TECHNICAL REPORT

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2000

AMENDMENT 1
2002-06

Amendment 1

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 3:
Reports and recommendations of CISPR

Amendement 1

Spécifications des méthodes et des appareils de mesure des perturbations radioélectriques et de l'immunité aux perturbations radioélectriques –

Partie 3:
Rapports et recommandations du CISPR

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FOREWORD

This amendment has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

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

CDV	Report on voting
CISPR/A/297/CDV	CISPR/A/329/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 the base publication and its amendments will remain unchanged until 2004. 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- withdrawn;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.

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Add the following after subclause 5.2:

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Add the following new clause:

6 Reports on uncertainties in standardized emission compliance testing

6.1 Introductory note

Clause 6 of CISPR 16-3 is a collection of documents (reports) dealing with the issue of uncertainties in standardized emission compliance tests.

The primary goal of this clause is to give guidance to those who are involved in the development or modification of CISPR emission standards. In addition, this clause is useful background information for those who apply the standards in practice.

Subclause 6.2 is still under consideration. Subclause 6.2 will contain details on the scope of clause 6 and will present the general aspects of standards compliance uncertainty in emission testing. To compensate for the absence of 6.2, this introductory note on uncertainties in standardized compliance testing is given. This note can be deleted after subclause 6.2 is included in clause 6.

The term Standards Compliance Uncertainty (SCU) is used to distinguish the associated uncertainty contributions from those arising from the measurement instrumentation only.

In a standardized emission compliance test, the emission level of an electrical or electronic product is measured, after which compliance with the associated limit is determined. The measured level only approximates the true level to be measured, due to uncertainties in the influence quantities. However, in classical metrology, all relevant influence quantities are specified and the classical Measurement Instrumentation Uncertainty (MIU) can be identified. In EMC compliance testing, very relevant influence quantities turn out to be non-specified, while no quantitative information is available about their values. Hence, the estimate of the associated uncertainty will, in general, differ significantly from the estimate following the classical measurement uncertainty considerations. Therefore, the term Standards Compliance Uncertainty (SCU) has been introduced to distinguish between the uncertainties encountered during an EMC compliance test, and the classical Measurement Instrumentation Uncertainty (MIU) used in metrology.

NOTE The measurement instrumentation uncertainty budgets of various CISPR emission tests are published in CISPR 16-4.

Subclause 6.2 will give some general and basic considerations on the subject of SCU in emission tests and can be considered as an 'uncertainty handbook' on uncertainties in emission compliance testing. The following aspects will be addressed in this handbook.

a) The definition of SCU and that of some other relevant EMC and uncertainty specific terms.
b) The various classes of uncertainties that can be encountered for EMC testing and the distinction between SCU and MIU.
c) Description of the steps to be taken to incorporate uncertainty considerations for a certain purpose. In this subclause also, guidance is given on the application of SCU in the compliance criterion.

The guidance given in this handbook shall be used when modifying existing or when drafting new CISPR recommendations.

The result of the application of this handbook to existing or new CISPR recommendations will lead to proposals to improve and harmonize the uncertainty aspects of these CISPR recommendations. Such proposals will also be published as a report within this clause 6.

The structure of documents related to the CISPR SCU work is depicted in the figure below. Report 6.2 (under consideration) is the first part dealing with the basic and general aspects of the SCUs in EMC emission measurements. Subclause 6.3 contains the uncertainty considerations related to voltage measurements. Subclause 6.4 is reserved for SCU-consideration of radiated emission measurements.

Also for immunity tests, uncertainty work is projected. The SCU considerations of immunity tests differ from the emission SCU considerations at particular points. For instance, for an immunity test, the measurand is often a functional attribute of the EUT and not a quantity. This may cause additional specific problems. The SCU documents related to immunity tests will be published in a separate clause within CISPR 16-3.

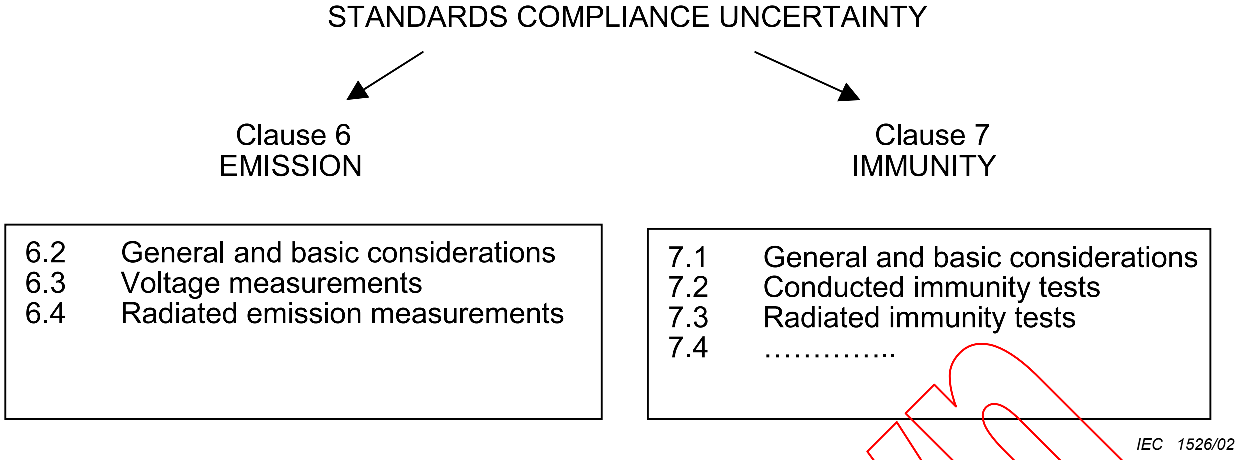

Figure 6.1-1 – Standards compliance uncertainty

6.2 General and basic considerations

Under consideration.

6.3 Voltage measurements

6.3.1 Introduction

This report deals with modeling of CISPR standardized voltage measurements in order to identify the possible contributions to the standards compliance uncertainty, with the exception of

a) product variability that is covered by the CISPR 80%/80% sampling procedure, and

b) test house induced uncertainties (see report 6.2).

After a discussion of the voltage measurement basics in 6.3.2.2, voltage measurements using a voltage probe are discussed in 6.3.3. Voltage measurements using a V-terminal artificial mains network applied to Class II appliances with only a mains cable are discussed in 6.3.4. Additional voltage measurements, for example, those on appliances equipped with a protective earth, appliances with more than one connected cable and appliances connected to ancillary equipment are under consideration.

6.3.2 Voltage measurements (general)

6.3.2.1 Introduction

Subclause 6.3.2.2 presents a consideration of the voltage measurements basics, followed by some remarks about voltage measurements using a voltage probe (6.3.3). After that, the most commonly used conducted emission measurement is discussed, i.e. the emission measurement using a V-type artificial mains network (6.3.4). Throughout the discussion, it is assumed that the EUT is a two-terminal device: only one two-wire mains cable is connected to the EUT. N-terminal devices (N > 2) with or without connections to ancillary equipment are under consideration.

6.3.2.2 Voltage measurements basics

6.3.2.2.1 Specification of the measurement loop

A voltage is always measured between two specified terminals. Figure 6.3 -1 illustrates such a measurement. U_{12} is the voltage of interest. The measurement leads transport the signal to the terminals 3 and 4 of the load impedance Z_L formed by the input impedance of the voltmeter, and U_{34} is the actual measured voltage. The EUT, leads and voltmeter load impedance form a loop of which the contour is denoted by C, and the loop area by S.

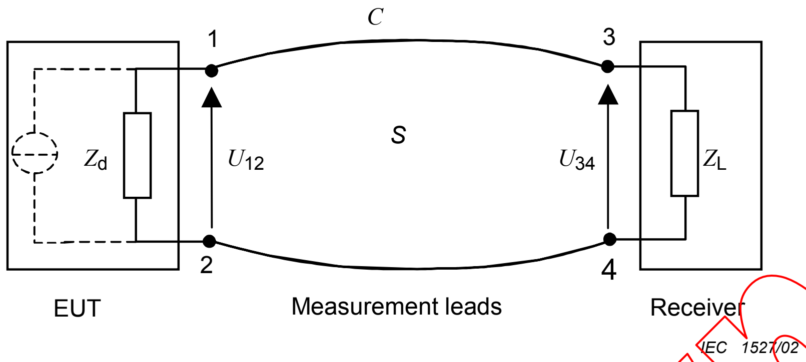

Figure 6.3-1 – Basic circuit of a voltage measurement

In particular when the internal impedance of the disturbance source is unknown (as is usually the case in compliance testing) care shall be taken that $Z_L >> Z_d$ otherwise the measured voltage depends in an unknown way on Z_L, thus creating large contributions to the standards compliance uncertainty. Consequently, Z_L has to be specified starting from estimated or measured values of Z_d of the class of subject EUTs.

NOTE 1 Specifying only one terminal, the 'hot' terminal, and assuming that the other terminal can be any point that is 'grounded' is only allowed in electrostatics, i.e. at d.c. (zero frequency) (see 6.3.3).

NOTE 2 Stray capacitances may limit the maximum value of Z_L (see 6.3.3).

6.3.2.2.2 Measurement loop constraint

The result of the voltage measurement has a physical meaning if, and only if, the circumference of the measurement loop, the contour C, is electrically small, i.e. if the circumference of the loop is small compared to the wavelength of the signal, or signal component to be measured.

If this condition is not satisfied, resonance effects will occur, creating large and undefined uncertainty contributions. These uncertainties may be reduced to an acceptable level placing the load impedance close to the terminals where the voltage has to be measured and to transport the measurement signal to the receiver via a transmission line, such as a coaxial cable. The characteristic impedance of that line should match the input impedance of the receiver. The possible mismatch is often expressed as a voltage standing wave ratio (VSWR). See also 6.3.4.6.2.

If the condition 'C electrically small' is satisfied, the use of a lumped element equivalent circuit to describe a voltage measurement is allowed. Unless indicated otherwise, it is assumed that this condition has been satisfied.

6.3.2.2.3 The measured voltage

Faraday's law is always applicable to a voltage measurement loop. For the loop given in figure 6.3-1 this means that

$$\oint_{c} \vec{E} \cdot \mathrm{d}\vec{l} = -\frac{\partial}{\partial t} \oiint_{S} \vec{B} \cdot \mathrm{d}\vec{s} \qquad (6.3\text{-}1)$$

where the electric field $\vec{E}$ and the magnetic flux $\vec{B}$ are generated by the disturbance source inside the EUT, or by some ambient disturbance source. Unless specified otherwise, the latter source is assumed to be negligibly small; for example, the measurement set-up is sufficiently screened.

From equation (6.3-1) it follows that the voltage U_{34} is given by

$$U_{34} = \int_3^4 \vec{E} \cdot \mathrm{d}\vec{l} = U_{12} - \int_1^3 \vec{E} \cdot \mathrm{d}\vec{l} - \int_4^2 \vec{E} \cdot \mathrm{d}\vec{l} - \frac{\partial}{\partial t} \oiint_S \vec{B} \cdot \mathrm{d}\vec{s} \quad (6.3\text{-}2)$$

where U_{12} is the voltage to be measured. In this equation the contribution of the magnetic field term to U_{34} often dominates. Therefore, the voltage measuring method shall include a sufficiently accurate description of the layout of the measuring leads.

A numerical example illustrating the importance of the influence of the physics described by Faraday's law on the measurand is given in annex 6.3-A.

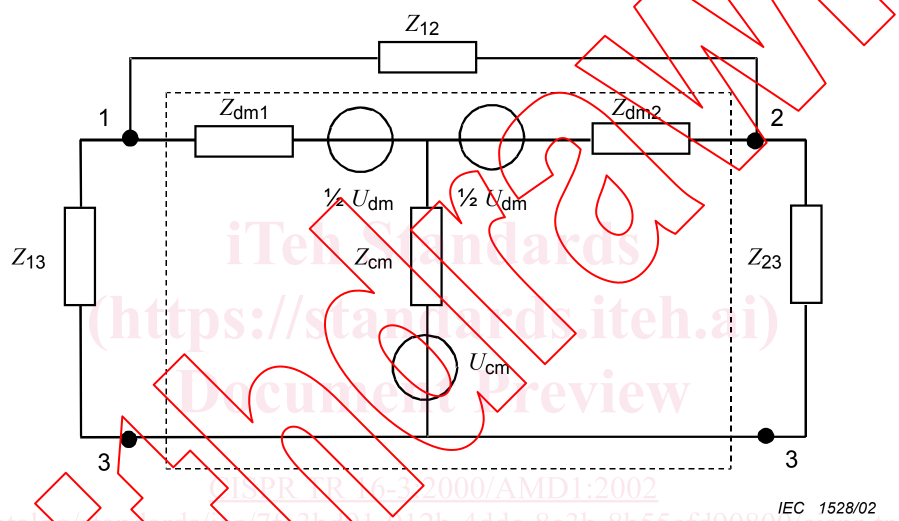

Figure 6.3-2 – Basic circuit of a loaded disturbance source (N = 2)

6.3.2.3 The disturbance source and types of voltage

At the interface the disturbance voltage is measured while the measurement loop constraints are satisfied. The source creating that voltage can be described by a lumped element n-port. Since differential-mode (DM) and common-mode (CM) phenomena are of importance, the number of terminals of the n-port equals N + 1, where N is the actual number of terminals. The additional terminal represents the surroundings of the source to which coupling via electric and magnetic fields is possible and to which the source may have a galvanic connection. It is the task of the standard drafter to define the surroundings in such a way that this additional terminal is a relevant reference point in the voltage measurement.

In this section N = 2 is assumed, so that a three-terminal network results and the equivalent circuit of figure 6.3-2 applies. An example of an EUT presenting an N = 2 disturbance source is

a) an appliance with only a two-wire mains lead, and

b) the voltage is to be measured at the mains connector terminals.

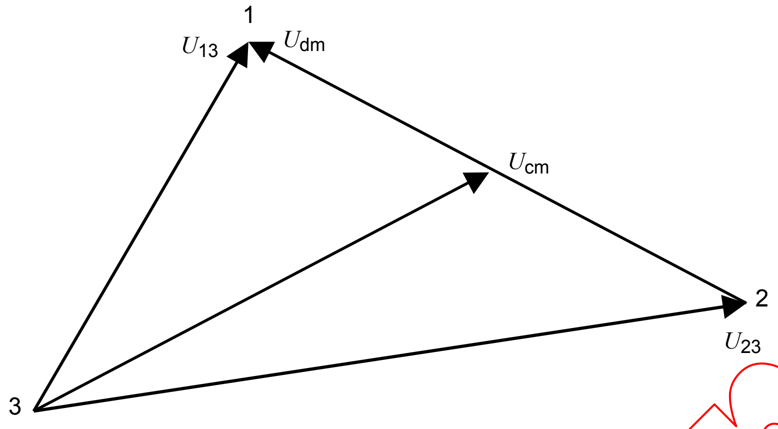

Figure 6.3-3 –Relation between the voltages

In figure 6.3-2, all elements are – in principle – frequency-dependent. Z_{dm1} and Z_{dm2} represent the internal impedance of the equivalent DM source with open-circuit voltage U_{dm}. In general, $Z_{dm1} \neq Z_{dm2}$ as at the frequencies of interest the circuit will seldom be symmetrical. Z_{cm} is the internal impedance of the equivalent CM source with open-circuit voltage U_{cm}. The load is represented by the impedances Z_{13} and Z_{23} between the actual terminals 1 and 2 and the reference 3, and the impedance Z_{12} between the actual terminals. Denoting the voltages across Z_{13} and Z_{23} by U_{13} and U_{23}, the relation between these voltages and U_{dm} and U_{cm}, is given in figure 6.3-3.

6.3.2.3.1 Interference probability

The DM- and the CM-conducted emission voltage level are, in general, a figure of merit for the interference potential of an appliance when the main coupling mechanism to the victim is crosstalk. In addition, the CM-conducted emission voltage level is generally also a figure of merit when the main coupling mechanism is (far-field) radiation. However, in the latter case, the CM current is generally a more direct figure of merit (see 6.3-B5). The so-called unsymmetrical conducted emission levels U_{13} or U_{23} give, in general, no information about the interference potential of an appliance. Additional information about the phase angle between U_{13} and U_{23} is needed to convert these voltages into the relevant voltages U_{dm} and U_{cm}. So in compliance probability studies, both the DM and CM properties of the disturbance signal have to be considered.

6.3.2.3.2 CM/DM and DM/CM conversion

The parasitic properties, for example, parasitic capacitance and stray inductance, of a voltage measuring device may cause an unwanted conversion of DM disturbances into CM disturbances, and vice versa. Therefore, the DM/CM or CM/DM conversion properties of a voltage-measuring device may play a part in uncertainty studies, in particular those of artificial or impedance simulation networks. The conversion properties may also be desired in the case where these properties dominate the compliance probability in actual situations. To give some examples:

a) If the device is used to simulate a telephone-subscriber line, the conversion properties should be related to the actual conversion properties of those lines.

b) If the device is used to investigate the conversion properties of telephone-subscriber lines, the conversion properties of the device shall not influence the results of that investigation.

c) If the device is used to characterize the CM-disturbance signal emitted by a given EUT via the telephone-subscriber line port, the DM/CM conversion properties of the device shall not influence the measurement results. In addition, the DM/CM conversion properties of the ancillary equipment, connected to that port during the emission test, shall not influence the measurement results.

6.3.3 Voltage measurements using a voltage probe

When using a voltage probe it is very important to specify the two terminals between which the voltage is to be measured. As already mentioned in note 1 of 6.3.2.2, specifying only one terminal, the ‘hot’ terminal, and assuming that the other terminal can be any point that is ‘grounded’ is only allowed in electrostatics, i.e. at d.c. (zero frequency). In the case of a two-terminal disturbance source, the circuit of figure 6.3-2 applies, where Z_{13}, Z_{12} and Z_{23} represent the generally unknown and unequal load impedances of the source, for example, those formed by the mains network. If, for example, the voltage between terminals 1 and 3 is measured, the input impedance of the voltage probe is in parallel with Z_{13} and in parallel with $(Z_{12} + Z_{23})$.

In addition, the layout of the measurement loop has to be specified to assure that the measurement loop constraint is met (6.3.2.2.2), as resonance effects contribute to the uncertainty in the voltage to be measured. That layout specification should be such that it minimizes the voltage that may be induced by the magnetic field emitted by the EUT itself. The latter voltage contributes to the uncertainty of the voltage to be measured. A numerical example is given in annex 6.3-A.

In the CISPR specifications [3] the voltage probe is a device having a large input impedance (for example, 1 500 Ω). As a consequence, attention has to be paid to the possible effect of the stray capacitance between the ‘hot’ input terminal of the probe and its surroundings. That capacitance reduces the effective input impedance of the probe (Z_{13}), thus creating an uncertainty contribution. In addition, if the input impedance is not very much larger than the source impedance (*a priori* unknown in a compliance test), an additional uncertainty may be introduced as a result of the uncertainty in the voltage division factor. Moreover, the loading by the voltage probe having an insufficiently large input impedance may cause an unbalanced loading of the disturbance source, and since generally $Z_{dm1} \neq Z_{dm2}$, this unbalance may differ when measuring the voltage between the terminals 2 and 3, compared to that between 1 and 3.

Finally, the unsymmetrical voltage measured by the probe is not a direct figure of merit for the interference potential of the EUT. Hence, it gives no information about the interference probability so the standardized use of the probe should be kept to an absolute minimum.

In summary, in a well-written standard both EUT terminals in the voltage-probe measurement shall be carefully specified, as well as the layout of the leads between these two terminals and the two terminals of the probe. Moreover, attention should be paid to the magnitude of the input impedance of the probe relative to the actual load impedance of the EUT disturbance source. In annex 6.3-B, attention is paid to possible improvements of CISPR standards.

6.3.4 Voltage measurement using a V-terminal Artificial Mains Network

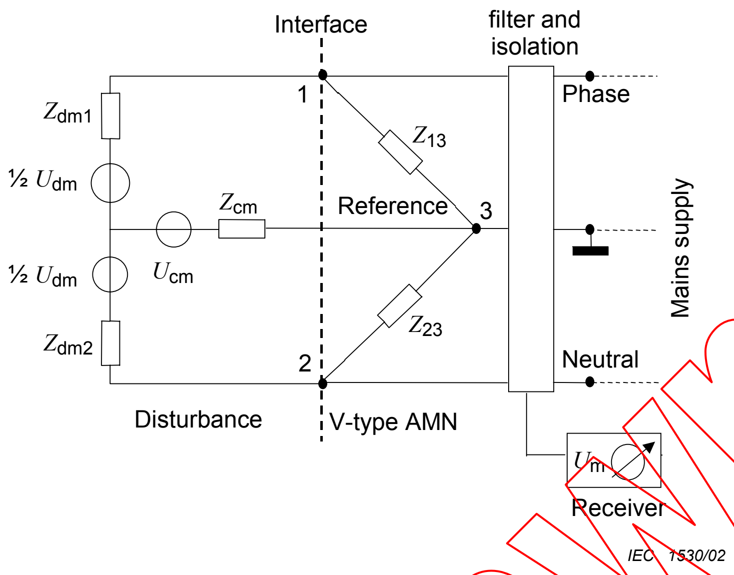

Figure 6.3-4 – Basic circuit of the V-AMN voltage measurement (N = 2)

6.3.4.1 Introduction

The V-terminal artificial network (V-AMN) essentially forms a T-network or π-network loading of the disturbance source. Throughout 6.3.4, it is assumed that the EUT is a two-terminal device: only one two-wire mains cable is connected to the EUT. Assuming a π-network loading, the basic circuit with the impedances Z_{13}, Z_{23} and Z_{12} as given in figure 6.3-2 applies at the interface of the measurement impedances. Subclause 4.1.1 of CISPR 16-1 specifies the two unsymmetrical impedances Z_{13} and Z_{23}, including the tolerance of the absolute value of these impedances. In 4.1.1 of CISPR 16-1, the shunt-impedance Z_{12} is a non-specified influence quantity; it seems that CISPR assumes that Z_{12} is always 'infinitely' large.

The basic circuit can be described as in figure 6.3-4. The filter and isolation between the measurement circuit and the mains terminals is, to some extent, also specified in CISPR 16-1. The unsymmetrical voltages across Z_{13} and Z_{23} have to be measured (see 2.2.3.1 for comments with regard to interference probability).

Valuable information about uncertainties associated with this type of measurement, that also may influence the calibration of the V-AMN, can be found in [9] and [12].

6.3.4.2 Basic circuit diagram of the voltage measurement

When reading the level U_m at the CISPR receiver, the circuit of figure 6.3-4 'reduces' to that of figure 6.3-5. In figure 6.3-5 U_d and Z_d, being non-specified influence quantities, represent the effective disturbance source at the interface formed by the subject unsymmetrical input terminal of the V-AMN and the reference of the voltage measurement set-up. The latter is normally the metal enclosure of the V-AMN. Z_{in} is the input impedance of the measurement set-up as experienced by the disturbance source. Z_{in} is a specified influence quantity that can be influenced by non-specified or by not sufficiently specified quantities (see 6.3.4.6). The factor $\alpha = U_m/U_{in}$, where U_{in} is the voltage across Z_{in}. This factor is, to a large extent, deterministic. In the absence of uncertainties, that is in the ideal situation, $Z_{in} = Z_{13} = Z_{23}$, for example, equal to 50 Ω in parallel with 50 µH, and α = 1.

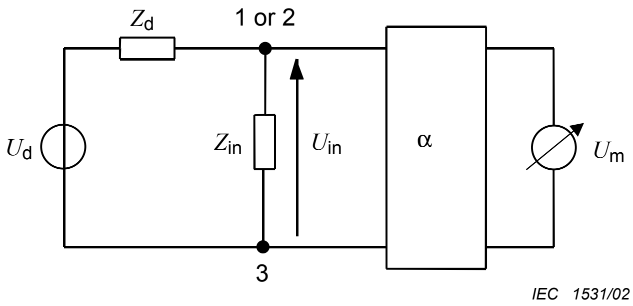

Figure 6.3-5 – Basic circuit of the V-AN measurement during the reading of the received voltage U_m (the numbers refer to figure 6.3-4)

6.3.4.3 Voltage measurement and standards compliance uncertainty

If U_{mt} is the true level of the voltage reading at the CISPR receiver in the ideal situation, U_{mt} is given by

$$U_{mt} = \frac{\alpha_0 Z_{13}}{Z_{d0} + Z_{13}} U_{d0} \qquad (6.3\text{-}3)$$

where α_0 is the true value of α. Z_{d0} and U_{d0} are the true values of the disturbance source parameters when the source is loaded with the ideal impedance Z_{13}. However, in the actual set-up, the actual parameters are α, Z_{in}, Z_d and U_d, so the voltage reading U_m is given by

$$U_m = \alpha \frac{Z_{in}}{Z_d + Z_{in}} U_d \qquad (6.3\text{-}4)$$

After substitutions of $U_m = U_{mt} + \Delta U_m$, $\alpha = \alpha_0 + \Delta\alpha$, $Z_{in} = Z_{13} + \Delta Z_{in}$, $Z_d = Z_{d0} + \Delta Z_d$ and $U_d = U_{d0} + \Delta U_d$ it follows from equation (6.3-3) and equation (6.3-4) that

$$\frac{\Delta U_m}{U_{mt}} = \frac{Z_{d0} + Z_{13}}{Z_d + Z_{in}} \left(\frac{\Delta\alpha}{\alpha_0} + \frac{\Delta U_d}{U_{d0}} \right) + \frac{Z_{d0}}{Z_d + Z_{in}} \left(\frac{\Delta Z_{in}}{Z_{13}} - \frac{\Delta Z_d}{Z_{d0}} \right) \qquad (6.3\text{-}5)$$

if higher order terms in Δ are neglected. If knowledge is available about the actual value and deviations it may be possible to apply corrections [6]. For example, if from independent measurements it can be concluded that the actual value of Z_{13} shows a systematic difference with its ideal value and the difference is within the allowed tolerance of Z_{13}, the actual value may be inserted in equation (6.3-5).

In equation (6.3-5), ΔU_m can be identified as the compliance uncertainty margin, which depends on the non-specified influence quantities Z_d and U_d, and the specified influence quantities α and Z_{in} (i.e. the influence quantities that can be determined from independent measurements and do not depend on the EUT properties). Moreover, two sensitivity coefficients can be identified:

$$c_1 = \frac{Z_{d0} + Z_{13}}{Z_d + Z_{in}} \approx \frac{Z_{d0} + Z_{13}}{Z_{d0} + Z_{13}} = 1 \qquad (6.3\text{-}6)$$

$$c_2 = \frac{Z_{d0}}{Z_d + Z_{in}} \approx \frac{Z_{d0}}{Z_{d0} + Z_{13}} = \frac{1}{1 + \rho\, e^{j\varphi}} \qquad (6.3\text{-}7)$$