International Telecommunication Union

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Radiocommunication Sector of ITU

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Evaluation of radiated electromagnetic disturbances of household appliances and their interferences over an Internet of Things network in the 915 MHz frequency band

SM Series
Spectrum management

International Telecommunication Union

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Note*: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R SM.2503-0

Evaluation of radiated electromagnetic disturbances of household appliances and their interferences over an Internet of Things network in the 915 MHz frequency band

(2022)

Scope

Electronic devices and their networks, including those not used for telecommunications, can produce significative electromagnetic disturbances that may affect the functionalities of current and future telecommunications systems such as Internet of Things (IoT) and their applications. This Report evaluates the levels of electromagnetic disturbances generated by household appliances and how these interferences may affect the functioning of a Wireless Sensor Network (WSN) operating in the 915 MHz band in some administrations, a system which is widely used within IoT due to its technical flexibility and low cost. The work was divided into three stages. The first stage evaluated the electromagnetic disturbances coming from the household appliances, the second stage involved the characterization of the WSN by evaluating the Received Signal Strength Indication (RSSI) and the Packet Error Rate (PER), and finally, the third stage consisted in the assessment of the RSSI and PER with the insertion of the household appliance in the test. The results showed that the researched household appliances did not follow normative limits and significantly affected the functioning of a WSN.

Acronyms and Abbreviations

ABNT	Associação Brasileira de Normas Técnicas (Brazilian Association of Technical Standards)
CISPR	International Special Committee on Radio Interference
IEC	International Electrotechnical Commission
NBR	Norma Brasileira (Brazilian Standard)
PER	Packet error rate
RSSI	Received signal strength indication
SAC	Semi-anechoic chamber
Vac	Volts alternating current
WSN	Wireless sensor network

1 Introduction

Modern electro-electronic equipment and their networks, including those not intended to telecommunications, can produce relevant electromagnetic disturbances.

These occurrences are related to the operational dynamics of its electronic systems, the presence of switched power supplies, nonlinear loads, electromechanical devices and logic circuits among others. These electrical influences can be manifested both in radiated and in conductive ways and, if not mitigated at its source, can degrade and pollute the electromagnetic spectrum.

This context is potentially serious in a residential environment, rich in density, quantity and diversity of electro-electronic equipment and their networks which can directly affect the functionalities of radiocommunications services in the users or consumers area.

This study evaluated the behaviour of a Wireless Sensor Network (WSN) when submitted to the disturbances caused by household appliances through the analysis of Received Signal Strength Indication (RSSI) and Packet Error Rate (PER).

The work was divided into three stages. The first measured the electromagnetic emissions of the household appliances. Subsequently, the characterization of a WSN was performed with the respective RSSI and PER. Finally, the WSN was evaluated in the same criteria when home appliances were inserted in the test.

2 Equipment and installations

All the measurements took place inside an ETS-LINDGREN Semi-anechoic Chamber (SAC) workable from 9 kHz to 220 GHz, with a turntable.

Two antennas were used: UltraLog, model HL562E, for measurements from 30 MHz to 1 GHz, and Double Ridged Guide antenna, model 3117, for measurements from 30 MHz to 6 GHz.

The meter was a Rohde & Schwarz, model ESIB 40 EMI Test Receiver with selectable bandwidths of 200 Hz, 9 kHz, 120 kHz and 1 MHz with peak, average and quasi-peak detectors as requested by IEC CISPR 16-1.

Variable attenuators from JFW Industries, models 50R-029 (0 to 70 dB with the precision of 0.5 dB) and 50R-019 (0 to 10 dB with the precision of 0.2 dB) where applied to the WSN. A network analyser from Agilent Technologies, model E5071B, was used to evaluate these attenuators.

The radio module was a BE900, homologated by Anatel (Agência Nacional de Telecomunicações). It features wireless communication for monitoring and control applications using 2-FSK modulation with maximum 250 kbit/s. It carries a programmable ATmega328 AVR processor, CC1101 RF transceiver with 10 dBm power output, sensitivity of −112 dBm with 1% of PER, using a band-pass filter adjusted to operate in the Industrial, Scientific and Medical (ISM) bands 902-907.5 MHz and 915-928 MHz.

This work considers the measurements made with two blenders (220 Vac and 127 Vac) and a vacuum cleaner as the household appliances. Additionally, a microwave oven and a refrigerator were used for combined measurements. They were chosen because they are typical in residential environments and were available at the time of the research, and were used with the aim to extract more complete results.

The measurements were developed in *Instituto de Pesquisas Eldorado* as part of graduate research at *Pontifícia Universidade Católica de Campinas* (São Paulo, Brazil).

3 Methodology

First was performed the validation of the SAC based on methodology presented by ABNT NBR IEC/CISPR 22[1]. The background noise analysis was also performed scanning the spectrum with antenna ranging from 1 to 4 metres of height, in vertical and horizontal positions. Attenuators were also analysed from 400 MHz to 1 000 MHz with the Network Analyzer to obtain the performance compared with the datasheet.

In order to develop measurements of radiated electromagnetic disturbances, the household appliances were placed 80 cm away from the floor on a wooden table and over the turntable, keeping the distance of 10 metres from the measuring antenna, as can be seen in Fig. 1.

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1 Implementation of CISPR Publication 22 in Brazil.

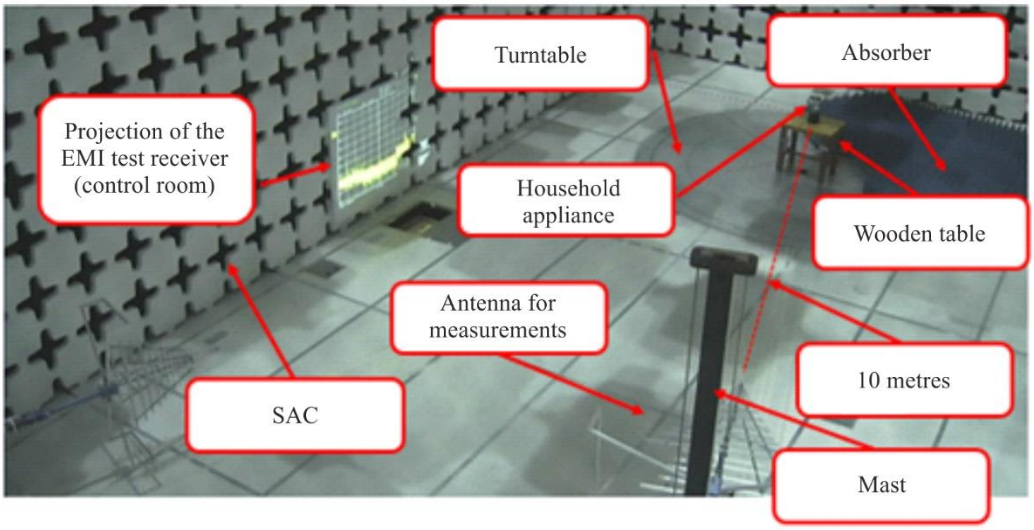
The measurements were taken in the frequency range from 30 MHz to 1 GHz, according to requirements given by CISPR 14-1; while CISPR 22 was used for measurements up to 6 GHz.

The first analysis used peak detector, while the final measurements was based in quasi-peak at the peaks above the limit and near the frequencies of the WSN, especially 915 MHz band considering the flowchart of Fig. B.1 in the ABNT NBR IEC/CISPR 22. In order to carry out these measurements, EMC32 software from Rohde & Schwarz was used.

To evaluate the WSN, a computational code was created using the Python programming language. A 52-byte packet was sent by the serial through USB connection of the computer to the WSN base. The detection was performed at the WSN to evaluate the RSSI (both uplink and downlink) and PER. Both were placed inside the SAC to evaluate the behaviour of the network in a controlled environment, according to Fig. 2. Attenuators were inserted before the base to evaluate the level of sensitivity. The computer for data collection was placed under the floor of the SAC to avoid influencing the measurements. The distance between the base and the sensor node was approximately 4.5 metres, placed on a tripod 1 metre from the ground.

FIGURE 1

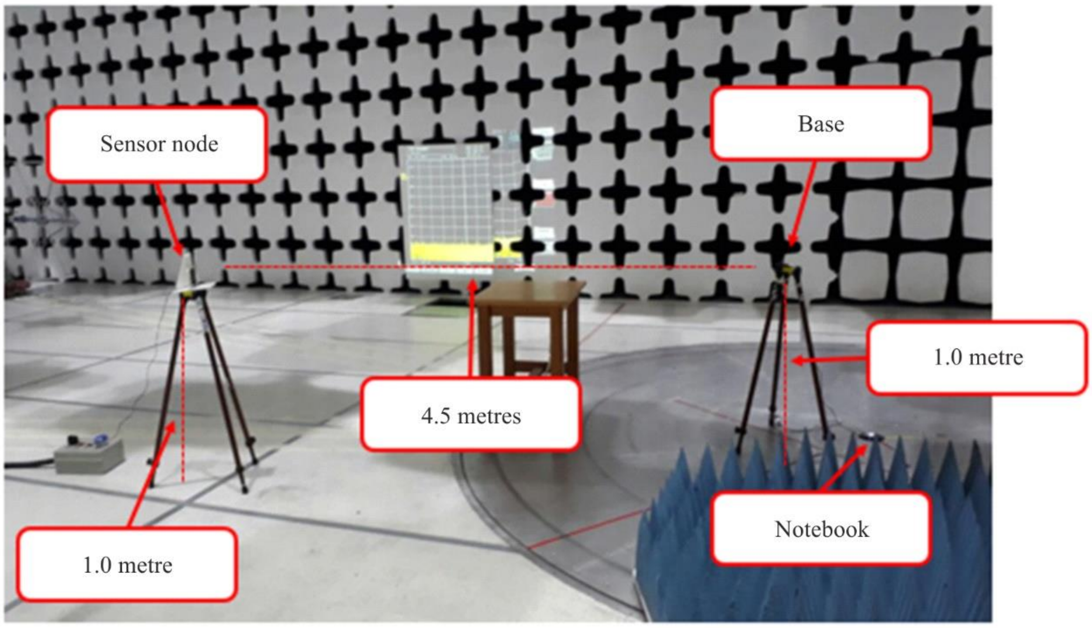
Test configuration used for measure electromagnetic disturbances



Report SM.2503-1

FIGURE 2

WSN configuration inside the SAC without the household appliances



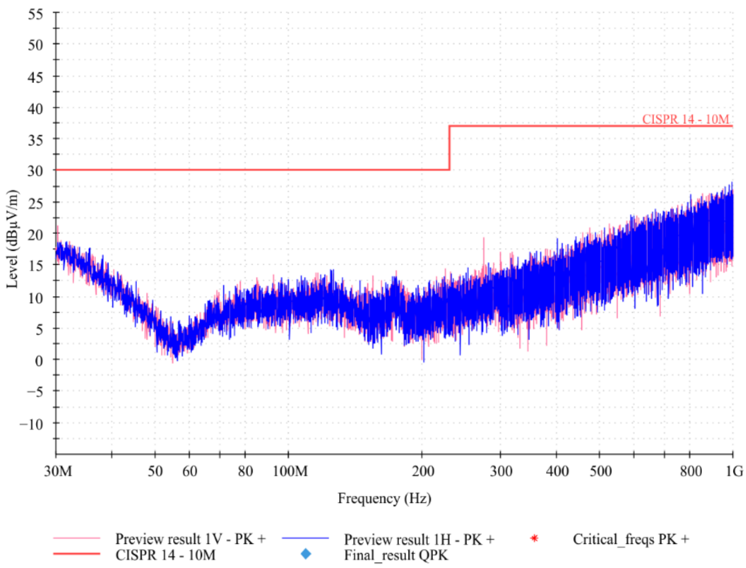
Report SM.2503-2

4 Measurements of the disturbances

Figure 3 shows the background noise measured with the household appliances switched off. Figures 4 to 7 present the results obtained in the measurements of radiated electromagnetic disturbances with household appliances switched on.

FIGURE 3

Result of disturbance measurement – Background noise

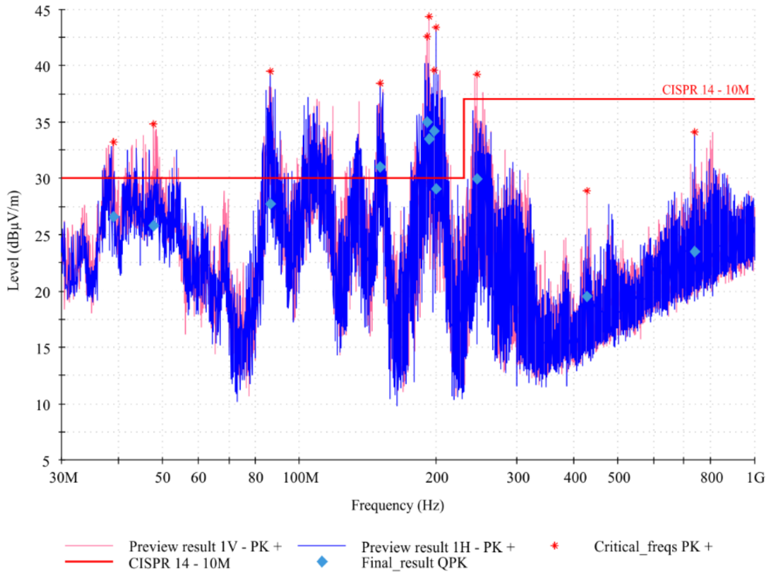


Report SM.2503-3

As can be observed in Fig. 4, in the peak scan, values obtained are above the normative limit. Frequencies near 150, 190, 193 and 197 MHz were above the limit for quasi-peak measurement, with highest level of 4.97 dB compared with the limit. It is possible to conclude that this vacuum cleaner does not meet the normative requirement.

FIGURE 4

Result of disturbance measurement – Vacuum cleaner

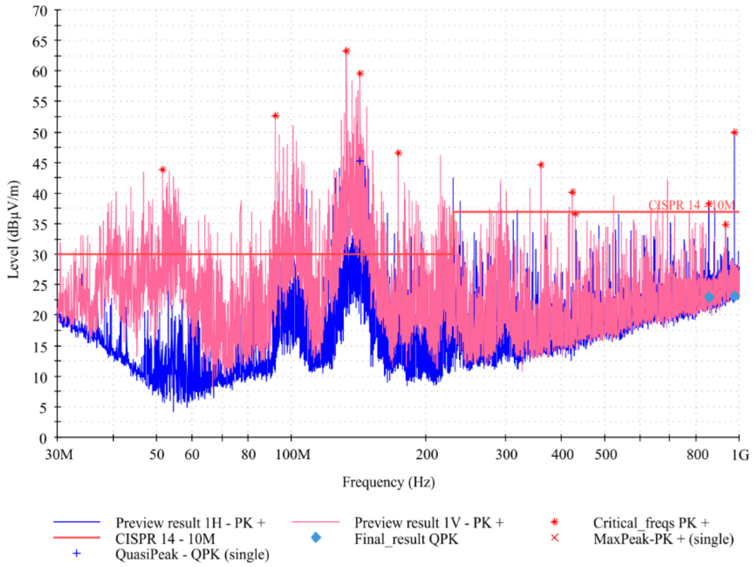


Report SM.2503-4

Figure 5 shows the measured disturbances of a 127 Vac blender. Values obtained in the peak scan were above the normative limit. When evaluating quasi-peak measurements, the values were below the limit closer to 900 MHz; however, the evaluation must consider all frequencies tested to meet the requirements. Noticeably, the device presented high level of disturbances in the region surrounding 150 MHz, but not restricted to it.

FIGURE 5

Result of disturbance measurement – Blender 127 Vac

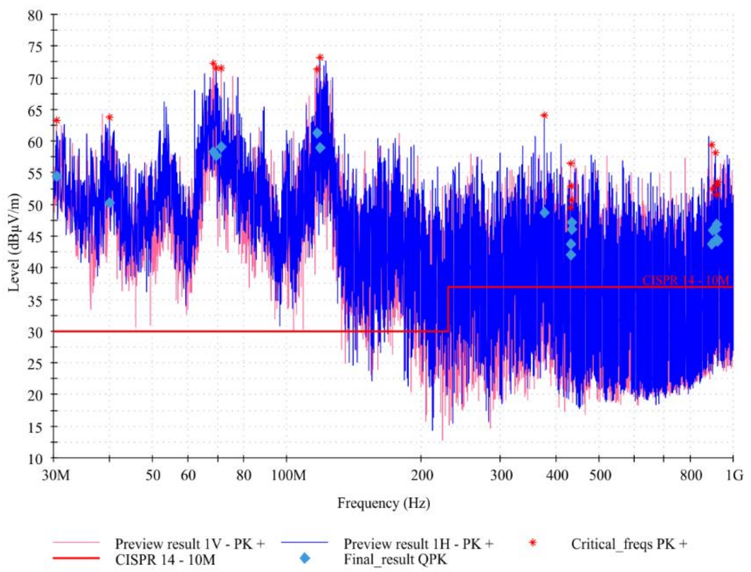


Report SM.2503-5

Figure 6 shows the result of the measured disturbances of a 220 Vac blender. It demonstrates a significant level of electromagnetic disturbances, exceeding the normative limit in more than 25 dB. In the range of the WSN, the perturbations were close to 10 dB above the normative limit. Through this measure, because of the high levels of disturbance, this appliance was chosen to be used in evaluation with the WSN.

FIGURE 6

Result of disturbance measurement – Blender 220 Vac

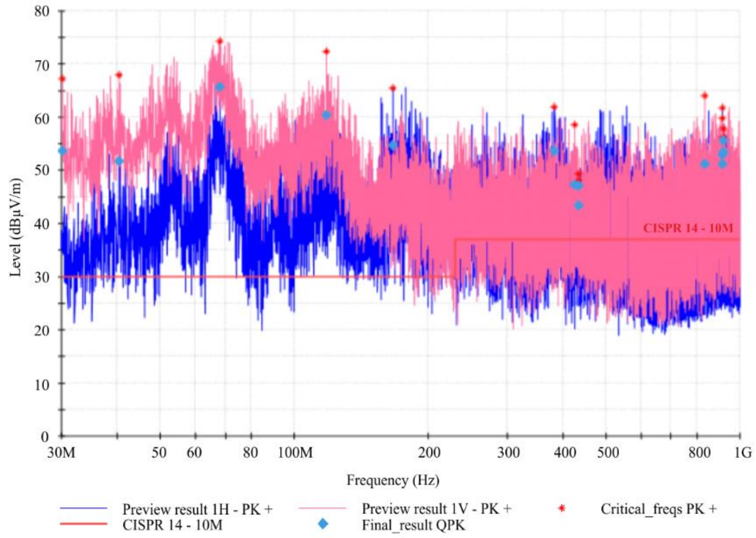


Report SM.2503-6

Figure 7 presents the measured disturbances when both blenders operated simultaneously. The levels exceed the normative limit in more than 30 dB and, in the frequency range of the WSN; the perturbations were approximately 15 dB above the normative limit.

FIGURE 7

Result of disturbance measurement – Blenders 127 Vac and 220 Vac

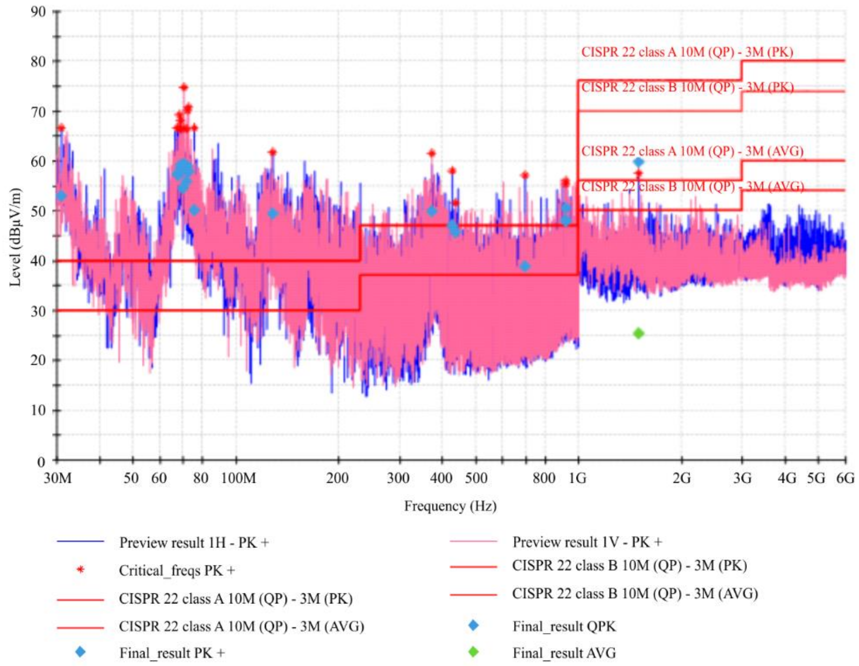


Report SM.2503-7

Additionally, measurements of combined perturbations coming from different types of household appliances were performed. Figure 8 presents the measurements with a microwave oven, a refrigerator and a 127 Vac blender. The levels exceeded the limits in several frequencies, including above 1 GHz.

FIGURE 8

Result of disturbance measurement – Microwave oven, refrigerator, blender (127 Vac)



Report SM.2503-8

5 Evaluation of the interferences

Figure 9 shows the collection of 100 measurements of the WSN RSSI with the household appliance (220 Vac blender) in the SAC. The yellow indications show the packet losses caused by the electromagnetic interference coming from the blender. The PER obtained was 42%, resulting in a significant loss of data traffic in the operationalization of the WSN.

FIGURE 9

RSSI analysis with household appliances – 100 measurements

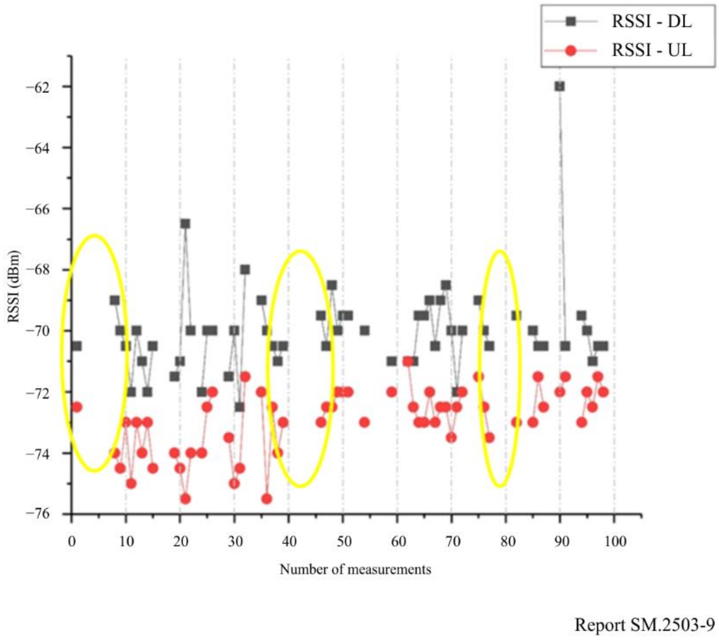
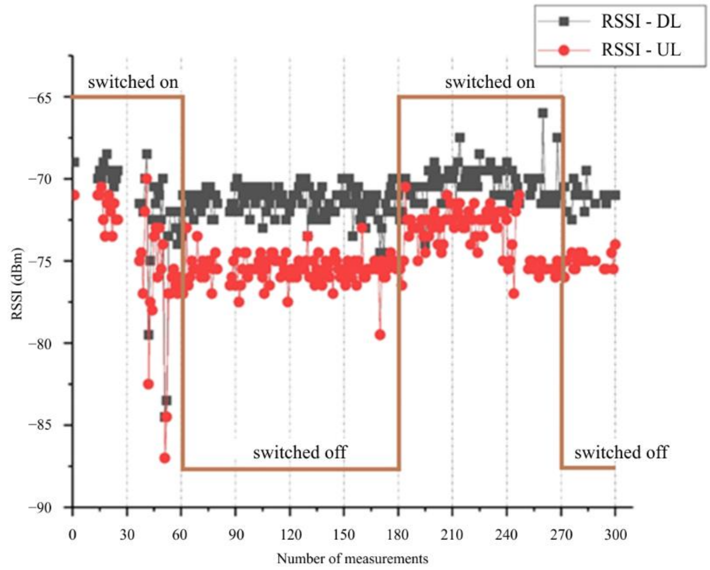


Figure 10 shows 300 measures carried over time, when the appliance was turned on and off. In measures 60 to 180, when the household appliance was switched off, the WSN keeps the RSSI stable; however, from measure 180 to 270, the household appliance was switched on and packets were lost with unstable RSSI.

FIGURE 10

RSSI analysis with household appliances – 300 measurements



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6 Conclusions

Based on the presented results, it can be concluded that the researched household appliances had levels of radiated electromagnetic disturbances above the normative limit, capable to significantly affect the functioning of a WSN.

In order to verify how these perturbations affected the WSN, RSSI and PER levels were collected over time inside a SAC. The RSSI had stable levels and no loss of packets when the network was not in the presence of the household appliance. By inserting the selected household appliance in the test, it was possible to verify unstable RSSI and 42% of PER, concluding that the interferences produced by the researched household appliance significantly affect the functioning of the network.

This work focused on IoT WSN around 915 MHz band; however, some perturbances produced by the household appliances were detected and measured in many frequencies, some of them presenting much higher levels than indicated for most of the studied band. Therefore, other radiocommunications services could also be affected by the disturbances. Frequencies below 30 MHz were not considered in this study, where interferences could be even more prominent.

This Report encourages investigations to cover these and other potential interference cases and shows the need to continue studies on these phenomena in the frequency bands used or envisaged for IoT networking, in order to cover the disturbances and interferences possible from household appliances to other IoT network configurations.

Considering a wider view of this work, new technologies such as IoT can be planned or designed but when placed into the practical real field, especially in residential environment, their networks might not function properly due to unexpected interferences coming from different kinds of non-intentional emitters, threatening the advancement of the technology and their applications.

Since the development of smart grid and smart cities progressively demands more convergent and integrated electro-electronic equipment and networks, it is of the utmost importance to consider the technical concepts of electromagnetic compatibility, and any necessary requirements to prevent and avoid interferences coming from non-intentional emitters, especially in order to protect the current and future radiocommunication services.