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Results of a Recently Concluded Interlaboratory Comparison on CISPR 25 ALSE Test Method

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Abstract

Results of an interlaboratory comparison of radiated emission measurements performed in 2020-21 according to the CISPR 25 Absorber Lined Shielded Enclosure test method are here reported. Comparison with results of a similar activity carried out in 2016-17 demonstrates that measurement reproducibility can be significantly improved, and systematic errors largely reduced by taking simple precautions.

1. Introduction

The reproducibility of the Absorber Lined Shielded Enclosure (ALSE) radiated emission test method, defined in the standard CISPR 25 [1], was evaluated through an interlaboratory comparison (ILC) that started on September 2016 and concluded in February 2017. Nineteen data sets were received and analyzed. The investigated frequency range was from 1 MHz to 1000 MHz. The most critical (worst reproducibility) frequency range was the one from 10 MHz to 50 MHz where the robust (outlier-resistant) standard deviation of the measured values was comprised between 5 dB and 8 dB. In the frequency range from 50 MHz to 1000 MHz the robust standard deviation was comprised between 2 dB and 3 dB. The main causes of non-reproducibility were identified, and test setup adjustments aimed at improving the reproducibility were proposed (see [2], were results of the past IC are also described and discussed).

A similar activity was reproposed in the period between December 2020 and July 2021. Again, nineteen laboratories took part in the ILC providing as many measurement data sets. Hints were given in the instructions of the 2020-21 ILC to improve measurement reproducibility. Further, several laboratories had implemented the ALSE performance verification procedure described in the informative Annex J in edition 4 of CISPR 25 (published in October 2016, i.e., when the first ILC was running). We here report the results of this second ILC.

This work is in the vein of others devoted to the investigation of the measurement reproducibility of basic test methods in electromagnetic compatibility (EMC). In particular, in papers [3-5] the reproducibility of radiated emission measurements is quantified, [6] analyses the reproducibility of conducted emission measurements of voltage disturbances, [7-8] are focused on the reproducibility of radiated immunity tests, [9] concerns the reproducibility of immunity tests against currents induced at radiofrequency, [10] deals with the reproducibility of immunity tests to impulse (surge) phenomena.

In the next section 2 we provide a general description of the activity. In section 3 the robust statistical analysis used for processing measurement results is introduced. Details about the structure of the travelling sample are reported in section 4. The measurement procedure is outlined in section 5. The measurement results produced by the participants in the ILC are finally presented and briefly analyzed in section 6.

2. Description of the ILC

The ILC consisted in the comparison of the measurements of a travelling sample provided by the coordinator. Each laboratory made a quantitative examination (measurement) of the travelling sample thus providing the coordinator with a measurement result. The coordinator designed and assembled the travelling sample.

The coordinator assigned to the travelling sample a reference value and the corresponding uncertainty. The reference value, x^*, and its standard uncertainty, s^*, were obtained by the coordinator through the statistical analysis of the measurement results provided by the laboratories during the ILC. The reference value x^* and the standard uncertainty s^* were disclosed to participants at the end of the ILC, after that the last participating laboratory had submitted its measurement results.

The scheme of participation in the ILC was sequential. The coordinator passed the travelling sample to the 1st participating laboratory. The 1st laboratory performed the measurement thus obtaining the 1st measurement result. Then, the 1st laboratory passed the travelling sample to the 2nd laboratory, and so on. The last laboratory passed back the travelling sample to the coordinator. The ILC was completed when the last participating laboratory had submitted its measurement results to the coordinator.

The measurement result provided by each laboratory consisted of the electric field x at given harmonic orders and corresponding frequencies. Frequencies were selected by the coordinator. The measurement results provided by each laboratory were compared, frequency by frequency, against the reference values assigned by the coordinator.

Participation was open to electromagnetic compatibility test laboratories that could perform electric field emission measurements in accordance with the method described in §6.5 of [1], in the frequency range from 150 kHz to 1000 MHz. Accreditation to ISO/IEC 17025 [12] was not required for admission to the ILC. The activity was designed assuming participation of both accredited and non-accredited laboratories.

3. Statistical Analysis

The measurement result provided by each laboratory was compared against the reference value x^* and its standard uncertainty s^*. The assessment of the performance of the laboratory was based on the *z*-score (symbol z, see §9.4.1 of [13]). The measurement result x_i provided by the i-th Laboratory ($i = 1, 2, ..., p$, where p is the number of participating laboratories) was compared with the robust mean x^* and robust standard deviation s^* assigned by the Coordinator as follows

$$z_i = \frac{x_i - x^*}{s^*} \qquad (1)$$

The value of z_i was calculated for each laboratory and for each investigated frequency. Therefore, as many values of z_i were calculated as the number of investigated frequencies (for example, ten frequencies investigated, ten values of z_i for the i-th laboratory). The measurement result provided by the i-th laboratory produced a warning signal if, at least at one frequency, we had z_i less than −2 or greater than +2. The measurement result provided by the i-th laboratory produced an action signal if, at least at one frequency, we had z_i less than −3 or greater than +3. If at all frequencies, we had z_i greater than −2 and less than +2 then the measurement result provided by the i-th laboratory did not highlight any anomaly.

The values of x^* and s^* were obtained by the coordinator by using the robust analysis (Algorithm A) described in Annex C of [13], §C.3.1. The robust analysis is based on an iterative calculation. At the first step of iteration

$$x^* = \text{median of } x_i \quad (i = 1, 2, ..., p) \qquad (2)$$

and

$$s^* = 1.483 \cdot \left\{ \text{median of } \left| x_i - x^* \right| \right\} \quad (i = 1, 2, ..., p) . \qquad (3)$$

Notably, the factor 1.483 which appears in (3) represents the ratio between the standard deviation σ and the median of the absolute deviations from the median, *MAD*, assuming normal distribution. It is indeed possible to show that in the case of symmetric distribution, $MAD / \sigma = \Phi^{-1}(3/4)$, where Φ is the cumulative distribution function. In the case of normal distribution $\Phi^{-1}(3/4) = 0.6745$ and therefore $\sigma = 1.4826 \cdot MAD$.

4. Travelling Sample

The travelling sample was an electromagnetic field source made of the combination of a battery-operated comb generator, a field-generating fixture, a load and an adapter (see Figure 1).

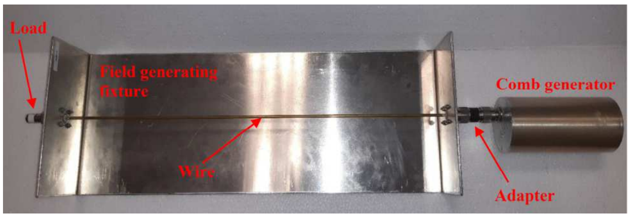

Figure 1. Picture of the Sample (comb generator, adapter, field-generating fixture, load and wire).

Two battery operated comb generators were provided. At least four hours of reliable operation of the comb generators was permitted by using fresh batteries. The charge level of the batteries was easily checked by observing the intermittence of a LED (fast intermittence indicated enough charge, slow intermittence indicated insufficient charge and batteries had to be replaced). The comb generator LF01 generated harmonics from 125 kHz to 29.875 MHz at 250 kHz step. The comb generator HF01 generated harmonics from 5 MHz to 1000 MHz at 5 MHz step. The comb generators did not require warm up prior to measurement. The coordinator identified the harmonics to be measured through their ordinal number and the approximate frequency value. For example: the 5th harmonic of the LF01 comb generator was approximately at 1125 kHz, the 8th harmonic of the HF01 comb generator was at approximately 40 MHz. What identified the harmonic was its order not its frequency. Frequencies were given only for guidance.

The field-generating fixture consisted in a round wire whose diameter was 4 mm, placed at 5 cm height above the ground plane and having 50 cm length. The wire was between by two vertical plates whose size was 20 cm x 10 cm. Two N-type, female, connectors permitted to connect the wire to the comb generator on one side, and to the load, on the opposite side. The comb generator had an N-type, female, connector, hence a male-to-male, N-type adapter was provided by the coordinator for connecting the comb generator to the field-generating fixture.

A 2 dB matching pad was provided by the coordinator as the load termination to the round wire. The N-male port of the load was connected to the field-generating fixture. The N-female port of the matching pad was left open.

The comb generators, the field-generating fixture, the load and the adapter were enclosed in a case for shipment to participating laboratories.

5. Measurement Procedure

Field measurement was preceded by a preliminary verification of the correct operation of the travelling sample. Verification was carried out by measuring the power delivered to a 50 Ω load by comb generators LF01 and HF01 at specified frequencies. Measurement results had to match a specified power with assigned tolerance

(0 dBm ± 3 dB at 625 kHz for LF01 and −24 dBm ± 3 dB at 100 MHz for HF01). Further, the load was connected to one port of the field-generating fixture and by using a hand-held multimeter, the resistance seen at the input of the other port was measured. The reading of the multimeter had to be 243 Ω ± 2 Ω.

Measurement of the field generated by the travelling sample was carried out by using different receiving antennas, depending on the measurement frequency. Measurement frequencies are reported in Table 1. Measurement setup is shown in Figure 2.

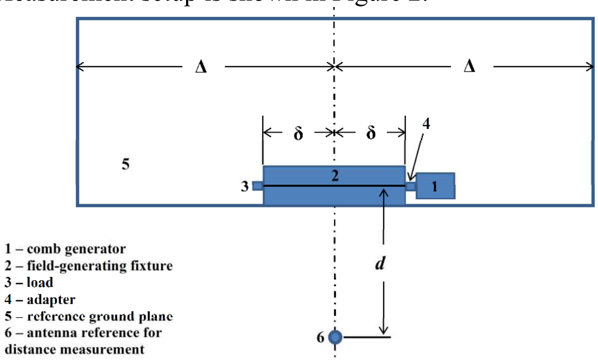

Figure 2. Measurement setup.

Distance d (1 m) from the wire of the field-generating fixture to the reference point of the receiving antenna was 1000 mm (horizontal). The receiver's detector was set to average. Details of the measurement setup not specified by the coordinator were provided by the standard [1]. The use of the same measuring instrumentation and setup as used for ordinary testing activity was recommended for the ILC. The measurement results provided by the laboratories were the estimates x, expressed in dB(μV/m), of each electric field-strength harmonic.

Measurements in the frequency range from 150 kHz to 30 MHz were carried out by using a vertical monopole antenna. The reference of the monopole antenna for distance measurement was the rod.

Measurements in the frequency range from 30 MHz to 300 MHz were carried out by using a biconical antenna. Both vertical polarization and horizontal polarizations were measured, and the estimate of the electric field strength had to be the maximum reading between the two polarizations. The reference point of the biconical antenna for distance measurement was its phase center.

Measurements in the frequency range from 300 MHz to 1000 MHz were carried out by using a log-periodic antenna (LPDA). Also in this frequency range, both vertical polarization and horizontal polarization were measured, and the estimate of the electric field strength was the maximum reading between the two polarizations. The reference point of the LPDA for distance measurement was the tip.

If a bilog receiving antenna was employed in the frequency range from 30 MHz to 1000 MHz then the antenna reference point for distance measurement was the one used for antenna calibration.

Based on the experience of the previous ILC [2] the following hints were given to participants:

- Minimize common mode current along the receiving antenna cable by routing the cable perpendicular to the wire of the travelling sample and parallel to the floor.
- Check possible intermodulation effects when using the monopole antenna by inserting an attenuator (e.g., 6 dB) between the output of the comb generator output and the input of the field generating fixture (the receiver reading should decrease by no more than 6 dB).
- Check the balance of the biconical antenna by rotating it by 180° (the receiver reading should not significantly vary). Repeat the check in horizontal polarization and in vertical polarization.
- Take measures to assure good electrical contact between the field-generating fixture and the reference ground plane by cleaning the respective surfaces, clamping the fixture to the table, and using metallic tape to increase the contact surface.

6. Measurement Results

The measurement results, in terms of deviation between raw measured values and reference values, are shown through the plot in Figure 3. The anonymous code assigned to each participant is represented on the horizontal axis.

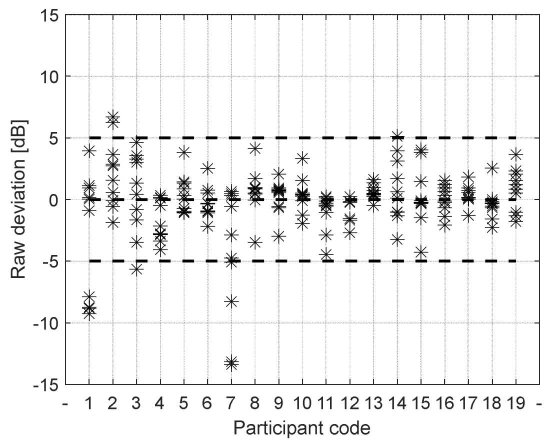

Figure 3. Raw deviations between the measurement results of the participants in the ILC and the reference values.

It is seen from the plot in Figure 1 that, with few exceptions, the raw deviations from robust average are comprised within ±5 dB. Outliers are mainly associated to a couple of laboratories, namely those with codes 1 and 7. In the 2016-17 experience the observed spread was much larger, especially in the monopole antenna band. Robust standard deviation was indeed larger than 6 dB at some frequencies and 4 dB in the average, over the frequency range from 1 MHz to 30 MHz (30 measurement frequencies at 1 MHz step were investigated at that time). The worst-case value of 3.3 dB was observed in the 2020-21 ILC, see Table 1, where the robust mean x^* and standard deviation s^*, at the ten measurement frequencies selected by the coordinator, are reported.

It is important to note that, since the same field generating fixture defined in Annex J in [1] was used in both ILCs, the radiated field can be predicted from the reference values in

Table J.1 in [1], once that corrections for source power and load are applied.

Table 1. Robust standard deviation s^* at the ten measurement frequencies selected by the coordinator of the interlaboratory comparison.

Receiving antenna	**Comb generator**	**Harmonic** #	**Frequency** MHz	s^* dB
Monopole	LF01	2	0.375	1.2
Monopole	LF01	6	1.375	1.4
Monopole	LF01	25	6.125	1.9
Monopole	LF01	109	27.125	3.3
Biconical	HF01	8	40	1.8
Biconical	HF01	20	100	1.7
Biconical	HF01	44	220	3.0
LPDA	HF01	80	400	1.5
LPDA	HF01	140	700	1.1
LPDA	HF01	190	950	1.4

These corrections are feasible at low frequency, where wave phenomena within the field generating fixture are negligible (the length of the fixture is short with respect to wavelength) and the load does not significantly departs from the resistive behavior. It is seen that the systematic error (deviation between x^* and the reference value in Table J.1 in [1], after correction) was 1.4 dB and 1.7 dB at 375 kHz and 1.375 MHz, respectively, in the 2020-21 ILC, while it was 15 dB at 1 MHz in the 2016-17 ILC, see [2]. The *z*-scores of each participant, are finally shown in the plot in Figure 4, where we see that few action signals were issued (8 action signals over 180 measured values).

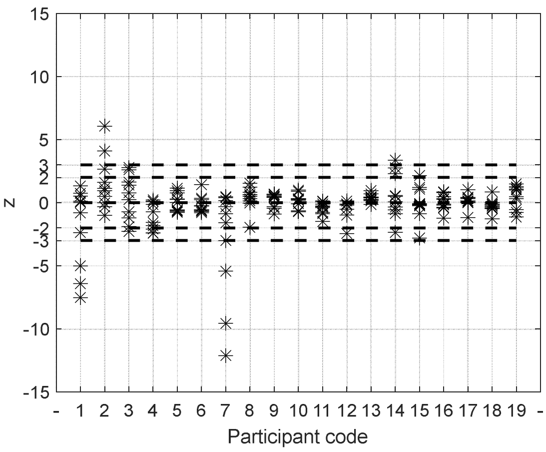

Figure 4. *z*-scores of each participant in the interlaboratory comparison. The critical threshold levels ±2 and ±3 are represented with dashed lines.

References

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