CISPR TR 16-3

Edition 3.0 2015-09

TECHNICAL REPORT

colour inside

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

AMENDMENT 2

Specification for radio disturbance and immunity measuring apparatus and methods –
Part 3: CISPR technical reports

CISPR TR 16-3:2010-08/AMD2:2015-09(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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FOREWORD

This amendment has been prepared by subcommittee A: Radio-interference measurements and statistical methods, of IEC technical committee CISPR: International special committee on radio interference.

The text of this amendment is based on the following documents:

DTR	Report on voting
CISPR/A/1102/DTR	CISPR/A/1109/RVC

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

3.2 Abbreviations

Add, to the existing list of abbreviations, the following new abbreviations:

CDN	Coupling decoupling network
CDNE	CDN for emission measurement
CM	Common mode
DM	Differential mode
RRT	Round robin test

Add, after the existing subclause 4.11.2 added by Amendment 1, the following new subclause:

4.12 Background on CDNE equipment and measurement method

4.12.1 General

The CDN measurement method was originally developed for assessment of radiated disturbances of lighting equipment from 30 MHz to 300 MHz. In October 2006 the CDN method was adopted by a first amendment of Edition 7 of CISPR 15, published in 2006 [91].

A CISPR joint Task Force between CISPR SC/A and CISPR SC/F on the 'CDN measurement method of radio frequency disturbances for lighting equipment in the frequency range 30 MHz to 300 MHz' (CDNE JTF A/F) was established in 2008, and tasked with transferring the CDN method of emission measurement in the frequency range 30 MHz to 300 MHz to the CISPR 16 series. This was to give the method a more generic status and enable use for other types of equipment. An additional aim was to improve the CDN method uncertainties.

The CDNE JTF developed specifications and measurement methods for a CDNE, which is the CDN for emission measurement. Between 2008 and 2014 the CDNE specification, the associated measurement method, the measurement instrumentation uncertainties and the correlation with the classical radiated measurement method were implemented in respectively CISPR 16-1-2 [95], CISPR 16-2-1 [8], CISPR 16-4-2 [96] and CISPR 16-4-5 [97].

The following subclauses give background information and rationales on the CDN and the CDNE equipment and measurement method.

4.12.2 Historical overview

4.12.2.1 Situation around 1996

Before the first amendment to Edition 7, lighting products were subject to conducted and radiated RF disturbance measurements according to CISPR 15 [98] in the frequency range below 30 MHz. Radiated disturbance measurements above 30 MHz according to CISPR 22 [99] were carried out on a voluntary basis to assure quality and to avoid complaints in specific environments. Generally the emission levels of lighting products with bipolar circuit technology were negligible for frequencies above 30 MHz.

In 1996, within the EMC group of Philips Research in Eindhoven, the Netherlands, an investigation was started on possible workbench methods as an alternative for the radiated tests in the frequency range 30 MHz to 300 MHz. The CDN, which is known from RF immunity tests in the range of 150 kHz to 80 MHz according to IEC 61000-4-6 [15], seemed a suitable candidate for application to measurement of RF disturbances as well. Therefore, a method using the CDN for disturbance measurements was developed and investigated. Especially the relationship with the established radiated disturbance measurement method in a SAC was explored.

It is generally accepted that correlation between two test methods only makes sense when both methods have good reproducibility and low uncertainty. The established radiated RF disturbance measurement method has a fairly large compliance uncertainty (7 dB) due to variability in cable layout and termination, while the CDN method has a moderate compliance uncertainty (4 dB) provided that the EUT is small and the cable length between the CDN and EUT is limited. Still, a reasonable correlation between the CDN method and the 3-m and 10-m radiated method was demonstrated for luminaires of different sizes.

4.12.2.2 CDN concept for disturbance measurements introduced in 1999

The feasibility and concept of the CDN method was presented in a paper at the 1999 Zurich EMC conference by Stef Worm [93]. In that paper, the radiated disturbance measurement method in a 3 m SAC and the CDN method (refer to Figure 200) are compared. It is demonstrated by modelling that the CM current in a cable (single wire – see NOTE 1) connected to the EUT is a good metric for the E-field measured using the 3 m SAC/OATS method.

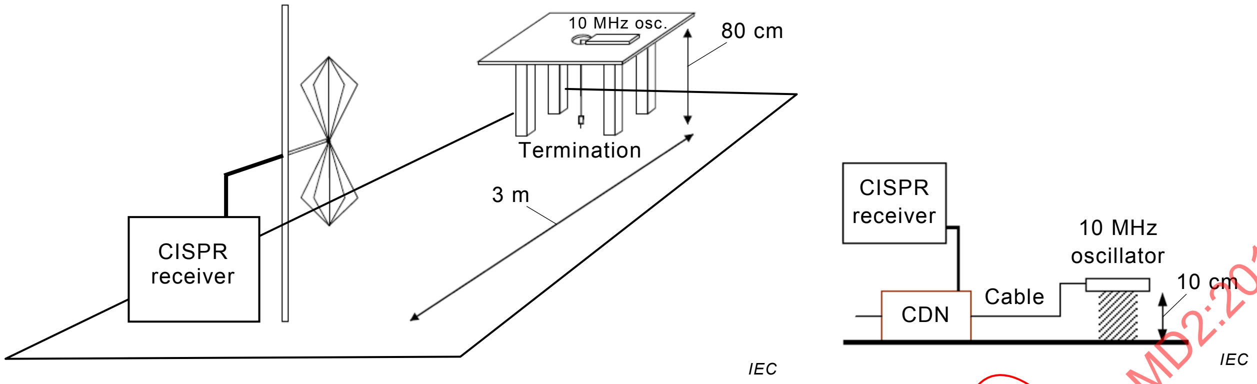
NOTE 1 The single wire and its impedance is the model of a cable with one or more wires including the protective earth wire. The CM impedance mentioned in the report represents the "total" CM impedance of the cable.

NOTE 2 At the time of this investigation the 3 m SAC/OATS was used as reference. Later it was agreed more formally (see CISPR 16-4-5 [97]) that the 10 m SAC/OATS is the reference, called the established test method.

Note that the cable does not necessarily need to be a mains cable and is not connected to a network. The E-field/CM-current ratio depends on the termination impedance. Measurement results [92] have shown (see Figure 201) that the response is reasonably flat if the termination impedance of the cable (single wire) equals 150 Ω. Also the impact of cable layout and set-up of the EUT and CDN has been investigated. The 150-Ω impedance also provides a good match with the disturbance source, which prevents standing waves. Different options for the 150-Ω impedance have been compared in [93], where it was concluded that the best candidate for the 150-Ω termination impedance was the existing CDN used for immunity tests.

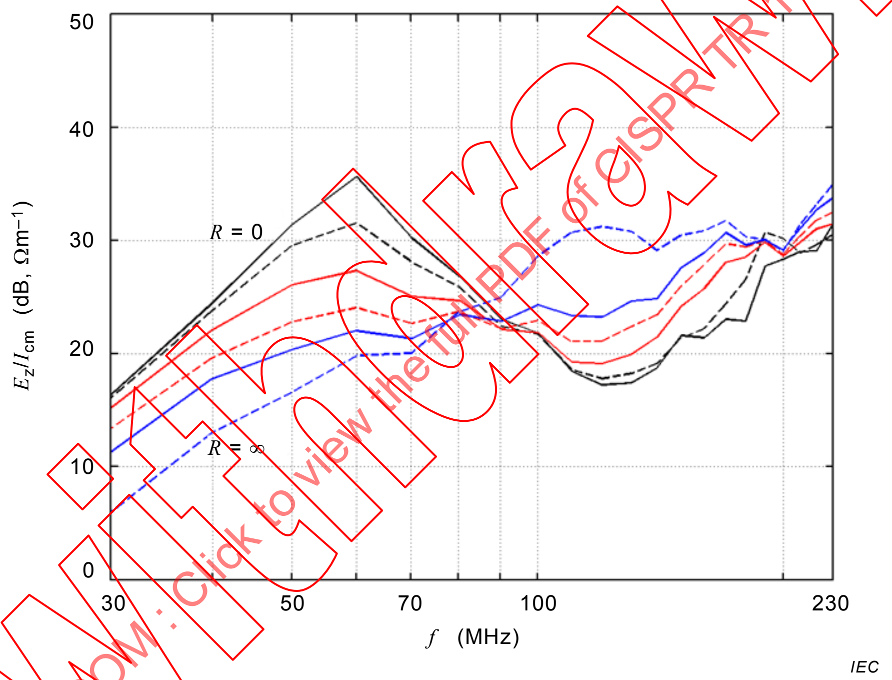
So, in the original and basic concept of the CDN method, the purpose of the CM impedance of 150 Ω is to enable a good match (no standing waves) with the disturbance source. With this property, a relatively simple relation between the E-field limit and the limit applicable for the CDN method could be derived and implemented in Table B.1 of CISPR 15:2013 [98]. It has not been the intention that the CDN emulates the CM impedance and LCL − or whatever other property of the network to which the (mains) cable could be connected.

The CDNE method is an alternative method to assess radiated disturbance of a product in the frequency range of 30 MHz to 300 MHz, under specific limitations of the product characteristics. Hence it addresses the radiation coming from the enclosure port of the EUT. Another example of a radiated disturbance assessment method is the absorbing clamp method in the frequency range between 30 MHz and 1 000 MHz.



3 m SAC/OATS-method CDN method

Figure 200 – Equivalent radiated measurement methods (30 MHz to 300 MHz)



The red curve is the 150-Ω termination.

Figure 201 – Measured relationship between field strength E_z and CM current I_{cm} for various termination resistances R

4.12.2.3 Derivation of the CDN limit

The asymptotic curve given in Figure 202 (using the equations given in [92]; matched case $\Gamma = 0$), is used to translate the limit levels $E_{\text{Rad}}^{\text{Lim,3 m}}$ of the existing 3 m (see NOTE 2 of 4.12.2.2) radiated disturbance limits to the limit $I_{\text{CDN}}^{\text{Lim}}$ for the CM current of the CDN test method limit with the following equation:

$$I_{\text{CDN}}^{\text{Lim}} = \frac{E_{\text{Rad}}^{\text{Lim,3m}}}{E/I \text{ ratio}} \quad (106)$$

where the E/I ratio is the average relationship between field strength and CM current for various CM-impedance terminations, i.e. the black straight dashed line shown in Figure 202.

The CDN current limit is expressed in terms of terminal voltage limit across a 150-Ω impedance ($V_{\text{CDN}}^{\text{Lim}}$), so

$$V_{\text{CDN}}^{\text{Lim}} = 150\,\Omega \times \frac{E_{\text{Rad}}^{\text{Lim,3 m}}}{E/I \text{ ratio}} \tag{107}$$

For example, a radiated disturbance limit of 40 dB(μV/m) at 3 m and 100 MHz translates to a terminal voltage limit of 20 lg (150) + 40 − 30 = 54 dB(μV). The CISPR 15 radiated limits translate in this way to the values given in Table B.1 of CISPR 15:2013 [98]; see also Figure 203.

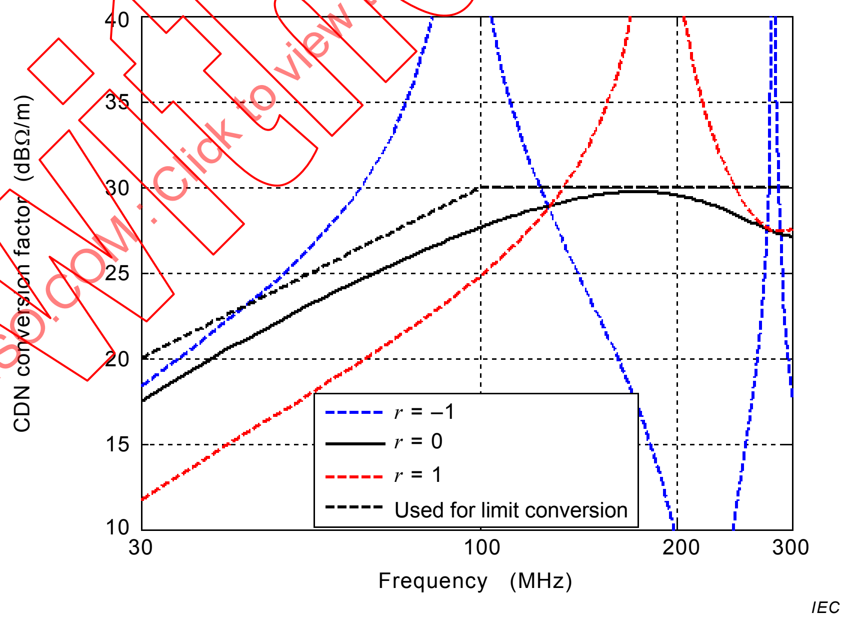
Note that the voltage division factor F_{CDNE} (in dB) and the value of the attenuator external to the CDN are added to achieve the CM-terminal voltage across 150 Ω, i.e. -20 lg(50/150) + dB-value of the external attenuator (6 dB):

$$F_{\text{CDNE}} = -20 \lg (50/150) + 6 \tag{108}$$

The CDNE-disturbance level V_{CDNE}, then can be calculated as follows:

$$V_{\text{CDNE}} = V_{\text{meas}} + F_{\text{CDNE}} \tag{109}$$

where V_{CDNE} and V_{meas} are in dB(μV).



The black straight dashed lines are an asymptotic boundary curve used for translation of the limit.

Figure 202 – Modelled relationship between field strength E_z and CM current I_{cm} using EUT height 0,8 m, measurement distance 3 m, receive antenna height 1 m

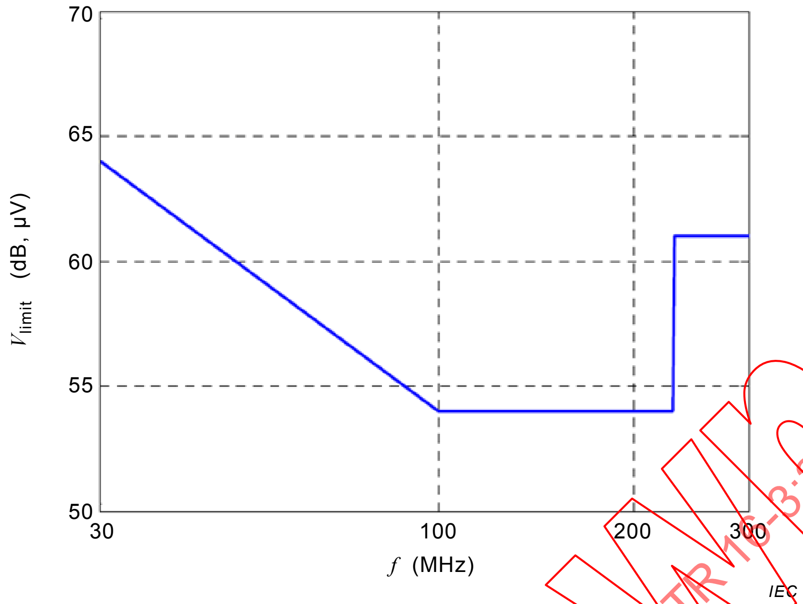


Figure 203 – Limit for the terminal voltage at the CDN

4.12.2.4 2006: first implementation of the CDN method in CISPR 15

In October 2006 the CDN method was adopted in the first amendment of Edition 7 of CISPR 15 [91] published in 2006 [91].

The CDN measurement method, the CDN specification and the CDN limits were included in a separate normative Annex B of CISPR 15:2005/AMD1:2006.

Basically, the CDN should satisfy the specifications of IEC 61000-4-6 [15], and the specification of the CM-impedance of 150 Ω was extended to 300 MHz.

The limit given in CISPR 15 is the same as given in Figure 203.

4.12.3 From CDN to CDNE

4.12.3.1 Shortcomings

After applying the CDN method for testing of lighting equipment for a few years, a number of shortcomings of the CDN method were found, including:

– lack of reproducibility of tests when using CDNs from different manufacturers;
– no restrictions on the size of the EUT;
– absence of an uncertainty budget;
– specification to only 230 MHz − CISPR 15 specified the CDN for measurements to 300 MHz;
– no documented correlation between the CDN method and the classical radiated method.

As an example, Figure 204 gives the results of an RRT. CDN measurement results from 11 laboratories within Philips were obtained using class 1 and class 2 artificial EUTs consisting of a comb generator and a coupling unit that launches both DM and CM disturbances. Each laboratory applied its own CDN from different manufacturers. The results of the class 1 EUT (CDN-M3) exhibited an especially large spread due to the variation in the performance of the CDNs. More in-depth investigations revealed that the main reason for the large spread was the absence of a DM-impedance specification of the CDN, large tolerances of the CM impedance, the absence of impedance specification above 230 MHz and the absence of phase angle tolerance of the CM impedance.

4.12.3.2 CISPR A/F JTF

A joint task force between CISPR/A and CISPR/F was formed on the ‘CDN measurement method of radio frequency disturbances for lighting equipment in the frequency range 30 MHz to 300 MHz’ (CDNE JTF A/F). That JTF was established in 2008 and tasked with transferring the CDN method of emission measurement in the frequency range 30 MHz to 300 MHz to the CISPR 16 series. An additional aim was to improve the reproducibility of the CDN method. Also in view of the EMC-standardization debate on the subject of ‘alternative test methods’ there was a need to consolidate the relationship between the CDN method and the classical radiated test method in CISPR 16-4-5 [97].

The JTF work included the following projects:

– adding CDNE specifications and validation methods in CISPR 16-1-2 [95];
– adding measurement set-up and method in CISPR 16-2-1 [8];
– adding background and rationale in CISPR TR 16-3 (this subclause);
– adding uncertainty aspects in CISPR 16-4-2 [96];
– adding conditions for alternative methods in CISPR TR 16-4-5 [97].

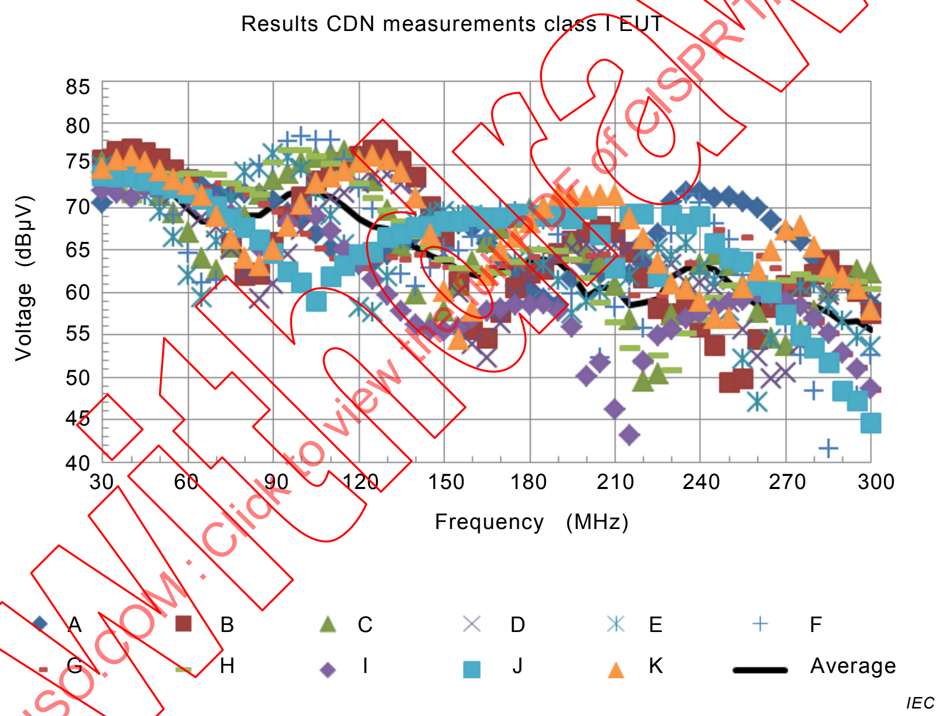


Figure 204 – Results of a Philips 11-lab internal CDN RRT using an artificial class 1 EUT – expanded uncertainty nearly 10 dB

4.12.3.3 Improvements of the CDNE

The main function of the CDNE has not changed compared with the CDN, i.e. the CDNE couples asymmetric (CM) disturbance voltage from the EUT into the input lead of the measuring receiver, and decouples that lead from any emissions or influences present in the test environment. It measures the CM disturbance in a short cable connected to the EUT (often AC mains but not absolutely necessary) through a nominal impedance of 150 Ω (see 4.12.2.2).

The most important changes in the CDNE specification are as follows (see CISPR 16-1-2 [95]).

a) A specification for the phase tolerance of the CM impedance has been added: 0° ± 25°;

b) The tolerance of the magnitude of the CM impedance of the CDNE (150 Ω) has been reduced to +10 Ω/–20 Ω;

c) A specification and tolerance of the DM impedance at the EUT port has been added, i.e. 100 Ω ± 20 Ω. Any symmetric (DM) disturbance coming from the EUT is loaded either by a symmetric impedance of 100 Ω at the EUT mains port (CDNE-M2 and CDNE-M3), or by the external symmetric load at the AE port of the CDNE-Sx. The value of 100 Ω equals the DM impedance of a mains network/LISN. However, the main reason of the CDNE JTF to specify the 100 Ω DM impedance was based on the fact that the reproducibility of test results was improved when this 100 Ω DM impedance was applied;

d) Instead of a separate external attenuator of 6 dB, a fixed internal attenuator of at least 6 dB is applied. This avoids mistakes in setting up the test method without an external attenuator at the receiver port;

e) A tolerance of the voltage division factor has been added: ± 1,5 dB;

NOTE This tolerance refers to the theoretical voltage division factor given in Equation (108). Normally the actual voltage division factor of a CDNE obtained during calibration is applied during a measurement. Then the value of ±1,5 dB is not used as the basis for the uncertainty contribution. The basis is the uncertainty of the voltage division factor calibration which is typically much lower; see CISPR 16-4-2.

f) A decoupling attenuation of at least 30 dB has been added to decouple disturbances coming from the AE or mains port towards the measuring receiver. Thereby the measured CM current is also insensitive for variations of the CM/DM impedances of the network connected to the AE/mains port;

g) A longitudinal conversion loss (LCL) of at least 20 dB is specified for the CDNE-M2 and CDNE-M3. For EUTs that apply the CDNE to the mains port, in general above 30 MHz, the level of asymmetric disturbance voltage is much higher than the level of symmetric disturbance voltage. Therefore a minimum LCL value of 20 dB is adequate to prevent any influences of the symmetric voltage on the measurement results. In contrast, the assessment of EUTs using the DM for communication on unscreened leads requires specific LCL values (minimum and maximum value) of the CDNE;

h) A more detailed validation/verification procedure for each of the above specifications has been added.

4.12.3.4 Improvements of CDNE test method

The test method has changed significantly as follows (set-up and procedure specified in CISPR 16-2-1 [8]; see Figure 205):

a) tighter specification for the distance of the EUT to any other metallic object; the distance is ≥ 0,8 m; for a shorter distance, but not less than 0,4 m, an additional uncertainty of 0,2 dB is added;

b) more elaborate specifications for CDNE tests where two CDNEs are applied;

c) a more detailed measurement procedure.

Furthermore the limitations for application are given more explicitly, i.e.:

a) the CDNE cannot be used for applications on a mains network with intentional DM signals, e.g. where transmitting of a wanted differential signal would require a specific LCL, minimum and maximum value, to take the network quality into account;

b) when the largest dimension of the EUT enclosure is larger than a quarter wavelength at the highest frequency of measurement, unless otherwise specified by the product committee;

c) the rated supply voltage should not exceed 600 V;

d) the EUT should not have more than two cables.

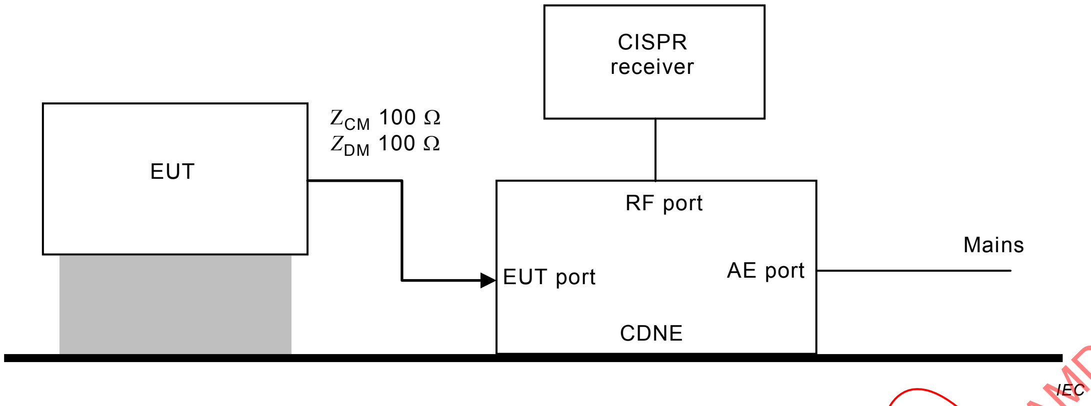


Figure 205 – Block diagram for CDNE-measurement method

4.12.3.5 Reduced measurement uncertainty

An aim of all the changes in the CDNE-specification and test method is to reduce the measurement instrumentation uncertainty. The uncertainty budget published in CISPR 16-4-2 [96]) gives an expanded uncertainty value of U(V) = 2u_c(V) = 3,79 dB.

4.12.3.6 Conversion of limits

The factor for conversion of the established 10-m SAC/OATS limit to the CDNE limit is reported in CISPR TR 16-4-5 [97]. In this case the conversion factor is determined using the procedure for measurement results given in Clause 7 of CISPR TR 16-4-5:2006/AMD1:2014 [97].

Bibliography

Add, after the existing reference [90], added by Amendment 1, the following new references as follows:

[91] CISPR 15:2005, *Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment*
CISPR 15:2005/AMD 1:2006
CISPR 15:2005/AMD 2:2008

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[96] CISPR 16-4-2:2011, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Measurement instrumentation uncertainty*
CISPR 16-4-2:2011/AMD 1:2014