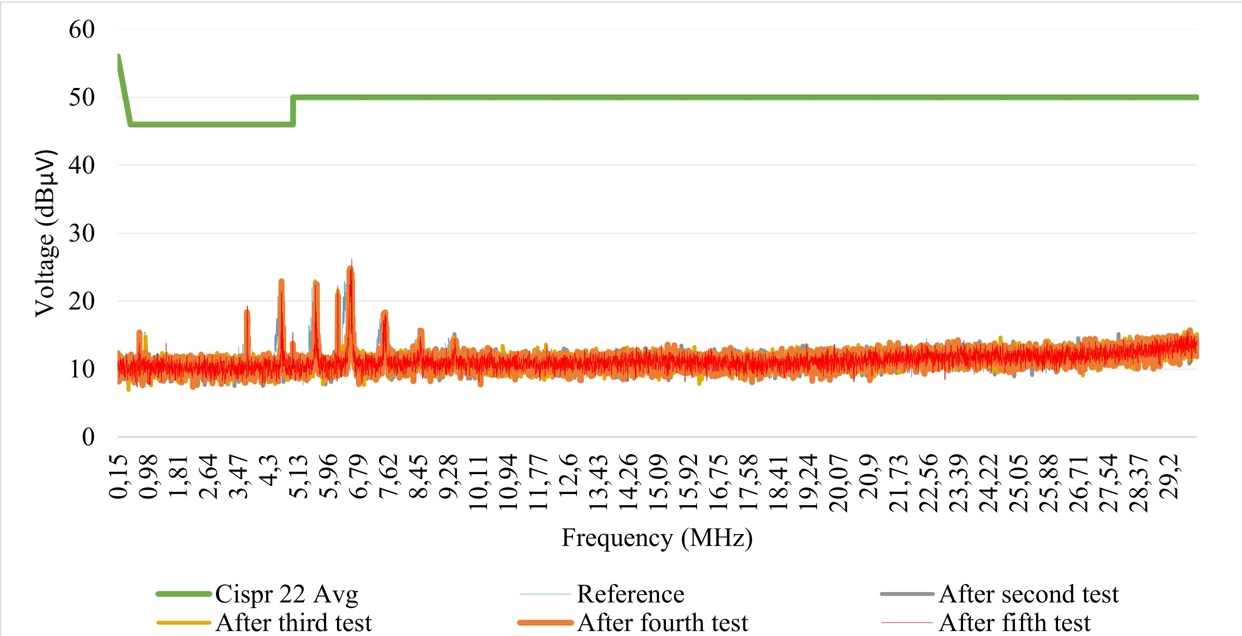

Figure A 24 - Spectrum of the conducted emissions, Average, Neutral

DUT number 7

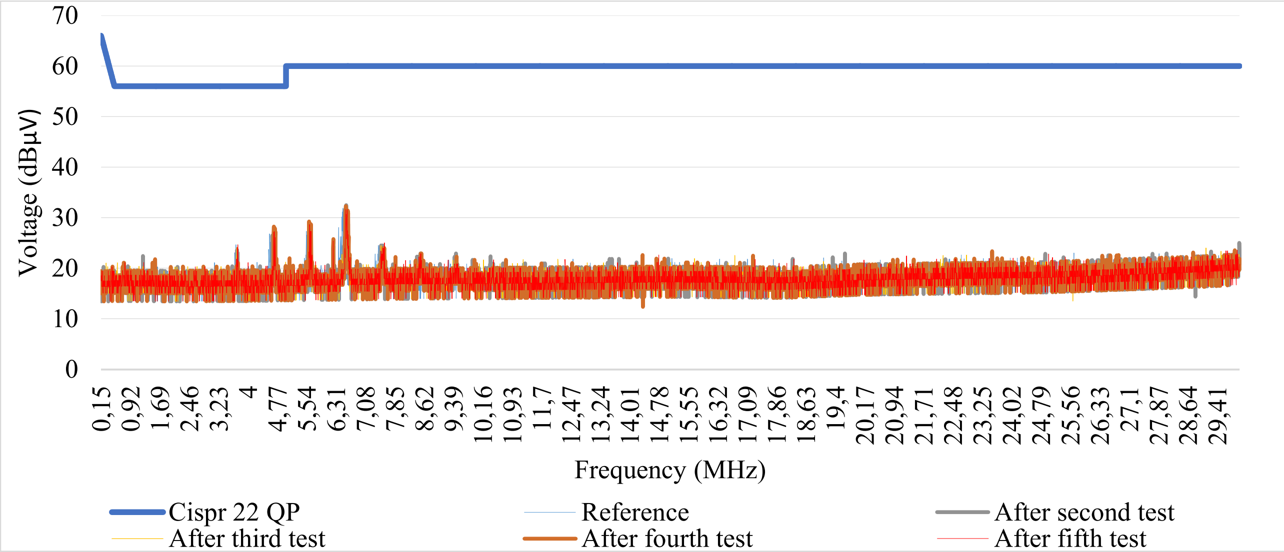

Figure A 25 - Spectrum of the conducted emissions, Peak, Phase

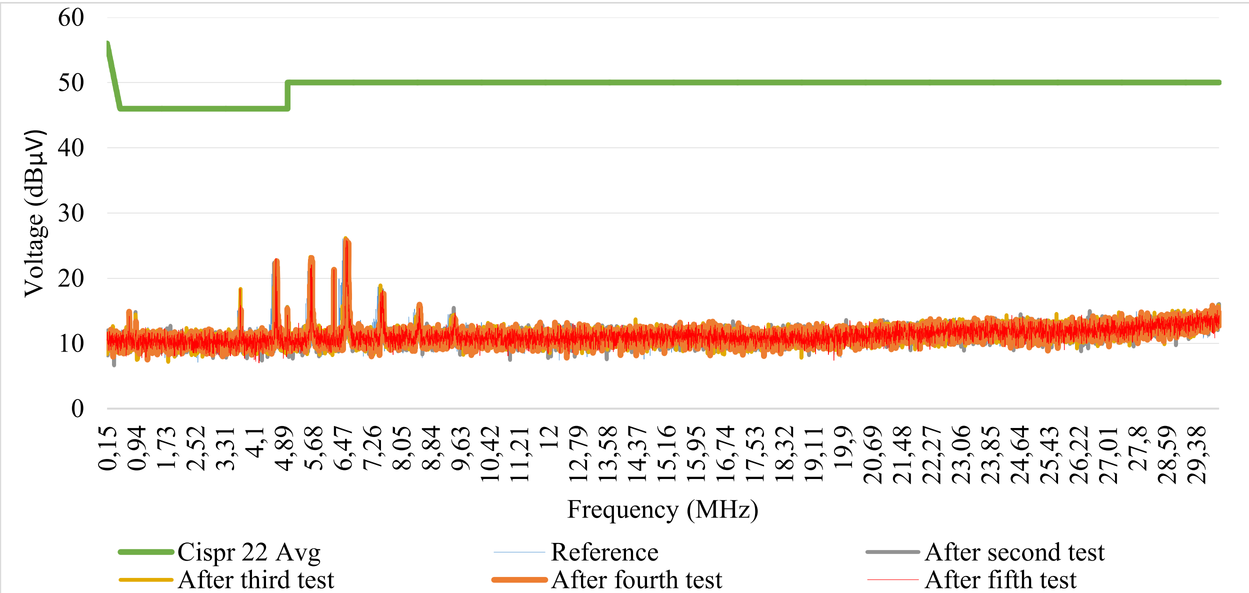

Figure A 26 - Spectrum of the conducted emissions, Average, Phase

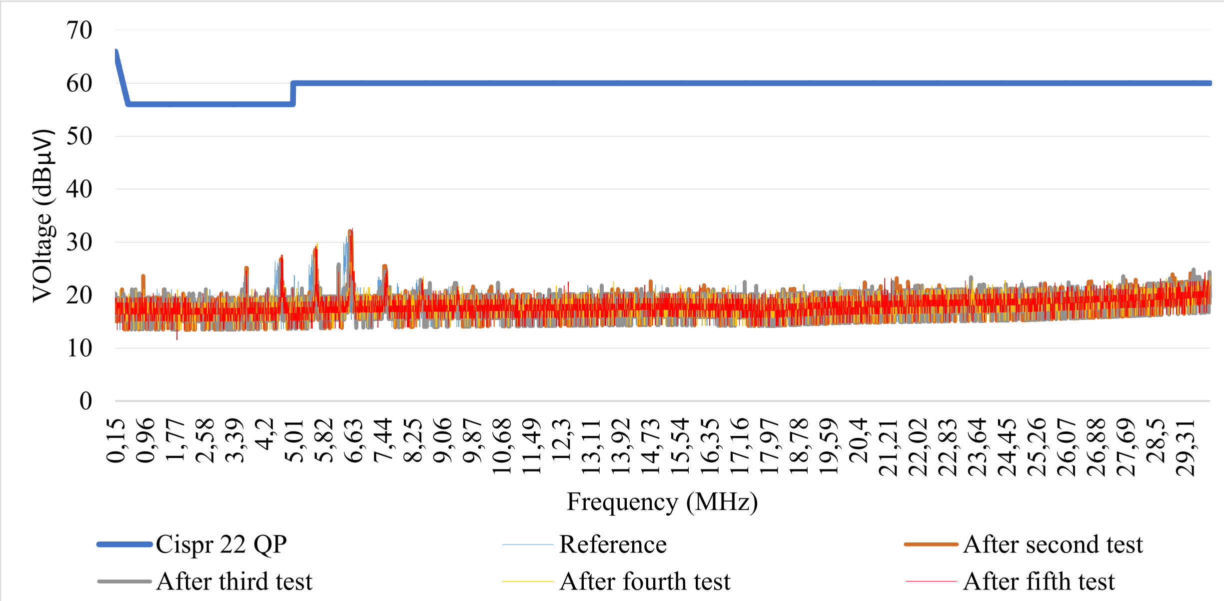

Figure A 27- Spectrum of the conducted emissions, Peak, Neutral

Figure A 28 - Spectrum of the conducted emissions, Average, Neutral

DUT number 8

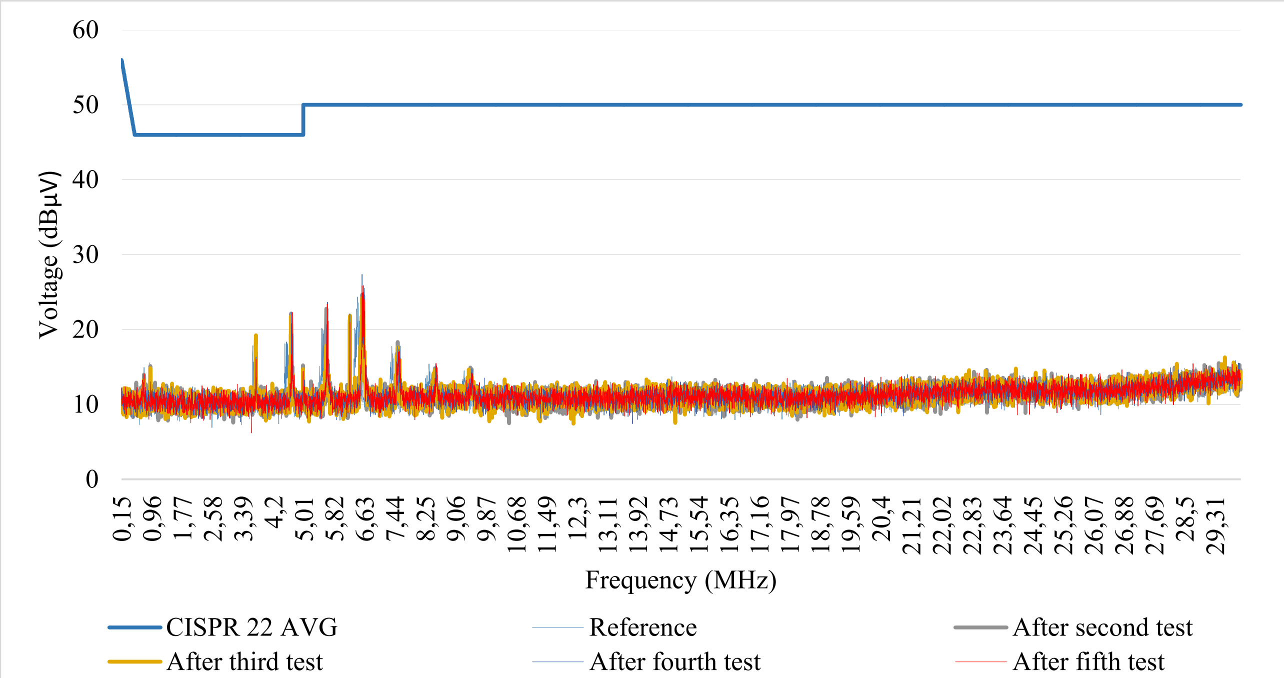

Figure A 29 - Spectrum of the conducted emissions, Peak, Phase

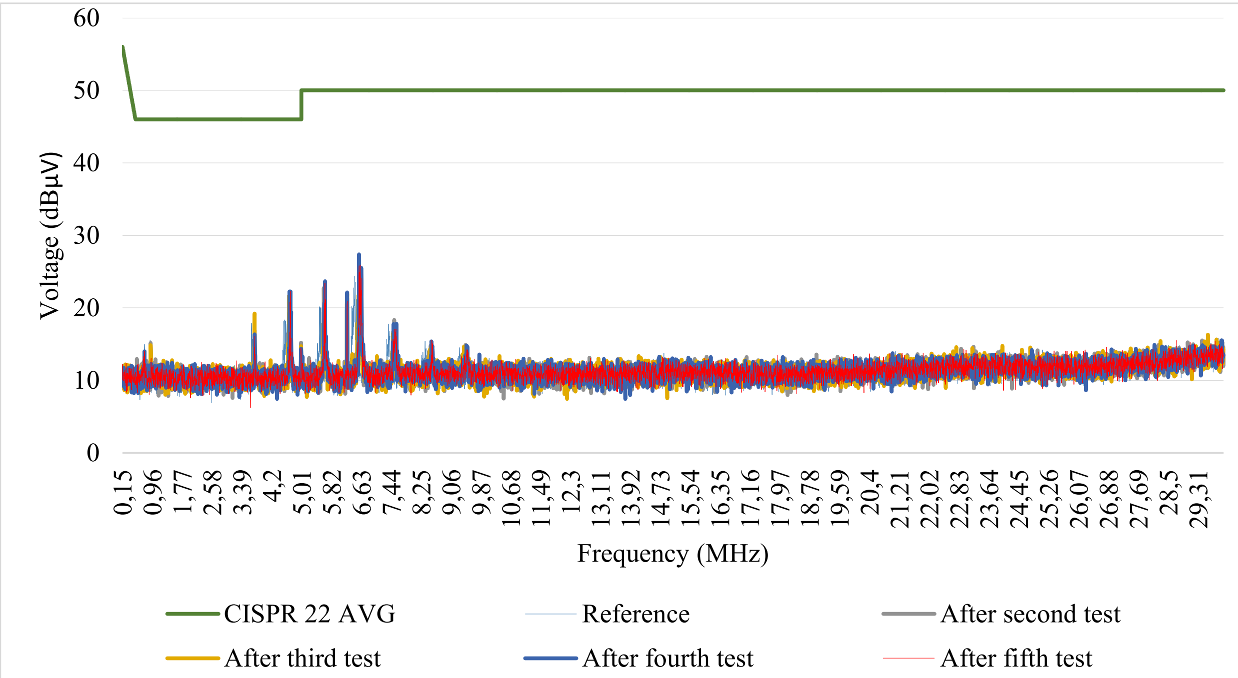

Figure A 30 - Spectrum of the conducted emissions, Average, Phase

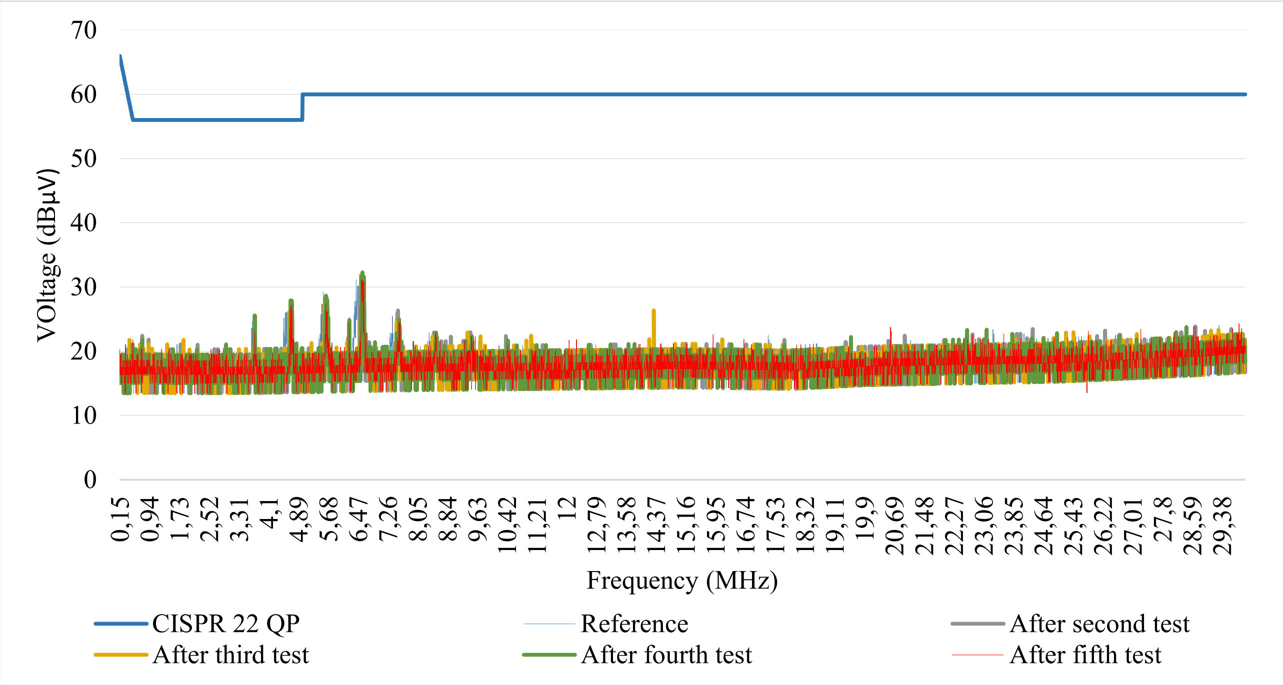

Figure A 31 - Spectrum of the conducted emissions, Peak, Neutral

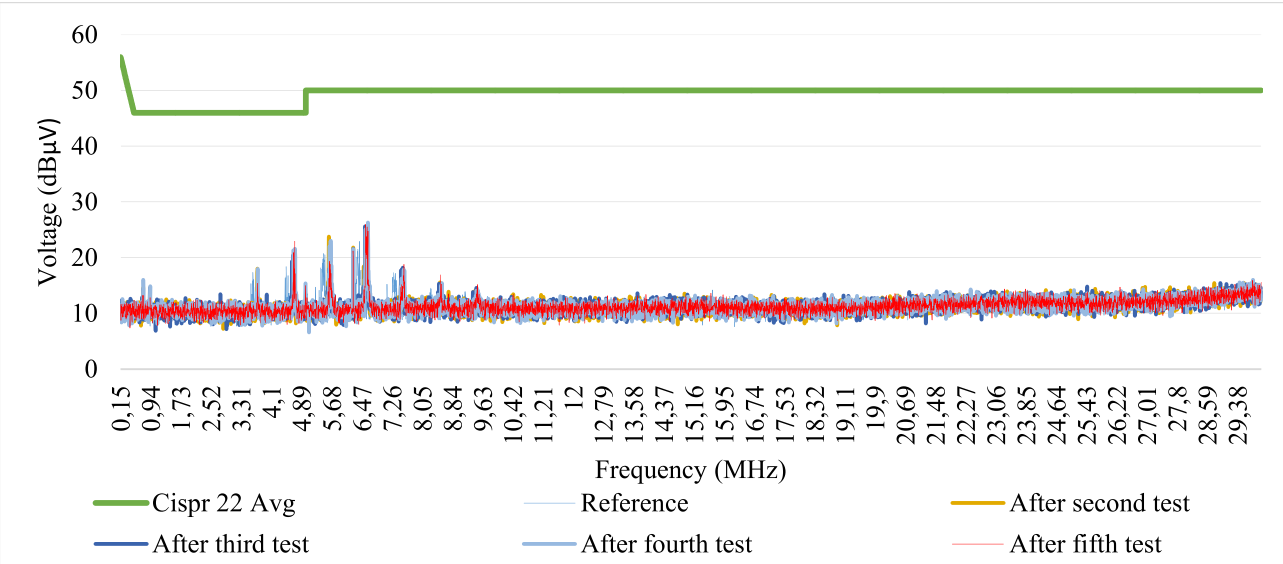

Figure A 32 - Spectrum of the conducted emissions, Average, Neutral

Ageing and EMC Platform - Electrical Power Circuit

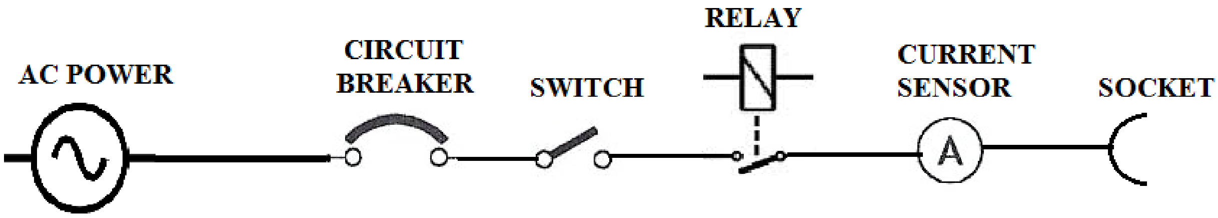

Figure A 33 – Basic sketch of the electrical circuit installed in the platform