Publishable Summary for 21NRM06 EMC-STD
Metrology for Emerging Electromagnetic Compatibility Standards

Overview

All electronic devices sold in the European Market are required to meet the essential criteria outlined in the European EMC Directive 2014/30/EU. Compliance with this directive is demonstrated through the use of standardized electromagnetic compatibility (EMC) measures. However, the rapid growth of radio services and cutting-edge technologies like Smart Grids, Internet of Things (IoT), and electromobility has created new scenarios where existing standards fall short in addressing interference issues effectively. Consequently, there is a need for validated and traceable methods to assess electromagnetic emissions in complex situations, including in-field testing of large and high-powered equipment (particularly covered by CISPR 37 & CISPR 11) and interference in wireless communications (mainly addressed by CISPR 16).

This project's objective is to make substantial contributions to the enhancement of CISPR 37 and the revision of CISPR 11 and CISPR 16. This will be achieved through the development of new test methods for electromagnetic emissions in challenging environments, the implementation of fully traceable time-domain measurement techniques, the introduction of novel calibration techniques for receiver response to pulses, and the statistical analysis of interferences in compliance evaluations.

Need

All electronic devices sold in the European Market are obligated to meet the fundamental criteria outlined in the European EMC Directive 2014/30/EU. The customary procedure involves demonstrating adherence to harmonized standards by conducting EMC tests at specialized laboratories. Nonetheless, as novel scenarios of interference emerge due to the rise of radio services and cutting-edge technologies, like Smart Grids, IoT, electromobility, and sustainable energy applications, the existing standardized EMC testing methods are no longer sufficient or suitable. This concern has been underscored by both CENELEC TC 210 and CISPR, which are continually striving to establish updated and innovative EMC standards. Similarly, IEC is also addressing EMC issues at lower frequencies, with a current focus on interference below 150 kHz, particularly concerning smart energy meters.

A developing standard, CISPR 37 Ed. 1.0, aims to address the gaps left by CISPR 11, particularly regarding on-site testing outside established test sites. To facilitate the development of CISPR 37, the CISPR\CIS\B\WG7 was established, seeking assistance from universities and NMIs to create traceable electromagnetic emissions measurement techniques tailored for on-site evaluation of large-scale/high-power equipment (such as photovoltaic installations, electric road systems, and high-capacity electric vehicle charging stations).

As indicated by CISPR\CIS\A, there is a need for metrological research in applying time-domain electromagnetic interference (EMI) measurement techniques based on direct sampling methods. The standard defining characteristics and essential specifications of measuring receivers, CISPR 16-1-1, lacks clarity in terms of the metrological definition of the calibration method and the standard reference for ensuring the traceability of pulse response of detectors. A comprehensive waveform specification for receiver pulse calibration is imperative.

Furthermore, given the growing number of wirelessly connected devices due to the proliferation of IoT and the advent of 5G, the statistical analysis of interference and its correlation with communication quality metrics are of paramount importance. The APD measuring function can evaluate the degradation experienced by digital

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communication systems, but it requires modification in two key aspects: extension below 1 GHz and adjustment of the measurement bandwidth based on the characteristics of the communication channel. These adjustments should be incorporated into standards like CISPR 16-1-1 and CISPR 11. Similarly, a distinct calibration method for the APD measuring function of EMI receivers needs to be formulated to ensure the necessary traceability.

Objectives

The overall aim of the project is to support standardisation in electromagnetic compatibility (EMC) through the introduction of new, validated, and traceable emissions measurement methods for the revision of and forthcoming development of CISPR EMC standards.

1. To develop traceable electromagnetic emissions measurement methods optimised for in situ assessment of large-size/high-power equipment and to validate the proposed test procedures in harsh environments (e.g., factory premises and photovoltaic installations), which requires development and improvement of live impedance measurement methods in low (30 Hz – 150 kHz) and high (150 kHz – 30 MHz) frequency ranges for conducted emission testing with a target uncertainty of 6 dB. This also includes the characterisation of influence factors such as non-stationary interferences and sources of background noise, correcting the impact of transient interference, and defining a measurement protocol for selecting adequate antenna location, height, and polarisation, and other relevant parameters for the radiated emissions test setup. A report on the methods will be submitted to CISPR/CIS/B/WG7 to support the development of the forthcoming CISPR 37.
2. To provide metrological evidence of the validity of time-domain electromagnetic interference (EMI) measurement systems, based on direct sampling techniques, and to define standardisable conditions at which the usage of oscilloscopes/baseband digitisers is acceptable or preferred in comparison to measuring receivers based on frequency sweep or stepped scan techniques. The estimation of the uncertainty in time-domain EMI measurement systems will be addressed. A report recommending an amendment of Annex B and Annex C of the current CISPR 16-1-1 standard will be submitted to CISPR/CIS/A/WG1 & WG2.
3. To improve the standard calibration method for the response to pulses of measuring receivers through a complete waveform specification of the calibration pulse generator. To develop alternative reference waveforms with well-defined mathematical description and spectral properties to include in standards as a means of validating the weighting function of the detectors, thus reducing the uncertainty of the receiver’s response to pulses calibration to 0.2 dB. A report on the proposed calibration methods for the response to pulses of measuring receivers will be submitted to CISPR/CIS/A/WG1 & WG2 to support amendment of CISPR 16-1-1.
4. To redefine the standard amplitude probability distribution (APD) measuring function in EMI measuring receivers as part of the emissions compliance assessment based on the communication quality metrics. To define the criterion for establishing emissions limits based on APD measurements making it part of the emission compliance assessment. A report on the redefined APD measuring function will be submitted to CISPR/CIS/A/WG1 & WG2 and CISPR/CIS/B/WG1 to support amendment of CISPR 16-1-1 and CISPR 11 respectively.
5. To contribute to the standards development work of the technical committees CISPR/CIS/A/WG1 & WG2 (supporting revision of CISPR 16-1-1), CISPR/CIS/B/WG1 (supporting revision of CISPR 11), and CISPR/CIS/B/WG7 (supporting development of new CISPR 37) to ensure that the outputs of the project are aligned with their needs. To communicate quickly to those developing the standards and to those who will use them (test laboratories and manufacturers related to IoT, E-mobility, and technologies), and in a form that can be incorporated into the standards at the earliest opportunity.

Progress beyond the state of the art and results

Development of emission test methods for harsh environments (Objective 1)

A novel conducted emission measurement method in the 30 Hz – 2 kHz frequency range has been developed utilizing the live mains impedance measurement method. It has been proven that there is a precise correlation between the mains impedance and the measured conducted emission current. Further investigations for the 2 kHz – 150 kHz range will continue. In order to complete the whole frequency range up to 30 MHz,time-domain techniques and phase information will be also included to improve accuracy and uncertainty . After the method has been repeated in different laboratories and obtained consistent results in comparison measurements, the consortium will perform joint in-situ measurements for high-power/physically large atypical equipment (e.g. photovoltaic systems and EV high power chargers). Companies from different countries such as Türkiye, Spain and Italy are interested but the final exact mesauremet locations/factories list will be created in consultion with the Chief-stakeholder.

Design of a compact impedance measurement has been completed and the construction is ongoing. It has been designed to measure the live impedance of a low voltage AC (230 V) grid and vehicle DC networks. A measurement campaign for comparison involving two projectparticipants is planned. This device will serve as an essential part of the novel conducted emission measurement method.

Additionally, research and improvement on uncertainty calculation of conducted emission measurement has been studied. Particularly, uncertainty arising from AMNs (Artificial Mains Network) is of a concern among the EMC experts. Since there is not a comprehensive guide for the uncertainty contribution of LISNs to the uncertainty budget, free software has been developed. The tool will be free to download on project website after official publication.

For radiated emission testing, methods proposed by the draft standard CISPR 37 have been investigated. . Efficiency of time domain measurement has been demonstrated with 3 sample in industry. Also, multi-resolution bandwidth analysis, allows unmasking overlapped EUT and ambient noise frequency components at the CISPR resolution bandwidth (RBW). Moreover, the measurement speed and efficiency characterizing FFT-based receivers allow real-time analysis independently of the selected RBW, therefore, they are ideal for analysing emissions in dynamic and time-sensitive environments. Another key advantage, from now on, is the possibility to perform off-site reprocessing, maintaining the efficiency of the measurements during the campaign and allowing the detailed analysis of each case separately. Furthermore, time-gating is employed to remove sporadic and transient events from the final results. As the last improvement, time decomposition to exclude stationary ambient noise between impulsive events generated by the EUT.

Specifying time-domain interference measuring receivers in EMC standards (Objective 2)

A measuring receiver benchmark for conducted and radiated emissions has been performed by comparing a low-cost USB digitizer, a high-performance bench-top oscilloscope and a high-end fullly compliant EMI receiver. Simulated signals were applied to receivers in order to see real-life scenarios. Benchmark results show that time-domain measurements with oscilloscopes are highly promising. Given the excellent quality of the results obtained, it is recommended to take advantage of the wide availability of oscilloscopes for doing EMI checks, for supporting the electronic design teams at pre-compliance stages, and streamline compliance evaluation.

Further investigations on time-domain techniques will continue in order to obtain a repeatable and reliable measurement method especially for the assessment of challenging in-situ measurement methods thereby ensuring that the method can be implemented in CISPR 16-1-1 and in CISPR 37 standards.

Methods for calibration of measuring receivers (Objective 3).

Several methods for the calibration of baseband pulse generators were reviewed using instrumentation available at CMI (‘Fourier transform of time-domain pulse waveform’, ‘Intermediate-frequency measurement method’, ‘Measurement of pulse amplitude and duration’ and ‘Measurement of one spectrum line amplitude’). The Fourier transform method was determined as the most suitable and easy-to-use.

A review of the CISPR 16-1-1 standard specifications was completed. Firstly, no waveform characteristics are given for the reference pulses. In particular, the peak amplitude of the pulse that would be required, its rise time, or its mean duration are not given in the corresponding standard. That is a key omission that should be fixed. Secondly, from the standard definition, the typically used calibration pulses won’t meet the cutoff frequency requirement. The corresponding theoretical values have been calculated and are rather extreme, particularly for the amplitude. There is no strong justification for the need to use such pulses for calibration purposes. A document summarizing these two main points will be prepared during last quarter of 2023.

Work on characterising the alternative pulse waveform for the calibration of EMI receivers is ongoing. Main target is to generate pulse waveforms by less complicated hardwares (i.e. arbitrary waveform generator).

The APD interference detector in emissions compliance assessment (Objective 4)

The APD measuring function defined in CISPR 16-1-1 has been reviewed and a new definitionhas been proposed. This proposal gives a more flexible and general definition for the APD measuring function, offering relevant advantages compared to the standard method. The new definition avoids unsubstantiated specifications or conditions currently identified in the standard APD measuring function. Also, the proposed method aligns with the core purpose of APD since it considers and handles the measured amplitude as a random variable. Therefore, the new approach allows significant APD estimations to be obtained using smaller samples, that is, in less measurement time. Under the same conditions, the algorithm delivers low probability levels that the standard procedure fails to detect. This is possible because of the application of Kernel Density Estimation instead of the histogram method.

In the following months, fully adapting the APD detector to the time-domain measurement method and supporting the new APD definition with the proven uncertainty calculation are envisaged.

Outcomes and impact

A stakeholder committee of 10 members (including standard committee members and company representatives) was created at the start of the project. The first stakeholder workshop. was held alongside the CISPR 37 draft standard committee meeting in April 2023, Barcelona. The consortium informed stakeholders about the project and received their suggestions with regards to the latest targetted standardisation projects. Live impedance measurement method and the novel conducted emission test method based on live impedance measurement were demonstrated in the stake holder workshop (held in CISPR 37 draft standard committee meeting). The same technical progress was also presented to the MTC 036 committee of Türkiye.(National mirror committee of Türkiye on EMC). EMC-BCN separately attended to IEC 62920, CISPR 11 and CISPR 16-1-1 meetings and made joint measurements (time-domain radiated emission) with the chief stakeholder (also member of CISPR 37 WG7 and the convener of IEC 62920). EMC Barcelona organized a training for the ETERNITY Doctoral Network in Barcelona on 6th July, 2023 during a network-wide event of ETERNITY, with the participation of 12 PhD candidates and 15 researchers and representatives of the ETERNITY consortium. In addition, TUBITAK made a presentation as an introduction to the members of the national committee (mirror committee 36 – EMC) at the online meeting on 23th February, 2023. A project website has been created and is regularly being updated by CMI with information such as news, events, training material, project reports, papers published by the participants, project meetings and the project's promotional material including its publishable summary and e-newsletters.As of M9 of the project, one paper has been published in the IEEE Open Journal of Instrumentation and Measurement and one paper published as conference proceedings for 2023 Photonics & Electromagnetics Research Symposium (PIERS). In addition, a further paper has been accepted (but yet to be published) by IEEE EMC Magazine and a further 4 papers accepted to be presented at the EMC Europe Symposium 2023. The consortium will host a special session at the EMC Europe Symposium 2023 titled as "In-situ Electromagnetic Emissions Measurements: Challenges and Solutions for Assessing Atypical Equipment". 8 will be given in this special from both consortium participants and other entities.

Outcomes for industrial and other user communities

TUBITAK started to use the impedance measurement method in its EMC lanoratory. In addition several trails of conducted emission in the 30 Hz – 10 kHz range were done with the live-impedance measurement. Results are in line with conventional method but the complete frequnct range (30 Hz – 30 MHz) is still investigated.

The time domain method was taken up by EMC-BCN in a test campaign with a representative (the chiefstakeholder) from Fuji Electric Europe for the measrments in large scale photovoltaic energy systems in Magdeburg, Germany. EMC-BCN also performed many measurements from different atypical devices (i.e. palette washing machine, a passanger boarding bridge for airplane). More time-domain measurements will be implemented during the lifetime of the project.This method allows industry to acquire short duration/transient interference and worst-case emission measurements in harsh environments in real time. As opposed to conventional frequency-domain instrumentation like EMI receivers, this allows industry to achieve a drastic reduction of measurement time, from hours to less than a minute.

The software solutions will be taken up by TUBITAK and EMC BCN and provided to end users (e.g., other EMC laboratories and manufacturers) who need onsite EMC testing for their products. This will provide accurate and practical on-site test opportunities for them to validate their products as per the relevant EMC standards such as CISPR37.

The instrumentation will be taken up by TUBITAK, RISE, EMC BCN, UNIGE and incorporated into their measurement and consultancy services and offered as a service to customers who need on-site EMC testing for their products and require verification and comparison tests for their EMC test systems. This will allow industry to validate their products which are not suitable for transferring to EMC laboratories due to physical and power constraints. Participants will also consider the possibility of transforming this development into a commercially available product it to third parties such as EMC test laboratories, either sold or as part of a verification service.

In addition, the test methods and assessment methodologies based on APD detectors will be taken up by CISPR/CISA committees to facilitate more reliable measurement procedures for radiated electromagnetic emissions at real sites, backed up by the quantification of disturbance to telecommunication systems. This will allow manufacturers (e.g., railways that feature large moving sources, potentially disturbing deployed telecommunication systems with signalling functions) to demonstrate the compliance and safety assessment in a more straightforward way. This will facilitate reduced duration of safety assessment and demonstration of compliance (usually blocking the permit to operate). Additionally, the broader use of APD as an interference detector will benefit industry because it mitigates the risk of over/under testing their products, which inevitably happens today due to the utilisation of non-optimum weighting detectors for emissions assessments.

Outcomes for the metrology and scientific communities

The time domain receivers and calibration methods will allow NMIs and DIs to update their calibration services and provide the necessary traceability and reduce the measurement uncertainties in comparison to the typical figures in the standards. In addition, through their contribution to the project both NMIs and calibration/testing laboratories will benefit from facilitating interlaboratory comparisons of EMI receivers and pulse generators. In addition, the report on comparison of a measuring receiver calibration using the traditional pulse generator and the new alternative reference waveform with a commercial arbitrary waveform generator (AWG) will be made publicly available. This will allow other NMIs, calibration testing/laboratories and members from the scientific community to take up results from the project and improve the calibration of their capabilities.

The joint interdisciplinary research of emissions measurements in harsh environments and the further development of APD as an interference detector will improve scientific understanding in this technical field. New research lines are expected to be generated. For example, doctoral Networks (Marie Skłodowska-Curie Actions) addressing EMC challenges in innovative applications (e.g., ETERNITY for EMC in medical equipment, PETER for electromagnetic risks management, ETOPIA for power applications). Technical training for ETERNITY Doctoral Network has been accomplished. This training reached to approximately 40 researchers from academia. By this training, researchers were informed about advantages and aspects of time-domain measurement. It is envisaged that spreading time-domain knowledge will make faster integration of the method in relevant standards. Besides, this training will provide awareness on in-situ measurements which are very useful for large medical devices those interesting the ETERNITY network.

One paper has been published in the IEEE Open Journal of Instrumentation and Measurement and one paper published as conference proceedings for 2023 Photonics & Electromagnetics Research Symposium (PIERS). In addition, a further paper has been accepted (but yet to be published) by IEEE EMC Magazine and a further 4 papers accepted to be presented at the EMC Europe Symposium 2023.

Outcomes for relevant standards

Project partners informed several standardisation experts on various platforms. Information about the project has been shared with the StandICT.eu 2023 initiative partners. Since StandICT direcly focuses on standardisation it has a wide impact on the community.

Since the chiefstakeholder is already active in various standardisation projects (CISPR 37, IEC 62920,) joint measurement activities performed by EMC-BCN and Fuji Electric is directly contributes in increasing the awareness of standardisation committies.

TUBITAK presented the EMC-STD project in a genrela meeting of the Turkish EMC mirror technical committee. This presentation reached to Turkey’s largest electronic equipment manufacturers.

EMC-BCN attended to meetings of several standardisation committies. These are CISPR/CIS/A Joint Work Group 9 (CISPR 16-1-1), IEC TC 82 Work Group 6 (IEC 62920), European Cooperation for Space Standardization ECSS-E-ST-20-07C committee.

Longer-term economic, social and environmental impacts

One sector that will considerably benefit from project outcomes is the industrial, scientific and medical (ISM) one because the most prominent target standards in the scope of the project is CISPR 37. Like CISPR 11 that was partially used for years as a reference standard for large equipment, CISPR 37 is expected to be effective on renewables and wireless power transfer, their integration in microgrids and power distribution infrastructure, railways, automotive and large machine manufacturers. Uptake of novel methods proposed by this project has partially started but the wider impact is naturally a time-consuming process.

In particular, as declared by the European Commission (EC), the objective for solar energy is to establish Photovoltaic (PV) systems as a clean, competitive and sustainable energy technology. Therefore, the improvement and production of new EMC standards for atypical equipment can improve the certification of PV installations and consequently achieve the objective of implementing solar energy, which will benefit economically the end-users, to reduce their energy consumption and produce their own clean energy, and the companies which provide the PV infrastructure.

The EC also supports European industry in the move to a low-carbon economy and improves the energy efficiency of products through eco-design legislation. This is strictly related to the energy industries like PV and green transport. The new EMC standards will contribute, from an EMC point of view to evaluation of all the novel electric engines and energy-efficient functional modes like regenerative braking that is employed by Electrical Vehicle (EV) such as trains, metros and e-buses. Some EV charger manufacturers from Europe (one in Spain, one in Turkey) declared their interests in the project during wokshops. Particularly, EV high-power DC chargers are a concern of power distribution installations.

Moreover, citizens can have direct social benefits from the energy and transport industries. A sustainable mobility is beneficial for the free movement around the European Union (EU), and according to the European Economic and Social Committee (EESC), these movers represent a poll for innovation, creativity, and willingness to work hard. The use of renewable energy technologies has a direct positive impact on the health of the European citizens. Therefore, the validation and procedures developed with the actual official standards in lieu of non-standard methods will allow speeding up the certification and the confidence in being compliant with the European Directives. In addition, taking advantage in the improvement of standardised, repeatable and traceable methods for in situ EMC testing of large-size/high-power equipment, reliable test results for a wide variety of locations will be obtained. Thus, manufacturers, conformity assessment bodies and consumers can benefit from reliable and faster compliance processes with the European EMC Directive 2014/30/EU and this presents significant opportunities for free movement of goods in European Single Market, promising potential cost savings and time.

List of publications

Azpúrua, Marco A. et al (2023) 'Measuring Receiver Benchmark for Conducted and Radiated Emissions Testing in Space Applications', 2023 International Symposium and Exhibition on Electromagnetic Compatibility. Available at https://doi.org/10.5281/zenodo.8375139

Solé-Lloveras, Jordi et al (2023) 'Strategies Using Time-Domain Measurements for Radiated Emissions Testing in Harsh Environments', IEEE Open Journal of Instrumentation and Measurement 2 p. 1-11. Available at https://doi.org/10.1109/OJIM.2023.3303950

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

<table>
<tr><td colspan="2">Project start date and duration:</td><td>1 October 2022, 36 months</td></tr>
<tr><td colspan="3">Coordinator: Serdar Büyük, TUBITAK Tel: +90 262 679 5000-Ext:3656 E-mail: serdar.buyuk@tubitak.gov.tr
Project website address: https://emc-std.cmi.cz/index.php</td></tr>
<tr><td colspan="2">Chief Stakeholder Organisation:
Fuji Electric Europe GmbH</td><td>Chief Stakeholder Contact: Yasutoshi Yoshioka</td></tr>
<tr><td>Internal Beneficiaries:
1. TUBITAK, Türkiye
2. CMI, Czechia
3. GUM, Poland
4. INTA, Spain
5. RISE, Sweden
6. SIQ, Slovenia</td><td>External Beneficiaries:
7. EMC-BCN, Spain
8. UNIGE, Italy
9. UTwente, Netherlands</td><td>Unfunded Beneficiaries:
n/a</td></tr>
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